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股市漲跌幅放寬對信用交易之最低整戶擔保維持率之調整

Adjusting Minimal Maintenance Margin Requirement When Price Limits Widening

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摘要：本研究旨在探討台股放寬漲跌幅限制時，現行信用交易的整戶擔保維持率是否需要調整以確保授信機構的債權。本研究藉 GARJI 模型估計風險值，推估不同漲跌幅之最低擔保維持率臨界值，再以最低擔保維持率的上限值為基準，利用台股過去不同信心水準、風險程度、模擬投資人的投資組合，推估放寬漲跌幅時最低擔保維持率臨界值，同時以保障係數比較台指期與證券信用交易。實證結果發現：漲跌幅放寬為 10%時，現行法定最低擔保維率 120%對授信機構之債權保障可能有些微不足；另一方面，即時性的證券市場之信用交易保障程度是近似於期貨市場。本研究結果提供政策制定者，於價格限制放寬時，對信用交易有關整戶擔保維持率提供最適設定。

關鍵詞：價格限制；最低擔保維持率；風險值

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ABSTRACT：This study aims at to investigate whether the minimal maintenance margin requirement (MMMR) need to adjust considering sufficient safety of the credit trading when the regulators in Taiwan Stock Exchange widen the price limits. Based on different confidence interval, risks, and multiple simulations of portfolios, we estimate Value-at-Risk (VaR) by GARJI model to derive the MMMR threshold according to the upper bound of MMMR. Furthermore, as a key reference of index future in TAIFEX, we establish a credit security degree for standardizing to compare the difference between maintenance margin requirement in spots and future market. Our empirical results show that the MMMR at 120% could be slightly insufficient to secure claims under widening to reach 10% price limits. On the other hand, the credit security degree of instantaneous maintenance margin in spots market might approximate to futures market. This study provides the critical economical implicate for policy makers to set the optimal MMMR when the price limits widen.

Keywords: Price Limits; Minimal Maintenance Margin Requirement (MMMR); Value-at-Risk (VaR)

1. Introduction

To avoid irrational trading behavior in the stock market, there are various degrees or methods of limitation for price volatility all over the world[2]. Price limits restrain the excessive volatility of share prices, by which individual investors with less information are protected, and irrational trading behavior in the market is avoided. However, price limits also bring side effects, such as volatility spillovers, delay in price discovery, and reduction in liquidity, which will cause the reduction of trading quality in the market (Cho, Russell, Tiao and Tsay, 2003). The purpose of the securities credit trading system lies in activating the stock

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[2] At present, the daily price limits in various countries: there is not any price limit in U.S.A., UK, Australia, Germany, Hong Kong, and Singapore. The price limits are 15% in France and Korea, 30% in Thailand, 10% in China, and 14~30% in Japan.

market, providing hedging, balancing share prices, and urging the stock market to develop toward safety and stability. The minimal maintenance margin requirement (MMMR) is established in the credit trading system to ensure a safety mechanism in securities credit trading. A lower MMMR will increase the financial leverage of investors, which is helpful for activating the stock market, but it may increase the probability that the investors may breach contracts when share prices fluctuate drastically. Therefore, when a stock exchange enters an opener and more competitive international stock market, it is necessary to widen price limits in order to enhance the trading quality. Nevertheless, the volatility of share prices will relatively increase, and the safety of credit trading will be influenced when there is not adequate protection. In other words, both price range and the safety mechanism of credit trading influence and have a tradeoff relationship with the trading quality and safety of the stock market. When policy makers decide to widen the upper price limit, they should also review the safety mechanism of credit trading and bring up relevant support measures.

Intuitively, narrow price range will reduce market volatility and decrease the probability that extreme prices will appear in a short time, which is favorable to control the contract-default risk of credit trading. On the contrary, wide price range will enlarge market volatility and increase the contract-default risk of credit trading. In addition, excessively high margin percentage in credit trading can reduce the contract-default risk of credit trading, but it will also reduce the incentives for investors to use financial leverage and decrease liquidity in the market. Furthermore, Moore (1966) and Figlewski (1984) considered that one of the purposes of margin is to ensure safe claims. Hence, trading liquidity and safety should both be taken into account in margin setting, that is, it is a critical safety issue how to set the minimal margin when price range widens. However, there is not any functional relationship proven between price range and the safety mechanism of credit trading so far due to different national conditions and regulations. Risk estimation was mainly used in this study to find out the optimal MMMR of Taiwan stocks in different types of price range for ensuring the purpose of safe claims, which was addressed by Moore (1966) and Figlewski (1984). Meanwhile, the credit security degree for margin and the MMMR of credit trading in TAIFEX were compared, which can be provided policy makers as a reference when they widen price limits and bring up suitable supporting measures related to the credit trading system. Moreover, policy makers can employ the research methodology and results of this study to establish the optimal MMMR of credit trading in order to balance the trading liquidity and safety of Taiwan stocks.

In credit trading, it is the most worried that the market collapses, and the investors suddenly have huge losses, which further increases the contract-default probability. Thus, the setting of the MMMR will ensure that investors fulfill trading contracts according to the contracts in the worst situation, which will further protect the claims of credit institutions[3]. Although a high maintenance margin requirement will reduce the contract-default risk, an excessively high maintenance margin requirement will decrease the incentives for investors to increase financial leverage, reduce transactions, and further reduce market liquidity. Therefore, when policy makers decide a maintenance margin requirement, they confront a trade-off relationship between claim security and trading activities. According to relevant regulations in the Regulations Governing Margin Purchase and Short Sale of Securities by Securities Firms and the Operating Rules for Securities Firms Dealing with Margin Purchases and Short Sales in Taiwan Stock Exchange Corporation (TSEC), a securities dealer should notify the client of paying the margin for margin purchase in two business days when the maintenance margin requirement is less than 120%. Otherwise, the collateral will be disposed on the following business day. Thus, a MMMR should cover at least the risk of the maximum decline of two business days, such as 125%~130% in U.S.A., 120% in Japan, and 130% in China. It is a critical issue

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[3] Qualified securities dealers, not limited to securities and financial enterprises, can carry out margin transactions, according to regulations, such as Article 60 in Securities and Exchange Law amended and promulgated on Jan. 29, 1988, Regulations Governing Margin Purchase and Short Sale of Securities by Securities Firms, Operating Rules for Securities Firms Dealing with Margin Purchases and Short Sales in Taiwan Stock Exchange Corporation (TSEC), Contract for the Margin Transactions of Securities Dealers, and Refinancing Operation of Securities and Financial Enterprises for Securities Dealers. Therefore, all dealers undertaking credit transactions are called credit institutions.

how to achieve the purpose of ensuring debt safety in terms of widening the price limits of credit trading. However, there have been less price changes internationally, so there is not specific information on either the functional relation between price range and the safety mechanism of credit trading or how policy makers should set and maintain a margin (Argiriou, 2009).

Value at Risk (VaR) is often regarded as a tool for the risk management and measurement of return on assets. VaR is the amount of loss of return on assets while the MMMR of credit trading is the threshold of loss of a credit institution. When the assets loss of an investor exceeds the VaR in credit trading, it indicates that the net assets of an asset holder are zero, or even minus. In other words, VaR indicates the MMMR threshold of a credit institution. Consequently, scholars in Taiwan employed VaR as the MMMR threshold in their studies in the past (Chou and Chen, 2004; Hung *et al*., 2005). There are three methods for calculating VaR: historical simulation, variance-covariance approach, and Monte Carlo simulation. Among these methods, the calculation of the variance-covariance approach is easy and speedy, so it is usually employed (e.g. Hung *et al*., 2005). The most critical factor in VaR calculation is the volatility of return on assets. The higher the volatility is, the more drastically the value of the collateral changes. That will further increase the probability that the value of the collateral is lower than the claims.

GARCH and its derivative models, or the GARCH family in short, have been extensively adopted in the measurement of volatility. However, the distribution of return on financial assets usually displays a leptokurtic and fat-tailed phenomenon, so it is impossible to apply the GARCH family models to precise estimation. Jarrow and Rosenfeld (1984), Ball and Torous (1985), and Jorin (1988) discovered in succession that an unstable jumps phenomenon exists among stock returns, which can not be completely caught by the GARCH models. Hence, the factor of jumps was added to the GARCH models, so they are commonly known as GARCH-jump. The parameter and distribution of jumps play a critical role in GARCH-jump. Press (1976) addressed that share price jumps are a Poisson distribution. Other scholars brought up the continuous-time SV jump-diffusion theory (Anderson, Benzoni and Lund, 1999). Lin and Yeh (1999) studied the prices of Taiwan stocks and discovered that the GARCH-jump model explained the Taiwanese stock returns better. Chan and Maheu (2002) addressed the approach of inferring post-jumping distribution by filtering conditions, altered conditional jump intensity according to time, and brought up the ARJI family model by obeying the ARMA form. The ARJI model has been applied to research on return on assets extensively in Taiwan in recent years (Hung, 2005; Chiu *et al.*, 2005; Hu *et al.*, 2008; Su *et al.*, 2007). Maheu and Mccurdy (2004) further suggested that the directions of jumps should be sorted, such as good news and bad news, in order to improve the disadvantages that GARCH can only catch stable return volatility, and sudden news will cause significant volatility in return on assets. For stock markets, good (bad) news may cause share prices to significantly rise (fall), which will further cause maintenance margin requirements to reduce, so credit institutions can not ensure claims, and the contract-default risk will increase. Influences resulting from good news and bad news can be simultaneously taken into account in Maheu and Mccurdy's (2004) GARJI model, so the model better corresponds to the short-term ups and downs in a stock market, especially the short-term ups and downs caused by news. Wong (2010) found that phenomena in return on assets include jumps, skewed, and fat-tailed distribution, which make catching the VaR in a great crash. Nevertheless, the GARJI model can still be employed to generate estimation in this worst case. That is, the GARJI model can be used to improve previous disadvantages and adequately estimate the VaR of current financial assets volatility. When the margin of credit trading is influenced by news, it is easy to cause contract-default risk in credit trading in a short term. Therefore, the GARJI model which can be used to respectively catch the variation of good (bad) news better corresponds to the purpose of this study theoretically. After comparing the ARJI family and the GARJI model, Maheu and Mccurdy's (2004) GARJI model was employed to estimate volatility parameters in this study.

There are three features in this study, which are different from the features of previous studies. First, Maheu and Mccurdy's (2004) GARJI model was compared and employed in this study, which enabled the estimated parameters to better correspond to the actual situations and stabilize the results. On the contrary, scholars all employed the ARJI model in Taiwan in the past (e.g. Hung *et al.*, 2005; Chiu *et al.*, 2005; Hu *et al.*, 2008; Su *et al.*, 2007), so good news and bad news were difficult to be distinguished in the estimation although the influences of good news and bad news on a stock market is the most important factor in stock volatility. Secondly, it was only verified in previous research if the claims of credit institutions can be sufficiently ensured by the current MMMR (120%) in the current price range (7%) (Chou and Chen, 2004; Hung *et al.*, 2005). If the price range is widened to 10% or other levels in the future, there will not be any reference to the adjustment of the MMMR for policy makers. Finally, the credit security degree brought up in this study was used to compare the maintenance margin of TAIFEX and the MMMR of credit trading. This can be further provided to policy makers as a reference to policies, used as an active tool to activate a stock market, and enable credit trading to develop well and steadily.

The research data were the daily return data of Taiwan stocks retrieved from the archive of Taiwan Economic Journal (TEJ) between January 4, 1980[4] and December 31, 2010. The percentages of price range were respectively 5% and 7% during the sampled period. Meanwhile, when critical political and financial events happened domestically or internationally, the official authorities reduced the price range to respectively 3% and 3.5% for many times. Hence, the thresholds of the maintenance margin requirements of different confidence levels were respectively estimated according to different periods of price range, and, based on the upper bound of the thresholds of the maintenance margin requirement, the percentage that each threshold accounted for in the upper bound was used to analogize the reference threshold of the MMMR when the price range was 10%[5]. Overall, the

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[4] These were the earliest data provided by the archive of TEJ.

[5] The current price range of the stock market in Taiwan is 7%, which is only higher than Vietnam in Asia and low when compared with other countries all over the world. Aiming at widening price limits, Chi Schive, Chairman of TWSE, addressed that widening the upper bond of the price limits will be achieved as long as the supporting measures and regulations are ripe when he attended the "2010 Taiwan Investment Forum" on March 15, 2010. To synchronize with international standards, it is only a problem of time for Taiwan to increase the price range. The range tends to be widened gradually. Since 10% tends to be the goal of the first stage, it was regarded as the research standard in this study.

empirical result displayed that the current MMMR is 120%, and the protection for the claims of credit institutions may be slightly insufficient when the price range is widened to 10%. In addition, the maintenance margin system of the futures market and the maintenance margin requirement of securities credit trading are both designed for ensuring that the investors fulfills the contracts. Although the time and approaches of balancing, pursuing payment, and paying off are different, an identical economic function still exists for maintaining the trading quality of the market. A credit security degree was thus designed in this study to compare futures and stock markets. The empirical result showed that the simulation result of the credit security degree of the credit trading of the real-time stock market is similar to the credit security degree of futures.

The remainder of this paper is organized as follows. Section 2 presents a review of the literature arguments. Section 3 presents research design and methodology, in which VaR, models related to GARCH-jump, MMMR, and credit security degree are introduced. Our empirical results are presented and discussed in Section 4, followed in Section 5 by conclusion and suggestion drawn from this study.

2. Literature Review

2.1 The Margin System of Credit Trading and Stock Volatility

The nature of credit trading includes providing investors with hedging operation and activating market transactions. When a margin standard is too high, the financial leverage of investors will reduce, which is unfavorable to the goal of activating the stock market. On the contrary, when a margin standard is too low, it will be impossible to protect investors from having contract-default risk due to enormous stock price volatility. The worst situation may even cause systematic contract-default risk in the stock market. Moore (1966) and Figlewski (1984) considered that the margin of credit trading mainly includes three purposes: (1) ensuring debt safety; (2) prevent resources from being excessively invested in speculative economic activities; (3) preventing investors from having high financial leverage and reducing pyramiding-depyramiding[6] price volatility risk. In the past, scholars brought up totally different empirical results for the third purpose. For example, Largay and West (1973), Officer (1973), Ferris and Chance (1988), Kupiec (1989), Schwert (1989), Hsieh and Miller (1990), Sentana and Wadhwani (1992), Moore (1996), and Ayadi *et al.* (2010) argued that increasing margin will not result in any influence on volatility in the stock market. The other school of scholars, such as Luckett (1982), Hardouvelis (1988), and Hsieh and Miller (1990), addressed that margin and volatility are negatively correlated. Furthermore, Kupiec and Sharpe (1991) discovered that the phenomenon is caused by different risk preferences behind the market microstructure. Thus, the relationship between margin standards and volatility in the stock market was not completely consistent in the past. In practice, there was not any margin system used in U.S.A. as a tool for stabilizing the stock market since 1974. Therefore, the third purpose addressed by Moore (1966) and Figlewski (1984) can not be completely supported, namely disputes exist. That is, the critical issue of the margin system of credit trading should lie in a safety mechanism for preventing investors from defaulting contracts and the prevention of excessive speculation in the stock market.

The optimal margin standard is mainly influenced by stock market volatility, the methods of account settlements, and the systems of margin pay-off. The best condition is to have safety and liquidity simultaneously. Margin can be divided into initial margin requirements and maintenance margin requirement. Initial margin requirements are related to the capability of investors for financial leverage whereas maintenance margin requirement is to ensure the claims safety

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[6] Pyramiding indicates overly optimistic investors buy shares by margin purchase and cause the price of stock to increase irrationally, but the unreasonable stock price will reverse after a long time, which will cause more investors to sell more shares and, eventually, the price of stock will fall drastically. Depyramiding means that overly pessimistic investors sell shares by short sale and cause the price of stock to decrease irrationally, but the excessively low stock price will reverse after a long time, which will cause more investors to buy more shares, and, eventually, the price of stock will increase drastically. The two phenomena will cause stock price overraction and enlarge volatility in the stock market.

of credit institutions. In the past, the initial margin requirements[7] of Taiwan stocks were regarded as one of the tools for credit control and adjusted for many times due to stock market changes and the economic environment. For example, initial margin requirements were set by the official authority of securities before July 4, 1989. Afterward, they were linked with the weighted stock index. On October 21, 1997, they stopped to be linked with the index and started to be set by the official authority again. As for maintenance margin requirement (margin purchase and short sale are combined and calculated as one account; it is collectively called "MMMR"). The stock prices in Taiwan fell unceasingly due to the Asian financial crisis in 1997. To avoid the terminative selling pressure of credit trading, the official authority reduced the original MMMR from 140% to 120%, which is continued until now, since June 5, 1998. Policy makers from various countries also regard margin as a tool for controlling credit and stabilizing the stock market (Ayadi *et al.*, 2010) and respectively set the initial margin requirements and the maintenance margin requirement. For instance, the initial margin requirements are both 50% whereas the maintenance margin requirements of margin purchase and short sale are respectively 125% and 130%. In terms of credit trading in Japan, the ratio of the initial margin requirements is adjusted according to money supply, inflation, and the condition of the stock market, and it should not be less than 30% according to the Ministry of Finance, so Japan adjusts the initial margin requirements more frequently than other countries. The lowest margin ratio reached 30% in Japan. However, after 1978, the Japanese stock market continues to rise, so the margin ratio rises to 60%, and the MMMR is 120%. Based on specific criteria, such as risk condition, size, and performance, Canada reduces the initial margin requirement of each qualified stock from 50% to 30% by means of the list of securities for reduced margin (LSERM) every season. If one stock is delisted from the LSERM, the margin will be adjusted back to 50% again (Ayadi *et al.*, 2010). According to the Shenzhen Stock Exchange,

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[7] In financing, the percentage of margin is (100% - the financing ratio), namely the so-called "margin for margin purchase." In terms of short sale, it's called short margin. For the convenience of explanation, they were both called "margin" in this study.

China, the initial margin requirement is 50% while the MMMR is 130%. Specifically, the setting approaches and standards of the optimal maintenance margin requirement vary from country to country and from regulation to regulation. There are not specific guidelines. It depends on the judgment of policy makers on risk and the quality of trading.

In the futures market similar to credit trading, a margin system will increase the financial leverage of investors and be helpful for activating transactions. In terms of economic functions, the maintenance margin requirement system and the MMMR are consistent among futures. Two types of theoretical models related to futures margin requirement exist in currently available literature, which are for setting the optimal margin level. The first type is economic models used to derive an endogenous optimal margin level. Brennan (1986) measured brokerage cost by using the settlement costs generated by margin levels and contract-default loss and convert it into the optimal margin level on the premise of cost minimization. Figlewski (1984) brought up a model for calculating contract-default risk to analyze the contract-default probability when the margin is insufficient in futures trading and the probability that futures prices continue to decline and exhaust the margin when clients do not complement the margin. Moreover, Fenn and Kupiec (1993) proposed a theoretical model to obtain the corresponding ratio of the optimal margin and price volatility, that is, when the margin is set, if the minimized contract cost is used to estimate futures price volatility, the corresponding margin level can be calculated. They regarded S&P 500, NYSE Composite, and MMI index futures as the research objects and discovered that the margin regulations of these three types of futures are all higher than the margin level estimated by the model.

The second type is to use statistical techniques to set the rate of returns in line with normal or non-normal distribution and employ nonparametric methods or parametric methods to find the optimal margin level, such as adopting VaR or the extreme value theory (EVT) to estimate contract-default risk and set margin accordingly. Login (1999) discovered that when normal distribution is used to estimate contract-default risk, the probability of extreme events will be significantly underestimated, and the margin which should be requested will thus be underestimated; the optimal margin will be obtained if the EVT is used to analyze the tail distribution of futures returns. The research object in the EVT is the outlier among samples, namely the tail of the distribution. In the EVT, it is unnecessary to make any assumption on the entire distribution pattern, but still, the features of the tail distribution can be precisely described. The percentile of daily return distribution estimated by the EVT is the appropriate margin level of futures. When the EVT is employed to decide the appropriate futures margin level, an exchange can set an acceptable contract-default level for futures according to the risk preference, namely setting the contract-default probability that futures margin is insufficient in the next trading day and, according to the model of the EVT, calculating the margin level which should be charged under this probability. Fama and French (1988), Poterba and Summers (1988), and Jegadeesh (1991) considered that stock returns are autocorrelated, which is different from the EVT, which is independent and identically distributed (i.i.d.), so it is suggested that this approach should not be used to estimate the risk of stock returns. In addition, Lam, Sin, and Lenug (2004) applied the GARCH model and Huang, Wan and Chen (2011) applied the Markov chain to their estimations. The current margin system used in the Taiwan Futures Exchange is based on previous volatility, and 1% of confidence is used to calculate the margin level, so it belongs to this type of setting approach. However, the current MMMR of credit trading in Taiwan is a fixed ratio set by policy makers. For example, the MMMR of Taiwan stocks reduced from 140% to 120% on June 5, 1998, which was subjectively decided by the competent authority. Nevertheless, after a great number of political and economic events, there has not been any critical or systematic contract-default case so far. Hence, the MMMR of 140% was too high in the past. Can the MMMR of 120% achieve the goal of safety control? It was proved in recent research in Taiwan that the number is sufficient to cover the risk of credit institutions under the price range of 7% (e.g. Chiu *et al.,* 2004; Chou and Chen, 2004; Hung *et al.,* 2005).

2.2 VaR

The contract default of credit institutions for credit trading starts to happen when the account maintenance margin requirement of investors is lower than 100%, excluding trading taxes and handling charges, which may be caused by stock market volatility, especially significant volatility. VaR is to evaluate the maximum possible amount of loss because of possessing an investment under certain confidence during a period of time. In other words, when confidence is set under (1-α%), the corresponding threshold will be the watershed of possible statistical loss. VaR and the MMMR of credit trading, or the setting standard of futures maintenance margin requirement are actually two sides to one coin, so VaR is often used as a tool for controlling the risk of credit trading (e.g. Hung *et al.*, 2005).

VaR is extensively applied to risk management. There are three methods for estimating the distribution of profit and loss: variance-covariance approach, historical simulation, and Monte Carlo simulation. The advantages of the variance-covariance approach include: (1) The assumption of ROA is made to conform to normal distribution, so a formula solution exists in the estimation of VaR, which can be used to quickly calculate the VaR of a single asset. (2) The risk of portfolios is included in the correlation coefficient matrix between different return on assets, which is favorable for solving the influence of portfolios covariance. (3) Normal distribution conditions are easy for comparing the VaRs of different confidence levels during different evaluation periods. The disadvantages include: (1) The return characteristics of nonlinear profit-and-loss goods can not be indeed described. (2) There will be model risk when assumed returns conform to normal distribution. Among the three calculation methods of VaR, the variance-covariance approach is the most frequently employed. The calculation method can be further divided into Simple Moving Average (SMA), Exponential Weighed Moving Average (EWMA), and the GARCH model for volatility.

Recently, relevant literature and research showed that new empirical methods are brought up in order to precisely estimate VaR and solve the disadvantages of the variance-covariance approach, especially the GARCH model. It is necessary to have appropriate assets volatility estimation as the basis of VaR. When the accuracy of volatility anticipation becomes higher in the future, the estimation of VaR will be more accurate. Volatility is one of the important variables in VaR calculation. Bollerslev's (1986) GARCH model started the new era of another estimation approach. The GARCH model is a regression model tailor-made for financial data. It is mainly used to estimate the variance of errors and widen the assumptions in which returns need to conform to normal distribution. Therefore, the GARCH model can be used to describe the clustering phenomenon common in financial market volatility, that is, great volatility follows by great volatility while small volatility follows by small volatility. Furthermore, GARCH can be used to explain the fat-tailed phenomenon of financial data. Consequently, GARCH is particularly suitable for analyzing and anticipating volatility. These analyses are very important for investors when they make decisions, so GARCH is extensively valued and used.

2.3 The Review of Garch-jump Related Models

The GARCH model has been improved in recent studies. For example, it was discovered in previous empirical research that stock market return distribution is usually leptokurtic; jumps exist in return on asset, such as stocks; it is also possible that unexpected news causes share prices to significantly rise or decline and indirectly causes the parameters generated by the GARCH model to produce bias. Therefore, scholars insisted on not ignoring the characteristic of jumps and developed GARCH into the GARJI model in which volatility is based on jump-diffusion in the previous estimation of stock returns volatility (e.g. Jorion, 1988; Vlaar and Palm, 1993; Nieuwland *et al.*, 1994; Daal *et al.*, 2007). Scholars in Taiwan also adopted the characteristic of jumps into the GARJI model to establish empirical research models relevant to stock returns (e.g. Hung *et al.*, 2005; Chiu *et al.*, 2005; Hu *et al.*, 2008; Su *et al.*, 2007). The variables calculated by these models are gradually more accurate in the variance estimation of financial data and favorable for the estimation of VaR. Recently, in Chan and Maheu's (2002) ARJI model and Maheu and Mccurdy's (2004) GARJI model, conditional jump intensity is allowed to display an autoregressive structure according to the previous jump intensity. Generally, it is considered that stock returns display a leptokurtic and fat-tailed phenomenon mainly due to the insufficient reaction or overreaction of the market to bullishness or bearishness.

The GARCH model is used to catch stabile volatility, but it can not be used to explain a greater change. At the moment, jumps can be regarded as explanation for external news or events (Chiu *et al.*, 2006). Wong (2010) discovered that jumps, skewed, and fat-tailed distribution exist in ROAs, so it is more difficult to catch the VaR in a great crash. However, successful estimation can still be generated by the GARJI model in the worst situation. That is, the GARJI model can be used to improve previous disadvantages and suitable for the VaR estimation of current financial assets volatility. Chiu, Lee and Hung (2005) and Hung, Lee and Liu (2008) compared the VaRs estimated by GARJI, ARJI, and Asymmetric GARCH and discovered that the GARJI model is highly accurate and the most efficient. These studies were all aimed at that stock market volatility does not conform to normal distribution, the estimation method was based on the variance-covariance approach, and abnormal stock market volatility was considered in order to solve the disadvantages in normal distribution. Based on the GARJI model, VaR was estimated in this study, which coincides with Wong's (2010) approach. The main issues include normal volatility (in line with normal distribution) as well as the variance estimated by the influence of good/bad news on the stock market (jump-diffusion and non-normal distribution). Therefore, the disadvantages, that the variance-covariance approach is assumed to be normal, can be improved.

Due to price limits, Taiwan stocks are influenced by public information easily, which will cause continuous and unexpected ups and downs in terms of share prices. Hence, it is necessary to simultaneously consider the jumps of returns in a particular period of time.(Wu and Wang, 2006; Hu *et al.*, 2008) Moreover, Hung *et al.* (2005) found empirically that in terms of Taiwan stocks, the fit capacity is the best when the factor of jumps is added to the GARCH model. Lin and Yeh (1999) modified Jorion's (1988) approach and derived the GARCH-jump model. They studied Taiwan stocks and also found that the GARCH-jump model with the factor of jumps best explains stock returns. Chiu *et al.* (2005) and Su *et al.* (2007) both adopted Chan and Maheu's (2002) ARJI model when investigating the volatility of Taiwan stocks. Hu *et al.* (2008) and Tzou and Pai (2009) respectively adopted the ARJI model to empirically study

Taiwan's exchange rate and crude oil. On the other hand, Maheu and Mccurdy (2004) argued that jumps react differently to unexpected good news and bad news, so if they are not distinguished, the sizes of jumps will be influenced and offset by jumps from different directions, and the obtained parameters will be only stable values.

2.4 The Relationship between Price Limits and the MMMR

Brennan (1986) and Ackert and Hunter (1994) found that price limits and margin ratios are alternative to the reduction of price volatility. Narrower price range can significantly stop the extreme changes of prices, reduce price volatility, and further decrease the probability of insufficient margin. On the contrary, when price range is widened, price volatility will become drastic, and the probability of insufficient margin will thus increase. Brennan (1986) argued that when investors can not obtain complete information, price limits are an effective tool to improve the futures margin system, and they can reduce the cost of market participants, namely price limits can be the alternative of margin. Meanwhile, Chowdhry and Nanda (1998) were of the opinion that price limits are helpful for increasing the stabilization of market transactions. Lin and Chou (2011) discovered that irrationality exists in the market, and price limits are helpful for market stabilization.

Ma, Rao and Sears (1989), Arak and Cook (1997), and Chung and Gan (2005) discovered that price limits can indeed be used to avoid the abnormal volatility caused by irrational reaction in the market. They have a cooling effect during the crazy trading period, and they can protect individual investors from the damage resulting from extreme price volatility. However, it was also proved in the literature that price limits may harm market volatility and liquidity. Price limits will delay market price discovery and cause a successive increase in the volatility of daily trading (Fama, 1989; Kim and Rhee, 1997; Kim, 2001). Furthermore, price limits have a magnetic effect, which will cause greater volatility to occur among share prices more easily (Du, Liu and Rhee, 2009), result in irrational share price volatility, and delay the arrival of reasonable market prices (Kim and Rhee, 1997). Moreover, price limits will interfere with transactions. When prices are limited, the quantity of transactions will decrease, which will reduce market liquidity (Fama, 1989; Lauterbach and BenZion, 1993; Kim and Rhee, 1997). Thus, there is not any fixed conclusion in academic research and market practice whether or not price limits will reduce stock market volatility. If price limits are widened, market efficiency will be increased, and stock market volatility will be further reduced. In that case, stock exchanges may not need to increase the statutory MMMR.

This study was aimed to investigate when price limits are adjusted from 7% to 10%, if the current MMMR of 120% is enough for ensuring the claims of the credit trading of securities and financial institutions in order provide policy makers with a reasonable empirical result as a reference. Basically, when the claims of the credit trading of financial institutions are protected, price limits and the upper bound of the threshold of the MMMR are positively correlated. Hence, when price limits is adjusted to 10%, it is necessary to estimate the thresholds of the MMMRs of different confidence levels, respectively 99%, 95%, and 90%, will exceed the MMMR of 120% in order to prevent insufficient claims protection and avoid increasing the statutory MMMR because of being overly conservative. After price range is widened, it's possible that stock market volatility will decrease, but the thresholds of the MMMRs of different confidence levels will still be likely positively correlated with price limits. Consequently, this study was aimed at whether or not the claims of financial institutions can be sufficiently protected instead of volatility changes. In the past, the MMMR of Taiwan stocks was ratiometric and set by the competent authority in accordance with the administrative discretion. The MMMR was seldom changed unless it was necessary. On the other hand, price range is an important trading rule in the market, and there are seldom opportunities for changes. Therefore, there has not been literature about the relationship between price range and the MMMR. There was not any record of the price range of 10% in the TWSE. The changes of the thresholds of the MMMRs of different confidence levels can only be inferred from the previous data in which the price range was widened from 5% to 7%. It was found that thresholds of the MMMRs significantly increased. Thus, it was assumed that price limits and the thresholds of the MMMRs are positively correlated.

3. Research Design and Methodology

When the price range is 7%, the current MMMR of credit institutions is sufficient for guaranteeing the contract-default risk (Chiu *et al.*, 2004; Chou and Chen, 2004; Hung *et al.*, 2005). However, when the price range is widened to 10%, the potential volatility may increase, which may cause collaterals to be less than claims, so that the contract-default risk will increase in credit institutions. Literature related to price range and MMMR lacks, so the upper bound percentage approach based on the upper bound of the MMMR thresholds was brought up in this study to estimate the MMMR threshold sufficient to ensure the claims of financial institutions when the price range is widened to 10%. VaR is often employed to measure the MMMR threshold (Chiu *et al.*, 2004; Hung *et al.*, 2005). The Garch-jump model with the element of jumps was employed in this study to compare the Taiwan stocks weighted index, and the optimal model was selected for the VaR estimation of each individual stock. In addition to the estimations by different levels of price range, factors, such as portfolios and the risks of individual stocks, were taken into account for the robustness of research. Meanwhile, the MMMRs of futures and securities were compared in order to provide policy makers a reference to MMMR adjustment. The design is detailed as follows:

3.1 The Volatility of Individual Stock Returns under Different Levels of Price Range

First, Chan and Maheu's (2002) ARJI family model and Maheu and Mccurdy's (2004) GARJI model, which are employed by scholars in Taiwan the most frequently, were compared in this study. Secondly, the optimal model was used to calculate the conditional variances of all the listed companies as the calculation basis of VaR. The ARJI model was the discrete-time jump model brought up by Chan and Maheu (2002), which changes as time goes on, and in which the feature of jumps are combined with GARCH in the estimation. The estimation formula of the ARJI model is listed as follows:

$$R_t = \mu + \sum_{i=1}^{t} \phi_i R_{t-i} + \sqrt{h_t} z_t + \sum_{k=1}^{n_t} Y_{t,k} \tag{1}$$

in which R_t is stock returns; μ is the mean of stock returns; h_t is heterogeneous variance; $z_t \sim NID(0,1)$. $Y_{t,k}$ is the size of a jump, $Y_{t,k} \sim N(\theta, \delta_t^2)$, and n_t indicates the number of jumps in a particular period of time, which is a Poisson random variable[8]. Therefore, jump probability is $P(n_t = j \mid \Phi_{t-1}) = \exp(-\lambda_t)\lambda_t^j / j!$. Jump intensity is assumed as

$$\lambda_t = \lambda_0 + \sum_{i=1}^{r} \rho_i \lambda_{t-i} + \sum_{i=1}^{s} \gamma_i \zeta_{t-i} . \tag{2}$$

in which the residual for jump intensity is $\zeta_{t-i} = E[n_{t-i} \mid \lambda_{t-i}] = \sum_{j=0}^{\infty} jP(n_{t-1} = j \mid \Phi_{t-1}) - \lambda_{t-i}$. Meanwhile, assume that $f(R_i \mid n_t = j, \Phi_{t-1})$ represents the conditional density of stock returns, so according to Bayes rule, the probability of *j* occurring in the *t* time will be:

$$P(n_t = j \mid \Phi_t) = f(R_t \mid n_t = j, \Phi_{t-1}) P(n_t = j \mid \Phi_{t-1}) \big/ P(R_t \mid \Phi_{t-1}) \tag{3}$$

Therefore, the conditional density of returns can be inferred:

$$P(R_t \mid \Phi_{t-1}) = \sum_{j=0}^{\infty} f(R_t \mid n_t = j, \Phi_{t-1}) P(n_t = j \mid \Phi_{t-1}) \tag{4}$$

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[8] Press (1967) addressed that the jumps of stock returns obey Poisson's distribution.

Finally, according to Formulas (2), (3), and (4), the maximum likelihood estimation method was used to estimate all the parameters in the ARJI model. Meanwhile, Chan and Maheu (2002) adjusted the variances and brought up $ARJI-h_t$ and $ARJI-R_{t-1}^2$ respectively as follows:

$$ARJI-h_t : \delta_t^2 = \zeta_0^2 + \zeta_1^2 h_t \tag{5}$$

$$ARJI-R_{t-1}^2 : \delta_t^2 = \zeta_0^2 + \zeta_{t-1}^2 \tag{6}$$

Furthermore, Maheu and Mccurdy (2004) addressed that the GARJI model improves the disadvantage that unexpected good news and bad news have different reactions to jumps. The differences between the GARJI model and the ARJI model are listed as follows:

$$r_t = \mu + \varepsilon_{1,t} + \varepsilon_{2,t} \tag{7}$$

where $\varepsilon_{1,t} = \sigma_t z_t$; $z_t \sim NID(0,1)$; $\varepsilon_{2,t} = \sum_{k=1}^{n_t} Y_{t,k} - \theta\lambda_t$, $Y_{t,k} \sim N(\theta, \delta^2)$. Meanwhile,

$$\sigma_t^2 = \omega + g(\wedge, \Phi_{t-1})\varepsilon_{t-1}^2 + \beta\sigma_{t-1}^2 \tag{8}$$

where

$$\varepsilon_{t-1} = \varepsilon_{1,t-1} + \varepsilon_{2,t-1} \tag{9}$$

$$g(\Lambda, \Phi_{t-1}) = \exp(\alpha + \alpha_j E[nt-1 \mid \Phi_{t-1}] + I(\varepsilon_{t-1})(\alpha_\alpha + \alpha_{a,j} E[n_{t-1} \mid \Phi_{t-1}])) \tag{10}$$

where $I(\varepsilon_{t-1}) = 1$; if $\varepsilon_{t-1} < 0$, or it will be 0. Φ_{t-1} denotes information for the previous period. When there is good news, and there is not any jump,

$g(\Lambda,\Phi_{t-1})=\exp(\alpha)$. When there is good news, and there is one jump, $g(\Lambda,\Phi_{t-1})=\exp(\alpha+\alpha_j)$. When there is bad news, and there is not any jump, $g(\Lambda,\Phi_{t-1})=\exp(\alpha+\alpha_\alpha)$. When there is bad news, and there is one jump, $g(\Lambda,\Phi_{t-1})=\exp(\alpha+\alpha_\alpha+\alpha_j+\alpha_{\alpha,j})$. Likewise, the maximum likelihood estimation method was used to estimate all the parameters. A better fit model was then selected and applied to the following VaR calculation.

3.2 Finding MMMR Thresholds by the VaR Approach under Different Levels of Price Range and Confidence Level

After the optimal stock price behavior model optimal for Taiwan stocks was selected, individual stock parameters were estimated as the calculation basis of VaR, and VaR was used to estimate the threshold of the account MMMR. Different levels of confidence and the condition of two business days were employed to search for the thresholds of individual stock returns under extreme variability:

$$P\lfloor R_{t,2d} < -VaR_t \rfloor = \alpha \tag{11}$$

$R_{t,2d}$: the two-trading-day rate of return of collateral at the t point in time; VaR_t: collateral VaR. α indicates confidence level, which can be 10%, 5% or 1%. According to two-day expected volatility, confidence level, and two-day individual stock return, VaR was converted into the threshold of a maintenance margin requirement. When the MMMR touches the threshold of a maintenance margin requirement, it indicates that the maximum loss of the value of a collateral within two days at the threshold is equal to the VaR. The formula is listed as follows:

(1) Margin Purchase Position:

$$-\frac{Collateral - Debt}{Collateral} = -VaR$$

$$\Rightarrow \frac{1}{Collateral/Debt} - 1 = -VaR \Rightarrow \frac{1}{CValue} - 1 = -VaR$$

$$\Rightarrow CValue = \frac{1}{1 - VaR} \tag{12}$$

(2) Short Sale Position:

$$\frac{-SMoney}{P_0} = -VaR \Rightarrow SMoney = VaR \times P_0$$

$$CValue = \frac{Collateral}{Debt} = \frac{P_0 + SMoney}{P_0} = \frac{P_0 + VaR \times P_0}{P_0} = 1 + VaR \tag{13}$$

where $Collateral$: account collateral value; $Debt$: the account claims value of a credit institution; $Margin = \frac{Collateral}{Debt}$: margin purchase (short sale) maintenance margin requirement; $CValue$: the threshold of MMMR; $SMoney$: short sale margin; P_0 : short-sale stock price.

A MMMR threshold means that under certain confidence level, when the maintenance margin requirement of an individual stock decreases to this threshold, the collateral value is equal to the claims value, that is, a maintenance margin requirement lower than the threshold will cause investors to breach the contracts and thus make creditors start to undertake the loss caused by the contract-default risk. There was barely research on the relationship between price range and MMMRs in the past. What is known is the price limits ever used in Taiwan's stock market in the past, including respectively 5% and 7% in normal times and 3% and 3.5% in abnormal times. This study was aimed to investigate if the current 120% MMMR is sufficient to ensure the claims of the credit trading of securities and financial institutions when the current price limit is adjusted from 7% to 10% in order to provide policy makers with a reasonable empirical result as a reference.

3.3 Estimating the MMMR Thresholds under the 10% Price Range by the Upper Bound Percentage Approach

Basically, price limits and MMMR thresholds are positively related when the claims of the credit trading of financial institutions are guaranteed. To take price limits and the upper bound of the MMMR thresholds in normal times ($NCValue\_Upper$) as an example, when two continuous business days are both limit-up (short sale) or limit-down (margin purchase), it is necessary to set the upper bound of the MMMR thresholds of the $j\%$ price limit as follows in order to at least guarantee claims and ensure that no loss will be caused.

$$NCValue\_Upper_{j\%} = \frac{100}{(1 - j\%)^2} \tag{14}$$

The upper bounds of the MMMR thresholds of the price limits of 5%, 7%, and 10% were respectively 110.8, 115.62, and 123.46, which showed that price limits and the upper bounds of the MMMR thresholds are indeed positively correlated. However, under the current 7% price limits, the 120% MMMR is not lower than the upper bound of the MMMR thresholds, namely 115.62. If the price limits are adjusted to 10%, the 120% MMMR will be lower than the upper bound of the MMMR thresholds, namely 123.46. Nevertheless, an upper bound indicates the most extreme situation, and the probability of occurrence is very low, so it is necessary for further analyses in order to avoid increasing the statutory MMMR due to excessive conservativeness.

The upper bound of MMMR thresholds is an actual value calculated by means of the price limits of two continuous business days. A more precise MMMR threshold can be obtained by using an actual value as the standard. The approach in which an upper bound is used as the standard was named the upper bound percentage approach in this study. The price range used in normal times in the TWSE included 5% and 7%. In this study, the stock price behavior model optimal for Taiwan stocks was used to estimate individual stock conditional variance and calculate the VaR of the confidence level of respectively 99%, 95%, and 90%. Formulas (12) and (13) were then used to convert each value into a

MMMR threshold. The upper bound of MMMR was regarded as the datum point for considering the relationship between MMMR thresholds ($NCValue_{j\%}^{i\%}$) and upper bounds when the price range of respectively 5% and 7% was under different levels of confidence and calculating the percentage ($NCValue\%_{j\%}^{i\%}$) that the $i\%$ MMMR threshold and the $j\%$ price limit occupied the upper bound in normal times. The formula is listed as follows:

$$NCValue\%_{j\%}^{i\%} = \frac{NCValue_{j\%}^{i\%}}{NCValue\_Upper_{j\%}} \tag{15}$$

The percentage that a threshold occupies an upper bound is helpful to understand the distribution of the MMMR thresholds above the most accurate upper bound datum under different price limits and various levels of confidence. More importantly, the percentage that a threshold occupies an upper bound varies with price limits and forms a trend under the same confidence level. Hence, a linear approach can be used to estimate the trend of percentage according to the trend that the percentages of the thresholds of the price limits of respectively 5% and 7% changes in the upper bound. First, when the price range is widened to $z\%$ in normal times, the percentage of the threshold of the $i\%$ confidence level in the upper bound ($NCValue\%_{z\%}^{i\%}$) will be estimated. The formula is listed as follows:

$$NCValue\%_{z\%}^{i\%} = NCValue\%_{x\%}^{i\%} + \frac{\left(NCValue\%_{y\%}^{i\%} - NCValue\%_{x\%}^{i\%}\right)}{y\% - x\%} \times (z\% - x\%) \tag{16}$$

Where $x\%$ is the original price range, $y\%$ is the changed price range, and $z\%$ is the target price range of an exchange. The estimated $NCValue\%_{z\%}^{i\%}$ and the upper bound of the threshold of the most accurate $z\%$ maintenance margin requirement are then used to reversely analogize the MMMR threshold

($NCValue_{z\%}^{i\%}$) of the $i\%$ confidence. The formula is listed as follows:

$$NCValue_{z\%}^{i\%} = NCValue\%_{z\%}^{i\%} \times NCValue\_Upper_{z\%} \tag{17}$$

The greatest advantage of the upper bound approach lies in that the upper bound of the MMMR obtained from the worst situation of two continuous business days is used as the anticipation criterion. In fact, the upper bound of the MMMR is the actual value of the extremest situation, it can be obtained without assuming any stock price behavior, and it can be regarded as the MMMR threshold under the 100% confidence. Therefore, the actual value is regarded as the estimation criterion, and the relationship between the base value and the MMMR thresholds of different levels of confidence are considered for anticipating the linear relational trend. Although the relationship is assumed as linear in this approach, the threshold of each MMMR is standardized into a percentage by the upper bound, which will make the estimation result more precise. Moreover, it is unnecessary to assume that the relationship between MMMR thresholds and price range is linear, that is, it is also possible to obtain a nonlinear relationship, so the possible point of fall of the threshold of the maintenance margin requirement under market volatility will be more precisely caught.

In addition, when critical domestic or international financial and political events caused Taiwan stocks to crash continuously, the competent authorities decreased the price range for many times, in which the price range was decreased to respectively 3% and 3.5%, and the volatility range was 0.5%. Thus, it was also estimated that the price range decreased from 10% to 4%, and the volatility range was 0.5% in abnormal time. Similarly, the percentage approach was employed to estimate the threshold of the maintenance margin requirement in abnormal times, and the MMMR thresholds in normal times were used as the criteria, so the estimated thresholds for abnormal times would be more referential. Hence, the MMMR thresholds in normal times were employed as the criterion in this paper, and the relationship between the MMMR thresholds in abnormal times

($ECValue_{Ej\%}^{i\%}$) and the MMMR thresholds in normal times ($NCValue_{j\%}^{i\%}$) under different confidence levels of 5% and 7% were considered in order to calculate the percentage ($ECValue\%_{Ej\%}^{i\%}$) that the MMMR thresholds in abnormal times occupied the threshold of MMMR when the price range changed from $j\%$ to $Ej\%$ under the $i\%$ confidence level. The formula is listed as follows:

$$ECValue\%_{Ej\%}^{i\%} = \frac{ECValue_{j\%}^{i\%}}{NCValue_{Ej\%}^{i\%}} \tag{18}$$

Based on the changes of the percentages that the thresholds in abnormal times occupied the thresholds in normal times ($ECValue\%_{Ej\%}^{i\%}$), a linear approach can be used to estimate the trend of percentage, the $z\%$ price range is anticipated becoming $Ez\%$ in abnormal times, and the percentage ($ECValue\%_{Ez\%}^{i\%}$) that the threshold in abnormal times occupied the threshold in normal times under the $i\%$ confidence level can be estimated. The formula is as follows:

$$ECValue\%_{Ez\%}^{i\%} = ECValue\%_{Ex\%}^{i\%} + \frac{\left(ECValue\%_{Ey\%}^{i\%} - ECValue\%_{Ex\%}^{i\%}\right)}{Ey\% - Ex\%} \times (Ez\% - Ex\%) \tag{19}$$

The estimated $ECValue\%_{Ez\%}^{i\%}$ and the MMMR threshold ($NCValue_{z\%}^{i\%}$) under the $z\%$ price limit and $i\%$ confidence in normal times were used to reversely estimate the MMMR threshold ($NCValue_{Ez\%}^{i\%}$) under the $i\%$ confidence when the price range decreased from $z\%$ to $Ez\%$. The formula is displayed as follows:

$$ECValue_{z\%}^{i\%} = ECValue\%_{Ez\%}^{i\%} \times NCValue_{z\%}^{i\%} \tag{20}$$

Similarly, this type of anticipation approach can be used to catch the non-linear relationship between MMMR thresholds of and price range in abnormal times, and the MMMR thresholds in abnormal times will be more precise when the values in normal times are used as the criteria in the estimation.

4. Empirical Result and Analysis

4.1 The Description of Sample Data

To make the MMMR threshold calculation precise and simultaneously include all the volatility of previous price range of Taiwan stocks, the data of this study were retrieved from the daily return data of the listed companies in the archive of TEJ after ex-rights and ex-dividend. The research period was from January 4, 1980[9] to December 31, 2010, totally 30 years. In the TWSE, there is not any limit of price range for new stocks within the first five days after being listed, so if the GARCH-jump model is applied to the estimation of parameters, it is easy to cause estimation errors, so they are excluded. Meanwhile, according to the Standards Governing Margin Purchase and Short Sale of Securities, the TWSE will announce that a common stock is allowed having margin purchase and short sale transactions after a common stock is listed for six months, there is not any abnormal phenomenon, such as drastic stock price volatility, excessive concentration of shareholding, or abnormal trading volume, the book value per share is more than the face value, and the number of units are more than sixty-million units. Therefore, newly listed companies can not obtain the qualification in the beginning. For the convenience of calculation, the samples and stocks which were listed for less than six months and whose capital was less than NT$600 millions were eliminated. Finally, the research days were 8,515 days in total, including 2,536 days with the price range of 5%, during which the price range was reduced to 3% for 297 days, unnecessarily continuous, and 5,604 days

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[9] This was the earliest data in the archive of TEJ.

with the price range of 7%, during which the price range was reduced to 3.5% for 78 days, unnecessarily continuous. To discover if futures maintenance margin requirements and securities MMMR result in different guaranties for futures brokers or credit institutions, products linked to the spots market of Taiwan stocks, such as the Large TAIEX, the Small TAIEX, the Taiwan 50 futures, the electronic futures, and the financial futures, were selected, and the day return data of the recent month were regarded as the calculation basis. The data were also retrieved from the archive of TEJ, and the data of futures maintenance margin requirements were manually sorted and retrieved from the official documents on the website of the Taiwan Futures Exchange about the adjustment of futures maintenance margin requirements. The data were compared by respectively two people in order to avoid mistakes.

4.2 The Estimation Result of the GARCH-jump Parameters

Before the variance-covariance approach was used to calculate VaR, a model with the feature of jumps was applied to the parameter estimation of the historical data of all the listed stocks. Table 1 displays the estimation result of the Taiwan stocks weighted index by means of the ARJI(1,1) and GARJI(1,1) models[10]. In terms of optimal model test, it was found in the Schwarz Criterion and the Likelihood ratio test that the GARJI model was better than the ARJI family model, and it was also shown in the LR test that the GARJI model was better than the ARJI family model. Furthermore, when the Q test statistic of Ljung-Box, indicating whether or not autocorrelation still existed among the residuals of the estimated models, was behind 15 periods, none reached any statistical significance except the ARJI-constant model. ρ and γ were both significantly different from 0 in the ARJI family model and the GARJI model. ρ is "persistence parameter," indicating that the arrival of jump events is considerably high. A greater ρ also represents that the effect of changes over time is significant. γ represents the influence of the residuals of jump intensity in early days. A greater value indicates

[10] The number of maximum jumps within a unit time was set as 20 times in this study. Please refer to Chan and Maheu (2002).

Table 1
The Estimation Values of the ARJI and GARJI Parameters

Parameter	Constant	*ARJI*	$ARJI-R_{t-1}^2$	$ARJI-h_t$	*GARJI*
μ	0.0985 (0.0142)	0.1017 (0.0152)	0.1069 (0.0154)	0.2393 (0.0157)	0.0072 (0.1256)
ϕ_1	0.0677 (0.0111)	0.0622 (0.0116)	0.0619 (0.0130)	-0.2221 (0.0308)	
ϕ_2	0.0042 (0.0107)	-0.0017 (0.0111)	-0.0027 (0.0113)	0.0105 (0.0113)	
ω	0.0010 (0.0032)	0.0106 (0.0027)	0.0101 (0.0025)	-0.0064 (0.0012)	0.0092 (0.0017)
β	0.9052 (0.0068)	0.9213 (0.0075)	0.9220 (0.0074)	0.9193 (0.0041)	0.9291 (0.0131)
α	0.0805 (0.0061)	0.0633 (0.0068)	0.0622 (0.0069)	0.0292 (0.0013)	-3.2341 (0.4235)
α_j					-1.4810 (0.2443)
α_a					1.6286 (0.3425)
$\alpha_{a,j}$					-1.0967 (0.2221)
ζ_0	1.5158 (0.1564)	1.5158 (0.1419)	1.4058 (0.1511)	-0.3134 (0.0352)	
ζ_1			-0.0198 (0.0388)	0.4547 (0.0239)	
λ_0	0.0845 (0.0223)	0.0212 (0.0063)	0.0291 (0.0080)	0.2189 (0.0154)	0.0221 (0.0067)
ρ		0.8015 (0.0624)	0.7736 (0.0642)	0.9278 (0.0075)	0.6672 (0.0012)
γ		0.4451 (0.1274)	0.6713 (0.1688)	-0.0935 (0.0754)	0.8178 (0.018)
η_0	-0.7259 (0.1949)	-0.7723 (0.1778)	-1.0864 (0.2138)	-0.0810 (0.0116)	0.2878 (0.0014)
η_1			0.3359 (0.1449)	0.1285 (0.0126)	
η_2			-0.2578 (0.0846)	0.0947 (0.0136)	
LGL	-14,599.00	-14,586.81	-14,578.10	-14,552.98	-6,266.23
SC	11,832.69	9,865.23	9,763.54	9,755.18	4,786.23
LR	10.74	25.67***	26.56***	34.12***	54.72***
$Q^2(15)$	35.19**	8.34	8.12	7.98	6.45

Note : The number inside the parentheses are the standard errors; LGL means Likelihood ratio test; SC indicates Schwarz Criterion; Q2 is the modified Q statistic.

that jumps cluster together. The estimation results were similar to Maheu and Mccurdy's (2004) and Chen and Sun's (2010) studies. The unconditional jump intensity was 0.166 according to [$E[\lambda_t \mid \Phi_t] = \lambda_0/(1-\rho)$], which was very close to the post-jump expectation, namely (λ_t =0.164), indicating that the jump expectations estimated by the GARJI model were not biased. The pre-jump variance accounted for 0.356 in the total return variance[11], namely 35% of the conditional variance could be regarded as the jump element. The result of American stocks was between 20% and 90% (Maheu and Mccurdy, 2004). Meanwhile, it indicates that the variation factors representing the GARCH model could only catch stable daily volatility, but the GARJI model could catch the volatility caused by sudden news in the market, which is in favor of an accurate estimation of the MMMR threshold when drastic changes occur in the market and further results and critical for guaranteeing accurate results. Overall, the GARJI model is better than the ARJI family model and the GARCH model in terms of the volatility estimation of Taiwan stocks. Therefore, GARJI(1,1) was employed to estimate the conditional variance of each stock to further calculate the VaR in this study.

4.3 Estimating Thresholds by VaR

In this study, the GARJI(1,1) model was first used to estimate the conditional variance parameters of individual stocks, and the VaR under the confidence of 99%, 95%, and 90% was respectively calculated and converted into the MMMR thresholds by means of Formulas (12) and (13). The estimation result is listed in Table 2. As expected, the higher the confidence is, the higher the MMMR threshold is. That is, the threshold of the 99% confidence was higher than the threshold of the 95% confidence while the threshold of the 95% confidence was higher than the threshold of the 90% confidence. In normal price range, (5% and 7%), the thresholds of different levels of confidence within the 7% price range were all higher than the thresholds with the 5% price range due to greater

[11] The formula: [$Var(\varepsilon_{2,t} \mid \Phi_{t-1}) / Var(r_t \mid \Phi_{t-1})$]。

Table 2

The Descriptive Statistics of the Return Thresholds of the Listed Securities in the TWSE

Price Limits	Confidence Level	Mean	S.D.	Min	Max
All Samples	99%	113.32%	5.29%	100.18%	143.76%
	95%	109.12%	3.51%	100.13%	128.36%
	90%	106.98%	2.65%	100.10%	121.14%
3.0%	99%	111.84%	2.21%	100.18%	125.33%
	95%	108.16%	1.49%	100.13%	116.99%
	90%	106.27%	1.13%	100.10%	112.89%
3.5%	99%	116.87%	4.98%	101.25%	136.95%
	95%	111.48%	3.28%	100.88%	124.25%
	90%	108.77%	2.46%	100.68%	118.18%
5.0%	99%	109.91%	4.78%	100.18%	128.08%
	95%	106.83%	3.23%	100.13%	118.74%
	90%	105.25%	2.46%	100.10%	114.17%
7.0%	99%	113.53%	5.25%	100.18%	143.76%
	95%	109.26%	3.48%	100.13%	128.36%
	90%	107.09%	2.62%	100.10%	121.14%

conditional variance. On the other hand, when the price range declined, the MMMR thresholds were all higher than the thresholds within the normal price range under different levels of confidence. For example, when the price range decreased from 7% to 3.5% (or from 5% to 3%), the MMMR thresholds within the decreased price range were all higher than the thresholds within the original price range. The reason should be related to the time-space environment in which the price range decreased. When special political or economic events occur, the competent authorities tend to take temporary measures to prevent investors from overreacting, which may cause stock prices to decline rapidly. When the stock market stabilizes, the authorities will adjust the range back to the original one, so the volatility of stock prices will be greater within the decreased price range. This is consistent with the hypotheses of Huang *et al*. (2001) and Cho *et al*. (2003) that investors tend to accelerate stock prices when they are close to price limits and result in overreaction. Kim and Rhee (1997) and Chen (1998) addressed that when stock prices reaches the upper price limit (lower price limit), the trends of the stock prices will continue on the next day likely since the information transfer hypothesis in which investors respond to the content of information causes great volatility in stock prices within a short time. When price range is widened in the future, impact caused by potential political and economic events are still inevitable. Hence, it is necessary to consider the maximum loss in abnormal times instead of depending on the MMMR estimated by means of the thresholds in normal times. Fortunately, the data for abnormal times were included in this study, which increased the reliability of this study.

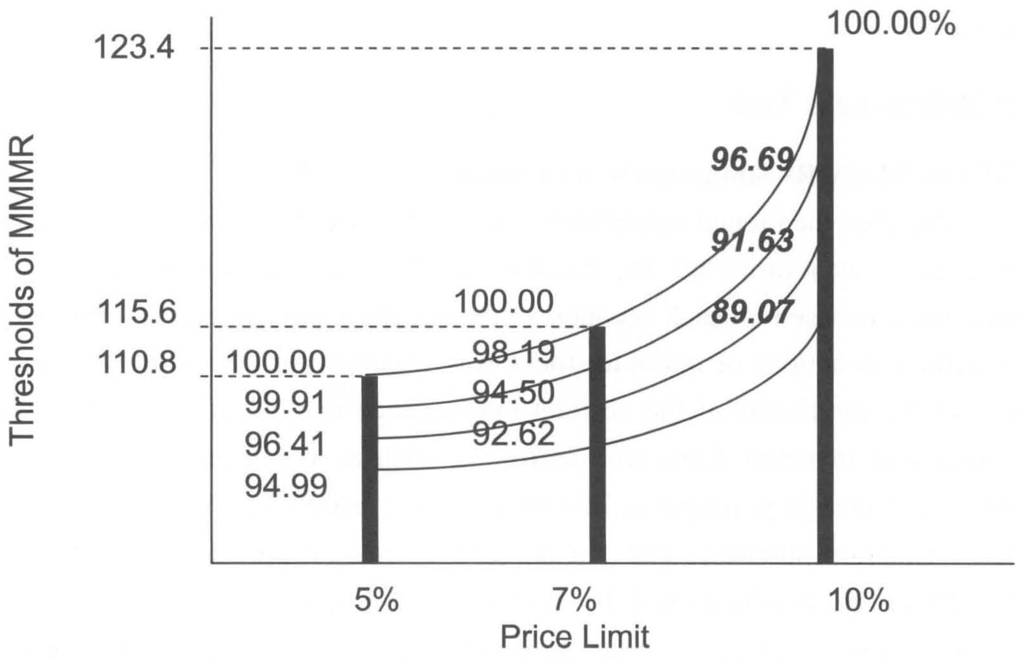
4.4 The MMMR Thresholds of the 10% Price Range Analogized by Different Levels of Price Range

According the MMMR thresholds of the price range of respectively 5% and 7% in normal times in Table 2, the upper bound percentage approach was used to estimate the thresholds of the maintenance margin requirements of the 10% price range. Table 3 displays the MMMR thresholds of the 10% price range under the confidence level of respectively 99%, 95%, and 90% by means of the upper bound percentage approach. It was found that although the MMMR threshold was 119.37 when the confidence was 99%, the threshold was still lower than the current MMMR of 120%, indicating the current MMMR of 120% can still ensure the claims safety of credit institutions. Figure 1 shows the non-linear relationship between MMMR thresholds and price limits. It was found that the lower the confidence is, the lower the percentage of the MMMR threshold is in the upper bound. For instance, when the price limit was 5%, the percentages of the thresholds of the confidence levels of 99%, 95%, and 90% in the upper bounds were respectively 99.91%, 96.41%, and 94.99%. More importantly, it was found that under the same confidence, the percentages of the thresholds in the upper bounds tended to decline. For example, when the confidence was 99%, the threshold of the 5% price limit accounted for 99.91% of the upper bound, but when the price limit became 7%, the threshold accounted for 98.19% of the upper bound. Similarly, the thresholds descended in the confidence of respectively 95% and 90%. Therefore, the descending trend of the percentages that the thresholds of the 5% and 7% price limits accounted for in the upper bounds were based, and a

Table 3
The Thresholds of New Price Range in Normal Times by the Upper Bound Percentage Approach

Confidence Level	Price Limits					
	5% Price Limits		7% Price Limits		Estimation of the 10% Price Limits	
	% of the Threshold in the Upper Bound	Threshold of MMMR	% of the Threshold in the Upper Bound	Threshold of MMMR	% of the Threshold in the Upper Bound	Threshold of MMMR
Upper Bound 100% C. Level	100%	110.80	100%	115.62	100%	123.46
99% C. Level	99.19%	109.91	98.19%	113.53	***96.69%***	***119.37***
95% C. Level	96.41%	106.83	94.50%	109.26	***91.63%***	***113.12***
90% C. Level	94.99%	105.25	92.62%	107.09	***89.07%***	***109.97***

Figure 1
The non-linear relationship between MMMR thresholds and price limits



linear approach was used to calculate the descending trend of the percentages. The hypothesis was linear in this approach, but each MMMR threshold was standardized into a percentage by the upper bound, so a non-linear relationship might exist between the finally obtained MMMR thresholds and price limits.

Similarly, based on the MMMR thresholds in normal times, the percentage approach was used to estimate the thresholds of the maintenance margin requirements in abnormal times. Table 4 shows the MMMR thresholds of the 4% price range in abnormal times under the confidence of respectively 99%, 95%, and 90% by means of the normal-time threshold percentage approach. It was found that the MMMR threshold in abnormal times was 124.3 only when the confidence was 99%, which is higher than the current MMMR, namely 120, indicating that the current 120% MMMR is only slightly insufficient in abnormal times. Moreover, if price range declined in abnormal times, under the price limits of 3%, 3.5%, and 4%, the upper bounds of the thresholds of the MMMR were respectively 106.28, 107.39, and 108.51, which were all lower than the current 120% MMMR. Consequently, when price range declines in abnormal times, the 120% MMMR is still sufficient to ensure the claims of securities and financial companies.

4.5 Robustness Test

4.5.1 The MMMRs Simulated by Portfolios

The aforementioned calculation of the MMMR thresholds was based on individual stock returns, but the calculation of the current maintenance margin requirement is based on each account, so the situation that an investor engages in the credit transactions of multiple stocks was simulated in this study in order to discover the thresholds of the account maintenance margin requirement. It was assumed that investors form nine portfolios, such as 1 margin purchase and 1 short sale, 1 margin purchase and 20 short sales, 1 margin purchase and 50 short sales, 20 margin purchases and 1 short sale, 20 margin purchases and 20 short sales, 20 margin purchases and 50 short sales, 50 margin purchases and 1 short sale, 50 margin purchases and 20 short sales, and 50 margin purchases and 50 short sales. The purpose of analyzing the nine portfolios is to simulate the volatility confronted by the portfolios of an account in different situations. For instance, when margin purchases and short sales are extremely unbalanced, the volatility confronted by the portfolios of an account will be different, so the threshold of the account maintenance margin requirement will also be different. The previously calculated individual stock parameters were used to establish the collateral value and claims value of each portfolio. Similarly, the expected volatility of two continuous days under different levels of price range and the 99% confidence were applied to the calculation of the portfolios in order to obtain the thresholds of account maintenance margin requirements and further analogize the threshold of the MMMR of each portfolio under the 10% price range for understanding the MMMR of each possible portfolio.

According to different levels of price range, the nine portfolios were respectively sampled for 100 times, and the statistics were then compiled[12]. The result is displayed in Table 5. The formulas for calculating the thresholds of margin purchases and short sales are different, such as Formulas (12) and (13). Hence, it was impossible to combine the portfolios and then compile the statistics of the thresholds. In addition, investors may only have investment in either margin purchase or short sale. Therefore, it is better to calculate them separately, so they are listed in two separate columns. Theoretically, the more constituent stocks there are in a portfolio, the better the non-systematic risk is dispersed, that is, the less constituent stocks there are, the higher the risk is. Meanwhile, the risk of possessing either margin purchases or short sales is higher than the risk of simultaneously possessing both margin purchases and short sales.

Panel A in Table 5 shows the statistic result of combining different levels of price range. It was found that in terms of margin purchase, when there was only one stock, the threshold tended to be high. For example, the Max threshold of Portfolio (1,50) was 116.61%, which was the highest, and the standard deviation (SD) of the threshold was higher. Furthermore, in terms of short sale, when there

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[12] According to the number of the stocks in the portfolios, they were randomly selected. The statistic volume of each random constituent stock was first calculated, and the statistic volume of 100 times was then calculated.

Table 4
The Thresholds of New Price Range in Abnormal Times by the Normal-Time Threshold Percentage Approach

Confidence Level	Price Limits					
	3% Price Limits		3.5% Price Limits		Estimation of the 4% Price Limits	
	% of the Abnormal-time Threshold in the Normal-time Threshold	Threshold of Abnormal-time MMMR	% of the Abnormal-time Threshold the Normal-time Threshold	Threshold of Abnormal-time MMMR	% of the Abnormal-time Threshold in the Normal-time Threshold	Threshold of Abnormal-time MMMR
Upper Bound 100% C. Level		106.28		107.39		108.51
99% C. Level	101.76%	111.84	102.94%	116.87	***104.13%***	***124.30***
95% C. Level	101.24%	108.16	102.03%	111.48	***102.82%***	***116.31***
90% C. Level	100.97%	106.27	101.57%	108.77	***102.17%***	***112.35***

Table 5

The Thresholds of Different Portfolios

Panel A: All Samples

Portfolios	Margin Purchase				Short Sale			
	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.
(1,1)	111.81%	109.41%	114.92%	2.02%	110.81%	110.36%	111.06%	0.27%
(1,20)	112.21%	109.10%	112.55%	1.09%	111.40%	110.95%	111.70%	0.25%
(1,50)	111.69%	107.44%	**116.61%**	2.86%	111.48%	111.19%	111.68%	0.17%
(20,1)	113.42%	112.60%	114.49%	0.60%	112.41%	111.02%	**114.00%**	0.73%
(20,20)	112.57%	111.79%	113.32%	0.61%	111.79%	111.43%	112.21%	0.29%
(20,50)	113.12%	112.43%	114.23%	0.53%	111.57%	111.30%	111.97%	0.23%
(50,1)	113.39%	112.64%	113.76%	0.30%	111.57%	110.11%	**114.00%**	1.39%
(50,20)	113.23%	112.78%	113.70%	0.35%	111.54%	111.07%	111.83%	0.24%
(50,50)	113.47%	113.13%	113.79%	0.22%	111.46%	111.25%	111.67%	0.13%

Note: The numbers inside the parentheses of the portfolios indicate the numbers of the margin purchase and short sale stocks.

Panel B: The Samples of the 5% Price Range

Portfolios	Margin Purchase				Short Sale			
	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.
(1,1)	111.43%	109.41%	**115.97%**	1.91%	110.82%	106.00%	**116.61%**	3.38%
(1,20)	109.38%	105.72%	115.86%	2.59%	108.83%	108.34%	109.31%	0.35%
(1,50)	109.37%	107.96%	113.23%	1.71%	108.88%	108.68%	109.20%	0.16%
(20,1)	110.03%	108.11%	111.28%	0.83%	110.76%	102.87%	115.29%	5.09%
(20,20)	109.82%	109.26%	110.49%	0.44%	108.63%	108.09%	109.21%	0.37%
(20,50)	109.97%	109.51%	110.72%	0.39%	108.92%	108.54%	109.16%	0.18%
(50,1)	109.91%	109.66%	110.17%	0.18%	104.91%	102.87%	109.21%	2.41%
(50,20)	109.87%	109.54%	110.22%	0.21%	108.88%	108.15%	109.42%	0.41%
(50,50)	109.99%	109.53%	110.84%	0.44%	108.82%	108.27%	109.16%	0.32%

Note: The numbers inside the parentheses of the portfolios indicate the numbers of the margin purchase and short sale stocks.

Panel C: The Samples of the 7% Price Range

Portfolios	Margin Purchase				Short Sale			
	Mean	Min	Max	S.D.	Mean	Min	Max	S.D.
(1,1)	111.88%	109.28%	114.84%	2.10%	110.87%	110.32%	112.07%	0.48%
(1,20)	112.14%	108.91%	112.50%	1.13%	111.56%	111.12%	111.89%	0.27%
(1,50)	111.72%	107.42%	**116.61%**	2.81%	111.62%	111.36%	111.81%	0.14%
(20,1)	113.41%	112.53%	114.46%	0.62%	112.42%	111.02%	**113.93%**	0.74%
(20,20)	112.73%	112.00%	113.61%	0.60%	111.81%	111.43%	112.21%	0.31%
(20,50)	113.30%	112.69%	114.36%	0.49%	111.69%	111.50%	111.96%	0.16%
(50,1)	113.54%	112.76%	113.83%	0.30%	111.54%	110.13%	**113.93%**	1.37%
(50,20)	113.39%	112.91%	113.82%	0.31%	111.63%	111.36%	111.83%	0.13%
(50,50)	113.71%	113.23%	114.07%	0.26%	111.73%	111.49%	111.91%	0.12%

Note: The numbers inside the parentheses of the portfolios indicate the numbers of the margin purchase and short sale stocks.

Table 6

The Thresholds of Portfolios within the 10% Price Range by the Upper Bound Percentage Approach

Portfolios	Estimation of the 10% Price Limits			
	Margin Purchase		Short Sale	
	% of the Threshold in the Upper Bound	Threshold of MMMR	% of the Threshold in the Upper Bound	Threshold of MMMR
(1,1)	91.06%	112.42	89.70%	110.75
(1,20)	94.40%	116.54	93.89%	115.91
(1,50)	93.50%	115.44	93.95%	115.99
(20,1)	96.26%	118.85	93.13%	114.98
(20,20)	95.08%	117.38	94.70%	116.92
(20,50)	96.11%	118.65	94.05%	116.11
(50,1)	96.71%	119.39	99.15%	**122.41**
(50,20)	96.44%	119.06	93.97%	116.02
(50,50)	96.97%	119.72	94.27%	116.38

Note: The numbers inside the parentheses of the portfolios indicate the numbers of the margin purchase and short sale stocks.

was only one stock, the threshold also tended to be high. For instance, the Max thresholds of Portfolios (20,1) and (50,1) were 114.0%, which was the highest, and the SDs were also higher than the SDs of the portfolios with 20 or 50 short-sale constituent stocks. It indicates that the threshold of the single-stock portfolio tends to be high, and the volatility tends to be great. Secondly, Panel B displays the statistic result of the 5% price range. The threshold of the single-stock portfolio was higher than the thresholds of other portfolios in terms of margin purchase and short sale. The margin-purchase and short-sale Max thresholds of Portfolio (1,1) were respectively 115.97% and 116.61, which were both the highest. Panel C shows the statistic result of the 7% price range. Similarly, the threshold of the single-stock portfolio was higher than the thresholds of other portfolios in terms of margin purchase and short sale. The margin-purchase Max threshold of Portfolio (1,50) was 116.61%, which was the highest while the short-sale Max thresholds of Portfolios(20,1) and (50,1) were both 113.93%, which was the highest. According to the results, the current 120% MMMR is still sufficient for the risk of credit institutions. The conclusion is similar to the conclusions of Chiu *et al.* (2004), Chou and Chen (2004), and Hung et al. (2005) that the 120% MMMR is sufficient for the risk of credit institutions within the 7% price range.

Similarly, it was assumed that price range was widened to 10%, and the upper bound percentage approach was used to estimate the thresholds of the maintenance margin requirements of different portfolios. Table 6 displays the thresholds of different portfolios under the 10% price range, which were estimated by the upper bound percentage approach. It was found that in terms of short sale, the threshold of the maintenance margin requirement of Portfolio (50,1) was 122.41%, higher than the current 120% MMMR. None of the thresholds of other portfolios exceeded the current 120% MMMR. It indicates that when the price range is widened to 10%, the 120% maintenance margin requirement only results in slight risk for the safety of credit institutions.

Table 7
The Descriptive Statistics Based on the Threshold Groups of Maintenance Margin Requirements

Price Range	Risk Group	N	Mean	S.D.	Min	Max
	L	7,517	109.73%	2.05%	100.16%	111.76%
3.0%	M	10,021	111.90%	0.47%	105.71%	113.31%
	H	7,516	113.88%	1.74%	106.30%	124.00%
	L	9,689	111.18%	2.29%	101.25%	114.95%
3.5%	M	12,917	116.70%	1.68%	106.79%	121.60%
	H	9,688	122.79%	2.48%	115.11%	137.04%
	L	51,811	104.92%	2.03%	100.16%	107.61%
5.0%	M	69,080	109.27%	1.33%	104.43%	112.53%
	H	51,810	115.79%	2.97%	105.80%	129.41%
	L	722,620	108.09%	1.54%	100.16%	111.93%
7.0%	M	963,493	112.77%	1.65%	104.98%	119.78%
	H	722,619	119.98%	3.77%	107.56%	133.43%

Note: Risk Group L indicates low risk (30%); M indicates medium risk (40%); H indicates high risk (30%)

4.5.2 The MMMRs of Stock Groups under Different Risks

In practice, investors may include highly risky constituent stocks in their portfolios and cause the contract-default risk to increase individually. Therefore, Anderson, Bollerslev, Diebold and Ebens's (2001) realized volatility was employed to classify the risks into three risk groups, respectively high risk, medium risk, and low risk[13], and the aforementioned approach was used to analogize the MMMR thresholds within the 10% price range in order to understand the differences between risk constituent stocks. The MMMR threshold of the expected high-risk group will be higher than that of the medium-risk group while the MMMR threshold of the medium-risk group will be higher than that of the low-risk group. Based on the 99% confidence, the statistics of the thresholds

[13] The statistic volumes of the three risk groups were respectively 30%, 40%, and 30%.

of the maintenance margin requirements within different levels of price range and in different risk groups were compiled, the result of which is displayed in Table 7. When the price range was 3.5%, the thresholds of the three groups were all higher than the thresholds within other levels of price range. In abnormal times in which the levels of price range were 3% and 3.5%, the thresholds of the three risk groups were all higher than the thresholds in normal times. The phenomenon further explained that when a particular event occurs, the volatility of Taiwan stocks will be higher than the volatility in normal times, that is, the risk will become higher. The period is also the time in which investors engaging in credit trading will highly likely have systematic contract breach, so it is very important to control risk by means of MMMR.

Table 8

The Grouping Results of the Thresholds of Maintenance Margin Requirements within the 10% Price Range by the Percentage Approach

Risk Group	Estimation of the 10% Price Limit			
	Normal Times		Abnormal Times	
	% of the Threshold in the Upper Bound	Threshold of MMMR	% of the Threshold in the Upper Bound	Threshold of MMMR
L	91.68%	113.19	101.13%	114.47
M	95.91%	118.41	104.56%	**123.81**
H	102.67%	**126.76**	106.33%	**134.79**

The percentage approach was used to further analogize the MMMRs under different risks in order to discover the MMMR which can ensure safety whenextreme risk occurs. The result is shown in Table 8. In the first column, the upper bound percentage approach was used to analogize the thresholds in normal times. The thresholds within the 10% price range were analogized by means of the thresholds within the 5% and 7% price range. Only the threshold of the high-risk group, namely 126.75, which is higher than the current statutory maintenance margin requirement, namely 120, indicating that when the price range is widened to 10%, it is necessary to simultaneously and appropriately increase the MMMR. In the second column, the normal-time threshold percentage approach was used to analogize the thresholds in abnormal times. The thresholds within the 4% price range were analogized by means of the thresholds within the 3% and 3.5% price range. The maximum thresholds of the medium-risk and high-risk groups were respectively 123.81 and 134.79, which are higher than the current statutory maintenance margin requirement, namely 120.

4.5.3 Comparing the Guarantees of TAIEX and Credit Trading

The margin trading system adopted in futures trading represents the promise of investors for futures trading contracts, and it is collateral for futures trading. The purpose is to be not only the guarantee that the contract will be fulfilled but also the capital of investors for settling the profit and loss when futures prices change. In other words, the collaterals of the future margin system and securities credit trading are both designed for increasing the financial leverage of investors and ensure the claims safety. It is just that the margin standard is based on an absolute amount of money (margin system) whereas the other is based on a ratio (maintenance margin requirement). Thus, the margin level of futures was converted into an account maintenance margin requirement in this study for the convenience of comparing it with the account maintenance margin requirement of securities credit trading. Aimed at futures trading, products linked to the spots market of Taiwan stocks, such as the TAIEX Futures, the Mini-TAIEX Futures, the Taiwan 50 Futures, the TSE Electronic Sector Index Futures, and the TSE Financial Sector Index Futures, were applied to the comparison, and the equivalent maintenance margin requirements in different price levels were respectively calculated.

For futures, the follow conversion formula was used to calculate the equivalent maintenance margin requirements of the TAIEX Futures, the Mini-TAIEX Futures, the Taiwan 50 Futures, the TSE Electronic Sector Index Futures, and the TSE Financial Sector Index Futures.

$$\begin{aligned}\text{Futures margin} &= (\text{The on-the-day closing price of futures} + \text{Futures account margin}) \\ &\quad - \text{The on-the-day closing price of futures} \\ &= \text{Futures collateral value} - \text{Futures claims value} \\ &\approx \text{Futures claims value} \times (\text{Account maintenance margin requirement} - 1)\end{aligned} \tag{21}$$

The following formula was obtained after transposition: ,

$$\begin{aligned}&\text{Equivalent maintenance margin requirement of futures}(FCV) \\ &= 1 + \frac{\text{Futures account margin}}{\text{The on-the-day closing price of futures}}\end{aligned} \tag{22}$$

Futures products were regarded as securities in this study. The GARJI(1,1) model was used to calculate the previous one-month data of the futures indexes in order to estimate the volatility and obtain the MMMR thresholds of the futures indexes. Table 9 displays the equivalent maintenance margin requirements of each futures index and the MMMR thresholds of the futures indexes under different levels of confidence. It was found that the MMMR thresholds of the futures indexes were all lower than the thresholds of securities credit shown in Table 2. Certainly, the equivalent maintenance margin requirements of the indexes is much lower than the statutory maintenance margin requirements of current security credit trading, namely 120%.

The marked-to-market approach is adopted in futures trading, so a futures company balances the daily position of each investor according to the closing price, and the floating profit and loss will then be directly added to the net value of the investor. There will be a margin call when the net value of a customer is lower than the level of the maintenance margin requirement. When the customer receives the call notice from the futures company, the customer has to add margin to make up the initial margin level. When the quotations continue to be unfavorable for the futures position of the customer and causes the net value of the customer to be lower than the maintenance margin requirement, and the customer can not make up the initial margin level in time, the futures company should avoid any possible loss caused by the contract breach of the customer

Table 9

The Thresholds of the Maintenance Margin Requirements of Futures

	N	Mean	S.D.	Min	Max
Panel A: Taiwan 50 Futures (T5F)					
FCV	1180	103.42%	0.66%	102.43%	105.92%
VaR(1-α= 99%)	1179	104.48%	1.50%	102.58%	113.10%
VaR(1-α= 95%)	1179	103.12%	1.03%	101.81%	108.92%
VaR(1-α= 90%)	1179	102.41%	0.79%	101.40%	106.82%
Panel B: TAIEX Futures (TX)					
FCV	1199	103.58%	0.72%	102.48%	106.28%
VaR(1-α= 99%)	1198	103.99%	1.81%	101.96%	112.50%
VaR(1-α= 95%)	1198	102.78%	1.24%	101.38%	108.53%
VaR(1-α= 90%)	1198	102.15%	0.95%	101.07%	106.52%
Panel C: Mini-TAIEX Futures (MTX)					
FCV	1180	103.42%	0.66%	102.43%	105.92%
VaR(1-α= 99%)	1179	104.48%	1.50%	102.58%	113.10%
VaR(1-α= 95%)	1179	103.12%	1.03%	101.81%	108.92%
VaR(1-α= 90%)	1179	102.41%	0.79%	101.40%	106.82%
Panel D: TSE Electronic Sector Index Futures (TE)					
FCV	1180	103.47%	0.76%	102.37%	106.84%
VaR(1-α= 99%)	1179	104.36%	1.76%	102.42%	111.59%
VaR(1-α= 95%)	1179	103.04%	1.20%	101.70%	107.93%
VaR(1-α= 90%)	1179	102.35%	0.92%	101.32%	106.07%
Panel A: TSE Financial Sector Index Futures (TF)					
FCV	1180	103.96%	0.94%	102.74%	107.82%
VaR(1-α= 99%)	1179	105.09%	2.39%	102.22%	115.22%
VaR(1-α= 95%)	1179	103.53%	1.62%	101.56%	110.30%
VaR(1-α= 90%)	1179	102.73%	1.24%	101.21%	107.85%

Note: FCV is the equivalent maintenance margin requirement of futures.

resulting from exhausted margin. Thus, the company has the right to place a stop order in order to offset the futures position of the customer before the margin is exhausted. Therefore, futures are of an immediate stop-loss function. However, for securities credit trading, securities companies can only place a stop order in two business days after sending the margin call notice in order to avoid the credit trading settlement default of investors.

For the convenience of comparing the claims security in both TAIEX Futures and Spots, a standardized approach was used in this study to calculate credit security degree as follows:

$$\begin{aligned}&\text{Immediate stop - loss futures credit security degree\%}\\&=\frac{\text{Equivalent maintenance margin requirement of futures} - \text{MMMR threshold of futures}}{\text{MMMR threshold of futures}}\times 100\%\end{aligned} \tag{23}$$

$$\begin{aligned}&\text{Two - trading - day credit trading security degree\%}\\&=\frac{120\% - \text{MMMR threshold of securities credit trading}}{\text{MMMR threshold of securities credit trading}}\times 100\%\end{aligned} \tag{24}$$

Futures have an immediate stop-loss function, so futures companies can immediately settle the position of a customer within a trading day and highly timely prevent the claims from being eroded. Nevertheless, in terms of securities credit trading, a customer just needs to add margin to make up the margin level in two trading days after the maintenance margin requirement reaches the current statutory 120% MMMR. Although they are both standardized by the credit security degree formulas, their guarantee periods are different. Hence, to make their comparison bases more consistent, the approximate immediate security that the 30-minute trading of securities credit transactions provides was calculated. The approximate security of 30-minute trading = the security of two business days / 18 business half-hours[14]. The purpose is to assume the security when securities

[14] There are 4.5 business hours in a business day.

credit trading also has an immediate stop-loss function, like futures, and a security company can settle the position of a customer immediately.

The calculation results of Formulas (23) and (24) are listed in Table 10. Panel A in Table 10 shows respectively the credit security degrees of securities credit trading during different security trading periods and under different levels of confidence. Panel B in Table 10 shows the credit security degrees[15] of futures. It was found that the two-business-day credit security degrees of securities credit trading were all higher than the credit security degrees of futures. The finding is similar to the finding of Chou and Chen (2004) that the margin ratio of futures is lower than the theoretical value. According to Chou and Chen (2004), the main reason is that the security period of securities credit trading has to maintain for two business days, but futures trading has an immediate stop-loss function. Therefore, the security of a shortened security period of securities credit trading was converted in this study in order to simulate an immediate stop-loss function in securities credit trading. It was found that the approximate security of half-hour securities credit trading is similar to the security of futures trading. The reason is to assume that the credit trading of an investor can also be cleared within half an hour in securities credit trading, which will be similar to the security of stop-loss liquidation in futures. It implies that if securities companies also have the right to place an immediate stop order, the current statutory 120% MMMR of securities credit trading and the current margin ratio of futures are barely different in terms of security.

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[15] Futures exchanges set the margin standards in order to cover the market risks, and they apply the risk price coefficient to the calculation. The so-called risk price coefficient is an value estimated by referring to the price range over a period of time, which can cover one-day price volatility and 99% confidence. Hence, when futures exchanges calculate previous price data and find that the volatility becomes bigger, they will increase the margin standards. It is thus very possible that when the volatility increases, a futures exchange does not increase the margin standard, yet, and thus causes the estimated immediate trading security of index futures to be negative under the 99% confidence.

Table 10

The Security Comparison between the Futures Market and the Securities Trading Market

Panel A: The Security of Securities Credit Trading

Confidence Level	All Samples	3%	3.5%	5%	7%
The Security of two Business Days					
99%	5.89%	7.30%	2.68%	9.18%	5.70%
95%	9.97%	10.95%	7.64%	12.33%	9.83%
90%	12.17%	12.92%	10.32%	14.01%	12.06%
The Approximate Security of 30-Minute Trading					
99%	0.33%	0.41%	0.15%	0.51%	0.32%
95%	0.55%	0.61%	0.42%	0.68%	0.55%
90%	0.68%	0.72%	0.57%	0.78%	0.67%

Panel B: The Immediate Security of Futures Trading

Confidence Level	Taiwan 50 Futures (T5F)	TAIEX Futures (TX)	Mini-TAIEX Futures (MTX)	TSE Electronic Sector Index Futures (TE)	TSE Finance Sector Index Futures (TF)
99%	-1.01%	-0.40%	-1.01%	-0.85%	-1.08%
95%	0.29%	0.77%	0.29%	0.43%	0.41%
90%	0.98%	1.39%	0.98%	1.10%	1.20%

5. Conclusion and Suggestion

The setting of a MMMR is highly related to active market transactions and trading safety. Excessively high maintenance margin requirements will effectively protect the claims of credit institutions, but they strangle the quality of stock market trading. Similarly, the price range of a stock market is also highly relevant to the quality of stock market trading, and it directly influences the volatility of a stock market. When the volatility increases, the risk of the claims of credit trading will increase. In particular, a fixed ratio system is applied to the current MMMR, so it is a critical issue whether or not the MMMR should be adjusted when the price range is widened in the stock market. Nevertheless, in terms of the relationship between price range and MMMR, previous research was only focused on empirically verifying if the MMMR is sufficient to ensure the safety of credit trading (eg. Chiu *et al.*, 2004; Chou and Chen, 2004; Hung *et al.*, 2005). Thus, this paper can be used to compensate for the lack and, meanwhile, provided to policy makers as a reference to the setting of the optimal MMMR when they widen the price range of Taiwan stocks.

The variance-covariance approach was used in this study to estimate VaR as the threshold of the MMMR. Back testing is adopted in this approach, which increases the research reliability. The influences of good news and bad news on ROA are differentiated in the GARJI model (Maheu and McCurdy, 2004), which improves the disadvantage that the GARCH model can only catch smooth movements but not sudden changes affected by news. In a smooth credit trading period, credit institutions should be able to sustain incidental contract-default cases. However, when sudden news affects a stock market, it is easy to cause a great deal of contract-default risk, which will further cause systematic contract-default risk in the credit trading market. Based on this practical perspective, the estimated parameters of the GARJI model with the element of jumps are more reliable than those of the GARCH model. According to the comparison, the GARJI model is better than the GARCH model and Chan and Mauheu's (2002) ARJI model adopted by a lot of scholars in Taiwan in the past.

There were two types of price range, respectively 5% and 7%, in the history of Taiwan stocks. In addition, the price range ever decreased to 3% and 3.5% due to political and economic events. The periods of four price range values were used in this study to respectively estimate the MMMR thresholds. Then, based on the upper bound of the thresholds of maintenance margin requirements, the percentage that each threshold occupied the upper bound was employed to analogize the referential MMMR threshold under the 10% price range in order to understand if the 120% MMMR will sustain the volatility when the price range is widened to 10%. Meanwhile, to obtain a more robust result, the investment strategies possibly adopted by investors were employed to simulate the portfolios of different margin purchase and short sale positions. According to the realized volatility suggested by Anderson *et al.* (2001), the risks were divided into three groups, namely high risk, medium risk, and low risk, to respectively examine the current MMMR threshold. Moreover, the MMMR and the margin system of the futures market have the same economic function. Thus, the credit security degree was designed in this study for comparing their guarantees for creditors (futures brokers and credit institutions).

In terms of the influence of stock price limits on volatility, theoretically, the wider the price range is, the greater the volatility is. The empirical result of this study showed that in the times of normal price range (5% and 7%), when the price range was 7%, the volatility was greater, so the thresholds under different levels of confidence were all higher than the thresholds within the price range of 5%. However, when the price range decreased due to political and economic events, the volatility was higher than that in the normal times, so the thresholds were higher than those in the times of normal price range, indicating that when a stock market is affected by particular events, the systematic risk should be considered when the MMMR is set. The percentage approach based on the upper bound of the thresholds of maintenance margin requirements was employed to analogize the MMMR thresholds under different levels of confidence after the price range was widened to 10% in normal times (price range: 5% and 7%). Furthermore, based on the normal times, the MMMR thresholds were analogized after the price range was widened in abnormal times (3% and 3.5%). It was found that only the result under the 99% confidence was slightly higher than the current 120% MMMR in abnormal times. However, the upper bound of the thresholds in abnormal times was also lower than 120% due to the reduced price range. Consequently, the claims of credit institutions can still be secured if the price range decreases in abnormal times.

Investors having credit transactions may use different portfolios and cause different risks. Based on different periods of price range, nine portfolios were applied to the statistics by random sampling in this study. The empirical result showed that when the price range was widened to 10%, the MMMR threshold of the portfolio with a single position was slightly higher than the current 120% MMMR. It means that when the price range is widened to 10%, the security of the claims of credit institutions may be slightly insufficient. On the other hand, when an investor intensively invests in highly risky individual stocks, the individual contract-default risk may also increase accordingly. The empirical result also supported that when the price range was widened to 10%, the current 120% MMMR would also be insufficient for ensuring the contract-default risk of credit institutions. In summary, the MMMR estimated by VaR showed that when the price range was widened to 10%, the current 120% MMMR would not completely ensure the contract-default risk of investors. Therefore, it is suggested that policy makers should also adjust the MMMR when widening the price range of the stock market.

The credit security degree was brought up in this study for the security comparison between the claims of spots and futures since TAIEX Futures and Spots are linked. The result showed that the credit security degree of the two-business-day securities credit trading was much higher than the immediate credit security degree of futures. It is probably because the marking-to-market approach is applied to the futures market, which is timelier, and the margin call system takes less time than securities trading, so fewer margins is required in the futures market. Hence, the security of a shortened security period of securities credit trading was converted in order to simulate the stop-loss function of securities credit trading. It was found that the approximate security of timely securities credit trading was similar to the security of futures trading.

This study can be provided to policy makers as a reference to the supporting measures of credit trading, which is one of the critical contributions of this study. In the recent decade, the ARJI model or the GARCH model has been applied to all the statistic research on the volatility of return on asset in Taiwan. It was proved in this study that the estimation of the GARJI model is better than the estimations of other models, which is another contribution of this study. The credit trading of both futures and spots provide investors greater financial leverage in terms of investment. In addition to the highly related targets, the economic functions are also the same. Therefore, the credit security degree brought up in this study can be used to compare the claims security of the financial leverage of investors, which is the other contribution of this study.

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