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Examining Trading Duration of TAIEX Index: Impact of 2008 Price-Down-Limit Policy

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Abstract

This study looks into the global financial crisis caused by the subprime crisis in 2008, which also triggered the global stock market crash, by adopting the EACD model developed by Engle and Russell (1998). In this study, the researchers probe into the relationship between the trading duration and trading volume of TAIEX under three categories of traders – natural person, futures proprietary merchant (FPM) and foreign institutional investor (FINI), as well as the relation of trading duration and trading volume to returns before, during and after Taiwan's implementation of the narrowed price down limit of 3.5%. The empirical results show that: 1. trading duration is sustainable when traders are FPMs; 2. trading volume of TAIEX is indeed influenced by the narrowed price down limit, and trading volume increases considerably after the limit is lifted, with the magnitude of increase in descending order being FPMs, natural persons and FINIs; 3. regarding the relation between trading duration and trading volume of TAIEX before, during and after the implementation of the narrowed price down limit of 3.5%, a significant negative relation is shown for natural persons and FPMs only, while no significant relation is shown for FINIs; as for the relation of trading duration and trading volume to returns, no significant relationship is shown for FPMs before and during the implementation, and for FINIs after the implementation.

Keywords: Trading duration; Price limit; ACD model; Cubic spline

I. Introduction

In the financial securities market, trading data tend to show irregular pattern of trading durations. Subject to the constraint of information technology in relation to financial economics in the past, financial markets used to adopt a data selection criterion based on a fixed trading duration, for example, one piece of data per five or fifteen minutes. In the stock market, transactions of relatively popular stocks could be completed every few seconds. Consequently, such analysis of trading data has the drawback of failing to take into account thoroughly some data input in the financial asset market. That is why Engle and Russell (1995) developed a model of trading data at irregular time intervals, for finding out the correlation between each piece of trading data, and recording each piece of trading data upon price changes for research purpose. With the rapid development of computer technology and storage memory, in addition to the diversified information transmission channels, the speed of information transmission has been greatly enhanced. News from whatever distances could be transmitted and disseminated within very short time. Therefore, with the ever-increasing speed of information inflow and outflow in the investment market, information could be easily disclosed in the market, and the time required to respond to news becomes shorter and shorter, leading to increasingly vigorous economic activities in the market. Thus, by studying the time required to complete each transaction, one may glimpse at and understand the situation of information entering the financial market.

As Taiwan's financial market internationalizes and liberalizes, the percentage of foreign fund in the local securities market has been escalating. Apart from hedging, traders partake in the futures market also for the purposes of speculation, arbitrage, and spread trading, etc. Taiwan relaxed the investment restrictions on foreign professional investment institutions in 1990, and hence foreign funds were initially allowed to engage directly in local futures trade with the purpose of hedging. On March 27, 2006, Financial Supervisory Commission (FSC) further opened the local futures market to foreign funds for non-hedging direct investment, in the hope to increase foreign funds' desire to partake in Taiwan's futures market. This helps the internationalization of Taiwan's futures market, and enhances our market's visibility and scale in the international arena, not to mention the effect of boosting trade in the futures market, and hence enabling more effective price formation, so that Taiwan's futures market can be deepened and broadened. Furthermore, overseas foreign funds were also allowed to engage indirectly in local futures trade via an omnibus account at the same time, simplifying the procedures by which foreign funds may participate in Taiwan's futures market. It would also offer a faster and more convenient channel for overseas Chinese and foreigners to partake in Taiwan's futures market.

When it is known that the trading duration of a sample may change at different points of time and with different market mechanisms, one may further ask how a change of the price limit in the financial market imposed by the government would affect trading activities in the futures market, and hence the length or speed of the trading duration would be explored. Trading activities in the stock market are most active after opening and before closing of the market, but tend to slow down during the middle of the market time. Similarly, such transaction clustering is even more obvious in the forex market. All forex markets around the world have the busiest trading activities after opening of the markets, but the activities become most meager in the forex market before closing. A noteworthy phenomenon is that trading activities usually show irregular trading durations. However, we may often observe sudden outbreak of a great quantities of transactions in the market, and this may be attributable to new information entering the market or pure transactions not backed by any information.

If a trading duration of 1 hour is taken as the standard for sample selection in a study, Taylor (2004) pointed out, when extraordinary volatility of the original sample data occurs in a certain period during the trading time, the selected data may not even show any fluctuation during that trading time. Furthermore, when a shorter trading duration is taken, it may result in inclusion of unnecessary information, and thus causing inconsistent variance of the research sample. Therefore, in order to avoid the above circumstances, the trading duration model should stress the time interval between the points of time when the previous and the next transactions emerge, while no assumption should be made about the sampling frequency.

Anderson, Bollerslev and Das (1998) believe that picking a piece of data at a frequency of five minutes will most unlikely distort the irregular time series. But selecting data in this way may prevent the real message that the market wishes to convey from being integrally revealed by the selected data. In view of this, Engle and Russell (1998) developed a model for studying the trading data with irregular trading durations: the autoregressive conditional duration (ACD) model, to probe into the correlation between each piece of trading data.

Taylor (2004) mentioned that Engle and Russell's (1998) ACD model shows a negative relation between the expected trading duration and the volatility of conditional return. This negative relation also reveals that expected price changes will become quicker when the expected trading duration shortens, and the vice versa. Thus, by confirming the trading duration through the ACD model, this model will be a good way to interpret the volatility of conditional return.

One of the characteristics of financial data is the extremely high frequency. Therefore, from Taiwan Futures Exchange one may obtain the trading data of Taiwan's futures market in every second. The advantage of using extremely high-frequency data, apart from having a greater quantity of data samples than low-frequency data, is that they may reveal the real market condition more comprehensively. The relatively greater degree of freedom of the extremely high-frequency data may also avoid the possible bias of a small sample.

Bauwens and Giot (2000) studied the price durations of three NYSE-listed stocks – Boeing, Walt Disney and IBM. In order to explore the nature of trade, they introduced other explanatory variables into the ACD model, including trading intensity, average trading volume and average bid-ask spread, etc., and studied their effect on price duration. Easley and O'Hara (1992), Engle and Russell (1998) studied the trading data of IBM stock, and further explored the relationship between the ACD model and the theoretical hypothesis of market microstructure; other explanatory variables were added in the EACD model, including trading intensity, bid-ask spread and average trading volume. Taylor (2004) took the FTSE 100 futures contracts traded in London International Financial Futures and Options Exchange (LIFFE) as the subject of study, and introduced other explanatory variables in the ACD model which include price deviation, bid-ask spread and trading volume; the TACD model developed by Zhang et al. (2001) was also applied, and the result showed that the three explanatory variables under study play critical roles in influencing trade activities. That is, the greater the trading volume, the shorter the trading duration; the smaller the trading volume, the longer the trading duration. Many empirical studies found that by adding other explanatory variables, their decisive role on the trade activities would be discovered, and therefore, this study also considered adding other explanatory variables to understand how they might affect trade activities.

In face of the global stock market crash, Taiwan stocks could not escape the catastrophe of course, not to mention that the stock market had plunged more than NT$13 trillion since August 2008, i.e., almost NT$1 trillion drop in every 2 weeks. The speed of the collapse was comparable to the bubble bursting of technology stocks in 2000. Therefore, FSC promulgated the implementation of 3 measures. Firstly, for the two weeks from October 13 to 24, 2008, the price down limit for the stock market was adjusted down from the original 7% to 3.5%, while price up limit remained at 7%. Secondly, short sales were entirely prohibited from October 14, 2008 extending to December 31, 2008, but put warrants issued by securities firms before September 30, 2008 and short sold as required for hedging were not subject to this restriction. Thirdly, National Financial Stabilization Fund (NFSF) agreed to continue the intervention in the stock market for one month. This study reviewed the government's price limit measures on the stock market and futures market during the period from October 13 to October 24, 2008, that is, narrowing the price down limit from the original 7% to 3.5%, while keeping the price up limit unchanged at 7%. In this study, this policy's impact on different investors' TAIEX trading activities before, during and after the implementation of the 3.5% price down limit were discussed.

Engle and Russell's (1998) EACD model was adopted in this study to review the price limit measures implemented on the stock and futures markets by the government during the period from October 13 to October 24, 2008. Three types of traders – general investors (commonly known as individual or retail investors), i.e., natural persons, futures proprietary merchants (FPMs), and foreign institutional investors (FINIs) – are discussed in this study, to see if their TAIEX trading activities have significant difference before, during and after the implementation of the narrowed price down limit of 3.5%: (1) Examine if the trading durations for the three types of traders, i.e., natural persons, FPMs and FINIs, in the TAIEX trade are auto-correlated. That is, whether autocorrelation exists between the expected trading duration and the past trading duration; (2) With the EACD empirical model, examine traders in the TAIEX market – natural persons, FPMs and FINIs – to understand the relationship between their trading durations and trading volumes; (3) With the EACD empirical model, examine traders such as natural persons, FPMs and FINIs, and compare their trading volumes and trading durations of TAIEX before, during and after the implementation of the narrowed price down limit of 3.5%.

II. Literature Review

Literature review for this study is distinguished into two main parts: firstly, reviewing literature relating to the studies of price limits; secondly, reviewing literature relating to the studies of autoregressive conditional duration (ACD) model. Both cover the review of local and international literature.

II.1 Literature relating to price limits

Lee and Kim (1995) studied the trading data of Korea's stock market to explore the relationship between price limits and return volatility of stocks in the local market. Data were ranked according to the price limit percentages, and the high price limit portfolio (HPLP) and low price limit portfolio (LPLP) were defined; return volatility of the two were then compared. The empirical result showed that with the company-specific risks being controlled, price limits can reduce volatility of stock prices.

Thomas and Hwang (1995) studied the trading data of Japan's securities market to discuss whether implementation of price limits will affect volatility of stock prices. On the basis of the opening and closing prices in two trading days, the daily returns were calculated for comparison and verification. The empirical result showed that only frequently traded stocks will have a greater price volatility calculated from the daily opening price than that calculated from the closing price. Moreover, two variables, namely price dispersion of the opening price and price adjustment of the closing price, will affect the structure of stock price volatility. Since the intensity of trading volume is related to the above two variables, price limits will thus have significant influence on the price volatility structure in Japan's stock market. Also, price limits have different degrees of influence on stocks with different trading volumes.

Kim and Rhee (1997) examined the relevant hypotheses of price limits on market efficiency with the stock data of Tokyo Stock Exchange. The empirical result did not support such hypotheses as the delayed price discovery process, volatility spillover hypothesis and trading inference hypothesis. That means price limits not only delay the price discovery process, but also fail in reducing volatility, and may even increase volatility after the price limits are lifted. Their conclusion thus does not support the implementation of the price limits policy.

Kim and Limpaphayom (2000) studied the prices and returns in daily trading data and monthly trading data of Taiwan's and Thailand's stock markets from 1990 to 1993. The generalized method of moments (GMM) and quintile were used to analyze and explain the characteristics of individual stocks that are more susceptible to price limits in the two countries' stock markets: stocks of higher risk are more likely to reach the price limits; trading volume is positively related to the frequency of reaching the price limits; company size and scale is negatively related to the frequency of reaching the price limits; variables considered that are likely to affect a stock's property of reaching the price limits include Beta, residual risk, trading volume, book-to-market ratio and scale, etc. Research result showed that daily trading data of both Taiwan and Thailand stock markets display uniform distribution, but neither calendar effect nor industry effect exists, and so price limits do not have a relatively weak influence on the markets. This contradicts with people's perception in the past.

With the trading data of Korea's stock market, Berkman and Lee (2002) probed into the effect that price limits make on the market. The empirical result showed that if the price limits were relaxed, the market volatility would be heightened, reducing the overall trading volume of the market. In addition, it was also pointed out that such influence has a greater effect on the stock of relatively smaller companies. Researchers also made possible explanations for the reasons why emerging markets prefer using price limits.

Chen, Kim and Rui (2005) studied the effect of price limits on A shares and B shares with the trading data of China's stock market. The empirical result showed that under the same price limits, prices of B shares are more likely to reach the price limits. On the other hand, price limits on stocks with poorer liquidity need to be relaxed.

Wang, Liu and Zeng (2008) studied the magnet effect of price limits on stock market with the trading data of Shanghai's stock market. The empirical result showed that when a stock price approaches the price limits, volatility of trading volume and price will increase, pushing the stock price towards the price limits more rapidly. Moreover, it was also pointed out that when a stock price reaches the price limits, the trading volume and trading size will be lower than the general market trade level, but the bid-ask spread will be bigger.

Wu and Zhou (1996) used the method of Gibbs sampler to study price limits' effect on the risk and return of stocks in Taiwan's stock market after the implementation of the price limits. The empirical result revealed that price limits have a cooling effect, and the effect is more obvious in holding back the plunge down to the limit. Evidence showed that the cooling effect and magnet effect are asymmetric.

Hu and Liang (1995) studied price limits' impact on volatility of Taiwan's stock market by using the GMM. Based on the three adjustments of price limits by Taiwan Stock Exchange in 1987, 1988 and 1989, the empirical result found no consistent evidence that may demonstrate the price stabilizing effect of price limits, and adjusting price limits had no consistent influence on volatility of the stock market. But the study did find some evidence that shows price limits may affect the hypothesis of trade operation.

Tseng (1998) conducted a research on the effect of Taiwan's stock price limits on the efficiency of the securities market. Data of daily volatility of 367 listed companies' share prices were studied by non-parametric analysis. The result showed that despite price limits' effective control on daily volatility of stock prices, they will cause over-volatility of stock prices afterwards. Moreover, price limits have no preventive effect against over-reaction of stock prices, but will delay the discovery of equilibrium price instead.

Hong (2001) examined whether there is significant difference in the futures market's lead over the stock market due to economic levels under the implementation of the narrowed price down limit. After the launch of TAIEX, Taiwan had implemented a narrowed price down limit for five times, for different reasons in each occasion. They can be distinguished into three categories based on the economic level: foreseeable economic factor, foreseeable non-economic factor and unforeseeable natural disaster. The empirical result showed that: (1) Implementation due to natural disaster was required because the 921 Earthquake had brought considerable uncertainties about the future. Investors in the futures market had divergent views about the future, and there was no major change in price within the short term. That is why the futures market failed to lead the stock market, or even the stocks were leading the futures instead; (2) implementation due to non-economic factor (political factor) involves a lot of unpredictable outcomes and uncertainties, and so futures' lead over stocks is not obvious. Only Taiwan index futures or electronics index futures lead over stocks, but the effect is not as strong as the economic factor; (3) implementation due to economic factor usually occurs when economic data are announced. At this time, the index futures market's lead will intensify significantly, and the market information will enter the futures market before the stock market, resulting in the futures significantly leading the stocks. In addition, it is found that when the local stock market is affected by the poor international market performance, the futures' lead over the stocks will be even stronger, because the international spillover effect and the investors' anticipation will cause the information of a country passing to other countries.

Huang (2002) studied two groups of data – those reaching the price limits and those approaching the price limits – in different industries and made comparative analysis on three hypotheses. Binomial test was used to verify the delay price discovery hypothesis; based on the volatility index and liquidity index, Wilcoxon non-parametric test was used to examine the volatility spillover hypothesis and trading interference hypothesis. The empirical result showed that in whatever industry, price limits will delay the equilibrium price discovery, and cause volatility spillover as well as interference with trade, resulting in reduced liquidity and interference with trade on the day of the event.

Chen (2007) made the trade of listed stocks in Taiwan the subject of his study, and studied whether investors would over-react to price limits in the market and discussed the impact of market volatility. The result found that there is over-reaction to the stock price after it reaches the price limits, and the over-reaction to low- and medium-priced stocks, stocks of small-scale companies and non-technology stocks is stronger than that to other types of stocks. The reason for the stronger over-reaction may be generated from information asymmetry. Over-reaction to stocks being locked at the limit (share price at the limit when the market closes) is stronger than that to non-locked stocks. It was also found that at the time of market crash, over-reaction to stocks reaching the down limit is even stronger, leading to highly volatile share price. Therefore, the price limits set by the government are unable to achieve the intended effect.

II.2 Literature relating to autoregressive conditional duration (ACD) model

Engle and Russell (1998) proposed the concept of trading duration based on the irregular time between two consecutive transactions, and developed the ACD model in 1995. But when price changes are the subject of study, the trading duration refers to the time interval between two consecutive price changes. In 1998, they studied the trading data of IBM stock, trying to confirm the existence of autocorrelation and clustering phenomenon, and verify the market microstructure hypothesis by applying the price duration. The empirical result showed significant estimated values for α and β parameters in both EACD(1,1) and EACD(2,2) models, and the value of $\alpha+\beta$ approximates 1, representing a very strong continuity of the trading duration. The trading duration showed roughly an inverted U shape before the periodic adjustment, representing a relatively higher frequency of transactions after opening and before closing, while the frequency significantly dropped by noon. It was also found that the WACD model of Weibull distribution is more in line with the actual data distribution than the EACD model of exponential distribution.

Bauwens and Giot (2000) made the price durations of NYSE-listed Boeing, Walt Disney and IBM stocks the subjects of their study. The Logarithmic ACD model was used for the study and for comparison with the ACD model. The study found that the LACD has got rid of the non-negative condition of the linear ACD model, that is, the estimated value of parameters may be negative. This is beneficial to testing hypotheses about the market microstructure. It was verified that data with relatively high trading intensity, trading volume and bid-ask spread, etc. would shorten the expected trading duration. This result is consistent with the hypothesis of Easley and O'Hara (1992).

Zhang, Russell and Tsay (2001) developed the threshold ACD model to work around the over-dispersive property of the non-linear data and errors, and the distribution of errors was assumed. Again, the trading duration of IBM stock was studied. It was found that the trading duration showed a non-stationary state, and there were entirely different dynamic patterns for rapid and slow trading weeks. Using the three explanatory variables – bid-ask spread, trading volume and price volatility for verification, vigorous market situation may be attributed to market participants who grasp new information. On the contrary, a slack market may result from the absence of new information.

Taylor (2004) studied the FTSE 100 futures contracts of LIFFE, and discussed the three explanatory variables – price error, bid-ask spread and trading volume. It was found that bid-ask spread and trading volume have significant negative relation with trading duration, while degree of information asymmetry in the market is positively related to return volatility. A bigger difference between the market price and formula price of futures will lead to greater intensity in the trading time afterwards, and vice versa. The research result showed that when there is a bigger price error in the market, the intensity of trading activities will be greater afterwards, implying that hedgers' trading activity is the major cause of price difference between stocks and futures.

Fernandes and Grammig (2006) combined some of the common characteristics of the ACD and GARCH, and adopted Hentschel's (1995) method of developing the asymmetric GARCH family. The ACD family was developed from the process of conditional duration via Box-Cox conversion and asymmetric reaction to impulse, with the restrictive conditions well established by means of higher order moments, and this is the augmented ACD (AACD) model. In this model, the process of trading duration is limited to strict stationary, geometric ergodicity, and it must be β-mixing property with exponential decay. By the power λ in the duration process, the recurrence relation of moments and auto-covariance function are deduced. The empirical result showed that models proposed in the past literature failed to find a good fit for trading data of IBM stock. Also, after observing parameters of different ACD models, it was found that the impulse reaction curve shows the property of a concave function, which is not unique to IBM; similar situation is also seen in the trading data of other research subjects.

Meitz and Terasvirta (2006) proposed the smooth transition ACD (STACD) model and an ACD model with parameters varying with time (time-varying ACD; TVACD). In the STACD model, a transfer function is added in the conditional duration equation to solve the problem of the linear ACD model making prediction of exceedingly long expected duration after extremely short and extremely long duration. This model is similar to the threshold ACD model, with the only difference in the STACD's structural transfer being continuous while the TACD's structural transfer is interrupted. On the other hand, the TVACD model allows parameters to vary with the passage of intra-day time; that is, the model allows intra-day pattern in the duration series.

With the trading data of Morgan Stanley Capital International Taiwan Index Futures (MSCI-TW), Chen (2001) used the ACD model together with the hypothesis of Weibull distribution for conditional probability distribution of errors to explore the length of trading duration required for price changes and the information reaction phenomenon. The result showed significant autocorrelation in the trading durations required for price changes. The expected trading duration derived from the WACD(1,1) model and the past return can significantly explain the current yield arising from the price change at the time of appropriate extent of price change (around 0.5 tick of stock index). That is, the longer the trading duration, the higher the investors' expectation on returns, and this result accords with the concept of time premium. The relationship between information reaction and trading duration in the market can be explained by using the inverse relationship between the price volatility and trading duration; that is, the more vigorous the price volatility, the shorter the trading duration is required.

By considering two variables – trading volume and bid-ask spread simultaneously, Hsieh (2003) developed the trading duration process using the ACD model, and explored the impact of decimalization in the American Stock Exchange on the exchange traded funds (ETFs) by using the augmented ACD model. Hsieh probed further into the varying relationship between ETF and ETF-corresponding index futures. The empirical result showed that the trading duration and bid-ask spread of ETFs declined significantly after decimalization, but the trading volume did not increase with the declined trading duration and bid-ask spread. Therefore, decimalization may not necessarily bring about increased liquidity, and it may not have the same significant effect on the index futures. It was also found that the bid-ask spread and trading volume are negatively and significantly related to the subsequent trading durations. It is also believed that there may be a front-running phenomenon in the process of ETF transactions.

Hsieh (2006) studied the financial market data of extremely volatile days in 17 Asian and European countries which had experienced financial turmoil in the 1990s. The points of time with huge volatility in the exchange rates and total market indexes were taken as the proxy variables for the occurrence of extreme financial volatility in the market. The ACD family models – EACD(1,1), WACD(1,1), GACD(1,1) and BoxCox ACD models – were used to predict the point of time when financial crisis may possibly occur in the future. The empirical result found that all four types of ACD models are capable of lowering the Ljung-Box statistical value, with the Box-Cox ACD model performing the best. Among the other three models, the EACD(1,1) model that assumes the exponential distribution for the residual terms, represents the most appropriate hypothetic distribution for analyzing extreme financial volatility.

Li (2006) studied the persistence of limit-hit durations of Taiwan stocks. Engle and Russell's (1998) autoregressive conditional duration model was used to assess if there is autocorrelation between limit-hit durations in Taiwan's stock market under the price limits on Taiwan stocks, and whether there exists a significant relationship between the past limit-hit duration and the expected limit-hit duration as well as the future expected limit-hit duration, so as to make reasonable prediction about the trading duration in which the limits may be hit in the future. Also, the existence of autocorrelation in the duration for hitting the up limit and the duration for hitting the down limit was also discussed respectively. By adopting the five variables that may affect stocks' proneness to the price limits used by Kim and Limpaphayom (2000), Li's study further explored whether the five variables have significant explanatory power for the coefficients in the ACD model as well as the average limit-hit duration. The empirical result revealed that the interpretation of the properties of coefficients α and β in the ACD model is not comprehensive, but the average limit-hit duration does have relatively significant explanatory power.

Wu (2007) reviewed the augmented ACD family models and conducted an empirical study on the trading data of Taiwan stocks. According to the empirical result, price duration is highly auto-correlated and has calendar effect. Results of the parameter estimates showed that differences exist between various models of the augmented ACD family. Moreover, conditional price durations in various models all show Markov process of geometric ergodicity and strict stationary state, while β-mixing displays exponential decline property. If the models' fitness is assessed by the log likelihood estimate, AIC value and SBIC value, then the asymmetric ACD model, i.e., the linear ACD model with impulse reaction function of asymmetric effect existing in the model, has the best performance. On the other hand, the Burr distribution is found to be the most appropriate hypothetic distribution for the test of the residual hypothesis.

Li (2008) made use of Taiwan's trading data of limit-hit durations in Taiwan's stock market, and conducted empirical analysis with the augmented ACD family models and smooth transition ACD model developed by Fernandes and Grammig (2006) and Meitz and Terasvirta (2006) respectively. The empirical result found high autocorrelation for anterior and posterior limit-hit durations. Results of parameter estimates in various models showed that differences do exist between different ACD models. In addition, if the models' fitness is assessed by the log likelihood estimate, AIC value and SBIC value, then the smooth transition ACD (STACD) model outperforms others, meaning that the STACD model has a better effect in grasping the dynamic process of limit-hit duration.

III. Methodology

III.1 Autoregressive conditional duration model

Engle and Russell (1998) found in the data of trading information that long trading duration usually follows long trading duration, and short trading duration follows short trading duration. This characteristic is similar to the autocorrelation of market volatility, and they developed the autoregressive conditional duration model accordingly to study the irregularity of trading duration.

Put the time change series representing a certain market characteristic as $\{t_1, t_2, ..., t_n\}$, where $t_1 < t_2 < \cdots < t_n$, then the trading duration can be defined as $x_i = t_i - t_{i-1}$, that is the time interval between two transactions, where t_i is the time when the *i*th transaction occurs. And the conditional expected duration ψ_i for the *i*th transaction can be expressed as:

$$E(x_i | x_{i-1}, x_{i-2}, ..., x_1) = \psi_i(x_{i-1}, x_{i-2}, ..., x_1; \theta) \equiv \psi_i \quad \text{(3-1)}$$

The above illustration is known from the ensemble of information of all the past trading durations, and the expected value of trading duration is called the conditional expected duration. If it is further assumed that

$$x_i = \psi_i e_i \quad \text{(3-2)}$$

where residual term e_i conforms to $i.i.d$; the probability density function for formula (3-2) is $p_i(e;\phi)$; e and ϕ are parameters to be estimated. It is known from the above formula (3-2) that conditional expected duration is subject to the influence of the past trading duration.

In order to deduce the generalized conditional density function, $\lambda_0(t)$ is set to be the Baseline Hazard Function independent of any conditional information. It can be defined as:

$$\lambda_0(t)=\frac{P_0(t)}{S_0(t)} \quad \text{.. (3-3)}$$

where P_0 is the probability distribution of residual terms; S_0 is the survival function of the residual terms.

The generalized conditional density function of the ACD model can be expressed as follows:

$$\lambda(t\,|N(t),t_1,\ldots,t_{N(t)})=\lambda_0\left(\frac{t-t_{N(t)}}{\psi_{N(t)+1}}\right)\frac{1}{\psi_{N(t)+1}} \quad \text{..................... (3-4)}$$

Formula (3-4) above expresses that historical information in the past affects the conditional density of the baseline hazard function via the additive effect and movement. If the trading duration is proved to be the conditional expected duration, then the baseline hazard function is 1, and the conditional density function is:

$$\lambda(t\,|N(t),t_1,\ldots,t_{N(t)})=\frac{1}{\psi_{N(t)+1}} \quad \text{........................... (3-5)}$$

Formula (3-5) above shows the reciprocal of the conditional expected duration.
When considering m lagged trading durations and n lagged conditional expected durations, the ACD model can be expanded n times to be infinite ACD(m,n) models. This can be expressed as the following linear function:

$$\psi_i=\omega+\sum_{j=1}^{m}\alpha_j x_{i-j}+\sum_{j=1}^{n}\beta_j\psi_{i-1} \quad \text{............................. (3-6)}$$

The above illustrated that the conditional expected duration of the *i*th transaction is jointly determined by the *m*th trading duration and the *n*th conditional expected duration, and this is called the ACD(m,n) model. In this model, restrictive conditions include $\omega>0$, $\alpha=(\alpha_1,\alpha_{2,}\cdots\alpha_m)\geq 0$, $\beta=(\beta_1,\beta_{2,}\cdots\beta_n)\geq 0$, $\alpha+\beta\leq 1$, which ensure the stability of the random process. The last condition ensures the existence of unconditional mean of the trading duration, while other conditions ensure a positive conditional expected value of the trading duration. It can be seen from formula (3-6) that the ACD model and GARCH model have highly similar pattern; the difference lies in that the GARCH model describes the clustering of volatility, while the ACD model describes the clustering of trading durations.

III.2 Cubic spline method

The most common method for making intra-day adjustment of sample data is the Cubic Spline method used by Engle and Russell (1998) and Meitz and Terasvirta (2006).

Cubic Spline method removes the intra-day factor in the trading durations, so that the trading durations in the sample approximate the average duration. This intra-day adjustment process was also adopted in this study to make intra-day adjustment of the sample. First of all, the trading time in a day was divided into segments of 30 minutes, that is, 8:45-9:15, 9:15-9:45… and 13:15-13:45, etc. Thus, the daily trading time was cut into 10 segments, and the average trading duration in each segment was calculated. Finally, the sample data were fitted with the Cubic Spline using the following formula:

$$\phi(t_i)=\sum_{j=1}^{10}I_j\left[c_j+d_{1j}(t_i-k_j)+d_{2j}(t_i-k_j)^2+d_{3j}(t_i-k_j)^3\right] \quad \text{........ (3-7)}$$

where t_i is the time of each transaction; k_j is the beginning time of each segment; I_j is the pointer variable for the *j*th segment of Spline, and that means when $k_j\leq t_i<k_{j+1}$,

$I_j = 1$, while $I_j = 0$ in other conditions; c_j is the average trading duration between k_j and k_{j+1}; d_{1j}, d_{2j} and d_{3j} are the parameters to be estimated; $\phi(t_i)$ is the intra-day factor.

Then, the original trading duration was divided by the intra-day factor in this study to get the intra-day adjusted trading duration. This intra-day adjusted duration is also called the transfer trading duration.

III*3.3 ACD-X model*

When considering m lagged trading durations and n lagged conditional expected durations, the ACD model can be expanded into infinite-phase ACD models. The ACD model is expressed as follows:

$$x_{z,i} = \psi_{z,i} e_{z,i} \quad \text{(3-8)}$$

$$\psi_{z,i} = \omega_z + \sum_{j=1}^{m} \alpha_{z,j} x_{z,i-j} + \sum_{j=1}^{n} \beta_{z,j} \psi_{z,i-j} \quad \text{(3-9)}$$

where $x_{z,i}$ is the *i*th trading duration for trader type *z*, $\psi_{z,i}$ is the *i*th conditional expected duration for trade type *z*, $e_{x,i}$ is the *i*th residual for trader type *z*. Restrictive conditions include $\omega > 0$, $\alpha = (\alpha_1, \alpha_{2,} \cdots \alpha_m) \ge 0$, $\beta = (\beta_1, \beta_{2,} \cdots \beta_n) \ge 0$, $\alpha + \beta \le 1$ in order to ensure the stability of the random process. The last restrictive condition ensures the existence of unconditional mean for trading durations, while other restrictive conditions ensure a positive conditional expected value of trading durations.

When trading volume is added into consideration, the ACD model becomes the ACD-X-a model. The ACD-X-a model is expressed as follows:

$$x_{z,i} = \psi_{z,i} e_{z,i} \quad \text{(3-10)}$$

$$\psi_{z,i} = \omega_z + \sum_{j=1}^{m} \alpha_{z,j} x_{z,i-j} + \sum_{j=1}^{n} \beta_{z,j} \psi_{z,i-j} + \gamma_z V_{z,i-1} \quad \text{(3-11)}$$

where $V_{z,i-1}$ is the *i-1*th trading volume for trader type *z*.

When the trading volume and rate of return are added into consideration, the ACD model becomes the ACD-X-b model. The ACD-X-b model is expressed as follows:

$$x_{z,i} = \psi_{z,i} e_{z,i} \quad \text{(3-12)}$$

$$\psi_{z,i} = \omega_z + \sum_{j=1}^{m} \alpha_{z,j} x_{z,i-j} + \sum_{j=1}^{n} \beta_{z,j} \psi_{z,i-j} + \gamma_z V_{z,i-1} + \kappa_z R_{z,i-1} \quad \text{(3-13)}$$

where $R_{z,i-1}$ is the rate of change for the *i-1*th price for trader type *z*.

IV. Analysis of Empirical Results

In this study, the existence of autocorrelation for trading durations of TAIEX is explored, and then the relationship between trading duration and trading volume in the TAIEX market is explored with the EACD model. In this chapter, the data processing method is explained in three sections, supported with empirical results and analyses. First of all, the first section explains the source of data, subject of study and the sampling time; secondly, the second section presents the descriptive statistical analysis of the sample data; and finally, the third section presents the analysis of results from the empirical model.

IV.1 Source of data and subject of study

Data in this study come from the daily trade statistics of Taiwan Futures Exchange, and are distinguished by traders' identity. The subject of the daily trade statistics is Taiwan stock index futures, and the subject of Taiwan stock index futures trade is Taiwan Stock Exchange Capitalization Weighted Stock Index (TAIEX). Value of the futures contracts is TAIEX times NT$200, and the margin is about 8% of the contract value. Since November 10, 2008, only 50% of the margin at maximum can be pledged against securities, and only three types of securities are eligible: 1. Centrally registered bond (except strip bond) to be valued at 5% discount. 2. International bond in foreign currencies, to be valued at 10% discount off the market price, including bonds issued by Deutsche Bank and BNP Paribas Taiwan and traded in OTC now. 3. Taiwan 50 Index Stocks and underlying stocks of equity options, to be valued at 30% discount off the market price (totally 57 listed stocks now). The current daily price limits are 7%. The contract months for futures trade are the two consecutive months from the transaction month, plus three consecutive months in one of the March, June, September and December quarters, and the final transaction day and settlement day is the third Wednesday of the delivery month. It is stipulated that for stock index futures and options contracts, the way to determine the final settlement price is changed to the simple arithmetic average price at 1:00-1:30 p.m. on the third Wednesday, and the settlement price is announced at 3:00 p.m. At the same time, the closing time on the settlement day is also changed to 1:30 p.m. The above new system of settlement came into practice on December 17, 2008, and settlement is to be made in cash.

Subjects of study are investors who trade in the TAIEX market, that is, three types of traders are selected – natural persons, FPMs and FINIs. The three types of investors are compared, and the relationship between their individual trading durations and trading volumes are observed before, during and after the implementation of the narrowed price down limit of 3.5%.

The study is divided into three segments, that is, the periods before, after and during the implementation of the narrowed price down limit on the futures market. The restrictive measures is to narrow down the existing price down limit from 7% to 3.5%. The sampling time for the period before the policy implementation is from October 1 to October 12, 2008, for the period during the implementation of the narrowed price down limit is from October 13 to October 24, 2008, and for the period after the implementation is from October 25 to November 5, 2008. Empirical tests were conducted in the first, second and third periods sequentially as mentioned above. Moreover, the numbers of data acquired through individual sampling for the three types of investors – natural persons, FPMs and FINIs – were, in sequence, 380,572, 92,513 and 28,416 in the first period; 355,960, 95,516 and 33,831 in the second period; and 639,320, 195,932 and 36,911 in the third period.

IV.2 Descriptive statistics of sample data

Most time-series data in financial studies are characterized by leptokurtic distribution (kurtosis coefficient $k > 3$). In this study, three types of traders are distinguished. Although individual sample sizes in each type seem relatively small compared to the total trading volume, the leptokurtic distribution characteristic is still seen for individual sample data. Statistical tables and charts are given below for explanation.

Table 4-1 lists the trading durations of TAIEX in Period I: basic statistics (before the narrowed price down limit 2008/10/1~2008/10/12), including mean, standard deviation, coefficient of skewness, kurtosis coefficient, Jarque-Bera normal test statistics and sample size.

In terms of the mean, individual investors (i.e., local natural persons) have the shortest average trading duration (0.1291 second), followed by FPMs, and FINIs have the longest trading duration (1.7663 second). Standard deviations for natural persons, FPMs and FINIs are 0.1893, 0.6236 and 2.0742 respectively, revealing that FINIs have the largest standard deviation, meaning greater volatility. The coefficients of skewness for all three types are positive, representing a distribution with the end extending rightward (right skew), and all are significant. Thus, it can be seen that relatively more data skewed towards one side during this research period, that is, to the right side. As for the coefficients of excess kurtosis, all are greater than 0 and significant, representing a distribution peaking around the mean, with rapidly declining slopes, resulting in the phenomenon of leptokurtosis. Therefore, the distributions of trading duration data for all three types of traders during Period I are right skewed and kurtic. In addition, as shown in the Jarque-Bera normal test, they all have high J-B values, particularly natural persons who have the highest value of 160,975.6312, and all three types showed a significance level of 0.01, meaning significant refusal to follow the normal distribution. In terms of the sample sizes, it can be seen that the trading volumes in this period are 380,572, 92,513 and 28,416 respectively, with natural persons recording the highest number of contracts traded.

Table 4-1 Basic statistics for TAIEX trading durations – the period before the narrowed price down limit

Type	Mean	S.D.	Min.	Max.	Skewness	Kurtosis	J-B value	Sample size
49	0.1291	0.1893	0.0000	0.7700	1.4768***	1.1948***	160,975.6312***	380,572
50	0.6164	0.6236	0.0000	2.5500	1.2183***	0.6578***	24,551.9316***	92,513
65	1.7663	2.0742	0.0000	8.6970	1.5368***	1.5241***	13,935.3062***	28,416

Notes: 1. Unit (second). 2. Type: 49 is for natural persons, 50 for FPMs, and 65 for FINIs. 3. J-B value is the Jarque-Bera normal test statistics, and Chi-square distribution is with degree of freedom equaling 2. Null hypothesis is that test variables follow normal distribution. 4. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Table 4-2 lists the trading durations of TAIEX in Period II: basic statistics (during the narrowed price down limit period 2008/10/13~2008/10/24), including mean, standard deviation, coefficient of skewness, kurtosis coefficient, Jarque-Bera normal test statistics and sample size.

In terms of the mean, individual investors (i.e., local natural persons) have the shortest average trading duration (0.1358 second), followed by FPMs, and FINIs have the longest trading duration (1.4458 second). Standard deviations for natural persons, FPMs and FINIs are 0.1996, 0.6389 and 1.7260 respectively, revealing that FINIs have the largest standard deviation, meaning greater volatility. The coefficients of skewness for all three types are positive, and FINIs have the largest coefficient (1.5941). All three types have a distribution with the end extending rightward (right skew), and all are significant. Thus, it can be seen that relatively more data skewed towards one side during this research period, that is, to the right side. As for the coefficients of excess kurtosis, all are greater than 0 and significant, representing a distribution peaking around the mean, with rapidly declining slopes, resulting in the phenomenon of leptokurtosis. Therefore, the distributions of trading duration data for all three types of traders during Period II are right skewed and kurtic. In addition, as shown in the Jarque-Bera normal test, they all have very high J-B values, particularly natural persons who have the highest value of 163,858.0118, and all three types showed a significance level of 0.01, meaning significant refusal to follow the normal distribution.

In terms of the sample sizes, it can be seen that the trading volumes in this period are 355,960, 95,516 and 33,831 respectively, with natural persons recording the highest number of contracts traded. Comparing the trading volumes of Period II and Period I, only natural persons' trading volume reduced by 24,612 among the three types of traders, while those of the others increased, and overseas FINIs' trading volume increased by 19% which is a greater increase than FPMs'. Therefore, an inhibiting effect is seen on the trading volume of natural persons during the implementation.

Table 4-2 Basic statistics for TAIEX trading durations – during the narrowed price down limit

Type	Mean	S.D.	Min.	Max.	Skewness	Kurtosis	J-B value	Sample size
49	0.1358	0.1996	0.0000	0.7800	1.5169***	1.3579***	163,858.0118***	355,960
50	0.6251	0.6389	0.0000	2.6400	1.2270***	0.6920***	25,873.7193***	95,516
65	1.4458	1.7260	0.0000	7.5660	1.5941***	1.8477***	19,141.1583***	33,831

Notes: 1. Unit (second). 2. Type: 49 is for natural persons, 50 for FPMs, and 65 for FINIs. 3. J-B value is the Jarque-Bera normal test statistics, and Chi-square distribution is with degree of freedom equaling 2. Null hypothesis is that test variables follow normal distribution. 4. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Table 4-3 lists the trading durations of TAIEX in Period III: basic statistics (after the narrowed price down limit 2008/10/25~2008/11/05), including mean, standard deviation, coefficient of skewness, kurtosis coefficient, Jarque-Bera normal test statistics and sample size.

In terms of the mean, individual investors (i.e., local natural persons) have the shortest average trading duration (0.0821 second), followed by FPMs, and FINIs have the longest trading duration (1.5042 second). Standard deviations for natural persons, FPMs and FINIs are 0.1190, 0.3209 and 1.6024 respectively, revealing that FINIs have the largest standard deviation, meaning greater volatility. The coefficients of skewness for all three types are positive, and natural persons have the largest coefficient (1.3897). All three types have a right-skew distribution, and all are significant. Thus, it can be seen that relatively more data skewed towards one side during this research period, that is, to the right side. As for the coefficients of excess kurtosis, all are greater than 0 and significant, representing a distribution of leptokurtosis. Therefore, the distributions of trading duration data for all three types of traders during Period III are right skewed and kurtic. In addition, as shown in the Jarque-Bera normal test, they all have very high J-B values, particularly natural persons who have the highest value of 229,101.5440, and all three types showed a significance level of 0.01, meaning significant refusal to follow the normal distribution.

The sample sizes experienced the greatest change during this period. The respective trading volumes are 639,320, 195,932 and 36,911 respectively. Number of contracts traded increased for all types of traders during this period, with natural persons still recording the greatest number of contracts traded. Analysis of the magnitude of increase is as follows: 1. For natural persons, the trading volume in Period III had 1.8-fold and 1.68-fold increases from Period II and Period I respectively. And the trading volume of Period II decreased by 24,612 compared to Period I, because implementation of the restriction aimed at encouraging rational thought among general investors and abating the plunging trend of the market; 2. The absolute number of transactions by FPMs seemed relatively small, but they actually had the greatest increase as calculation shows. Transactions in Period III increased about 2.05 times and 2.12 times from Period II and Period I. The increase in trading volume may be due to the decline in their risk exposure level; 3. Transactions by FINIs also increased progressively and they had the least magnitude of increase.

Table 4-3 Basic statistics for TAIEX trading durations – the period after the narrowed price down limit

Type	Mean	S.D.	Min.	Max.	Skewness	Kurtosis	J-B value	Sample size
49	0.0821	0.1190	0.0000	0.4400	1.3897***	0.9354***	229,101.5440***	639,320
50	0.3273	0.3209	0.0000	1.2970	1.0679***	0.2875***	37,912.7682***	195,932
65	1.5042	1.6024	0.0000	6.8100	1.3396***	1.0752***	12,817.4221***	36,911

Notes: 1. Unit (second). 2. Type: 49 is for natural persons, 50 for FPMs, and 65 for FINIs. 3. J-B value is the Jarque-Bera normal test statistics, and Chi-square distribution is with degree of freedom equaling 2. Null hypothesis is that test variables follow normal distribution. 4. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Figure 4-1 to Figure 4-8 are the intra-day charts of daily trading durations at 15-minute interval for the three types of TAIEX traders – natural persons, FPMs and FINIs before, during and after the implementation of the narrowed price down limit. The restrictive measures refer to the narrowing of the original price down limit from 7% to 3.5%, while keeping the price up limit unchanged at 7%. Period I refers to the time before implementation of the policy: October 1 to October 12 of 2008; Period II refers to the time during implementation of the narrowed price down limit: October 13 to October 24 of 2008; and Period III refers to the time after the implementation: October 25 to November 5 of 2008.

It can be seen from Figure 4-1, with traders being local natural persons, that a transaction occurred in TAIEX market in every 0.1125 second at shortest before the implementation of the narrowed price down limit in 2008. A roughly U-shape chart can be seen from the distribution. That is, the TAIEX market had busier transactions at 12:15 (within 0.11~0.115 second) and 13:00 (trading durations are short); and the trading durations during other time segments are longer.

In Figure 4-2, the intra-day factor in the trading duration is removed by applying Cubic Spline, so that trading durations in the sample approximate the average duration. It is shown in Figure 4-2 that before the implementation of the narrowed price down limit, a transaction occurred in the TAIEX market every 0.955 second at shortest. Transactions are more frequent in the TAIEX market after opening (0.954 second), around 10:45 (0.97 second) and at closing (about 0.98 second) (trading durations are short). A roughly inverted U-shape chart is seen, and this agrees with the research result of Engle and Russell (1998), whose trading duration chart also showed an inverted U shape.

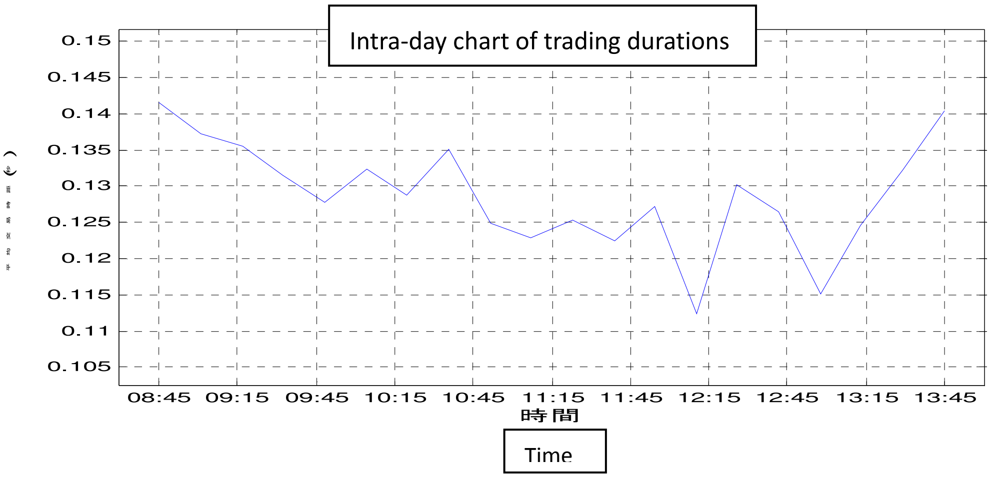

Figure 4-1 Intra-day chart of trading durations — natural persons 2008/10/01~10/12 before adjustment

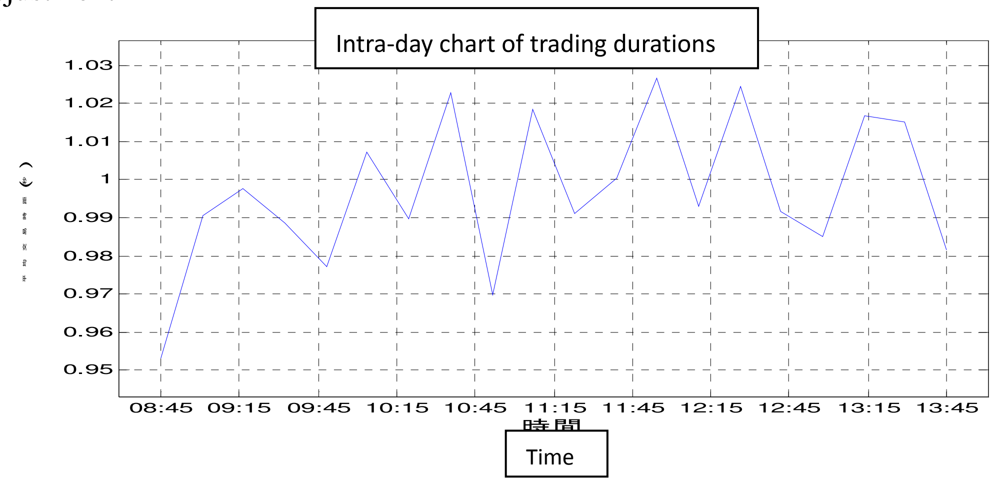

Figure 4-2 Intra-day chart of trading durations — natural persons 2008/10/01~10/12 adjusted

It can be seen from Figure 4-3 below, with traders being local natural persons, that a transaction occurred in TAIEX market in every 0.12 second at shortest in Period II during the implementation of the narrowed price down limit in 2008. A roughly U-shape chart can be seen from the distribution. That is, the TAIEX market had busier transactions at 12:45 (about 0.12 second) and 13:15 (0.12 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-4 shows the adjusted trading durations chart and it can be seen that during the implementation of the narrowed price down limit (i.e., Period II), a transaction occurred in the TAIEX market every 0.94 second at shortest. Transactions are more frequent in the TAIEX market after opening (within 0.94 second), around 11:45 (within 0.97 second) and at closing (about 0.99 second) (trading durations are short). Thus, a roughly inverted U-shape chart of trading durations is seen, and this agrees with the research result of Engle and Russell (1998).

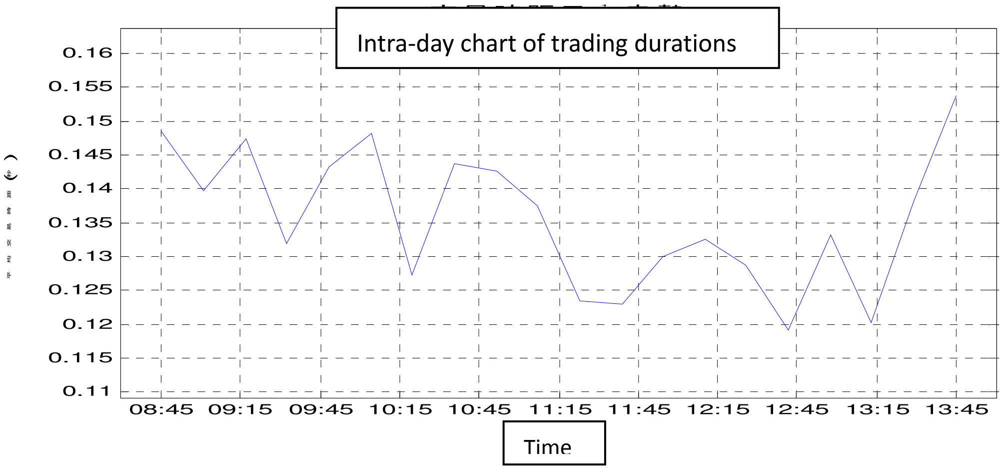

Figure 4-3 Intra-day chart of trading durations — natural persons 2008/10/13~10/24 before adjustment

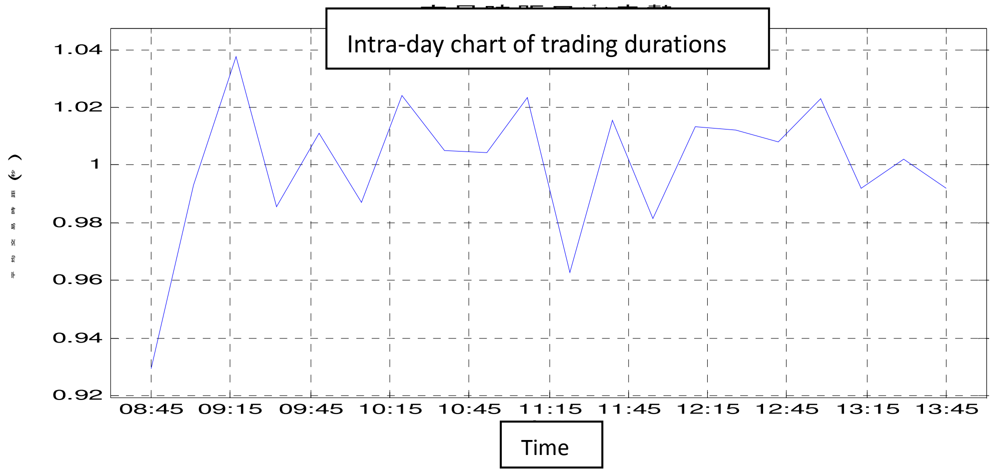

Figure 4-4 Intra-day chart of trading durations — natural persons 2008/10/13~10/24 adjusted

It can be seen from Figure 4-5 below, with traders being local natural persons, that a transaction occurred in TAIEX market in every 0.07 second at shortest in Period III after the implementation of the narrowed price down limit in 2008. A roughly U-shape chart can be seen from the distribution. That is, the TAIEX market had busier transactions at 12:15 (about 0.075 second) and 13:15 (about 0.07 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-6 shows the adjusted trading durations chart and it can be seen that after the implementation of the narrowed price down limit (i.e., Period III), a transaction occurred in the TAIEX market every 0.985 second at shortest. Transactions are more frequent in the TAIEX market at opening (0.985 second), 9:30 (within 0.99 second), 10:05 (within 0.99 second), around 11:40 (within 0.99 second) and at closing (within 1 second) (trading durations are short). Thus, a roughly inverted U-shape chart of trading durations is seen, and this agrees with the research result of Engle and Russell (1998).

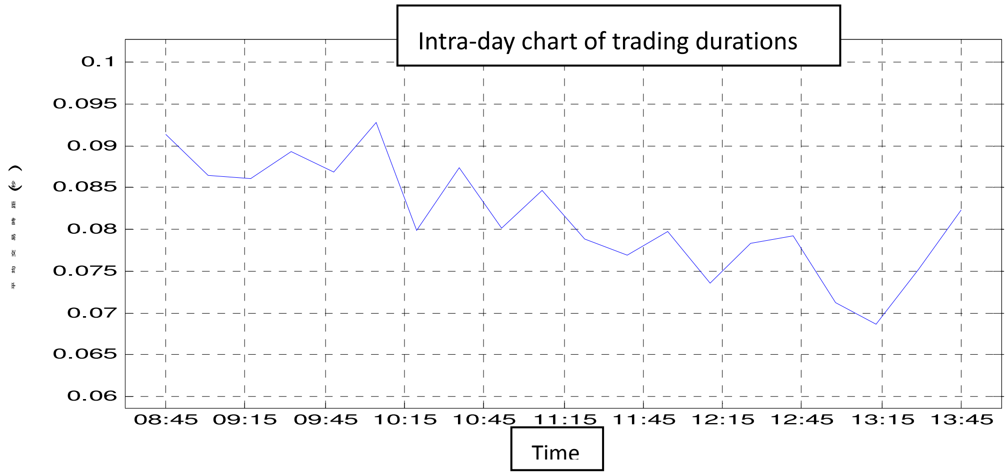

Figure 4-5 Intra-day chart of trading durations — natural persons 2008/10/25~11/05 before adjustment

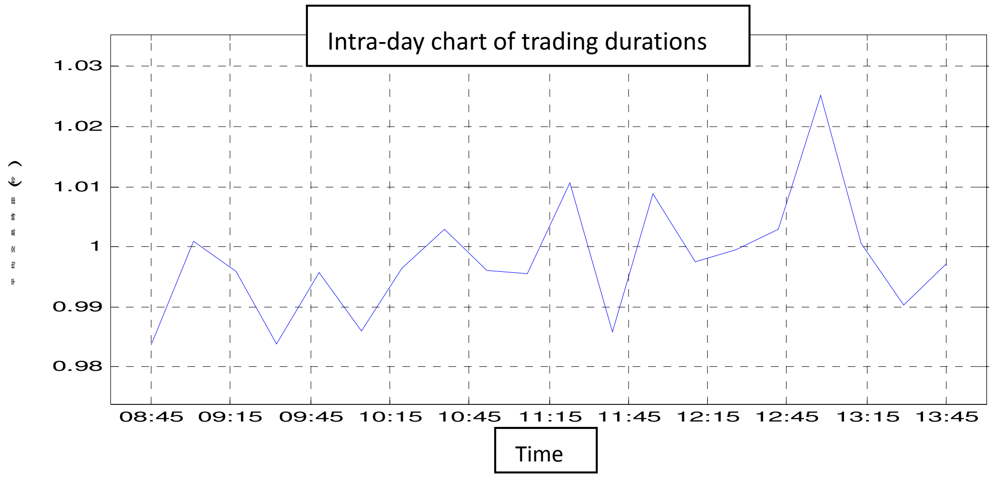

Figure 4-6 Intra-day chart of trading durations — natural persons 2008/10/25~11/05 adjusted

It can be seen from Figure 4-7 below, with traders being FPMs, that a transaction occurred in TAIEX market within every 0.55 second at shortest before the implementation of the narrowed price down limit in 2008. And a roughly inverted U shape can be seen in the chart. That is, the TAIEX market had busier transactions at opening (within 0.55 second), 12:15, 12:45, 13:15 (within 0.6 second at these three points of time) and at closing (within 0.55 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-8 is the Cubic Spline adjusted chart, and it shows that before the implementation of the narrowed price down limit, a transaction occurred in the TAIEX market every 0.97 second at shortest. Transactions are more frequent in the TAIEX market after opening (0.97 second), around 9:45 (about 0.98 second), 10:45 (about 0.98 second), 12:45 (about 0.98 second) and at closing (about 0.98 second) (trading durations are short). A roughly inverted U-shape chart is seen, and this agrees with the research result of Engle and Russell (1998).

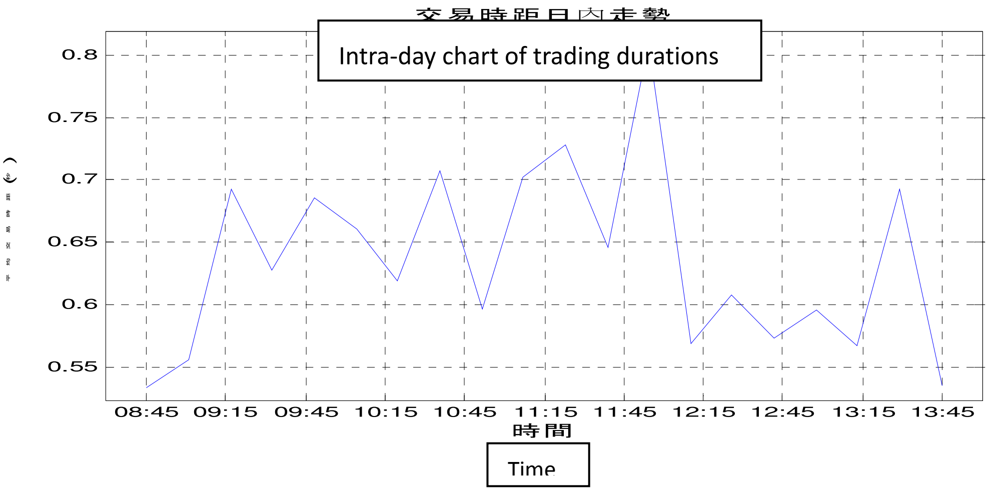

Figure 4-7 Intra-day chart of trading durations — FPMs 2008/10/01~10/12 before adjustment

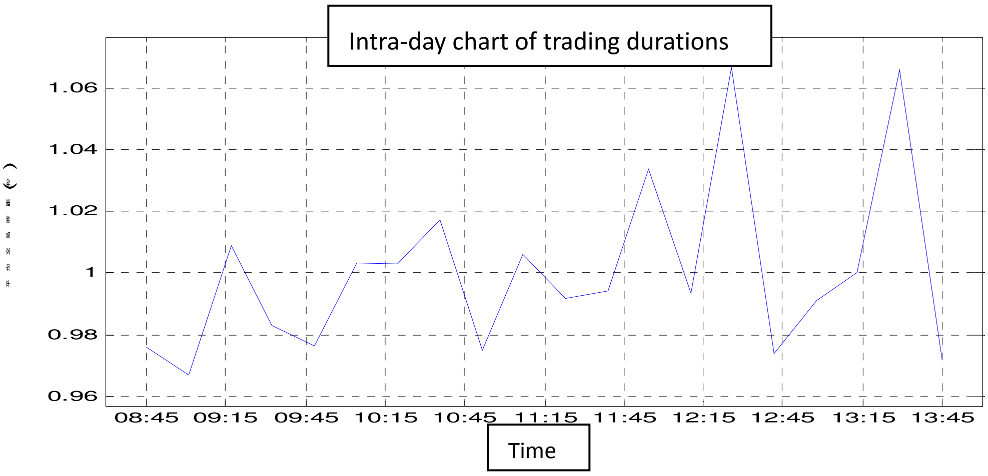

Figure 4-8 Intra-day chart of trading durations — FPMs 2008/10/01~10/12 adjusted

It can be seen from Figure 4-9 below, with traders being FPMs, that a transaction occurred in TAIEX market within every 0.54 second at shortest in Period II during the implementation of the narrowed price down limit in 2008. From the distribution, a shape highly similar to an inverted U can be roughly seen. That is, the TAIEX market had busier transactions at opening (0.54 second) and 13:15, i.e., 30 minutes before closing (0.54 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-10 is the adjusted chart, and it shows that during the implementation of the narrowed price down limit (i.e., Period II), a transaction occurred in the TAIEX market within every 0.94 second at shortest (opening). Transactions are more frequent in the TAIEX market at opening (0.94 second), around 11:45 (about 0.97 second) and at closing (about 0.97 second) (trading durations are short). An inverted U-shape chart is seen, and this agrees with the research result of Engle and Russell (1998).

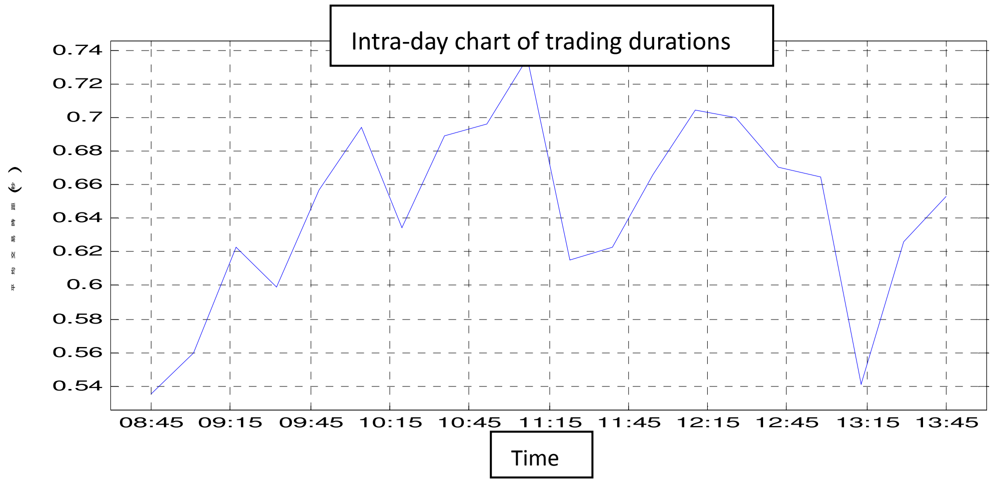

Figure 4-9 Intra-day chart of trading durations — FPMs 2008/10/13~10/24 before adjustment

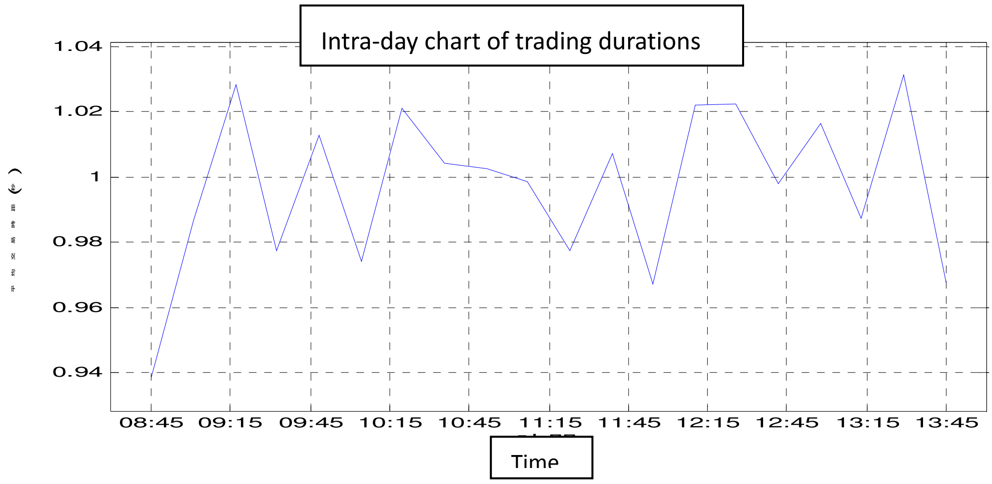

Figure 4-10 Intra-day chart of trading durations — FPMs 2008/10/13~10/24 adjusted

It can be seen from Figure 4-11 below, with traders being FPMs, that a transaction occurred in TAIEX market in every 0.41 second at shortest in Period III after the implementation of the narrowed price down limit in 2008. From the distribution, a roughly inverted U shape can be seen. That is, the TAIEX market had busier transactions 15 minutes after opening at 9:00 (0.41 second) and 30 minutes before closing at 13:15 (0.42 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-12 is the adjusted chart, and it shows that after the implementation of the narrowed price down limit (i.e., Period III), a transaction occurred in the TAIEX market around 0.975 second at shortest. Transactions are more frequent in the TAIEX market at opening (about 0.975 second) and at closing (around 0.98 second) (trading durations are short). The trading durations chart shows a roughly inverted U-shape, and this agrees with the research result of Engle and Russell (1998).

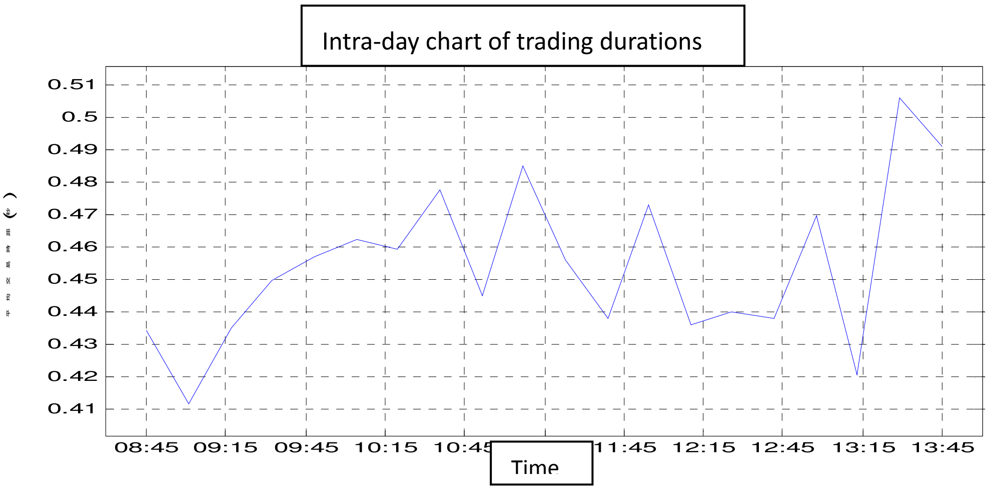

Figure 4-11 Intra-day chart of trading durations — FPMs 2008/10/25~11/05 before adjustment

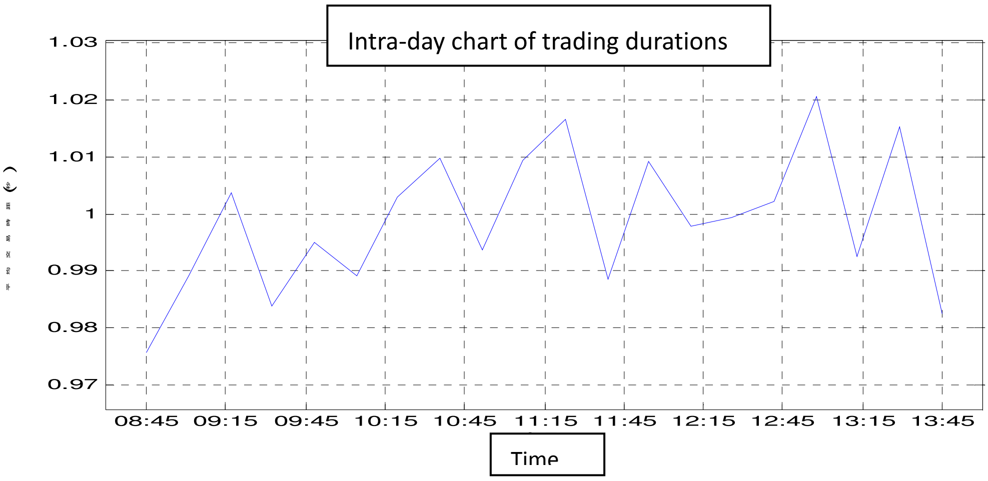

Figure 4-12 Intra-day chart of trading durations — FPMs 2008/10/25~11/05 adjusted

It can be seen from Figure 4-13 below, with traders being FINIs, that a transaction occurred in TAIEX market within every 1.4 second (opening) at shortest before the implementation of the narrowed price down limit in 2008. And the distribution in the chart shows a roughly inverted U shape. That is, the TAIEX market had transactions at the shortest trading duration 15 minutes after opening (within 1.4 second) relatively busier transactions at 11:45 (1.6 second), 12:45 (1.65 second) and at closing (1.6 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-14 is the Cubic Spline adjusted chart, and it shows that before the implementation of the narrowed price down limit, a transaction occurred in the TAIEX market every 0.97 second (after opening) at shortest. Transactions are more frequent in the TAIEX market around 9:30 (0.95 second), around 11:15 (about 0.96 second) and 12:45 (about 0.95 second) (trading durations are short). A roughly inverted U-shape chart is seen; so the chart shows an inverted U shape in both cases no matter if the intra-day factor is adjusted or not, and this agrees with the research result of Engle and Russell (1998).

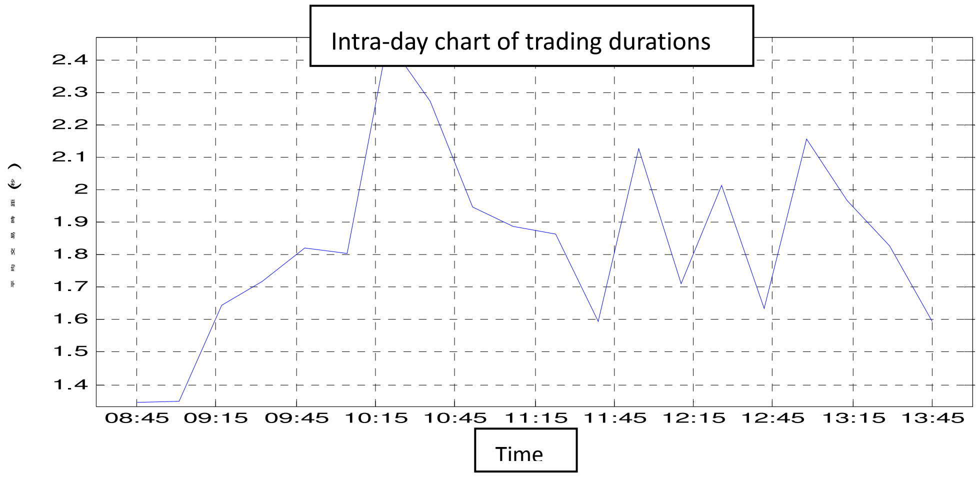

Figure 4-13 Intra-day chart of trading durations — Overseas FINIs 2008/10/01~10/12 before adjustment

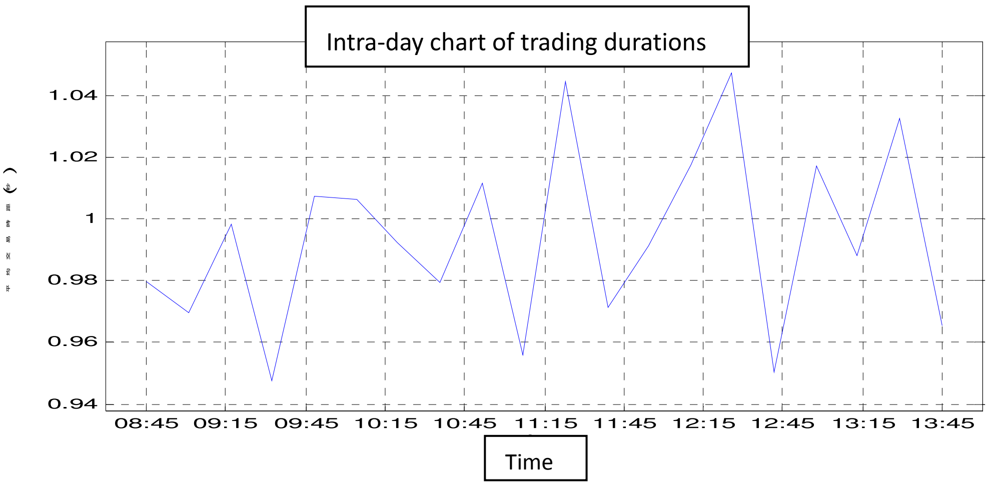

Figure 4-14 Intra-day chart of trading durations — Overseas FINIs 2008/10/01~10/12 adjusted

It can be seen from Figure 4-15 below, with traders being FINIs, that a transaction occurred in TAIEX market within every 1.2 second (opening) at shortest in Period II during the implementation of the narrowed price down limit in 2008. From the distribution, a roughly inverted U-shape chart can be seen. That is, the TAIEX market had busier transactions at opening (within 1.2 second) and 9:30 (1.3 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-16 is the adjusted chart, and it shows that during the implementation of the narrowed price down limit (i.e., Period II), a transaction occurred in the TAIEX market every 0.965 second at shortest. Transactions are more frequent in the TAIEX market at 9:45 (about 0.97 second), around 11:45 (around 0.965 second) and at closing (about 0.975 second) (trading durations are short). An inverted U-shape chart is seen. So the chart shows an inverted U shape in both cases no matter if the intra-day factor is adjusted or not, and this agrees with the research result of Engle and Russell (1998).

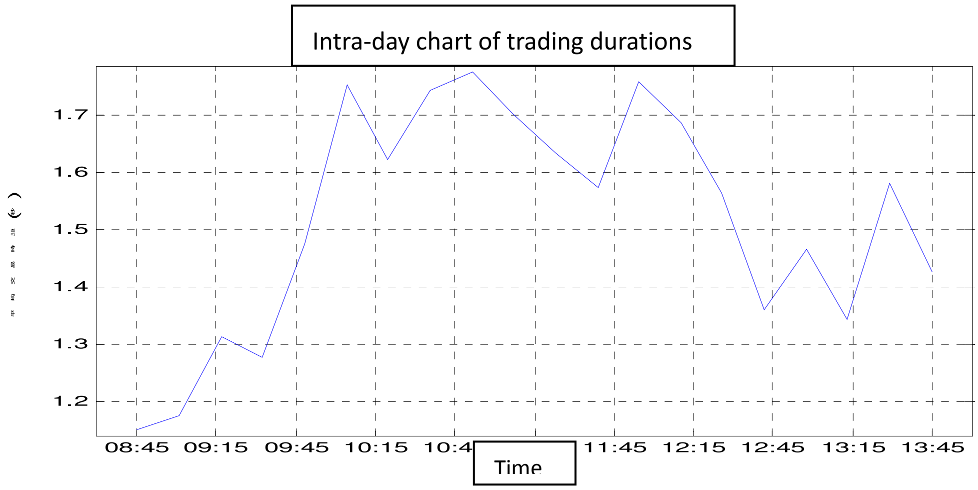

Figure 4-15 Intra-day chart of trading durations — Overseas FINIs 2008/10/13~10/24 before adjustment

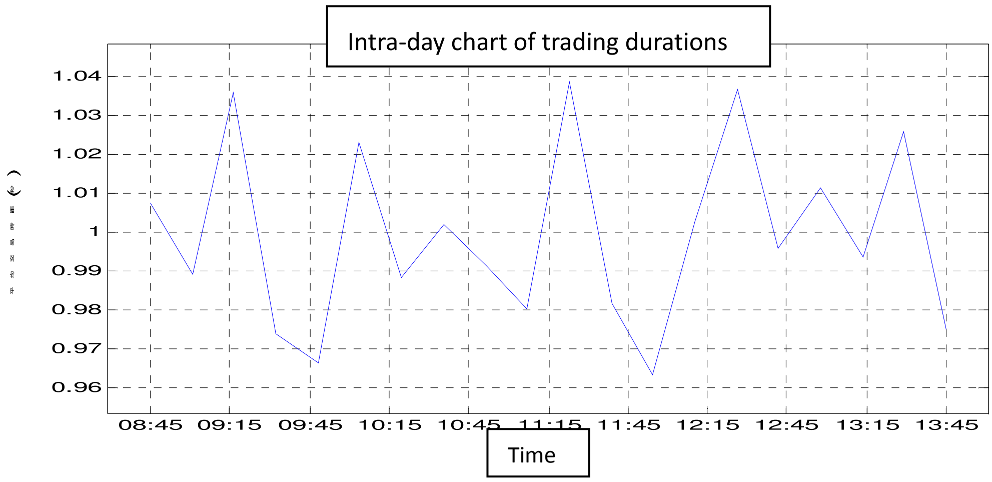

Figure 4-16 Intra-day chart of trading durations — Overseas FINIs 2008/10/13~10/24 adjusted

It can be seen from Figure 4-17 below, with traders being FINIs, that a transaction occurred in TAIEX market within every 1.3 second at shortest in Period III after the implementation of the narrowed price down limit in 2008. From the distribution, a roughly inverted U shape can be seen. That is, the TAIEX market had busier transactions 15 minutes after opening at 9:00 (1.3 second), at 11:15 (about 1.35 second), 12:45 (1.4 second) and at closing (about 1.35 second) (trading durations are short); and the trading durations during other time segments are longer.

Figure 4-18 is the adjusted chart, and it shows that after the implementation of the narrowed price down limit (i.e., Period III), the shortest duration where a transaction occurred in the TAIEX market changed to almost 0.96 second. Transactions are more frequent in the TAIEX market around 11:45 (about 0.96 second), at 13:15 (0.97 second) and at closing (0.98 second) (trading durations are short). An inverted U-shape chart is seen. So the chart shows an inverted U shape in both cases no matter if the intra-day factor is adjusted or not, and this agrees with the research result of Engle and Russell (1998).

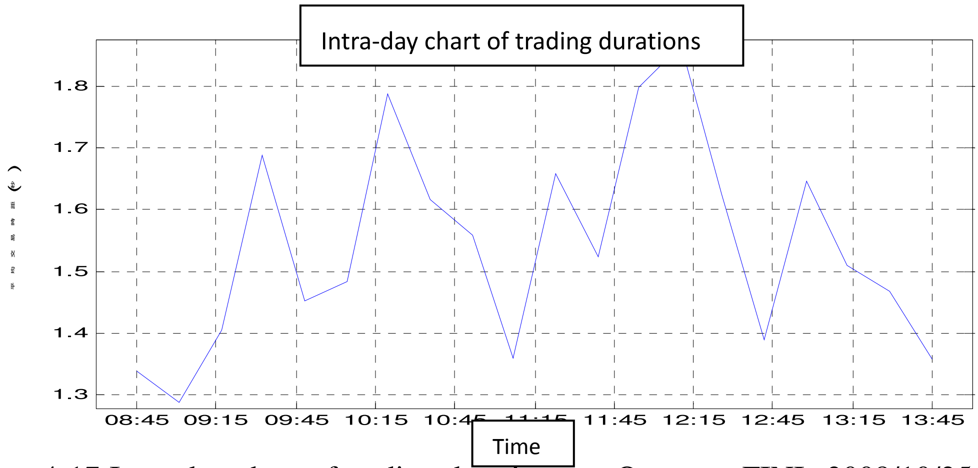

Figure 4-17 Intra-day chart of trading durations — Overseas FINIs 2008/10/25~11/05 before adjustment

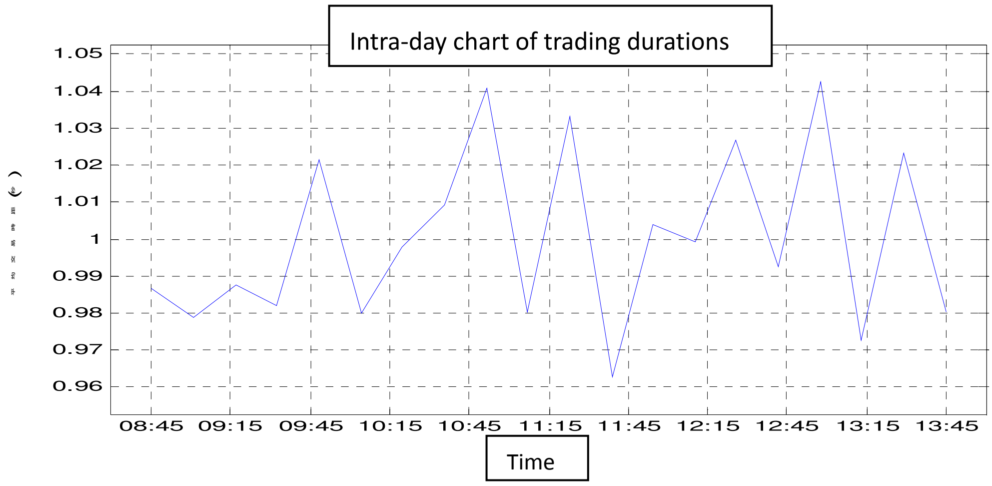

Figure 4-18 Intra-day chart of trading durations — Overseas FINIs 2008/10/25~11/05 adjusted

Concluding from the above Figures 4-1 to 4-18, analysis points to the following changes in trading durations in the TAIEX market for different types of traders and in different periods before, during and after the implementation of the narrowed price down limit in 2008: (1) For the single intra-day trading durations of natural persons and FPMs, the shortest adjusted durations with the intra-day factor removed by means of Cubic Spline method become longer than those before adjustment. For example, it is shown in the figure that natural persons had a transaction in every 0.1125 second in Period I, which lengthened to 0.955 second; (2) The single intra-day trading durations of overseas FINIs differ from other types of traders in that the shortest adjusted duration shortens after adjustment. For example, it is shown in the figure that they had a transaction in every 1.3 second in Period III, which shortened to 0.96 second; (3) Only natural persons' charts show an obvious change before and after adjustment in any period, from U shape to inverted U shape.

IV.3 Analysis of results from the empirical model

In this study, researchers followed Engle and Russell (1998) in using the EACD as the empirical model. Empirical analysis was done on the trading activities of three types of traders – natural persons, FPMs and FINIs – before, during and after the implementation of the narrowed price down limit to 3.5% in 2008, examining the relationship between their

TAIEX trading durations and trading volumes, and how the trading duration and trading volume are related to returns.

From Table 5-1, Table 5-4 and Table 5-7 concerning TAIEX trade before the narrowed price down limit (i.e., Period I), the EACD(1,1) model shows positive and significant values of $\omega > 0$ for natural persons, FPMs and overseas FINIs, with values of the α coefficient and values of the β coefficient both greater than 0 and significant.

It can be seen from the model's empirical results that values of $\alpha + \beta$ for all three types of traders are smaller than 1, meaning the model meets the condition of stability. Analyzing the parameter values of $\alpha + \beta \leq 1$, it is found in the EACD(1,1) that they are 0.8554, 0.9722 and 0.9954 respectively for natural persons, FPMs and overseas FINIs before the narrowed price down limit (Period I); they are 0.9130, 0.9805 and 0.9959 respectively during the narrowed price down limit (Period II); and they are 0.8505, 0.9882 and 0.2562 respectively after the narrowed price down limit (Period III). From these figures, it can be judged whether volatility of trading durations in the TAIEX market is stabilizing, and the carryover effect (from Period I to Period III) of trading duration volatility can be understood. For natural persons, it shows a weakening tendency from slightly strong volatility, and the tendency is also from stronger to weaker for overseas FINIs, whereas FPMs' trading durations tend to be sustaining.

Table 5-1 Estimate result of the EACD model – before the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1476***	0.0087	0.0331***	0.0027	0.0103***	0.0018
α_1	0.1798***	0.0064	0.0746***	0.0026	0.0214***	0.0014
β_1	0.6756***	0.0132	0.8976***	0.0043	0.9739***	0.0019
$\alpha_1 + \beta_1$	0.8554		0.9722		0.9954	
FV	-26,711.0817		-89,686.1348		-30,8971.2252	

Note: Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Table 5-2 Estimate result of the EACD-X-a model – before the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1614***	0.0088	0.0493***	0.0036	0.0254***	0.0033
α_1	0.1788***	0.0060	0.0641***	0.0024	0.0304***	0.0017
β_1	0.6725***	0.0122	0.9047***	0.0044	0.9625***	0.0023
γ	-0.0048***	0.0009	-0.0069***	0.0009	-0.0068***	0.0013
$\alpha_1 + \beta_1$	0.8513		0.9687		0.9929	
FV	-26,708.3494		-89,562.6677		-308,710.1631	

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-a model is the original EACD model adding the variable of the number of contracts traded.

Table 5-3 Estimate result of the EACD-X-b model – before the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.3032***	0.0040	0.0548***	0.0037	0.0242***	0.0032
α_1	0.2455***	0.0051	0.0858***	0.0030	0.0290***	0.0016
β_1	0.4761***	0.0034	0.8800***	0.0050	0.9643***	0.0022
γ	-0.0072***	0.0011	-0.0087***	0.0010	-0.0065***	0.0012
κ	0.1640***	0.0526	-0.0675	0.0700	0.3377**	0.1337
$\alpha_1+\beta_1$	0.7216		0.9658		0.9933	
FV	-26,774.0181		-89,760.5752		-308,728.4938	

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-b model is the original EACD model adding the variables of the number of contracts traded and rate of return.

Table 5-4 Estimate result of the EACD model – during the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.0975***	0.0078	0.0235***	0.0024	0.0093***	0.0019
α_1	0.1215***	0.0048	0.0600***	0.0025	0.0269***	0.0019
β_1	0.7915***	0.0104	0.9205***	0.0040	0.9690***	0.0024
$\alpha_1+\beta_1$	0.9130		0.9805		0.9959	
FV	-32,702.9658		-92,547.7335		-291,315.4018	

Note: Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Table 5-5 Estimate result of the EACD-X-a model – during the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1073***	0.0073	0.0279***	0.0025	0.0335***	0.0042
α_1	0.1195***	0.0047	0.0490***	0.0022	0.0498***	0.0019
β_1	0.7864***	0.0100	0.9320***	0.0037	0.9390***	0.0028
γ	-0.0007	0.0006	-0.0029***	0.0004	-0.0053***	0.0010
$\alpha_1+\beta_1$	0.9059		0.9811		0.9887	
FV	-32,663.8534		-92,330.1168		-291,129.5775	

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-a model is the original EACD model adding the variable of the number of contracts traded.

Table 5-6 Estimate result of the EACD-X-b model – during the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1147***	0.0070	0.0426***	0.0034	0.0313***	0.0041
α_1	0.1388***	0.0046	0.0756***	0.0028	0.0468***	0.0021
β_1	0.7609***	0.0090	0.8947***	0.0049	0.9428***	0.0032
γ	-0.0022***	0.0006	-0.0046***	0.0004	-0.0050***	0.0010
κ	0.3182***	0.0583	0.0010	0.0537	-0.0871***	0.0824

$\alpha_1+\beta_1$	0.8997	0.9703	0.9895
FV	-32,622.7484	-92,607.1547	-291,149.2061

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-b model is the original EACD model adding the variables of the number of contracts traded and rate of return.

Table 5-7 Estimate result of the EACD model – after the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1547***	0.0073	0.0145***	0.0018	1.7397***	0.1182
α_1	0.2114***	0.0062	0.0302***	0.0016	0.0246***	0.0028
β_1	0.6391***	0.0115	0.9580***	0.0028	0.2316***	0.0516
$\alpha_1+\beta_1$	0.8505		0.9882		0.2562	
FV	-34,819.1349		-191,331.5949		-508,491.4209	

Note: Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *.

Table 5-8 Estimate result of the EACD-X-a model – after the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1578***	0.0069	0.0145***	0.0018	2.2663***	0.0161
α_1	0.2112***	0.0055	0.0297***	0.0016	0.0237***	0.0040
β_1	0.6379***	0.0103	0.9595***	0.0026	0.0100	0.0103
γ	-0.0008***	0.0006	-0.0008***	0.0003	-0.0070***	0.0021
$\alpha_1+\beta_1$	0.8491		0.9892		0.0336	
FV	-34,821.8702		-191,184.3794		-508,495.5268	

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-a model is the original EACD model adding the variable of the number of contracts traded.

Table 5-9 Estimate result of the EACD-X-b model – after the narrowed price down limit

Trader type	FINIs		FPMs		Local natural persons	
Variable	Coefficient	S.D.	Coefficient	S.D.	Coefficient	S.D.
ϖ	0.1518***	0.0073	0.0183***	0.0020	0.0143***	0.0023
α_1	0.2100***	0.0065	0.0355***	0.0017	0.0176***	0.0011
β_1	0.6449***	0.0112	0.9507***	0.0029	0.9771***	0.0017
γ	-0.0009	0.0007	-0.0009***	0.0002	-0.0015**	0.0007
κ	0.1081**	0.0541	-0.0431*	0.0250	0.0164	0.0521
$\alpha_1+\beta_1$	0.8548		0.9862		0.9947	
FV	-34,793.4698		-191,151.3792		-508,017.1180	

Notes: 1. Significance level at 0.01 is marked as ***; 0.05 marked as **; 0. 1 marked as *. 2. The EACD-X-b model is the original EACD model adding the variables of the number of contracts traded and rate of return.

V. Conclusion

Following the research model of Engle and Russell (1998) in their study of the trading data of IBM stocks, this study applied the EACD(1,1) model to examine the relationship between TAIEX trading duration and number of contracts traded. Empirical analysis was conducted on the trading data of TAIEX before, during and after Taiwan government's measures of maintaining the price up limit at 7% while narrowing the price down limit to 3.5% in response to the financial turmoil caused by the globally influential subprime crisis, to see if there are significant changes in the trading durations and trading activities in the TAIEX market, and explore the relationship between trading duration and trading volume, as well as their relationship with the rate of return.

Regarding the empirical analysis of information transmission, ω in the EACD(1,1) model represents the uncertainty that originally exists in the futures market; α is the coefficient for lagged trading durations, representing the importance of recent market information (latest news); β is the coefficient for lagged conditional expected durations, and since β is related to the conditional expected duration of the previous phase, it can be explained as the influence of long-term market information (dated news) on the future conditional expected duration.

Comparison of Table 5-1 and Table 5-2 shows the different performances of coefficient α that indicates the importance of recent market news and coefficient β that reflects the long-term market news in different periods of time in the TAIEX market. In the EACD(1,1) model, coefficient α is 0.0257 before the 2004 presidential election (20040315~20040319) and 0.0471 after the 2004 presidential election (20040322~20040326), meaning there really was new information entering the TAIEX market during the 2004 presidential election period, which in turn influenced the TAIEX, accelerating information transmission for TAIEX.

As for coefficient β, it can be considered a proxy variable for the sustainability of dated news. In the EACD(1,1) model, coefficient β is 0.9701 before the 2004 presidential election and 0.9413 after the 2004 presidential election. They reflect that the carryover effect of the dated news on market volatility tends to abate after the 2004 presidential election.

From the empirical results of the model, it can be seen that in both the EACD(1,1) and EACD(2,2) models, the values of α + β are smaller than 1 before and after the 2004 presidential election, meaning the models meet the condition of stability. When analyzing the parameter value of α + β, it was found to be 0.9958 before the 2004 presidential election and 0.9884 after the election in EACD(1,1); and it was 0.9914 before the 2004 presidential election and 0.4829 after the election in EACD(2,2). It means that volatility in the TAIEX market tended to stabilize after the 2004 presidential election, and the carryover effect of volatility diminished slightly. Finally, it was attempted to judge which model, EACD(1,1) or EACD(2,2), fits the TAIEX better by R2. Result showed that before the 2004 presidential election, the EACD(1,1) model seemed to perform better than the EACD(2,2) model, but only with slight difference; after the 2004 presidential election, the EACD(1,1) also seemed to perform better than the EACD(2,2), but again only with slight difference. Therefore, it is concluded by the research result of this study that the EACD(1,1) model is a better fit for TAIEX.

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