# Comparison of relative market efficiency in different trading system: Open-outcry and electronic trading system for Nikkei 225 Futures in Singapore Exchange Derivatives Trading※

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## Abstract

In our paper, we compare two types of trading system, open-outcry and electronic trading system (ETS), of Nikkei 225 futures in Singapore Exchange Derivatives Trading in terms of market efficiency. Convergence speed of any assets returns to its equilibrium level can be one of the indicators of the market efficiency. If the market is efficient, price adjustment ends as soon as new information comes into market. The longer the adjustment time becomes, the lower the efficiency level of market is. This adjustment speed can be measured by impulse response curve.

In addition to convergence speed, we are going to explore market efficiency in terms of volatility persistency in GARCH analysis. If the market is efficient, volatility in each price interval should be independent. Therefore, we cannot conceive volatility persistency if the market is efficient.

In preliminary analysis, the number of trades in a given time interval and the ratio of the trades with price change indicate that ETS might be better in terms of market efficiency. This fact finding is consistent to the research to date. The number of trades in a given interval in ETS is more than that in open-outcry. The ratio of the trades with price change is higher in open-outcry and the ratio of trades with price unchanged is higher in ETS. These facts are showing that the efficiency of market in ETS period is better than that in open-outcry.

Impulse responses are employed to test convergence speed and smoothness of the path to equilibrium level. For estimating volatility persistency, we estimate GARCH model and use coefficient in conditional variance equation. Higher convergence speed and smoother convergence path suggest higher market efficiency. Shorter volatility persistency also indicates higher market efficiency.

As for convergence speed, regardless of type of trading system, returns converge within about 3 minutes. Nikkei 225 futures return shows significant volatility persistency in both trading system. These results denote that the markets in both trading system are not strictly efficient. But future returns in ETS converges through smoother path to equilibrium level. The estimated length of volatility persistency in ETS is shorter than that in open-outcry. By these findings, we confirm that the market in ETS is more efficient than the market in open-outcry. Therefore, ETS is better trading system than open-outcry system in terms of market efficiency concept.

## 1. Introduction

Recently, new trading system has been introduced into futures market all over the world. A lot academics and practitioners are exploring the market efficiency with comparing the market performance in different trading systems. In some research, they explore two markets in which one market is adopting open-outcry and another is employing Electronic Trading System (ETS). Others are taking up the opportunity that some markets newly introduce ETS in place of open-outcry. Almost all research on this subject finds that the introduction of ETS contributes to improve market efficiency.

A series of research done by Huang (Huang (2004b), Huang (2004a) ) is investigating the subject we pointed out above with the data in Singapore market which we also use in this paper. Huang (2004a) compares the trading costs and liquidity of Taiwan Stock Index Futures listed on both Taiwan Futures Exchange (TAIFEX) and Singapore Exchange Derivatives Trading (SGX-DT). Since the TAIFEX maintains electronic trading system while SGX-DT makes use of open-outcry trading system, this study examines the relative performance of electronic trading market and open-outcry market. Empirical results reveal that quoted and effective spreads in TAIFEX are lower than that of SGX-DT and the market depth of TAIFEX is deeper than that of SGX-DT. This paper concludes that these results imply TAIFEX has better market performance than SGX-DT. Huang (2004a) also examines the relative performance of TAIFEX and SGX-DT and suggests that open-outcry markets are more vulnerable to information asymmetry than electronic markets. Chung and Chiang (2006) investigates price clustering of DJIA, S&P 500 and NASDAQ-100 index futures that are traded in both open-outcry and electronic market. Their empirical results show that price clustering tends to be higher in open-outcry market. Ap Gwilym and Alibo (2003) also investigates price clustering of FTSE100 Stock Index futures and shows that the price clustering decreased after introduction of electronic trading.

There are series of researches which analyze same market with different trading system such as SGX-DT which we use this paper. Fung, *et al.* (2005), Aitken, *et al.* (2004) and Tse and Zabotina (2001) are the papers which conduct a detail research on different market in this way. Tse and Zabotina (2001) examines the effects of the introduction of electronic trading into Hang Seng Index (HSI) futures market. They reveal the fact that relative bid-ask spread of HSI futures is getting narrower after the introduction of electronic trading platform. In addition, they find that the electronic-traded futures contributes more important role in terms of price discovery. Aitken, *et al.* (2004) analyzes how the introduction of electronic trading effect on bid-ask spreads for three futures markets: London International

Financial Futures and Options Exchange, Sydney Futures Exchange and Hong Kong Futures Exchange. They provide evidence that electronic trading leads to similar or lower bid-ask spreads for the futures markets, after controlling for price volatility and trading volume change. Tse and Zabotina (2001) investigates the effect of introducing electronic trading for FTSE 100 index futures on the bid-ask spreads and market quality. The study shows that bid-ask spread is getting narrower in electronic trading market. Using the Hasbrouck (1993) model, they also suggest that open-outcry market has higher market quality than electronic market.

In our paper, we compare two types of trading system of Nikkei 225 futures, open-outcry and ETS in terms of market efficiency. Convergence speed of any assets returns to its equilibrium level can be one of the indicators of the market efficiency. If the market is efficient, price adjustment ends as soon as new information comes into market. The longer the adjustment time becomes, the lower the efficiency level of market is. This adjustment speed can be measured by impulse response curve.

In addition to convergence speed, we are going to explore market efficiency in terms of volatility persistency in GARCH analysis. If the market is efficient, volatility in each price interval should be independent. Therefore, we cannot conceive volatility persistency if the market is efficient.

The rest of the section is preceded as follows. In the second section, we examine the feature of our dataset. Models and estimation results are shown in section 3. We will discuss the implication also in section 3 and conclude our discussion in section 4.

## 2. Data Description

Intraday tick data of Nikkei 225 futures traded in SGX-DT is from “Tick Data and Daily Statistic for Stock Indices 2004-2005 edition” provided by SGX-DT. The dataset contains contract year, month, trading date, quotation time, price and the type of price, say bid, ask or traded[1]. The nearby contracts are used in our analysis since they are the most active contracts in terms of trading volume.

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[1] The dataset does not contain trading volume. Furthermore, bid and ask prices are not available for electronic trading. Because of this data availability, we cannot examine market depth and resiliency of the SGX-DT with trading volume.

In order to examine the effect of the introduction of electronic trading, we divide our sample into two subsamples. From July 1, 2004 to October 29, 2004, this market had been adopting only open-outcry system, and electronic trading system was introduced on November 1, 2004. Period from November 1, 2004 to March 31, 2005 are special. In this period, both the open-outcry and electronic trading systems were employed in this market simultaneously. Because of this reason, we exclude these data from our analysis. There are some records when quotations come into market after or before the regular trading time. We also exclude these records as abnormal records. Total records in the first subsample are 127163 and 459314 in the second subsample.

## 3. Preliminary Analysis

### The Number of trades

The number of trades in given time interval is closely related to market liquidity. If the number of trades in given time interval is relatively high, we can analogize that market is liquid. Figure 1 shows daily number of trades before and after the introduction of ETS. This figure suggests that the introduction of the ETS gives rise to the number of trades. From t-test statistics, average number of trades in a day is different before October 29, 2004 and after April 1, 2005 at 1% significant level[2]. Therefore, the introduction of ETS gathers more trades into market, then this contributes to improve market liquidity.

[2] t-statistics is -18.0, and p-value is less than $7.0 \times 10^{-30}$.

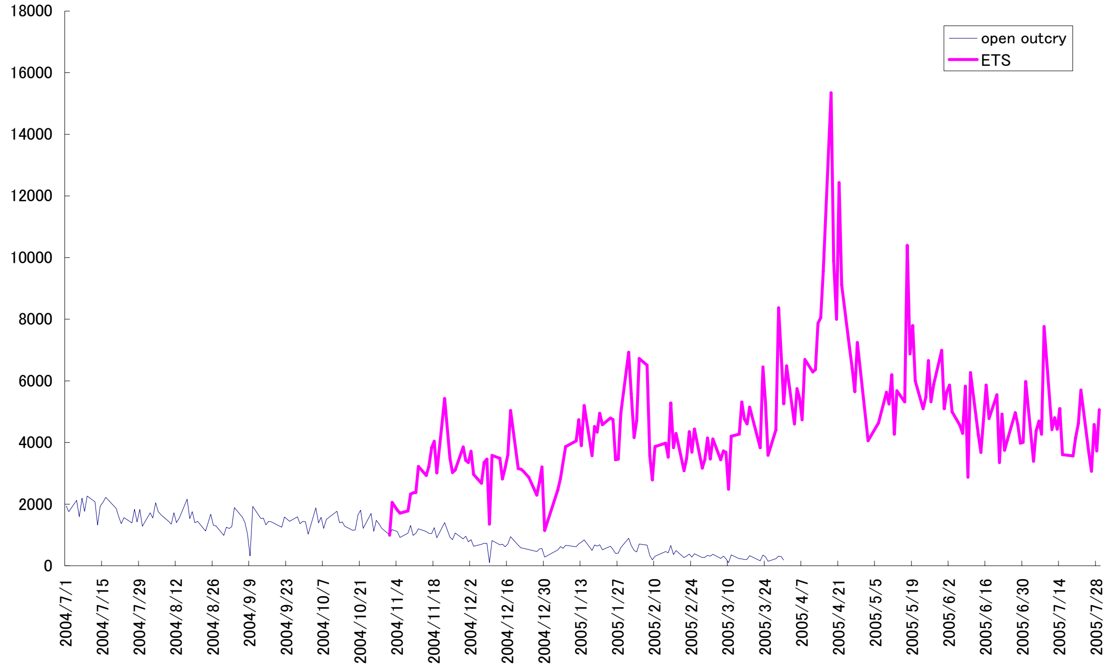


**Figure 1. Total number of trades in a day by trading systems**

Figure 2 shows median of the number of trades in 5-minutes interval in a day. U-shaped pattern is appeared. This U-shaped pattern is reported in many literatures[3]. At the start and close, except the trading time when Osaka Stock Exchange (OSE) is closed, the number of trades is relatively high comparing to intraday trading time. For conducting time series analysis, we have to eliminate this daily seasonality.

[3] See, for example, Gerety and Mulherin (1994), Andersen and Bollerslev (1997), McMillan and Speight (2004) for daily seasonality in financial market.

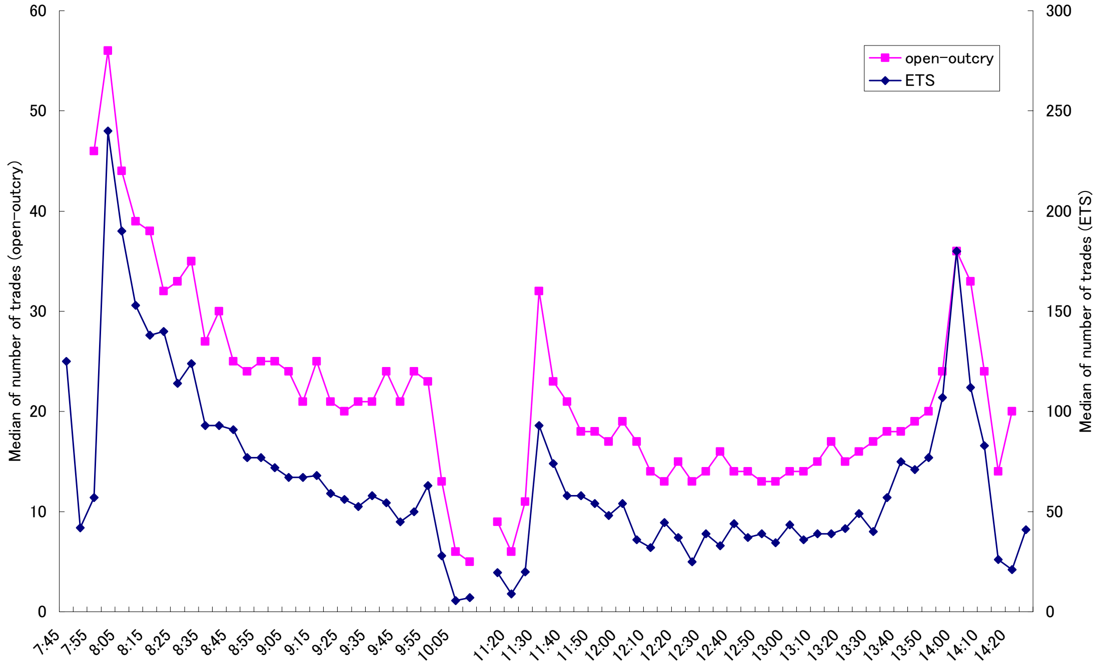


Figure 2. Daily seasonality of the number of trades

**Ratio of trades whose price is changed from previous trading price**

There are three types of trade in terms of price change, up, down and unchanged. Given the condition that there exist so many traders who want to execute their trade at same price, the more the market participant can execute their trade at same price, the higher the market liquidity becomes. The number of trades with price unchanged can be the proxy of market liquidity. High number of this kind of trades indicates high market liquidity.

The ratio of trades in which price is changed from previous price can be regarded as proxy for return volatility. Table 1 shows the statistics on the number of trades and the price change from previous trading price. The ratio of the number of trades in which trading price does not change from previous trade in electronic trading period is higher than the ratio in open-outcry period. $\chi^2$ test statistics also rejects the null hypothesis of identical distribution between two periods[4]. This suggests that electronic market is less volatile than open-outcry market.

[4]Test statistics for $\chi^2$-test is 281568.6, and p-value is less than $2.2\times10^{-22}$.

Table 1. Number of trades and price change from previous trading price

| | | Open-outcry period | | Electronic trading period | |
|---|---|---|---|---|---|
| | | Number of trades | ratio | Number of trades | ratio |
| price | up | 24472 | 19.4% | 18932 | 4.1% |
| | unchanged | 75667 | 60.1% | 421410 | 91.7% |
| | down | 25774 | 20.5% | 18972 | 4.1% |
| | total | 125913 | | 459314 | |

Figure 3 shows the ratio of trades with price change. If market is volatile, this ratio will be high. Therefore, this ratio can be considered as proxy for return volatility. Similar to the number of trades as in Figure 2, this ratio exhibits daily seasonality for both open-outcry and ETS period. That is, the ratio is relatively high around the market opening and closing time in the morning and afternoon session respectively.

It is also noticeable that the ratio is, in contrast to the number of trades, relatively high during 7:55-8:00, 10:00-10:15, 11:15-11:30 and 14:10-14:30 for electronic trading period. These periods are corresponding to the periods OSE, where Nikkei 225 futures are also traded, is closed.

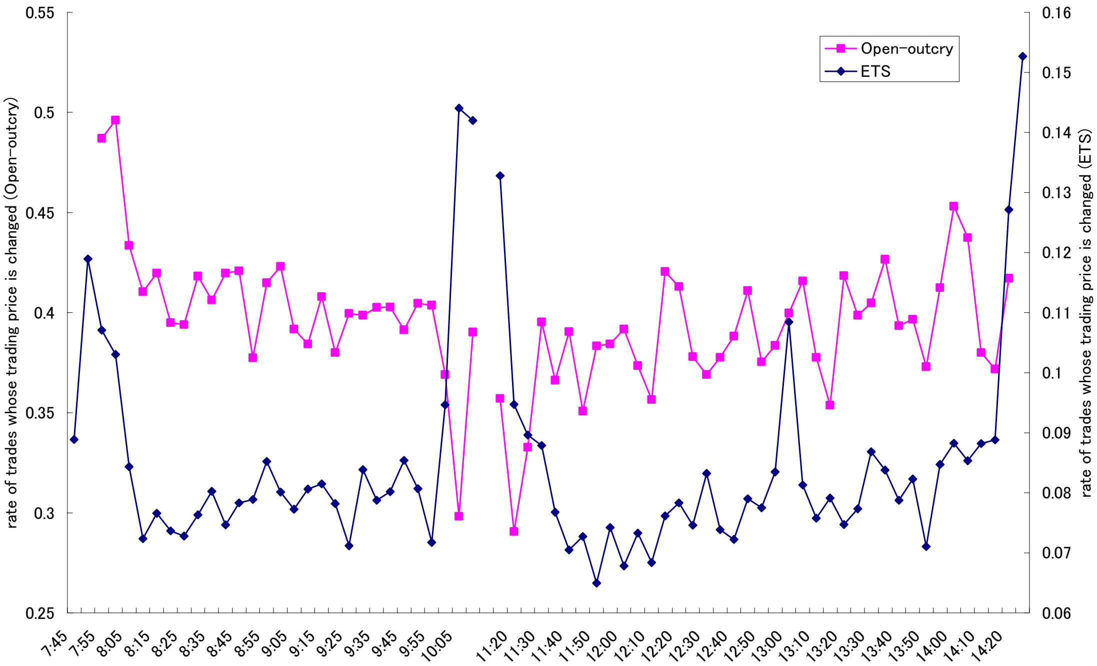


Figure 3. Ratio of trades in which price is changed from previous trading price

## 4. Analysis of Convergence Speed

### Daily seasonal adjusted return

In this section, we conduct time series analysis with 1-minute interval return of Nikkei 225 futures to investigate whether trading system affects the convergence speed and volatility persistency. Since preliminary analysis in previous section shows that intra-daily returns exhibit daily seasonality, we exclude daily seasonality by the method proposed by Gallant, *et al.* (1992). The procedure of de-seasonarizing is as follows.

First of all, we estimate the model below by OLS:

$$y = X\beta + u \tag{1}$$

where $y$ is the series that we want to eliminate daily seasonality, and is 1-minute returns of Nikkei 225 futures, and $\beta$ is a coefficient vector, $X$ is a matrix that contains intra-daily seasonality dummy and $u$ is a vector of error term[5]. In the next step, we estimate the equation below by OLS:

$$\ln \hat{u}^2 = X\zeta + \nu \tag{2}$$

where $\hat{u}$ is residual obtained from equation (1), and $\nu$ is a vector of error term. In a final stage, we produce new series, $y_{adj}$, by calculating

$$y_{adj} = a + b(\hat{u} / \exp(X\zeta / 2)) \tag{3}$$

where $a$ and $b$ are chosen so that sample mean and sample variance of $y_{adj}$ and $y$ are the same.

[5] In order to create the intra-daily seasonality dummy, trading time is divided into 13 time zones.

## Model

### Impulse Response Analysis

If dynamics of the Nikkei 225 futures return, $y_t$, can be captured by stationary ARMA $(p,q)$ model, we can express $y_t$ as follows:

$$y_t = c + \sum_{i=1}^{p} \phi_i y_{t-i} + \sum_{j=1}^{q} \theta_j \varepsilon_{t-j} \tag{4}$$

where $\varepsilon_t$ is white noise process. This process also has MA($\infty$) representation:

$$y_t = \varepsilon_t + \sum_{i=1}^{\infty} \eta_i \varepsilon_{t-i} \tag{5}$$

Since $\partial y_t / \partial \varepsilon_{t-i} = \eta_i$, the coefficient $\eta_i$ represents the impact of a unit shock at time $t-i$ on the level of $y$ at time $t$, and $(\eta_1, \eta_2, \ldots)$ are referred to as impulse responses. In our analysis, we use maximum likelihood method to estimate ARMA model and choose the lag length $(p,q)$ by AIC.

### Analysis of Volatility Persistence

We estimate the following GARCH(1,1) model (Bollerslev (1986)):

$$\begin{aligned} y_t &= \mu + \sum_{i=1}^{n} \phi_i y_{t-i} + \sigma_t \varepsilon_t, \quad \varepsilon_t \sim NID(0,1) \\ \sigma_t^2 &= \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2 \end{aligned} \tag{6}$$

where $y_t$ is 1-minute intra-daily returns of Nikkei 225 futures. By estimating the model, we can measure the volatility persistency of Nikkei 225 futures in open-outcry market and electronic trading market. The GARCH model is estimated by maximum likelihood method with BHHH algorithm.

If $\hat{\alpha}_1 + \hat{\beta}_1$ is close to unity, the autocorrelation function of $y_t^2$ decay quite slowly, which means the volatility of $y_t$ is persistent[6]. For exploring the market efficiency in terms of volatility persistency between open-outcry and ETS, we can use the estimates of $\hat{\alpha}_1 + \hat{\beta}_1$.

[6] See, for example, Harvey (1993).

## Results

### Impulse Response Curve

Estimation result of equation (4) is shown in Table 2. After identifying lag length, we choose ARMA(4,5) for open-outcry series and ARMA(5,5) for ETS series. With the satisfaction of invertibility and stationality condition, we can reconstruct MA representation from ARMA model to derive impulse responses.

**Table 2. Estimation result of ARMA model for log returns of Nikkei 225 Futures.**

| | Open-outcry trading period | | Electronic trading period | |
|---|---|---|---|---|
| Coefficient | Estimate | Std. Error | Estimate | Std. Error |
| $c$ | 0.000 | (0.000) | 0.000 | (0.000) |
| $\phi_1$ | -0.417 | (0.424) | 1.009 | (0.167) |
| $\phi_2$ | 0.984 | (0.418) | -0.429 | (0.301) |
| $\phi_3$ | 0.238 | (0.328) | -0.414 | (0.317) |
| $\phi_4$ | -0.412 | (0.334) | 0.474 | (0.202) |
| $\phi_5$ | | | 0.110 | (0.058) |
| $\theta_1$ | 0.253 | (0.424) | -1.135 | (0.167) |
| $\theta_2$ | -1.052 | (0.366) | 0.547 | (0.320) |
| $\theta_3$ | -0.072 | (0.373) | 0.366 | (0.351) |
| $\theta_4$ | 0.459 | (0.296) | -0.552 | (0.233) |
| $\theta_5$ | -0.059 | (0.060) | -0.033 | (0.071) |
| No. of Obs | 27213 | | 27770 | |
| Log Likelihood | 45849.9 | | 53887.4 | |
| AIC | -91679.8 | | -107752.7 | |

Log return is defined as $100\log(y_t / y_{t-1})$, where $y_t$ is the price of the nearby Nikkei 225 Futures price as of the end of minute $t$.

Impulse response curve can be obtained by the MA representation of estimated ARMA model above and drawn as in Figure 4.

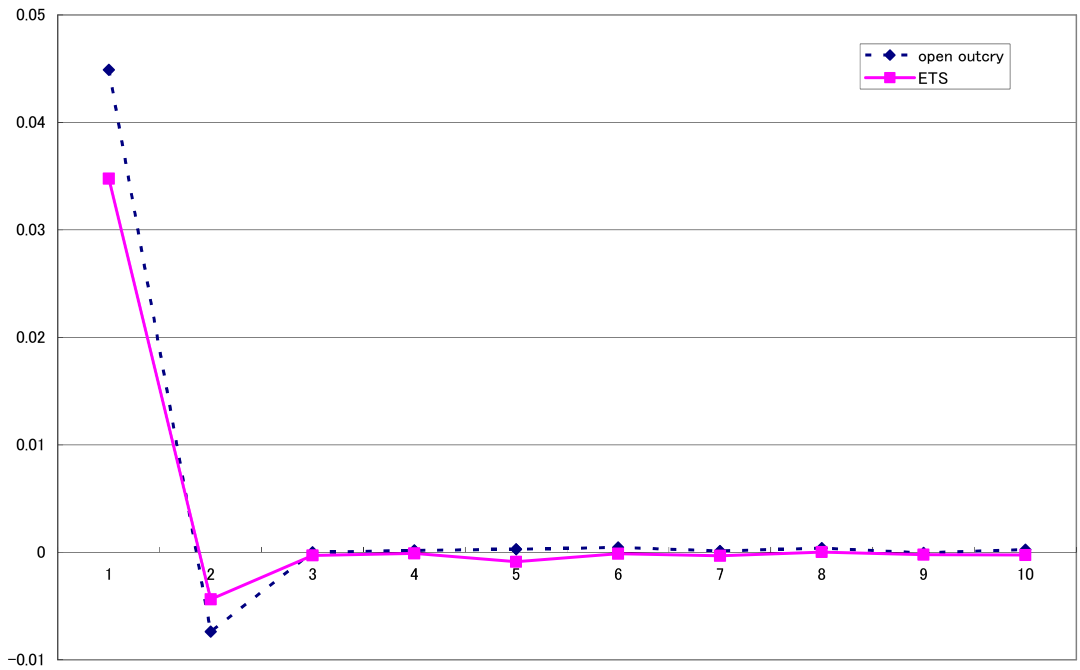


**Figure 4. Estimated impulse response function of log returns of Nikkei 225 Futures.**

Convergence speed of Nikkei 225 futures returns in each period is shown in Figure 4. Solid line represents ETS data and dotted line gives open-outcry case. The shapes of two impulse response curves look alike. Three minutes after a shock comes to market, both returns seem to converge to their equilibrium level. With given shock to both markets, the reaction of the return in open-outcry case is bigger than that of ETS.

### Volatility Persistency

Table 3 shows the estimation result of GARCH model. In Table 3, only the estimated results in conditional variance equation are shown because we will focus on volatility persistency in both cases. All the coefficients are significantly estimated at 5% level.

Table 3. Estimation result of GARCH(1,1) model for log returns of Nikkei 225 Futures.

| | Opem-outcry trading period | | Electronic trading period | |
|---|---|---|---|---|
| Coefficient | Estimate | Std. Error | Estimate | Std. Error |
| $\alpha_0$ | 0.000 | (0.000) | 0.000 | (0.000) |
| $\alpha_1$ | 0.124 | (0.003) | 0.148 | (0.002) |
| $\beta_1$ | 0.811 | (0.004) | 0.756 | (0.002) |
| No. of Obs. | 27213 | | 27770 | |
| Log Likelihood | 45849.9 | | 53887.4 | |

It is well known that volatility persistency can be calculated with the value of $\hat{\alpha}_1$ and $\hat{\beta}_1$. Sum of the estimated coefficients $\hat{\alpha}_1 + \hat{\beta}_1$ in open-outcry case are bigger than that of ETS.

## Discussion

In our paper, we compare two kinds of trading system of Nikkei 225 futures, open-outcry and ETS in terms of market efficiency. As we have discussed above, the convergence speed of Nikkei 225 futures returns to its equilibrium level can be one of the indicators to evaluate market efficiency. Impulse response curve can be used to measure the convergence speed to equilibrium level.

From the market efficiency concept, the level of efficiency is high if the convergence speed is faster. Figure 4 shows that the time to equilibrium level in both trading systems is about same, 3 minutes. The difference of each trading system in terms of convergence path to equilibrium level is the degree of reaction with given shock to market. As for the first reaction, the response in open-outcry system period is bigger than that of ETS period. Turning to second reaction, the response in open-outcry system period is minus and smaller. The shape of impulse response curve shows that the reaction of market trading activity to given shock is bigger in open-outcry system than that in ETS, even though the convergence speed to equilibrium level is about same.

In other words, it might be said that the convergence path to equilibrium level is smoother in the market with ETS. This means the volatility of Nikkei 225 futures returns can be smaller under ETS. If actual return can converge to equilibrium level more smoothly, then this market can be said as being more efficient.

We are going to explore market efficiency in terms of volatility persistency in GARCH analysis. If the market is efficient, volatility in each price interval should be independent. Therefore, we cannot find any volatility persistency if market is efficient.

Volatility persistency shows how past volatility has an affect on present volatility, and this can be measured by the size of estimated coefficients of the lagged variance of error term and conditional variance in conditional variance equation in GARCH model. The closer the sum of each coefficient value to unity, the persistency of the volatility of the system stays longer.

We will compare the degree of persistency between two types of trading system with GARCH estimation results. In open-outcry case, persistency is represented by the value $\hat{\alpha}_1 + \hat{\beta}_1$ , 0.935. This indicator for ETS goes to 0.904 from Table 3. Comparing these values, the persistency of the volatility in open-outcry system is longer than that of ETS. From the efficient market view, the market with ETS system is more efficient than that with open-outcry system.

## 4. Conclusion

We take an opportunity that Nikkei 225 futures market in Singapore introduced electronic trading system in place of open-outcry to explore better trading system in terms of the efficiency of market. Not alike as other papers that use market depth proxy with volume data, we use market adjustment speed and volatility persistency as an indicator to compare the contribution of two types of trading system to market efficiency.

In preliminary analysis, the number of trades in a given time interval and the ratio of the trades with price change indicate that ETS might be better in terms of market efficiency. This fact finding is consistent to the research so far. The number of trades in a given interval in ETS is more than that in open-outcry. The ratio of the trades with price change is higher in open-outcry and the ratio of trades with price unchanged is higher in ETS. These facts are all showing that the efficiency of market in ETS period is better than that in open-outcry.

Convergence speed of Nikkei 225 futures returns and volatility persistency can be used to compare the level of market efficiency between two different trading systems. Impulse responses are employed to test convergence speed and smoothness of the path to equilibrium level. For estimating volatility persistency, we estimate GARCH model and use coefficient in conditional variance equation. Higher convergence speed and smoother convergence path suggest higher market efficiency. Shorter volatility persistency also indicates higher market efficiency.

As for convergence speed, regardless of type of trading system, returns converge within about 3 minutes. Nikkei 225 futures return shows significant volatility persistency in both trading system. These results denote that the markets in both trading system are not strictly efficient. But future returns in ETS converges through smoother path to equilibrium level. The estimated length of volatility persistency in ETS is shorter than that in open-outcry. By these findings, we confirm that the market in ETS is more efficient than the market in open-outcry. Therefore, ETS is better trading system than open-outcry system in terms of market efficiency concept.

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