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Return Transmission and Volatility Spillover in Dual-listed Nikkei 225 Index Futures Markets: A Multivariate GARCH Analysis

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Abstract:

By means of a multivariate asymmetric VECM-GARCH-M model, this paper investigates the price transmission mechanism of the dual-listed Nikkei 225 Index futures through both return and volatility channels. Using daily data from the Chicago Mercantile Exchange and the Osaka Stock Exchange, we test the two prevailing schools of thought in global financial information transmission namely the international center hypothesis and the home bias hypothesis. Our results show significant support for the former in the return channel while support for the latter in the volatility channel. Return transmission reflects the fundamental linkage between the U.S. and Japanese economies as well as the psychological responses of global investors. Volatility spillovers between these two markets indicate the gradual release of private information from the Japanese market and the overreaction of the U.S. market.

Keywords: MV-GARCH, GARCH-M, TGARCH, VECM, Market Microstructure

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1. Introduction

Through a range of security markets, previous papers have investigated how information is transmitted within individual national markets, especially for major economies such as the U.S., the U.K., and Japan. For stock markets, Hamao, Masulis, and Ng (1990) study close-to-open and open-to-close intra-daily returns for Tokyo, London and New York stock markets; Karolyi and Stulz (1996) explore the cross-country equity returns covariance between the U.S. and Japan; they both find positive correlations in daily returns between different stock exchanges. For interest rates, Fung and Lo (1995) examine the relationship between the Treasury bill futures and the Eurodollar futures; Tse (1998) analyses the three-month Euromark futures on the U.K. and Singapore; they both discover that the interest rates markets are growing more integrated and that information transmission is very efficient. For exchange rates, Engle, Ito, and Lin (1990) study the Yen/Dollar exchange rates and report that intra-daily volatility spills over from the foreign market to the domestic market, rather than being country-specific.

The information transmission mechanism between the U.S. and Japan is the topic of our study. These two countries are both major economies (i.e., the first and the third largest) in the world with well developed and highly liquid financial markets. It is imperative to our study that there are no significant differences in liquidity premium and market frictions in their cross-listed securities. Many studies in the 90s use these two markets to evaluate the global impact of the 1987 market crash. The U.S. has been taken to represent the western economy and Japan the Asian economy. Similarly, as there have been two financial crises since 2000, it is interesting to have a retrospective comparison and see whether there are structural differences in behaviors of both markets in the recent decade.

Our study object, Nikkei 225 Index futures belongs to the family of cross-listed futures, among which are also Eurodollar futures, Euro-Yen TIBOR futures, etc. Multi-listed futures are traded on different national markets across time zones, but are almost[1] identical securities. These settings create a platform for worldwide investors to exchange information and views. Market participants can trade according to their most up-to-date locally or globally available information through the international market on almost a 24-hour basis. Trading contains the market perception on news impact. Information transmission is less efficient for single listed futures because of the geographical and participation constraints to foreign investors. Another important reason for using dual-listed futures, as stated by Fung, Leung, and Xu (2001), is that one can control factors that are unique to individual instruments. The understanding of the market microstructure of dual-listed futures markets can provide international investors with more effective strategies for forecasting, hedging, and speculating.

To investigate the information transmission pattern, researchers study both return and volatility characteristics of financial assets. In the data, the volatility of stock prices is time varying and the magnitude of market volatilities may affect market comovements (Karolyi and Stulz, 1996). Therefore, it is crucial to model both mean and variance when studying price transmission. In our paper, we examine the interactions between the two Nikkei 225 Index futures markets through both of the statistical moments.

As mentioned by Cox (1976), futures markets can serve as efficient channels for information transmission. One might expect an even flow of information among exchanges. Nevertheless, financial economists document asymmetries in

[1] Multi-listed futures with the same underlying assess could be different from each other in contract size, transaction cost, trading mechanism, exchange volume, etc. In efficient global exchanges, their prices are bounded by the cash and carry no arbitrage condition.

information transmission among countries (See, e.g., Fung and Lo, 1995; Tse, 1998). We test the information flow process between the U.S. and Japan against two hypotheses, the international center hypothesis and the home bias hypothesis. According to the former, the U.S. market should play a leading role in the transmission of information (See, e.g., Eun and Shim, 1989; Cheung and Mak, 1992). Alternatively, as implied by the latter, Japan, as the home country of the Nikkei 225 Index, should play a dominant role in the dissemination of information to other markets (See, e.g. Kang and Stulz, 1997; Choe, Kho, and Stulz, 2005).

We use the Vector Error Correction Model (VECM) to capture the dynamics in the return channel and allow for long run equilibrium among markets. Then, to check whether volatility spillovers occur, a bivariate asymmetric Generalized Autoregressive Conditional Heteroskedastic (GARCH) model is employed to account for the conditional variances of the residuals in the VECM mean equations. The model is estimated by the maximum likelihood estimator.

In short, our paper investigates both the return transmission and volatility spillover of Nikkei 225 Index futures contracts to seek a better understanding of information flows mechanism between the U.S. and Japanese markets, by applying the VECM and the GARCH model. At a glance, our results provide significant support for the international center hypothesis in which U.S. dominates the information flows in the return channel. Meanwhile, the results support the home bias hypothesis as Japan dominates in the volatility channel. The U.S. and Japanese Nikkei 225 Index futures markets are cointegrated. There are bidirectional flows of price information. Volatility spillovers are profound and there are overreactions to shocks.

The strong economic linkage between the U.S. and Japan explains the big influence that the U.S. has over the Japanese Nikkei futures market. Having similar monetary policy, these two countries tend to have linked business cycles. The gradually disseminated private information in the Japanese market is the main cause of volatility spillover. Both markets need time to have the differences in return expectation resolved. The U.S. investors' heterogeneous beliefs about Japanese domestic news partially explain the home bias effect and also the overreaction of the U.S. market to shocks.

Our paper has two important features. Firstly, the incorporation of GARCH in mean model (GARCH-M) captures the risk premium of bearing the conditional volatility. Secondly, the sampling periods of most previous studies were during the infancy of the Nikkei 225 Index futures on the Chicago Mercantile Exchange (CME) and the Osaka Stock Exchange (OSE) with limited demands and relatively small trading volumes. From 2000 to 2010, the trading volumes on both markets increased approximately by a factor of four with respect to the previous decade. The futures markets were more mature and more liquid. The developments allow us to look into the structural changes in the information transmission pattern between the U.S. and Japan.

The remainder of this article is organized as follows: Section 2 gives a comprehensive review of the literature concerning the theories and methodologies. Section 3 presents the two hypotheses we test. Section 4 specifies the model. Section 5 describes our data. Section 6 focuses on the empirical results and the interpretation of our findings. The last section summarizes the main conclusions of this paper.

2. Literature reviews

2.1 Return transmission channel

With the relaxation of capital controls and the integration of financial markets over the last two decades, many papers have investigated the patterns of information flow in the global market through a range of security markets.

In terms of the transmission of information on interest rates, Fung and Lo (1995) use the U.S. Treasury Bill futures and the Eurodollar futures to study the ex-ante relationship between domestic and international markets from 1982 to 1991. Their results reveal that the ex-ante domestic interest rates have a direct and inverse effect on European futures. The finding is in line with the view that the Eurodollar futures anticipates its underlying cash market's interest rate movement, which in turn affects the Treasury Bill market as these two markets grow more integrated. Examining the Euromark futures traded on London and Singapore markets, Tse (1998) finds that their prices are cointegrated and that the information transmissions are very rapid. In addition, the relatively liquid London market is more informationally efficient than the Singapore market. Karolyi and Stulz (1996) investigate the return comovements between the U.S. stocks and the American Depository Receipts (ADRs) of Japanese stocks. They find that their comovements are significantly related to the level of fluctuations in the S&P 500 Index. Nevertheless, systematic macroeconomic variables fail to explain market comovements. They suggest market contagion as a feasible explanation in which enthusiasm for stocks in the local market leads to the same enthusiasm for stocks in foreign markets. In other words, there is a herd instinct among countries. Foreign markets are driven more by market sentiments than by fundamentals.

2.2 Volatility spillover channel

When the information transmission among markets was first investigated, studies were mostly done via the first moment of the time series. Since Ross (1989) argues that the volatility of prices is directly related to the rate of information flow in an arbitrage-free economy, jointly with the rapid development in ARCH family models, researchers have put more attention on the volatility channel which can provide a deeper understanding of the information flow patterns.

To examine the causes of volatility clustering in the Yen/Dollar exchange rates, Engle, Ito, and Lin (1990) use a multivariate GARCH model to test whether the influence of volatility is solely country-specific, or the volatility spills over from one market to other markets. Their results show that the today's foreign news is more crucial than yesterday's domestic news. They claim that volatility clustering and spillovers can be caused by gradual release of private information, heterogeneous beliefs, market failures, and international policy coordination. For example, if the policy switch by the Fed causes the change of the monetary stance of the Bank of Japan, it would give rise to volatility spillovers. Hill, Schneeweis, and Yau (1990) analyze trading and non-trading periods of the Eurodollar futures and the U.S. Treasury Bond futures traded in Chicago, London, and Singapore. They find that variances during trading periods seem to be positively related to the flows of information. For foreign currency futures markets, Harvey and Huang (1991) show that the volatility of the U.S. European FX futures during the U.S. trading time is approximately double that during European trading time, implying that the influence of the U.S. news released within the CME trading period dominates the effect of news from the London market. They also compare the International Monetary Market (IMM) open-to-close return variances of Dollar-Yen futures with its weekday close-to-open variances. The security is 2.2 times more volatile during the IMM trading times than during the active period of the Japanese market. They thus confirm the essential role that the U.S. market plays in the global information generation.[2]

2.3 Conditional Heteroskedastic Models (ARCH/GARCH)

Volatility in financial assets is not directly observable. It is usually estimated by the sample variance of an asset's returns or squared returns. There are some well documented empirical facts concerning volatility. Firstly, returns of similar magnitude tend to cluster (volatility clustering) as they are conditionally dependent on each other. Secondly, volatility evolves progressively over time. Huge surges and sharp spikes are seldom observed. Thirdly, volatility is often stationary. Lastly, volatility reacts asymmetrically to positive and negative shocks. Negative shocks tend to have larger impact.

Engle (1982) pioneers the modeling of financial asset volatility by introducing the ARCH model. Volatility depends on the past evolution of shocks. Nonetheless, ARCH model usually requires a large lag structure to capture the volatility development. In response, Bollerslev (1986) provides a parsimonious generalized ARCH (GARCH) model. Under this regime, volatility depends on both previous shocks and past conditional variances. To account for the asymmetric (leverage) effect, Glosten, Jagannathan, and Runkle (1993) develop the threshold GARCH (TGARCH/GJR) model that measures the additional contribution of negative shocks to volatility. To analyze the effect of conditional variance on asset returns, Engle, Lilien, and Robins (1987) introduce the ARCH in mean (ARCH-M) model to measure the risk premium of volatility. Higher conditional variance means higher uncertainty in returns distribution. Risk-averse individuals require compensation for taking higher risks.

Bollerslev, Engle, and Wooldridge (1988) extend the univariate GARCH into

[2] For a comprehensive literature review on recent development in international asset pricing, please refer to Karolyi, G.A. and Stulz, R.M. 2003. Are Assets Priced Locally or Globally? *The Handbook of the Economics of Finance*, North Holland.

the multivariate Diagonal Vectorization (VEC) Model. The major drawbacks of VEC are the possible violation of positive-definite covariance matrix constraint and the neglect of possible dynamic dependence between volatility series. Engle and Kroner's (1995) Baba-Engle-Kraft-Kroner (BEKK) model addresses these two problems. Yet, the BEKK model parameters grow rapidly with lags and number of series. This inevitably increases the difficulty in estimating and interpreting the model. Bollerslev's (1990) constant conditional correlation (CCC) model tackles the issue of dimensionality by imposing time invariant restriction on correlation coefficient.[3]

2.4 Cointegration and error correction model

Engle and Granger's (1987) discovery of cointegation leads to modeling of the long run relations between economic variables. In the short run, economic variables often deviate from equilibrium. The error correction model (ECM) is applied to capture how variables adjust towards equilibrium. Johansen (1988, 1991) extends the cointegration test to the VAR framework. His approach permits reverse causality in economic variables and thus allows more than one cointegrating vector between two variables. Variables are treated as endogenous and this resolves the endogeneity bias.

[3] For more information concerning ARCH family model, please refer to Engle, R.F. 2001. GARCH 101: The use of ARCH/GARCH models in applied econometrics. *Journal of Economic Perspectives*, 15: 157-468 & Bauwens, L., Laurent, S. and Rombouts, J.V.K. 2006. Multivariate GARCH models: A survey. *Journal of Applied Econometrics*, 21: 79-109.

3. Hypotheses

3.1 International center hypothesis

The international center hypothesis suggests that information flows from a global financial center to offshore markets. Because of the increasing international portfolio diversification, a global financial center, such as the U.S. market, is believed to be a global factor which drives the development of other markets. Many papers studying the information transmission mechanism have found evidences supporting the dominant role of the U.S. market in information formation in the world economy. Using data from nine stock markets, Eun and Shim (1989) identify a substantial pattern of efficient information transmission from the U.S. to the Asia-Pacific and European markets, but find no significant influence from any foreign market to the U.S.. Cheung and Mak (1992) examine the relationship between the emerging Asia-Pacific markets and the developed U.S. and Japanese markets. Their results indicate that the U.S. market is more influential among the emerging markets, while the Japanese market, as the regional factor in Asia, has less significant impact. Engle, Ito, and Lin (1994) examine the returns and volatilities correlations between Tokyo and New York Indexes by using intra-daily data. They report bidirectional correlations between the two markets. New York's influence on Tokyo is twice as large as the reverse. Studying three financial futures cross-listed in the U.S., Japan, and Singapore from 1991 to 2000, Fung, Leung, and Xu (2001) find that the U.S. market plays a leading role in the return transmission between the U.S. and Asian markets. Based on the previous findings, there is a general consensus that information flows mainly originate from the U.S..

3.2 Home bias hypothesis

The home bias hypothesis implies that the key market information primarily flows from the domestic market to the external markets. There are several potential factors that give rise to the home bias effect. A leading explanation is that domestic investors have superior information over foreign investors. According to the findings of Kang and Stulz (1997), foreign investors in Japan prefer large stocks over small stocks. They conjecture that the information disadvantage of foreign investors is smaller for large stocks. There are several studies supporting the home bias hypothesis in global asset markets. Examining the minute by minute data of Bund futures traded on the LIFFE and the Deutsche Terminborse (DTB), Shyy and Lee (1995) discover that price movements in the German market Granger cause the price movements in the U.K. market. Furthermore, the price transmission is so fast that even one-minute lag variable for the DTB has a significant impact on the LIFFE. It suggests the existence of home bias in the lead-lag relationship between Germany and the U.K.. By applying a bivariate GARCH model to the futures markets in the U.S. and Asia, Fung, Leung, and Xu (2001) find that the volatility-spillover effects are stronger from the Japanese market to the U.S. market for Dollar-Yen currency futures. Brennan and Cao (1997) propose an international equity investment flow model which explains the home bias puzzle with information asymmetry between local and foreign investors. In their settings, the information leakage is a gradual process and domestic investors have superior information acquisition ability over foreigners. They find that Japanese investors are better informed about the Japanese market than the U.S. investors.

4. Methodology

4.1 Conditional mean equations (VECM Model)

$$R_{JP,t} = \alpha_0^{JP} + \sum_{r=1}^{JP,r} \alpha_r^{JP} R_{JP,t-r} + \sum_{s=1}^{JP,s} \beta_s^{JP} R_{US,t-s} + \gamma^{JP}\left(P_{JP,t-1} - P_{US,t-1}\right) + \varphi^{JP}\sigma_{JP,t}^2 + \theta^{JP} DMon_t + \varepsilon_{JP,t} \quad (1)$$

$$R_{US,t} = \alpha_0^{US} + \sum_{r=1}^{US,r} \alpha_r^{US} R_{US,t-r} + \sum_{s=1}^{US,s} \beta_s^{US} R_{JP,t+1-s} + \gamma^{US}\left(P_{US,t-1} - P_{JP,t}\right) + \varphi^{US}\sigma_{US,t}^2 + \theta^{US} DMon_t + \varepsilon_{US,t} \quad (2)$$

For modeling the return transmission between the CME and the OSE, we use the VECM framework. Each return series is explained by its own market return lags and the cross market return lags. The own market autoregressive (AR) terms $\{\alpha_r\}$ are used to remove linear dependency in the series and the cross market AR terms $\{\beta_s\}$ are used to capture the first moment information transmission between markets. It is worth mentioning that the lag structures for the two equations are different as the OSE and the CME have non-overlapping trading hours. The two time series have an intrinsic lead-lag relationship as the OSE trading precedes the CME trading on the same day. The GARCH-M terms φ are used to measure the risk premium of the conditional volatility in futures returns. The error correction terms γ are incorporated to allow for cointegrating relations between the two price indexes and they describe the speed of adjustment towards the long run equilibrium. Both cointegrating vectors are defined as one. Details for the stationarity test and the cointegration test are presented in appendix Table A and Table B. The Monday dummies θ isolate the effect of the weekend anomaly in daily data. σ_t^2, the conditional variance of residuals ε_t, are modeled by the following GARCH equations.

4.2 Conditional variance equations (GARCH Model)

$$\sigma^2_{JP,t} = \phi_0^{JP} + \phi_1^{JP}\sigma^2_{JP,t-1} + \sum_{q=1}^{JP,q}\eta_q^{JP}\,\varepsilon^2_{JP,t-q} + \delta^{JP}\left(\varepsilon^2_{JP,t-1}I_{JP,t-1}\right) + \sum_{m=1}^{JP,m}\lambda_m^{JP}\varepsilon^2_{US,t-m} + \psi^{JP}DMon_t \quad (3)$$

$$\sigma^2_{US,t} = \phi_0^{US} + \phi_1^{US}\sigma^2_{US,t-1} + \sum_{q=1}^{US,q}\eta_q^{US}\,\varepsilon^2_{US,t-q} + \delta^{US}\left(\varepsilon^2_{US,t-1}I_{US,t-1}\right) + \sum_{m=1}^{US,m}\lambda_m^{US}\varepsilon^2_{JP,t+1-m} + \psi^{US}DMon_t \quad (4)$$

$$\sigma_{US,JP,t} = \omega_0 + \omega_1\sigma_{US,JP,t-1} + \omega_2\left(\varepsilon_{JP,t-1}\varepsilon_{US,t-1}\right) \quad (5)$$

For modeling the volatility spillover between the CME and the OSE, we use a bivariate asymmetric GARCH model. It allows for the second statistical moment dynamic dependences and accounts for the correlation between the two series. Each conditional variance depends on the square of the individual lagged shocks ε^2_{t-q}, its own former conditional variance σ^2_{t-1} and the square of the cross market lagged shocks $\varepsilon^2_{JP,t+1-m}$, $\varepsilon^2_{US,t-m}$. The $\{\lambda_m\}$ terms measure the volatility spillover effect. The δ terms capture the asymmetric effect in volatility. The two binary indicator functions I_t take value of one when the conditional residual is negative. To reduce the number of variance equations, we use the CCC-GARCH model by assuming constant correlation between the CME and the OSE Nikkei 225 Index futures returns. The assumption is reasonable as the two futures based on the same underlying assets should not deviate significantly from each other. We perform Tse (2000) LM test[4] for constant conditional correlation in multivariate GARCH. The test statistics support our argument. Similarly to the conditional mean equations, the lag structures for the two are in a nonsynchronous

[4] The Tse (2000) LM test for constant conditional correlation is conducted by a code available on the Estima website. The null hypothesis of constant conditional correlation cannot be rejected at 1% level.

manner and Monday dummies are included to capture the anomaly as well. We use the Maximum Likelihood Estimation (MLE) methodology to estimate the nonlinear bivariate GARCH model (See Appendix 8.2 for more details).

4.3 Mathematical representations for hypotheses

International center hypothesis:

$$H_{0,\text{Mean}}: \sum_{s=1}^{US,s} \left|\beta_s^{US}\right| < \sum_{s=1}^{JP,s} \left|\beta_s^{JP}\right|$$

$$H_{0,\text{Variance}}: \sum_{m=1}^{US,m} \left|\lambda_m^{US}\right| < \sum_{m=1}^{JP,m} \left|\lambda_m^{JP}\right|$$

Home bias hypothesis:

$$H_{A,\text{Mean}}: \sum_{s=1}^{US,s} \left|\beta_s^{US}\right| > \sum_{s=1}^{JP,s} \left|\beta_s^{JP}\right|$$

$$H_{A,\text{Variance}}: \sum_{m=1}^{US,m} \left|\lambda_m^{US}\right| > \sum_{m=1}^{JP,m} \left|\lambda_m^{JP}\right|$$

To determine which hypothesis is supported by the data, the above notations are specified in accordance with the setup of our estimated equations. The summation of $\{\beta_s\}$ terms represents the aggregate return transmission effect while the summation of $\{\lambda_m\}$ terms represents the aggregate volatility effect. Absolute values of $\{\beta_s\}$ and $\{\lambda_m\}$ terms are used to avoid offsetting estimated parameters.

5. Data

5.1 Nikkei 225 Index futures

In 1986, the Singapore International Monetary Exchange (SIMEX) first launched the Nikkei 225 Index futures, based on the Nikkei 225 Stock Average. The Nikkei 225 Stock Average has been published daily as a price-weighted average of 225 top-rated Japanese companies listed on the Tokyo Stock Exchange (TSE) since 1950. The Nikkei 225 Index futures became the first index futures contract in Japan when the OSE issued it in 1988. It is now the most frequently traded Japanese index futures contracts, with an annual trading volume over 20 million units. The CME introduced the Nikkei 225 Index futures in 1990. By the end of 20th Century, the Nikkei 225 Index futures grew to be the world’s largest stock index futures, surpassing the Chicago’s S&P 500 Futures.

These three Nikkei 225 Index futures markets, the OSE, the CME, and the Singapore Exchange (SGX), differ from each other in several aspects. The OSE, as the home market, has higher volume of electronically traded Nikkei 225 Index futures. The SGX and the CME have lower transaction costs because of their mutual offset agreement on the futures contracts. The SGX serves as the satellite market of Japan. Both the SGX and the OSE have similar trading hours, so efficient market prohibits huge deviations between the two markets. Furthermore, Singapore, as a small open economy, is unlikely to have huge impact on the Japanese economy. For the above reasons, our emphasis on the comparison of the global center and the home market, and the simplicity of the GARCH analysis, the Singapore market is excluded from our research.

A particular issue worthy of attention is the trading time of the U.S. market and the Japanese market. In Greenwich Mean Time (GMT), the OSE is open from 00:00 to 06:15 and the CME from 14:00 to 21:15. The trading periods are depicted in Figure 1.

FIGURE 1

Nikkei 225 Index futures trading hours in GMT

The trading hours of the OSE precede those of the CME. Suppose that the Japanese market is influenced by the U.S. market. The Japanese market would not be able to respond to a U.S. market movement on the same day. Rather, it would respond with a one-day lag. On the other hand, if Nikkei 225 Index futures listed on the U.S. market is mainly influenced by its home market, the CME can respond to news from the OSE on the same calendar day if market is of high efficiency.

Table I shows contract specification, margin requirements, and liquidity measures of the Nikkei 225 Index futures traded in the U.S. and Japan.

TABLE I

Contract Specification, Margin Requirements and Liquidity of the Nikkei 225 Index Futures

Nikkei 225 Index Futures	*CME*	*OSE*
Contract size	US$5 × Nikkei 225 Index	JPN¥1,000 × Nikkei 225 Index
Trading hours	Chicago time: 08:00-15:15	Japan time: 09:00-15:15, 16:30-23:30
Initial margin	US$5,313	JPN¥600,000
Maintenance margin	US$4,250	JPN¥600,000
Open interest	23,574.33	270,956.27
Volume (turnover)	4,714.85	78,387.76

Note: Contract information is based on June 2011.
Daily average open interest and volume (in number of contracts) during the sample period.
Data are obtained from the website of CME and OSE.

5.2 Summary statistics

Daily Nikkei 225 Index futures closing price data from the CME and the OSE are obtained from the Thomson Reuters DataStream. We use the sample period for future contracts from 3 January, 2000 to 31 December, 2010. Table II summarizes the descriptive statistics for the daily returns in the two markets.

TABLE II

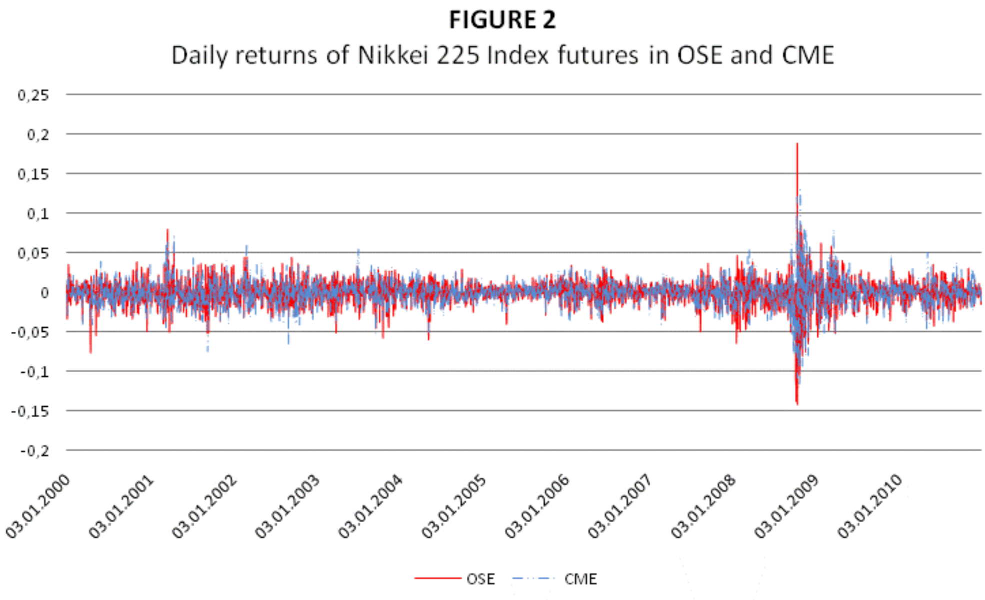
Descriptive Statistics

Nikkei 225 Index Futures	*CME*	*OSE*
Mean	- 0.000214	- 0.000213
Standard deviation	0.016627	0.016304
Skewness	- 0.075862	- 0.182430
Kurtosis	9.433956	15.80810
Observations	2,870	2,870

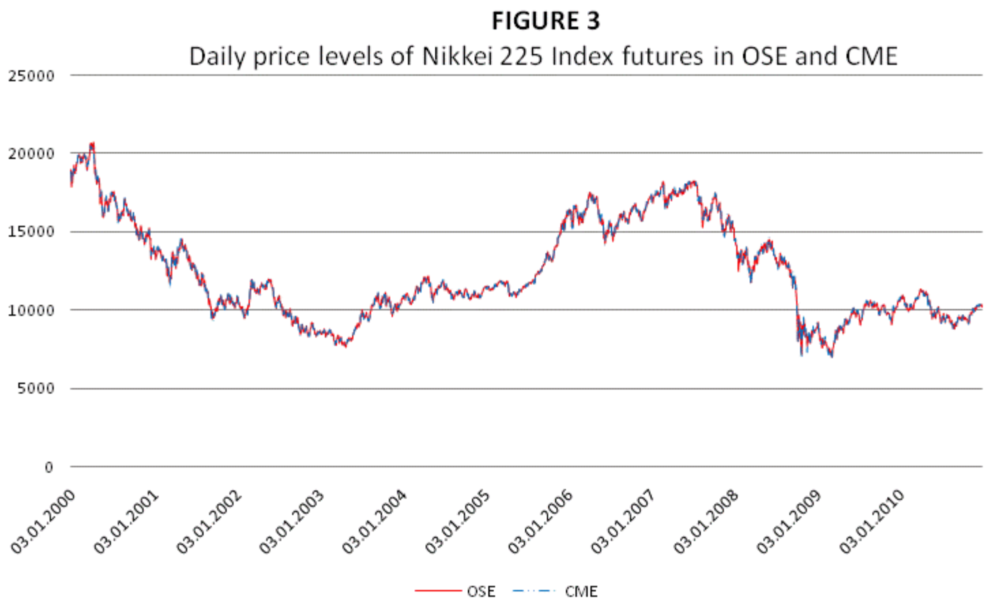
Note. Daily logarithmic returns are used.

Both series exhibit excess kurtosis and negative skewness. There are more extreme and negative observations in our sample than in a standard normal distribution. As shown by Bollerslev (1986), the GARCH distribution is leptokurtic. Together with GJR term, our model can adequately capture fat tails and asymmetry.

Figure 2 is the plot of daily returns in the OSE and the CME.



The daily returns oscillate around the mean of zero. Under efficient market hypothesis, asset prices should follow random walk and behave like a martingale. However, there are some serially dependences between returns. Price changes of similar size tend to bundle with each other. Apparently, this indicates volatility clustering. This justifies our use of GARCH type model in the analysis. Figure 3 is the plot of daily price levels in the OSE and the CME.



We observe that the two series move together. This is reasonable as the two futures indexes have the same underlying asset. In equilibrium, the two indexes should converge to eliminate arbitrage opportunities. To avoid misspecification bias in our system, we have to take into account of the potential cointegrating relationship between the two by including error correction terms.

6. Empirical results

The parameters estimates are presented in Table III.

TABLE III

VECM-GARCH Model for the Nikkei 225 Index Futures Dual-listed in Chicago and Osaka

Nikkei 225 Index Futures	*CME*		*OSE*	
Conditional Mean Equations (Pricing-Transmission Parameters)				
α_0 Constant term	2.03E-04	(0.825)	- 9.09E-04***	(-2.734)
α_1 Own-market return lag 1	- 0.0207	(-1.250)	- 0.0681***	(-2.998)
β_1 Cross-market return lag 1	0.0698**	(2.556)	0.0822***	(3.119)
γ Error correction term	- 4.42E-05***	(-16.817)	- 5.52E-05***	(-23.155)
θ Monday dummy variable	4.83E-04	(1.152)	9.48E-04**	(2.048)
φ GARCH in mean term	5.1796***	(2.792)	- 2.7471	(-1.240)
Conditional Variance Equations (Volatility-Spillover Parameters)				
ϕ_0 Constant term	6.56E-06***	(5.153)	3.67E-06***	(5.076)
ϕ_1 GARCH lag 1	0.9061***	(91.196)	0.8380***	(73.780)
η_1 ARCH lag 1	0.0151*	(1.944)	0.0371***	(3.653)
δ Asymmetric term	0.0830***	(7.551)	0.0968***	(5.252)
λ_1 Volatility-spillover lag 1	0.0810***	(5.465)	0.0512***	(5.517)
λ_2 Volatility-spillover lag 2	- 0.0651***	(-4.609)		
ψ Monday dummy variable	- 2.45E-05***	(-4.364)	9.38E-06**	(2.151)

Note. The t-Statisitcs are in parentheses.
* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

6.1 Return transmission results

For conditional mean equations, the cross-market return lag 1 terms β_1 in both markets are significant, implying bilateral flows of returns. In line with previous empirical studies, the U.S. market has greater influence on the Japanese market in the return channel. This result is attributable to fundamental linkage of the two economies, coordinating monetary policies as well as market contagion. These three underlying reasons are discussed in detail in Section 6.3.

We find a significant negative own-market return lag 1 term α_1 in the OSE.

The error correction terms γ in both markets are highly significant and negative. It justifies the incorporation of cointegrating relationship in our model. This is in line with Harris et al.'s (1995) recognition of the importance of cointegration and error correction in modeling the price discovery of informationally linked securities. As a result, negative corrections are made to positive errors, and vice versa. The model captures the reversion of variables towards the long run equilibrium. The speed of adjustments is slightly faster in the OSE than in the CME. The Monday effect is only significant in the OSE. In contrast to previous findings, the Monday dummy parameters are positive, indicating possible risk compensation for the uncertainty over weekend. Despite this, their overall effects are negligible. For the GARCH-M terms φ, we find positive and significant risk premium for the conditional variance on the CME's returns but negative and insignificant risk premium for the OSE counterpart. One possible explanation is that the CME participants are more risk averse and require higher compensation for holding a volatile security. The risk of conditional variance could be idiosyncratic to the OSE investors. As a result, Japanese investors earn no premium as they can diversify the risk away. As shown by Ross (1989), volatility of prices is directly related to the rate of information flows. So another reason is perhaps that U.S. specific information flow rate is important to Nikkei 225 Index futures prices.

6.2 Volatility spillover results

For the conditional variance equations, we find large and highly significant GARCH lag 1 terms Φ_1 in both markets. Most variation in the conditional variance is explained by its previous period conditional variance. It indicates persistence in the evolution of conditional variance. ARCH lag 1 terms η_1 and the asymmetric terms δ are also positive and significant in the two exchanges. The conditional variances of the two series depend on previous period shocks and innovations. Moreover, negative return shocks (bad news) have larger impacts on volatility. Markets react asymmetrically to the nature of news. The Monday effect term is negative and significant in the CME while positive and significant in the OSE, but its overall impact is tiny. No matter how small the parameters are, given they are statistically significant, including them in the model still reduces the omitted variable bias in estimation.

Significant bidirectional volatility spillovers are observed in our data. The aggregate volatility spillover effect is slightly larger for the direction from Japan to the U.S.. This indicates that the home bias hypothesis is applicable to volatility channel in dual-listed Nikkei 225 Index futures.

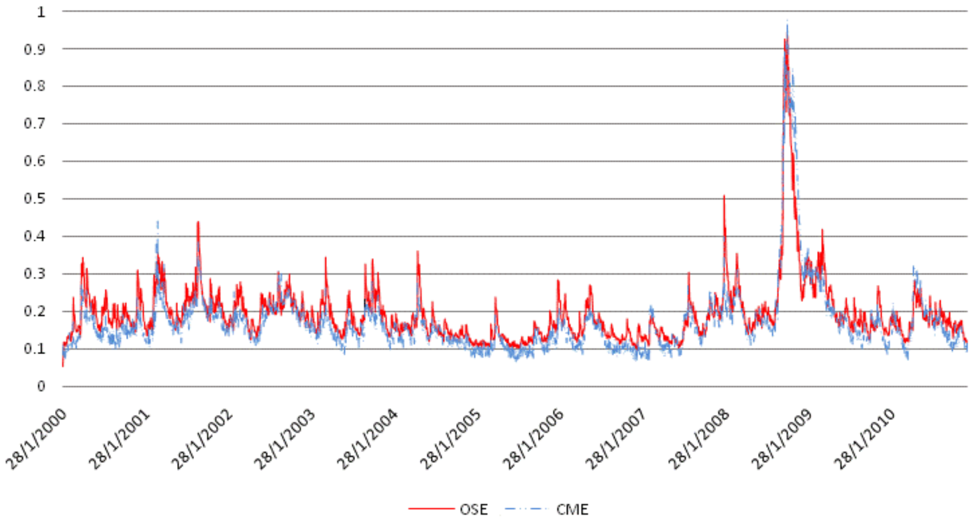
A natural reason for home bias effect is that domestic investors are better informed of domestic information and have advantages in acquiring private information over foreign investors. According to French and Roll’s research in 1986, most volatility in stock return is due to the release of price-decisive private information caused by the trading of informed investors. The diversity of private information among traders gives rise to heterogeneous expectations. Moreover, heterogeneous expectations can be caused by the existence of speculative traders and arbitrageurs who trade in attempt to profit from their perceived mispricing in the market. In contrast, hedgers only trade to manage risk in their portfolio. It is hard to tell which investor type represents the majority in the two exchanges. In an idealistic equilibrium, there will be no trade as price incorporates all available information and investors have homogeneous beliefs. But the high trading volumes reflect highly dispersed views in the market. Anderson, Ghysels, and Juergens (2005) find that heterogeneity of beliefs can be included as a price factor in traditional asset pricing models to explain the return volatility. Furthermore, private information is gradually incorporated into prices during trading hours. Such dynamics could induce the continuity of volatility after a shock ends. In our case, the dispersed predictions and private information among Japanese traders induce the volatility in the OSE. By observing the volatile future prices and volume change in the Japanese market, the CME investors make inferences on the acquired Japanese information and trade accordingly. Thus through the dual-listed Nikkei 225 Index futures, the volatility spills over to the U.S. market while the futures prices keep fluctuating before they finally reflect all private information. The reverse can undoubtedly occur. However, as we conjecture that Japanese investors have information advantage, the overall volatility flow is still predominated by the OSE. Also, the gradual dissemination of private information causes the persistence of return volatility in both markets.

On the other hand, the home bias in volatility channel could also be partially attributed to the U.S. investor's diverse interpretation or heterogeneous beliefs about the Japanese fundamentals. It is more challenging for foreign investors to make an accurate prediction on the impact of specific domestic news. The U.S. market needs more time to interpret the meaning of news (public or private) from Japan and to have the expectational differences resolved, while Japanese investors can respond to home shocks and innovations more quickly and precisely. Engle, Ito, and Lin (1990) suggest that volatility spillover can be caused by international policy coordination or competition and market failures such as asset bubbles and crashes. As the data supports home bias in volatility channel, gradual release of private information from Japanese market should play a more significant role in volatility spillover formation.

It is interesting that volatility-spillover lag 2 term λ_2 in the CME is negative and significant. We conjecture that investors in the U.S. market tend to overreact to the first lag foreign volatility because of market contagion. Consequently, they have to correct the overreactions in the second period. As mentioned above, the U.S. investors are more uncertain about how local news actually affects the performance of the Japanese market. In contrast, the spillover only lasts for 1 lag in Japan. This can be an indication that the home market is relatively more informationally efficient. In other words, there is no prolonged volatility spillover from the U.S. to Japan.

FIGURE 4

Estimated volatility for Nikkei 225 Index Futures



From our fitted GARCH model, we obtain the estimated conditional volatilities for the two markets. The plot of the two time series is shown in Figure 4 above.

The daily conditional volatilities are annualized with an average of 245 trading days per year. The two markets show similar cyclical pattern. Volatile periods are usually followed by relatively tranquil periods. There are several noticeable spikes and we can relate them to real world events. The two significant spikes in 2000 and 2001 could be explained by the burst of the IT industry bubble and the 911 attack. From 2007 to 2009, in the midst of credit crisis, the failures of major financial institutions such as Bear Stearns and Lehman Brothers also caused extraordinary spikes. The annualized daily volatility once reached a level of over 90%. Interestingly, all the above events occurred in the U.S. but they all had great impact on the volatility of the Japanese market. The dual-listed Nikkei 225 Index futures is proven to be an efficient channel of volatility spillovers between these two countries. This also indicates that major economies are integrated. Correlations in major worldwide stock indexes could sharply increase during crises and abrupt changes. The conventional wisdom of global diversification may underestimate the true systematic risk of international portfolios as regional shocks can severely affect global markets. It is clear that the volatility only surges for a short period. Before long, the mean reverting mechanism brings the conditional volatility back to the level of unconditional mean volatility of around 25% annually.

We obtain the best fit of the model by selecting one β lag and two λ lags in the CME while one β lag and one λ lag in the OSE. Table C in the appendix summarizes the SBC for different combinations of lags. It is worth mentioning that the conclusion can be drastically different if univariate (UV) GARCH model is applied separately to the two markets. For instance, UV GARCH implicitly assumes the conditional residuals of the U.S. and Japan are independent. Under this paradigm, the results support the home bias hypothesis in both channels. Nonetheless, this conclusion is erroneous as one omits the correlation between the two returns series and foreign market returns are considered as exogenous to the system. This creates endogeneity bias in the estimations. Therefore, the estimates from UV GARCH are not used as the starting values for the MLE. To get the proper starting values, we use the estimated parameters from a VECM system in which all variables are endogenously determined. This resolves the issue of bias.

6.3 Influence of S&P 500 Index futures on Nikkei 225 Index futures

To answer why Nikkei 225 Index futures are more influenced by the U.S. market than its home market in return channel, we set up the following VAR system between the S&P 500 Index futures and the CME-listed Nikkei 225 Index futures to investigate their causal relationship.

$$R_{S,t} = \alpha_S + \sum_{p=1}^{S,p} \beta_{S,p} R_{S,t-p} + \sum_{q=0}^{S,q} \gamma_{S,q} R_{N,t-q} + \varepsilon_{S,t} \quad (6)$$

$$R_{N,t} = \alpha_N + \sum_{p=1}^{N,p} \beta_{N,p} R_{N,t-p} + \sum_{q=0}^{S,q} \gamma_{N,q} R_{S,t-q} + \varepsilon_{N,t} \quad (7)$$

The rationale of using data solely from the CME is that the trading of the two securities is synchronous. So we do not have to account for the implicit calendar day lead-lag relationship between exchanges in different time zones. We can study how news in the U.S. affects the CME traded Index futures. This setting permits investigations of contemporaneous information flow patterns. The S&P 500 Index futures serves as a good proxy for the U.S. economy. Because of the highly liquid market, macroeconomic shocks and sector-specific surprises in the U.S. are rapidly reflected in the price of futures. Traders can assess how these shocks and surprises affect the Japanese market, and trade on the CME according to their price expectations before the opening of the OSE. The changes in the price of the CME-listed Nikkei 225 Index futures reveal potential influence of the information released in the U.S. trading hours on the Japanese market. As the regressors are different in each equation and we suspect that residuals are correlated across equations, Seemingly Unrelated Regression (SUR) is used for estimation for it gains efficiency over the OLS.

TABLE IV

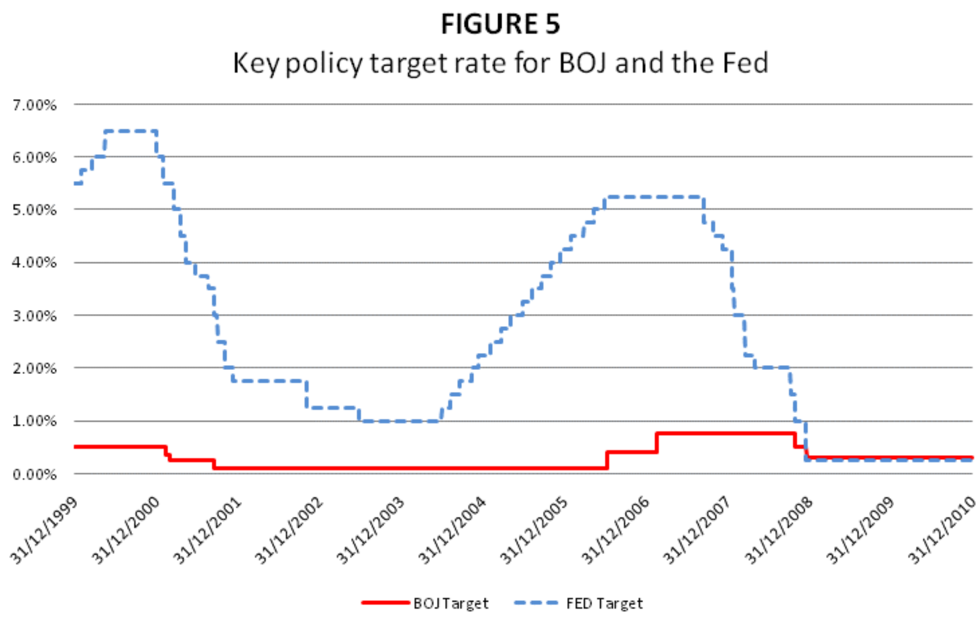
Seemingly Unrelated Regression Between Nikkei 225 Index Futures and S&P 500 Index Futures

	Chicago Mercantile Exchange	*Nikkei 225 Index Futures*		*S&P 500 Index Futures*	
α	Constant term	- 1.63E-04	(-0.769)	- 1.22E-04	(0.703)
β_1	Own-market return lag 1	0.0138	(0.738)	0.0056	(0.302)
β_2	Own-market return lag 2	- 0.0404**	(-2.168)	- 0.0454**	(-2.438)
β_3	Own-market return lag 3	- 0.0037	(-0.196)	- 0.0101	(-0.544)
γ_0	Cross-market return	1.1633***	(92.344)	0.7797***	(92.344)
γ_1	Cross-market return lag 1	- 0.0124	(-0.544)	- 0.0134	(-0.878)
γ_2	Cross-market return lag 2	0.0497**	(2.188)	0.0300**	(1.965)
γ_3	Cross-market return lag 3	0.0131	(0.578)	0.0034	(0.225)

Note. The t-Statisitcs are in parentheses.
* Significant at the 10% level
** Significant at the 5% level
*** Significant at the 1% level

Table IV presents the SUR results for the relationship between the S&P 500 Index futures and the CME-listed Nikkei 225 Index futures. We observe strong and highly significant contemporaneous interactions between the two securities. As expected, the S&P 500 Index futures have greater influence on the Nikkei 225 Index futures than the other way around. The dual-listed Nikkei 225 Index futures then acts as the indirect channel for information transmission, so the news in the U.S. market indeed affects the price discovery in the Japanese market. The analysis further strengthens the international center argument. In contrast to the simultaneous relations, the lead-lag interaction is far less profound. Only the cross market return lag 2 terms are significant. One possible reason is that the market is not fully efficient. Some of the pricing information is only translated into prices two days after its initial release. This is also the source of volatility spillovers. Nevertheless, the associate changes in returns based on the two days lagged information are almost negligible.

Japan, as the third largest economy in the world, relies heavily on international trade. According to the World Bank's statistics, approximately 12% of Japanese GDP comes from exports. The U.S. is the second largest importer of Japanese goods and services. Undoubtedly, boom and bust in the U.S. economy can greatly affect Japanese exports because of the fluctuations in the U.S. aggregate demand.



The historical key policy target rates of the Bank of Japan (BOJ) and the Federal Reserve (Fed) are presented in Figure 5. Key policy target rate is the tool for central bank to conduct stabilization policies through interest rate and foreign exchange rate channels. In the first channel, by changing the short term interest rates target, the central bank can influence the public's expectations on future interest rates and thus alter the shape of the yield curve. Economic agents will increase or delay their consumption because of the intertemporal substitution effect. This affects the aggregate output of the economy. In the second channel, foreign exchange rates will also change under the interest rate parity condition. Economic agents will switch between the consumption of domestic and foreign goods. This influences the balance of trade of an economy. [5]

According to Blenck et al. (2001), central banks in developed economies

[5] For a detailed explanation on how monetary policy affects business cycle, please refer to Bernanke, B.S. and Reinhart, V. R. 2004. Conducting Monetary Policy at Very Low Short-Term Interest Rates. American Economic Review. 94(2), pp. 85-90.

have similar stabilization monetary policies. Japan faces the problem of liquidity trap as its nominal interest rate is near zero. The low nominal interest rate policy by the BOJ attempts to ease the prolonged deflation which is the aftermath of the lost decades since 1990s. Bernanke and Reinhart (2004) claim that the BOJ's commitment on maintaining a zero interest rate policy can increase the policy's credibility and its effectiveness. To mitigate the negative impact of foreign countries' monetary policies on its exports, the BOJ also carries out open market operations to influence market interest rate and foreign exchange rate directly as there is little room for lowering the target rate further. For example, facing the increasingly appreciating Japanese Yen, the BOJ injects capital to international FX market and artificially drives down the USD/JPY exchange rate. In spite of the fundamental differences in the two economies for the last decade, we can still observe similar pattern of the key policy rates in Japan and the U.S. during the periods of 2000 to 2001 and 2007 to 2008 respectively. By inspecting the data closely, we find that the Fed's decisions on reducing target rate in the two periods both precede that of the BOJ. During the recent global debt crisis, as nominal interest rates in both countries approach zero, the BOJ and the Fed implement similar quantitative easing policies by injecting capital directly to the private sector. They attempt to stimulate the economy by increasing the money supply and restoring market confidence. Therefore, business cycles of the two countries are linked by their monetary policy interaction.

Broad stock market indexes are mainly comprised of large stocks. Unlike small stocks, in which home bias effects are stronger since the acquisition of domestic information is more difficult for foreign investors, large stocks are more vulnerable to influences from abroad. This intuition is in line with our findings.

Karolyi and Stulz (1996) find no role of systematic macroeconomic factor in market comovements between Japan and the U.S.. Fundamentals alone may not be sufficient in explaining the interaction of the two markets. Alternatively, the behavioral school of thought provides a different perspective in explaining our findings. Apart from the quantitative evidences, a questionnaire survey of investor behavior conducted by Shiller, Kon-Ya, and Tsutsui (1991) reveals that the Japanese institutional investors consider the drop of U.S. stock prices during the 1987 market crash as the primary cause of the decline in Japanese market. Japanese institutional investors also prefer psychological factors over fundamentals when explaining the collapse in the Japanese market. Market contagion appears to be a valid argument especially during financial distress. As the Japanese market has experienced downturn for more than 15 years, their views back in the early 1990s can no longer reflect the reality. The structural change in Japanese economy is the culprit of its prolonged lag in economic growth relative to other developed economies. Hayashi and Prescott (2002) believe that Japan suffers from a lower steady state growth path after the 1990s. We cannot rule out the psychological impacts in the short run during crisis, but market sentiment should never have long run effect as individuals correct expectational errors given sufficient time.

6.4 Evaluation of the model

TABLE V

Portmanteau Statistic for VECM-GARCH Model

Nikkei 225 Index Futures	*CME*		*OSE*	
	Ljung and Box Q-Statistics for Linear Temporal Dependence			
Lag 4	7.071	(0.132)	2.614	(0.624)
Lag 8	10.261	(0.247)	7.724	(0.461)
Lag 12	15.424	(0.219)	9.360	(0.672)
	Ljung and Box Q-Statistics for Nonlinear Temporal Dependence			
Lag 4	4.295	(0.368)	3.553	(0.470)
Lag 8	4.736	(0.785)	7.539	(0.480)
Lag 12	14.908	(0.247)	9.338	(0.674)

Note. Probability values are in parentheses.

We conduct Ljung and Box (1978) portmanteau test to evaluate the goodness of fit of our VECM-GARCH model. In effect, it is a joint test on the autocorrelation coefficients between lagged variables. Table V shows that the null hypotheses of no serial correlation and no conditional heteroskedasticity cannot be rejected at the 1% significance level. So we conclude that our model is adequate in explaining linear dependence in returns and nonlinear dependence in variances.

7. Conclusion

This paper investigates the return transmissions and volatility spillovers between the CME and the OSE dual-listed Nikkei 225 Index futures markets by using a multivariate asymmetric VECM-GARCH-M model. Coinciding with previous studies, our results show a strong role that the U.S. plays in the global information transmission. For return, there are apparent bilateral flows of information between the U.S. and Japan. We gain further insight by studying the relationship between the S&P 500 Index futures and the CME traded Nikkei 225 Index futures. Information released in the U.S. trading hours is of paramount importance to the Japanese market. The dual-listed futures markets provide an indirect channel for transmitting shocks, innovations, and beliefs from Chicago to Osaka. We believe the international center hypothesis gets its supports from fundamental linkages between the U.S. and Japanese economies as well as the psychological market contagion effect. In terms of volatility, there exists a home bias effect. The heterogeneous beliefs induced by the dispersion of private information in the Japanese market are the principal cause of volatility in the Nikkei 225 Index futures market. Since it takes time for the private information to be fully incorporated into prices, the volatility tends to be persistent; and the Nikkei 225 Index futures serves as a channel for the volatility spillover from Osaka to Chicago. Volatility clustering and asymmetry are readily observed in our data.

For further research, there are a few feasible improvements to our current study. Firstly, one can use higher frequency intraday data. This permits the decomposition of close-to-close returns into daytime open-to-close returns and overnight close-to-open returns. Investors may behave differently in the two sub-periods. Secondly, by extending the current GARCH model from bivariate to trivariate, one can study the interaction between the U.S., Japan, and Singapore. This provides a more comprehensive understanding of the multi-listed Nikkei 225 Index futures markets. Last but not least, systematic risk factors can be added to our time series model. This provides researchers with better insight into which factors actually affect return and variance of the security. If systematic risk factors do significantly influence price and volatility, the fundamentals explanation would be more appropriate than the psychological explanation.

8. Appendix

8.1 Test for stationarity and cointegration

TABLE A

Unit Root Test Statistics for Nikkei 225 Index Futures

Nikkei 225 Index Futures	*CME*		*OSE*	
	Augmented Dickey-Fuller (ADF) Unit Root Test			
Level test	- 2.4536	(0.1273)	- 2.4569	(0.1264)
First difference test	- 9.3453***	(0.0000)	- 9.2594***	(0.0000)
	Kwiatkowski-Phillips-Schmidt-Shin (KPSS) Unit Root Test			
Level test	0.6961**		0.7005**	
First difference test	0.1917		0.1934	

Note. Probability values are in parentheses.
** Significant at the 5% level
*** Significant at the 1% level

Confirmatory data analysis is conducted on our sample data set. The test statistics for ADF and KPSS unit root tests both indicate that the two price series are first difference stationary I(1).

TABLE B

Johansen test for cointegration

Cointegration system	*PUS,t & PJP,t*		*PUS,t-1 & PJP,t*	
	Unrestricted Cointegration Rank Test (Trace)			
Number of hypothesized CE	Test statistics	Probability	Test statistics	Probability
None	1,253.509***	(0.0000)	1,371.709***	(0.0000)
At most 1	4.655**	(0.0309)	4.722**	-0.0298
	Unrestricted Cointegration Rank Test (Maximum Eigenvalue)			
Number of hypothesized CE	Test statistics	Probability	Test statistics	Probability
None	1,248.853***	(0.0000)	1,366.988***	(0.0000)
At most 1	4.655**	(0.0309)	4.722**	(0.0298)
	Normalized cointegrating vectors			
On US price index	- 1.0024		1.0000	
On JP price index	1.0000		- 0.9977	

Note. Probability values are in parentheses.
** Significant at the 5% level
*** Significant at the 1% level

Johansen cointegration test is performed on the price indexes on the U.S. and Japanese markets. Both trace test and maximum eigenvalue test show support for cointegrating relation between the CME's and the OSE's Nikkei 225 Index futures.

8.2 Estimation method

To estimate the nonlinear bivariate GARCH model, we make use of the Maximum Likelihood Estimation (MLE) methodology. The estimator maximizes the log-likelihood function by choosing parameters in the five equations simultaneously. By assuming that the conditional errors from Equations (1) and (2) are normally distributed, the product of likelihood functions for the whole system is then specified by Equation (8).

$$L = \prod_{t=1}^{T} \frac{1}{2\pi\sqrt{|H_t|}} \exp\left[-\frac{1}{2}\varepsilon_t' H_t^{-1} \varepsilon_t\right] \tag{8}$$

s.t.

$$H_t = \begin{bmatrix} \sigma_{JP,t}^2 & \sigma_{US,JP,t} \\ \sigma_{US,JP,t} & \sigma_{US,t}^2 \end{bmatrix} \tag{9}$$

$$\varepsilon_t = \begin{bmatrix} \varepsilon_{JP,t} \\ \varepsilon_{US,t} \end{bmatrix} \tag{10}$$

By taking log of equation (8), we obtain equation (11).

$$\ln L = -\frac{T}{2}\ln(2\pi) - \frac{1}{2}\sum_{t=1}^{T} \ln|H_t| - \frac{1}{2}\sum_{t=1}^{T} \left[\varepsilon_t' H_t^{-1} \varepsilon_t\right] \tag{11}$$

The estimation procedure requires recursive iterations. We have to define all the starting values for the estimates. To facilitate the estimation process, the simplex algorithm is first applied to refine our initial starting values. Berndt, Hall, Hall, and Hausman's (1974) BHHH algorithm is then used for the final numerical optimization process. It maximizes the log-likelihood function in Equation (11) up to the pre-defined convergence limit. The lag structure for the model is determined by minimizing the Schwarz Bayesian Criterion (SBC). The SBC is chosen over the Akaike Information Criterion (AIC) as the SBC is asymptotically consistent and it generally gives a more compact lag structure which keeps our model parsimonious.

8.3 Selection of time series lags

TABLE VI

SBC with Different Lags for β and λ

			Lag for Lambda λ			
	US		1		2	
		JP	1	2	1	2
Lag for Beta β	1	1	-16.1669	-16.1656	**-16.1721**	-16.1709
		2	-16.1643	-16.1629	-16.1696	-16.1683
	2	1	-16.1647	-16.1635	-16.1698	-16.1687
		2	-16.1621	-16.1609	-16.1672	-16.1661

We use the following definition for calculating SBC:

$$\mathrm{SBC} = \frac{1}{\mathrm{T}}[-2\ln L + \mathrm{n}\ln(\mathrm{T})]$$

in which n is the number of estimated parameters and T is the number of observations. We choose the appropriate lag lengths by minimizing the SBC. The SBC for β lags over 2 and λ lags over 2 are not reported for the following reasons. First, the parameters estimates become insignificant when the system is over-specified. The additional noise of the irrelevant variables increases the standard errors of estimates. Second, we observe monotonic increase in the SBC for lags beyond the current setting. The increase in likelihood is outweighed by the penalty of including more parameters.

8.4 Frequently used mathematical notations

$R_{JP,t}$: daily logarithmic return for Japanese market at time t

$R_{US,t}$: daily logarithmic return for U.S. market at time t

$P_{JP,t}$: daily price level for Japanese market at time t

$P_{US,t}$: daily price level for U.S. market at time t

α_0^{JP} : constant term for Japanese market mean equation

α_0^{US} : constant term for U.S. market mean equation

α_r^{JP} : own market return of lag order r for Japanese market

α_r^{US} : own market return of lag order r for U.S. market

β_s^{US} : cross market return of lag order s for Japanese market

β_s^{JP} : cross market return of lag order s for U.S. market

γ^{JP} : error correction term for Japanese market

γ^{US} : error correction term for U.S. market

φ^{JP} : GARCH in mean term for Japanese market

φ^{US} : GARCH in mean term for U.S. market

θ^{JP} : Monday dummy for Japanese market mean equation

θ^{US} : Monday dummy for U.S. market mean equation

$\sigma_{JP,t}^2$: conditional variance of Japanese market at time t

$\sigma_{US,t}^2$: conditional variance for U.S. market at time t

$\sigma_{US,JP,t}$: conditional covariance between Japanese and U.S. market at time t

ϕ_0^{JP} : constant term for Japanese market conditional variance equation

ϕ_0^{US} : constant term for U.S. market conditional variance equation

ϕ_1^{JP} : GARCH term of lag order 1 for Japanese market

ϕ_1^{US} : GARCH term of lag order 1 for U.S. market

η_q^{JP} : ARCH term of lag order q for Japanese market

η_q^{US} : ARCH term of lag order q for U.S. market

δ^{JP} : asymmetric term for Japanese market

δ^{US} : asymmetric term for U. S. market

$I_{JP,t-1}$: indicator fuction for Japanese market

$I_{US,t-1}$: indicator fuction for U. S. market

λ_m^{US} : volatility spillover term of lag order m for Japanese market

λ_m^{JP} : volatility spillover term of lag order m for U. S. market

ρ^{JP} : Monday dummy for Japanese market conditional variance equation

ρ^{US} : Monday dummy for U. S. market conditional variance equation

8.5 Model specifications

Mean equation (VECM Model)

$$R_{JP,t} = \alpha_0^{JP} + \sum_{r=1}^{JP,r} \alpha_r^{JP} R_{JP,t-r} + \sum_{s=1}^{JP,s} \beta_s^{JP} R_{US,t-s} + \gamma^{JP}\left(P_{JP,t-1} - P_{US,t-1}\right) + \varphi^{JP}\sigma_{JP,t}^2 + \theta^{JP} DMon_t + \varepsilon_{JP,t} \quad \text{(i)}$$

$$R_{US,t} = \alpha_0^{US} + \sum_{r=1}^{US,r} \alpha_r^{US} R_{US,t-r} + \sum_{s=1}^{US,s} \beta_s^{US} R_{JP,t+1-s} + \gamma^{US}\left(P_{US,t-1} - P_{JP,t}\right) + \varphi^{US}\sigma_{US,t}^2 + \theta^{US} DMon_t + \varepsilon_{US,t} \quad \text{(ii)}$$

Variance equation (GARCH Model)

$$\sigma_{JP,t}^2 = \phi_0^{JP} + \phi_1^{JP}\sigma_{JP,t-1}^2 + \sum_{q=1}^{JP,q} \eta_q^{JP} \varepsilon_{JP,t-q}^2 + \delta^{JP}\left(\varepsilon_{JP,t-1}^2 I_{JP,t-1}\right) + \sum_{m=1}^{JP,m} \lambda_m^{JP}\varepsilon_{US,t-m}^2 + \rho^{JP} DMon_t \quad \text{(iii)}$$

$$\sigma_{US,t}^2 = \phi_0^{US} + \phi_1^{US}\sigma_{US,t-1}^2 + \sum_{q=1}^{US,q} \eta_q^{US} \varepsilon_{US,t-q}^2 + \delta^{US}\left(\varepsilon_{US,t-1}^2 I_{US,t-1}\right) + \sum_{m=1}^{US,m} \lambda_m^{US}\varepsilon_{JP,t+1-m}^2 + \rho^{US} DMon_t \quad \text{(iv)}$$

$$\sigma_{US,JP,t} = \omega_0 + \omega_1\sigma_{US,JP,t-1} + \omega_2\left(\varepsilon_{JP,t-1}\varepsilon_{US,t-1}\right) \quad \text{(v)}$$

8.6 WinRATS code for estimation

```
OPEN DATA "C:\Users\user\Desktop\00_10data.xls"

DATA(FORMAT=xls,ORG=COLUMNS) 1 2871 osx cme dum

set r_osx = log(osx(t)/osx(t-1))

set r_cme = log(cme(t)/cme(t-1))

set h1 = 0.0

set h2 = 0.0

nonlin a0_j a1_j b1_j g1_j t1_j m1_j a0_u a1_u b1_u g1_u t1_u m1_u o0_j o1_j
n1_j u1_j l1_j p1_j o0_u o1_u n1_u u1_u l1_u l2_u p1_u rho

frml e_jp =
r_osx(t)-a0_j-a1_j*r_osx(t-1)-b1_j*r_cme(t-1)-g1_j*(osx(t-1)-cme(t-1))-t1_j*dum
-m1_j*h1(t)

frml e_us =
r_cme(t)-a0_u-a1_u*r_cme(t-1)-b1_u*r_osx(t)-g1_u*(cme(t-1)-osx(t))-t1_u*dum
-m1_u*h2(t)

set gjr_j = %if(e_jp> 0,0,1)

set gjr_u = %if(e_us> 0,0,1)

frml gvar_jp =
o0_j+o1_j*h1(t-1)+n1_j*e_jp(t-1)**2+u1_j*gjr_j(t-1)*e_jp(t-1)**2+l1_j*e_us(t-
1)**2+p1_j*dum

frml gvar_us =
o0_u+o1_u*h2(t-1)+n1_u*e_us(t-1)**2+u1_u*gjr_u(t-1)*e_us(t-1)**2+l1_u*e_j
p**2+p1_u*dum+l2_u*e_jp(t-1)**2

frml gdet = -0.5*(log(h1(t)=gvar_jp(t))+log(h2(t)=gvar_us(t))+log(1.0-rho**2))

frml garchln =
gdet-0.5*((e_jp(t)**2/h1(t))+(e_us(t)**2/h2(t))-2*rho*e_jp(t)*e_us(t)/sqrt(h1(t)*
```

```
h2(t)))/(1.0-rho**2)
smpl 20 2871
compute a0_j = 0, a1_j = 0,    b1_j = 0.05, g1_j = 0, t1_j = 0, m1_j = 0, a0_u = 0,
a1_u = 0,    b1_u = 0.05, g1_u = 0, t1_u = 0, m1_u = 0, o0_j = 0, o1_j = 0.9,
n1_j = 0.05,    u1_j = 0.1, l1_j = 0, p1_j = 0, o0_u = 0, o1_u = 0.9,    n1_u = 0.05,
u1_u = 0.1, l1_u = 0, l2_u = 0, p1_u = 0
compute rho = 0.5
maximize(pmethod=simplex,piters=50,method=bhhh,recursive,iterations=150,cvc
rit=0.0000001) garchln
set fv1 = gvar_jp(t)
set resid1 = e_jp(t)/sqrt(fv1(t))
set residsq1 = resid1(t)*resid1(t)
cor(qstats,number=12,span=4) resid1
cor(qstats,number=12,span=4) residsq1
set fv2 = gvar_us(t)
set resid2 = e_us(t)/sqrt(fv2(t))
set residsq2 = resid2(t)*resid2(t)
cor(qstats,number=12,span=4) resid2
cor(qstats,number=12,span=4) residsq2
set L1 = garchln
compute L2 = %sum(L1)
@regcrits
compute sbc = (-2.0*L2/%nobs)+(%nreg*log(%nobs)/%nobs)
display 'SBC' sbc
print 20 2871 fv1 fv2
```

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BI Norwegian School of Management - Preliminary Thesis Report

Information Transmission and Volatility Spillover in Global Financial Futures Markets: A multivariate GARCH study

Supervisor:

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17.01.2011

Campus:

BI Oslo

Programme:
Master of Science in Financial Economics
Master of Science in Business and Economics

The Economic Problem:

International market liberalizations and integrations are prevalent in stock market for the last few decades. According to P. Henry (JFE, 2000), under the International Asset Pricing Model (IAPM) framework, market liberalizations can lead to investment booms in developing countries due to reduction in cost of capital. Similarly, market liberalizations and integrations also occur to derivatives markets. For instance, Nikkei 225 Index futures contracts are listed on the Singapore Exchange (SGX), the Osaka Securities Exchange (OSE) and the Chicago Mercantile Exchange (CME). Another example is Eurodollar futures market where contracts are jointly listed on CME, SGX and the Euronext. They are both said to be dual-listed on both the US and the Asia Pacific market. This setting facilitates global investors to hedge, speculate and arbitrage across different time zones. These securities permit the transmission of information across markets. In this paper, we want to investigate the price discovery, volatility spillover and information transmission mechanisms of dual-listed futures contracts. We seek a better understanding of the market microstructure in these global futures contracts. The paper by Fung, Leung and Xu (JFM, 2001) provided the point of departure of our study. Futures markets are very liquid and efficient. One might suspect an even flow and exchange of information. Nevertheless, financial economists documented asymmetries in information transmission across different countries. There are two schools of thought in the information flows across markets. The first one is the international center hypothesis. The US, as the international center of finance, dominates the information flows in global market. In the context of our study, according to this hypothesis, the CME should play a leading role in the transmission of information in both futures market. In contrast, the alternative school is the home bias hypothesis. It states that home country has information advantage. Home country market participates receive first hand local corporate and economics information. According to this hypothesis, as Japan is the home country of Nikkei 225 Index, Japan should play a dominate role in disseminating information to other markets.

Significance of the topic

Market integration brings opportunities as well as threats. In recent financial crisis, as markets were increasingly interdependent, we witnessed huge drops in asset prices across global financial markets and drastic surge in market volatility. Due to the popularity of derivatives trading, dual listed futures contracts become the highly effective information transmission channel. Since Fung, Leung and Xu did their paper back in 2001 using the data from 1991 to 2000, it will be interesting to know if the new sample period (i.e., 2001 to 2010) will give different conclusion.

Literature review

International-center hypothesis

International transmission of stock market returns and volatility has got more and more attention with the development in the liberalization of capital movements and securitization of stock markets. The international-center hypothesis suggests that a financial center plays an essential role in transmitting information to other markets (Fung, Leung & Xu 2001). The pattern of information flows is from the global financial center (US market) to the offshore markets. Many studies have investigated the international spillover effects; and evidences are provided on the price and volatility spillovers among closely-related countries and from the developed markets to emerging markets (Eun & Shim 1989). In this paper, we are interested to find out whether the international-center hypothesis applies to US dual (or triple) listed futures contracts.

Home bias hypothesis

Recognizing the deregulation of financial markets and relaxation of capital controls over the last two decades, many studies have analyzed the potential gains from diversification of investment portfolios across national markets (Tesar & Werner, 1995). One of the most striking features of international portfolio investment, however, is the extent to which equity portfolios are concentrated in the domestic equity market of the investor (Cooper and Kaplanis 1994). This home bias implies that investors forego the benefits from international diversification of equity portfolios (Gehrig, T. 1993). According to previous studies, there are some features of international portfolio investment that offset gains from diversification. The home bias hypothesis suggests that information flows between markets primarily go out from the home market (Fung, Leung & Xu 2001). Home bias arises mainly because investors are normally better informed about domestic firm-specific information such as earnings, dividends, and financing announcements. By looking into the data of Eurodollar futures and Nikkei 225 Index futures, we are to find out whether domestic markets play a significant role in information transmission across national markets.

Eurodollar futures

Introduced in December 1981, by the Chicago Mercantile Exchange (CME), the Eurodollar futures contract is currently one of the most actively traded futures contracts in the United States and in the rest of the world. This contract settles to 90-day LIBOR, the yield derived from the underlying asset that is the 90-day Eurodollar time deposit. Extending out to several years into the future, the ED futures contracts are used to hedge positions in interest rate swaps, also to create synthetic swap positions, forward rate agreements and other swap-related derivatives. Currently, Eurodollar futures contracts with virtually identical specifications are traded at the International Monetary Market (IMM) in Chicago, the Singapore International Monetary Exchange (SIMEX), and the London International Financial Futures Exchange (LIFFE). These three markets trade almost identical Eurodollar futures and are participated by the same type of investors. Tse, Lee and Booth (1996) suggest that investors may treat the three markets as one continuously trading market in the context of an information transmission mechanism, which provides investors with more efficient strategies for hedging or speculating interest rate risk associated with ED deposits. It is noted that IMM and SIMEX have common clearing systems, whereby Eurodollar futures positions established in one exchange can be offset in the other (Sundaresan 2009). This mutual offset arrangement makes the contracts more flexible and less costly than those traded at the LIFFE. This plus the fact that trading volume at the LIFFE is much smaller than the trading volumes at the IMM and SIMEX brought our decision to have IMM and SIMEX as study subjects in this paper.

Nikkei 225 Index futures

In 1986, the Singapore International Monetary Exchange (SIMEX) first introduced the Nikkei 225 Index Futures, based on the Nikkei 225 Stock Index. By 1990, Nikkei 225 Futures grew to be the world's largest stock index futures product, surpassing Chicago's S&P 500 Futures. Today, it continues to be one of the world's leading stock index futures products, listed on the Singapore Exchange (SGX), the Osaka Stock Exchange (OSE) in Japan and Chicago Mercantile Exchange (CME). The Osaka Stock Exchange (OSE), as the home market, has higher volume of Nikkei 225 Futures trade electronically. SGX, used to trade Nikkei 225 futures only on the open outcry, from November 2004, allowed electronic trading (ETS Nikkei) during the normal trading hours. The same as ED futures, SGX and IMM have a mutual offset agreement offering trading almost round the clock. The SGX future on the Nikkei 225 has a number of advantages over the Japanese-based trading on the OSE: lower transactions costs, no exchange tax, no suspension of trading for a lunch break, open for 15 minutes longer than the OSE and the ability to trade other futures quoted on SGX (Charles M. S. Sutcliffe 1998). We decided to study all three markets of Nikkei 225 Index Futures to examine the pattern of information flows and the two hypotheses.

Methodology

We want to study the information flows in futures markets by using a multivariate GARCH model. A simplified version of bivariate GARCH model used by Fung, Leung and Xu is presented as follows:

In the mean equation, the first statistical moment (log-returns) is modeled.

The US market returns:

$$R_{u,t} = \alpha_0^u + \sum \alpha_r^u R_{u,t-r} + \sum \beta_s^u R_{a,t+1-s} + \varepsilon_{u,t}$$

The Asian market returns:

$$R_{a,t} = \alpha_0^a + \sum \alpha_r^a R_{a,t-r} + \sum \beta_s^a R_{u,t-s} + \varepsilon_{a,t}$$

The β_s^u and β_s^a in mean equations measure the cross market effect. For instance, the β_s^u for US market mean equation depicts the effect of Asian market on its return. By comparing the relative strength of the parameter, we can observe which market dominates in influencing the first order moment. Granger (1969, Econometrica) provided a causality test which is applicable to analyze bilateral causality between home market and cross market returns.

In the variance equation the second statistical moment (volatility) is modeled.

$$H_{uu,t} = \phi_0^u + \phi_1^u H_{uu,t-1} + \sum \eta_q^u \varepsilon^2{}_{u,t-q} + \sum \lambda_m^u \varepsilon^2{}_{a,t+1-m}$$

$$H_{aa,t} = \phi_0^a + \phi_1^a H_{aa,t-1} + \sum \eta_q^a \varepsilon^2{}_{a,t-q} + \sum \lambda_m^a \varepsilon^2{}_{u,t-m}$$

$$H_{ua,t} = \omega_0 + \omega_1 H_{ua,t-1} + \omega_2 (\varepsilon_{u,t-1} \varepsilon_{a,t-1})$$

Similarly, λ_m^u and λ_m^a in the conditional variance equation measures the effect of volatility spillovers across markets.

The model is estimated by the maximum likelihood estimator. The optimal lag structure for all the above equations will be determined by minimizing Schwarz's Bayesian Information criteria.

Data

All daily Nikkei 225 Index futures and Eurodollar futures data from US and Asian markets are obtained from DataStream. Nikkei 225 Index futures are traded on both the Chicago Mercantile Exchange (CME) in the United States and the Osaka Securities Exchange in Japan. Eurodollar futures are dual-listed on the Chicago Mercantile Exchange and the Singapore Stock Exchange. We will use the sample period for both future contracts from 1 January 2001 to 31 December 2010.

Table1. Descriptive data for the sample:

	Eurodollar Futures		Nikkei 225 Futures	
	CME	SGX	CME	OSE
Mean	2.08E-05	2.04E-05	-0.00011	-0.0001
Standard deviation	0.000481	0.000495	0.016876	0.016455
Skewness	0.812872	0.553546	-0.07974	-0.15122
Kurtosis	28.40664	27.49686	9.662919	16.43814
Observation	2600	2600	2600	2600

Chart 1.

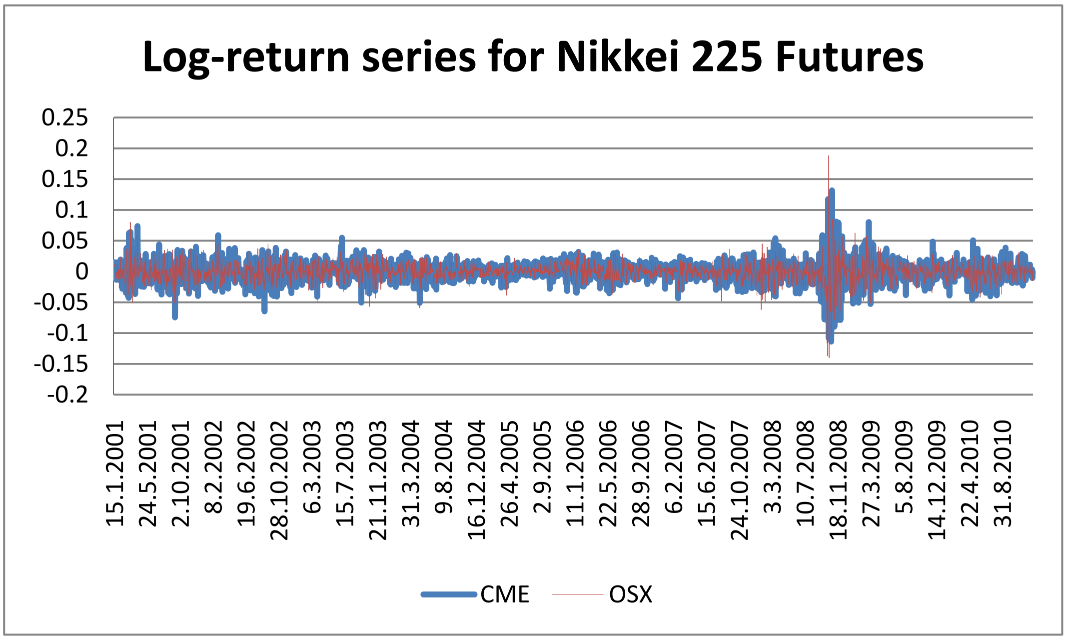
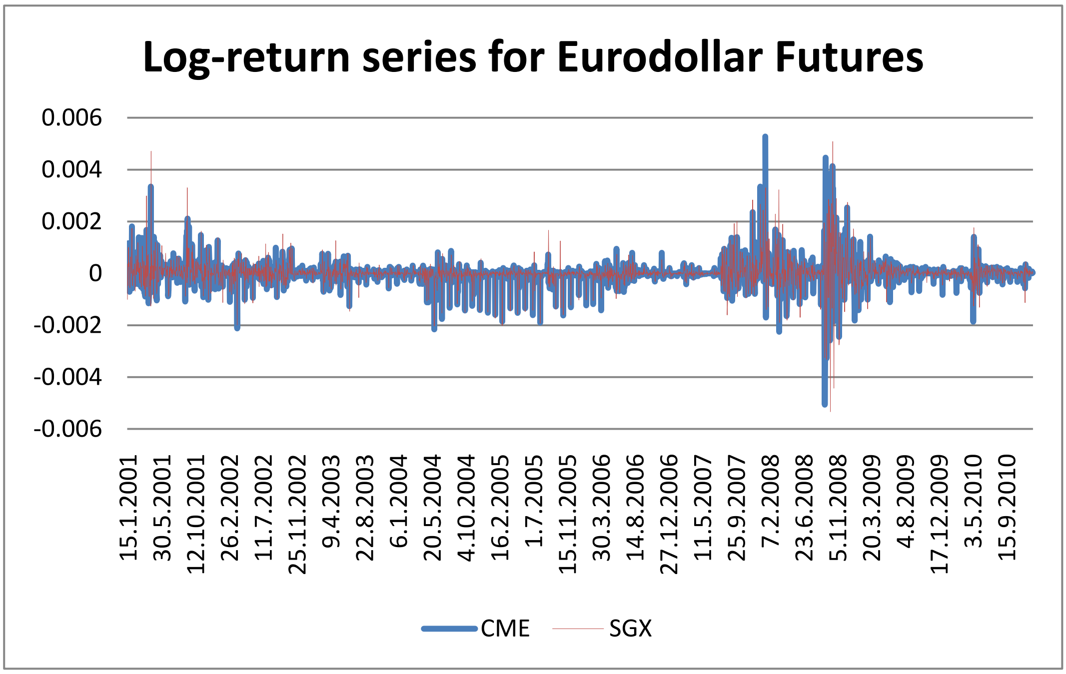


Chart 2.



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