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A COMPARATIVE STUDY OF THE TAIWAN AND JAPAN EQUITY AND FOREIGN EXCHANGE MARKETS: MODELING, ESTIMATION AND APPLICATION OF THE COMPONENT GARCH-IN-MEAN MODEL

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ABSTRACT

The main purpose of this paper is to verify the effectiveness of the bivariate Component GARCH-in-mean (GARCH-M) model and analyze the interactions and risk premium of equity markets by exploring the short- and long-run volatility components on both the Taiwanese and Japanese equity markets. We show that unexpected shocks of volatility will in general influence the fluctuations of both equity and foreign exchange markets. Persistence on the long-run volatility components of both markets is also found. The results also reveal that the positive risk-return relation on equity markets can be further verified when the impacts of short and long-run volatility components are decomposed by the Component GARCH-M model. The decomposition can also facilitate reflecting the transitory and permanent volatility impacts of foreign exchange exposure on the returns of equity markets.

Keywords: ARCH, Component GARCH-in-mean model (GARCH-M), Risk premium, Foreign currency exposure, Equity market, Transitory and permanent volatilities.

JEL Classification: G1; C32; F31.

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Contribution/ Originality

This study is one of very few studies which have investigated risk premium and the interactions between equity markets, by exploring the short- and long-run volatility components on both the Taiwanese and Japanese equity and foreign exchange markets via estimating bivariate Component GARCH-in-mean (GARCH-M) mode.

1. INTRODUCTION

It is widely believed that exchange rates affect the value of assets. Exchange rates are one of the major sources of uncertainty, being that they are typically four times as volatile as interest rates. The analysis of the correlation between equity returns and foreign exchange rates has received much attention in financial econometric studies in recent years. The ways of modeling these financial time series have been enriched by standard GARCH processes. However, when capturing the long-term and short-term volatility effects, how to choose an appropriate model is a complicated problem. It has been observed in the literature that volatility effects may be better modeled using a

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Component GARCH-M model. To consider the permanent and transitory effects of the impact on rate of returns and the effects of short- and long-run volatility components on both Taiwanese and Japanese equity markets, this paper adopts the Component GARCH-M model developed by Engle and Lee (1999).

Considering that Taiwan and Japan have a close interaction both economically and financially In South-East Asia, Taiwan and Japan's economic model may play a part in their respective exchange rate risk. It is important to note that Taiwan and Japan have a close relationship on trades and investments, and thus exchange rates can potentially influence both side's capital and equity markets. And furthermore reduce the risk reduction for portfolio investment. The purpose of this paper is to verify the effectiveness of the bivariate Component GARCH-M model and analyze the risk premium of equity markets by exploring the effects of the short and long-run volatility components on both Taiwanese and Japanese equity markets. Under the Component GARCH-M framework, time series effects of volatility are decomposed into short and long-run volatility components. The estimated model reveals that there is a rich interaction between the rates of return for both the Taiwan and Japan equity markets. The Component GARCH-M model appropriately captures the effect of foreign currency exposure on the volatility of equity markets. Furthermore, it also better delineates the effect of equity shocks on the volatility of equity markets.

This paper is organized as follows. The literature review is presented in section 2, followed by section 3, where a theoretical framework of the Component GARCH-M model is presented. The data and variables definitions are described in section 4. Section 4 also presents empirical results of this study. Section 5 concludes this article.

2. LITERATURE REVIEW

Traditional econometric models have a constant one-period forecast variance. Engle (1982) generalized this setup and develops a new class of econometric processes called autoregressive conditional heteroscedastic (ARCH) processes. Time-varying volatility is not only important in forecasting future market movements but is also central to a variety of financial issues, such as portfolio design, risk management, and derivative pricing. Although it is common to find a significant statistical relationship between current volatility and lagged volatilities, it is generally difficult to decide the exact models that appropriately capture the inter-temporal dependencies observed on the data series. Bollerslev (1986) generalizes the ARCH framework introduced by Engle (1982) into the GARCH framework, where it incorporates past conditional variances into current conditional variance, In his study, stationary conditions and autocorrelation structures of the GARCH model for this new class of parametric models are derived, furthermore, maximum likelihood estimation and testing procedures are also considered.

Engle *et al.* (1987) continue to extend the ARCH model into the ARCH-in-Mean (ARCH-M) model, in which the conditional mean is an explicit function of the conditional variance of the ARCH-M process. Since the ARCH in mean model can deal with the trade-off of the risk-return profile in finance research, it causes a boom of finance research on the time-varying conditional variance. When the volatility of financial asset returns changes, agents naturally suspect that time-varying risk premia may be operative. Later on Lee (1999) also applies the multivariate component model for conditional asset return covariance, which is an extension of the invariant volatility component model. The conditional covariance is divided into a long-run (trend) component and a short-run (transitory) component. Through the decomposition, the long-run correlation and volatility co-persistence can be studied separately. Through their research, Christoffersen *et al.* (2008) proposed a model with the volatility of returns consisting of two components. One is a long-run component, which can be modeled as fully persistent, and the other is a short-run component that has a zero mean. The model can be viewed as a refined version of Engle and Lee (1999) allowing for easy valuation of European options.

Watanabe and Harada (2006) examine the effects of Bank of Japan's (BOJ) intervention on the volatility and the level of the yen/dollar exchange rate. Specifically, the conventional GARCH model and the component GARCH model, where the volatility consists of short-run and long-run components, are estimated using the BOJ's and the Federal Reserve's system intervention data. Results based on the component GARCH model show new evidence on the effects of the BOJ's intervention on the volatility of the yen/dollar exchange rate. Yau and Nieh (2009) investigate the exchange rate effects of the New Taiwan Dollar against the Japanese Yen on stock prices in Japan and Taiwan by the threshold error correction model (TECM). The finding suggests that there is a long run equilibrium relationship between NTD/JPY and the stock prices of Japan and Taiwan. However in the short run, the results of TECM Granger causality tests show that no short run causal relationships exist between the two financial assets considered for both countries` cases. Recently, Lee *et al.* (2010) adopt the Component GARCH model to examine the relationships between volatility and trading volume in five major Asian index futures markets. Their empirical results confirm that the volatility of stock index futures in Asian markets includes permanent and transitory components. Also, the information conveyance in these markets is not very efficient.

In general, regarding emerging markets around the East-Asia region not quite much research has been done on the interactive effects of the stock and foreign exchange markets regarding the view of the short- and long-run volatility components by the Component GARCH model. Some researches refer to the connections between the stock and foreign exchange markets through the spillovers of market volatility by GARCH-type models or via linear or even nonlinear co-integration analysis. Even though both the GARCH model (focused on market volatility spillovers) and the co-integration analysis (focused on the co-integration vector variation of the long-term correlation after exogenous chocks), these methods still cannot help to detect the impacts of information transmission on the permanent and transitory return volatility between the stock and foreign exchange markets. In light of such short- and long-run characteristics of return volatility, our study applies the Component GARCH model, modified from the traditional GARCH model by Engle and Lee (1999) that decomposes conditional variance into permanent and transitory components.

3. THEORETICAL FRAMEWORK

3.1. The Framework of Component GARCH Model

To explore the short- and long-run volatility components and interactions on Taiwanese and Japanese equity with foreign exchange markets, this article proposes an application and extension of the univariate Component GARCH model developed by Engle and Lee (1999). The framework of the Component GARCH model is as follows:

$$y_t = x_t \lambda + \varepsilon_t \qquad \varepsilon_t \mid \psi_{t-1} \sim N(0, h_t) \tag{1}$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} \tag{2}$$

Where y_t is a covariance-stationary process; x_t includes the regressors; ψ_t is the information set available at time t; and h_t is a conditional variance measurable in respect to ψ_{t-1}. The multi-step-ahead forecast of conditional variance is denoted as $h_{t+k} \equiv Var(y_{t+k} \mid \psi_{t-1})$. Assuming $(\alpha + \beta) < 1$, the multi-step-ahead forecast of conditional variance under GARCH (1, 1) framework is

$$h_{t+k} = \omega \left[1 - (\alpha + \beta)^k\right] / (1 - \alpha - \beta)$$

$$= \omega / (1 - \alpha - \beta) \quad \text{as } k \to \infty \tag{3}$$

Which will converge to unconditional variance $\sigma^2 \equiv Var(h_t)$ (Bollerslev, 1986). Therefore, the GARCH (1, 1) framework can be rewritten as

$$h_t = (1-\alpha-\beta)\sigma^2 + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1}$$

$$= \sigma^2 + \alpha(\varepsilon_{t-1}^2 - \sigma^2) + \beta(h_{t-1} - \sigma^2) \quad (4)$$

Where the expected values of the last two terms are zero.

The Component GARCH model permits both a long-run volatility component of q_t and a short-run volatility component of $(h_t - q_t)$. The long-run volatility component is slowly mean reverting, whereas the short-run component is more volatile. Following Engle and Lee (1999) the conditional variance of Component GARCH model is defined as follows:

$$h_t = q_t + \alpha(\varepsilon_{t-1}^2 - q_{t-1}) + \beta(h_{t-1} - q_{t-1}) \quad (5)$$

$$q_t = \omega + q_{t-1} + \phi(\varepsilon_{t-1}^2 - h_{t-1}) \quad (6)$$

It is clear that σ^2 in expression (4) is replaced with q_t in expression (5) and $(\varepsilon_{t-1}^2 - h_{t-1})$ is the prediction error of q_t in expression (6).

Define q_{t+k} to be the multi-step-ahead forecast of long-run component q_t under information set ψ_{t-1}:

$$q_{t+k} = k\omega + q_t \quad k > 0 \quad (7)$$

Then the multi-step-ahead forecast of short-run component $(h_t - q_t)$ is

$$h_{t+k} - q_{t+k} = (\alpha+\beta)(h_{t+k-1} - q_{t+k-1}) + (\alpha+\beta)^k (h_t - q_t) \quad (8)$$

If $(\alpha+\beta) < 1$ and $(h_t - q_t)$ is a stationary $AR(1)$ process, then the value of multi-step-ahead forecast of short-run component $(h_t - q_t)$ tends to zero when k approaches infinity:

$$h_{t+k} - q_{t+k} = 0 \text{ as } k \to \infty \quad (9)$$

Therefore, the conditional variance of the Component GARCH model will be equal to its long-run component in the long-run.

3.2. The Property of Component GARCH Model

To incorporate the non-unit root process into the framework, the Component GARCH model can be generalized as follows:

$$h_t = q_t + \alpha\left(\varepsilon_{t-1}^2 - q_{t-1}\right) + \beta\left(h_{t-1} - q_{t-1}\right) \quad (10)$$

$$q_t = \omega + \rho q_{t-1} + \phi\left(\varepsilon_{t-1}^2 - h_{t-1}\right) \quad (11)$$

As long as $\rho > \alpha + \beta$, q_t indicates that the conditional variance would exhibit the behavior of long-term memory. The multi-step-ahead forecast of short- and long-run component under a more generalized Component GARCH framework can be obtained as follows:

$$h_{t+k} - q_{t+k} = (\alpha + \beta)^k (h_t - q_t) \quad (12)$$

$$q_{t+k} = [(1-\rho^k)/(1-\rho)]\omega + \rho^k q_t \quad (13)$$

The long-run volatility component will diminish faster than the short-run component when $\rho < 1$, $(\alpha + \beta) < 1$, and $\rho > (\alpha + \beta)$. The conditional variance will converge to a constant when the long-run volatility component is stationary:

$$h_{t+k} = q_{t+k} = \omega/(1-\rho) \text{ as } k \to \infty \quad (14)$$

To examine the relationship between Component GARCH and GARCH models, substituting expression (11) into expression (10) obtains

$$h_t = (1-\alpha-\beta)\omega + (\alpha+\phi)\varepsilon_{t-1}^2 + [-\phi(\alpha+\beta) - \alpha\rho]\varepsilon_{t-2}^2$$
$$+(\rho+\beta-\phi)h_{t-1} + [\phi(\alpha+\beta) - \beta\rho]h_{t-2} \quad (15)$$

Thus, GARCH (2, 2) describes the conditional variance of Component GARCH framework. Distinguishing short- and long-run volatility components enables Component GARCH framework to appropriately depict volatility dynamics. The Component GARCH framework will be degenerated into GARCH (1, 1) model when $\alpha = \beta = 0$ or $\rho = \phi = 0$ in expression (15). Therefore, the GARCH (1, 1) model only portraits plain dynamic relationships of conditional variance through decomposition and component GARCH framework will portrait volatility dynamics better than GARCH (1, 1) model.

Defining the prediction error $v_t \equiv \left(\varepsilon_t^2 - h_t\right)$, expression (15) can be rewritten as

$$\varepsilon_t^2 = (1-\alpha-\beta)\omega + (\rho+\alpha+\beta)\varepsilon_{t-1}^2 - (\alpha+\beta)\rho\varepsilon_{t-2}^2$$
$$+v_t - (\rho+\beta-\phi)v_{t-1} - [\phi(\alpha+\beta) - \beta\rho]v_{t-2} \quad (16)$$

The squared innovation of Component GARCH framework follows an ARMA (2,2) process. We obtain the following through expression (16):

$$\varepsilon_t^2 - \rho\varepsilon_{t-1}^2 = (1-\alpha-\beta)\omega + (\alpha+\beta)\left(\varepsilon_{t-1}^2 - \rho\varepsilon_{t-2}^2\right)$$
$$+v_t - (\rho+\beta-\phi)v_{t-1} - [\phi(\alpha+\beta) - \beta\rho]v_{t-2} \quad (17)$$

Here it follows an ARIMA (1, 1, 2) process when ρ= 1. The GARCH (1,1) model with α = β = 0 could be characterized by an ARIMA (0,1,1) process. Analogous to expressions (5) and (6), the previous expressions can be obtained:

$$\varepsilon_{t-1}^2 - q_t = (\alpha + \beta)(\varepsilon_{t-1}^2 - q_{t-1}) + v_t - (\alpha + \beta)v_{t-1} \quad (18)$$

$$q_t = \omega + q_{t-1} + \phi v_{t-1} \quad (19)$$

The maximum likelihood method is used to estimate the parameters of the variance process due to the heterogeneity of error terms. The GARCH process is a covariance-stationary process if and only if the sum of its dynamic parameters is less than one (Bollerslev, 1986). Under Component GARCH framework, the conditions of stationary implies

$$(\alpha + \beta)(1 - \rho) + \rho < 1 \quad (20)$$

The stationary conditions will achieve when ρ<1 and $(\alpha + \beta)$<1. If both short- and long-run volatility components are covariance-stationary, the conditional variance also is covariance-stationary.

3.3. Volatility Persistency Test and Explanation

If the long-run component of conditional variance exhibits a unit-root process, i.e., an IGARCH (2, 2) the impact of innovations on volatility will exhibit a persistent effect (Engle and Bollerslev, 1986). Therefore, we need to explore the impact effect of volatility under Component GARCH framework. The following comparative statics can be obtained from expressions (10) and (11):

$$\partial q_t / \partial \varepsilon_{t-1}^2 = \phi \quad (21)$$

$$\partial (h_t - q_t) / \partial \varepsilon_{t-1}^2 = \alpha \quad (22)$$

Therefore, ϕ and α portrait the effects of unexpected shocks from short and long-run components of conditional variance, respectively. The multi-period-ahead effects of a past innovation on short and long-run volatility components are

$$\partial q_{t+k} / \partial \varepsilon_{t-1}^2 = \rho^k \partial q_t / \partial \varepsilon_{t-1}^2 = \rho^k \phi \quad (23)$$

$$\partial (h_{t+k} - q_{t+k}) / \partial \varepsilon_{t-1}^2 = (\alpha + \beta)^k \partial (h_t - q_t) / \partial \varepsilon_{t-1}^2 = (\alpha + \beta)^k \alpha \quad (24)$$

The impact effect on volatility components will slowly decay when 1>ρ>$(\alpha + \beta)$. If $\rho = 1 > (\alpha + \beta)$, the impact effect on short-run volatility components will gradually vanish. However, the impact effect on long-run volatility components will persist:

$$\partial q_{t+k} / \partial \varepsilon_{t-1}^2 = \partial q_t / \partial \varepsilon_{t-1}^2 = \phi \quad (25)$$

Under the Component GARCH framework, the Lagrange-multiplier and likelihood ratio tests can be used to test the persistence of volatility.

3.4. Non-Negativity of Conditional Variance under Component GARCH Framework

To explore the non-negativity of conditional variance under the Component GARCH framework, substituting expression (10) into expression (11) obtains

$$h_t = \omega + (\rho - \alpha - \beta)q_{t-1} + (\alpha + \phi)\varepsilon_{t-1}^2 + (\beta - \phi)h_{t-1} \quad (26)$$

In which h_t follows time-varying GARCH (1, 1) process. If 1>ρ>$(\alpha+\beta)$>0 , β>ϕ >0, α>0, $\beta > 0$, ϕ >0, and ω >0, the conditional variance h_t maintains its non-negativity, so does the long-run volatility component q_t .

Substituting expression (10) into expression (11) q_t can be simplified to GARCH (2, 2) process in terms of past squared innovations:

$$q_t = (1-\beta)\omega + \phi\varepsilon_{t-1}^2 - \phi(\alpha+\phi)\varepsilon_{t-2}^2 + (\rho+\beta-\phi)q_{t-1} + [\phi(\alpha+\beta) - \beta\rho]q_{t-2} \quad (27)$$

Under the Component GARCH framework, the non-negativity of long-run volatility component will be achieved when 1>ρ>$(\alpha+\beta)$>0, β>ϕ >0, α>0,$\beta > 0$, ϕ >0, and ω >0 (Nelson and Cao, 1992).

4. EMPIRICAL ANALYSIS

We explore the interactions between equity and exchange markets for Taiwan and Japan based on the econometric models presented above. The main purpose here is to examine the goodness of fit of the Component GARCH-M models for our data. Meanwhile, we will test the equity and foreign exchange risk impacts on the expected returns of equity market. Firstly, we briefly describe the characteristics of the data. Secondly, we present the results of unit root tests, serial correlation tests and ARCH effect tests on our data. Thirdly, the empirical model is established. Finally, the empirical results of the Component GARCH-M models are presented.

4.1. Data Characteristics

We collected data for Taiwan's weighted equity index and daily exchange rate data as well as for the Japan Nikkei 225 equity index and daily exchange rate data. All data are daily close price and extracted from the Datastream database. The sample period is from January 1, 1992 to December 31, 2011. Before the year 2000, in Taiwan Saturdays were also trading days, meaning a total of six trading days per week; however, equity and exchange markets in Japan are closed on Saturdays. To match the data, we deleted Saturday's trading data in Taiwan before 2000. In general, investors focus more on asset returns than on prices. From the viewpoints of econometrics, the price series are not stationary. Hence, it is necessary to transform the price series into returns series. Traditionally, we can achieve this by taking logarithmic and making first difference for the consecutive prices, i.e; $R_{i,t}$ = (ln $P_{i,t}$ – ln$P_{i,t-1}$). Where $R_{i,t}$ denotes the return at the period t for the i-th country; and $P_{i,t}$ is the closing price at the t day for the i-th country. As for the foreign exchange market, the same method is applied for the closing price of exchange rates, letting $r_{i,t}$ = (ln $p_{i,t}$ – ln $p_{i,t-1}$). We distinguish the data of foreign exchange markets from equity markets with lower case letters. Other than this, the definitions of variables are similar to the equity markets.

We summarize in Table 1 the basic statistics of the raw data for equity and foreign exchange markets in Taiwan and Japan. Returns data for equity markets and foreign exchange markets in Taiwan and Japan also are outlined in Table 2. In Table 1, both Taiwanese equity and foreign exchange markets display positive skewness. However, both Japanese equity and foreign exchange markets are

Table-1. Summary statistics for equity prices and foreign exchange rates in Taiwanese and Japanese markets

	Equity Market		Foreign Exchange Market	
	Taiwan	Japan	Taiwan	Japan
Mean	6322.983	15181.33	30.783	112.638
Std dev	1528.443	3906.092	3.2186	11.261
Max	10202.200	23801.000	35.165	147.210
Min	3135.560	7054.980	24.507	80.620
Skewness	0.265	- 0.179	0.497	- 0.065
Kurtosis	2.634	1.894	1.723	3.016
Jarque-Bera	141.353***	249.195***	500.511***	143.403***
$Q(24)$	71.324.000***	72.044.000***	74.104.000 ***	70.112.000***

Note: *** represents significant at 1% level.

Table-2. Rate of returns of equity prices and foreign exchange rates for Taiwanese and Japanese markets

	Equity Market		Foreign Exchange Market	
	Taiwan	Japan	Taiwan	Japan
Mean	0.005	- 0.008	0.002	- 0.003
Std dev	0.673	0.679	0.114	0.311
Max	2.833	5.748	1.470	2.786
Min	- 3.029	- 5.260	- 1.165	- 2.773
Skewness	- 0.112	0.108	1.295	- 0.419
Kurtosis	4.955	8.057	32.284	8.993
Jarque-Bera	768.037***	4724.693***	165184.600***	7206.899***
$Q(24)$	74.124***	31.825***	308.812***	38.421***
$Q^2(24)$	532.810***	460.115***	984.227***	794.134*** 794.134***

Note: *** represents significant at 1% level.

Negatively skewed. Meanwhile, the Jarque-Bera statistics show that the data are not normally distributed. Finally, autocorrelation tests (Q(24)) also reject the data being white noise. This shows that it is important to take the first difference for stationarity.

We display the summary statistics for returns in Table 2. For our sample period, the returns for equity and foreign exchange markets in Taiwan are positive. However, they are both negative for equity and foreign exchange markets in Japan. As for skewness, the Taiwanese exchange market and Japanese equity market appear to be positive skewed and other markets are negatively skewed. For the fourth moments (kurtosis) of the series, we find equity markets and foreign exchange markets for these two countries to be more than 3. Namely, the data for equity and exchange markets possesses fat tails. From Table 2, the data do not appear to be normally distributed from the J-B statistics.

4.2. Unit Root, Serial-Correlation and ARCH Effect Tests

The early and pioneering work on testing for a unit root in a time series was done by Dickey and Fuller (DF). Subsequently, Phillips and Perron (PP) developed a more comprehensive theory on the unit root non-stationarity. The tests are similar to the augmented Dickey-Fuller (ADF) tests, but they incorporate an automatic correction to the DF procedure to allow for auto-correlated residuals.

If we find that the data does possess a unit root, it means that the series is not stationary. One can use first order difference to remedy the stationarity. After taking first order difference and changing the time series into a stationary one, it is said to be integrated to the order of one, i.e., denoted I (1). In Tables 3, 4 and 5, we present the results for the unit root test using the ADF test and the PP test, respectively. No matter which functional type is used for the original data, namely the constant term and/or time trend, all of their test statistics are lower than the critical value. Therefore, the price series and exchange rates are not stationary. However, after the first order differencing, all data follows a stationary process based on conventional levels of significance.

We further test for series correlation. It is conventional to fit the auto-regressive model for the return's mean equation. However, these models have to satisfy no serial correlation for the residual terms and follow white noise. For this purpose, we introduce Ljung-Box Q statistics developed by Ljung and Box. Meanwhile, the index of AIC and SBC are incorporated for the selection of appropriate lag periods. All of the results are presented in Tables 6 to 8. Basically, the optimal number of lag terms in the conditional mean equation is determined by the likelihood ratio test, the results show that optimal lag length for the Taiwanese stock market is 4. And for the Taiwanese foreign exchange market, Japanese stock and foreign exchange market, the optimal lag lengths are 2, based on the values of AIC/BIC (Table 6, 7 and 8) under Ljumg–Box Q test.

Table-3. Unit root testing results of ADF and PP tests

	Drift and Trend	Drift	W/o Drift and Trend
	ADF		
Taiwan Equity (5)	-1.815	-1.982	-1.521
Japan Equity (3)	-2.410	-1.201	-1.082
Tw Exch. Rate (3)	-1.924	-0.801	-1.411
J. Exch. Rate (3)	-2.201	-2.101	-0.358
	PP		
Taiwan Equity (5)	-1.945	-1.982	-1.952
Japan Equity (3)	-2.582	-1.701	-1.705
Tw Exch. Rate (3)	-2.105	-0.902	-1.421
J. Exch. Rate (3)	-2.055	-2.123	-2.215

Note: The number of lag periods is in parenthesis.

Table-4. The ADF and PP test results for logarithm of equity prices and exchange rates

	Drift and Trend	Drift	W/o Drift and Trend
	ADF		
Taiwan Equity (5)	-1.852	-2.145	-1.576
Japan Equity (3)	-1.812	-0.464	-1.831
Two Exch. Rate (3)	-1.802	-0.785	-1.412
J. Exch. Rate (3)	-2.101	-2.012	-0.711
	PP		
Taiwan Equity (5)	-1.953	-1.988	-1.648
Japan Equity (3)	-2.301	-1.384	-1.925
Tw Exch. Rate (3)	-2.162	-0.991	-1.546
J. Exch. Rate (3)	-2.114	-1.041	-0.615

Note: The number of lag periods is in parenthesis

Table-5. ADF and PP tests results for the equity returns and the rate of returns of exchange rates

	Drift and Trend	Drift	w/o Drift and Trend
	ADF		
Taiwan Equity (5)	-25.815***	-25.810***	-25.161 ***
Japan Equity (3)	-34.112 ***	-34.152 ***	-34.168***
Tw Exch. Rate (3)	-25.710 ***	-25.812 ***	-25.144 ***
J. Exch. Rate (3)	-32.452 ***	-32.115 ***	-33.699 ***
	PP		
Taiwan Equity (5)	-55.112 ***	-55.912 ***	-54.612***
Japan Equity (3)	-58.143 ***	-58.321 ***	-58.415 ***
Tw Exch. Rate (3)	-69.112 ***	-69.665 ***	-69.713 ***
J. Exch. Rate (3)	-57.623 ***	-57.182***	-57.145 ***

Note: *** represents significant at 1% level.

The number of lag periods is in parenthesis.

Table-6. The optimal number of lag periods for equity markets

No	Taiwan Equity		Japan Equity	
	AIC	**BIC**	**AIC**	**BIC**
1	-169.596	-155.022	-1537.785	-1387.723
2	-170.762	-149.152	-1541.433***	-1388.335***
3	-169.863	-149.127	-1539.598	-1377.464
4	-175.868***	-148.188***	-1539.598	-1377.464
5	-174.195	-141.479	-1536.243	-1362.029
6	-172.027	-134.274	-1535.987	-1355.747

Note: *** represents significant at 1% level.

Table-7. Optimal number of lag periods for foreign exchange markets

	Tw Exch. Rate		J. Exch. Rate	
	AIC	BIC	AIC	BIC
1	-9790.187	-9968.056	-5923.128	-5850.999
2	-9800.945***	-9872.780***	-5924.317***	-5843.152***
3	-9799.024	-9864.823	-5919.631	-5835.430
4	-9803.647	-9863.410	-5918.182	-5827.956
5	-9849.565	9903.288	-5916.361	-5828.090
6	-9848.139	-9895.831	-5916.260	-5813.953

Note: *** represents significant at 1% level.

Table-8. Residual tests of conditional mean equations for Taiwanese and Japanese equity and foreign exchange markets

	Equity Market		Foreign Exchange Market	
	Taiwan	Japan	Taiwan	Japan
Q(8)	1.832	2.512	2.657	3.612
Q(16)	15.012	10.682	13.778	13.672
Q(24)	21.116	25.195	24.621	23.118
$Q^2(8)$	403.665***	173.812***	426.334***	82.512***
$Q^2(16)$	603.182***	255.812***	631.578***	109.612***
$Q^2(24)$	800.565***	324.417***	840.415***	198.201***

Note: *** represents significant at 1%.

Finally, we show the results for ARCH effect. We perform the ARCH-LM test to determine whether an ARCH-effect is present in the residuals of an estimated model, such as AR (p). We gather the AR (p)'s residuals, square the residuals, and then regress them on their own lags to test for ARCH to the order of p. We can obtain R^2 from this regression. The test statistics is defined as TR^2 from regression where T is the total number of observations, and is distributed as a chi-squared distribution with the p degree of freedom. We describe these results in Table 9. It is clear that these return series exhibit ARCH effects. Hence, it is appropriate to fit a GARCH model for further analysis.

Table-9. ARCH-LM tests of squared residuals of conditional mean equations for Taiwanese and Japanese equity and foreign exchange markets

	Equity Market		**Foreign Exchange Market**	
Lag	Taiwan	Japan	Taiwan	Japan
1	631.522***	652.471***	391.885***	293.645***
2	661.801***	640.471***	392.732***	305.852***
3	668.150***	665.114***	516.551***	307.152***
4	690.150***	675.114***	625.401***	310.402***
5	682.11***	674.801***	630.712***	310.614***

Note: *** represents significant at 1% level.

4.3. Model Setups for Empirical Study

To understand the interactions of transitory and permanent risks on equity and foreign exchange markets, the variable of return volatility is incorporated as a regressor into the conditional mean equation. The process can provide the Information about risk premium in the short- and long-run situation. To build up various Component GARCH-M models, we first define the relevant variables and parameters, and then construct the univariate Component GARCH-M models to conduct our empirical analyses.

The relevant variables and parameters for various univariate Component GARCH-M models are defined as follows:

RS and RE represent the Taiwanese equity and foreign exchange markets, respectively;

y_t^{RS} and y_t^{RE} represent the rate of returns of the Taiwanese equity and foreign exchange markets in period t, respectively;

ε_t^{RS} and ε_t^{RE} represent the innovations of the Taiwanese equity and foreign exchange markets in period t, respectively;

h_t^{RS} and h_t^{RE} represent the conditional variance of the rate of returns of the Taiwanese equity and foreign exchange markets in period t, respectively;

q_t^{RS} and q_t^{RE} represent long-run volatility component of the Taiwanese equity and foreign exchange markets in period t, respectively;

s_t^{RS} and s_t^{RE} represent short-run volatility component of the Taiwanese equity and foreign exchange markets in period t, respectively, where $s_t = h_t - q_t$;

$\alpha, \beta, \omega, \rho, \phi, c, c_1, c_2, d, d_1, d_2, \delta_1, \delta_2$ and δ_2 are relevant parameters to be estimated in various univariate Component GARCH-M models.

The corresponding variables and parameters for the Japanese equity and foreign exchange markets are similarly defined with RS and RE replaced by JS and JE respectively.

There are three Component GARCH-M models considered in this study. The first Component is the GARCH-M model which is constructed to investigate the impact of endogenous equity volatility and exogenous foreign exchange volatility on the rate of returns in equity markets and also to explore the effects of the short and long-run volatility components on both Taiwanese and Japanese equity markets. Cases 1 and 2 characterize the corresponding conditional mean and variance equations for Taiwanese and Japanese equity markets examined in the first Component GARCH-M model:

CASE 1: Impact of endogenous equity volatility

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + c^{RS} h_t^{RS} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS} \left[\left(\varepsilon_{t-1}^{RS} \right)^2 - q_{t-1}^{RS} \right] + \beta^{RS} \left(h_{t-1}^{RS} - q_{t-1}^{RS} \right)$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + c^{JS} h_t^{JS} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right)$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \quad (28)$$

CASE 2: Impact of exogenous foreign exchange volatility

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + c^{RE} h_t^{RE} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - q_{t-1}^{RS}\right] + \beta^{RS}\left(h_{t-1}^{RS} - q_{t-1}^{RS}\right)$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + c^{JE} h_t^{JE} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right)$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \quad (29)$$

The second Component GARCH-M model is constructed to investigate the impacts of the short- and long-run volatility components of endogenous equity volatility and exogenous foreign exchange volatility on returns of equity markets and to explore the effects of the short and long-run volatility components on equity markets. Cases 3 and 4 characterize the corresponding conditional mean and variance equations in the second Component GARCH-M model:

CASE 3: Impact of the short- and long-run volatility components of endogenous equity volatility

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + c_1^{RS} q_t^{RS} + c_2^{RS} s_t^{RS} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - q_{t-1}^{RS}\right] + \beta^{RS}\left(h_{t-1}^{RS} - q_{t-1}^{RS}\right)$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + c_1^{JS} q_t^{JS} + c_2^{JS} s_t^{JS} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right)$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \quad (30)$$

CASE 4: Impact of the short- and long-run volatility components of exogenous foreign exchange volatility

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + c_1^{RE} q_t^{RE} + c_2^{RE} s_t^{RE} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - q_{t-1}^{RS}\right] + \beta^{RS}\left(h_{t-1}^{RS} - q_{t-1}^{RS}\right)$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + c_1^{JE} q_t^{JE} + c_2^{JE} s_t^{JE} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right)$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \quad (31)$$

The third Component GARCH-M model is constructed to investigate the impact of foreign exchange volatility from the previous period and the short- and long-run volatility components of foreign exchange volatility from the previous period on returns of equity markets and to explore the effects of the short- and long-run volatility component on equity markets. Cases 5 and 6 characterize the corresponding conditional mean and variance equations in the third Component GARCH-M model:

Case 5: Impact of exogenous foreign exchange volatility in the previous period

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - q_{t-1}^{RS}\right] + \beta^{RS}\left(h_{t-1}^{RS} - q_{t-1}^{RS}\right) + d^{RE} h_{t-1}^{RE}$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right) + d^{JE} h_{t-1}^{JE}$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \quad (32)$$

Case 6: Impact of the short- and long-run volatility components of exogenous foreign exchange volatility in the previous period

$$y_t^{RS} = a_0^{RS} + \sum_{k=1}^{4} a_k^{RS} y_{t-k}^{RS} + \varepsilon_t^{RS}$$

$$h_t^{RS} = q_t^{RS} + \alpha^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - q_{t-1}^{RS}\right] + \beta^{RS}\left(h_{t-1}^{RS} - q_{t-1}^{RS}\right) + d_1^{RE} q_{t-1}^{RE} + d_2^{RE} s_{t-1}^{RE}$$

$$q_t^{RS} = \omega^{RS} + \rho^{RS} q_{t-1}^{RS} + \phi^{RS}\left[\left(\varepsilon_{t-1}^{RS}\right)^2 - h_{t-1}^{RS}\right]$$

$$y_t^{JS} = a_0^{JS} + \sum_{k=1}^{2} a_k^{JS} y_{t-k}^{JS} + \varepsilon_t^{JS}$$

$$h_t^{JS} = q_t^{JS} + \alpha^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - q_{t-1}^{JS}\right] + \beta^{JS}\left(h_{t-1}^{JS} - q_{t-1}^{JS}\right) + d_1^{JE} q_{t-1}^{JE} + d_2^{JE} s_{t-1}^{JE}$$

$$q_t^{JS} = \omega^{JS} + \rho^{JS} q_{t-1}^{JS} + \phi^{JS}\left[\left(\varepsilon_{t-1}^{JS}\right)^2 - h_{t-1}^{JS}\right] \tag{33}$$

4.4. Empirical Results

This article employs the BHHH algorithm to obtain the estimates of consistent estimators. Tables 10 to 15 present the estimated coefficients of conditional mean and variance equations from six cases of the three Component GARCH-M models. It can be seen from Tables 10 to 15 that the restrictions of the coefficients ($\alpha>0$, $\beta>\phi>0$, $\omega>0$ and $\alpha+\beta<\rho<1$), are fully satisfied for all cases of the three Component GARCH-M models, indicating that all Component GARCH-M models constructed in this study are economically meaningful.

The Ljung-Box test statistics in Tables 10 to 15 reveal that for the first and second order moments of the residual series on Taiwanese and Japanese equity and foreign exchange markets, the distributions of these residual series are neither auto-correlated nor hetroskedastic. These verify that all Component GARCH-M models constructed are appropriate for our empirical analyses.

Tables 10 and 11 summarize the impacts of equity and foreign exchange volatility on returns of equity markets and the effects of the short and long-run volatility components on both the Taiwanese and Japanese equity markets. As indicated in Table 10, the Taiwanese equity market returns are significantly affected by lagged second and fourth periods, implying that investors exhibit bias expectations or the information is not fully reflected. The Taiwanese equity market may not be efficient in the sense that the investors cannot have more time to be fully adjusted when some shocks or events occur, however current returns may be predicted by using past information. The significantly positive coefficient c^{RS} reveals that the Taiwanese equity market returns are also affected by the equity volatility. The positive risk-return relation indicates a positive risk premium in the market.

The significantly positive coefficient α^{RS} of the conditional variance equation shows that the unexpected shock of volatility will impact the fluctuations in the Taiwanese equity market. For the long-run volatility components, the estimated coefficient ρ^{RS} is .957, which is significant and close to one, indicating persistency in the long-run volatility components of the Taiwanese equity market. Finally, the significantly positive coefficient ϕ^{RS} reveals that the long-run volatility components of the Taiwanese equity market will fluctuate when unexpected shocks of volatility arrive on the market.

Similar results are found in Table 10 for the Japanese equity market except for the insignificant coefficient c^{JS}, which shows that there is no significant positive risk-return relationship in the Japanese equity market due to possible biases in investor's expectations (Fu *et al.*, 2011).

Table-10. Impact of endogenous equity volatility: Case 1

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	-0.001*	-1.870	a_0^{JS}	-0.012	-1.612
a_1^{RS}	0.018	1.032	a_1^{JS}	-0.043*	-1.835
a_2^{RS}	0.062**	2.615	a_2^{JS}	-0.002	-0.114
a_3^{RS}	0.007	0.483	c^{JS}	5.143	1.773
a_4^{RS}	-0.053**	-2.342			
c^{RS}	6.585**	2.855			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.052***	3.502	α^{JS}	0.059***	3.667
β^{RS}	0.284	1.214	β^{JS}	0.212	0.607
ω^{RS}	0.001***	7.084	ω^{JS}	0.004***	7.554
ρ^{RS}	0.961***	140.003	ρ^{JS}	0.980***	184.115
ϕ^{RS}	0.083***	12.115	ϕ^{JS}	0.081***	10.215
$Q(24)$	14.339		$Q(24)$	17.524	
$Q^2(24)$	21.492		$Q^2(24)$	24.152	

Note: *, ** and *** represents significant at 10%, 5% and 1% level, respectively.

Table-11. Impact of exogenous foreign exchange volatility: Case 2

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	0.001	1.154	a_0^{JS}	-0.001	-0.203
a_1^{RS}	0.031	1.265	a_1^{JS}	-0.042 *	-1.817
a_2^{RS}	0.051 **	2.634	a_2^{JS}	-0.002	-0.071
a_3^{RS}	0.021	0.571	c^{JE}	0.901	0.181
a_4^{RS}	-0.062 **	-2.241			
c^{RE}	0.181	0.046			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.0113	0.824	α^{JS}	0.0512 ***	3.477
β^{RS}	0.831 ***	2.820	β^{JS}	0.285	0.867
ω^{RS}	0.001 ***	3.815	ω^{JS}	0.002 ***	7.555
ρ^{RS}	0.982***	121.004	ρ^{JS}	0.981***	200.116
ϕ^{RS}	0.067 ***	4.262	ϕ^{JS}	0.081 ***	9.943
$Q(24)$	17.446		$Q(24)$	18.343	
$Q^2(24)$	22.110		$Q^2(24)$	21.470	

Note: *, ** and *** represents significant at 10%, 5% and 1% level, respectively.

We find very similar results in Table 11 except for the foreign exchange exposure. The insignificant c^{RE} and c^{JE} in Table 11 indicate that both the Taiwanese and Japanese equity market returns are not affected by their foreign exchange exposure. This is somewhat surprising. One of the possible reasons is that the risk of foreign exchange rate consists of short-term risk (accounting risk) and long-term risk (economic risk) (Chiang *et al.*, 2000). Thus, the short-and long-term effects will not be fully reflected if short- and long-term risks are not decomposed appropriately in the models.

Table-12. Impact of the short- and long-run volatility components of endogenous equity volatility: Case 3

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	-0.009*	-1.982	a_0^{JS}	-0.001*	-1.846
a_1^{RS}	0.021	0.993	a_1^{JS}	-0.042**	-2.016
a_2^{RS}	0.043**	2.235	a_2^{JS}	-0.021	-0.690
a_3^{RS}	0.046*	1.928	c_1^{JS}	9.142***	5.012
a_4^{RS}	-0.068***	-3.412	c_2^{JS}	2.415	1.542
c_1^{RS}	1.701	0.281			
c_2^{RS}	29.112***	2.995			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.0612 ***	3.401	α^{JS}	0.053***	3.411
β^{RS}	0.547	1.412	β^{JS}	0.681	1.281
ω^{RS}	0.0122	1.063	ω^{JS}	0.001***	7.532
ρ^{RS}	0.912 ***	101.703	ρ^{JS}	0.982 ***	199.336
ϕ^{RS}	0.071 ***	11.813	ϕ^{JS}	0.092 ***	11.333
$Q(24)$	18.336		$Q(24)$	19.221	
$Q^2(24)$	22.113		$Q^2(24)$	20.778	

Note: *, **and *** represents significant at 10%, 5% and 1% level, respectively.

Tables 12 and 13 summarize the impact of the short and long-run components of equity and foreign exchange volatility on the rate of returns and the effects of the short and long-run volatility component of both the Taiwanese and Japanese equity markets. We focus on exploring the impacts of the short- and long-run components of equity and foreign exchange volatility on returns of both markets. These results are very similar to those shown in Tables 10 and 11. The insignificant c_1^{RS} and significant c_2^{RS} in Table 12 indicate that there is significant positive risk-return relation and risk premium in the short-term on the Taiwanese equity market; in the long-term, the equity risk is not fully reflected, possibly because there is a trading price limit and investors and enterprises take advantage of financial instruments to hedge their risks or there are more individual investors in Taiwanese equity market who are irrational, or institutional investors are less risk adverse (Barber *et al.*, 2009; Chuang and Susmel, 2011).

On the other hand, the significant c_1^{JS} and insignificant c_2^{JS} indicate that there is significant positive risk-return relation and risk premium only in the long-term on the Japanese equity market. The possible reason is that the proportion of financial institutional investors is large enough that only in the long-term will the equity market generate structural change and greater fluctuations, and hence require more risk premium.

Table-13. Impact of the short- and long-run volatility components of exogenous foreign exchange volatility: Case 4

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	-0.003	-1.032	a_0^{JS}	-0.001	-1.124
a_1^{RS}	0.032	1.314	a_1^{JS}	-0.031	-1.613
a_2^{RS}	0.058**	2.512	a_2^{JS}	-0.004	-0.171
a_3^{RS}	0.021	0.665	c_1^{JE}	13.117	1.463
a_4^{RS}	-0.051**	-2.245	c_2^{JE}	-32.812**	-2.545
c_1^{RE}	18.554	1.062			
c_2^{RE}	-8.912	-0.915			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.012	0.656	α^{JS}	0.055 ***	3.412
β^{RS}	0.837**	2.136	β^{JS}	0.241	0.889
ω^{RS}	0.000156 ***	2.931	ω^{JS}	0.002***	8.247
ρ^{RS}	0.982 ***	96.298	ρ^{JS}	0.982***	198.996
ϕ^{RS}	0.061***	2.723	ϕ^{JS}	0.081 ***	9.994
$Q(24)$	18.493		$Q(24)$	18.562	
$Q^2(24)$	20.151		$Q^2(24)$	21.403	

Note: ** and *** represents significant at 5% and 1% level, respectively.

Table-14. Impact of exogenous foreign exchange volatility in previous period: Case 5

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	0.0013	1.381	a_0^{JS}	-0.001	-0.142
a_1^{RS}	0.0211	1.422	a_1^{JS}	-0.031	-1.273
a_2^{RS}	0.0521 ***	2.613	a_2^{JS}	-0.001	-0.083
a_3^{RS}	0.0112	0.713			
a_4^{RS}	-0.061 ***	-2.282			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.004	0.898	α^{JS}	0.051 ***	3.241
β^{RS}	0.971***	212.531	β^{JS}	0.283	0.813
ω^{RS}	0.001***	2.831	ω^{JS}	0.002 ***	6.815
ρ^{RS}	0.991 ***	118.652	ρ^{JS}	0.874***	190.335
ϕ^{RS}	0.072 ***	8.714	ϕ^{JS}	0.078 ***	8.815
d^{RS}	0.020 ***	2.715	d^{JS}	-0.010	-0.734
$Q(24)$	17.141		$Q(24)$	19.114	
$Q^2(24)$	24.323		$Q^2(24)$	21.497	

Note: *** represents significant at 1% level.

Table-15. Impact of the short- and long-run volatility components of exogenous foreign exchange volatility in previous period: Case 6

Conditional Mean Equation			**Conditional Mean Equation**		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
a_0^{RS}	0.001	1.413	a_0^{JS}	-0.001	-0.272
a_1^{RS}	0.031	1.246	a_1^{JS}	-0.051*	-1.743
a_2^{RS}	0.051**	2.644	a_2^{JS}	-0.002	-0.073
a_3^{RS}	0.015	0.743			
a_4^{RS}	-0.046**	-2.415			
Conditional Variance Equation			Conditional Variance Equation		
Taiwan			Japan		
	coefficient	t-value		coefficient	t-value
α^{RS}	0.051	1.514	α^{JS}	0.051***	3.243
β^{RS}	0.921***	58.342	β^{JS}	0.287	0.816
ω^{RS}	0.001***	3.489	ω^{JS}	0.001***	7.876
ρ^{RS}	0.993***	126.314	ρ^{JS}	0.981***	185.493
ϕ^{RS}	0.018	0.725	ϕ^{JS}	0.081***	9.999
d_1^{RS}	-0.271***	-3.414	d_1^{JS}	-0.010	-0.813
d_2^{RS}	0.081**	2.164	d_2^{JS}	-0.004	-0.064
$Q(24)$	17.334		$Q(24)$	19.114	
$Q^2(24)$	24.816		$Q^2(24)$	20.412	

Note: *, ** and *** represents significant at 10%, 5% and 1% level, respectively.

However, in the short run, the risk-return tradeoff in Japanese equity market may be caused by the bias expectations of investors, or investors simply do not react to the new information quickly (Tai, 1999; Chiang and Yang, 2003; Lin *et al.*, 2009). The impacts of the short- and long-run components of foreign exchange volatility on returns of both markets are reported in Table 13. As shown in Table 13, the insignificant c_1^{RE} and c_2^{RE} indicate that returns of the Taiwanese equity market are not affected by its foreign exchange exposure in either the short- and long-run, possibly since investors and enterprises employ financial instruments to hedge their risks (Yau and Nieh, 2006;2009). The significantly negative c_2^{JE} reveals that returns of the Japanese equity market decreases when foreign exchange risks increase in the short-term. A possible reason is that a large proportion of financial institutional investors possess a relatively high tolerance for risk taking in the short-term (Yau and Nieh, 2006;2009). Compared with the results of case 2, the decomposition of the short and long-run components of foreign exchange volatility facilitates reflecting the relative impact of foreign exchange exposure on returns of the Japanese equity market. This result is supported by similar results from Pan *et al.* (2007) and Tai (2007).

Tables 14 and 15 report the results of the impacts of foreign exchange volatility in previous periods on contemporaneous volatility. They also show the effects of the short and long-run volatility components on both equity markets. We focus on investigating the impact of foreign exchange volatility in previous periods on contemporaneous volatility. Other results are also similar to those found in Tables 10 and 11.

It can be seen from Tables 14 and 15 that the contemporaneous volatility will be significantly affected by the short and long-run foreign exchange exposure in previous periods of the Taiwanese equity market, whereas the contemporaneous volatility will not be affected by the short and long-run foreign exchange exposure in previous periods of the Japanese equity market. The lagged response of foreign exchange exposure in previous periods on the volatility of the Taiwanese equity market possibly reflects relatively greater foreign exchange rate risk for the large trading volume of imports and exports that characterizes Taiwan's economy (Wu, 1997; Yau and Nieh, 2006;2009; Liu and Tu, 2012). This also confirms that there exists a cross-volatility spillover effect on the Taiwanese equity market, including the short-term accounting and the long-term economic risks. Moreover, the insignificant response of lagged foreign exchange exposure on the Japanese equity market possibly demonstrates that the Japanese economy relies more on domestic demand and thus has a lower degree of the risk of foreign exchange rate (Choi *et al.*, 1998; Homma *et al.*, 2005; Yau and Nieh, 2006;2009).

5. CONCLUSIONS

Recognizing the rising interest of financial econometrics on the investigation of the correlation between returns in equity markets and the foreign exchange rates on foreign currency markets, we employed the bivariate Component GARCH-M model. The analysis was based on Taiwan and Japan weighted equity index and exchange rate to analyze the risk premium for both Taiwanese and Japanese equity markets. We further explore the permanent and transitory effects of the short and long-run volatility components on both equity markets, and thus verify the effectiveness of the model.

We find that through decomposing the time series effects of volatility into short and long-run components, the conditional covariance trend (long-run) and transitory (short-run) components can be studied separately with a clear improvement in the model's performance due to its richer dynamics that makes it easier to jointly obtain the long and short-term market returns.

For the returns of both Taiwanese and Japanese equity markets, the empirical results are significantly affected by lagged periods, implying that both markets may not be fully efficient in the sense that the investors do not react quickly to shocks or new events. Thus, returns are likely to be predicted by using past information and the unexpected shock of volatility might in general influence fluctuations in both equity markets. In addition, persistency on long-run volatility components from both markets was also found.

The positive risk-return relation indicates that there is risk premium in the Taiwanese equity market. On the other hand, there is no significant positive risk-return relation in the Japanese equity market if the impacts from the short and long-run volatility components are not decomposed.

Taking into account the short and long-run volatility components, the Taiwanese equity market exhibits positive risk-return relation and risk premium only in the short-run. In the long-run, the equity risk is not fully reflected possibly because there is a trading price limit and investors and enterprises take advantage of financial instruments to hedge their risks. Furthermore, there are more individual investors in Taiwan equity market who are irrational or institutional investors who are less risk adverse. On the other hand, the Japanese equity market exhibits positive risk-return relation and risk premium only in the long-run, implying that the large proportion of financial institutional investors may generate structural change and greater fluctuations, and hence require more risk premium in the long-run. However, in the short-run, the risk-return tradeoff in the Japanese equity market may be caused by the bias expectations in investors, or because they simply do not react quickly to new information.

The impact from short and long-run components of the foreign exchange volatility on returns from both markets indicate that returns of the Taiwanese equity market are not influenced by its own foreign exchange exposure in either the short or long-run. Possibly because investors and enterprises employ financial instruments to hedge their risks or there are more individual investors in the Taiwanese equity market who are irrational. Or in other cases, institutional investors may be less risk adverse. However, returns in the Japanese equity market decreases when the foreign exchange risk in the short-run increases. Possibly since large proportions of financial institutional investors possess relatively high tolerance on risk taking in the short-run or as the expected volatility risk rises. This might lead the market uncertainty to increase, and the rational investors (speculators) might need incremental risk premium to induce them to arbitrage away the mispricing. The decomposition of the short and long-run components from foreign exchange volatility better detects the relative impact of foreign exchange exposure on returns of the Japanese equity market.

Finally, the contemporaneous volatility is significantly affected by the short and long-run foreign exchange exposure in previous periods of the Taiwanese equity market. The difference in characteristics of Taiwan and Japan's economic model may play a part in their respective exchange rate risk. While Taiwan's exports account for roughly 60% of its GDP, Japan can potentially weather fluctuations in exchange rates by relying on domestic consumption since its ratio of domestic consumption as a percentage of its GDP is above 55%.

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