Asymmetric Causal Relationship between Stock and Exchange Rate—Evidence from Japan and Taiwan

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Abstract

This paper investigates the asymmetric causal relationships between exchange rate and stock indices of Japan and Taiwan, respectively. M-TART is first found to be the most applicable model for adjustment to long-run equilibrium between the exchange rate and stock index for both countries. The evidence from our M-TART estimations supports the long-run equilibrium relationships between exchange rates and stock indices, but an asymmetric threshold cointegration relationship only exists in Taiwan, not in Japan. Further evidence from M-TECM Granger-Causality tests illustrates that no short-run causal relationship exists between the two financial assets. However, in the long-run, when the differences in the previous disequilibrium term are above their threshold value, a positive causal relationship running from stock index to exchange rate (by European quotation) in Japan supports the portfolio approach, whereas a positive causal relationship running exchange rate (by American quotation) to stock index in Taiwan argues for the traditional approach. Another interesting finding from our M-TECM estimations is that the speed of adjustment towards long-run equilibrium in relationship between stock indices and exchange rates is faster in the higher regime than in the lower regime for both countries' cases.

Keywords: Exchange rate, Stock index, Threshold Error-Correction Model, Asymmetric causality

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I Introduction and Review of Literature

The issue of whether stock prices and exchange rates are related has brought out considerable attention for long periods. Two theories about the dynamic relationship between exchange rates and stock prices: the traditional and portfolio approaches, have been discussed and no consensus on them for a long time. The traditional approach claims that a depreciation of domestic currency makes local firms more competitive, leading to an increase in their exports, and consequently raises their stock prices. This implies a positive correlation between exchange rates (by American quotation) and stock prices.[1] The inference from the above traditional approach suggests that exchange rates lead stock prices.

The portfolio approach, on the contrary, argues that an increase in stock prices induces investors to demand for more domestic assets and thereby causes an appreciation in domestic currency, which implies that stock prices lead exchange rates and they are negatively related.[2] [3] The "stock-oriented" model of exchange rates by Branson (1983) specified the exchange rate was viewed as serving to equate the supply and demand for assets such as stocks and bonds.

Empirically or theoretically, many economists suggested a significant relationship between exchange rates and stock prices. However, the results are quite mixed with the sign and causal direction between exchange rates and stock prices.[4] Mok (1993) found weak bi-directional causality between stock prices and the exchange rates, while Bahmani-Oskooee and Sohrabian (1992) and Nieh and Lee (2001) argued for a bi-directional causality between stock prices and exchange rates in the short-run but not in the long-run. In addition, there are some studies that have found very weak or no association between stock prices and exchange rates (for instance, Franck and Young, 1972, Bartov and Bodnar, 1994 and Fernandez, 2006).

There was a tremendous change of the exchange rate of the Japanese Yen (JPY) and the New Taiwan Dollar (NTD) against USD (JPY/USD and NTD/USD hereafter)

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[1] In addition, the theory of the "Uncovered Interest Rate Parity" (UIRP) suggests that the expectations of relative currency values influence the levels of domestic and foreign interest rates. This, in turn, affects costs of capital and thereby profitability and price competitiveness of a firm, and consequently the present value (stock price) of a firm may vary.

[2] The appreciation of domestic currency attracts more foreign capital or investments into domestic market, and leads to further currency appreciation.

[3] By European quotation, the relationship between stock prices and exchange rates of traditional or portfolio approach is just the reverse.

[4] For instance, Aggarwal (1981), Soenen and Hennigar (1988), Smith (1992), Bodnar and Gentry (1993), Dropsy and Nazarian-Ibrahimi (1994), Choi and Prasad (1995), Prasad and Rajan (1995), Ajayi and Mougoue (1996), Fang and Loo (1996), Abdalla and Murinde (1997), Kwon, Shin, and Bacon (1997), Kanas (2000) and Bhattacharya and Mukherjee (2003) among others.

during the period of 1985 through 1988, which was primarily the consequence of the "Plaza-Louvre intervention accord". The revaluation of NTD/USD since July 1986 mainly showed a linked reaction of interference appreciation of JPY/USD since September 1985 as caused from the G-5 "Plaza intervention accord". The Plaza-Louvre cooperation marked the new era of managing floating exchange rates.

Suggestions to build a Yen Bloc[5] were firstly spurred in early 1990s, in light of great changes in Asia economies. The weight of exports to the United States in the total Asian exports has decreased significantly since middle 1980s, as the intra-regional trade increases rapidly. On the other hand, the economic influence of Japan in this region has expanded through its trades and investments in the region. Asia may need an international currency to reduce transaction costs and foreign exchange risks in its regional trades and investments. However, it is better for Japanese yen, rather than US dollar, to fulfill this objective.

Taiwan is a country of typical island-style economic system, which is highly open to international trade and investment. Thus the volatility of NTD/JPY may affect both the exporters and importers significantly in Taiwan. For an extended period of time, Taiwan has experienced a widening trade gap (deficit) with Japan. The main explanation could be that the majority of Taiwan imports from Japan are more capital-intensive and comparable expensive goods; while the majority of Taiwan exports to Japan are more labor-intensive and cheaper goods. This degenerating condition of trade imbalance with Japan has remained unchanged so far. Additionally, as an export-oriented country, Taiwan heavily depends on electronics products exported to its major trading partners. Japan, like most of the other Asia-Pacific countries, is a main competitor to Taiwan. In the case when NTD/JPY appreciates, Taiwan exporters may lose their competitiveness in the world markets and their stock prices would shrink. Studies investigating the causal relations and the international transmission between these two financial assets of Japan and Taiwan can be found in Sewell, *et al.* (1996), Chen and Wu (1997), Granger, Huang and Yang (2000), Pilbeam (2001) and Yau and Nieh (2006).

Due to the mutual effects of exchange rates and stock prices on each other as mentioned above, it is difficult to predict the overall impact of the varying exchange rate on the Taiwanese and Japanese stock markets. Whether it is favorable or unfavorable depends on the entire industrial structure within a country. Studies emphasizing on the impact of the exchange rate on stock price for Taiwan can be found in Wu (1997), Guo and Wu (1998) and Chiao, Hung and Nwanna (2001);

[5] Yen Bloc refers to a grouping of countries that use the JPY as an international currency and maintain stable exchange rates against the JPY.

whereas Choi, Hiraki and Takezawa (1998), He and Ng (1998), Doukas, Hall and Lang (1999), Caporale, Pittis and Spagnolo (2002), Elyasiani and Mansur (2005), Homma, Tsutsui and Benzion (2005) and Kurihara (2006) among others, studied the relationship between the exchange rate and stock price of Japan.

In prior empirical studies concerning the exchange rate, the US dollar was mostly utilized as the base-currency, while a few studies used the Japanese Yen instead.[6] [7] Because Japan is one of the major trading partners of Taiwan, the NTD/JPY plays a crucial role and may possibly influence Taiwan's economy as well as stock market. Therefore, while investigating the relationship or financial transmission between these two countries, it may be more appropriate to consider JPY as the base-currency.

More recently, it has been suggested that linear conventional time series methodologies fail to consider information across regions. This leads to inefficient estimations and, therefore, has lower testing power. One proposed approach to increase power in testing is to consider the nonlinear techniques instead. In order to be more persuaded than the traditional vector error correction model (VECM), we attempt to employ the advanced time-series methodologies assuming that the nature of causal relationship between the variables is on the basis of the nonlinearity. The main purpose of this study tends to concentrate on the causal relationship between the two major financial assets, the exchange rate (NTD/JPY) and stock indices of both countries considered, by employing the newly threshold error-correction model (TECM) elaborated by Enders and Granger (1998) and Enders and Siklos (2001). The findings of the asymmetric causal relationships among the three variables considered may provide the multinational enterprises and the international investors an excellent reference for their asset allocations.

The remainder of this paper is organized as follows. Section II describes the data. Section III introduces all the methodologies used and analyzes the empirical results. Section IV concludes this paper.

II Data

This paper is done on the basis of NTD/JPY, closing Taiwan Stock Exchange

[6] Enders and Hurn (1994) believed that using Japanese Yen as the base-currency can be crucial in investigating the macro-fundamental issues, especially among the Asian countries.

[7] The issue examining the dominant power or considering of the impact of either the US or Japan on other countries' financial markets can be found in Karolyi and Stulz (1996), Varela and Naka (1997), Sun and Tong (2000) and Durand, Kee and Watson (2001).

Index (TW stock) and the Nikkei 225 Index (JP stock). Data are collected from the AREMOS Statistical Data Bank of Ministry of Education, Taiwan. The sample period runs from January 1991 to July 2005, a total of 175 monthly observations are obtained for each variable. This specific period is chosen due to the fact that the 1997 Asian Financial Crisis (AFC) and 2000 internet bubbles happened in the middle of this period, thus we may capture a full picture before and after the Crisis and the bubbles (See Figure 1 and 2). We observe from Figure 1 that both stock indices had experienced a similar up-and-down moving pattern. However, the volatility of the JP stock is much higher than that of the TW stock. The JP stock is in fact in a downward trend through all the sample period, it had experienced dramatic drops before the month of September 1998 when it hit its local lowest of 13406 from its local highest of 20604 in June 1997 and from 20337 to 9775 in the period between March 2000 and September 2001.[8] Moreover, it is seen clearly from Figure 2 that, after the AFC, JPY appreciated against NTD up to the year 2000. Figure 1 combining with Figure 2 also show that the increasing of the JP stock most likely accompanies with the JPY depreciation (again NTD), whereas the TW stock increases with the NTD appreciation (against JPY). The summary statistics of the three variables investigated are presented in Table 1.

<Insert Figure 1 and Figure 2 about here>

<Insert Table 1 about here>

III Methodologies and Empirical Results

This paper aims to empirically investigate the asymmetric causal relationships between NTD/JPY and stock indices for Japan and Taiwan, respectively. To fully capture the causal relations among variables investigated, both linear and nonlinear examinations are employed in our study.

3.1 Conventional Linear Unit Root Tests

Among various testing strategies, this paper firstly tests for “stationarity” of each variable by employing three traditional unit-root test techniques, ADF (Dickey and

[8] The second serious drop illustrates that the JP stock was heavily hurt during the period of worldwide broken-down of the internet bubbles in the year 2000.

Fuller, 1981), PP (Phillips and Perron, 1988) and NP (Ng and Perron, 2001).[9] Since the estimation might be biased if the lag length and bandwidth are pre-designated without rigorous determination, based on the "principle of parsimony", modified Akaike information criterion (Modified-AIC or MAIC) suggested by Ng and Perron (2001) for unit root of ADF and NP and Bartlett kernel based criterion proposed by Newey and West (1994) for PP are utilized to determine the optimal number of lags and optimal bandwidth, respectively.

The results of the three unit root tests, ADF, PP and NP, are summarized in Table 2, which show that the null of non-stationarity cannot be rejected for any levels of the series. After first differencing, however, the null is rejected at least at the 5% significance level for all series. We thus conclude that all the variables considered in this paper are the I(1) type series.

<Insert Table 2 about here>

3.2 Advanced Nonlinear ESTAR Unit Root Test

Recently, there is a growing consensus that exchange rate and stock price might exhibit non-linearities and that conventional unit root tests have lower power in detecting its mean reverting (stationary) tendency. As such, this study employs a newly developed nonlinear stationary test advanced by Kapetanios et al. (2003) (henceforth, KSS) to determine if the stock prices of Taiwan and Japan and the exchange rate are nonlinear stationary.

The KSS nonlinear stationary test is based on detecting the presence of non-stationarity against nonlinear but globally stationary exponential smooth transition autoregressive (ESTAR) process:

$$\Delta Y_t = \gamma Y_{t-1}\{1-\exp(-\theta Y_{t-1}^2)\} + \nu_t , \qquad (1)$$

where Y_t is the data series of variables considered, ν_t is an i.i.d. error with zero mean and constant variance and $\theta \geq 0$ is known as the transition parameter of the ESTAR model that governs the speed of transition. We are now interested in testing the null hypothesis of $\theta = 0$ against the alternative of $\theta > 0$. Under the null hypothesis, Y_t follows a linear unit root process, whereas it is a nonlinear stationary ESTAR

[9] The test statistic of NP test is MZ_t in this paper.

process under the alternative. However, the parameter γ is not identified under the null hypothesis. Kapetanios et al. (2003) used a first-order Taylor series approximation to $\{1-\exp(-\theta Y_{t-1}^2)\}$ under the null of $\theta = 0$, and approximate Equation (1) by the following auxiliary regression:

$$\Delta Y_t = \xi + \delta Y_{t-1}^3 + \sum_{i=1}^{k} b_i \Delta Y_{t-i} + \nu_t, \quad t = 1, 2, \ldots, T \qquad (2)$$

Then, the null hypothesis and alternative hypotheses are expressed as $\delta = 0$ (non-stationarity) against $\delta < 0$ (nonlinear ESTAR stationarity).[10] Table 3 presents the results of KSS's (2003) nonlinear ESTAR stationary test, which shows that all three variables considered in this paper are I(1) series at least at the 10% significant level.

<Insert Table 3 about Here>

3.3. EG-ES Threshold Cointegration Tests

The findings of the I(1) series for both stock indices of Japan and Taiwan and NTD/JPY exchange rate enable us to proceed with further long-run equilibrium relationship (cointegration) test. On the basis of the nonlinearity, we employ the threshold cointegration techniques elaborated by Enders and Granger (1998) and Enders and Siklos (2001). This is indeed a residual-based two-stage estimation as developed by Engle and Granger (1987). The differences between them are addressed on the formulation of linearity and nonlinearity from their second stage of unit root test. The equation is expressed as follows in the first stage.

$$Y_{1t} = \alpha + \beta Y_{2t} + u_t \qquad (3)$$

where Y_{1t} and Y_{2t} are two I(1) series of the stock price and exchange rate, respectively. α and β are estimated parameters and u_t is the disturbance term that may be serially correlated. The second stage focuses on the coefficient estimates of ρ_1 and ρ_2 in the following regression:

$$\Delta u_t = I_t \rho_1 u_{t-1} + (1 - I_t)\rho_2 u_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta u_{t-i} + \varepsilon_t \qquad (4)$$

[10] The simulated critical values for different K were tabulated in Kapetanios et al. (2003) (Table 1 as of p.363).

where ε_t is a white-noise disturbance and the residuals, μ_t, in (4) are extracted from (3) to be further estimated. I_t is the Heaviside indicator function such that $I_t = 1$ if $u_{t-1} \geq \tau$ and $I_t = 0$ if $u_{t-1} \leq \tau$, where τ is the threshold value. A necessary condition for $\{\mu_t\}$ to be stationary is: $-2 < (\rho_1, \rho_2) < 0$. If the variance of ε_t is sufficiently large, it is also possible for one value of ρ_j to between –2 and 0 and for the other value to equal zero. Although there is no convergence in the regime with the unit-root (i.e., the regime in which $\rho_j = 0$), large realization of ε_t will switch the system into the convergent regime. Enders and Granger (1998) and Enders and Siklos (2001) both pointed out in either case, under the null hypothesis of no convergence, the F-statistic for the null hypothesis $\rho_1 = \rho_2 = 0$ has a nonstandard distribution. The critical values for this non-standard F-statistic are tabulated in their paper. Enders and Granger (1998) also indicated that if the sequence is stationary, the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution.

Equation (4) is a threshold autoregressive (TAR) model of the disequilibrium error, where the test for threshold behavior of the disequilibrium error is termed threshold cointegration test for variables in equation (3). Assuming the system is convergent, $\mu_t = 0$ can be considered as the long-run equilibrium value of the sequence. If μ_t is above its long-run equilibrium, the adjustment is $\rho_1 \mu_{t-1}$; and if μ_t is below its long-run equilibrium, the adjustment is $\rho_2 \mu_{t-1}$. We test the null of $\rho_1 = \rho_2 = 0$ for the cointegration relationship and the rejection implies the existence of cointegration relationship between variables. The finding of $\rho_1 = \rho_2 = 0$ put it valuable to further test for symmetric adjustment (i.e., $H_0 : \rho_1 = \rho_2$) by using a standard F-test. When the coefficients of regime adjustment are equal (symmetric adjustment), equation (4) converges the prevalent ADF test. Rejecting both the null hypotheses of $\rho_1 = \rho_2 = 0$ and $\rho_1 = \rho_2$ implies the existence of threshold cointegration and the asymmetric adjustment.

Instead of estimating equation (4) with the Heaviside indicator depending on the level of μ_{t-1}, the decay could also be allowed depending on the previous period's change in μ_{t-1}. The Heaviside indicator could then be specified as $I_t = 1$ if $\Delta u_{t-1} \geq \tau$ and $I_t = 0$ if $\Delta u_{t-1} \leq \tau$, where τ is the threshold value. According to Enders and Granger (1998), this model is especially valuable when adjustment is asymmetric such that the series exhibits more 'momentum' in one direction than the other. This model is termed momentum threshold autoregressive (M-TAR) model. The TAR model is used to capture 'deep' cycle process if, for example, positive deviations are more prolonged than negative deviations. On the other hand, the M-TAR model allows the autoregressive decay to depend on $\Delta\mu_{t-1}$. As such, the M-TAR representation may capture 'sharp' movements in a sequence.

In most cases, the value of τ is unknown, it has to be estimated along with the value of ρ_1 and ρ_2. By demeaning the $\{\mu_t\}$ sequence, the Enders and Granger (1998) test procedure employs the sample mean of the sequence as the threshold estimate of τ. However, the sample mean is a biased threshold estimator in the presence of asymmetric adjustments.[11] A consistent estimate of the threshold τ can be obtained by employing Chan's (1993) methodology of searching over possible threshold values to minimize the residual sum of squares (RSS) from the fitted model. Enders and Siklos (2001) estimated the threshold value of τ by applied Chan's (1993) methodology and used the same method incorporating with a Monte Carlo approach to obtain the F-statistic for the null of $\rho_1 = \rho_2 = 0$.[12] As there is generally no presumption as to whether to use TAR or M-TAR model, the recommendation is to select the adjustment mechanism by a model selection criterion such as the AIC or SBC.

The results of our estimations of threshold cointegration relationships between NTD/JPY exchange rate and each of the country stock indices (Japan and Taiwan) are illustrated in Table 4 and Table 5, respectively. Based on the 'Principle of Parsimony', both AIC and SBC suggest that the most applicable model for variables adjustment to long-run equilibrium in both countries is M-TAR model with threshold value (M-TART hereafter), where the threshold values of τ are founded to be -0.033 and –0.014 for Japan and Taiwan cases, respectively, based on the Chan's (1993) method. (see Figure 3 and Figure 4 for the RSS plots of M-TART model for both countries) For the further analyses, the empirical evidence for the Japanese case in Table 4 shows that the null of no cointegration ($\hat{F}_C$) is rejected, which indicates the existence of a long-run equilibrium relationship between the NTD/JPY and the JP stock. However, the null of symmetric adjustment ($\hat{F}_A$) is not rejected, suggesting that there is no significant threshold cointegration relationship between the two variables considered. On the other hand, the evidence for the Taiwanese case is shown in Table

[11] For instance, if autoregressive decay is more sluggish for positive deviations of μ_{t-1} from τ than for negative deviations, the sample mean estimator will be biased upwards.
[12] The critical values of this non-standard F-statistic for testing this threshold cointegration relationship are tabulated in their paper.

5 that both the null of no cointegration ($\hat{F}_C$) and symmetric adjustment ($\hat{F}_A$) are rejected at least at the 10% level, which suggests the existence of an asymmetric threshold cointegration relationship between the NTD/JPY and TW stock during the period investigated even the asymmetric phenomenon is weak.

<Insert Table 4 about Here>

<Insert Table 5 about Here>

3.4. M-TECM Granger-Causality Tests

Given the threshold cointegration results found in the previous section, the next step, we proceed with the Granger causality test using the advanced momentum threshold error-correction model (M-TECM) by Enders and Granger (1998) and Enders and Siklos (2001). The M-TECM is expressed as follows:

$$\Delta Y_{it} = \alpha + \gamma_1 Z_{t-1}^{+} + \gamma_2 Z_{t-1}^{-} + \sum_{i=1}^{k_1} \delta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \theta_i \Delta Y_{2t-i} + v_t \qquad (5)$$

where $Y_{it} = (JS_t, EX_t)$ for Japanese case and $Y_{it} = (TS_t, EX_t)$ for Taiwanese case, JS_t, TS_t and EX_t are symbols for JP stock, TW stock and NTD/JPY at time t, respectively. $Z_{t-1}^{+} = I_t \hat{u}_{t-1}$ *and* $Z_{t-1}^{-} = (1 - I_t)\hat{u}_{t-1}$, given that $I_t = 1$ if $\Delta u_{t-1} \geq -0.033$ and $I_t = 0$ if $\Delta u_{t-1} \leq -0.033$ for Japanese case and $I_t = 1$ if $\Delta u_{t-1} \geq -0.014$ and $I_t = 0$ if $\Delta u_{t-1} \leq -0.014$ for Taiwanese case. v_t is a white-noise disturbance.

From this formulation, the Granger-Causality tests are employed to examine whether all the coefficients of $\Delta Y_{1,t-i}$ or $\Delta Y_{2,t-i}$ are jointly statistically different from zero based on a standard F-test and/or whether the γ_j coefficients of the error-correction term are significant. Since Granger-Causality tests are very sensitive to the selection of lag length, we apply the AIC criterion to determine the appropriate lag lengths and empirically find that, for both Japanese and Taiwanese cases, the two lag lengths of k_1 and k_2 are all one (i.e., $k_1 = k_2 = 1$).

Table 6 presents the results of Granger causality tests, symmetric and asymmetric, based on the corresponding ECM and M-TECM for Japan Stock Index (JS) and

NTD/JPY exchange rate (EX). They clearly illustrate that no short-run causal relationship between this two financial assets (insignificant of $H_0 : \delta_1 = \delta_2 = 0$ and $\theta_1 = \theta_2 = 0$), however, there exists a unidirectional causality relationship running from JP stock to NTD/JPY in the long-run when the difference in the previous disequilibrium term is well above the threshold value of -0.033 (the significant of $H_0 : \delta_1 = \delta_2 = \gamma_1 = 0$ and insignificant of $H_0 : \theta_1 = \theta_2 = \gamma_1 = 0$, $\theta_1 = \theta_2 = \gamma_2 = 0$ and $\delta_1 = \delta_2 = \gamma_2 = 0$). This result argues that stock prices lead the movement of exchange rates. Moreover, the positive sign (by European quotation for Japanese case) can well describes that an increase in stock prices induces investors to demand for more domestic assets and thereby causes an appreciation in domestic currency, which strongly supports the portfolio approach as mentioned before. However, the insignificant findings of the null of $\gamma_1 = \gamma_2$ in either financial asset consistent with the finding of our previous M-TART estimations indicate that our findings of asymmetric unidirectional causal relationship are not well acceptable. Nonetheless, the empirical results from conventional ECM estimation show that JP stock and NTD/JPY are bidirectional causal related in the long-run, whereas, not in the short-run.

For the volume of the adjustments towards long-run equilibrium in JP stock and NTD/JPY, Table 6 shows that there are only 0.7% and 1% (the coefficients of Z_{t-1}^{-}) adjustments in the JP stock and NTD/JPY to revert to the equilibrium level when differences in the previous disequilibrium term is below the threshold value of -0.033. On the other hand, it is statistically significant and approximately 4.3% and 6.9% (the coefficients of Z_{t-1}^{+}) of the deviations in the JP stock and NTD/JPY can be reverted to the equilibrium level in the higher value regime. These indicate that the speeds of adjustment towards long-run equilibrium in relationship between JP stock and NTD/JPY are faster in the higher regime than in the lower regime.

<Insert Table 6 about Here>

The results of the symmetric and asymmetric, short-run and long-run, Granger causality tests based on the corresponding ECM and M-TECM for the Taiwan Stock Index (TS) and NTD/JPY exchange rate are presented in Table 7. They again show that no short-run causal relationship between the two financial assets (insignificant of $H_0 : \delta_1 = \delta_2 = 0$ and $\theta_1 = \theta_2 = 0$). However, in terms of long-run situation, a unidirectional causal relationship running from NTD/JPY to TW stock is found for the regime above the threshold value of -0.014 for $\Delta\mu_{t-1}$. This is interpreted as the significant of $H_0 : \theta_1 = \theta_2 = \gamma_1 = 0$ and the insignificant of $H_0 : \delta_1 = \delta_2 = \gamma_1 = 0$, $\theta_1 = \theta_2 = \gamma_2 = 0$ and $\delta_1 = \delta_2 = \gamma_2 = 0$.

The finding that exchange rates lead the movement of stock prices combing with the positive sign (by American quotation) argue that the traditional approach well describes the phenomenon of the price transmission between exchange rates and stock prices in Taiwanese financial markets. A depreciation of NTD makes Taiwanese firms more competitive, leading to an increase in their exports, and consequently raises TW stock. Moreover, the significant finding of the null of $\gamma_1 = \gamma_2$ in TW stock (at 10% level) consistent with our previous finding from M-TART argues that there exists weak asymmetric causal relationship between the NTD/JPY and TW stock. The conventional ECM estimation for Taiwanese case again shows a significant bidirectional causal relationship between its stock prices and exchange rates in the long-run, but not in the short-run situation.

For the volume of the adjustments towards long-run equilibrium in TW stock and NTD/JPY, similar findings to the Japanese case of the point estimates of adjustment coefficients are presented in Table 7. It shows that it is significant and approximately 12.3% and 4.3% (the coefficients of $\mathrm{Z}^{+}_{\mathrm{t-1}}$) of the deviations in the TW stock and NTD/JPY can be reverted to the equilibrium level in the higher value regime and there are only 2.4% and 4.0% (the coefficients of Z^{-}_{t-1}) adjustments in the TW stock and NTD/JPY to revert to the equilibrium level when differences in the previous disequilibrium term is below the threshold value of -0.014. Thus, for Taiwanese case, the speeds of adjustment towards long-run equilibrium in relationship between stock prices and exchange rates are still faster in the higher regime than in the lower regime.

<Insert Table 7 about Here>

IV Conclusion

It is generally argued that the relationship between exchange rates and stock prices has important implications. This paper aims to empirically investigate the asymmetric causal relationships between exchange rate of NTD/JPY and stock indices of Japan and Taiwan, respectively. In the model specification, we first found that the most applicable model for adjustment to long-run equilibrium between the exchange rate and stock indices are the M-TART model for both countries. Moreover, there exists strong evidence supporting the long-run equilibrium relationships between exchange rates and stock indices from our M-TART estimations, but an asymmetric threshold cointegration relationship only exists in Taiwanese, not in Japanese financial market.

Further evidence from M-TECM Granger-Causality Tests illustrates that no short-run causal relationship exists between these two financial assets, both in Japanese and Taiwanese cases. However, in the long-run, there is an interesting finding that the two financial assets in different countries possess different unidirectional causal relationships when the differences in the previous disequilibrium term are above their threshold value. The positive causal relationship running from stock index to exchange rate (by European quotation) in Japan supports the portfolio approach, whereas the positive causal relationship running exchange rate (by American quotation) to stock index in Taiwan argues for the traditional approach. However, consistent with the finding of M-TART estimations, the asymmetric unidirectional causal relationship in Japan is not well acceptable. Nonetheless, the empirical results from conventional ECM estimation show that stock indices and exchange rates in both countries considered are bidirectional causal related in the long-run, but not in the short-run situation. Another interesting finding from our M-TECM estimations is that the speed of adjustment towards long-run equilibrium in relationship between stock indices and exchange rates is faster in the higher regime than in the lower regime for both countries' cases.

The estimations for the symmetric and asymmetric causal relationships between the two financial assets of stock index and exchange rate for countries of Japan and Taiwan are indeed a crucial subject, especially to the multinational enterprises and the international investors. Our interesting findings may provide them an excellent reference for their asset allocations.

Reference

Abdalla, Issam S A and Victor Murinde (1997), "Exchange Rates and Stock Price Interactions in Emerging Financial Markets：Evidence on India, Korea and the Philippines," *Applied Financial Economics*, 7, 25-35.

Aggarwal, R. (1981), "Exchange Rates and Stock Prices: A Study of The U.S. Capital Markets under Floating Exchange Rates," *Akron Business and Economic Review,* 7-12.

Ajayi, Richard A. and M. Mougoue (1996), "On the Dynamic Relation Between Stock Prices and Exchange rates, "*The Journal of Financial Research*, 19,193-207.

Bahmani-Oskooee, M. and A. Sohrabian (1992), "Stock Prices and the Effective Exchange Rate of the Dollar," *Applied Economics,* 24 (4), 459-464.

Bhattacharya, B. and J. Mukherjee (2003), "Causal Relationship Between Stock Market and Exchange Rate. Foreign Exchange Reserves and Value of Trade Balance: A Case Study for India," *Paper presented at the Fifth Annual Conference on Money and Finance in the Indian Economy on January 2003.*

Bodnar, G. M. and Gentry, W. M. (1993), "Exchange Rate Exposure and Industry Characteristics: Evidence from Canada, Japan and U.S.," *Journal of International Money and Finance*, 12, 29-45.

Bartov, E. and G. M. Bodnar (1994), "Firm Valuation, Earnings Expectations, and the Exchange -Rate Exposure Effect," *Journal of Finance*, 49, 1755-1785.

Branson, W. H. (1983). Macroeconomic Determinants of Real Exchange Risk, in *Managing Foreign Exchange Risk* (Herring, R. J., ed.), Chapter 1. Cambridge: Cambridge University Press.

Caporale, Guglielmo Maria, Nikitas Pittis and Nicola Spagnolo (2002), "Testing for Causality-in-Variance: an Application to the East Asian Markets," *International Journal of Finance & Economics*, 7(3), 235-245

Chan, K.S. (1993). Consistency and Limiting Distribution of the Least Squares Estimator of a Threshold Autoregressive Model, *The Annals of Statistics*, 21, 520-533.

Chen, Show-Lin and Jyh-Lin Wu (1997), "Sources of Real Exchange-Rate Fluctuations: Empirical Evidence from Four Pacific Basin Countries," *Southern Economic Journal*, 63(3), 776-787

Chiao, Chaoshin, Ken Hung and Gladson I. Nwanna (2001), "The Impact of Market Liberalization on Firms' Exchange Rate Exposure," *Competitiveness Review***,** 11(1), 40-52

Choi, J. J., Takato Hiraki and Nobuya Takezawa (1998), "Is Foreign Exchange Risk Priced in the Japanese Stock Market?" *Journal of Financial and Quantitative Analysis*, 33(3), 361-382

Choi, J. J. and A. M. Prasad (1995), "Exchange Risk Sensitivity and Its Determinants: A Firm and Industrial Analysis of U.S. Multinationals," *Financial Management*, 24(3), 77-88.

Enders, W. and C.W. F. Granger (1998), "Unit-root Tests and Asymmetric Adjustment with an Example Using the Term Structure of Interest Rates," *Journal of Business Economics & Statistics*, 16, 304-311.

Enders, W. and P.L. Siklos (2001), "Cointegration and Threshold Adjustment", *Journal of Business Economics & Statistics*, 19, 166-176.

Dickey, D.A. and W.A. Fuller (1981), "Likelihood Ratio Statistics for Autoregressive Time Series with Unit Root", *Econometric*, 49, 1057-1072.

Doukas, John, Patricia H. Hall and Larry H. P. Lang (1999), "The Pricing of Currency Risk in Japan," *Journal of Banking and Finance*, 23(1), 1-20

Dropsy, V. and F. Nazarian-Ibrahimi (1994), "Macroeconomic Policies, Exchange Rate Regimes and National Stock Markets," *International Review of Economics and Finance*, 3 (2), 195-220.

Durand, R. B., Kho Sze Kee, and I. Watson (2001), "Who Moved Asian-Pacific Stock Markets? A Further Consideration of the Impact of the US and Japan," *Australian Journal of Management*, 26(2), 125-145.

Elyasiani, Elyas and Iqbal Mansur (2005), "The Association Between Market and Exchange Rate Risks and Accounting Variables: A GARCH Model of the Japanese Banking Institutions," *Review of Quantitative Finance and Accounting*, 25(2), 183-206.

Enders, W. and S. Hurn, (1994), "Theory and Tests of Generalized of Purchasing Power Parity: Common Trends and Real Exchange Rates in the Pacific Rim," *Review of International Economics*, 2(2), 179-190.

Engle, R. and C. Granger (1987), "Co-Integration and Error Correction Representation, Estimation and Testing," *Econometrica*, 55, march, 251-267.

Fang, Hsing, Jean C. H. Loo (1996), "Foreign Exchange Risk and Common Stock Returns: A note on International Evidence," *Journal of Business Finance and Accounting*, 23(3), 473-480

Fernandez, Viviana (2006), "External Dependence in European Capital Markets, *Journal of Applied Economics*, 9(2), 275-293

Franck, P. and A.,Young (1972), "Stock price Reaction of Multinational Firms to Exchange Realignments," *Financial Management*, 1, 66- 73.

Granger, C. W. J., B. N. Huang, and C. W. Yang (2000), "A Bivariate Causality

Between Stock Prices and Exchange Rates：Evidence from Recent Asian Flu," *Quarterly Review of Economics and Finance*, 40, 337-354.

Guo, Jang-Ting and Rong-Chang Wu (1998), "Financial Liberalization and the Exchange-Rate Exposure of the Taiwanese Firms: A Nonparametric Analysis," *Multinational Finance Journal*, 2(1), 37-61

He, Jia and Lilian K. Ng (1998), "The Foreign Exchange Exposure of Japanese Multinational Corporations," *The Journal of Finance*, 53(2), 733-754

Homma, Tetsushi, Yoshiro Tsutsui and Uri Benzion (2005), "Exchange Rate and Stock Prices in Japan," *Applied Financial Economics*, 15(7), 469-478.

Kanas, A. (2000), "Volatility Spillovers Between Stock Returns and Exchange Rate Changes：International Evidence," *Journal of Business and Accounting* , 27(3/4), 447-467.

Kapetanios, G., Shin Yongcheol., and Snell, A. (2003). Testing for a unit root in the nonlinear STAR framework, *Journal of Econometrics*, 112, 359-379.

Karolyi, G Andrew and Rene M. Stulz (1996), "Why do markets move together? An investigation of U.S.-Japan stock return comovements," *The Journal of Finance*, 51(3), 951-986

Kurihara, Yutaka (2006), "The Relationship between Exchange Rate and Stock Prices during the Quantitative Easing Policy in Japan," *International Journal of Business*, 11(4), 375-386

Kwon, C. S., T. S. Shin, and F. W. Bacon (1997), "The Effect of Macroeconomic Variables on Stock Markets Returns in Developing Markets," *Multinational Business Review*, 5, 63-70.

Mok, H. (1993), "Causality of Interest Rate, Exchange Rate and Stock Price at Stock Market Open and close in Hong Kong," *Asia Pacific Journal of Management*, 10, 123-143.

Newey, W. and K. West (1994), "Automatic lag selection in covariance matrix estimation," Review of Economic Studies, 61, 631-653.

Ng, S. and P. Perron (2001), "Lag length selection and the construction of unit root tests with goof size and power," *Econometrica*, 69, 1519-1554.

Nieh, C. C. and C. F. Lee (2001), "Dynamic Relationship Between Stock Prices and Exchange Rates for G-7 Countries," *Quarterly Review of Economics and Finance*, 41(4), 477-490.

Phillips, P.C.B. and P. Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrika*, 75, 335-346.

Pilbeam, K. (2001), "The East Asian Financial Crisis: Getting to the Heart of the Issues," *Managerial Finance*, 27(1/2), 111-133

Prasad, Anita Mehra and Murli Rajan (1995), "The Role of Exchange and Interest risk in Equity Valuation: A Comparative Study of International Stock Markets," *Journal of Economics and Business*, 47(5), 457-472

Sewell, Susan P., Stanley R. Stansell, Insup Lee and Scott D. Below (1996), “Using Chaos Measures to Examine International Capital Market Integration,” *Applied Financial Economics*, 6(2), 91-101

Smith, C. E. (1992), “Stock Markets and the Exchange Rate: A Multi-Country Approach,” *Journal of Macroeconomics*, 14(4), 607-629

Soenen, Luc A. and E. S. Hennigar (1988), “An Analysis of Exchange Rates and Stock Prices—The U.S. Experience Between 1980 and 1986,” *Akron Business ＆ Economic Review*, 19, 7-16.

Sun, Qian and Wilson H. S. Tong (2000), “The Effect of U.S. Trade Deficit Announcements on the Stock Prices of U.S. and Japanese Automakers,” *The Journal of Financial Research***.** 23(1), 15-43

Varela, Oscar and Atsuyuki Naka (1997), “The London International Stock Exchange's Foreign Currency Exposures to the Dollar, Yen and Mark,” *Managerial Finance*, 23(7), 45-57

Wu, Jyh-Lin (1997), “Foreign Exchange Market Eefficiency and Structural Instability: Evidence from Taiwan,” *Journal of Macroeconomics*, 19(3), 591-607

Yau, Hwey-Yun and Chien-Chung Nieh (2006), “Interrelationships among Stock Prices of Taiwan and Japan and NTD/Yen Exchange Rate,” *Journal of Asian Economics*, 17(3), 535-52

Table 1. Summary Statistics of JP Stock, TW Stock and NTD/JPY Exchange rate

	JP Stock	TW Stock	NTD/JPY
Mean	16219.62	5989.92	0.2653
SD	4475.31	1494.86	0.0343
Maximum	26409.22	10066.35	0.3202
Minimum	7831.42	3374.56	0.1911
Skewness	-0.0069	0.6085	-0.570188
Kurtosis	2.1518	2.8450	2.417095
Jarque-Bera	5.2467*	10.9746***	11.9600***
Probability	0.0726	0.0041	0.0025

Notes: 1. JP Stock, TW Stock, and NTD/JPY are the symbols for the Nikkei 225 Index, Taiwan Stock Exchange Index and NTD/JPY exchange rate, respectively.
2. SD denotes standard error.
3. ***, ** and * indicate significance at the 1%, 5% and 10%, respectively

Table 2. The results of conventional linear unit root tests

		JP Stock			TW Stock			NTD/JPY		
ADF	Level	-2.860	[3]	(0)	-2.487	[2]	(0)	-1.976	[2]	(6)
	First difference	-5.052***	[1]	(4)	-8.383***	[1]	(1)	-6.448***	[1]	(2)
PP	Level	-2.857	[3]	(2)	-2.543	[2]	(1)	-2.592	[3]	(2)
	First difference	-13.883***	[1]	(0)	-12.910***	[1]	(6)	-13.269***	[1]	(5)
NP	Level	-0.487	[2]	(0)	-2.118	[3]	(0)	-2.009	[3]	(6)
	First difference	-3.016**	[3]	(9)	-4.351***	[3]	(9)	-4.216***	[3]	(2)

Notes: 1. JP Stock, TW Stock, and NTD/JPY are the symbols for the Nikkei 225 Index, Taiwan Stock Exchange Index and NTD/JPY exchange rate, respectively.
2. ***, **, and * denote significant at 1%, 5%, and 10% levels, respectively.
3. The critical values for 1%, 5%, and 10% levels of ADF, PP and NP, are (-4.011663;-3.435858; -3.141996), (-4.011663; -3.435858; -3.141996) and (MZt：-3.42000; -2.91000; -2.62000), respectively. The critical values for the ADF t-statistics are from the MacKinnon (1996) table.
4. The test statistic of the NP test is MZ_t.
5. The numbers in the brackets indicate model specification. The numbers in the parentheses of

ADF, and NP are the appropriate lag lengths selected by MAIC, whereas the numbers in the parentheses of PP is the optimal bandwidths decided by the Bartlett kernel of Newey and West (1994).

6. The appropriate models selected for the level and the first difference are based on the decision procedures suggested by Dolado, Jenkinson and Sosvilla-Rivero (1990).

Table 3. The results of Nonlinear Unit Root Test - KSS test

	t Statistic on $\hat{\delta}$	
	Level	First difference
JP Stock	0.3294(0)	-2.4836(4)**
TW Stock	-1.2858(0)	-3.7593(6)***
EX Rate	0.0341(0)	-1.7783(0)*

Note: 1. The numbers in the parentheses are the appropriate lag lengths selected by MAIC (modified Akaike information criterion) suggested by Ng and Perron (2001).

2. The simulated critical values for different K were tabulated in Kapetanios et al. (2003) (Table 1 as of p.363).

Table 4. Model Specification for Japan (Enders and Granger (1998) Approach)

	J (TAR)	J (M-TAR)	J (TART)	J (M-TART)
$\hat{\rho}_1$	-0.059(-1.690)*	-0.051(-1.556)	-0.074(-2.032)**	-0.071(-2.482)**
$\hat{\rho}_2$	-0.038(-1.192)	-0.043(-1.298)	-0.029(-0.935)	-0.001(-0.037)
$\hat{F}_C$	2.137[0.121]	2.054[0.130]	2.501[0.085]*	3.680[0.048]**
$\hat{F}_A$	0.194[0.660]	0.030[0.863]	0.904[0.343]	2.036[0.155]
l	0	0	0	0
AIC	-22.75	-22.58	-23.46	**-24.60**
SBC	-16.43	-16.26	-17.14	**-18.28**

Notes: 1. J represents Japan. M-TART indicates momentum-threshold autoregressive model with threshold value.

2. Lag-length (l) selection is based on the Ng and Perron (2001) unit root procedure.

3. Numbers in parentheses and bracklet are t statistics and p value, respectively

4. $\hat{F}_C$ and $\hat{F}_A$ denote the F-statistics for the null hypothesis of no cointegration and symmetry. Critical values are taken from Enders and Siklos (2001).

5. The threshold value, τ , of TAR and M-TAR models are 0.156 and -0.033, respectively.

6. The model is specified, based on the 'principle of parsimony' of AIC and SBC, as M-TART model with the threshold value of -0.033.

7 *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 5. Model Specification for Taiwan (Enders and Granger (1998) Approach)

	T (TAR)	T (M-TAR)	T (TART)	T (M-TART)
$\hat{\rho}_1$	-0.054(-1.421)	-0.082(-1.976)**	-0.038(-1.104)	-0.012(-3.237)***
$\hat{\rho}_2$	-0.100(-2.386)**	-0.069(-1.786)*	-0.144(-3.032)***	-0.017(-0.419)

$\hat{F}_C$	3.085[0.023]**	3.547[0.031]**	5.205[0.006]***	5.325[0.006]***
$\hat{F}_A$	0.644[0.423]	0.054[0.816]	3.239[0.074]*	3.470[0.064]*
l	0	0	0	0
AIC	56.45	57.05	53.86	**53.63**
SBC	62.77	63.37	60.18	**59.95**

Notes: 1. T represents Taiwan. M-TART indicates momentum-threshold autoregressive model with threshold value.
2. Lag-length (l) selection is based on the Ng and Perron (2001) unit root procedure.
3. Numbers in parentheses and bracket are t statistics and p value, respectively
4. $\hat{F}_C$ and $\hat{F}_A$ denote the F-statistics for the null hypothesis of no cointegration and symmetry. Critical values are taken from Enders and Siklos (2001).
5. The threshold value, τ , of TART and M-TART models are -0.247 and -0.014, respectively.
6. The model is specified, based on the 'principle of parsimony' of AIC and SBC, as M-TART model with the threshold value of -0.014.
7. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 6. Estimates of the ECMs for Japan Stock Index and NTD/JPY

	Asymmetric		Symmetric	
	JS	EX	JS	EX
Constant	-0.004(-0.896)	0.002(1.095)	-0.003(-1.283)	0.002(1.323)
JS(-1)	0.004(0.055)	0.013(0.336)	-0.004(-0.083)	-0.021(-0.528)
JS(-2)	-0.033(-0.426)	-0.012(-0.312)	0.008(0.184)	0.037(0.923)
EX (-1)	0.096(0.618)	-0.001(-0.011)	0.039(0.438)	0.001(0.065)
EX (-2)	-0.091(-0.585)	0.077(1.019)	-0.085(-0.95)	0.005(0.240)
Z^{+}_{t-1}	**-0.043(-1.696)***	**-0.069(-2.869)*****		
Z^{-}_{t-1}	0.007(0.198)	-0.010 (-0.202)		
ECT_{t-1}			0.693(18.635)***	0.748(21.302)***
$H_0: \gamma_1 = \gamma_2 = 0$	1.463[0.235]	4.127[0.018]**		
$H_0: \theta_1 = \theta_2 = 0$	0.368[0.692]		0.555[0.575]	
$H_0: \delta_1 = \delta_2 = 0$		0.109[0.897]		0.031[0.970]
$H_0: \theta_1 = \theta_2 = \gamma = 0$			116.485[0.00] ***	
$H_0: \theta_1 = \theta_2 = \gamma_1 = 0$	1.198[0.312]			

	Asymmetric		Symmetric	
	JS	EX	JS	EX
$H_0: \theta_1 = \theta_2 = \gamma_2 = 0$	0.257[0.856]			
$H_0: \delta_1 = \delta_2 = \gamma = 0$				151.799[0.00]***
$H_0: \delta_1 = \delta_2 = \gamma_1 = 0$		2.890[0.037]**		
$H_0: \delta_1 = \delta_2 = \gamma_2 = 0$		0.082[0.970]		
H_0 :(JS) $\gamma_1 = \gamma_2$	1.359[0.245]			
H_0 :(EX) $\gamma_1 = \gamma_2$		1.145[0.286]		
AIC	-75.06	-324.06	-268.19	-544.25
SBC	-53.03	-302.03	-249.31	-525.37
Q(4)	1.164[0.281]	8.312[0.004]***	1.681[0.195]	0.050[0.823]
Q(12)	0.837[0.504]	25.666[0.002]***	13.468[0.14]	5.201[0.816]
ARCH(4)	1.012[0.4.3]	0.995[0.412]	1.769[1.138]	0.915[0.456]
J-B	1.472[0.479]	11.038[0.004]***	3.711[0.156]	0.999[0.607]

Notes: 1. JS and EX represent Japan stock index and exchange rate of NTD/JPY, respectively.

2. Numbers in parentheses and bracket are t statistics and p value, respectively

3. Threshold Error-Correction Model:

$$\Delta Y_{it} = \alpha + \gamma_1 Z_{t-1}^{+} + \gamma_2 Z_{t-1}^{-} + \sum_{i=1}^{k_1} \delta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \theta_i \Delta Y_{2t-i} + v_t$$

where $Y_{it} = (JS_t, EX_t)$, $Z_{t-1}^{+} = I_t \hat{u}_{t-1}$, $Z_{t-1}^{-} = (1 - I_t)\hat{u}_{t-1}$ such that $I_t = 1$ if $u_{t-1} \geq -0.033$, $I_t = 0$ if $u_{t-1} \leq -0.033$ and v_t is a white-noise disturbance.

4. Symmetric Error-Correction Model: $\Delta Y_{it} = \alpha + \gamma \hat{u}_{t-1} + \sum_{i=1}^{k_1} \delta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \theta_i \Delta Y_{2t-i} + v_t$

5. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 7. Estimates of the ECMs for Taiwan Stock Index and NTD/JPY

	Asymmetric		Symmetric	
	TS	EX	TS	EX
Constant	0.003(0.510)	0.002(0.972)	0.001(1.006)	0.001(0.665)
TS(-1)	0.074(0.941)	-0.022(-0.819)	-0.006(-0.494)	0.014(-0.531)
TS(-2)	0.109(1.419)	-0.008(-0.300)	0.003(0.271)	0.018(0.672)

	Asymmetric		Symmetric	
	TS	EX	TS	EX
EX (-1)	-0.1346(-0.602)	-0.015 (-0.187)	-0.016(-0.481)	0.001(0.111)
EX (-2)	0.123(0.548)	0.068(0.859)	0.027(0.806)	0.008(0.858)
Z^{+}_{t-1}	**-0.123(3.297)***	**-0.043(-2.133)**		
Z^{-}_{t-1}	-0.024(-0.570)	-0.040(-1.175)		
ECT_{t-1}			0.946(87.434)***	0.813(35.680)***
$H_0 : \gamma_1 = \gamma_2 = 0$	5.609[0.004]***	2.968[0.054]*		
$H_0 : \theta_1 = \theta_2 = 0$	0.337[0.714]		0.456[0.635]	
$H_0 : \delta_1 = \delta_2 = 0$		0.386[0.681]		0.377[0.687]
$H_0 : \theta_1 = \theta_2 = \gamma = 0$			2551.816[0.00] ***	
$H_0 : \theta_1 = \theta_2 = \gamma_1 = 0$	3.674[0.013]**			
$H_0 : \theta_1 = \theta_2 = \gamma_2 = 0$	0.395[0.757]			
$H_0 : \delta_1 = \delta_2 = \gamma = 0$				425.675[0.00]***
$H_0 : \delta_1 = \delta_2 = \gamma_1 = 0$		1.722[0.165]		
$H_0 : \delta_1 = \delta_2 = \gamma_2 = 0$		0.668[0.573]		
H_0 :(TS) $\gamma_1 = \gamma_2$	3.140[0.078]*			
H_0 :(EX) $\gamma_1 = \gamma_2$		0.009[0.926]		
AIC	38.78	-321.76	-614.32	-689.17
SBC	60.82	-299.73	-595.44	-670.28
Q(4)	0.534[0.465]	8.909[0.003]***	10.573[0.001]***	1.418[0.234]
Q(12)	16.056 [0.066]*	24.360[0.004]***	19.502[0.021]***	9.869[0.361]
ARCH(4)	0.431[0.786]	0.867[0.485]	0.777[0.542]	0.403[0.806]
J-B	6.072[0.048]**	10.417[0.005]***	23.162[0.000]***	22.751[0.000]***

Notes: 1. TS and EX represent Taiwan stock index and exchange rate of NTD/JPY, respectively.
2. Numbers in parentheses and bracket are t statistics and p value, respectively

3. Threshold Error-Correction Model:

$$\Delta Y_{it} = \alpha + \gamma_1 Z_{t-1}^{+} + \gamma_2 Z_{t-1}^{-} + \sum_{i=1}^{k_1} \delta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \theta_i \Delta Y_{2t-i} + v_t$$

where $Y_{it} = (TS_t, EX_t)$, $Z_{t-1}^{+} = I_t \hat{u}_{t-1}$, $Z_{t-1}^{-} = (1 - I_t)\hat{u}_{t-1}$ such that $I_t = 1$ if $u_{t-1} \geq -0.014$, $I_t = 0$ if $u_{t-1} \leq -0.014$ and v_t is a white-noise Idisturbance.

4. Symmetric Error-Correction Model: $\Delta Y_{it} = \alpha + \gamma \hat{u}_{t-1} + \sum_{i=1}^{k_1} \delta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \theta_i \Delta Y_{2t-i} + v_t$

5. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

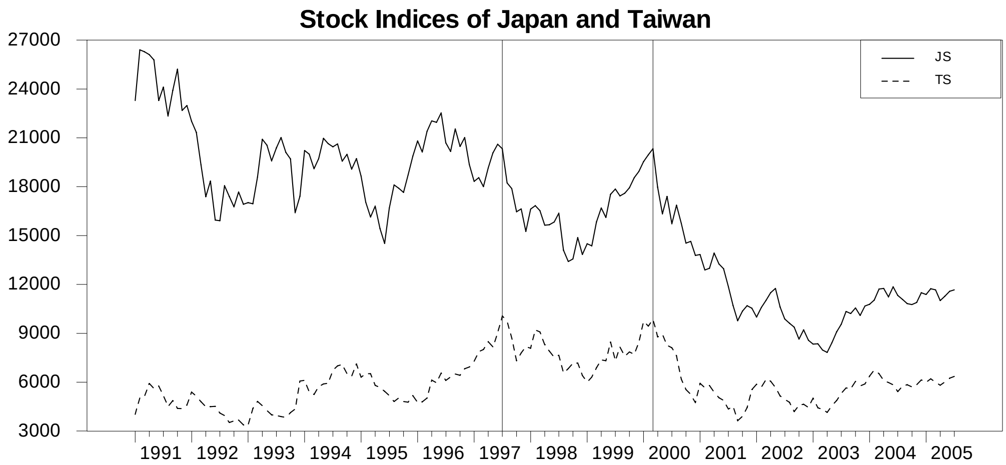

Fig. 1 Stock price movements of Japan and Taiwan

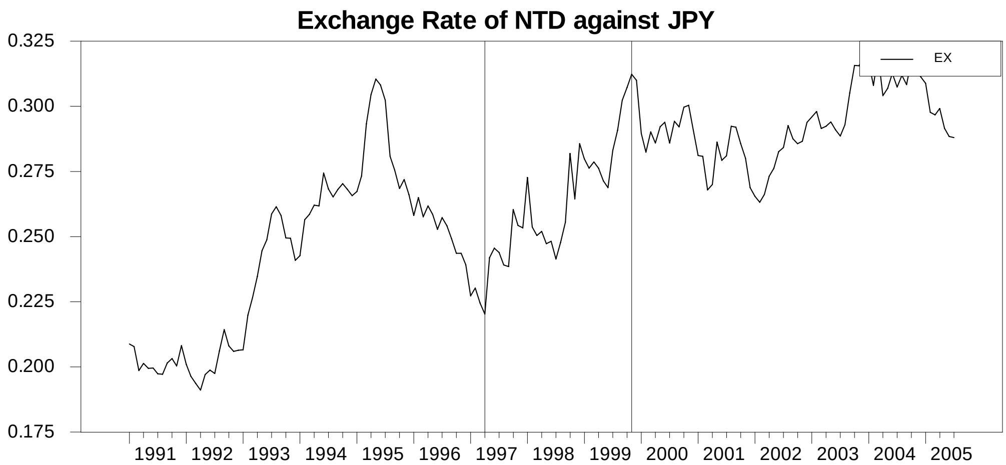

Fig. 2 Exchange rate movement of NTD against JPY

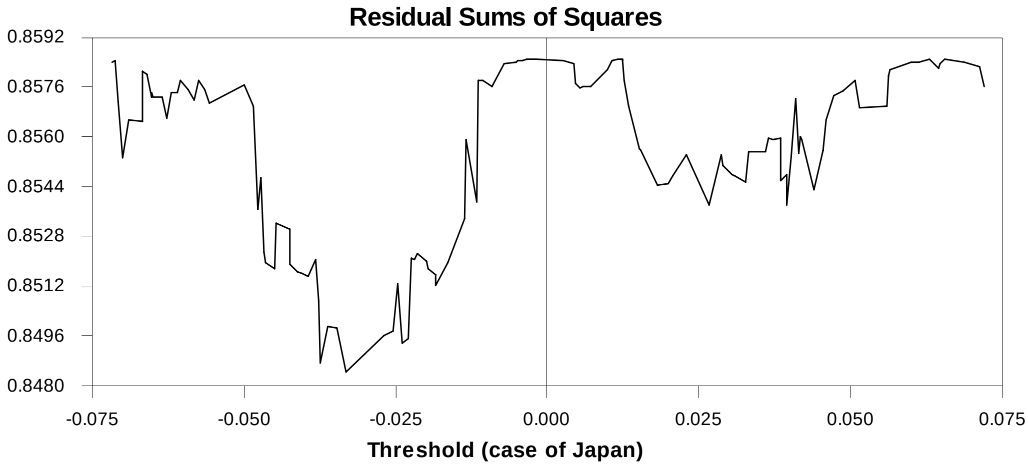

Fig. 3 RSS plots of M-TART model for Japanese case

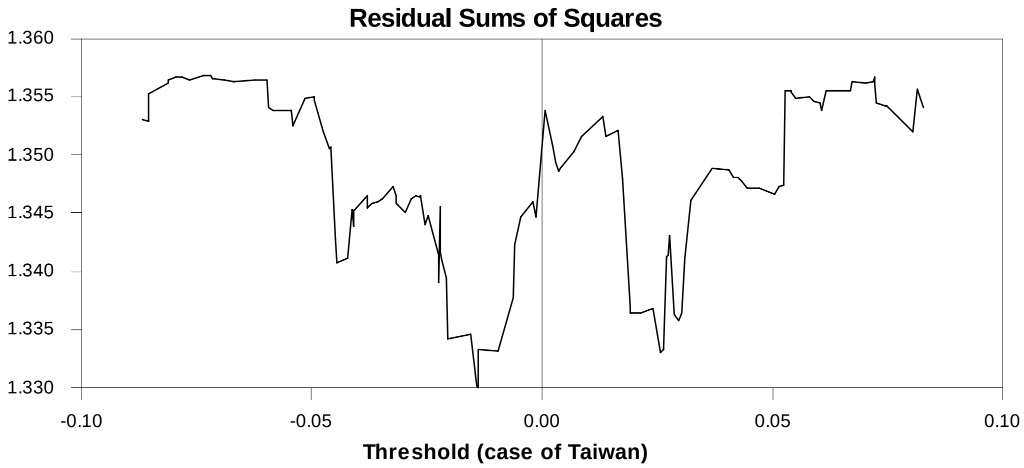

Fig. 4 RSS plots of M-TART model for Taiwanese case