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An Empirical Analysis of Nonlinear Dynamics Relationship between the United States and Taiwan Stock Markets

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Abstract: This paper investigates the co-integration and causal relationships by threshold model and non-linear adjustments relationship by STAR model between the U.S. and Taiwan stock market. The findings indicate that there exists an asymmetric threshold co-integration relationship between the U.S. and Taiwan stock markets. Moreover, this paper further finds that this is significant evidence of non-linearity in the TAIEX return, and the nonlinear dynamic adjustments of the S&P 500 and TAIEX prices follow the logistic transition function. The contribution of this study demonstrates that the LSTECM-GARCH is well suited to describing the short-run and long-run dynamic relationship between the U.S. and Taiwan stock markets.

Keywords: Asymmetric Threshold Co-integration, STECM-GARCH, Non-linear Adjustments Relationship

JEL Classification: C1, G5

Introduction

Investors in developed countries can either reduce their risk or increase their return by including emerging stocks in their portfolios.[1] While many researchers have already investigated stock market correlations or long-run cointegration relationships between developed countries and Asian emerging markets (Chan et al., 1992; Cheung and Mak, 1992; DeFusco et al., 1996; Liu and Pan, 1997; Wu and Su, 1998; Ghosh et al., 1999; Cha and Oh, 2000; Sheng and Tu, 2000; Darrat and Zhong, 2002), due to the size and global economic importance of the U.S market, the potential influence of this market on other markets cannot be ignored. Moreover, Eun and Shim (1989) and Cheung and Mak (1992) have provided evidence of the U.S. market leading worldwide trends. The United States is Taiwan's most important trading partner as evidenced by a total trade value of $34663.5 hundred million. In addition, the

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share of Taiwan's exports to the U.S. was 8.71%, and the share of Taiwan imports from the U.S. was 14.2% for the year 2008. In addition, the government of Taiwan relaxed formal barriers to the flow of capital and promoted the development of derivative securities. Thus the issue of international linkages in relation to the Taiwan stock market is important to international investors.

Ghosh et al. (1990) show that a co-integration relationship means that although two markets may deviate from each other in the short run, investors' preferences, market forces and government regulations will bring them back to their equilibrium in the long run. The long-term equilibrium relationship between the U.S. and Taiwan markets can be tested by means of an Error Correction Model (ECM) in order to adjust for the error term and thereby eliminate bias. However, most studies derive inconsistent results regarding the co-integration relationship between the U.S. and Taiwan stock markets.[2] Most previous studies that examined the traditional time series model assumed that the underlying variables exhibited linear and symmetrical adjustment processes; however, Dwyer et al. (1996), Enders and Granger (1998), Enders and Siklos (2001) and Lee and Hung (2007) have pointed out the problem of the low power of traditional co-integration tests and have argued that the non-linear Threshold Error Correction Model (TECM) is better than the linear ECM in describing the stock return. For this reason, this study investigates the asymmetric long-run relationship and causal relationship between the U.S. and Taiwan markets.

Under the assumption of homogeneous expectation, all investors engage in instantaneous trades captured by the TECM. However, Anderson (1997), Kawaller et al. (1987) and Stoll and Whaley (1990) indicate that investors have different opinions regarding the timing of information, tax and commission in the market, and Dumas (1994), Teräsvirta, (1994) and Granger and Lee (1999) observe that time aggregation or the aggregation of policy will enable the reward to have a smooth transformation. Thus Granger and Teräsvirta (1993) and Teräsvirta (1994) use the STAR (Smooth Transition Autoregressive) model to explain unreasonable assumptions. This model is highly appropriate in a stock market with many participants, each of which switches at different times owing to various reasons including heterogeneous beliefs, varying learning speeds, and different investment horizons. In particular, for non-constant conditional variances and volatility clustering in financial data, the GARCH (Generalized Autoregressive Conditional Heteroskedasticity) model successfully captures behaviors such as autocorrelation and the volatility clustering of financial assets. This study uses a nonlinear Smooth Transition Error Correction Model (STECM) that specifies that the error term follows the GARCH process (STECM-GARCH) by Chan and McAleer (2002) and Lee and Chiu (2009). Based on the above discussions and the need to respond to the serious lack of research in this area, the purpose of the present study is to examine the non-linear smooth adjustments relationship between the U.S. and Taiwan stock markets. Thus, this study investigates the non-linear smooth adjustments relationship between the U.S. and Taiwan stock markets.

The remainder of this paper is organized as follows. Section 2 describes the econometric model. Section 3 presents a description of the data and the empirical results. Concluding remarks and implications are presented in the final section.

Methodology

Threshold Co-integration Model

This study applies the threshold co-integration model by Enders and Granger (1998) and Enders and Siklos (2001). The model assumes that the variables x_t and y_t are I(1) processes, and the first regression takes the form:

$$y_t = \alpha + \beta x_t + \varepsilon_t, \tag{1}$$

where ε_t is the stochastic disturbance term. The second regression takes the form:

$$\Delta\varepsilon_t = I_t \rho_1 \varepsilon_{t-1} + (1 - I_t)\rho_2 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t, \tag{2}$$

where μ_t is an i.i.d. disturbance with zero mean, and I_t is the Heaviside indicator such that

$$I_t = \begin{cases} 1 & if \quad \varepsilon_{t-1} \geq 0 \\ 0 & if \quad \varepsilon_{t-1} < 0 \end{cases} \quad \text{or} \quad I_t = \begin{cases} 1 & if \quad \varepsilon_{t-1} \geq \tau \\ 0 & if \quad \varepsilon_{t-1} < \tau \end{cases} \tag{3}$$

where τ is the threshold value. When $\varepsilon_{t-1} > \tau$, equation (2) becomes $\Delta\varepsilon_t = I_t \rho_1 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t$, otherwise $\Delta\varepsilon_t = \rho_2 \varepsilon_{t-1} + \sum_{i=1}^{l} \gamma_i \Delta\varepsilon_{t-i} + \mu_t$ is used.[3] Enders and Granger (1998) and Caner and Hansen (1998) have shown that the Heaviside indicator depends on the change in ε_{t-1} (namely, $\Delta\varepsilon_{t-1}$) rather than on the level of ε_{t-1}. This leads to the Momentum-Threshold Autoregressive (M-TAR) model. The Heaviside indicator of equation (3) then becomes:

$$I_t = \begin{cases} 1 & if \quad \Delta\varepsilon_{t-1} \geq 0 \\ 0 & if \quad \Delta\varepsilon_{t-1} < 0 \end{cases} \quad \text{or} \quad I_t = \begin{cases} 1 & if \quad \Delta\varepsilon_{t-1} \geq \tau \\ 0 & if \quad \Delta\varepsilon_{t-1} < \tau \end{cases} \tag{4}$$

The M-TAR model implies that the adjustment mechanism of ε_t is dynamic, since the momentum of the series is greater in one direction than in the other.[4]

The Smooth Transition Error Correction Model with GARCH

The STECM can be represented as follows:

$$Y_{i,t} = \theta_0 + \alpha_1' W_t + (\theta_1 + b_1' W_t) G(Z_{t-d}; \gamma, \tau) + v_t, \; v_t \sim n.i.d.(0, \sigma^2) \tag{5}$$

where $Y_{i,t} = \ln(P_{i,t}/P_{i,t-1}) \times 100$ and $P_{i,t}$ are return and price on stock i $W_t = (Z_{t-1}, Y_{i,t-1}, \ldots, Y_{i,t-p})'$, $a_1 = (\alpha_0, \ldots, \alpha_p)'$ and $b_1 = (\beta_0, \ldots, \beta_p)'$; $G(Z_{t-d}; \gamma, \tau)$ is a transition function with the transition variable Z_{t-d}, and this paper defines Z_{t-d} as the error correction term. The parameter d is the delay parameter, γ is the smooth or slope parameter, and τ is the transition parameter. Equation (5) is termed the logistic STECM (LSTECM) and takes the following form:

$$G(Z_{t-d}; \gamma, \tau) = \left(1 + \exp\left\{-\gamma\left(Z_{t-d} - \tau\right)\right\}\right)^{-1}, \; \gamma > 0 \tag{6}$$

This transition function is monotonically increasing in Z_{t-d}. The slope parameter γ of G governs the transition speed from zero to unity, and the transition parameter τ determines the location of the transition. If G is termed the exponential STECM (ESTECM), it takes the following form:

$$G(Z_{t-d}; \gamma, \tau) = 1 - \exp(-\gamma (Z_{t-d} - \tau)^2), \; \gamma > 0 \tag{7}$$

In particular, the parameters in equation (7) change symmetrically around τ with- Z_{t-d}.

The null hypothesis of linearity in equation (5) is $H_0 : \gamma = 0$. Luukkonen et al. (1988) circumvented this problem via a third-order Taylor approximation to G about the null $\gamma = 0$. This approximation is expressed as:

$$y_t = \alpha_0 + \alpha_1' W_t + \psi_1' W_t Z_{t-d} + \psi_2' W_t Z_{t-d}^2 + \psi_3' W_t Z_{t-d}^3 + \xi_t \tag{8}$$

If the delay parameter d is assumed to be known, the linearity test is equivalent to the test of the hypothesis $H_0 : \psi_1 = \psi_2 = \psi_3 = 0$. Define an auxiliary regression as follows:

$$\hat{u}_t = \alpha_0 + \alpha_1' W_t + \psi_1' W_t Z_{t-d} + \psi_2' W_t Z_{t-d}^2 + \psi_3' W_t Z_{t-d}^3 + \eta_t \tag{9}$$

where $\hat{u}_t$ is the residual obtained from the regression $Y_{ti,} = \alpha_0 + \alpha_1' W_t + u_t$ under the null hypothesis of linearity. The LM-type test of the linearity against the STECM (including both the LSTECM and ESTECM) is used to calculate the following statistic:

$$LM = \frac{(SSR_0 - SSR_1)/3m}{SSR_1/(T - 4m - 1)} \tag{10}$$

where SSR_0 is the sum of the squared residuals $\hat{u}_t$, and SSR_1 is the sum of the squared residuals η_t obtained from equation (9).[5] This study distinguishes between the LSTECM and ESTECM through a sequence of tests. The following null hypothesis sequence is considered: $H_{01}: \psi_3 = 0$, $H_{02}: \psi_2 = 0 | \psi_3 = 0$ and $H_{03}: \psi_1 = 0 | \psi_2 = \psi_3 = 0$. A rejection of the null hypothesis H_{01} confirms the model to be of the LSTECM variety. Likewise, an ESTECM can be selected if the test results accept H_{01} and reject H_{02}. When the test results accept both H_{01} and H_{02} but reject H_{03}, then this is interpreted as support for the LSTECM.

The financial assets appear to exhibit autocorrelation and volatility clustering. Therefore, this study considers that the residual in the STECM is allowed to follow the GARCH process to capture the heteroskedasticity. The STECM-GARCH is constructed as follows:

$$Y_{TW,t} = \left(\theta_0 + \alpha_0 Z_{t-1} + \sum_{i=1}^{p} \alpha_i Y_{TW,t-i} + \sum_{j=P+1}^{q} \alpha_i Y_{US,t-j} \right) + \left(\theta_2 + \beta_0 Z_{t-1} + \sum_{i=1}^{p} \beta_i Y_{TW,t-i} + \sum_{j=P+1}^{q} \beta_i Y_{US,t-j} \right) \times G(Z_{t-d}; \gamma, \tau) + v_t \tag{11}$$

$$v_t | \Omega_{t-1} \sim N(0, h_t),\ h_t = \phi_0 + \phi_1 \varepsilon_{t-1}^2 + \phi_2 h_{t-1} \tag{12}$$

where $Y_{i,t-j}$ is *t-j* period by stock *i* return and $G(Z_{t-d}; \gamma, \tau)$ is a continuous transition function with the transition variable Z_{t-d} and parameters (γ, τ) that provide logistic or exponential non-linear functions. This study indicates that Z_{t-d} is also an error correction term. In addition, h_t denotes the conditionally heterogeneous variance.

Data and Empirical Analysis

The sample period extends from January 4, 2000 to December 31, 2008. The daily S&P 500 of the U.S. stock market and the Taiwan Stock Exchange Capitalization Weighted Index (TAIEX) for the Taiwan stock market transaction data were collected and transformed into daily returns. The daily data were obtained from http://www.yahoo.com/. The returns were defined as a logarithm in the form of $R_t = \ln(P_t / P_{t-1}) \times 100$, where P_t denotes the closing price at time *t*.

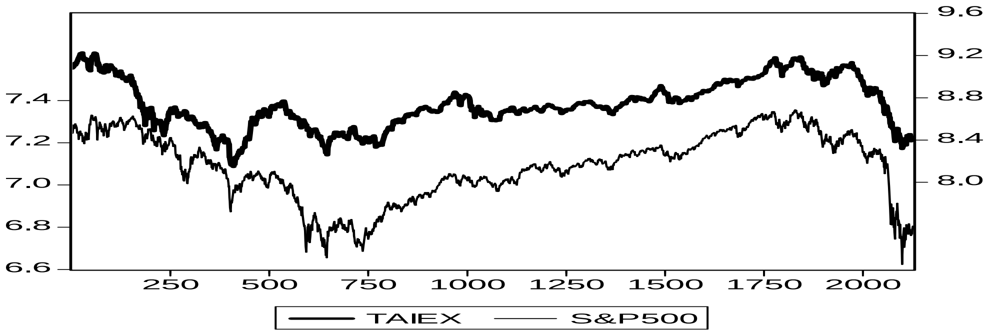
Table 1 shows summary statistics of the returns for the S&P 500 and TAIEX. The average returns of the S&P 500 and TAIEX are -0.0206 and -0.0304, respectively. Both returns are negatively skewed and leptokurtic and the JB statistics further significantly reject the normal distribution, implying that both returns have fatter tails and sharper peaks. The two returns exhibit autocorrelation, linear dependence and strong ARCH effects, and the Ljung-Box Q and Ljung-Box Q^2 tests are significant at the 1% level. Figure 1 shows that the S&P 500 and TAIEX may appear to be non-stationary and that both tend to move more or less together over time.

Table 1. Summary Statistics of Returns for the S&P 500 and TAIEX

Item	S&P500	TAIEX
Mean	-0.0206	-0.0304
SD	1.3762	1.7066
Skewness	-0.0546	-0.3693***
Kurtosis	10.7734***	6.4698***
Jarque-Bera Test	5351.1910***	1114.2810***
Q(12)	51.103***	48.030***
Q^2(12)	2327.490***	319.655***

Notes: 1. SD denotes standard error.
2. Q(12) and Q^2(12) are Ljung-Box Q and Ljung-Box Q^2 statistics with 12 lags.
3. The Jarque-Bera test denotes the normality test.
4. *** denotes rejection of the hypothesis at the 1% level.

Figure 1. The Price of the S&P 500 and TAIEX



Using the method of Chan (1993), the best threshold values obtained are 0.0506 and 0.0750 for the TAR and M-TAR models, respectively. This paper also finds that the F statistic rejects the null hypothesis of no co-integration in the TAR and M-TAR models in Panel A of Table 2. Of the two models, the M-TAR model with a threshold value of 0.0750 is clearly the best model based on AIC and SBC criteria; hence, the M-TAR model has better explanatory ability than the TAR model. Consequently, the null hypothesis is rejected for the M-TAR model with the threshold value, and this study finds that a threshold co-integration relationship exists between the S&P500 and TAIEX. This result is consistent with the existing literature (Lee and Hung, 2007)

Moreover, this study further employs Granger-Causality tests based on the M-TAR model to examine the causal relationship between S&P500 and TAIEX in Panel B of Table 2. This study finds that a unidirectional relationship exists from the S&P

500 to the TAIEX, implying that the finding could prove valuable to individual investors and financial institutions seeking to forecast the causality from the U.S. stock market to the Taiwan stock market. The results are consistent with the existing literature (Eun and Shim, 1989; Cheung and Mak, 1992; Cha and Oh, 2000; Lee and Hung, 2007) that concludes that the U.S. market is a global factor.

Table 2. Threshold Co-integration Test and Causality Test

Panel A: Threshold Co-integration Test				
Items	TAR		M-TAR	
Threshold Value	0.0000	0.0506	0.0000	0.0750
t	1.8974*	2.6196***	4.8933***	6.4474***
F	33.3241***	9.0557***	17.6417***	26.5010***
AIC	-42.1255	-45.3846	-62.3671	-79.7490
SBC	-25.1424	-45.3846	-45.3839	-62.7659
Panel B: Causality Test of the M-TAR Model				
TAIEX impact on S&P 500		1.2658		
S&P 500 impact on TAIEX		219.0008***		

Notes: 1. * and *** denote significance at the 10% and 1% levels, respectively.
2. F and t denote the null hypothesis of no co-integration and symmetry obtained the critical values Enders and Siklos (2001).

The results of the LM test of linearity against the non-linear STECM provide significant evidence of non-linearity in the returns of the TAIEX in Panel A of Table 3. This paper determines the optimal value for d to be one based on the maximum F statistics. Moreover, the results show that H_{01} is significantly rejected for d is one in Panel B of Table 3, indicating that LSTECM is a more appropriate model. Consequently, the logistic smooth transition function is designed to capture the different possible types of interactions between noise traders and informed traders in the next paragraph.

Table 3. Non-linearity Test and STECM Test

Panel A: Non-linearity Test						
d	1	2	3	4	5	6
H_0	3.4677***	2.7108***	2.7637***	2.9701***	2.8703***	3.0905***
Panel B: LSTECM vs. ESTECM Test						
d	H_{01} Statistic		H_{02} Statistic		H_{03} Statistic	
1	3.5345***		4.5505***		2.2342**	
2	2.3415**		2.8300***		2.9175***	
3	1.6326		3.6229***		2.9954***	
4	1.6145		4.2104***		3.0382***	
5	2.4273**		3.2062***		2.9265***	
6	2.5627**		2.6659***		3.9859***	

Notes: 1. **, and *** denote significance at the 5%, and 1% levels, respectively.
2. d is the optimal lag length for the transition variable Z_{t-d}.

Table 4 lists the estimation results for the ECM, ECM-GARCH and LSTECM-GARCH models and then presents the results of the diagnostic tests. The diagnostics of the standardized residuals reveal that the joint tests are not significant in any of the models, implying that there is no asymmetric volatility effect. Moreover, Q(12) and $Q^2(12)$ are not significant in the ECM-GARCH and LSTECM-GARCH models, but Q(12) and $Q^2(12)$ is significant at the 1% level in the ECM, implying that the model must use the GARCH effect in terms of its conditional variance. The parameters (ϕ_0, ϕ_1 and ϕ_2) in the ECM-GARCH and LSTECM-GARCH models are all significant at the 1% level; furthermore, the sum of the parameters ϕ_1 and ϕ_2, 0.9987 and 0.9989, is less than one, thus ensuring that the conditions for a stationary covariance hold. This study finds evidence of a strong GARCH effect and persistence in conditional variance and also discover that the ECM-GARCH and LSTECM-GARCH models are better than the ECM. In addition, the AIC, SBC and LR-test further confirm that the LSTECM-GARCH model is superior to the ECM-GARCH model in capturing the long-run adjustment relationship for the returns of the TAIEX.

The results of the LSTECM-GARCH model show that the τ=0.2187 and γ=79.4162 parameters are both significant at the 1% level in Panel A of Table 4, indicating that the speed of adjustment parameter with some sub-sample results depicts a quicker regime change than for other sub-samples. The logistic smooth transition function is $G(Z_{t-d};\gamma,\tau)=\left(1+\exp\left\{-79.4162\left(Z_{t-1}-0.2187\right)\right\}\right)^{-1}$. Figure 2 illustrates the smooth transition state, and shows that numerous samples fall in the band between the high and low regimes, implying that heterogeneous investors have different objects and restricted portfolios. Consequently, the dynamic return of the stock market again confirms that the smooth transition model is a more appropriate linear model of the return on the TAIEX.

In Panel B of Table 4, the null hypothesis of $\alpha_1=\alpha_2=0$ is rejected in the returns for the TAIEX, implying that the long-run adjustment terms for the two regimes are equal to 0 and that the null hypothesis of $\alpha_1=\alpha_2$ is rejected in the returns to the TAIEX, while also suggesting that the long-run adjustment terms for the two regimes are not the same. Moreover, these results support a threshold co-integration relationship before the threshold co-integration test. This paper finds that the α_1 and α_2 coefficients of the long-run adjustment term (Z_{t-1}) are -0.7599 and -7.2353, respectively, and are significant at the 1% level in Panel A of Table 4. In addition, this paper applys the LSTECM-GARCH model and find that the long-run adjustment coefficient is α_1 =-0.7599 when a negative disequilibrium exists between the S&P 500 and the TAIEX prices (Z_{t-1} is a large negative value). In addition, the long-run adjustment coefficient is $\alpha_1+\alpha_2$= -7.9952 when a positive disequilibrium between the S&P 500 and the TAIEX prices (Z_{t-1} is a large positive value) is found to exist. Consequently, this study finds the long-run adjustment coefficient when there is a positive disequilibrium to be larger than when there is a negative disequilibrium, implying the existence of asymmetric transactions costs, overconfident-up and conservative-down noise traders, as well as heterogeneous arbitrageurs by McMillan and Speight (2002).

Regarding the short-run situation, the coefficients from α_1 to α_6 range from 0.0033 to 0.4624 when the logistic smooth transition is a low regime which gives rise to a large negative deviation from equilibrium, and the coefficients from $\alpha_1 + \beta_1$ to $\alpha_6 + \beta_6$ range from -6.259 to 6.424 when the logistic smooth transition is a high regime which gives rise to a large positive deviation from equilibrium in Panel A of Table 4. This finding indicates that the information trader engages in transactions between the two markets to restore equilibrium and that this gives rise to large positive or negative deviations equilibrium. Then the noise trader engages in transactions between two markets to destroy the equilibrium which gives rise to small positive or negative deviations in equilibrium. Moreover, this study finds that $H_0 : \alpha_2 = \alpha_3 = \alpha_4 = 0$, $H_0 : \beta_2 = \beta_3 = \beta_4 = 0$ and $H_0 : \alpha_2 = \alpha_3 = \alpha_4 = \beta_2 = \beta_3 = \beta_4 = 0$ are significant at the 1% level in Panel B of Table 4, indicating the impact of the return of the S&P 500 on the return of the TAIEX when the logistic smooth transition is in a low or high regime. Consequently, the unidirectional short-run nonlinear adjustment relationship based on the impact of the return on the S&P 500 on the return on the TAIEX is further confirmed, and the finding could prove valuable to individual investors and financial institutions in different situations that are seeking to forecast the causality from the U.S. stock market to the Taiwanese stock market.

Table 4: Estimates of ECM, ECM-GARCH and LSTECM-GARCH and Diagnostic Tests

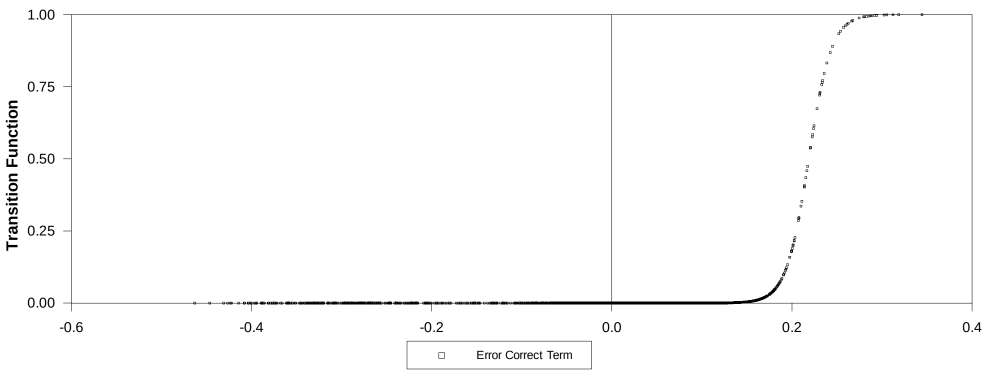
Panel A: Estimates of ECM, ECM-GARCH and LSTECM-GARCH				
Variable		ECM	ECM-GARCH	STECM-GARCH
Mean Equations				
Intercept	θ_1	-0.0169	0.0194	0.0196
Z_{t-1}	β_0			-7.2353***
Z_{t-1}	α_0	-0.7599***	-0.9814***	-0.9175***
$Y_{US,t-1}$	α_1	0.4125***	0.4545***	0.4624***
$Y_{US,t-2}$	α_2	0.1182***	0.1492***	0.1701***
$Y_{US,t-3}$	α_3	0.1427***	0.1329***	0.1413***
$Y_{TW,t-1}$	α_4	-0.0522**	-0.0522**	-0.0581***
$Y_{TW,t-2}$	α_5	0.0295	0.0068	0.0033
$Y_{TW,t-3}$	α_6	0.0058	0.0245	0.0244***
Intercept	θ_1			-0.1324
$Y_{US,t-1}$	β_1			-0.6805***
$Y_{US,t-2}$	β_2			-0.7960***
$Y_{US,t-3}$	β_3			-0.3234***
$Y_{TW,t-1}$	β_4			0.3400***
$Y_{TW,t-2}$	β_5			0.6391***
$Y_{TW,t-3}$	β_6			0.1197
Variance Equations				

Table 4 continued

Panel A: Estimates of ECM, ECM-GARCH and LSTECM-GARCH				
Variable		ECM	ECM-GARCH	STECM-GARCH
Intercept	ϕ_0		0.0094**	0.0107***
ε^2_{t-1}	ϕ_2		0.0563***	0.0629***
h_{t-1}	ϕ_2		0.9424***	0.9360***
Smooth Transition Functions				
Speed of adjustment parameter	τ			79.4162***
Threshold parameter	γ			0.2187***
Panel B: Diagnostic Tests				
$H_0: \alpha_2 = \alpha_3 = \alpha_4 = \beta_2 = \beta_3 = \beta_4 = 0$				330.5754***
$H_0: \alpha_2 = \alpha_3 = \alpha_4 = 0$		89.940***	271.8915***	601.8008***
$H_0: \beta_2 = \beta_3 = \beta_4 = 0$				59.3500***
$H_0: \alpha_1 = \alpha_2 = 0$				116.0824***
$H_0: \alpha_1 = \alpha_2$				133.9462***
Q(12)		29.4050***	17.6650	15.9170
$Q^2(12)$		292.6020***	12.7810	12.3100
Joint Test		0.6815	0.2217	0.4878
AIC		18256.0866	7596.7003	7509.6121
SBC		18301.3675	7658.9615	7628.1755
LL		-4003.6496	-3740.5744	-3518.6404

Note: 1. ** and *** denote significance at the 5% and 1% levels, respectively.
2. Q( ) and Q^2( ) denote the Ljung-Box Q test for serial correlation among the standardized residuals and squared standardized residuals.
3. The joint test by Engle and Ng (2003).

Figure 2. The logistic smooth transition functions



Conclusion

This study investigates the threshold co-integration and causal relationship between the U.S. and Taiwan stock markets. Subsequently, in order to capture the different return dynamics between the small and large deviations from the co-movement between the S&P 500 and TAIEX prices, this study applies a STECM-GARCH model to investigative the non-linear smooth adjustments relationship.

The empirical results indicate that an asymmetric co-integration relationship exists between the U.S. and Taiwan stock markets. This study further finds that this is significant evidence of non-linearity in the TAIEX return, and the nonlinear dynamic adjustments of the S&P 500 and TAIEX prices follow the logistic transition function. The logistic transaction function has many samples between two extreme sectors implying, as indicated by Tse (2001), that investors will be enabled to immediately trade so that they will have some factors to consider including the goal of investment and the investment portfolio limit. These findings should be valuable to individual investors and financial institutions seeking to understand the impact of the U.S. stock market on the Taiwan stock market.

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NOTES

[1] Bailey and Stulz (1990) suggest that U.S. investors can reduce risk by between 30% and 50% by including Asian stocks in their portfolio. This implies that the U.S. and the national equity markets in Asia perform very differently in any given period.

[2] Yang et al., (2004) and Lee and Hung (2007) found the Taiwan stock market to be cointegrated with the US stock market; however, Kwan, Sim and Cotsomitis, (1995), Cheng and Glascock (2005), Chang and Caudill (2006) and Chang and Tzeng (2009) indicated that no cointegration exists between the two markets.

[3] This representation not only captures the asymmetric effect, but can also test the long-run relationship between x_t and y_t.

[4] This study adopts the approach by Chan (1993) to obtain a consistent estimate of the threshold used by Enders and Siklos (2001). The consistent threshold estimate can be estimated by ordering the ε_t or $\Delta\varepsilon_t$ sequence in ascending order such that $\varepsilon_1 < \varepsilon_2 < ... < \varepsilon_T$ or $\Delta\varepsilon_1 < \varepsilon\Delta_2 < ... < \Delta\varepsilon_T$, where T is the number of usable observations. After truncating the upper and lower 15%, and substituting the remaining 70%

into the model, the estimated threshold yielding the lowest residual sum of squares is found to be a consistent estimate of the threshold. The same method can also be applied to the M-TAR model.

[5] The statistic has an asymptotic F distribution with $3m$ and $T - 4m - 1$ degrees of freedom under the null hypothesis of linearity.

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