Using Threshold Error-Correction Model to Investigate Asymmetric Price Transmissions between the Real Estate and Stock Markets in Taiwan

Tsangyao Chang*
Department and Graduate Institute of Economics
Feng Chia University, Taichung, TAIWAN
Chien-Chung Nieh
Department of Banking & Finance
Tamkang University, Taipei, TAiWAN

ABSTRACT

In this study, using a threshold error-correction model, we investigate price transmissions between the real estate and stock markets in Taiwan over the 1986Q1 to 2003Q2 period. The results from Granger-Causality tests based on corresponding threshold error-correction model (TECM) clearly point to unidirectional causality running from the real estate market to stock market in the short run. Furthermore, we find asymmetric price transmissions between these two markets in the long run. These findings ought to be made readily available to individual investors and financial institutions holding long-term investment portfolios in these two asset markets for their likely implications today.

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Key Words: Threshold Error-Correction Model, Real Estate and Stock Markets, Asymmetric Price Transmissions

*Corresponding author: Professor, Department and Graduate Institute of Economics, Feng Chia University, Taichung, Taiwan. TEL: 4- 2451-7250 ext. 4484. FAX: 4-2451-8737. E-mail: tychang@fcu.edu.tw.

I. INTRODUCTION

Identifying the relationship between real estate prices and stock prices has been a widely debated issue within academic circles and among practitioners, alike. Although current literature on the relationship between real estate and equity markets tends to show conflicting results, most of the empirical evidence seems to support the view that the two markets are segmented. Goodman (1981), Miles et al., (1990), Liu et al., (1990) and Geltner (1990), for example, argue for the existence of such segmentation within various real estate markets and stock markets. In direct contrast, Liu and Mei (1992), Ambrose et al. (1992) along with Gyourko and Keim (1992), report results that contradict that position, claiming that real estate and stock markets are in fact integrated. The predicament faced here, therefore, is whether the two markets are segmented or integrated. Our primary objective then is to ascertain whether any significant relationship does exist between these markets and, if so, to determine what implications it may have for active market traders. One fundamental motivation behind our study is that our findings can yield considerable insight for both investors and speculators that may facilitate forecasting future performance from one market to the other.

While previous studies focus on linear relationship between these two markets with the exception of Okunew and Wilson (1997), in this study, using a recently developed threshold error-correction model advanced by Enders and Granger (1998) and Enders and Siklos (2001), we investigate price transmissions between the real estate and stock markets in Taiwan over the 1986Q1 to 2003Q2 period. The results from Granger-Causality tests based on corresponding threshold error-correction model (TECM) clearly point to unidirectional causality running from the real estate market to stock market. Further, asymmetric price transmissions between these two markets are also found in the long run.

The remainder of this study is organized as follows. Section II presents the data used. Section III presents the methodologies used and discusses the findings. Finally, Section IV concludes.

II. DATA

The data sets used here consist of quarterly time series on the real estate price index (lresp) and stock price index (lstkp) for the 1986Q1 to 2003Q2 period. The stock price indexes are obtained from the *AREMOS database* of the Ministry of Education of Taiwan. The real estate price index is collected and compiled by Hsin-Yi Real Estate Inc. An examination of the individual data series makes it clear that logarithmic transformations are required to achieve stationarity in variance; therefore, all the data series are transformed to logarithmic form.

Descriptive statistics for both real estate and stock markets returns are reported in Table 1. We find that the sample means of the real estate price returns are positive (1.83%) and the stock price returns are also positive (2.31%). Both the skewness and kurtosis statistics indicate that the distributions of the returns of both markets are non-normal. The Ljung-Box statistics for 4 lags applied to the returns and square returns indicate that significant linear and non-linear dependencies exist in the real estate market. However, we only find significant non-linear dependencies in the stock market.

「Insert Table 1 Here」

III METHODOLOGY AND EMPIRICAL RESULTS

A. Unit Root Tests

Recently, there is a growing consensus that stock price and real estate price might exhibit nonlinearities and that a conventional test such as the ADF unit root test has lower power in detecting its mean reverting tendency. The finding of nonlinear adjustment does not necessary imply nonlinear mean reversion (stationary). As such, formal stationary tests based on nonlinear framework much be applied. In this study, our major objective is to determine whether the stock price and real estate price are nonlinear stationary, based on a nonlinear stationary test advanced by Kapetanios et al. (2003) (henceforth, KSS test)

Since it is a brand new test, we will briefly describe this test in the following. According to Kapetanois et al. (2003), their test is based on detecting the presence of non-stationarity against nonlinear but globally stationary exponential smooth transition autoregressive (ESTAR) process:

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

where Y_t is the data series of interest, v_t is an i.i.d. error with zero mean and constant variance and $\theta \ge 0$ 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 $\theta > 0$. Under the null Y_t follows a linear unit root process, whereas it is nonlinear stationary ESTAR process under the alternative. However, the parameter γ is not identified under the null hypothesis. Following Luukkonen et al. (1988) and Kapetanios et al. (2003), we use a first-order Taylor series approximation to $\{1-\exp(-\theta Y_{t-1}^2)\}$ under the null $\theta = 0$ 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. $\delta < 0$ (non-linear ESTAR stationarity). The simulated critical values for different K are tabulated at Kapetanios et al.'s (2003) Table 1 of their paper. Table 2 reports the Kapetanios et al. (2003) nonlinear stationary test results indicating that both two series are integrated of order one.

For comparison, we also incorporate the PP, NP (Ng and Perron, 2001) and KPSS (Kwiatkowski et al., 1992) tests into our study. Panels A and B in Table 3 present the results of the non-stationary tests for the stock price index (lstkp) and real estate price index (lresp) from the PP, NP and KPSS tests. We find each data series is nonstationary in levels but stationary in first differences, suggesting that all the data series are integrated of order one.

On the basis of these results, we proceed to test whether these two variables are cointegrated, and to do so, we used the recently developed threshold cointegration tests.

「Insert Tables 2 and 3 Here」

B. Threshold Cointegration Tests Based on Enders and Granger (1998) and Enders and Siklos's (2001) Approach

The Enders-Granger's threshold cointegration test consists of a two-stage procedure. Following Enders and Granger (1998) and Enders and Siklos (2001), in the first stage, we estimate the cointegration equations as follows:

$$Y_{1t} = \alpha + \beta Y_{2t} + u_t \qquad [3]$$

where Y_{1t} and Y_{2t} are stock price index and real estate price index, respectively, and both are integrated of order 1 or I(1). α and β are estimated parameters, and u_t

is the disturbance term that may be serially correlated. The second stag focuses on the OLS estimates of ρ_1 and ρ_2 in the following regression:

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

where ε_t is a white-noise disturbance and the residuals(μ_t) from [3] are used to estimate [4]. I_t is the Heaviside indicator function such that $I_t = 1$ if $u_{t-1} \geq \tau$, $I_t = 0$ if $u_{t-1} \leq \tau$ and $\tau =$ the value of threshold. A necessary condition for {μ_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 point 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 show that if the sequence is stationary, the least squares estimates of ρ_1 and ρ_2 have an asymptotic multivariate normal distribution.

Model using [4] is referred to as Threshold Autoregression Model (TAR), where the test for threshold behavior of the equilibrium error is termed threshold cointegration test. 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 $\rho_2 \mu_{t-1}$. The equilibrium error therefore behaves like a threshold autoregression. Thus, if the null hypothesis $\rho_1 = \rho_2 = 0$ is rejected, it is possible to test for symmetric adjustment (i.e., $\rho_1 = \rho_2$) using a standard F-test. Since adjustment is symmetric if $\rho_1 = \rho_2$, the Dickey-Fuller test is a special case of [4]. Rejecting both the null hypothesis of $\rho_1 = \rho_2 = 0$ and $\rho_1 = \rho_2$ imply that the residuals in [3] are stationary and the existence of threshold cointegraiton.

Instead of estimating [4] with the Heaviside indicator depending on the level of μ_{t-1}, the decay could also be allowed to depend on the previous period's change in μ_{t-1}. The Heaviside indicator could then be specified as $I_t = 1$ if $\Delta u_{t-1} \geq \tau$, $I_t = 0$ if $\Delta u_{t-1} \leq \tau$ and $\tau =$ the value of threshold. 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 Autoregression Model (M-TAR). The TAR model can capture 'deep' cycle process if, for example, positive deviations are more prolonged than negative deviations. The M-TAR model allows the autoregressive decay to depend on $\Delta\mu_{t-1}$. As such, the M-TAR representation can capture 'sharp' movements in a sequence.

In the most general case, the value of τ is unknown, it needs 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 actually employs the sample mean of the sequence as the threshold estimate of τ. Nevertheless, the sample mean is a biased threshold estimator in the presence of asymmetric adjustments. 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. A consistent estimate of the threshold τ can be obtained by using Chan's (1993) method of searching over possible threshold values to minimize the residual sum of squares form the fitted model. Enders and Siklos (2001) apply Chan's methodology to a Monte Carlo study to obtain the F-statistic for the null hypothesis for $\rho_1 = \rho_2 = 0$ when the threshold τ is estimated using Chan's procedure. The critical values of this non-standard F-statistic for testing the null hypothesis of $\rho_1 = \rho_2 = 0$ are also tabulated in their paper. 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.

Table 4 reports the threshold cointegration test results. From the AIC and SBC, we find the most preferable model for our adjustment mechanism is TAR model (where the threshold value of $\tau = 0.32103$ is also found based on the Chan's (1993) method). Since the null of no cointegration ($\rho_1 = \rho_2 = 0$) and symmetric adjustment ($\rho_1 = \rho_2$) are both rejected, these imply the existence of threshold cointegraiton between the real estate and stock markets in Taiwan over this testing period.

「Insert Table 4 Here」

C. Granger-Causality Tests Based on Threshold Error-Correction Model

Given the threshold cointegration found in previous section, we proceed to test the price transmissions using threshold error-correction model (TECM). The TECM can be expressed as follows (Enders and Granger, 1998; Enders and Siklos, 2001):

$$\Delta Y_{it} = \gamma_1 Z-plus_{t-1} + \gamma_2 Z-\min us_{t-1} + \sum_{i=1}^{k_1} \theta_i \Delta Y_{1t-i} + \sum_{i=1}^{k_2} \delta_i \Delta Y_{2t-i} + v_t \qquad [5]$$

where $Y_{it} = (lresp_t, lstkp_t)$, $Z-plus_{t-1} = I_t \hat{u}_{t-1}, Z-\min us_{t-1} = (1-I_t)\hat{u}_{t-1}$ such that $I_t = 1$ if $u_{t-1} \geq 0.32103$, $I_t = 0$ if $u_{t-1} \leq 0.32103$ and v_t is a white-noise disturbance. From the system, the Granger-Causality tests are examined by testing whether all the coefficients of $\Delta Y_{1,t-i}$ or $\Delta Y_{2,t-i}$ are statistically different from zero as a group based on a standard F-test and/or whether the ρ_j coefficient of the error-correction are also significant. Since Granger-Causality tests are very sensitive to the selection of lag length, the lag lengths are determined using Hsiao's (1979) sequential procedures, which are based on the Granger definition of causality. Based on this procedure, we find both lags length of $k_1 = k_2 = 2$.

Table 5 presents the results from our Granger-Causality tests based on the corresponding threshold error-correction models (TECMs). They clearly show that unidirectional causality running from the real estate market to the stock market in the short-run. This result is consistent with those found in Liu and Mei (1992), Ambrose et al. (1992) along with Gyourko and Keim (1992). In terms of long-run situation, however, we find feedback exists between these two markets. The empirical results show unidirectional causality running from the real estate market to stock market when the threshold variable is above 0.32103. On the other hand, when the threshold variable is below 0.32103, we find unidirectional causality running from the stock market to real estate market. These empirical results indicate that the price transmissions between these two markets are asymmetric in the long run. It is interesting to note that the adjustment coefficients of $Z-plus$ and $Z-\min us$ are markedly different for both markets. Focusing on adjustments of real estate market to restore equilibrium, the point estimates of adjustment coefficients given in

Table 5 indicate that, within a quarter, real estate prices adjust so as to eliminate approximately 13.5% of a unit negative change in the deviation from the equilibrium relationship created by changes in stock prices. On the other hand, real estate prices adjust by only 3.5% of a positive change in deviation from the equilibrium created by changes in stock prices. These findings indicate that adjustments towards the long-run equilibrium relationship between the real estate and stock markets are faster when changes in deviation are negative than when they are positive. In terms of stock market, we find the reverse adjustment process. Within a quarter, stock prices adjust so as to eliminate approximately 1.7% (86.9%) of a unit negative (positive) change in the deviation from the equilibrium relationship created by changes in real estate prices. These findings indicate that adjustments towards the long-run equilibrium relationship between the real estate and stock markets are faster when changes in deviation are positive than when they are negative. Indeed, F-statistic also indicates that the null hypotheses of $\gamma_1 = \gamma_2$ (the coefficients of $Z - plus$ and $Z - \min us$ are equal) from both markets are rejected. Further, we find that the error-correction term is significant for the equation concerning for stock market when the threshold variable is above 0.32103, however when the threshold variable is below 0.32103, the error-correction term is significant for the equation concerning for real estate market. Our interpretation is that, over time, as measured by the error-correction term, in order to restore the long-run relationship within system, it is real estate (stock) prices that must bear the brunt of adjustment rather than stock (real estate) prices, when the threshold variable is below (above) the value of 0.32103. These empirical results further indicate that price transmissions between these two markets are asymmetric.

By way of contrast, Table 5 also reports the estimates of symmetric error-correction model. In the case of symmetric adjustment, only the error-correction term on the stock market is significant at conventional levels. This result implies that the stock prices but not the real estate prices bear the brunt of adjustment process. In spite of the extra coefficient appearing in each equation of threshold model, the multivariate AIC selects threshold error-correction model over the symmetric error-correction model. The multivariate AIC is 70.151 for the threshold error-correction model and 81.295 for the symmetric error-correction model.

「Insert Table 5 Here」

IV. CONCLUSIONS

In this study we investigate the relationship between the real estate and stock markets in the Taiwan context over the 1986Q1 to 2003Q2 period, using a recently developed threshold error-correction (TECM). Granger-Causality test results from the corresponding TECM clearly point to unidirectional causality running from the real estate market to stock market in the short run. Furthermore, we find asymmetric price transmissions between these two markets in the long run. In terms of risk diversification, the two assets should not have been included in the same portfolio in Taiwan during the 1986Q1 to 2003Q2 period. Consequently, these findings ought to be made readily available to individual investors and financial institutions holding long-term investment portfolios in these two asset markets for their likely implications today.

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Table 1. Summary Statistics of Real Estate and Stock Markets Returns

	Real Estate Price Returns	Stock Price Returns
Mean	1.83%	2.31%
SD	5.204%	26.05%
Maximum	35.5%	99.48%
Minimum	-15.3%	-76.69%
Skewness	1.738	0.084
Kurtosis	9.398	6.299
J-B N Test	152.410*	31.382*
L-B (Q=4)	54.475*	3.965
L-B (Q=4)-Square	10.575**	16.320*

Note: 1. SD denotes standard error.
2. The standard errors of the skewness and kurtosis are $(6/T)^{0.5}$ and $(24/T)^{0.5}$, respectively. 3. J-B N Test denotes the Jarque-Bera normality test.
4. L-B (Q=k) represents the Ljung-Box test for autocorrelation up to k lags.
5. *, ** and *** indicate significance at the 1%, 5% and 10%, respectively

Table 2. Unit Root Test based on KSS (2003) Approach

	t Statistic on $\hat{\delta}$
lresp	0.308(1)
lstkp	-0.094(0)

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

Table 3. PP , NP and KPSS Unit Root Tests

	Panel A: PP		Panel A: NP		Panel B: KPSS (η_{μ})	
	level	difference	level	difference	level	difference
Lresp	-2.531(4)	–5.051(3)*	-2.922 (0)	-9.517(0)*	0.126(6)***	0.074(6)
Lstkp	–2.819(4)	–9.605(3)*	-1.932 (3)	-2.657(2)***	0.215(6)**	0.051(5)

Note: 1. The number in the parentheses of NP are the appropriate lag lengths selected by MAIC (modified Akaike information criterion) suggested by Ng and Perron (2001), whereas the number in the parentheses of PP and KPSS are the optimal bandwidth decided by Bartlett kernel of Newey and West (1994).
2. *, **, and *** denote significance at the 1%, 5% , and 10% levels, respectively.
3. Critical values for the KPSS test are taken from Kwiatkowski et al. (1992).
4. The test statistic for NP is MZ_t .

Table 4. Threshold Cointegration Tests Based on the Enders and Granger (1998) Approach (TAR model where the threshold value of $\tau = 0.32103$)

$\hat{\rho}_1$	$\hat{\rho}_2$	$\hat{F}_C$	$\hat{F}_A$	l
-0.646(5.109)*	-0.066(0.095)	13.296*	13.429*	0

Note: 1. *, **, and *** denote significance at the 1%, 5% , and 10% levels, respectively. Lag-length (l) selection is based on the procedure advanced by Perron (1989).
2. t statistics are in parentheses. $\hat{F}_C$ and $\hat{F}_A$ denote the F-statistics for the null hypothesis of

no cointegraion and symmetry. Critical values are taken from Enders and Siklos (2001)

Table 5. Estimates of the Error-Correction Models

	Asymmetric		Symmetric	
	dlresp	dlstkp	dlresp	dlstkp
Constant	0.002(0.298)	0.062(1.898)***	0.006(0.869)	0.013(0.404)
dlresp(-1)	0.388(2.637)**	1.020(1.737)***	0.477(3.111)*	0.812(1.236)
dlresp(-2)	0.092(0.681)	0.355(0.656)	0.130(0.918)	0.334(0.552)
dlstkp(-1)	-0.016(0.444)	-0.031(0.216)	0.007(0.185)	-0.281(1.867)***
dlstkp(-2)	-0.004(0.121)	-0.011(0.081)	-0.006(-0.163)	-0.168(1.160)
$Z-plus_{t-1}$	0.035(0.629)	-0.869(4.741)*		
$Z-\min us_{t-1}$	-0.135(-2.846)*	-0.017(0.138)		
ECT_{t-1}			0.073(1.361)	-0.309(2.242)**
$H_0:\delta_1=\delta_2=0$		3.111***		1.698
$H_0:\theta_1=\theta_2=0$	0.098		0.041	
$H_0:\delta_1=\delta_2=\gamma=0$				2.577***
$H_0:\theta_1=\theta_2=\gamma=0$			0.663	
$H_0:\delta_1=\delta_2=\gamma_1=0$		8.643*		
$H_0:\delta_1=\delta_2=\gamma_2=0$		2.087		
$H_0:\theta_1=\theta_2=\gamma_1=0$	0.254			
$H_0:\theta_1=\theta_2=\gamma_2=0$	2.805**			
H_0:(real estate) $\gamma_1=\gamma_2$	5.863**			
H_0:(StockPrice) $\gamma_1=\gamma_2$		15.341*		
Q(4)	1.667	1.341	1.404	1.791
ARCH(4)	0.357	6.341*	1.015	2.929**

Note: 1. *, **, and *** denote significance at the 1%, 5% , and 10% levels, respectively. t statistics are in parentheses.

2. Threshold Error-Correction Model:

$$\Delta Y_{it}=\gamma_1 Z-plus_{t-1}+\gamma_2 Z-\min us_{t-1}+\sum_{i=1}^{k_1}\theta_i\Delta Y_{1t-i}+\sum_{i=1}^{k_2}\delta_i\Delta Y_{2t-i}+v_t$$

where $Y_{it}=(lresp_t, lstkp_t)$, $Z-plus_{t-1}=I_t\hat{u}_{t-1}, Z-\min us_{t-1}=(1-I_t)\hat{u}_{t-1}$ such that $I_t=1$ if $u_{t-1}\geq 0.32103$, $I_t=0$ if $u_{t-1}\leq 0.32103$ and v_t is a white-noise disturbance.

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