E C O N O M I C S   B U L L E T I N

Does Rational Bubbles Exist in the Taiwan Stock Market? Evidence from a Nonparametric Cointegration Test

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Abstract

In this study, we revisit the issue as to the presence of rational bubbles in the Taiwan stock market during the June 1991 to February 2005 period using the Bierens (1997) nonparametric cointegration tests. The results from the Bierens nonparametric cointegration test attest to the absence of rational bubbles in the Taiwan stock market.

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1. INTRODUCTION

This study investigates whether rational bubbles were present in the Taiwan stock market during the June 1991 to February 2005 period. The occurrence of rational bubbles signifies that no long-run relationships exist between stock prices and dividends. In pursuit of determining whether or not stock prices and dividends are cointegrated, empirical studies have, for the most part, employed cointegration techniques. Among the most notable of these is the widely employed Johansen cointegration test (Johansen, 1988; Johansen and Juselius, 1990) which is based on the linear autoregressive model and, as such, assumes that the underlying dynamics are in a linear form. From a theoretical perspective, there is no sound reason to assume that economic systems are intrinsically linear (see, Barnett and Serletis, 2000). In fact, numerous studies have empirically demonstrated that financial time series, such as stock prices, exhibit nonlinear dependencies (see, Hsieh, 1991; Abhyankar et al., 1997). Besides this, substantive evidence from the Monte Carlo simulations in Bierens (1997), in fact, has indicated that inherent to the conventional Johansen cointegration framework is a misspecification problem when the true nature of the adjustment process is nonlinear and that the speed of adjustment varies with the magnitude of the disequilibrium. The work of Balke and Fomby (1997) also pointed out a potential loss of power in conventional cointegration tests under the threshold autoregressive data generating process (DGP).

Motivated by the above considerations, in this study, we examine the issue of rational bubbles in the Taiwan stock market during the June 1991 to February 2005 period, using the powerful nonparametric cointegration test, as developed by Bierens (1997). The results from the Bierens nonparametric cointegration test confirm the absence of rational bubbles.

2. DATA

The empirical study employs the monthly Taiwan weighted stock price index and dividends data over the June 1991 to February 2005 period which we take from Taiwan Stock Exchange Corporation publications. The data begin from June 1991 since dividend data are available from this period. Table 1 provides summary statistics for the stock price index return and dividends data. As shown in Table 1, the average annualized stock index returns in the Taiwan stock market was about -1.2% over the entire sample period. The Jarque-Bera tests show that the distribution of both the stock price index returns and dividends data is non-normal. The Ljung-Box statistics with time lags of 4 and 8 periods for both of the variables show that significant linear and nonlinear dependencies exist in the stock index returns and dividends of Taiwan market.

Table 1 Summary Statistics of the Data

	ΔLP	LD
Mean	-0.0010	5.3214
Std. Dev.	0.0701	0.2450
Max.	0.2039	5.8364
Min.	-0.1978	4.8037
Skewness	0.4593	-0.1733
Kurtosis	3.4183	1.8823
Jarque-Bera	6.9617**	9.4149***
	(0.0307)	(0.0090)
Ljung-Box Q(4)	20.247***	503.12***
Ljung-Box Q(8)	23.146***	831.31***
Ljung-Box Q^2(4)	9.178*	502.60***
Ljung-Box Q^2(8)	12.314	827.99***

Notes: 1. Numbers in parentheses indicate the p-value for J-B normality.

2. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 level, respectively.

3. $\Delta LP = \ln P_t - \ln P_{t-1}$, $LD = \ln D_t$.

3. METHODOLOGY AND EMPIRICAL RESULTS

3.1 Unit Root Tests.

Recently, a general consensus has been emerging in support of the likelihood that stock price data exhibits nonlinearities and that such conventional tests for stationarity as the ADF unit root test have too low of a power to be able to detect the mean-reverting tendency of a series. It follows, then that stationary tests must be applied in a nonlinear framework. To this end, in this study, we use the nonlinear logistic unit test advanced by Leybourne et al. (1998) (henceforth, the LNV test). Following Leybourne et al. (1998), we consider the following three logistic smooth transition regression models:

Model A: $Y_t = \alpha_1 + \alpha_2 S_t(\gamma, \tau) + v_t$ (1)

Model B: $Y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + v_t$ (2)

Model C: $Y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\gamma, \tau) + \beta_2 t S_t(\gamma, \tau) + v_t$ (3)

where v_t is a zero-mean I(0) process, $S_t(\gamma,\tau)$ is the logistic smooth transition function, based on a sample of size T, where

$$S_t(\gamma, \tau) = [1 + \exp\{-\gamma(t - \tau T)\}]^{-1} \quad \gamma > 0 \qquad (4)$$

The S function controls the smooth transition between regimes. The parameter τ determines the timing of the transition midpoint, for example, for $\gamma > 0$, we have $S_{-\infty}(\gamma,\tau)=0$, $S_{+\infty}(\gamma,\tau)=1$ and $S_{\tau T}(\gamma,\tau)=0.5$. The speed of transition is then determined by the parameter, γ. If γ is small, then the transition is slow-- $S_t(\gamma,\tau)$ takes a long period of time to traverse the interval (0,1). In the limiting case, with $\gamma = 0$, $S_t(\gamma,\tau)=0.5$ for all t. On the other hand, for large values of γ, $S_t(\gamma,\tau)$ traverses the interval (0,1) very rapidly> As γ approaches $+\infty$, this function changes value from 0 to 1 instantaneously at time $t=\tau T$.

If we assume that v_t is a zero-mean I(0) process, then Model A implies Y_t is stationary around a mean which changes from α_1 to $\alpha_1+\alpha_2$. Model B also allows the intercept to change from α_1 to $\alpha_1+\alpha_2$, but includes a fixed slope term. Model C is the most flexible. Model C allows the intercept to change from α_1 to $\alpha_1+\alpha_2$ and allows the slope parameter to change, with the same speed of transition, from β_1 to $\beta_1+\beta_2$. If γ < 0, the initial and final model states are reversed but the interpretation of the parameters remains the same.

The tests of the Leybourne et al. (1998) are based on the following hypothesis:

Ho: $Y_t = U_t, U_t = K + U_{t-1} + \varepsilon_t, U_0 = \varphi$ (5)

Ha: Model A, Model B or Model C, (6)

where ε_t and v_t are both assumed to be stationary autoregressive moving average (ARMA) processes with zero mean. The test statistics are calculated in two steps:

Step 1. Using a nonlinear least squares (NLS) algorithm, estimate the deterministic component of the model and compute residuals ($\hat{v}_t$) from Models A, B or C.

Step 2. Compute the ADF statistic, the t-ratio associated with $\hat{\rho}$ in the ordinary least squares (OLS) regression,

$$\Delta\hat{v}_t = \hat{\rho}\hat{v}_{t-1} + \sum_{i=1}^{P}\hat{\theta}_i\Delta\hat{v}_{t-i} + \hat{\eta}. \tag{7}$$

The ADF statistics are denoted by S_α, $S_{\alpha(\beta)}$ and $S_{\alpha\beta}$, respectively, where the residuals are calculated from Models A, B or C. Following the Leybourne et al. (1998), we also calculate critical values tailored to our present sample size (T = 165) using Monte Carlo simulation with 10,000 draws.

Table 2 presents the LNV nonlinear stationary test results, and they clearly indicate that both the stock prices and dividends series are integrated of order one.

For comparison, we also incorporate the Augmented Dickey and Fuller (1981, ADF), the Phillips and Perron (1988, PP) and the Kwiatkowski *et al.* (1992, KPSS) tests into our study. Table 3 shows the results from the non-stationary tests for the stock prices and dividends using the ADF, PP and the KPSS tests. Again, the test results further indicate that the stock prices and dividends are integrated of order one, I(1). In light of these results, we proceed to test whether there were rational bubbles in the Taiwan stock market during the sample period, and to this end, we employ the Bierens (1997) nonparametric cointegration approach.

Table 2 Nonlinear Logistic Unit Root Test Results

Variable	KSS Statistic	1%	5%	10%
LP	-4.635(1)[C]	-5.514	-4.917	-4.663
ΔLP	**-5.874(1)[C]*****			
LD	-3.726(1)[C]			
ΔLD	**-5.143(1)[C]*****			

Notes: 1. Simulated critical values are calculated based on Monte Carlo simulation with 10,000 draws.

2. The number in parentheses indicates the selected lag order of the testing model.

3. The character in the bracket indicates the model selected based on Schwartz Criteria (SC).

4. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

Table 3 Conventional Unit Root Test Results

A. Level						
	ADF		PP		KPSS	
	Intercept	Trend	Intercept	Trend	Intercept	Trend
LP	-2.8383(1)*	-2.8292(1)	-2.3333[1]	-2.3296 [1]	0.2263[10]	0.2264[10]***
LD	-2.2105(1)	-2.2177(1)	-2.3489[2]	-2.6794[0]	0.6796[10]**	0.2819[10]
B. First difference						
	ADF		PP		KPSS	
	Intercept	Trend	Intercept	Trend	Intercept	Trend
LP	-9.0021(0)***	-8.9724(0)***	-8.6359[8]***	-8.6001[8]***	0.0545[1]	0.0578[1]
LD	-16.3703(0)***	-16.3464(0)***	-16.3354[2]***	-16.2760[3]***	0.1046[7]	0.0623[7]

Notes: 1. The number in parentheses indicates the selected lag order of the ADF model. Lags are chosen based on Campbell and Perron(1991)

2. The number in brackets indicates the selected lag truncation for the Bartlett kernel, as suggested by the New-West(1987) test..

3. The ***, **, and * indicate significance at the 0.01, 0.05 and 0.1 levels, respectively.

3.2. Nonlinear Test of the Error-Correction Term

As mentioned earlier, the evidence from the Monte Carlo simulations in Bierens (1997) indicates that the conventional Johansen cointegration framework has a misspecification problem when the true nature of the adjustment process is nonlinear and the speed of adjustment varies with the magnitude of the disequilibrium. Bearing this in mind, we follow Granger and Teräsvorta (1993) by employing a nonlinear test on our error-correction term. The detailed procedures are not presented here due to space constraints but are available upon request Table 4 gives the results for the different delay parameters; these demonstrate that the true nature of the adjustment process is nonlinear and that the speed of adjustment varies with the magnitude of the disequilibrium.

Table 4 Nonlinearity Test

Null		Delay(d)					
		1	2	3	4	5	6
H_0	F-Statistic	1.1588	**2.0849***	1.3329	1.6587	2.0392	1.3631
	P-Value	0.3313	**0.0580**	0.2458	0.1349	0.0638	0.2331

Notes: An asterisk (*) indicates the lowest *P*-value

3.3. Nonparametric Cointegration Test of Bierens (1997)

Bierens (1997) pointed out that one of the major advantages of his nonparametric method lies in its superiority to detect cointegration when the error correction mechanism is nonlinear. Hence, we have full confidence in using this test in our study.

The Bierens nonparametric cointegration test considers the general framework to be:

$$y_t = \pi_0 + \pi_1 t + z_t \tag{8}$$

where $\pi_0(qx1)$ and $\pi_1(qx1)$ are the terms for the optimal mean and trend vectors, respectively, and z_t is a zero-mean unobservable process such that Δz_t is stationary and ergodic. Apart from these conditions of regularity, the method does not require further specifications of the DGP for y_t, and in this sense, it is completely nonparametric.

The Bierens method is based on the generalized eigenvalues of the matrices A_m and $(B_m + cT^{-2}A_m^{-1})$, where A_m and B_m are defined in the following matrices:

$$A_m = \frac{8\pi^2}{T}\sum_{k=1}^{m} k^2 \left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)z_t\right)\left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)z_t\right)' \tag{9}$$

$$B_m = 2T\sum_{k=1}^{m} \left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)\Delta z_t\right)\left(\frac{1}{T}\sum_{t=1}^{T}\cos(2k\pi(t-0.5)/T)\Delta z_t\right)' \tag{10}$$

which are computed as the sums of the outer-products of the weighted means of y_t and Δy_t, and where T is the sample size. To ensure invariance in the test statistics to drift terms, we recommend using the weighted functions of $\cos(2k\pi(t-0.5)/T)$. Very much like the properties in the Johansen likelihood ratio method are the ordered generalized eigenvalues that we obtain from this nonparametric approach. These serve as the solution to the problem $\det[P_T - \lambda Q_T] = 0$ when we define the pair of random matrices $P_T = A_m$ and $Q_T = (B_m + cT^{-2}A_m^{-1})$. Thus, we can use these to test the hypothesis for the cointegration rank r. To estimate r, Bierens (1997) proposed two statistics tests. One is the $\lambda \min$ test which corresponds to Johansen's maximum likelihood procedure, and it tests hypothesis $H_0(r)$ against hypothesis $H_1(r+1)$. The critical values are tabulated in his article (1997). The second set of statistic is determined by the $g_m(r_0)$ test, which is computed from the Bierens's generalized eigenvalues:

$$\hat{g}_m(r_0) = \begin{cases} (\prod_{k=1}^{n} \hat{\lambda}_{k,m})^{-1}, if ....r_0 = 0 \\ (\prod_{k=1}^{n-r} \hat{\lambda}_{k,m})^{-1}(T^{2r} \prod_{k=n-r+1}^{n} \hat{\lambda}_{k,m}), if ...r_0 = 1,....,n-1 \\ T^{2n} \prod_{k=1}^{n} \hat{\lambda}_{k,m}, if ....r_0 = n \end{cases} \tag{11}$$

This statistic employs the tabulated optimal values (see Bierens, 1997, Table 1) for m when $n > r_0$, provided that we select $m = n$ for $n = r_0$. This verifies that $\hat{g}_m(r_0) = O_p(1)$ for $r = r_0$, and in terms of probability, it converges to infinity if $r \neq r_0$. Hence, a consistent estimate of r is given by $\hat{r}_m = \arg\min_{r_0<n}\{\hat{g}_m(r_0)\}$. This statistic is an invaluable tool when double-checking the determination of r. Table 5 presents the results of from both the $\lambda \min$ test and the $g_m(r_0)$ test. The $\lambda \min$ test results strongly suggest that there are long-run relationships between stock price and dividends. These findings are further supported by the $g_m(r_0)$ statistics given in Table 5, with the smallest value only appearing in the cointegrating rank of $r = 1$. These results reveal that rational bubbles were nonexistent in the Taiwan stock market during the June 1991 to February 2005 period.

Table 5.Bierens Nonparametric Cointegration Test Results

A. $\lambda \min$ Test	5% critical value		10% critical value	
$H_0: r = 0$ $H_a: r = 1$	**0.00069****	(0, 0.005)	**0.00069***	(0, 0.017)
$H_0: r = 1$ $H_a: r = 2$	4.6873	(0, 0.111)	4.6873	(0, 0.054)

B. $g_m(r_0)$ Test	
Cointegration rank (r)	$g_m(r_0)$
$r_0 = 0$	30.9781e+001
$r_0 = 1$	**39.5168e-001**
$r_0 = 2$	23.3517e+005

Notes: 1. *, ** and *** denote significance at the 10%, 5% and 1% level, respectively.

2. Both the results of the $\lambda \min$ test and the $g_m(r_0)$ test indicate one cointegration rank.

4. CONCLUSIONS

In this study, we investigate whether rational bubbles existed in the Taiwan stock market during the June 1991 to February 2005 period by using the Bierens nonparametric cointegration test for data covering the same period. The results from the Bierens nonparametric cointegration test indicate that rational bubbles could not have been present in the Taiwan stock market in that period.

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