International Review of Accounting, Banking and Finance
Vol 2, No. 4, Winter 2010 Page 23~38

IRABF

Revisiting Mean Reversion in the Stock Prices for both the U.S.and its Major Trading Partners: Threshold Unit Root Test

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Abstract: This study aimed to re-investigate whether mean reversion of stock prices exists for the stock markets of the U.S. and its major trading partners: Canada, China, Japan and Mexico, using threshold unit root test developed by Caner and Hansen (2001). Sample periods are from November 1998 to August 2010. The empirical results from our threshold unit test indicate that the null hypothesis of I(1) unit root in stock prices can not be rejected for any of the U.S. and its major trading partners, with the exception of China. Our results highlight the fact that the efficient market hypothesis is valid in the stock markets of the U.S. and its major trading partners, with the exception of China. These findings should prove valuable to individual investors and financial institutions holding long-term investment portfolios in these markets.

1. Introduction

Researchers in finance have long been interested in the time-series properties of equity prices, with particular attention paid to determining whether stock prices can be characterized as random walk (unit root) or mean reverting (trend stationary) processes. Much research has focused on the best way to characterize the dynamic properties of economic and financial time series. The issue, whether stock prices follow a mean reverting or random walk process, has been much debated among economists.[1] The empirical evidence on the random walk hypothesis from these studies is mixed (see Fama & French, 1988; Poterba & Summers, 1988; Richardson & Stock, 1989; Kim et al., 1991; McQueen, 1992; Zivot & Andrews, 1992; Richardson, 1993; Lo and MacKinlay, 1997; Zhu, 1998; Grieb & Reyes, 1999; Balvers et al., 2000; Caner & Hansen, 2001; Chaudhuri & Wu, 2003; Alimov et al., 2004; Narayan, 2005, 2006, 2007, 2008; Narayan & Smyth, 2005, 2006; Narayan & Prasad, 2007).

If it is established that stock prices are mean reverting, i.e. they are I(0) stationary processes, then this implies that shocks to stock prices will have a transitory effect, in that prices will return to their trend path over time. From an investment point of view, this ensures that one can forecast future movements in stock prices based on past behavior, and trading strategies can be developed in order to earn abnormal returns. An important implication of the efficient market hypothesis (hereafter, EMH[2]) is that stock prices should follow a random walk, where the future price changes should be, for all practical purposes, random and therefore unpredictable. However, if it is found that stock prices are non-stationary (or a I(1) process) then shocks will have a permanent effect, implying that stock prices will attain a new equilibrium and future returns cannot be predicted based on historical movements in stock prices. This would signify that future returns cannot be predicted based on historical movements in stock prices and that volatility in stock markets will increase in the long run without bound (Chaudhuri & Wu, 2003; Narayan, 2008). Much of the controversy concerning the issue of mean reversion arises because of the speed of reversion; if it exists, perhaps very slow and standard econometric tests do not have sufficient power to discriminate a mean reversion process from a random walk process (Chaudhuri & Wu, 2003). Nelson and Plosser (1982) point out that whether stock prices are modeled as a trend stationary or as a difference stationary process has important implications regarding modeling, testing and forecasting.

Various methodological approaches have been utilized to investigate the random walk properties of stock prices. One such approach has been to test whether stock prices contain a unit root. The conventional unit root tests aimed at a unit root in stock prices have employed either the Augmented Dickey Fuller (ADF) unit root test or Phillips and Perron (PP) unit root test. Although numerous studies

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[1] For example, see Chaudhuri and Wu, 2003, Narayan (2005, 2006, 2008), and Narayan and Smyth (2005).

[2] The efficient market hypothesis (EMH) is built based on the assumption that newly generated information is instantaneously and sufficiently reflected in stock prices.

have found support for a unit root in stock prices, critics have staunchly contended that drawing such a conclusion may be attributed to the lower power of the conventional unit root tests employed when compared with near-unit-root but stationary alternatives (see Taylor et al., 2001). Perron (1989) proposes a model which imposes the null hypothesis that a given series has a unit root with drift and an exogenous structural break against the alternative of stationary regarding a deterministic trend which has an exogenous structural break. Perron (1989) argues that the conventional ADF and PP unit root tests are biased towards the non-rejection of the unit root null hypothesis in the presence of structural breaks. A number of authors, including Christiano (1992) and Zivot and Andrews (1992),[3] urge the importance of endogenous rather than exogenous selection of a break date. Enders and Granger (1998) also show that the standard tests for unit root all have lower power in the presence of erroneously specified dynamics. Taylor et al. (2000) demonstrate that the adoption of linear stationary tests is inappropriate for the detection of mean reversion if the true process of the data generation is in fact a stationary non-linear process. The presence of nonlinear mean-reverting adjustment for stock prices has been advanced by recent theoretical developments that emphasize the role of transaction costs. Taylor and Peel (2000), Taylor and Taylor (2004), Juvenal and Taylor (2008) and Lothian and Taylor (2008) argue that different speeds of adjustment at the disaggregated goods level average out to smooth nonlinearity at the aggregate level. An alternative view is that nonlinearity at the aggregate level is caused by other influences, such as the effects of official government intervention (Menkhof & Taylor, 2007; Reitz & Taylor, 2008) or heterogeneous agents (Kilian & Taylor, 2003). Additionally, the existence of structural changes in stock prices might imply broken deterministic time trends, resulting in a nonlinear pattern (Bierens, 1997). It should, therefore, not be unexpected that these shortcomings have seriously called into question many of the earlier findings based on a unit root in stock prices.

Motivated by the above consideration, in this study we revisit the issue of stock market mean reversion for the markets of the USA and its major trading partners of Canada, China, Japan and Mexico, using threshold unit root test developed by Caner and Hansen (2001). The main reason for choosing these four countries is that strong international trade-ties exist between the USA and these four countries. For the year 2009, the share of US exports to these four countries

[3] Christiano (1992) and Zivot and Andrews (1992) both argue that structural breaks should be treated as unknown a priori.

was 43.0% and the share of the US imports from these four countries was 50.9% (see Table 1). The results from this test suggest that a unit root in stock prices is not rejected for all countries, with the exception of China. This implies that returns on the U.S. and its major trading partners' stock market cannot be predicted using its own history of stock prices.

Table 1

UAS's International Trade with Top Five Trading Partners, 2000-2009

Panel A. The Proportional of Export

Country	Canada	Mexico	Japan	China	SubTotal	Rest of the world
2000	178.9	111.3	64.9	16.2	0.475	0.525
2001	163.4	101.3	57.5	19.2	0.468	0.532
2002	160.9	97.5	51.4	22.1	0.479	0.521
2003	169.9	97.4	52	28.4	0.48	0.52
2004	190.2	110.8	54.4	34.4	0.478	0.522
2005	211.3	120.1	55.4	41.2	0.475	0.525
2006	198.2	114.6	55.6	53.7	0.411	0.589
2007	213.1	119.4	58.1	62.9	0.395	0.605
2008	261.4	151.5	66.6	69.7	0.427	0.573
2009	204.7	129	51.2	69.6	0.43	0.57

* Exports of Total All Merchandise: in a hundred million ($ USD)

Panel B. The Proportional of Import

Country	Canada	Mexico	Japan	China	SubTotal	Rest of the world
2000	230.8	135.9	146.5	100	0.503	0.497
2001	216.3	131.3	126.5	102.3	0.505	0.495
2002	209.1	134.6	121.4	125.2	0.508	0.492
2003	221.6	138.1	118	152.4	0.501	0.499
2004	255.9	155.8	129.6	196.7	0.502	0.498
2005	287.9	170.2	138.1	243.5	0.502	0.498
2006	303	197.1	148.1	287.8	0.505	0.495
2007	312.5	210.2	144.9	321.4	0.505	0.495
2008	335.6	215.9	139.2	337.8	0.489	0.511
2009	224.9	176.5	95.9	296.4	0.509	0.491

* Imports of Total All Merchandise : in a hundred million ($ USD)

Source: FTDWebMaster, Foreign Trade Division, U.S. Census Bureau, Washington, D.C. 20233

The paper is organized as follows. Section 2 discusses the data used in this study. Section 3 first discusses the methodology employed and then the empirical findings. Some economic implications of our empirical findings are also discussed in this section. Section 4 summarizes and concludes the paper.

2. Data

The data set consists of weekly stock market indices for the U.S. and its major trading partners. The stock market indices for the U.S. and its major trading partners include: American S&P 500 Index, Mexico IPC Index, China Shanghai A Stock Index, Japanese NK-225 Index (Tokyo), and Canada S&P/TSX Composite Index. Sample periods span November 1998 to April 2010. Table 2 reports the summary statistics on the data studied. We find that Mexico (IPC) and Japan (NK-225) have the highest and lowest average stock market returns of 0.15% and -0.02%, respectively, over this sample period. The measures for skewness and excess kurtosis show that the stock market return series are highly leptokurtic and negatively skewed with respect to the normal distribution, with the exception of China, indicating that stock market returns are not normal. This result is consistent with that of the current literature.

Table 2

Summary Statistics of the Data: Δln P (1998.11.06-2010.08.30)

Statistic	USA	Mexico	Canada	Japan	China
Mean	-0.0000	0.0014	0.0005	-0.0003	0.0005
Sum Sq. Dev.	0.0931	0.1415	0.0861	0.1153	0.1580
Median	0.0005	0.0025	0.0016	0.0008	0.0008
Maximum	0.0718	0.0551	0.0523	0.0429	0.0835
Minimum	-0.1250	-0.1004	-0.1014	-0.1135	-0.0544
Std. Dev.	0.0124	0.0153	0.0119	0.0138	0.0162
Skewness	-2.0407	-0.7706	-1.7494	-1.0259	0.1680
Kurtosis	24.5210	7.3379	16.6206	10.6272	4.8061
Jarque-Bera	12075.24***	533.34***	4977.01***	1570.01***	84.94***
Observations	604	604	604	604	604

Notes: 1. *** and ** indicate significance at the 0.01 and 0.05 levels, respectively.

2. $\Delta \ln P = \ln P_t - \ln P_{t-1}$.

3. Methodology: Empirical Results and Economic Implications

3.1 Caner and Hansen (2001) Threshold Unit Root Test

Following the work of Caner and Hansen (2001),[4] we adopt a two-regime threshold autoregressive (TAR (k)) model with an autoregressive unit root as follows:

$$\Delta P_t = \theta_1^{'} \chi_{t-1} \mathrm{I}_{\{Z_t < \lambda\}} + \theta_2^{'} \chi_{t-1} \mathrm{I}_{\{Z \geq \lambda\}} + e_t \qquad t = 1,..,T \tag{1}$$

where P_t is the stock price indices for $t = 1,2,..,T$, $\chi_{t-1} = \left(P_{t-1,} v_t^{'}, \Delta P_{t-1},..., \Delta P_{t-k}\right)$, $\mathrm{I}_{\{\bullet\}}$ is the indicator function, e_t is an i.i.d. disturbance, $Z_{t-1} = P_{t-1} - P_{t-m}$ is the threshold variable, m represents the delay parameter and $1 \leq m \leq k$, v_t is a vector of exogenous variables including an intercept and possibly a linear time trend. The threshold value λ is unknown and takes the values in the compact interval $\lambda \in \Lambda = [\lambda_1, \lambda_2]$, where λ_1 and λ_2 are selected according to $P(\mathrm{Z}_t \leq \lambda_1) = 0.15$ and $P(\mathrm{Z}_t \leq \lambda_2) = 0.85$. The components of θ_1 and θ_2 can be partitioned as follows:

$$\theta_1 = \begin{pmatrix} \rho_1 \\ \beta_1 \\ \alpha_1 \end{pmatrix} \qquad \theta_2 = \begin{pmatrix} \rho_2 \\ \beta_2 \\ \alpha_2 \end{pmatrix} \tag{2}$$

where ρ_1 and ρ_2 are scalar terms. β_1 and β_2 have the same dimensions as v_t, and α_1 and α_2 are k-vectors. Thus (ρ_1, ρ_2) are the slope coefficients on P_{t-1}, (β_1, β_2) are the slopes on the deterministic components, and (α_1, α_2) are the slope coefficients on $(\Delta P_{t-1},...,\Delta P_{t-k})^{'}$ in the two regimes.

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4 Caner and Hansen (2001), using Monte Carlo simulations, show that when the data generating process has a nonlinear nature and bootstrapped critical values are employed, the R_{1T} and R_{2T} tests are more powerful than the conventional ADF test.

The threshold effect in Eq. [1] has the null hypothesis of $H_0 : \theta_1 = \theta_2$, which is tested using the familiar Wald statistic[5] $W_T = W_T\left(\hat{\lambda}\right) = \sup_{\lambda \in \Lambda} W_T(\lambda)$.[6] The stationary of the process P_t can be established in two ways. The first is when there is a unit root in both regimes (a complete unit root). Here, the null hypothesis $H_0 : \rho_1 = \rho_2 = 0$ is tested against the unrestricted alternative $H_1 : \rho_1 \neq 0$ or $\rho_2 \neq 0$ using the Wald statistic. This statistic is:

$$R_{2T} = t_1^2 + t_2^2 \tag{3}$$

Here, t_1 and t_2 are the t ratios for ρ_1 and ρ_2 from the least squares estimation. The parameters of ρ_1 and ρ_2 from Eq. [1] will control the regime-dependent unit root process of the stock price. If $\rho_1 = \rho_2 = 0$ holds, then we say that the stock price is I(1) and can be described as having a unit root. Second, when there is a unit root in only one of the regimes, a case of partial unit root, the alternative hypothesis is in the form, $H_1 : \rho_1 < 0$ and $\rho_2 = 0$, or $\rho_1 = 0$ and $\rho_2 < 0$. However, Caner and Hansen (2001) claim that the two-sided Wald statistic may have less power than a one-sided version of the test. As a result, they propose the following one-sided Wald statistic:

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[5] The asymptotic distribution of W_T for stationary data has been investigated by Davies (1987), Chan (1991), Andrews and Ploberger (1994), and Hansen (1996).

[6] $W_T = W_T\left(\hat{\lambda}\right) = \sup_{\lambda \in \Lambda} W_T(\lambda) \quad W_T(\lambda) = T\left(\dfrac{\hat{\sigma}_0^2}{\hat{\sigma}^2(\lambda)} - 1\right)$, where $\hat{\sigma}_0^2$ and $\hat{\sigma}^2$ are residual variances from least squares estimation of the null linear and TAR models, respectively.

$$R_{1T} = t_1^2 I_{\{\rho_1 < 0\}} + t_2^2 I_{\{\rho_2 < 0\}} \qquad (4)$$

To distinguish between the stationary case given as H_1 and the partial unit root case given as H_2 , Caner and Hansen (2001) suggest using individual t statistics t_1 and t_2. If only one of $-t_1$ and $-t_2$ is statistically significant, this will be consistent with the partial unit root case H_2 . This means that the stock price behaves like a non-stationary process in one regime, but exhibits a stationary process in the other regime, and vice versa. Caner and Hansen (2001) show that both tests R_{1T} and R_{2T} will have power against both alternatives.[7] To obtain maximum power from these tests, critical values are generated using bootstrap simulations with 10,000 replications, as suggested by Caner and Hansen (2001).

3.2 Empirical Results

Table 3 presents the country-by-country results for the unit root and stationary tests (i.e., the ADF, PP and the KPSS[8]). At first sight, the individual unit test statistics seem to show that stock prices are non-stationarity for the U.S. and its major trading partners. As stated earlier, there is a growing consensus that the stock prices exhibit nonlinearities; consequently, conventional unit root tests such as the ADF test, have low power in detecting the mean reversion of the stock prices. Therefore, we proceed to test the stock prices by using Caner and Hansen's (2001) Threshold Unit Root Test.

First, we use the Wald test W_T to examine whether or not we can reject the linear autoregressive model in favor of a threshold model. The results of the Wald test along with the bootstrap critical values generated at conventional levels of significance are reported in Table 4. The bootstrap p-value for $Z_{t-1} = P_{t-1} - P_{t-m}$ threshold variables of the form for delay parameters m varies from 1 to 12. Since the parameter m is generally unknown, there is no reason to assume that the

[7] As stated by Caner and Hansen (2001), R_{1T} has more power than that of R_{2T} ; here we only report the results of R_{1T} in our study.

[8] Kwiatkowski et al.'s (KPSS, 1992) unit root tests were also conducted, yielding identical results.

optimal delay parameter will be the same across countries. The selection of m can be made endogenous by choosing the least squares estimate of m that minimizes the residual variance. It follows that one can obtain m at the value that maximizes the W_T statistic (Caner and Hansen, 2001). We find that the W_T statistic is maximized for the U.S. and Canada when m=2, for the Mexico when m=9, for Japan when m=5, and for China when m=6. Taken together, these results imply strong statistical evidence against the null hypothesis of linearity at least at the 1% significance level in all countries' markets, indicating that simple linear models are inappropriate; the TAR model is our preference.

Table 3

Univariate Unit Root Tests: (1998.11.06-2010.08.30)

Panel A. Without trend

Country	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
USA	-1.774(1)	-1.963 [2]	0.292[18]	-28.683 (0)***	-28.683 [0]***	0.083[5]
Mexico	-0.947(0)	-0.955[6]	3.111[18]***	-24.826(0)***	-24.831[6]***	0.075[6]
Canada	-1.717(0)	-1.742[11]	1.997[18]***	-27.225 (0)***	-27.079[11]***	0.082[10]
Japan	-1.319(0)	-1.354[7]	0.469[18]**	-24.854(0)***	-24.852[6]***	0.115[6]
China	-1.221(0)	-1.426[9]	1.284[18]***	-23.970(0)***	-24.314[9]***	0.095[9]

Note: *** and ** indicate significance at the 0.01 and 0.05 levels, respectively. The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987).

Panel B. With trend

Country	Levels			First Differences		
	ADF	PP	KPSS	ADF	PP	KPSS
USA	-1.871(1)	-2.068 [2]	0.257[18]***	-28.665 (0)***	- 28.665[6]***	0.073[5]
Mexico	-1.880(0)	-1.961[6]	0.298[18]***	-24.811(0)***	-24.816[7]***	0.071[5]
Canada	-1.989(0)	-2.067[11]	0.236[18]***	-27.210 (0)***	-27.066[11]***	0.069[10]
Japan	-1.532(0)	-1.567[7]	0.322[18]***	-24.841(0)***	-24.839[6]***	0.106[6]
China	-1.345(0)	-1.645[9]	0.298[18]***	-23.951(0)***	-24.297[9]***	0.097[9]

Note: *** and ** indicate significance at the 0.01 and 0.05 levels, respectively. The number in parenthesis indicates the lag order selected based on the recursive t-statistic, as suggested by Perron (1989). The number in the brackets indicates the truncation for the Bartlett Kernel, as suggested by the Newey-West test (1987).

Table 4

Threshold test

Countries	Wald Statistic	Bootstrap p-value	Optimal delay parameter m	Threshold parameter λ	Number of observations in Regime 1 and its percentage
USA	78.22	0.004	2	-0.0112	111(18.8%)
Mexico	66.46	0.000	9	-0.0312	88(14.9%)
Canada	71.73	0.002	2	-0.0128	88(14.9%)
Japan	55.03	0.008	5	-0.0308	88(14.9%)
China	60.58	0.000	6	-0.0268	135(22.8%)

Note: Following much of the existing empirical literature on monthly stock prices, we set a maximum lag of 12 and base all our bootstrap tests on 10,000 replications. All of the statistics are significant, which supports the presence of threshold effects.

Table 5

One sided unit root tests

Countries	Optimal delay parameter m	R_{1T} Statistic	Bootstrap critical values			Bootstrap p-value
			10%	5%	1%	
USA	2	6.059	9.872	12.396	18.224	0.283
Mexico	9	1.162	9.314	11.271	16.258	0.847
Canada	2	1.847	9.581	11.840	17.353	0.756
Japan	5	2.493	9.336	11.590	17.092	0.674
China	6	23.443	9.383	11.524	15.944	0.001

In the preceding section, we found strong evidence that the U.S. and its major trading partners' stock prices were nonlinear processes. Next, we explore the threshold unit root properties of stock prices based on the R_{1T} statistic for each delay parameter m, ranging from 1 to 12. However, we will pay particular attention to the results obtained from the preferred models. The R_{1T} test results, together with the bootstrap critical value at the conventional levels of significance and the bootstrap p-value, are reported in Table 5. We are able to reject the unit root null hypothesis for the China market at the 1% significance level. Taken together, our results provide strong support for the EMH of the stock markets, with the exception of the China market for which the stock prices are characterized as non-linear stationary.

The one-sided test statistic of the R_{1T}, however, is unable to distinguish the complete and partial unit root in stock prices; we examine further evidence on the unit root hypothesis (partial unit root) by examining the individual t statistics, t_1^2 and t_2^2. The results are reported in Table 6. Also, for the China market, the statistics for t_1^2 are smaller than the critical value at the 1% level of significance, and this leads us to the conclusion that stock prices in the U.S.'s and its major trading partners' stock prices are nonlinear processes that are characterized by a unit root process, which is consistent with the EMH.

Table 6

Partial unit root results

Countries	Optimal delay parameter m	t_1^2 statistic	Bootstrap p-value	t_2^2 Statistic	Bootstrap p-value
USA	2	-0.697	0.937	2.461	0.113
Mexico	9	-0.710	0.928	1.078	0.497
Canada	2	0.364	0.735	1.309	0.425
Japan	5	1.398	0.392	0.733	0.625
China	6	4.605	0.001	1.497	0.362

3.3 Economic Implications

Several important economic implications emerge from our study. First, if the data were erroneously treated as non-stationary and the causality tests for stock prices and other macroeconomic variables were applied to the first difference, then a spurious causality would result. Second, overwhelming evidence in favor of the I(1) non-stationary hypothesis is found, implying that the stock markets in the US and its major trading countries (i.e., Canada, Japan and Mexico), with the exception of China, are characterized by the EMH, thereby showing that profitable arbitrage opportunities among the stock prices in these four countries (i.e., Canada, Japan, Mexico and the US) are not possible. Third, our findings suggest that shocks to stock price are permanent. This result implies that following a major structural change in the global financial markets, stock prices will not return to their original equilibrium over a period of time. The fact that stock prices show I(1) non-stationarity indicates that it should not be possible for the series to forecast future movement in stock prices based on past behavior.

Equally important, the results here are consistent with those of Narayan (2005, 2006) and Munir and Mansur (2009), since these three studies also used the TAR unit root test of Caner and Hansen (2001) and determined that the stock markets of the U.S., Australia/New Zealand and Malaysia exhibit nonlinear behaviors with a unit root process, respectively.

4. Conclusions

Testing for stationary or otherwise of stock prices has become an important topic in the financial economics literature. Faced with the possibility that stock prices may be characterized by a nonlinear data generating process, we were motivated to test for nonlinearities in stock prices for the U.S. and its major trading partners (i.e., Canada, China, Japan and Mexico). Results from the Caner and Hansen (2001) TAR unit root test indicate that a unit root in stock prices can not be rejected for all countries, with the exception of China. This implies that returns on the U.S.'s and its major trading partners' stock markets cannot be predicted using its own history of stock prices. These results might cast some doubts regarding the active investment strategies of international mutual funds.

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Acknowledgement: we would like to thank the anonymous referee for his helpful comments, suggestions and time spent in reading our paper. These all make this paper more valuable and readable. Any errors that remain are our own.