EVIDENCE OF NONLINEAR SPECULATIVE BUBBLES IN PACIFIC-RIM STOCK MARKETS

by

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"Abstract"

Increased volatility of many stock markets in recent years has sometimes been associated with rapid increases or decreases in asset values that may contain elements of speculative bubbles not justified by the underlying fundamentals. This paper studies the behavior of daily stock returns from ten pacific-rim countries by using a regime switching model to detect trends. Residuals from a VAR model of daily stock indices and presumed fundamentals like exchange rates, Far East and the World stock indices used in a regime switching model point to the existence of bubbles. The ARCH and BDS statistics also indicate strong evidence of non-linearities in all of these countries.

I. Introduction

Substantially increased international financial mobility and internal financial reforms in many countries have led to apparently increased volatility of their financial markets. This heightened volatility has sometimes been associated with rapid increases or decreases in asset values that many observers suspect contain elements of speculative bubbles and their associated crashes, not justified by rational expectations of underlying fundamentals. In addition, these possible bubbles may coincide with nonlinear dynamics beyond basic ARCH effects, thus being nonlinear speculative bubbles.

This paper applies a methodology used to study Pakistani stock market behavior presented in Ahmed and Rosser (1995) and Ahmed, et al (1996) to a set of ten countries representing different levels of economic development, all lying within the generally dynamic Pacific Rim regional economy. All of these (Australia, Hong Kong, Japan, the Republic of Korea, Malaysia, New Zealand, the Philippines, Singapore, Taiwan and Thailand) currently have reasonably free, open, and liquid financial markets. The selected sample represents significantly different economies. There is a considerable disparity in the size of each economy, degree of development, rates of growth and the structural changes, which are taking place in financial market of these economies. As table 1 shows, the size of economy varies from Japan, which has real GDP of $4.3 trillion to the Philippines which has a GDP of about $63 billion.

There are also differences in terms of the maturity of financial markets in these countries. Australia, Hong Kong, Japan and Singapore are considered developed markets, while the Republic of Korea, Malaysia, New Zealand, the Philippines, Taiwan and Thailand will be considered emerging markets. Table 2 shows the salient features of stock markets. Market capitalization ranges from $3.6 trillion in Japan to only $31.9 billion in New Zealand. The number of listed companies ranges from 2263 in Japan to only 205 in New Zealand. The highest increase in market capitalization (477 percent) took place in the Philippines and the lowest (about 17 percent) took place in Japan. For investment purposes, the Japanese market has achieved maturity similar to other OECD countries.

We examine daily stock market behavior in these countries over periods that end in April 1996 for all of the countries, but begin anywhere from January 1986 to December 1986 depending on the country. Our approach is as follows.

For each country we use a daily data set of the general index of local stock prices to estimate a Vector Autoregressive (VAR) model of its natural logarithm with that of daily foreign exchange rates, Far East Stock Indices and the World Stock indices as a measure of the presumptive fundamental.[2] Residuals of this VAR model are then analyzed using a regime-switching model to test for the existence of speculative trends.

Nonlinearity of the series is tested by estimating Autoregressive conditional heteroskedasticity (ARCH) effects and then estimating BDS statistics for the residual series after ARCH effects are removed. From the first test we reject the absence of trends which can be interpreted as speculative and from the second test we reject the absence of nonlinearities beyond ARCH effects in the residual series for all countries.

These results must be viewed with caution because our VAR model may not accurately estimate the fundamental. This reflects a more general problem in studying possible speculative bubbles known as the "misspecified fundamental" problem (Flood and Garber, 1980). It may be impossible to test for bubbles because no sequence of realized values of possible fundamental variables definitely is inconsistent with investors' expectations because the asymptotic objective probability distributions of those fundamentals values may be skewed. Thus, in any small sample observed by an econometrician, one may not observe values from the "long tail" whose unobserved yet a priori non-trivial probabilities of occurring are taken into account by rational investors, generating a rationally expected value for the series different from that of the sample mean.[3]

Nevertheless, even if we have not definitively shown the existence of speculative bubbles in our various stock markets, our study certainly strongly suggests their possibility. There is little question that increased volatility of markets has created a policy problems for authorities in many of these countries, on the one hand pleased with increasing values but also having to deal with the consequences of crashes in values. This latter problem has been especially evident in many of these countries since mid-1997. We note that out data series ends prior to the outbreak of those disturbances.

The next section of this paper will discuss the theory of speculative bubbles in their nonlinear form. This will be followed by a discussion of our econometric methodology and our data. Results for each of our tests will be discussed in the succeeding sections, followed by a concluding discussion.

II. Theoretical Issues[4]

An asset has a bubble in its price if B > 0 in (1),

$$P_t = F_t + B_t + \varepsilon_t, \qquad (1)$$

where P is the price of the asset in time t, F is the fundamental

Value of the asset in time t, B is the value of the bubble component in time t, and ε_t is an identically and independently distributed (i.i.d.) stochastic process.[5]

The misspecified fundamental problem arises from the difficulty in identifying the true fundamental of any asset from a set of observable data. Underlying this are serious problems in the theory of what the fundamental is. One general definition is the long-run, steady-state value of the asset that obtains in a competitive general equilibrium. But a difficulty is the possibility of multiple general equilibria suggesting that more than one possible fundamental might exist. Thus, a possible bubble may simply be an episode in which the asset price is "between" two different possible equilibria with its ultimate path uncertain during the time period in question. This would argue against the existence of bubbles.

More commonly, a partial equilibrium view is taken in which the fundamental becomes uniquely defined as the sum of the discounted stream of rationally expected future net earnings of the asset.[6] The difficulty of observing this rationally expected future stream is the usual source of the misspecified fundamental problem.

Tirole (1982) showed the impossibility of bubbles existing in a discrete-time world with a finite number of fully-informed, risk-averse, infinitely-lived agents, trading a finite number of real assets with real returns. Relaxing any of these assumptions allows possible bubbles of various sorts, although many of the allowed bubbles are stationary making them essentially impossible to observe in practice.[7] Models with imperfectly informed but otherwise rational agents as above can have bubbles if the bubble will crash with some probability that can be compensated for by its rising sufficiently fast to provide a risk premium for the investors (Blanchard and Watson, 1982). This model has been the basis of various efforts to identify "rational bubbles" in certain markets.[8]

A more recent trend in modeling bubbles has been to allow for the existence of heterogeneity among traders, with some characterized by less-than perfectly informed or rational behavior. Such models derive from the "noise trader" model of Black (1986) and may involve either asymmetric information with full rationality (Allen and Gorton, 1993), differences in initial wealth where individual wealth is private information (Bhattacharyya and Lipman, 1995), or some degree of risk-loving by some actors as exhibited in "positive feedback investment" behavior (De Long, et al, 1990).[9] Some observers argue that such behavior should be understood as inherently irrational and ignorant, yet nevertheless very real (Shiller, 1984; Kindleberger, 1989). Models with mixtures of degrees of rationality and information among heterogeneous agents have been labeled *quasi-rational* by Thaler (1991).

A model of heterogenous agents capable of generating nonlinear and chaotic bubble dynamics is due to Day and Huang (1990). There are three types of traders: rational fundamentalists, trend-chasing "sheep," and market specialists who set prices. In this model there is a constant fundamental equal to F. The actual price is P.

Rational fundamentalists know F and upper and lower bounds, respectively M and m. They sell when P is above F and buy when P is below F. Their excess demand is given by

$$a\,(F - P)f(P), \quad P\,\varepsilon[m, M]$$

$$a\ \alpha\,(P) = 0, \qquad P < m, P > M, \qquad (2)$$

with

$$\alpha(P) > 0, P < F \qquad (3)$$

$$\alpha(P) < 0, P > F \qquad (4)$$

$$\alpha(P) = 0, P = F, P < m, \text{ or } P > M \qquad (5)$$

$$\alpha'(P) \leq 0, m \leq P \leq M. \qquad (6)$$

The trend-chasing "sheep" cause the bubbles. Their excess demand is given by

$$b\,\beta\,(F) = 0 \qquad (7)$$

$$\beta'(F) > 0. \quad (8)$$

The combined excess demand of these two groups is

$$E(P) = a\,\alpha(P) + b\,\beta(P). \quad (9)$$

The market specialists affect the dynamics through an adjustment coefficient, c, such that

$$P_{t+1} = P_t + cE(P_t). \quad (10)$$

Equilibrium at F is unstable if sheep outweigh rational fundamentalists in the market, that is if

$$a\,\alpha'(F) + b\,\beta'(F) > 0. \quad (11)$$

This generates two temporary equilibria, $P_1 < F$ and $P_2 > F$, also both unstable if at $P = P_1$ and $P = P_2$

$$-2 > c[a\,\alpha'(P) + b\,\beta'(P)] \quad (12)$$

true if at both temporary equilibria

$$a(F - P)f'(P) - af(P) < -2/c - b\,\beta'(P). \quad (13)$$

This implies that there will be both up and down bubbles. Given sufficient nonlinearity of the excess demand functions, the unstable bubble dynamics can be chaotic.[10]

Econometric Methodology

A. Regime Switching Model

Dividends and interest rates are obvious candidates for determinants of stock market fundamentals. However, seeking some indicator of sentiments regarding fundamentals beyond stock markets themselves which varies reasonably frequently throughout all our sample of countries, we settled upon the exchange rate, two more global indices which may reflect strong relationship with local indices, interest rates and dividends not being available throughout on a daily basis. These indices are the Far East Stock Indices and World Stock Indices. These three series may reflect the degree of general confidence that global financial markets have in the prospects of an economy.[11] Our proxies for unobserved fundamental series are daily values of stock market indexes as estimated from VAR models using lagged values of the exchange rates, Far East Stock Indices, World Stock Indices and first differences of the natural logarithms of the stock market indexes themselves.[12]

From this VAR model a residual series is constructed which is then examined using the Hamilton (1989) regime switching model to test for trends and switches of trends, an approach also followed by van Norden and Schaller (1993). A residual series possibly driven by bubbles Gives

$$e_t = n_t + z_t \qquad (14)$$

where

$$n_t = \mu_1 + \mu_2 s_t \qquad (15)$$

and

$$z_t - z_{t-1} = \phi_1(z_{t-1} - z_{t-2}) + \ldots + \phi_r(z_{t-r} - z_{t-r-1}) + \varepsilon_t \qquad (16)$$

with s = 1 being a positive trend, s = 0 being a negative trend, and $\mu_i \neq 0$ indicating the possible existence of a trend element beyond the VAR process. Furthermore let

$$\text{Prob}\,[s_t = 1 \;\; s_{t-1} = 1] = p, \text{Prob}\,[s_t = 0 \;\; s_{t-1} = 1] = 1 - p \qquad (17)$$

$$\text{Prob}\,[s_t = 0 \;\; s_{t-1} = 0] = q, \text{Prob}\,[s_t = 1 \;\; s_{t-1} = 0] = 1 - q. \qquad (18)$$

Following Engel and Hamilton (1990) a "no bubbles" test proposes a null hypothesis of no trends given by p = 1 - q. This can be tested with a Wald test statistic given by

$$[p - (1-q)]/[\text{var}(p) + \text{var}(1-q) + \text{covar}(p, 1-q)]. \qquad (19)$$

Results of this test are presented in Section I.A with the actual statistics presented in Table 4.

B. Nonlinearity Tests

We test for nonlinearity of the VAR residual series in two stages. The first is to remove ARCH effects. Engle (1982) developed the nonlinear variance dependence measure of Autoregressive conditional heteroskedasticity (ARCH) as

$$x_t = \delta_t u_t \qquad (20)$$

$$\delta^2_t = \alpha_0 + \Sigma^n_{i=0} \alpha_i x_i^2 \qquad (21)$$

with u i.i.d. and the α_i's different lags. We use a three period lag and, as expected, found significant ARCH effects in all series.[13]

The second stage involves removing all variability attributable to these ARCH effects from the VAR residual series. The remaining residuals are then subjected to the BDS test, due to Brock, et al (1991) and Brock, et al (1997), a test for generalized nonlinear structure.

The correlation integral for a data series $\{x_t\}$, t = 1, ..., T results from forming m-histories such that x = $[x_t, x_{t+1}, ..., x_{t+m+1}]$ for any embedding dimension m. It is

$$c_m T(\varepsilon) = \Sigma_{t<s} I_\varepsilon(x^m_t, x^m_s)[2/T_m(T_m-1)] \qquad (22)$$

with a tolerance distance,[14] $I_\varepsilon(x^m_t, x^m_s)$ is an indicator function equaling 1 if $||x^m_t - x^m_s|| < \varepsilon$ and equaling zero otherwise, and $T_m = T - (m-1)$.

The BDS statistic comes from the correlation integral as

$$BDS(m, \varepsilon) = T^{1/2} \{C_m(\varepsilon) - [c_1(\varepsilon)]^m\}/b_m \qquad (23)$$

where b_m is the standard deviation of the BDS statistic dependent on the embedding dimension m. The null hypothesis is that the series is i.i.d. meaning that for a given ε and an $m > 1$, $c_m(\varepsilon) - [c_1(\varepsilon)]^m$

equals zero. Thus sufficiently large values of the BDS statistic indicate nonlinear structure in the data.[15] Our BDS tests are discussed in Section VI.B with the statistics presented in Table 5.

IV. Empirical Results

A. Data

Table 4 shows the sample periods covered for each country in the data set. Tables 6-15 show basic statistics like autocorrelations, partial autocorrelations and Q-Statistics of stock returns for each market. Figures 1-10 display graphical representations of the raw data series on stock market prices for each country over its respective sample period[16].

B. Regime Switching Models

Table 4 contains the results of the Wald test of the null hypothesis that $p = 1-q$. The critical value of $\chi^2(1)$ for this test is 3.84 with estimated values exceeding that indicating rejection of the null hypothesis. All nations exhibit figures substantially exceeding the critical value thus rejecting the null hypothesis of "no trends," ranging from 69.79 for Taiwan to 1328.60 for the Philippines. The number for Japan, with the most mature market is 563.13 indicating strong trends[17]. This failure to reject trends in the VAR residual series for eight out of nine of our sample countries is consistent with the possibility of speculative bubbles, although we cannot definitively say they are present because of the misspecified fundamental problem, not resolved by this or any other test on this data series, although possibly so for data with an independent measure of the fundamental such as closed-end funds (Ahmed, et al, 1997). Nevertheless, it is not surprising that some of these stock markets have crashed since the end of our data sample.

C. Nonlinearity Tests

The nonlinearity tests are not tests of trends, persistence, or bubbles, per se, but rather of more general volatility and complexity of dynamics results. Although not presented here, the results of the ARCH tests are significant for all countries studied. This is consistent with results widely observed in most asset markets.

Table 5 presents the results of the BDS tests on the VAR residual series after the variance due to estimated ARCH effects is removed.[18] Estimates were made for an embedding dimension of m = 3, following suggestions of Brock, et al (1991). The number of observations ranges from 2394 for Japan, New Zealand, and Singapore to 2652 for other countries. The null hypothesis is that the series is i.i.d. The critical value of the BDS for rejecting this null is around 6, that is BDS values exceeding 6 indicate rejection of the null. All ten countries generate BDS statistics clearly exceeding 6, indicating definitely significant results. Every country has over 500 observations indicating no small-sample bias in the BDS tests.

Thus there appears to be nonlinearity still adhering in the VAR residual series even after ARCH effects have been accounted for. However we stress that the BDS test does not itself tell us what form this nonlinearity consists of.[19] Furthermore, this result, like those on the trends and persistence tests, is subject to the meaningfulness of our original VAR specification. To the extent that it has little to nothing to do with the actual fundamental (assuming there is one), then the finding of nonlinear structure beyond ARCH may not mean much. Indeed, the true fundamental series itself may be nonlinear.

On the other hand it, the combination of all of the above results is supportive of the conclusion that most of the stock markets in our sample nations may have been subject to speculative bubbles during our sample periods, as well as volatility-induced volatility (ARCH effects), and that there may be greater degrees of nonlinear complexity beyond that for many of them as well.

VI. Conclusions

This paper examines the possible existence of nonlinear speculative bubbles in the stock markets of ten Pacific-Rim nations during the late 1980s and early 1990s. The method is to estimate for each country a possible fundamental of its daily stock market series by a vector autoregression of the first difference of the logarithms of the stock prices, the nation's foreign exchange rate, Far East Stock Indices and the World Stock Indices. Residuals of this estimated VAR model are then studied for evidence of possible trends and nonlinearities.

The technique for determining the presence or absence of trends in the residual series is the regime switching technique due to Hamilton (1989) as applied by Engel and Hamilton (1990). Wald tests of a null for no trends were carried out and the null was rejected for all ten countries studied. Thus the presence of speculative bubbles could not be ruled out for all countries included in the sample.

The presence of nonlinearities was first studied by estimating ARCH effects, which unsurprisingly were found for all series. Then each series was further filtered by removing variance due to the estimated ARCH effects. This series was then studied using the BDS statistic, which tests for a null of independently and identically distribution. Results were clearly definitive for all ten countries. This showed the presence of a considerable degree of nonlinearity in all of the series not explainable by ARCH effects.

However, we wish to remind the reader of the important caveat due to the misspecified fundamental problem. We have no way of knowing for sure that we have accurately estimated true fundamentals for any of these series with our VAR technique. Clearly if we have failed to identify the true fundamental series, then both our trends tests and nonlinearity tests results must be viewed as suspect.

Despite these doubts and questions, our results do correspond with widely made observations. Increasing deregulation of financial markets and increased international financial mobility seems to be related to an increase in volatility and possible speculative movements associated with up and down trends as larger and larger amounts of money slosh across borders from one country to another. This creates a new set of problems for financial management in many countries, both those, which are developed, as well as those which are less developed. Although we have not definitively proven this generalization, our results are certainly consistent with it and more recent developments in many Pacific-rim markets since the end of our data series in 1996 are also very consistent with it as well.

Table 1
Salient economics statistics of countries in the sample

Country	GNP[1] million US $ 1994	GNP Per Capita[2] US $	GNP Per Capita PPP Int$[3] 1994	Real GDP Growth[4] % 85-94	Inflation Rate[5] 85-94	Agriculture Share[6] 1994	Exports[7] % 1994	Investment[8] % 1994
Australia	320,705	17,980	19,000	1.2	4.1	3	19	20
Hong Kong	126,268	21,650	23,080	5.3	9.0	0	139	31
Japan	4,321,136	34,630	21,350	3.2	1.3	2	9	30
Korean Republic	366,484	8,220	10,540	7.8	6.8	7	28	38
Malaysia	68,674	3,520	8,610	5.7	3.1	14	90	39
New Zealand	46,578	13,190	16,780	0.5	4.7	7	31	21

Philippines	63,311	960	2,800	1.8	9.9	22	35	25
Singapore	65,842	23,360	21,430	6.9	3.9	0	177	32
Taiwan	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Thailand	129,864	2,210	6,870	8.2	5.1	10	39	40

Sources: IFC, Emerging Stock Markets Factbook-1996
and World Bank Atlas, 1996

1. 1994 data in U.S dollars.
2. 1994 data.
3. Purchasing Power Parity.
4. Real growth rate averages between 1985-1994.
5. Annualized average inflation rate between 1985-1994.
6. Share of agriculture in country's GDP.
7. Share of exports in country's GDP.
8. Investment as a percentage of GDP.

Table 2
Salient stock market statistics
for the year 1995

Country	Market Capitalization $ million	Turnover Ratio %	Number of Listed Companies
Australia	245,218	43.2	1,178
Hong Kong	303,705	37.3	518
Japan	3,667,292	30.9	2,263
Korea,South	181,955	97.8	721
Malaysia	222,729	35.9	529
New Zealand	31,950	28.1	205

Philippines	58,859	26.1	205
Singapore	148,004	42.2	212
Taiwan	187,206	174.9	347
Thailand	141,507	41.4	416

Source: IFC, Emerging Stock Markets Factbook-1996

Table 3
Market capitalization over 1991-1995
(US $ million)

Country	**1991**	**1992**	**1993**	**1994**	**1995**	Overall Growth 1991-1995
Australia	144,867	135,451	203,964	219,188	245,218	69.27
Hong Kong	121,986	172,106	385,247	269,508	303,705	148.97
Japan	3,130,863	2,399,004	2,999,756	3,719,914	3,667,292	17.13
Korea,South	96,373	107,448	139,420	191,778	181,955	88.80
Malaysia	58,627	94,004	220,328	199,276	222,729	279.90
New Zealand	14,336	15,348	25,597	27,217	31,950	122.87

Philippines	10,197	13,794	40,327	55,519	58,859	477.22
Singapore	47,637	48,818	132,742	134,516	148,004	210.69
Taiwan	124,864	101,124	195,198	247,325	187,206	49.93
Thailand	35,815	58,259	130,510	131,479	141,507	295.11

Source: IFC, Emerging Stock Markets Factbook-1996

Table 4
Wald test results on residuals from
four-variable VAR model
local stock indices, exchange rates,
far east stock indices and world stock indices

Country	**Sample**	**$H_0^{'}:P_1=1-P_2$** **□^{2}(1)**
Australia	January 2, 1986-April 22, 1996	135.34
Hong Kong	January 2, 1986- April 22, 1996	137.55
Japan	December 31, 1986- April 19, 1996	533.76
South Korea	January 2, 1986-April 22, 1996	563.13
Malaysia	January 2, 1986- April 16,	190.33

	1996	
New Zealand	January 2, 1987-April 22, 1996	109.40
Philippines	January 2, 1986-April 19, 1996	1328.60
Singapore	December 31, 1986-April 22, 1996	200.48
Taiwan	January 2, 1986- April 23, 1996	91.42
Thailand	January 2, 1986-April 23, 1996	69.79

Critical Value $\chi^2(1)= 3.84$

Table 5
BDS/SD statistics based on residuals from four-variable VAR model local stock indices, exchange rates, far east stock indices and world stock indices

Country	**Embedding dimensions(m)**	**T= No. Of observations**	**BDS/SD Statistics**
Australia	3	2653	8.40
Hong Kong	3	2653	11.81
Japan	3	2394	12.93
South Korea	3	2652	13.87
Malaysia	3	2653	15.04
New Zealand	3	2394	9.63
Philippines	3	2653	16.82

Singapore	3	2394	9.82
Taiwan	3	2653	16.08
Thailand	3	2653	14.81

Notes:
1. Data used for BDS tests are residuals from ARCH process
Conducted on residuals from VAR 2. For beginning and ending dates for each country, please see table 4.

Table 6
Correlogram of stock returns
Australia

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.108	0.108	31.102	0.000
*| |	*| |	2	-0.060	-0.073	40.870	0.000
|* |	|* |	3	0.073	0.090	55.372	0.000
|* |	|* |	4	0.114	0.093	90.455	0.000

Hong Kong

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
| |	| |	1	0.018	0.018	0.8295	0.362
| |	| |	2	0.000	-0.001	0.8296	0.660
|* |	|* |	3	0.083	0.083	19.163	0.000
| |	| |	4	0.021	0.018	20.336	0.000

Japan

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.085	0.085	17.633	0.000
*| |	*| |	2	-0.081	-0.089	33.758	0.000
| |	| |	3	-0.008	0.007	33.921	0.000
| |	| |	4	0.050	0.043	39.898	0.000

South Korea

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.105	0.105	29.758	0.000
|* |	|* |	2	0.127	0.117	73.406	0.000
| |	| |	3	0.032	0.008	76.187	0.000
| |	| |	4	0.036	0.017	79.624	0.000

Table 6 (Continued)
Malaysia

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.156	0.156	65.087	0.000
| |	| |	2	0.002	-0.023	65.099	0.000
| |	| |	3	0.000	0.004	65.100	0.000
| |	| |	4	0.030	0.030	67.445	0.000

New Zealand

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
| |	| |	1	0.048	0.048	5.7029	0.017
| |	| |	2	0.030	0.028	7.9049	0.019
| |	| |	3	0.001	-0.002	7.9084	0.048
| |	| |	4	0.003	0.002	7.9343	0.094

Philippines

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.157	0.157	66.356	0.000
| |	| |	2	0.008	-0.017	66.534	0.000
| |	| |	3	0.000	0.002	66.534	0.000
| |	| |	4	0.040	0.041	70.790	0.000

Table 6 (Continued)
Singapore

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|** |	|** |	1	0.205	0.205	101.68	0.000
*| |	*| |	2	-0.065	-0.111	111.83	0.000
| |	| |	3	0.012	0.052	112.18	0.000
| |	| |	4	0.043	0.023	116.73	0.000

Taiwan

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
|* |	|* |	1	0.096	0.096	24.583	0.000
|* |	|* |	2	0.079	0.071	41.582	0.000
|* |	| |	3	0.067	0.054	53.664	0.000
| |	| |	4	0.038	0.022	57.578	0.000

Thailand

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
	*			*		1	0.168	0.168	76.106	0.000
						2	0.025	-0.003	77.850	0.000
						3	0.054	0.052	85.728	0.000
						4	0.057	0.040	94.371	0.000

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[2]Other variables that might be used could include interest rates and dividends as Harvey (1994) did in his study of emerging markets. However Harvey's data series was monthly and not all of these variables are available on a daily basis, the time unit for our data series.

[3]One possible exception to this generalization may be the case of closed-end funds where it can be argued that the value of the fund should reflect the net asset value of its constituent assets. Ahmed, et al (1997) present evidence of bubbles in certain closed-end country funds from late 1989-early 1990.

[4]For a more thorough discussion see Rosser (1991, Chaps. 4-5).

[5]This includes the more commonly assumed Gaussian white noise process as a special case.

[6]For a non-income earning asset, it would be the sum of the discounted stream of rationally expected future net utilities, something impossible to observe, although Cardell, et al (1995) have estimated a model of postage fundamentals and bubbles from financial data.

[7]Examples leading to stationary bubbles include allowing overlapping generations of finitely-lived agents (Tirole, 1985) or an infinite number of commodities (Gilles and LeRoy, 1992; Magill

and Quinzii, 1996).

[8]Frankel's (1985) study of the US dollar in the early 1980's suggests the existence of a bubble, but the dollar did not move up rapidly enough for it to be rational, unless one assumes a declining expected probability of a crash as the bubble continued, an unlikely option. Dwyer and Hafer (1990) find similar results in stock markets in seven different countries.

[9]De Long, et al (1991) show that even though the expected outcome for such traders is to lose and disappear, some will not only survive, but may be the biggest winners in the market, thus assuring the survival of the breed.

[10]Gu (1993) has fit the Day-Huang model to stock market data. De Grauwe, et al (1993) present models of chaotic foreign exchange rate dynamics using heterogeneous trader models with somewhat different assumptions.

A sufficient condition for chaotic dynamics is the presence of sensitive dependence on initial conditions signaled by the existence of positive real parts of Lyapunov exponents for a time series. Many economic and financial series have been found to exhibit such positive real parts of Lyapunov exponents (Trippi, 1996). However, no such series has been shown to be capable of generating a model that can forecast usefully (Jaditz and Sayers, 1993; LeBaron, 1994), thus indicating that if any of these are truly chaotic they must be high dimensional.

[11]This approach was initiated by Canova and Ito (1991). Clearly there is not a perfect relationship between exchange rates and stock markets as there are offsetting sectoral effects with currency depreciations likely to aid stocks in export industries.

[12]Our VAR estimation method is that of Ahmed, et al (1988, 1989).

[13]Results of these tests are available from the authors on request.

[14]The conventional practice, which we follow, is to select ε as the standard deviation divided by the spread of the data.

[15]Estimates of the BDS statistic are notoriously subject to small sample bias, a problem we attempt to avoid by using daily data. An important cutoff for avoiding this problem is 500 data points, which we exceed for some countries and come close to for the others.

[16]The stock market indices and exchange rate series for all nine countries were obtained from Citicorp database services.

[17]. The Wald statistics are based on residuals from the VAR model. An alternative set of Wald tests was also conducted by removing all variability attributable to these ARCH effects from the VAR residual series. The residuals generated by this ARCH procedure were used to do Wald test. The χ^2 exceed the critical of value of 3.84 for all ten countries. The results are available from authors upon request.

[18] A caveat here is that there are many varieties of ARCH models and perhaps another one would be more appropriate for removing these effects.

[19] Possibilities include variations on ARCH and chaotic dynamics among a wide range of others.