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Are there rational speculative bubbles in Asian stock markets?

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Abstract

Six Asian stock markets (Hong Kong, Japan, Korea, Malaysia, Thailand and Taiwan) and the U.S. stock market are evaluated for evidence of rational speculative bubbles using two types of tests. First, the duration dependence and conditional skewness tests of McQueen and Thorley (1994) are used on the complete time series of returns. Second, explosiveness tests are applied to specific episodes of apparent bubbles. In general, the Asian stock returns exhibit some unusual characteristics, but these characteristics do *not* conform to the predictions of the *rational* speculative bubbles model.

JEL classification: G14; G15; C52; F30

Keywords: Bubbles; Asian stocks; Duration dependence; Market crash

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1. Introduction

Speculative bubbles, characterized by a long run-up in price followed by a crash, have recently received renewed interest in the academic literature. Famous historical examples of bubbles include the Dutch Tulipmania (1634–1637), the Mississippi Bubble (1719–1720) and the South Sea Bubble (1720). [1] The strong performance by U.S. stocks in the mid-1980s followed by a dramatic price drop in October of 1987 has sparked a renewed interest in bubbles, particularly, whether U.S. stock market bubbles were present in 1929 and 1987 (see, for example, Santoni, 1987; Hardouvelis, 1988; White, 1990).

Practitioners and the popular press often ascribe market drops in Asian markets to bubble bursts. For example, Melloan (1993), in his *Wall Street Journal* article notes that ‘‘Japan ... was the victim of a stock market bubble, or more precisely, the bursting of such a bubble in the 1990s’’ and Samuelson (1994) makes a point about potential equity bubbles by saying they ‘‘... will self-destruct in the way that the Tokyo Equity Bubble self-destructed after New Year’s Day 1990’’. Similarly, Brody (1990) in Barron’s notes that ‘‘the fantastic Taiwan stock bubble burst this spring with a loud bang’’.

Despite the speculation about the existence of bubbles in Asian markets, no systematic study exists addressing whether the price behavior in these markets is consistent with the characteristics of bubbles. The lack of theory about how bubbles evolve and burst makes empirical detection difficult; however, there are some regularities to which *rational* bubbles must conform. An important feature of *rational* speculative bubbles is that stock prices may deviate from their fundamental value without assuming irrational investors. Investors realize that prices exceed fundamental values, but they believe that, with high probability, the bubble will continue to expand and yield a high return which compensates them for the probability of a crash. Thus, the model shows the rationality of staying in the market despite the overvaluation. The exact compensation for the probability that the overvaluation could disappear causes rational bubbles to possess some special empirical properties. Our article examines the stock returns in six Asian markets as well as the U.S. market for these special empirical properties of rational speculative bubbles using two categories of tests.

The first category of tests are based on a new testable implication of the rational speculative bubbles model derived by McQueen and Thorley (1994). The new implication suggests that the probability that a run (sequence of observations of the same sign) of positive abnormal returns will end should decline with the length of the run (negative hazard functions). The McQueen and Thorley (1994) duration dependence and conditional skewness tests, unlike tests for autocorrela-

[1] Garber (1990) examines these three alleged bubbles and finds market fundamentals that *could* explain both the long run-up in prices and the crash for each episode.

tion, skewness and kurtosis, allow for the nonlinearity inherent in returns if bubbles exist. [2] Additionally, duration dependence is more unique to bubbles than attributes such as autocorrelation, skewness, or kurtosis. For example, time-varying risk premiums (e.g. Fama and French, 1988), fads (e.g. Poterba and Summers, 1988) and non-synchronous trading (e.g. Lo and MacKinlay, 1990a) could all induce autocorrelation. [3] Skewness could result from asymmetric fundamental news and leptokurtosis could be a consequence of the batched arrival of information (e.g. Tauchen and Pitts, 1983).

The second category of tests are anecdotal in nature. In these tests, returns from specific episodes of alleged bubbles are examined for rational speculative bubble 'footprints', specifically, increasing or explosive (not just high) returns before the crash and a quick (rather than gradual) crash. The first category of test uses all returns without presupposing periods of bubbles and crashes. The second category is anecdotal in the sense that returns just before and after alleged crashes are examined, rather than the whole time series of returns. [4]

Using simple return summary statistics, we find aspects of the Asian stock return distributions that are consistent with rational speculative bubbles. However, the more specific duration dependence tests and the anecdotal evidence yield little support for the existence of rational bubbles. Even the ardent believers in bubbles admit that they are rare events and typically allude to only four of them in our sample (the U.S. crash in October 1987, the Japan crash in December 1989, the Taiwan crash in January of 1990, and the January 1994 crash in Hong Kong, Malaysia and Thailand). This limited number of alleged bubbles admittedly limits the power of our test; yet, given the ubiquitous claims of bubbles in Asian markets, we believe that rigorous statistical tests are needed.

Our article is organized as follows. Section 2 briefly reviews the rational speculative bubble model. Section 3 describes the data, then reports autocorrelation, skewness and kurtosis statistics. Section 4 reviews, then applies, the duration dependence and conditional skewness tests of McQueen and Thorley (1994). Section 5 reports institutional characteristics (potentially related to bubbles) of the six Asian markets, and then examines specific anecdotal episodes for bubble characteristics. Our conclusions are presented in Section 6.

[2] Tests for bubbles based on return autocorrelation, skewness, and kurtosis include the Blanchard and Watson (1982) 'runs test' (autocorrelation) and 'tail test' (kurtosis), and the Evans (1986) 'median test' (skewness).

[3] McQueen (1992) finds that after correcting for heteroskedasticity and small sample sizes, the autocorrelation in long-horizon returns found by Fama and French (1988) and Poterba and Summers (1988) is not statistically significant.

[4] A third category of bubble tests, not presented in this article, compares actual stock prices to fundamentals such as dividends. See, for example, Flood and Garber (1980), Shiller (1981), West (1987) and Diba and Grossman (1988b), along with the critiques of this category of tests including Flood et al. (1987), Kleidon (1986) and West (1988).

2. Rational speculative bubble model

A simple efficient market condition is that an asset's expected return equals its required return,

$$E_t[R_{t+1}] = r_{t+1}, \tag{1}$$

where E_t denotes the mathematical expectation given the information set at time t, $R_{t+1} \equiv (p_{t+1} - p_t + d_{t+1})/p_t$, p_t is the price at time t, d_{t+1} is the dividend at time $t+1$, and r_{t+1} is the required rate of return. In terms of prices, the competitive equilibrium condition in Eq. (1) states that the current price equals the expected future price plus the dividend, both discounted at the return required by investors,

$$p_t = \frac{E_t[p_{t+1} + d_{t+1}]}{(1 + r_{t+1})}. \tag{2}$$

Solving Eq. (2) recursively yields one solution to the equilibrium condition: the *fundamental* value of the asset,

$$p_t^* \equiv \sum_{i=1}^{\infty} \frac{E_t[d_{t+i}]}{\prod_{j=1}^{i}(1 + r_{t+j})}. \tag{3}$$

However, Shiller (1978), Blanchard and Watson (1982) and West (1987), among others, note that any price of the form

$$p_t = p_t^* + b_t, \quad \text{where } E_t[b_{t+1}] = (1 + r_{t+1})b_t, \tag{4}$$

is a solution to the equilibrium condition as well. Thus, the market price can deviate from the fundamental value by a rational speculative bubble factor, b_t, if, on average, the factor grows at the required rate of return. [5]

Blanchard and Watson (1982) propose one type of rational bubble which allows the bubble to grow and burst:

$$\begin{aligned} b_{t+1} &= \frac{(1 + r_{t+1})b_t}{\pi} - \frac{1-\pi}{\pi}a_0 \quad \text{with probability } \pi \\ &= a_0 \quad \text{with probability } (1-\pi). \end{aligned} \tag{5}$$

In this process, the bubble factor grows by the exact amount needed to compensate investors for the probability, $1 - \pi$, that the bubble will crash and revert to the

[5] See Camerer (1989) for a review of the theoretic and empirical literature, and a more formal derivation of the rational speculative bubble model. Rational bubbles have been ruled out in certain situations including: negative bubbles (see Diba and Grossman, 1987, 1988a), bubbles when investors have infinite investment horizons (see Tirole, 1982) and bubbles in assets with terminal values (see Brock, 1982). Merton (1987) also notes that for bubbles to exist, the supply of stocks must be held constant.

small initial value, $a_0 > 0$. [6] In order for the Blanchard and Watson model to be consistent with the two traditional characteristics of bubbles, a long run-up in price followed by a crash, the probability of the bubble continuing, π, must be greater than $1/2$.

The rational speculative bubbles model allows for unexpected price changes, $\epsilon_{t+1} \equiv (R_{t+1} - r_{t+1}) p_t$, from two *unobservable* sources: unexpected changes in the fundamental value,

$$\mu_{t+1} = p^*_{t+1} + d_{t+1} - (1 + r_{t+1}) p^*_t, \tag{6}$$

and unexpected changes in the bubble,

$$\eta_{t+1} = b_{t+1} - (1 + r_{t+1}) b_t. \tag{7}$$

The *observable* unexpected price change, $\epsilon_{t+1} = \mu_{t+1} + \eta_{t+1}$, equals the sum of the fundamental and bubble changes:

$$\begin{aligned} \epsilon_{t+1} &= \mu_{t+1} + \frac{(1-\pi)}{\pi}\left((1 + r_{t+1}) b_t - a_0\right) \quad \text{with probability } \pi \\ &= \mu_{t+1} - (1 + r_{t+1}) b_t + a_0 \quad \text{with probability } (1-\pi). \end{aligned} \tag{8}$$

As required by the efficient markets condition, the expected value of the total price innovation is zero. However, the probability of a positive innovation or abnormal return can be greater than $1/2$ even if the fundamental innovations are symmetric around zero. This is due to the inherent skewness of the bubble innovations. If the bubble continues, its innovation is positive and small relative to an infrequent but large negative innovation if the bubble bursts. In addition to the skewness, the bubble process in Eq. (5) results in total price innovations that are explosive. The growth rate of the bubble factor increases each period the bubble survives to compensate investors for the potential crash of a progressively larger bubble. While it survives, the explosive bubble factor becomes a more dominant component in total price innovations, causing higher and higher observed returns leading up to the crash.

McQueen and Thorley (1994) show that the skewed and explosive nature of bubbles combined with the serially independent fundamental value innovations cause bubbles to leave 'footprints' in observed returns. [7] These footprints include positive autocorrelation (a preponderance of positive returns while the bubble grows), negative skewness (unusually large negative returns when the bubbles crashes) and leptokurtosis (fat tails due to the mixing of distributions as the bubble grows). Unfortunately, diagnostic tests for bubble-based return moments are inconclusive, even if significant, because fundamental price movements can also be associated with these attributes.

[6] Diba and Grossman (1988c) show that a rational bubble can start only on the first date of trading; thus, if it crashes completely it can never restart.

[7] Formally, innovations in the fundamental value must also be unimodal and stable in order to preserve the testable implication of duration dependence in returns.

McQueen and Thorley develop a more discriminating footprint since the growing bubble component makes negative abnormal returns less likely. A long run of positive excess returns suggests the presence of a bubble, and a bubble decreases the probability of a negative abnormal return. Taken together, these traits leave a unique footprint in observable returns: if prices contain bubbles, then runs of observed *positive* abnormal returns will exhibit duration dependence with an inverse relation between the probability of a run ending and the length of the run. Since bubbles cannot be negative, a similar inequality does not hold for runs of *negative* abnormal returns. Consequently, bubbles generate duration dependence in runs of positive, but not negative, abnormal returns.

The anecdotal examination of bubbles in Section 5 is also based on unique characteristics or footprints suggested by the rational bubble model. Eq. (5) shows that while the bubble lasts, it must grow faster than the required return to offset the possibility of a crash. For example, if $a_0 = 0$, then the bubble factor price relative, $1 + r^{b}$, is equal to $(1 + r_{t+1})/\pi$, where π is less than one. On the other hand, the fundamental factor's expected price relative, $1 + r^{*}$, is equal to $(1 + r_{t+1}) - d_{t+1}/p_t^{*}$, where the second term is the forward dividend yield. Thus, during the period just prior to a suspected bubble crash, the bubble factor will be growing faster than the fundamental factor, $1 + r^{b} > 1 + r^{*}$, for two reasons: first, to compensate investors for potentially larger and larger crashes; and second, to adjust for the lack of dividends on the bubble component. In other words, a pattern of *increasing* returns in the pre-crash period, not just high returns, can be used to validate anecdotal claims of bubbles. Whereas the model predicts that a rational bubble can grow over long periods of time, the crash or burst is theoretically instantaneous. If the burst proceeded slowly, market participants would be able to predict further drops. Armed with this prediction, they might try to sell as soon as possible causing the crash to speed-up. Thus, a second approach to validate alleged bubble episodes is to examine the speed of the crash.

3. Data

Tables 1 and 2 report summary statistics for monthly and weekly returns, respectively, on six Asian and the U.S. stock market indexes. All returns are continuously compounded. The Asian market data is from the Pacific Basin Capital Market Research Center (PACAP) and the U.S. data is from the Center for Research in Security Prices (CRSP) files. The specific country indexes used are: Hang Seng (Hong Kong), TOPIX (Japan), Seoul Composite (South Korea), Kuala Lumpur Composite (Malaysia), Bangkok Set (Thailand), Taipei Weighted (Taiwan) and the Standard and Poor's 500 (U.S.). The data are from January 1975 through April 1994, except for Korea and Malaysia which start in January of 1977 due to data availability. Fig. 1 illustrates weekly values in the seven stock indexes over the sample period.

Both monthly and weekly returns are examined for several reasons. First, the

Table 1
Summary statistics of monthly returns in local currencies on seven national stock indexes

Country	Hong Kong	Japan	South Korea	Malaysia	Thailand	Taiwan	USA
From (year/month)	75/01	75/01	77/01	77/01	75/04	75/01	75/01
To (year/month)	94/04	94/04	94/04	94/04	94/04	94/04	94/04
Mean	0.016	0.007	0.009	0.012	0.011	0.014	0.008
Standard deviation	0.091	0.051	0.068	0.081	0.076	0.118	0.043
Skewness	−1.35	−0.45	0.32	−1.09	−0.45	−0.20	−0.81
(SE)	(0.16)	(0.16)	(0.17)	(0.17)	(0.16)	(0.16)	(0.16)
E-Kurtosis	7.38	2.95	2.29	4.47	4.56	3.23	4.64
(SE)	(0.32)	(0.32)	(0.34)	(0.34)	(0.32)	(0.32)	(0.32)
ρ_1	0.05	0.01	−0.03	0.08	0.19	0.08	0.00
ρ_2	−0.02	−0.02	0.05	0.12	0.14	−0.03	−0.06
ρ_3	−0.07	0.00	−0.05	−0.10	0.01	−0.03	−0.08
ρ_4	−0.11	0.00	0.05	0.01	−0.09	0.04	−0.06
ρ_5	−0.09	0.06	0.05	0.03	−0.10	0.00	0.14
ρ_6	0.03	−0.02	0.12	−0.10	−0.08	−0.06	−0.07
ρ_7	0.05	−0.01	0.02	−0.01	0.03	−0.05	−0.02
ρ_8	−0.10	0.03	0.11	−0.05	0.01	−0.06	−0.06
ρ_9	0.07	0.07	0.05	−0.02	0.11	0.07	−0.07
ρ_{10}	0.11	0.07	0.07	0.07	0.12	0.09	0.07
ρ_{11}	0.08	0.00	0.01	0.10	0.12	0.05	0.01
ρ_{12}	−0.05	−0.01	0.10	−0.02	0.06	0.11	−0.04
$S(\rho)$	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
Q_{12}	16.5	3.6	12.5	13.4	29.9	11.0	12.5
(p-value)	(0.17)	(0.99)	(0.40)	(0.34)	(0.00)	(0.53)	(0.41)

All returns are continuously compounded nominal returns from the PACAP (six Asian countries) or CRSP (U.S.) data files. The stock market indexes used are Hang Seng (Hong Kong), TOPIX (Japan), Seoul Composite (South Korea), Kuala Lumpur Composite (Malaysia), Bangkok Set (Thailand), Taipei Weighted (Taiwan) and the Standard and Poor's 500 (U.S.). Numbers in parentheses below the skewness, and excess kurtosis (E-Kurtosis) coefficients are asymptotic standard errors, $(6/T)^{1/2}$ and $(24/T)^{1/2}$, respectively, where T is the number of monthly returns. ρ_t is the sample autocorrelation at log t and $S(\rho)$ is the asymptotic standard error of the autocorrelations under the null hypothesis of a random walk. $Q(12)$ is the Ljung–Box portmanteau test statistic for 12 autocorrelations and p-value is the marginal significance level of the Ljung–Box test.

bubble theory gives no indication as to the typical length of a bubble, although the practical literature implies that the bubbles may build up over a number of months and even years. [8] Second, McQueen and Thorley (1994) suggest that monthly

[8] The bubble literature is also silent about how and why rational bubbles begin and why and when they crash. This void in the theoretic literature plagues all empirical research on rational bubbles, including this article. Nevertheless, the theory does lead to some testable implications on the many references to bubbles in the popular press.

Table 2
Summary statistics of weekly returns in local currencies on seven national stock indexes

Country	Hong Kong	Japan	South Korea	Malaysia	Thailand	Taiwan	USA
T	1,003	997	890	895	989	987	1,007
Mean	0.0041	0.0018	0.0021	0.0027	0.0026	0.0035	0.0019
Standard deviation	0.0403	0.0220	0.0308	0.0351	0.0317	0.0470	0.0210
Skewness	−1.18	−0.41	−0.35	−1.72	−0.39	−0.32	−0.63
(SE)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)	(0.08)
E-Kurtosis	8.12	4.65	7.86	13.42	5.77	3.54	4.89
(SE)	(0.15)	(0.15)	(0.16)	(0.16)	(0.16)	(0.16)	(0.15)
ρ_1	0.13	0.02	−0.07	0.08	0.15	0.12	0.00
ρ_2	0.08	0.07	0.07	0.04	0.06	0.14	−0.02
ρ_3	0.00	0.05	0.04	0.03	0.10	0.03	0.05
ρ_4	−0.04	−0.01	−0.03	0.00	0.04	0.03	−0.05
ρ_5	−0.02	0.00	0.01	0.05	0.02	0.00	−0.03
$S(\rho)$	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)
Q_5	24.8	8.0	11.2	11.0	35.9	35.1	5.9
(p-value)	(0.00)	(0.16)	(0.05)	(0.05)	(0.00)	(0.00)	(0.32)

All returns are continuously compounded nominal returns from Wednesday close to Wednesday close from the PACAP (six Asian countries) or CRSP (U.S.) data files. The stock market indexes used are Hang Seng (Hong Kong), TOPIX (Japan), Seoul Composite (South Korea), Kuala Lumpur Composite (Malaysia), Bangkok Set (Thailand), Taipei Weighted (Taiwan) and the Standard and Poor's 500 (U.S.). Numbers in parentheses below the skewness and excess kurtosis (E-Kurtosis) coefficients are asymptotic standard errors, $(6/T)^{1/2}$ and $(24/T)^{1/2}$, respectively, where T is the number of weekly returns. ρ_t is the sample autocorrelation at log t and $S(\rho)$ is the asymptotic standard error of the autocorrelations under the null hypothesis of a random walk. $Q(5)$ is the Ljung–Box portmanteau test statistic for 5 autocorrelations and the p-value is the marginal significance level of the Ljung–Box test.

returns are appropriate because the high signal-to-noise ratio in weekly returns could cause bubble-related runs to be interrupted by noise. In testing data for the presence of bubbles, noise is introduced by fundamental price changes that make bubble detection difficult. Third, weekly returns may be appropriate since monthly tests may lack power given the relatively short data series for the Asian markets. Weekly returns are calculated from Wednesday close to Wednesday close. In the event of a holiday or non-trading on a Wednesday, the Tuesday close is used. If Tuesday data are also unavailable, the Monday close is used. In the rare case where the Monday close is also unavailable, the returns for the week are combined with the following week. [9]

Five of the six Asian markets have average monthly and weekly returns greater

[9] This convention for creating weekly returns explains why some countries may have a slightly different number of weekly observations over the same time frame.

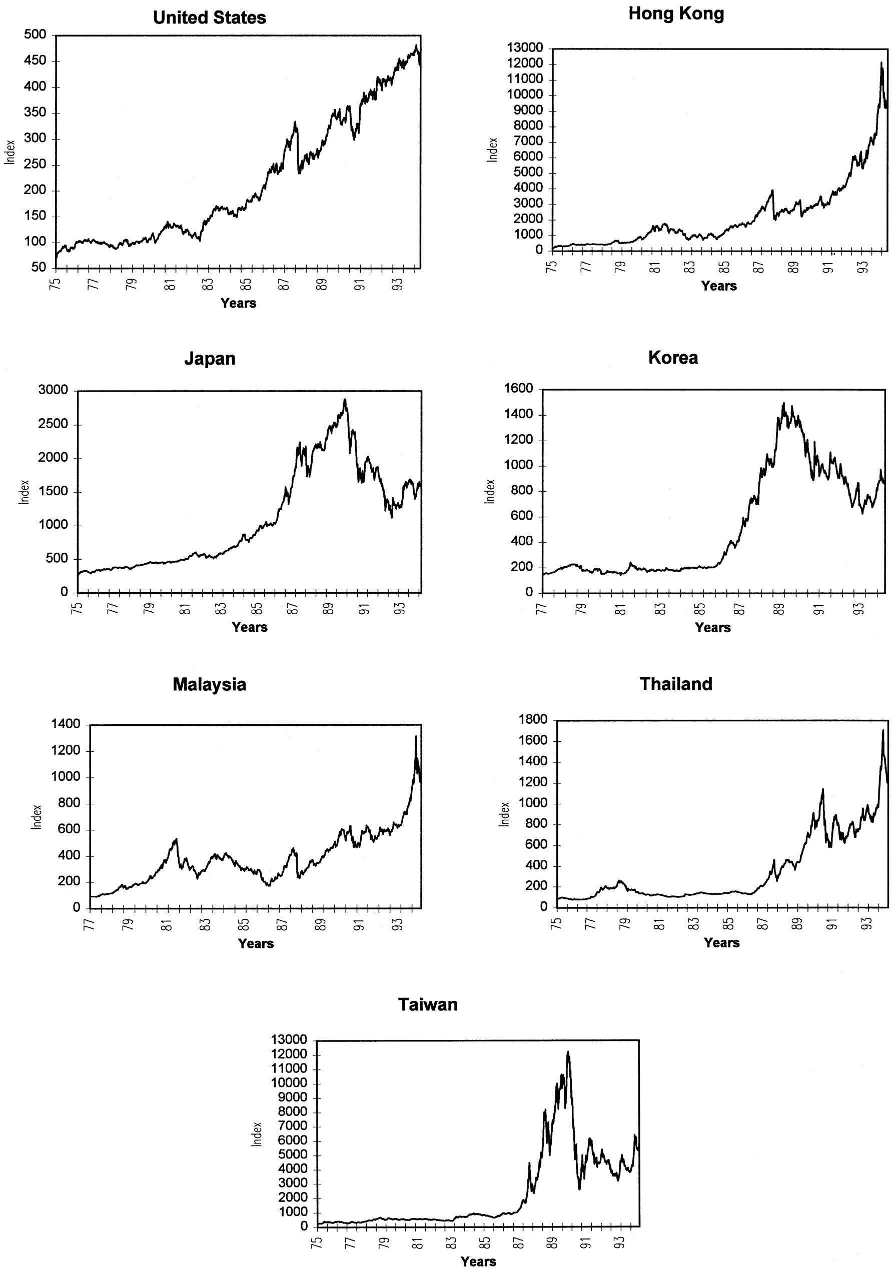

Fig. 1. Weekly stock index levels for U.S. and six Asian markets (January 1975–April 1994).

than the U.S. (Japan being the exception), with Hong Kong having the highest mean return (see Tables 1 and 2). All six Asian markets are more volatile than the U.S., with Taiwan having both the highest monthly and weekly standard deviations. The relatively high volatility in these Asian markets may be one reason why practitioners and the popular press generally believe that Asian markets contain bubbles. The rational speculative bubble model implies negative skewness in returns. For the monthly returns in Table 1, the markets generally have significant negative skewness, although South Korea exhibits positive skewness and Taiwan's negative skewness is not statistically significant. Consistent with the presence of bubbles, all seven of the weekly series (see Table 2) exhibit significant negative skewness. Also, consistent with the mixing of distributions associated with bubbles (higher and higher standard deviations as the bubble grows), the monthly and weekly return series for all seven countries are leptokurtic.

The rational speculative bubble model implies autocorrelation in returns because returns tend to be positive as the bubble grows. In Table 1, all countries except South Korea exhibit positive first-order autocorrelation although only Thailand's serial correlation is statistically significant. For weekly returns, Hong Kong, Malaysia, Thailand, and Taiwan have significant positive autocorrelation. [10] Overall, the consistent evidence of kurtosis and the mixed evidence of skewness and autocorrelation point to the potential for bubbles. However, such descriptive statistics may be driven by factors unrelated to bubbles.

4. Duration dependence tests

McQueen and Thorley (1994) duration dependence tests require that returns are transformed into series of run lengths on positive and negative observed abnormal returns. Formally, the data consist of a set, S_{T}, of T observations on the random run length, I. A run is defined as a sequence of abnormal returns of the same sign. Thus, I is a positive valued discrete random variable generated by some discrete density function, $f_i \equiv \mathrm{Prob}(I = i)$, and corresponding cumulative density function, $F_i \equiv \mathrm{Prob}(I < i)$. Define N_i as the count of completed runs of length i in the sample. [11] The density function version of the log likelihood is

$$L(\theta|S_T) = \sum_{i=1}^{\infty} N_i \ln f_i, \tag{9}$$

[10] To detect seasonalities, we report autocorrelation coefficients for twelve months (turn-of-the-year effects) and five weeks (turn-of-the-month effects).

[11] A partial run may occur at the beginning (left-censored) and at the end (right-censored) of the time period being examined. The tests derived by McQueen and Thorley (1994) and performed later in this section account for partial as well as completed runs.

where θ is a vector of parameters. The hazard function, $h_i \equiv \mathrm{Prob}(I = i | I \geqslant i)$, represents the probability that a run ends at i, given that it lasts at least until i. A hazard function specification describes data in terms of conditional probabilities in contrast to the density function specification which focuses on unconditional probabilities. The choice between a hazard and density specification depends on the economic question of interest. This article questions whether the probability that a return run continues depends on the length of the run; consequently, the hazard specification is appropriate. [12] The hazard function is related to the density function by

$$h_i = \frac{f_i}{(1 - F_i)} \quad \text{and} \quad f_i = h_i \prod_{j=1}^{i-1} (1 - h_j). \tag{10}$$

Using the relationships in Eq. (10), the hazard function version of the log likelihood is

$$L(\theta | S_T) = \sum_{i=1}^{\infty} N_i \ln h_i + M_i \ln(1 - h_i), \tag{11}$$

where M_i is the count of runs with a length greater than i.

To perform tests of duration dependence, a functional form must be chosen for the hazard function. Similar to McDonald et al. (1993), the log–logistic functional form is used,

$$h_i = \frac{1}{1 + e^{-(\alpha + \beta \ln i)}}. \tag{12}$$

The log–logistic function transforms the unbounded range of $\alpha + \beta \ln(i)$ into the (0, 1) space of h_i, the conditional probability of ending a run. The null hypothesis of no bubbles implies that the probability of a run ending is independent of the prior returns or that positive and negative abnormal returns are random. In terms of the model, the null hypothesis of no duration dependence is that $\beta = 0$ (constant hazard rate or geometric density function). The bubble alternative suggests that the probability of a positive run ending should decrease with the run length or that the value of the slope parameter, β, is negative (decreasing hazard rates). Tests are performed by substituting Eq. (12) into Eq. (11) and maximizing the log likelihood function with respect to α and β. The likelihood ratio test (LRT) of $\beta = 0$ is asymptotically distributed χ^2 with one degree of freedom.

Tables 3 and 4 report the maximum likelihood estimates of the log–logistic function parameters α and β for monthly and weekly returns, respectively. For

[12] Hazard rate tests of duration dependence have been used in other business applications, such as whether the probability of getting a job, resolving a strike, or ending a recession depends on the length of the unemployment spell, the strike, or the recession, respectively (see Kiefer, 1988). Hazard or conditional failure functions are also common in natural sciences (life testing) and engineering (reliability testing). (See, for example, Barlow and Proschan, 1975; Hahn and Shapiro, 1968).

Table 3
Tests of duration dependence for runs of monthly excess indexes returns

Country	Hong Kong	Japan	South Korea	Malaysia	Thailand	Taiwan	Joint tests: Six Asian	Joint tests: Four Asian	USA
Number of returns									
Positive	117	115	99	112	102	105	650	421	119
Negative	114	116	108	95	126	126	685	476	112
Total	231	231	207	207	228	231	1,335	897	231
Positive run test									
α	0.053	−0.020	0.068	−0.144	−0.081	−0.187			−0.065
β	−0.105	0.004	−0.359	−0.031	−0.377	0.443			0.348
LRT	0.1	0.0	1.2	0.0	1.6	1.4	4.3	3.2	0.9
(p-value)	(0.75)	(1.00)	(0.27)	(1.00)	(0.21)	(0.24)	(0.64)	(0.52)	(0.34)
Negative run test									
α	−0.171	−0.145	−0.633	0.477	−0.707	−0.137			0.139
β	0.517	0.221	0.566	−0.639	0.031	−0.272			0.184
LRT	1.9	0.4	2.7	3.1	0.0	1.1	9.2	4.2	0.2
(p-value)	(0.17)	(0.53)	(0.10)	(0.08)	(1.00)	(0.29)	(0.16)	(0.38)	(0.65)

Positive and negative excess returns are defined relative to the in-sample mean. A run of length i is a sequence of i excess returns of the same sign. The hazard rate, $h_i = N_i/(M_i + N_i)$, represents the conditional probability that a run ends at i, given that it lasts until i, where N_i is the count of runs of length i and M_i is the count of runs with a length greater than i. The log–logistic function is $h_i = 1/(1+e^{-(\alpha+\beta \ln i)})$ and parameters are estimated using the log-likelihood function in Eq. (11). The LRT (likelihood ratio test) of the null hypothesis, H_1: $\beta = 0$, of no duration dependence (constant hazard rate) is asymptotically distributed χ^2 with k degrees of freedom, where k is the number of countries included in the test (i.e. $k = 1$ for the single country tests). p-value is the marginal significance level, which is the probability of obtaining that value of the LRT or higher under the null hypothesis. The 'Six Asian' results represent a joint test, aggregating the run counts across all six Asian countries. The 'Four Asian' results aggregate the run counts from Japan, South Korea, Thailand and Taiwan; Hong Kong and Malaysia are excluded because of their high correlation with Thailand.Tests of duration dependence for runs of monthly excess indexes returns

the monthly returns, positive and negative excess returns are defined relative to the in-sample mean. Consistent with the rational bubble model prediction, the runs of *positive* excess returns yield point estimates of β that are negative in Hong Kong, South Korea, Malaysia and Thailand, but none of the coefficients are significant. On the other hand, Malaysia has significant duration dependence in runs of *negative* excess returns. Since rational bubbles cannot be negative, the evidence of duration dependence in Malaysia must be driven by chance or some other deviation from serially independent returns such as fads, but not by rational bubbles. [13]

After reporting individual country-by-country tests, Tables 3 and 4 also report joint tests, first over all six Asian countries, then over Japan, South Korea,

Table 4
Tests of duration dependence for run of weekly excess indexes returns

Country	Hong Kong	Japan	South Korea	Malaysia	Thailand	Taiwan	Joint tests Six Asian	Joint tests Four Asian	USA
Number of returns									
Positive	523	494	437	466	477	496	2,893	1,904	520
Negative	476	499	449	425	508	487	2,844	1,943	483
Total	999	993	886	891	985	983	5,737	3,847	1,003
Positive run test									
α	−0.235	0.000	−0.068	−0.137	0.137	−0.035			0.022
β	0.232	−0.099	−0.052	−0.054	−0.278	−0.056			−0.142
LRT	2.3	0.4	0.1	0.1	3.4	0.1	6.4	4.0	0.9
(p-value)	(0.13)	(0.52)	(0.74)	(0.72)	(0.06)	(0.71)	(0.38)	(0.41)	(0.34)
Negative run test									
α	0.028	−0.219	−0.302	0.131	−0.167	−0.250			0.077
β	0.101	0.288	0.285	−0.232	0.058	0.457			0.039
LRT	0.3	3.2	2.9	2.0	0.1	7.1	15.6	13.3	0.1
(p-value)	(0.56)	(0.08)	(0.09)	(0.16)	(0.70)	(0.01)	(0.02)	(0.01)	(0.81)

Positive and negative excess returns are defined relative to the sign of the error from a weekly AR(4) model. A run of length i is a sequence of i excess returns of the same sign. The hazard rate, $h_i = N_i/(M_i + N_i)$, represents the conditional probability that a run ends at i, given that it lasts until i, where N_i is the count of runs of length i and M_i is the count of runs with a length greater than i. The log–logistic function is $h_i = 1/(1+e^{-(\alpha+\beta \ln i)})$ and parameters are estimated using the log-likelihood function in Eq. (11). The LRT (likelihood ratio test) of the null hypothesis, H_1: $\beta = 0$, of no duration dependence (constant hazard rate) is asymptotically distributed χ^2 with k degrees of freedom where k is the number of countries included in the test (i.e. $k = 1$ for the single country tests). p-value is the marginal significance level, which is the probability of obtaining that value of the LRT or higher under the null hypothesis. The 'Six Asian' results represent a joint test, aggregating the run counts across all six Asian countries. The 'Four Asian' results aggregate the run counts from Japan, South Korea, Thailand and Taiwan; Hong Kong and Malaysia are excluded because of their high correlation with Thailand.

Thailand and Taiwan. The joint tests are conducted by aggregating the run counts from several countries into one data set. This data set is then tested against the null hypothesis of no duration dependence ($\beta = 0$ for positive run counts), where the alternative hypothesis allows for separate parameter estimates for each country within the set. Thus, the joint LRT statistic is simply the sum of the LRT values for the single country tests. However, the joint LRT statistic is distributed χ^2 with

[13] McQueen and Thorley (1994) find significant evidence of duration dependence in the U.S. market using monthly returns starting in 1947. One explanation for the different conclusions is that the shorter 1975 to 1994 sample period limits the power of the test.

k degrees of freedom where k is the number of countries in the set (i.e. the number of constraints imposed by the null hypothesis.)

Aggregating run counts across markets in the joint tests increases the sample size and thus adds power, however, a caveat is in order. The six Asian markets are clearly not independent and the joint test may constitute a form of ‘double counting’. For example, after a long run-up in prices during 1993, Hong Kong, Malaysia and Thailand all experienced historic drops starting on either the 4th or 5th of January, 1994. A joint test over all six Asian markets counts this possible bubble episode three times when it was likely just one event. The bias introduced by treating dependent data sets as if they were independent, or ‘double counting’, is to overstate the statistical significance of the estimated duration dependence parameter (i.e. the standard error of β is biased downward.) The size of the bias depends on how interdependent the separate country data sets are. However, even with the bias, the monthly results for all six countries combined fails to reject the no rational bubble hypothesis (LRT = 4.3, p-value = 0.64). One crude correction for the obvious dependence surrounding the simultaneous drops in Hong Kong, Malaysia and Thailand, is to exclude two of these markets before performing the joint test. [14]

Results labeled ‘Four Asian’ exclude Hong Kong and Malaysia. Thailand is included because it has the strongest (although insignificant) individual country evidence of rational bubbles. Thus, the ‘Four Asian’ results are biased toward rejecting the null because of (1) the dependence across the four Asian markets and (2) the deliberate inclusion of Thailand. Despite these biases, the ‘Four Asian’ monthly joint tests fail to reject the constant hazard rate hypothesis for runs of above average returns (p-value = 0.52).

Using weekly returns yields more observations than the monthly returns although weekly tests may miss bubbles due to noise if, as believed by the popular press, bubbles actually build up over periods of months or even years. Weekly runs are created using the sign of the error term from an AR(4) model of weekly returns. The AR(4) model, rather than the in-sample-mean, is used to focus on any bubble-based predictability above and beyond the predictability from other causes of autocorrelation such as nonsynchronous trading. For the runs of above average returns, only Thailand has a significantly negative β indicating that, consistent with the rational speculative bubbles hypothesis, the probability of ending a run of

[14] A more formal correction for dependence across Asian markets would: first, regress each country’s returns on the remaining five markets’ returns, second, create runs based on the orthogonal errors, and third, aggregate the run counts and test for duration dependence. This correction would allow for unbiased joint tests for country specific or country idiosyncratic bubbles. However, such a joint test would be unable, by construction, to detect bubbles simultaneously present in multiple markets. Alternatively, future research could test for common and specific country bubbles using a methodology related to the test of Engle and Hylleberg (1996) for common seasonal unemployment features across several countries.

positive excess returns decreases with the length of the run. The joint tests on all six and on the four selected Asian countries do not provide significant evidence against the null hypothesis. Three countries, Japan, South Korea and Taiwan, exhibit duration dependence in runs of below average returns. Specifically, the likelihood that a run of negative excess returns will be interrupted increases as the run grows longer. The joint tests also reject serial independence for runs of negative excess returns. This is a clear deviation from serially independent returns; however, the pattern cannot be caused by rational bubbles which must be positive.

Although the monthly tests may lack power due to short samples and the weekly samples may miss bubbles due to noise, the results on the duration tests yield only one case of duration dependence consistent with rational bubbles: the weekly runs of above average returns in Thailand. This one case suggests an apparent trading rule when a bubble exists: buy stock after observing several weeks with higher than expected returns since a below average return then becomes less likely. However, if the bubbles are *rational*, then the trading rule will fail because the expected value of the excess return remains zero. The conditional probability of an above average return is high because there is a strong likelihood of receiving a small, positive excess return if the bubble continues. However, this likely positive excess return is offset by a small chance of receiving a large negative excess return if the bubble crashes.

Table 5 tests the rationality of the Thailand market, along with the other markets, using the mean and skewness of returns conditional on the prior number of consecutive above-average returns. The rational speculative bubbles model implies that the conditional mean return is constant, even though the probability of a below-average return decreases. This is possible because of the crashes which should cause the conditional skewness measure to become more negative as the number of prior consecutive positive excess returns increases. Hypothesis H_2 states that the mean abnormal return conditional on prior runs between 1 and 4 weeks long, $\hat{\mu}_{1-4}$, is different from the mean abnormal return conditional on prior runs of 5 or more positive abnormal returns, $\hat{\mu}_{5+}$.[15] Consistent with rational bubbles in Thailand, H_2 cannot be rejected at traditional levels of significance, showing the failure of the apparent trading rule. However, the null hypothesis of constant conditional skewness, H_3: $\mathrm{SKEW}_{1-4} = \mathrm{SKEW}_{5+}$, is rejected (*p*-value less than 0.005), suggesting that the degree of negative skewness is greater after conditioning on prior runs of above average returns of 5 or more. Thus, consistent with rational speculative bubbles, as the prior run of positive abnormal returns grows, the conditional probability of observing a negative abnormal return decreases and the conditional skewness becomes more negative so that the condi-

[15] The use of 5 weeks in the conditional mean, H_2, and skewness, H_3, tests is arbitrary. Similar results are obtained using alternative cutoff rates, although the test results become unstable when higher run length cutoffs (10 weeks, for example) are used because few runs greater than 10 exist.

Table 5
Tests of conditional skewness in weekly returns

Country	Hong Kong	Japan	South Korea	Malaysia	Thailand	Taiwan	USA
Positive runs of length 1 to 4 weeks							
N_{1-4}	476	458	396	411	407	430	483
$\hat{\mu}_{1-4}$	0.0068	0.0023	0.0026	0.0053	0.0077	0.0082	0.0015
(SE)	(0.0017)	(0.0010)	(0.0016)	(0.0014)	(0.0015)	(0.0022)	(0.0009)
SKEW_{1-4}	−0.21	−0.42	−0.79	−0.68	0.32	−0.04	0.04
(SE)	(0.11)	(0.11)	(0.12)	(0.12)	(0.12)	(0.12)	(0.11)
Positive runs of length 5 or more weeks							
N_{5+}	41	46	40	64	60	67	40
$\hat{\mu}_{5+}$	−0.0036	0.0032	0.0059	0.0097	0.0051	0.0132	0.0003
(SE)	(0.0062)	(0.0030)	(0.0056)	(0.0049)	(0.0055)	(0.0067)	(0.0021)
SKEW_{5+}	−1.02	−0.21	−0.18	−2.68	−1.44	0.35	0.55
(SE)	(0.37)	(0.35)	(0.37)	(0.30)	(0.31)	(0.29)	(0.37)
H_2: $\mu_{1-4} = \mu_{5+}$							
t-stat	1.6	0.3	0.6	0.9	0.5	0.7	0.5
(*p*-value)	(0.11)	(0.76)	(0.55)	(0.37)	(0.62)	(0.48)	(0.62)
H_3: $\text{SKEW}_{1-4} = \text{SKEW}_{5+}$							
t-stat	2.1	0.6	1.6	6.2	5.3	1.2	1.3
(*p*-value)	(0.04)	(0.55)	(0.11)	(0.00)	(0.00)	(0.23)	(0.19)

N_{1-4} is the number of runs satisfying the condition of having between one and four consecutive prior positive excess returns. N_{5+} is the number of runs satisfying the condition of having five or more consecutive prior positive excess returns. H_2 tests whether the mean excess return conditional on having one to four consecutive prior positive excess returns, $\hat{\mu}_{1-4}$, equals the mean excess return conditional on having five or more consecutive prior positive excess returns, $\hat{\mu}_{5+}$. H_3 similarly tests for stability in the skewness coefficient.

tional mean abnormal return remains constant. In other words, the duration dependence and conditional skewness tests yield only one case where the evidence is consistent with the presence of rational speculative bubbles: weekly returns in the Thai market. [16]

5. Anecdotal evidence

In the previous sections, realized returns are examined for bubble footprints (autocorrelation, skewness, kurtosis, duration dependence, and conditional skew-

[16] Interestingly, the Hong Kong and Malaysia markets exhibit higher degrees of skewness in runs of above average returns greater than 5 weeks long. The lack of duration dependence in these markets (see Table 4), suggests that this conditional skewness is driven by something other than rational speculative bubbles, such as irrational bubbles.

ness) using all of the time-series data. By using all the data, these tests avoid the 'data snooping' problems (see Lo and MacKinlay, 1990b) associated with examining periods around local index peaks suspected of being bubbles. However, if each market only experienced one bubble, using all the data would result in a powerless test. Consequently, in this section, tests are preformed on return periods alleged to contain bubbles. That is, the tests are performed after 'snooping' at the data and, thus must be considered anecdotal but similar in nature to Santoni (1987), Hardouvelis (1988) and Miller (1990). Interestingly, even though the 'snooping' biases these anecdotal tests towards *finding* bubbles, we do *not* find evidence that completely conforms to the predictions of the *rational* speculative bubbles models.

Before performing the anecdotal tests, we briefly compare, in Table 6, some Asian market characteristics as of 1993, intended to indicate the level of development and possibly the susceptibility to bubbles. Japan has the largest stock market in terms of market capitalization and number of stocks listed in the stock exchanges – the number of stocks is more than three times the number in other countries and the capitalization is more than ten times. The daily turnover gives an indication of the stock market activity. Taiwan, with a capitalization only 3% of Japan's, has daily turnover almost 40% of Japan's, indicating that the stock market activity in Taiwan may be relatively speculative. The transaction costs (including commission costs and stamp duty) gives an indication of typical charges on a transaction of US $100,000. Investors in Hong Kong, Taiwan and Thailand enjoy a relatively low trading cost (less than 0.5%). Low transaction costs and the

Table 6
Stock market statistics and capital flow restrictions for the Asian markets as of 1993

Country	Hong Kong	Japan	South Korea	Malaysia	Taiwan	Thailand
Stock market statistics						
Capitalization (US$)	$298bn	$2,849bn	$105bn	$174bn	$95bn	$59bn
No. of domestic stocks	443	1651	688	321	256	320
Daily turnover (US$)	$580nm	$3240m	$800m	$480m	$1200m	$290m
Transaction costs (%)	0.4	1.15	0.6	1.0	0.44	0.5
Index futures	yes	yes	no[b]	no[b]	no	no
Futures beginning date	6/86	9/88	—	—	—	—
Capital market restriction						
Exchange control	no	no	some	some	some	some
Restrictions on foreign Participation	no	no	yes	yes	yes	yes
–aggregate limit	—	—	10%	30%	10%	49%
–individual limit	—	—	3%	—	5%	—

[a] Information is based on Asia-Pacific Securities Markets, ch. 2, Matthew Harrison, Longman, Hong Kong, 1994.
[b] Malaysia instituted trading on index futures in December of 1995 and South Korea in May of 1996, after the end of our sample period.

existence of index futures could both discourage bubbles by lowering the cost of arbitrage. Only Hong Kong (July 1986) and Japan (September 1988) had index futures in place before the alleged bubble bursts occurred.

We also report capital market restrictions based on the extent of foreign exchange control and restrictions of foreign investors buying domestic stocks. Hong Kong and Japan exert no control on foreign exchange; the conversion of currency is free of restrictions. In the other countries, the repatriation of a large amount of foreign capital may require approval. Neither Hong Kong nor Japan limits foreign ownership of domestic corporations except for a small number of strategically important companies. For the other Asian countries, foreign investors are permitted to acquire domestic stocks, although limits are placed on aggregate holdings as well as individual holdings. The most restrictive limits are in South Korea and Taiwan, which have an aggregate limit of 10% foreign investment in each stock. In fact, for both countries, prior to 1990, direct foreign investment in listed securities was not permitted. Foreigners could acquire securities only indirectly through a mutual fund.

To choose episodes of possible speculative bubbles for our anecdotal tests, the Dow Jones Text-Search Service was searched for reports which alleged the occurrence of speculative bubbles in any of these six Asian stock markets. The following three suspected bubble periods involving five countries (Japan, Taiwan, Hong Kong, Malaysia, and Thailand) were identified: [17]

1. Japan's stock market from 1986 to 1989. The Japanese stock market rose dramatically from 1986 to 1989. The giant utility NTT rose to an historic PE of 333 in March 1988. At its peak in December 1989, the Nikkei index stood at 38,916 and the stock market capitalization was US $4.4 trillion. In 1990, however, the Japanese stock market declined sharply. The Nikkei index plunged below 14,300 in August 1992.
2. Taiwan's stock market from 1987 to 1990. Taiwan's stock market boomed during late 1980s. The Taipei Weighted Index gained 120% in 1987, 118% in 1988 and 97% in 1989. The P/E ratio was about eight times that in New York or London. Average daily turnover in 1989 amounted to US $3.4 billion, ranking the Taiwan Stock Exchange as the world's third most active exchange after Tokyo and New York. Market capitalization rose to a peak of US $298 billion, or 186% of GNP, and the average PE ratio reached 56. But in 1990, the stock market plunged. From a peak of 12,495 on 10 February 1990, the Taipei Weighted Index fell to a low of 2,485 on 12 October 1990.
3. Asian stock markets in 1993. Several Asian stock markets rose dramatically in 1993. During 1993, Hong Kong's stock market was up 76.9%, Malaysia's was up 68.3% and Thailand's was up 63.3%. However, in 1994 these markets all tumbled, each losing about 30% of their value in 2 to 3 months.

[17] Appendix A contains excerpts of the reports on these incidents.

Additionally, the U.S. experience in October 1987 is examined. [18] The exact start and end dates of these alleged bubbles is not known and consequently assigned arbitrarily. The bubble ending or peak date is assigned as the local maximum, specifically: December 18, 1989 for Japan, February 12, 1990 for Taiwan, January 4 or 5, 1994 for Hong Kong, Malaysia and Thailand, and October 13, 1987 for the U.S. Beginning dates of 18, 24 and 30 months prior to the local maximum are considered.

If these apparent bubble periods are rational, then they should leave a 'footprint' showing that returns are not only high, but also increasing or 'explosive' during the bubble period. Returns during the alleged bubble period will be high by construction since the crash or burst date is chosen as the local index maximum; that is, chosen after looking at the data. Thus, the interesting bubble 'footprint' is not high returns but higher and higher returns leading up to the local maximum – a testable implication of the bubble model which is not compromised by assigning the crash date ex-post. Fig. 2 displays the logarithms of the daily stock index levels 3 years before and 1 year after the local maximum for these six markets. [19] If returns increase over the bubble period, the slope (change) of logarithms of stock index levels will get steeper as long as the bubble does not burst. This increasing return 'footprint' seems visually apparent for the Malaysia and Thailand episodes and perhaps for the Hong Kong episode as well.

To formally investigate whether returns increase during the bubble period, returns are regressed on the number of months since the beginning of the bubble period using the specifications in Eqs. (13) and (14):

$$\text{Model 1:} \quad R_t = \alpha + \beta_t \tau_t + \epsilon_t, \tag{13}$$

$$\text{Model 2:} \quad R_t = \alpha + \beta_1 \tau_1 + \beta_2 R_{\mathrm{US},t} + \epsilon_t, \tag{14}$$

where τ_t is the number of periods (months or weeks) since the beginning of the bubble and $R_{\mathrm{US},t}$ is the U.S. market return. The U.S. market return is included in the second specification to reduce fundamental noise. One source of fundamental value changes is the global market factor, represented by the S&P 500 return in the Asian indexes' regressions. The alternative hypothesis (bubbles) of increasing returns is that $\beta_1 > 0$. Test results are reported in Tables 7 and 8 for monthly and weekly returns, respectively.

[18] Just as Garber (1990) gives fundamental explanations for the historical price drops in assets such as tulips, many researchers tie the declines in the three Asian markets and the October 1987 market to changing fundamentals. See for example, the Schwartz and Ziemba (1991) discussion of the Japanese stock market and the Miller (1990) discussion of the U.S. market.

[19] The local maximum for Hong Kong, Malaysia and Thailand occurs in the first week of January 1994 and yet the sample period is through April 1994. Consequently, the stock index graphs include additional data through December 1994 collected from the Bloomberg database. The graphs include index values for all business days from 3 years before to 1 year after the local maximum. Because of Saturday trading and varying numbers of holidays, each graph illustrates a different number of trading days although they all have the same total of 4 years.

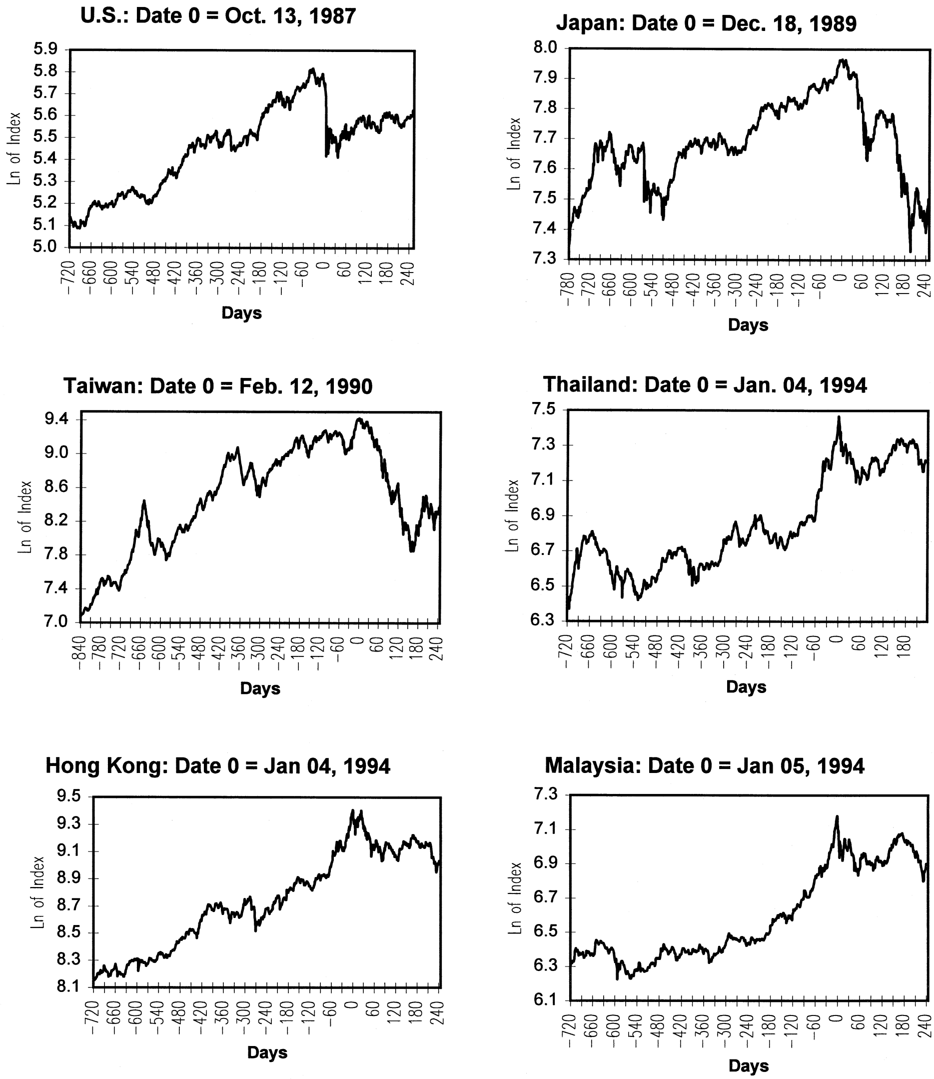

Fig. 2. Logarithms of daily stock index levels for U.S. and Asian markets around the peak of the suspected bubble period.

Point estimates of the β_1 coefficients in Table 7 are actually negative in six out of twelve cases for the alleged Japan and Taiwan bubbles (two different models and three different starting periods) although the estimates are significantly positive in Japan's 24-month results and the 30-month results using model 2. The weekly regression in Table 8 yields insignificant positive and negative estimates of the β_1 coefficients. The returns prior to the alleged Japan and Taiwan bursts are

Table 7
Tests for increasing monthly returns during alleged bubble periods. Model 1: $R_t = \alpha + \beta_1 \tau_t + \epsilon_t$. Model 2: $R_t = \alpha + \beta_1 \tau_t + \beta_2 R_{US,t} + \epsilon_t$

Country	Month of local max.	Coeff.	18-month period Model 1	18-month period Model 2	24-month period Model 1	24-month period Model 2	30-month period Model 1	30-month period Model 2
USA	Sept. 87	$\beta_1(\times 10^{-2})$	−0.664	NA	−0.367	NA	−0.197	NA
			(3.48)		(2.79)		(2.50)	
Japan	Dec. 89	$\beta_1(\times 10^{-2})$	−0.025	−0.009	0.095	0.076	0.133	0.076
			(0.58)	(−0.22)	(2.20)	(1.83)	(1.46)	(1.83)
		β_2		0.394		0.503		0.503
				(2.87)		(3.65)		(3.65)
Taiwan	Jan. 90	$\beta_1(\times 10^{-2})$	0.252	0.077	−0.166	−0.266	−0.117	−0.266
			(1.25)	(0.48)	(−0.58)	(−0.90)	(−0.80)	(−0.90)
		β_2		−0.730		−1.214		−1.214
				(−1.86)		(−1.81)		(−1.81)
Hong Kong	Dec. 93	$\beta_1(\times 10^{-2})$	0.785	0.857	0.410	0.425	0.214	0.425
			(8.01)	(7.09)	(3.97)	(4.79)	(2.21)	(4.79)
		β_2		1.140		0.714		0.714
				(1.79)		(1.25)		(1.25)
Malaysia	Dec. 90	$\beta_1(\times 10^{-2})$	0.885	0.877	0.608	0.611	0.344	0.611
			(10.25)	(9.64)	(8.44)	(8.28)	(5.29)	(8.28)
		β_2		−0.113		0.177		0.177
				(−0.16)		(0.37)		(0.37)
Thailand	Dec. 93	$\beta_1(\times 10^{-2})$	1.128	1.160	0.729	0.724	0.350	0.724
			(8.88)	(8.94)	(5.21)	(5.19)	(3.16)	(5.19)
		β_2		0.523		−0.272		−0.272
				(0.94)		(−0.58)		(−0.58)
Joint tests, $\beta_1 = 0$								
Five Asian		p-value	[0.105]	[0.147]	[0.028]	[0.046]	[0.087]	[0.139]
Three Asian		p-value	[0.248]	[0.222]	[0.105]	[0.119]	[0.246]	[0.421]

Regression of returns at month t (R_t) for the Asian stock markets during suspected bubble periods, on the number of months (τ) since the beginning of the bubble period, with and without controlling for U.S. market returns ($R_{US,t}$). The bubble periods are identified as the 18-, 24- or 30-month period prior to the local maximum of the stock index levels during episodes of the speculative bubbles. The month of the local maximum is based on month-end values. T-statistics, in the parentheses, are based on standard errors adjusted for autocorrelation and heteroskedasticity using Hansen's (1982) correction. The 'Five Asian' results represent p-values, in brackets, of a joint test that $\beta_1 = 0$ in all five markets and the 'Three Asian' results are for a joint test of $\beta_1 = 0$ in Japan, Taiwan and Thailand. The joint tests allow for cross-market correlation using the seemingly unrelated regression technique.

high but generally do not exhibit the increasing returns characteristic of rational bubbles.

The bursts associated with the Japan and Taiwan episodes are relatively slow, also uncharacteristic of rational bubbles. Although the lack of a practical definition of 'instantaneous' precludes a statistical test, a description of the market decline in

Table 8
Tests for increasing weekly returns during alleged bubble periods. Model 1: $R_t = \alpha + \beta_1 \tau_t + \epsilon_t$. Model 2: $R_t = \alpha + \beta_1 \tau_t + \beta_2 \mathrm{R}_{\mathrm{US},t} + \epsilon_t$

Country	Week of local max.	Coeff.	18-month period		24-month period		30-month period	
			Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
USA	Sept. 87	$\beta_1(\times 10^{-2})$	−0.029	NA	−0.021	NA	−0.012	NA
			(−2.47)		(−3.31)		(−2.48)	
Japan	Dec. 89	$\beta_1(\times 10^{-2})$	0.005	0.005	−0.003	−0.003	0.005	0.001
			(0.79)	(0.76)	(−0.54)	(−0.72)	(0.82)	(0.29)
		β_2		0.139		0.197		0.472
				(1.20)		(2.70)		(5.58)
Taiwan	Jan. 90	$\beta_1(\times 10^{-2})$	0.007	0.003	−0.020	−0.020	−0.010	−0.013
			(0.22)	(0.10)	(−1.16)	(−1.18)	(−0.47)	(−0.72)
		β_2		−0.780		−0.144		0.414
				(−2.20)		(−0.52)		(1.49)
Hong Kong	Dec. 93	$\beta_1(\times 10^{-2})$	0.043	0.043	0.012	0.011	0.010	0.010
			(3.00)	(3.00)	(1.35)	(1.27)	(1.76)	(1.82)
		β_2		0.388		0.379		0.299
				(1.36)		(1.95)		(2.24)
Malaysia	Dec. 93	$\beta_1(\times 10^{-2})$	0.037	0.037	0.027	0.027	0.022	0.022
			(3.75)	(3.76)	(4.54)	(4.52)	(4.50)	(4.59)
		β_2		0.011		0.010		0.155
				(0.66)		(0.08)		(1.38)
Thailand	Dec. 93	$\beta_1(\times 10^{-2})$	0.036	0.036	0.025	0.026	0.019	0.019
			(2.40)	(2.43)	(2.39)	(2.55)	(2.53)	(2.50)
		β_2		−0.332		−0.412		−0.244
				(−1.33)		(−2.20)		(−1.71)
Joint tests, $\beta_1 = 0$								
Five Asian		p-value	[0.047]	[0.055]	[0.003]	[0.004]	[0.001]	[0.002]
Three Asian		p-value	[0.253]	[0.310]	[0.153]	[0.138]	[0.062]	[0.071]

Regression of returns at week t (R_t) for the U.S. and Asian stock markets during suspected bubble periods, on the number of months (τ) since the beginning of the bubble period, with and without controlling for U.S. market returns ($R_{\mathrm{US},t}$). The bubble periods are identified as the 18-, 24- or 30-month period prior to (inclusive) the monthly local maximum of the stock index levels during episodes of the speculative bubbles. The week of the local maximum is based on Wednesday closing prices. T-statistics, in the parentheses, are based on standard errors adjusted for autocorrelation and heteroskedasticity using the Hansen (1982) correction. The 'Five Asian' results are p-values, in brackets, of a joint test that $\beta_1 = 0$ in all five markets and the 'Three Asian' results are for a joint test of $\beta_1 = 0$ in Japan, Taiwan, and Thailand. The joint tests allow for cross-market correlation using the seemingly unrelated regression technique.

Japan and Taiwan is interesting. The TOPIX index in Japan peaked at 2,884.8 on 18 December 1989 and then took over two-and-a-half years to lose 62% of its value and fall to 1,102.5 on 18 August 1992, losing the first 25% in 60 trading days. The Taipei index of Taiwan reached a high of 12,424.53 on 12 February 1990 before falling 79% over 8 months to a low of 2,560.47 on 1 October 1990, losing the first 25% in 44 trading days. The lack of increasing returns prior to the crash and the slowness of the alleged burst suggest that even though the Japan and Taiwan markets exhibited a run-up in price followed by a large drop, they do not conform to the theory of rational speculative bubbles. Perhaps the run-ups and drops occurred because of fundamental value changes or were the results of irrational bubbles.

For Hong Kong, Malaysia and Thailand the β_1 coefficients in Tables 7 and 8 are generally significantly greater than zero, indicating increasing returns, consistent with rational bubbles. On the crash side of the bubbles, the evidence is less impressive. For example, all three markets lost over 10% of their value in the first six trading days, although it took 42, 45 and 48 trading days, respectively, before the markets lost 25% of their value. Furthermore, the Hang Seng index fell for a week, then actually climbed for several weeks nearly back to its maximum level before falling a second time. Thus, these three Asian markets appear to have had explosive returns as required by the rational bubbles theory, but their crashes do not conform to the theoretically instantaneous crash.

The last two rows of Tables 7 and 8 report a joint test for any time dependence in returns prior to all five alleged Asian bubbles and then the subset of three alleged Asian bubbles (again excluding Hong Kong and Malaysia). The reported p-values are for a joint test that $\beta_1 = 0$ in all five or three markets. The tests are accomplished by stacking the country-by-country regressions into one regression. The joint estimation allows for correlated errors across markets using the seemingly unrelated regression technique. The Five Asian joint tests generally reject the null hypothesis and the rejection is particularly strong in the weekly results in Table 8. Obviously, this rejection is driven by strong individual country results in Hong Kong, Malaysia and Thailand. Counting the Hong Kong, Malaysia and Thailand episode as one event rather than three (Three Asian row) yields much less evidence of explosive bubbles.

The October 1987 U.S. experience exhibited characteristics just opposite to the January 1993 Asian experience. The run-up was not explosive; rather, it gradually died out (see negative β_1 estimates in Tables 7 and 8) but the crash was relatively quick, with the S&P losing over 25% of its value in just four trading days (from a Tuesday, 13 October 1989 index value of 314.52 to a 224.84 value on Monday, 19 October).

The anecdotal evidence suggests that the Japan and Taiwan markets had neither increasing returns before the crash nor a quick drop after the alleged burst. The Hong Kong, Malaysia and Thailand markets had only the former characteristic and the U.S. alleged bubble had only the latter.

As with all hypothesis tests, the inability to reject the null hypothesis (no bubbles) should not lead to the rejection of the alternative hypothesis (rational speculative bubbles). In the particular case of bubbles in the Asian and U.S. stock markets, several points need to temper our evidence suggesting the lack of bubbles. First, both categories of bubble tests will lack power to detect bubbles if only one bubble occurred in each market during the sample period. Second, the market returns are compared with the theoretic characteristics of one specific rational speculative bubble model, albeit the most common model in the literature. Future research using more general rational bubble models or more powerful statistical tests may yet find evidence of rational bubbles in Asian markets.

6. Conclusions

Without defining terms or performing formal tests, the popular press has been willing to ascribe large drops in the stock market indexes of Asian countries to the bursting of bubbles. This article examines monthly and weekly stock market returns of six Asian stock markets from January 1975 to April 1994 (Hong Kong, Japan, South Korea, Malaysia, Thailand and Taiwan along with the U.S. market) for evidence of rational speculative bubbles. The returns are examined for positive autocorrelation, negative skewness and leptokurtosis, generic characteristics of rational speculative bubbles. Then, the returns are examined for two more specific testable implications of the rational speculative bubbles model since autocorrelation, skewness and kurtosis could be the result of changes in fundamental value. The first category of tests are for duration dependence (decreasing hazard rates) and conditional negative skewness in runs of positive returns, following McQueen and Thorley (1994). In the second category, specific episodes of apparent bubbles are examined for explosive returns prior to the crash and for crashes that occur rapidly.

None of the seven markets have return characteristics that completely conform to the predictions of the rational speculative bubbles model. Consistent with the presence of rational speculative bubbles, the returns from the seven markets generally exhibited positive autocorrelation, negative skewness and leptokurtosis, although in varying degrees that are not always statistically significant. The seven return series are much less consistent with the presence of bubbles when the duration dependence and the conditional skewness test are used. Only in Thailand’s weekly returns did the probability of a negative return (and the degree of negative skewness) significantly decrease (increase) with the length of the run of positive returns. Finally, anecdotal evidence suggests that the alleged bubbles in Hong Kong, Malaysia and Thailand were explosive (increasing returns prior to the crash), which is consistent with the presence of rational speculative bubbles; however, these markets fell from their peaks over several months, unlike the instantaneous crash predicted by the theory. On the other hand, the October 1987 episode in the U.S. exhibited a relatively quick crash but the returns prior to the crash tapered off slowly, unlike the explosive returns suggested by the bubble theory being tested. Thus, none of the anectodal episodes are found to completely conform to the rational bubbles theory. In conclusion, despite the rhetoric in the popular press, we find at best only marginal empirical support for the existence of rational speculative bubbles in the six Asian markets investigated.

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Appendix A. Excerpts of popular press articles on speculative bubbles in Asian stock markets

A.1. Japan's stock market in 1986–89

''Was the Japanese stock market a speculative bubble that finally burst? For years, many American and other Western analysts warned that the highflying Tokyo stock market was headed for a fall. Despite a seemingly unending string of record peaks, they said, Tokyo share prices weren't justified by basic stock analysis'' (*Wall Street Journal*, 4/3/90).

''Bank of Japan Governor Yasushi Mieno warned that Japan's so-called economic bubbles haven't yet been crushed by the central bank's tight money policy. Although Mieno noted some progress in deflating the bubbles, he warned that loosening policy could cause the problem to return. The central bank governor said the state of the bubble economy must continue to be watched with concern. The term bubble economy usually refers to the explosion in the land, stock and other asset prices that took place during the easy-money period between 1985 and 1989'' (*Wall Street Journal*, 3/29/91).

A.2. Taiwan's stock market in 1987–90

''The fantastic Taiwan stock bubble burst this spring with a loud bang. Or rather, thousands of bubbles burst in a fusillade of loud bangs, week after week, like a string of Chinese firecrackers. The market index, which had soared, impossibly, from the 1,000 mark in 1986 to a high over 12,000 just four months ago, has been cut in half'' (*Barrons*, 6/11/90).

A.3. Asian stock markets in 1993

''The bursting of a speculative loan stock bubble helped end a four-day winning streak for Malaysian shares, as the Kuala Lumpur Composite Index lost 5% or 65.77 points to 1,248.69'' (*Business Times* (Singapore), 1/7/94).

‘‘At this time, most Hong Kong stocks are priced in Spaceville and you are playing with dynamite if you hold stocks during a bubble market. This was amply illustrated by the sharp correction in the Hang Seng Index late last week, when it plunged 1,166.45 points in two days’’ (*South China Morning Post* (Hong Kong), 1/9/94).

‘‘Investors recently got a chilling midwinter reminder that with high returns come high risk. The culprits: those red-hot stock markets of developing countries. From Turkey to Thailand, many of these bourses were overwhelmed by new money in 1993... Most of the damage was in Asia. Malaysia’s stock market plunged 25% in a week; Hong Kong’s fell 17%; Thailand’s sank 18%’’ (*Chicago Tribune*, 2/14/94).

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