Original Article

Rational speculative bubbles in the Asian stock markets: Tests on deterministic explosive bubbles and stochastic explosive root bubbles

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ABSTRACT The standard theory of asset pricing, in which a long-run relationship should exist between stock prices and dividends if there are no deterministic explosive bubbles, assumes the constancy of expected returns. However, the investor's expected returns are more likely to be time varying, which have led to the modification for the tests of rational bubble. One modification is that the tests should be applied to the log levels of stock price and dividend for allowing the detection of the stochastic explosive root bubble, which incorporates the possibility of time-varying expected returns. Accordingly, we test the existence or otherwise of both types of rational bubbles in the Asian stock markets by applying the unit root tests and the cointegration analyses. The empirical results suggest that the rational bubbles exist in the stock markets of Japan, Singapore, Korea, Taiwan, Thailand, Malaysia, Indonesia and Philippine, whereas Hong Kong is found to have no rational bubbles.

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INTRODUCTION

The East Asian region was an amazing and successful economic story. Between 1965 and 1990, the economies of East Asia had grown faster than all other regions of the world, roughly three times as fast as other developing regions and 25 times faster than the Sub-Saharan Africa. Real income per capita had increased more than four times in Japan and in the other Four Tigers (Hong Kong, Korea, Singapore and Taiwan), and more than doubled in the South East Asian newly industrialised economies, including Indonesia, Malaysia and Thailand (Sharma, 1998). Annual GDP growth in the ASEAN Five, that is, Indonesia, Malaysia, the Philippines, Singapore and Thailand, averaged close to 8 per cent over the 1980s. In the 1990s, the growth rates for the East Asia jumped to 9.9 per cent per annum between 1991 and 1997, while the OECD countries recorded an average growth rate of 2.1 per cent per annum for the same period (World Bank, 1993).

However, on 2 July 1997, the famous Asian Crisis erupted publicly, after Thailand's newly appointed finance minister allowed the Thai baht to float freely against the world's currency.[1] A domino effect followed in early July, first with the collapse of the Thai baht and, in quick order, the Malaysian ringgit, the Philippines peso and the Indonesia rupiah (El Kahal, 2001, pp. 16–17). One symptom of the Asian crisis was the turbulences experienced by the Asian stock markets during this period. Before the crisis, the equity markets for Asia-Pacific countries registered high growth rate. Between 1975 and 1994, for example, the South Korean stock market index rose 1604 per cent, Malaysia 1733 per cent and Thailand 1711 per cent (Henderson, 1998). However, after the crisis Thailand, Malaysia, Indonesia and South Korea had seen the dramatic fall in their stock prices. The stock markets of South Korea and Thailand, for example, had fallen 47 per cent and 50 per cent, respectively, since mid-1997 (Fischer, 1998). Nevertheless, not all Asia-Pacific economies have been affected by the crisis in the same way. Hong Kong and Singapore were more resistant to foreign economic contagion than others during the crisis. The Asian crisis also had a relatively light impact on Taiwan.

Japan in the late 1980s also had a similar experience in its economy. Some characteristics of the Japanese experience were analysed by Okina *et al* (2001, pp. 399–403), who define the 4 years from 1987 through 1990 as the 'emergence and expansion of the bubble period'. The first characteristic was that there was a sizable increase in money supply and credit in the bubble period. The growth of money supply (M2+CDs) hit the bottom of 8.3 per cent in the end of 1986, but gradually accelerated afterwards and exceeded 10 per cent in the mid-1987. The growth of credit regarding the funding of the corporate and household sectors rapidly increased from around 1988 and recorded a rate of growth close to 14 per cent on a year-on-year basis in 1989. The second was the overheating of economic activity. During this bubble period, real GDP and industrial production grew at an average annual rate of 5.5 per cent and 7.2 per cent, respectively. However, after the bursting of the bubble, average annual real GDP growth was only 0.8 per cent and industrial production declined 5.2 per cent annually from 1991 through 1993. The final characteristic was that Japan's asset prices exhibited a rapid rise. The asset prices began increasing in 1983, and it was around 1986 when the rise accelerated rapidly, especially stock prices. The Nikkei 225 index hits a peak of 38 915 at the end of 1989, 3.1 times higher than the level at the time of the Plaza Agreement in September 1985 (12 598). Then after the bubble burst in the early 1990s, Japan plunged into a prolonged economic recession. Similarly, its asset prices experienced a long adjustment period, and the stock prices fell sharply to 14 309 in August 1992, more than 60 per cent below the peak.

These economic and financial instabilities have been documented as 'bubble' periods, namely, the Asian Crisis (1997–1998) and the Japanese Asset Price Bubble (1987–1990) (see Siebert, 2002). The instabilities led to the belief that the stock market crashes in the East Asia have arguably had bubble phenomena as their driving forces. Shiratsuka (2003), for example, believes that the prolonged Japanese asset price bubble was based on excessively optimistic expectations with respect to the future. In other words, this bubble reflected the enthusiasm of market participants, not consistent projection of fundamentals. Shiratsuka (2003) therefore describes the Japanese Asset Price Bubble as 'the euphoria with the benefit of hindsight'.[2] However, there are also many financial players and observers who are willing to accept that markets in general are rational, and refute the view of sustained mass hysteria or 'irrational exuberance' as a major driver of asset prices. For example, the popular contagion hypothesis suggests that the Asian crisis quickly spread across the region through the real linkages of these economies, and hence the extent of the integration of the region is the decisive factor of the contagion (see Forbes and Rigobon, 2002; Kleimeier *et al*, 2003). The implication was that the dramatic rise and subsequent collapse of stock prices experienced by the Asian markets around the Asian Crisis was related to the erratic changing fundamentals.

Generally, asset price bubble will have impact on the real economy. Chirinko and Schaller (2001) and Gilchrist *et al* (2005), for example, argue that firms are more likely to engage in speculative projects in the presence of bubbles, whereas Poterba (2000) argues that asset price bubble will, via wealth effect, distort the householder's consumption behaviours. Bernanke and Gertler (1999) further argue that when bubble bursts, the deterioration of balance sheets of households and firms will affect aggregate demand in the short run and aggregate supply in the long run. The real economy will further be affected through magnification (Bernanke *et al*, 1996) and feedback effects (Kiyotaki and Moore, 1997). Consequently, the burst of a bubble is often accompanied by financial crisis but the impact is likely to further impinge on other areas of economic and social activity.[3] The negative effects a bubble can have on the real economy are profound, and therefore whether bubbles exist in asset markets is an important issue.

The empirical study of rational bubbles has reported different results in different asset markets. Brooks and Katsaris (2003), for example, find that stock prices and dividends in the London Stock Exchange are not cointegrated in the late 1990s, suggesting the presence of speculative bubbles. Junttila (2003) finds evidence of speculative explosive bubbles in the Helsinki Stock Exchange in the 1990s based on a cointegration analysis between stock prices and macro fundamentals. On the contrary, Jirasakuldech *et al* (2006) find no evidence of rational bubbles in the Russell 2000 index for the period from January 1980 to December 2003. Regarding other asset markets, Wang (2000) finds that rational bubble had not existed in the UK property markets from 1977 to 1997, while Black *et al* (2006) also cannot find evidence of rational bubbles in UK house prices over the period 1973 through 2004.

Although bubbles have been researched extensively, rational bubble tests applied to developing markets are relatively scarce. The aim of this article therefore is to test whether rational bubbles exist in the East Asian stock markets. By applying tests across different markets, the article adds to this strand of literature by widening bubble analysis to a range of developed and emerging markets. The remaining part is organised as follows. The next section examines the testable implication from the log level of the present value model, while the subsequent section examines the process of the stochastic explosive root (STER) bubbles, which can be detected by the log specification of unit root tests. The section after that describes the data set and their stationarity properties. The penultimate section presents and discusses the empirical results, and the final section concludes the remarks.

THE PRESENT VALUE RELATION

The standard market fundamentals model of stock price determination, derived from the present value model, states that the fair price to pay for a share today is the sum of the present values of all future income. Accordingly, stock prices should not move too far away from the discounted sum of anticipated future dividend payments to shareholders. Nevertheless, Blanchard and Watson (1982) demonstrate that a bubble component could sustain in the present value model and account for the observed excessive volatility component of stock prices. Although economic theory imposes strong restrictions on such rational bubble (see, for example, Tirole, 1982, 1985; Santos and Woodford, 1997), recently Abreu and Brunnermeier (2003) suggest that it can be optimal for rational investors to temporarily 'ride a bubble' that has emerged from the behaviour of irrational investors. On the empirical ground, Diba and Grossman (1988) notice that rational bubbles are driven by self-fulfilling expectations independent of fundamentals and hence, they have an explosive nature. In other words, without the presence of rational explosive bubble, stock prices should track expected (discounted) values of market fundamentals and should be stationary in *n*th differences if fundamentals were stationary in *n*th differences.

Such stationary relationship between market fundamentals and stock prices presumes that investor's expected return is constant. The rejections of the traditional constant return present value model (for example, West, 1988; Cochrane, 2011; Fama, 1991) have led to the reconsideration of cointegration analysis on testing rational bubbles. Timmermann (1995), for example, argues that when expected returns vary over time and are highly persistent, the present value model does not generally imply the existence of a stationary relationship between stock price and dividend. By contrast, Craine (1993) argues that the cointegration analysis is still valid when expected returns are time varying, if the test is performed between log levels of stock prices and dividends.

In essence, the present value model that allows expected return to be stochastic can be written as,

$$P_t = \mathrm{E}_t \sum_{i=1}^{\infty} \beta^i \left[\prod_{j=1}^{i} \left(\frac{1}{1+r_{t+j}} \right) \right] D_{t+i} \qquad (1)$$

$$where\ \beta<1$$

where P_t is the stock price ate time t, D_t is the dividend at time t and the market discount factor $1/(1+r_{t+\mathrm{j}})$ is generated from consumer's first order condition in a completer market. By dividing Equation (1) with D_t, we obtain,

$$\begin{aligned}\frac{P_t}{D_t} &= \mathrm{E}_t \sum_{i=1}^{\infty} \beta^i \left[\prod_{j=1}^{i} \frac{1}{1+r_{t+j}} \right] D_{t+i}/D_t \\ &= \mathrm{E}_t \sum_{i=1}^{\infty} \beta^i \left[\prod_{j=1}^{i} \frac{1}{1+r_{t+j}} g_{t+j} \right] \qquad (2)\end{aligned}$$

where $g_{t+j} = D_{t+j}/D_{t+j-1}$. Han (1996) shows that if the stock price is set by the present value model, the price-dividend ratio will be both strongly and weakly stationary when r_t and g_t are both strongly and weakly stationary. After taking logarithm, Equation (2) also shows that log level of stock prices and dividends is stationary. In other words, there is a cointegrating vector $(1, -1)'$ between logged stock prices and logged dividends that eliminates both stochastic and deterministic trends in these two variable.

To test the implication from Equation (2), we apply the Engle and Granger's (1987) residual-based approach for cointegration. However, there are some drawbacks in the residual-based approach. First, they tend to lack power as they fail to exploit all the available information about the joint dynamic interactions of the variables (Kremers *et al*, 1992). Second, the finite-sample bias of the OLS estimator of the cointegrating parameter can be severe even for large samples (Ellison and Satchell, 1993). Third, if the causality between the variables runs in both directions, there could be a simultaneous equation bias. That is, the hypothesis might be rejected for one normalisation and accepted for another (Davidson, 2000, p. 382). Accordingly, we also apply Johansen's (1991) maximum likelihood approach, which is based on system of equations. Phillips (1991) argues that Johansen's approach incorporates all prior knowledge about the presence of unit roots, and therefore eliminates part of the nuisance parameter dependencies and ensures that coefficient estimates are symmetrically distributed and median unbiased. Gonzalo (1994) argues that the Vector autoregression (VAR) adopted by Johansen's approach is dynamic, and therefore captures the interaction between the variables and overcome the low power of residual-based approaches. In addition, as the VAR is also a full system estimation model, the Johansen's approach eliminates the simultaneous equation bias and increases efficiency. Nielsen (2010) also argues that when the variables have a common stochastic trend but some of the variables also have an explosive root, cointegration analysis can still be done in the usual framework of Johansen's approach. Consequently, Johansen's maximum likelihood test is ideally suited to examine whether asset prices are driven by rational bubbles.

THE STOCHASTIC EXPLOSIVE UNIT ROOT PROCESS

Although Diba and Grossman (1988) show that rational speculative bubbles can be detected by unit root tests, Evans (1991) argues that the unit root tests may be misleading in the case of periodically collapsing bubbles (PCB). Charemza and Deadman (1995) further argue that the weakness of unit root tests also extends to the class of STER bubbles. Unlike the above works that conduct unit root tests on the price level of variables, recently Waters (2008) examines the power of unit root tests in identifying bubbles when the tests are performed on log level of variables. His result suggests that the STER bubbles can be detected by unit root tests, while the PCB cannot.

Specifically, in the present value model such as Equation (2), rational expectations admit any bubble process, B_t, that satisfies the sub-martingale condition,

$$\mathrm{E}_{t-1}(B_t) = (1+r)B_{t-1} \tag{3}$$

Diba and Grossman (1988) suggest a rational deterministic bubble process as follows,

$$B_t = \theta B_{t-1} + u_t \tag{4}$$

By contrast, the STER bubbles proposed by Charemza and Deadman (1995) follow a different process,

$$B_t = \theta_t B_{t-1} u_t \tag{5}$$

Any bubble process must satisfy two theoretical conditions. First, it must be a submartingale, and second, it must be non-negative. In the STER model, the random variables θ_t and u_t have means $1+r$ and 1, respectively, so the sub-martingale property of Equation (3) is satisfied. In the STER model, the non-negativity is achieved by assuming $\theta_t = \exp(\Theta_t)$ and $u_t = \exp(U_t)$, where $\Theta_t \sim IIN(\ln(1+r) - (\sigma_\theta^2/2), \sigma_\theta^2)$ and $U_t \sim IIN(-\sigma_U^2/2, \sigma_U^2)$. In particular, as θ_t is assumed to be stochastic in the STER model, the bubble process Equation (5) incorporates the possibility of time-varying expected returns. As illustrated by Charemza and Deadman (1995), the process described by Equation (5) is quite general and includes various financial process already investigated in literature, such as the rational deterministic process suggested by Diba and Grossman (1988), the geometric random walk analysed by LeRoy and Parke (1992) and the stochastic unit root process proposed by Granger and Swanson (1993).

In the general case where $\sigma_\theta^2 > 0$ and $r > 0$, process Equation (5) becomes a STER process and, in logarithms, becomes a process with a deterministic unit root and a stochastic drift equal to $\ln(1+r)$. The associated econometric model can be written as,

$$b_t = \mu + \rho b_{t-1} + \varepsilon_t \tag{6}$$

The model of a bubble Equation (6) is equivalent to Equation (5) for $b_t = \ln B_t$, $\mu = \ln(1+r)$, $\varepsilon_t = (U_t + (1/2)\sigma_u^2)$ and $\rho = 1$. Charemza and Deadman (1995) simulate

Equation (5) for various parameter values and test for $\rho = 1$ in Equation (6), and conclude that the failure of unit root tests in detecting STER bubbles. Subsequently, Waters (2008) argues that the linear model Equation (6) is more closely related to the log specification of unit root tests, and he simulates both the STER bubbles and PCB. His conclusion is that the STER bubbles are detectable by the log specification of unit root tests, but the PCB are not.

To test the implication from Equation (6), we apply two alternative unit root tests. The first is the Phillips and Perron's (1988) (PP) unit root test, which has the advantage that it does not assume independently and identically distributed errors. The PP test is therefore suitable to test a very wide class of weakly dependent and possibly heterogeneously distributed data. The second is the KPSS stationarity test, developed by Kwiatkowski *et al* (1992) that tests for the null of stationarity against the alternative of unit root.

THE PROPERTY OF THE DATA

To study the presence or otherwise of rational bubbles in the Asian stock markets, we collect monthly-frequency raw data of net price indices, gross price indices, dividend yields and consumer price indices from Thomson Reuters Datastream. A net price index is a capital appreciation index, which is constructed without dividends, while a gross price index includes both capital appreciation and dividends. The variables of interest are all in real terms being inflation adjusted by appropriate consumer price index. Monthly dividend series are constructed from dividend yield series. Gross stock returns constructed from gross price indices are continuously compounded. The sample includes nine Asian stock markets: Japan; Hong Kong; Singapore; South Korea; Taiwan; Thailand; Malaysia; Indonesia; and Philippine. Given the availability of the data for less developed markets, a common sample analysis would have necessarily had a starting point in the 1990s. As the analysis is mainly concerned with identifying the STER bubbles on an individual market basis, we utilise the full set of available data for each market. The full sample periods are listed in Table 1.

From Equation (2), the log level of the present value model suggests that the relationship between logged stock and logged dividend should be stationary if both the expected return expected return r and dividend growth rate g are stationary. In other words, the pre-condition for the tests of the STER bubbles is that the expected return expected return r and dividend growth rate g be stationary. The results of the stationarity or otherwise of the expected return and dividend growth are reported in the bottom two rows of Tables 2 and 3. The PP unit root tests in Table 2 reject the null of a unit root for both variables, and the KPSS stationarity test in Table 3 cannot reject the null of stationarity for both variables. The tests therefore suggest that the expected return r and dividend growth rate g are both stationary, which satisfy the pre-condition to test the cointegration relationship between logged stock prices and logged dividends.

Before we can utilise the cointegration analysis for testing the STER, the VAR system also requires that these two variables are difference-stationary in the same order. From Table 2, the PP unit root tests suggest that logged stock prices generally have units, except for Taiwan, while the first difference of logged stock prices are all stationary. The

Table 1: The markets and sample periods

Market	*Sample period*
Japan	January 1973–December 2011
Hong Kong	October 1980–December 2011
Singapore	January 1973–December 2011
Korea	September 1987–December 2011
Taiwan	May 1988–December 2011
Thailand	January 1987–December 2011
Malaysia	January 1986–December 2011
Indonesia	April 1990–December 2011
Philippine	September 1987–December 2011

Table 2: PP unit root tests

	Japan	Hong Kong	Singapore	Korea	Taiwan	Thailand	Malaysia	Indonesia	Philippine
Level									
Stock price	−1.68	−1.51	−1.89	−2.50	−2.98	−2.04	−2.11	−3.30	−2.04
Dividend	−1.82	−1.01	−1.99	−1.79	−2.55	−1.34	−1.64	−2.01	−1.58
Logged stock price	−1.36	−1.35	−1.74	−1.99	−3.14**	−2.51	−2.67	−2.31	−2.19
Logged dividend	−1.78	−1.65	−2.63	−1.92	−2.84	−1.40	−1.98	−2.55	−4.39***
First difference									
Stock price	−18.61***	−18.41***	−19.21***	−16.32***	−14.68***	−17.14***	−16.85***	−15.12***	−16.01***
Dividend	−16.04***	−19.45***	−22.30***	−14.60***	−11.93***	−16.57***	−16.90***	−15.94***	−16.11***
logged stock price	−19.05***	−17.87***	−18.60***	−15.46***	−14.02***	−15.75***	−15.92***	−13.92***	−15.42***
Logged dividend	−18.31***	−18.96***	−21.84***	−14.23***	−14.53***	−14.16***	−16.30***	−18.45***	−15.85***
Gross return	−19.07***	−17.02***	−18.61***	−15.47***	−14.02***	−15.75***	−15.91***	−13.91***	−15.42***
Dividend growth	−18.31***	−18.96***	−21.84***	−14.23***	−14.53***	−14.16***	−16.30***	−18.45***	−15.85***

The bandwidth of the PP statistic was selected by Newey–West using a Bartlett kernel. **denotes significance at the 5% level; ***denotes significance at the 1% level.

Table 3: KPSS stationarity tests

	Japan	Hong Kong	Singapore	Korea	Taiwan	Thailand	Malaysia	Indonesia	Philippine
Level									
Stock price	0.37***	2.05***	2.09***	0.92***	0.10	0.17**	0.81***	0.69**	0.21**
Dividend	0.34***	1.96***	1.91***	0.68**	1.58***	0.22***	1.47***	0.63**	1.55***
logged stock price	0.44***	2.11***	2.06***	0.79***	0.16	0.18**	0.98***	0.60**	0.22***
Logged dividend	0.34***	2.21***	2.09***	0.56**	1.76***	0.23***	1.51***	0.50**	1.50***
First difference									
Stock price	0.12	0.03	0.06	0.06	0.02	0.11	0.06	0.32	0.09
Dividend	0.06	0.06	0.13	0.09	0.05	0.13	0.25	0.08	0.13
Logged stock price	0.16	0.03	0.09	0.06	0.02	0.14	0.12	0.23	0.10
Logged dividend	0.07	0.11	0.06	0.09	0.03	0.12	0.18	0.09	0.17
Gross return	0.16	0.19	0.08	0.06	0.02	0.15	0.13	0.26	0.10
Dividend growth	0.07	0.11	0.06	0.09	0.03	0.12	0.18	0.09	0.17

The bandwidth of the KPSS statistic was selected by Newey–West using a Bartlett kernel. **denotes significance at the 5% level; ***denotes significance at the 1% level.

KPSS stationarity tests in Table 3 also suggest that logged stock prices are not stationary, expect for Taiwan, while the first difference of logged stock prices are all stationary. The empirical evidence therefore suggests that logged stock price is integrated to the first order, that is, *I*(1). As regards the logged dividend, the PP unit root tests on logged dividend generally cannot reject the null of a unit root, expect for Philippine, while the tests on the first difference of logged dividend all reject the null of a unit root. Further, the KPSS stationarity tests on logged dividend all reject the null of stationarity, while the tests on the first difference all cannot reject the null of stationarity. The empirical evidence therefore suggests that logged dividend is integrated to the first order. In short, the results suggest that the logged stock price and the logged dividend are both integrated to the same order.

In addition to the preliminary statistics before testing the STER bubbles, we also test whether the stock prices and the dividends are integrated to the same order, with results also reported in Tables 2 and 3. Specifically, Diba and Grossman (1988) suggest that stock prices and dividends should be integrated to the same order, when deterministic explosive bubbles are not present. Evidently, the PP unit root tests suggest that the stock prices are not stationary, but the first difference of the stock prices is stationary. The KPSS stationarity tests also suggest that the stock prices generally contains a unit root, except for Taiwan, while their first differences do not. The empirical evidence therefore indicates that the stock prices are integrated to the first order. As regards the dividends, both the PP unit root tests and the KPSS stationarity tests suggest that the dividend for all sample markets contains a unit root, while their first differences do not. In short, the stock price and the dividend are integrated to the same order, which is a weak evidence against the existence of the deterministic explosive bubbles in the stock markets.

Overall, the stock prices and the dividends, whether in logged level or in price level, are integrated to the same order. Furthermore, both the expected returns and the dividend growth rate are stationary. Given the conditions, the present value model suggests that there should be a cointegrating relationship between stock prices and dividends without deterministic explosive bubbles, or else there should a cointegrating relationship between logged stock prices and logged dividend without the STER bubbles. To further test the rational bubbles, we now turn to the cointegration analyses.

EMPIRICAL EVIDENCE

The log specification of the present value model in Equation (2) suggests that the price-dividend ratio should be stationary if the STER bubbles do not exist. Furthermore, according to Waters (2008), the log specification of the unit root tests should be able to detect the STER bubbles. In other words, Equation (6) implies that there should be a stationary relationship between logged stock prices and logged dividends if the STER bubbles do not exist. On the basis of these two implications, we therefore proceed to the unit root tests for both the price level and the logged level of price-dividend ratio, with the results reported in Table 4. The PP unit root tests suggest that the price-dividend ratio is not stationary for Japan, Taiwan and Philippine, while for Hong Kong, Thailand, Malaysia and Indonesia, the price-dividend ratio is borderline non-stationary. Further, the KPSS stationarity tests suggest that the price-dividend ratio for Japan, Singapore, Taiwan and Philippine is not stationary, while for the rest markets it is stationary. Taken two tests as a whole, the evidence based on the implication of Equation (2) suggests that the only case against the detection of the bubble is Korea, although for Hong Kong, Singapore, Thailand, Malaysia and Indonesia the evidences are relatively weak. In addition, the PP unit root tests suggest that the logged price-dividend ratio is not stationary for Japan, Taiwan, Thailand, Malaysia and

Table 4: Unit root tests for the STER bubbles

	Japan	*Hong Kong*	*Singapore*	*Korea*	*Taiwan*	*Thailand*	*Malaysia*	*Indonesia*	*Philippine*
PP tests									
Price-dividend ratio	−0.96	−3.19**	−4.04***	−4.21***	−2.25	−3.44**	−3.42**	−3.01**	−2.34
Logged price-dividend ratio	−0.61	−3.18**	−3.92**	−3.54**	−3.15	−2.73	−2.89	−3.26	−3.56***
KPSS tests									
Price-dividend ratio	0.83***	0.07	0.37***	0.21	1.37***	0.28	0.35	0.09	1.48***
Logged price-dividend ratio	0.56***	0.06	0.59**	0.09	0.17**	0.28***	0.37***	1.05***	0.16**

The bandwidth of the PP statistic was selected by Newey–West using a Bartlett kernel. The bandwidth of the KPSS statistic was selected by Newey–West using a Bartlett kernel. **denotes significance at the 5% level; ***denotes significance at the 1% level.

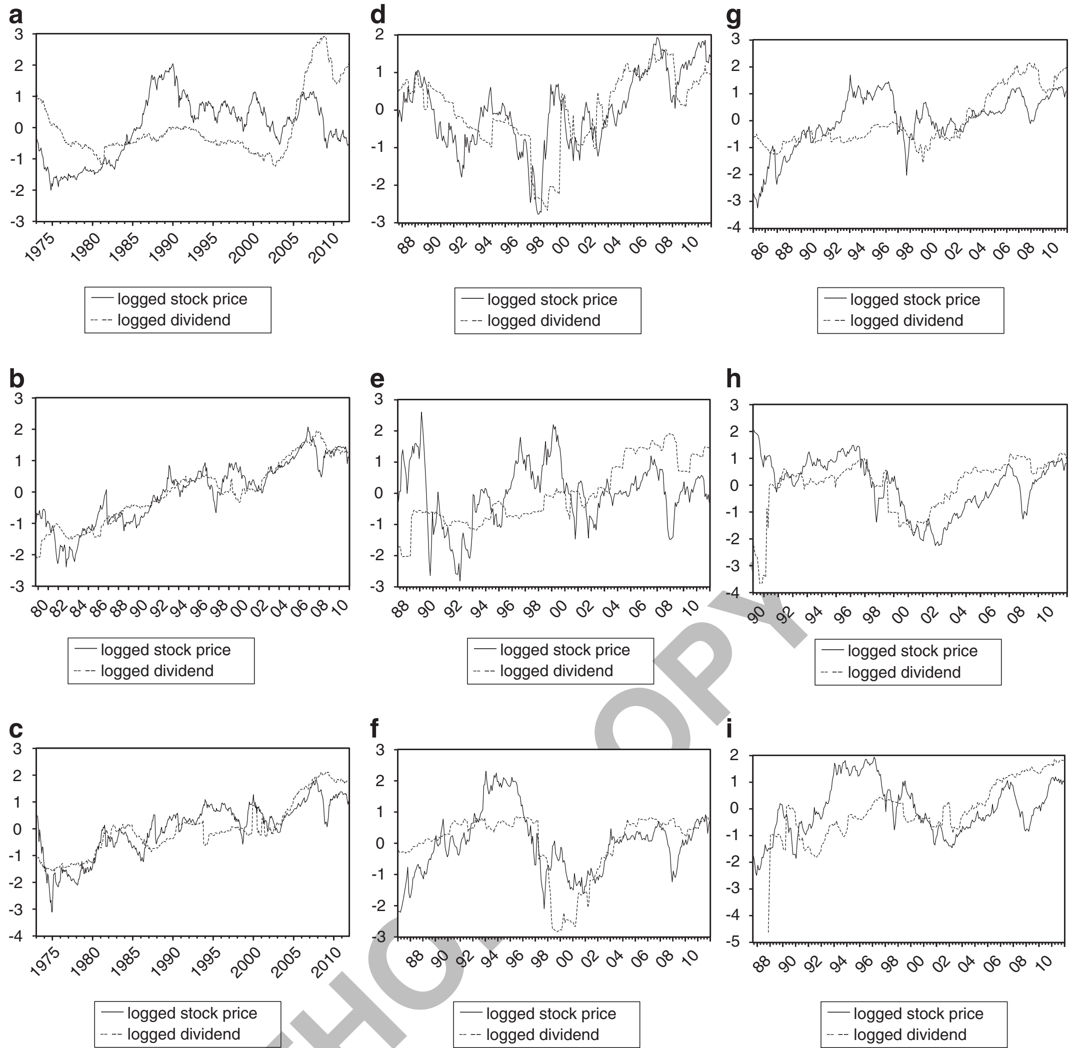

Figure 1: The relation between logged stock prices and logged dividends.

Indonesia, while for Hong Kong, Singapore, Korea it is borderline non-stationary. The KPSS stationarity tests suggest that the logged price-dividend is stationary only for Hong Kong and Korea. Taken two tests as a whole, the empirical evidence based on the implication of Equation (6) therefore suggest that there are only two cases against the detection of the STER bubble, that is, Hong Kong and Korea.

Overall, despite the evidence for the existence of the STER bubbles is not so strong from the PP tests, the KPSS tests suggest a high possibility of the existence of the STER bubbles in the Asian stock markets. As the PP unit root test has low power at deciding the borderline non-stationarity, especially when sample size is small, we believe that the STER bubbles have generally existed in the Asian stock markets. To verify this belief, we now proceed to the cointegration analyses, which suggest that the variables in interest should not move too far away from each other in the long term. According to the definition, the visual inspection of co-movement between the logged stock prices and the logged dividend should provide a good starting point to judge the likely existence of the rational bubbles. The inspection of the graph in Figure 1

Table 5: The Engle–Granger approach

	Stock price and dividend		*Logged price and logged dividend*	
Market	*τ-statistic*	*z-statistic*	*τ-statistic*	*z-statistic*
Japan	−1.66	−5.75	−1.41	−4.69
Hong Kong	−4.80***	−48.57***	−4.29**	−33.36**
Singapore	−4.07***	−33.16***	−4.53***	−33.42**
Korea	−3.13	−19.45**	−3.93**	−31.22**
Taiwan	−3.42**	−23.81**	−3.42	−23.77
Thailand	−2.50	−11.56	−3.00	−14.17
Malaysia	−3.11	−17.41	−2.87	−13.39
Indonesia	−3.81**	−14.14	−2.63	−10.98
Philippine	−1.90	−6.78	−3.46	−20.04

For the cointegration test between stock price and dividend, the augmented Dickey-Fuller (ADF) unit root test is applied to the residuals μ_t from the model $y_t=\beta_1+\beta_2x_t$, in which y_t and x_t are variables in interest. For the cointegration test between logged stock price and logged dividend, the ADF unit root test is applied to the residuals from the model $y_t=\beta_1+\beta_2x_t+\beta_3T$, in which y_t and x_t are variables in interest and T is the deterministic trend. Lag length was chosen based on the SIC criterion. The critical values for the EG test are taken from MacKinnon(1996). **denotes significance at the 5% level; ***denotes significance at the 1% level.

indicates that there are some degree of co-movements between these two variables for Hong Kong, Singapore and possibly Korea, while for the rest markets, the logged stock prices and the logged dividends seem to follow different paths. The general indication suggests that the rational bubbles exist in the Asian stock markets.

To test the presence of the deterministic explosive bubbles, the cointegration analyses should be applied to stock prices and dividends as proposed by Diba and Grossman (1988). We first apply the Engle–Granger residual-based approach, which suggests that a regression of the stock prices on the dividends will have a zero error term with the property of stationarity. However, if the residuals from the regression contain a unit root, the non-stationarity of the residuals can be interpreted as the evidence for the existence of deterministic explosive bubbles. In the application, we only allow for the intercept in the regression equation while the deterministic trend is excluded, so that the property of the deterministic explosive bubbles would show up in the residuals if the bubbles exist. The lag length of the models are chosen based on the Schwartz information criterion (SIC), and the critical values are taken from MacKinnon (1996). The results of the Engle–Granger residual-based approach are reported in the first part of Table 5. The τ-statistics suggest that the residuals are not stationary for Japan, Korea, Thailand, Malaysia and Philippine, while for Taiwan and Indonesia they are borderline stationary. The *z*-statistics suggest that the residuals are not stationary for Japan, Thailand, Malaysia, Indonesia and Philippine, while for Korea and Taiwan they are borderline stationary. Overall, the Engle–Granger approach suggests the existence of deterministic explosive bubbles in the Asian stock markets, except for Hong Kong, Singapore and Taiwan.

The second approach to test the deterministic explosive bubbles is the Johansen's VAR approach, which is designed to detect the possible number of cointegration rank between variables in interest. To test the deterministic explosive bubbles, only the constant is included in the cointegrating space while the linear trend is excluded, so as to allow the system to detecting the deterministic bubbles. In addition, the constant term in the VAR system is also excluded, as its allowance would imply a linear deterministic trend in the data. In the application, the lag lengths of the VAR system were chosen using the Akaike information criterion (AIC) and the SIC criteria, subject to the assumption that the residuals are not serially correlated, which we verify by using the portmantaeu Ljung–Box *Q*-statistic. However, when the SIC and AIC criteria are in conflict, we choose the lag length based on the residuals being white noise, so as to ensure we capture any long-run mean reversion or transitory components in the real stock prices. The critical values are taken from Osterwald-Lenum (1992), and the results of the Johansen's approach are reported in the first half of Table 6. The Max-Eigen statistics suggest that there is no cointegration rank for Japan, Singapore, Taiwan, Thailand,

Table 6: The Johansen's approach

Market	*Null/Alt.*	*Stock price and dividend*		*Logged price and logged dividend*	
		Max-Eigen statistic	*Trace statistic*	*Max-Eigen statistic*	*Trace statistic*
Japan	$r=0/r>0$	6.85	8.49	9.91	15.07
	$r=1/r>1$	1.64	1.64	5.16	5.16
Hong Kong	$r=0/r>0$	22.44***	25.17***	21.31**	27.40**
	$r=1/r>1$	2.73	2.73	6.09	6.09
Singapore	$r=0/r>0$	14.57	18.12	14.95	18.46
	$r=1/r>1$	3.55	3.55	3.50	3.50
Korea	$r=0/r>0$	21.43***	23.40**	25.81***	32.27***
	$r=1/r>1$	1.96	1.96	6.45	6.45
Taiwan	$r=0/r>0$	12.13	14.75	13.15	23.39
	$r=1/r>1$	2.61	2.61	10.24	10.24
Thailand	$r=0/r>0$	8.43	12.68	14.04	19.80
	$r=1/r>1$	4.24	4.24	5.75	5.75
Malaysia	$r=0/r>0$	11.53	13.85	14.65	18.26
	$r=1/r>1$	2.31	2.31	3.61	3.61
Indonesia	$r=0/r>0$	22.10***	25.00**	27.47***	30.53***
	$r=1/r>1$	2.90	2.90	3.06	3.06
Philippine	$r=0/r>0$	4.89	8.47	18.49	22.78
	$r=1/r>1$	3.58	3.58	4.29	4.29

For the cointegration test between stock price and dividend, only intercept is allowed in the cointegration equation, but intercept is not allowed in the VAR. For the cointegration test between logged stock price and logged dividend, both intercept and deterministic trend are allowed in the cointegration equation, but intercept is not allowed in the VAR. Lag length was chosen in all cointegration vectors based on the AIC and SIC criteria, subject to the assumption that equation residuals are not serially correlated by using the portmanteau Ljung–Box Q statistic. r is the number of cointegrating vectors under the null hypothesis. The critical values are taken from Osterwald-Lenum (1992). **denotes significance at the 5% level; ***denotes significance at the 1% level.

Malaysia and Philippine, while for Hong Kong, Korea and Indonesia, the cointegration rank is 1. The results from the Trace statistics are the same. Overall, the Johansen's approach suggests the existence of deterministic explosive bubbles in the Asian stock market, except for Hong Kong, Korea and Indonesia.

To test the presence of the STER bubbles, the cointegration analyses should be applied to logged stock prices and logged dividends as suggested from Equation (2). The regression from the Engle–Granger approach of the logged stock prices on logged dividends should have a stationary zero error term, if these two variables are cointegrated. The evidence of non-stationary residuals could indicate the existence of the STER bubbles. For testing the implied stochastic cointegration in Equation (2), we include both the constant term and the linear trend in the regression equation, so that the deterministic component is not included in the residuals. The results of the Engle–Granger residual-based approach are reported in the second part of Table 5. The τ-statistics suggest that the residuals are stationary only for Hong Kong, Singapore and Korea. The z-statistics also gave out the same results. The Engle–Granger approach therefore suggests the existence of the STER bubbles in the Asian markets, except for Hong Kong, Singapore and Korea. To allow for stochastic cointegration in the Johansen's VAR approach, Perron and Campbell (1993) propose that linear trends could be included in the estimated model. Accordingly, we include both the constant term and the determinist trend in the cointegrating space, while the constant term in the VAR system is excluded. The results of the Johansen's approach are reported in the second half of Table 6. The Max-Eigen statistics suggest that the logged stock prices and the logged dividends are cointegrated only for Hong Kong, Korea and Indonesia. The Trace statistics exactly confirm the same evidence. The Johansen's approach also suggests the existence of the STER bubbles in the Asian markets, except for Hong Kong, Korea and Indonesia.

Overall, the empirical evidence suggests that the deterministic explosive bubbles exist in the stock markets of Japan, Thailand, Malaysia and Indonesia, and they are also likely to exist in Singapore, Korea, Taiwan and Indonesia. In addition, the evidence also suggest that the STER bubbles exist in the stock markets of Japan, Taiwan, Thailand, Malaysia and Philippine, and they are also likely to exist in Singapore, Korea and Indonesia. In summary, our results suggest that there are rational bubbles in the Asian stock markets, except for Hong Kong.

CONCLUSION

The rise, fall and volatility of stock markets are often viewed as sustained outbursts of irrationally induced 'bubble' phenomena: Self-generating surges of optimism that pump up asset prices and misallocate investments and resources to such a great extent that a crash and major financial and economic distress inevitably follow. In other words, asset price bubbles generally will influence the behaviours of household and firms, leading to the decrease of economic fundamental values of private units. Subsequently, the consumption spending will declines through the magnification effect and the asset values will further decline due to feedback effects. The burst of a bubble therefore is often accompanied by financial crisis, with the impact rippling beyond economic activities.

To test the existence or otherwise of rational bubbles, the study encompassed the Asian stock markets that experienced several episodes, such as the Asian Crisis and the Japanese Asset Price Bubble, in which stock prices went through dramatic rises and subsequent collapses. Specifically, we tested the deterministic explosive bubbles and STER bubbles. On the basis of the unit root tests, the Engle–Granger approach and the Johansen's VAR approach, the evidence strongly suggested that both rational bubbles existed in Japan, Thailand, Malaysia and Philippine, which historically were all badly hit by the Japanese Asset Price Bubble or the Asian Crisis. By contrast, Hong Kong is the only exceptional market, where all three approaches supported against the existence of both bubbles. The evidence of the deterministic explosive bubble in Taiwan was not strong, though the existence of the STER bubble was evident. In addition, the evidence of the two rational bubbles existing in the stock market of Singapore was also not so strong. Our results therefore are consistent with the historical observation that these three markets are more resistant to the Asian Crisis.

Notably, the evidence of both bubbles existing in the stock markets was also relatively weak for Korea and Indonesia. Interestingly, these two markets are commonly perceived as having been particularly sensitive to 'bubble phenomena' because they were among the worst hit markets by the Asian crisis. One possible explanation is that the impact of the economic shock had been truly reflected in the fundamental factor of stock market, that is, the dividend paid out to investors. In other words, the dramatic events in the stock markets of Korea and Indonesia were caused by the erratic changing fundamentals. The other explanation is that these two markets may have other rational bubbles following different functional form, which our empirical approaches simply were unable to detect. The other functional form of rational bubbles, for example, could be the periodically collapsing bubble proposed by Evans (1991) or the intrinsic bubble proposed by Froot and Obstfeld (1991).

Although with different degree of confidences, our empirical evidence overall indicated the general existence of rational bubbles in the Asian stock markets, where only Hong Kong was found to have no rational bubbles. That the rational deterministic explosive bubbles existed in the Asian stock markets is not so surprising, as the tests were based on the implication that investor's expected returns are constant, which is quite unrealistic in practice. However, even with the incorporation of time-varying expected returns, the Asian stock markets were still found to have the rational STER bubbles. Contrary to what one might have reasonably expected that stock prices would converge to their fundamentals, the stock prices in the Asian markets appeared to be disconnected from their 'fundamentals' even in the long run, whether the time-varying expected return is considered or not. In short, the present value model, whether in log specification or not, is not so successful for stating the long-run relationship between stock prices and dividends for the Asian stock markets.

NOTES

1. The *Financial Times* places the beginning of the crisis back in early February 1997, when the first Thai financial institution missed payments on foreign debt (see Connelly, 1998).
2. While Shiratsuka (2003) called such enthusiasm as euphoria, Shiller (2000) uses a term 'irrational exuberance' to describe a similar phenomenon.
3. For example, the *BBC News* reported on 25 October 1999 that the 1997 Asian economic crisis helped spread HIV in Indonesia.

REFERENCES

Abreu, D. and Brunnermeier, M.K. (2003) Bubbles and crashes. *Econometrica* 71(1): 173–204.

Bernanke, B., Gertler, M. and Gilchrist, S. (1996) The financial accelerator and the flight to quality. *Review of Economics and Statistics* 78(1): 1–15.

Bernanke, B. and Gertler, M. (1999) Monetary policy and asset price volatility. *Economic Review, Federal Reserve Bank of Kansas City, issue Q IV*: 17–51.

Black, A., Fraser, P. and Hoesli, M. (2006) House prices, fundamentals and bubble. *Journal of Business Finance and Accounting* 33(9–10): 1535–55.

Blanchard, O.J. and Watson, M.W. (1982) Bubbles, rational expectations and financial markets. In: P. Wachtel (ed.) *Crises in the Economic and Financial System*, Lexington, MA: Lexington Books, pp. 295–315.

Brooks, C. and Katsaris, A. (2003) Rational speculative bubbles: An empirical investigation of the London stock exchange. *Bulletin of Economic Research* 55(4): 319–346.

Charemza, W. and Deadman, D. (1995) Speculative bubbles with stochastic explosive roots: The failure of unit root testing. *Journal of Empirical Finance* 2(2): 153–163.

Chirinko, R.S. and Schaller, H. (2001) Business fixed investment and 'bubbles': The Japanese case. *The American Economic Review* 91(3): 663–680.

Cochrane, J.H. (2011) Volatility tests and efficient markets: A review essay. *Journal of Monetary Economics* 27(3): 463–485.

Connelly, T.J. (1998) The great Asian fire drill. *Journal of Financial Planning* 11(2): 32–37.

Craine, R. (1993) Rational bubbles: A test. *Journal of Economic Dynamics and Control* 17(5): 829–846.

Davidson, J. (2000) *Econometric Theory*. Oxford, UK: Blackwell.

Diba, B.T. and Grossman, H.I. (1988) Explosive rational bubbles in stock prices? *The American Economic Review* 78(3): 520–530.

El Kahal, S. (2001) *Business in Asia Pacific: Text and Cases*. Oxford: Oxford University Press.

Ellison, G. and Satchell, S.E. (1993) The finite-sample properties of cointegration estimators with applications to testing. In: P.C.B. Phillips (ed.) *Models, Methods, and Applications of Econometrics* Oxford, UK: Blackwell, pp. 176–198.

Engle, R.F. and Granger, C.W.J. (1987) Co-integration and error correction: Representation, estimation, and testing. *Econometrica* 55(2): 251–276.

Evans, G.W. (1991) Pitfalls in testing for explosive bubbles in asset prices. *The American Economic Review* 81(4): 922–930.

Fama, E.F. (1991) Efficient capital markets: II. *Journal of Finance* 46(5): 1575–1617.

Fischer, S. (1998) The Asian crisis: A view from the IMF. *Journal of International Financial Management and Accounting* 9(2): 167–176.

Forbes, K. and Rigobon, R. (2002) No contagion, only interdependences: Measuring stock market comovements. *Journal of Finance* 57(5): 2223–2261.

Froot, K.A. and Obstfeld, M. (1991) Intrinsic bubbles: The case of stock prices. *The American Economic Review* 81(5): 1189–1214.

Gilchrist, S., Himmelberg, C.P. and Huberman, G. (2005) Do stock price bubbles influence corporate investment? *Journal of Monetary Economics* 52(4): 805–827.

Gonzalo, J. (1994) Five alternative methods of estimating long-run equilibrium relationships. *Journal of Econometrics* 60(1): 203–233.

Granger, C.W.J. and Swanson, N.R. (1993) *An Introduction to Stochastic Unit Root Processes*. San Diego, CA: University of California mimeo.

Han, H.L. (1996) Cointegration and tests of a present value model in the stock market. *Applied Economics* 28(2): 267–272.

Henderson, C. (1998) *Asia Falling? Making Sense of the Asian Currency Crisis and its Aftermath*. New York: McGraw Hill.

Jirasakuldech, B., Campbell, R.D. and Knight, J.R. (2006) Are there rational speculative bubbles in REITs? *The Journal of Real Estate Finance and Economics* 32(2): 105–127.

Johansen, S. (1991) Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica* 59(6): 1551–1580.

Junttila, J. (2003) Detecting speculative bubbles in an IT-intensive stock market. *Journal of Economics and Finance* 27(2): 166–189.

Kiyotaki, N. and Moore, J. (1997) Credit cycles. *Journal of Political Economy* 105(2): 211–248.

Kleimeier, S., Lehnert, T. and Verschoor, W.F.C. (2003) Contagion versus interdependence: A re-examination of Asian-crisis stock market comovements. *EFA 2003 Annual Conference Paper* No. 249.

Kremers, J.J.M., Ericsson, N.R. and Dolado, J.J. (1992) The power of cointegration tests. *Oxford Bulletin of Economics and Statistics* 54(3): 325–348.

Kwiatkowski, D., Phillips, P., Schmidt, P. and Shin, Y. (1992) Testing the null hypothesis of stationarity against the alternative of a unit root: How sure are we that economic time series have a unit root? *Journal of Econometrics* 54(1): 159–178.

LeRoy, S.F. and Parke, W.R. (1992) Stock price volatility: Tests based on the geometric random walk. *The American Economic Review* 82(4): 981–992.

MacKinnon, J.G. (1996) Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics* 11(6): 610–618.

Nielsen, B. (2010) Analysis of co-explosive processes. *Econometric Theory* 26(3): 882–915.

Osterwald-Lenum, M. (1992) A note with quantiles of the asymptotic distribution of the maximum likelihood cointegration rank test statistics. *Oxford Bulletin of Economics and Statistics* 54(3): 461–472.

Okina, K., Shirakawa, M. and Shiratsuka, S. (2001) The asset price bubble and monetary policy: Japans experience in the late 1980s and the lessons. *Monetary and Economic Studies* (*Special Edition*) 19(2): 395–450.

Perron, P. and Campbell, J.Y. (1993) A note on Johansen's cointegration procedure when trends are present. *Empirical Economics* 18(4): 777–789.

Phillips, P.C.B. and Perron, P. (1988) Testing for a unit root in time series regression. *Biometrik* 75(2): 335–346.

Phillips, P.C.B. (1991) The tail behaviour of maximum likelihood estimates of cointegrating coefficients in error correction models. *Econometrica* 62(1): 73–93.

Poterba, J.M. (2000) Stock market wealth and consumption. *The Journal of Economic Perspectives* 14(2): 99–118.

Santos, M.S. and Woodford, M. (1997) Rational asset pricing bubbles. *Econometrica* 65(1): 19–58.

Sharma, S.D. (1998) Asia's economic crisis and the IMF. *Survival* 40(2): 27–52.

Shiller, R.J. (2000) *Irrational Exuberance*. Princeton, NJ: Princeton University Press.

Shiratsuka, S. (2003) Asset price bubble in Japan in the 1980s: Lessons for financial and macroeconomic stability. *BIS Papers chapters* 21: 42–62.

Siebert, H. (2002) *The World Economy*. 2nd edn. London: Routledge.

Timmermann, A. (1995) Cointegration tests of present value models with a time-varying discount factor. *Journal of Applied Econometrics* 10(1): 17–31.

Tirole, J. (1982) On the possibility of speculation under rational expectations. *Econometrica* 50(5): 1163–1181.

Tirole, J. (1985) Asset bubbles and overlapping generations. *Econometrica* 53(6): 1499–1528.

Wang, P. (2000) Market efficiency and rationality in property investments. *Journal of Real Estate Finance and Economics* 21(2): 185–201.

Waters, G.A. (2008) Unit root testing for bubbles: A resurrection? *Economic Letters* 101(3): 279–281.

West, K.D. (1988) Bubbles, fads, and stock price volatility tests: A partial evaluation. *Journal of Finance* 43(3): 639–660.

World Bank (1993) The East Asian miracle, economic growth and public policy, World Bank Report, New York: Oxford University Press.