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Jen-Je Su, Eduardo Roca and Victor S.H. Wong

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Jen-Je Su, Eduardo Roca and Victor S.H. Wong*

Department of Accounting, Finance and Economics
Griffith Business School, Griffith University
Nathan, Queensland, Australia

Abstract:

There is now a voluminous literature investigating the issue of market efficiency, particularly in relation to the weak-form type of efficiency, which are based on autocorrelation tests. However, the results from this literature are mixed. There is a concern, however, that the autocorrelation tests used in these studies could have suffered from problems and biases arising from heteroskedasticity in the data. Over the last 15 years, financial markets have suffered from a number of crises which may have intensified the presence of heteroskedasticity in financial data. In this paper, we examine the efficiency of Asian markets based on two newly-developed tests - the Escanciano and Lobato (2009)'s automatic Box-Pierce Q_k test and Nankervis and Savin (2010)'s generalised Andrews-Ploberger test, which are robust to heteroskedasticity. Asia provides an interesting context as it has been the economic growth region over the last three decades but yet its financial markets are deemed to lag behind in terms of development. However, since the late 80s, it has implemented liberalisation and deregulation programs which were aimed at improving the functioning of its financial markets. Thus, it is debated as to whether or not Asian financial markets are or have become efficient. We examine 16 markets consisting of 5 developed, 9 emerging and 2 frontier ones. We confirm that all the developed markets are efficient while the frontier ones are all inefficient and mixed for the less developed ones. We also find that the level of efficiency of these markets varies over time – decreasing during the GFC and then increasing afterwards.

Keywords: market efficiency, Asian stock markets, emerging markets, global financial crisis, autocorrelation tests

JEL Classification Codes: G14, G15

* Corresponding author. Email: V.Wong@griffith.edu.au, Telephone: +61 7 3735 7598

1. Introduction

The issue of market efficiency is one that is at the core of financial economics theories and models and has very important practical implications. If markets are found to be efficient, then prices are not predictable and it is not possible to gain abnormal returns (Brown and Reilly, 2009). It also means that resources are efficiently allocated since prices reflect rational and fundamental factors. Ever since the issue of market efficiency was brought to the forefront by the work of Fama in the 1970s, a voluminous amount of studies has been conducted on this issue in the context of different financial and economic markets. Overall, the evidence is that markets, particularly developed ones, are efficient, although some pockets of inefficiencies exist, especially in less developed markets (Brown and Reilly, 2009).

However, inspite of this extensive literature, the debate on market efficiency rages on and has, in fact, intensified further, particularly during and after the onset of the global financial crisis (GFC). The bulk of these studies on market efficiency rely on autocorrelation tests. If prices are found to be not serially correlated, then markets are considered to be efficient, in the weak-form version of market efficiency. These autocorrelation tests, however, could suffer from low power as well as other biases such as size distortion arising from heteroskedasticity in the data. This is a very important issue as heteroskedasticity in financial data has been increasing over the years given that financial markets have witnessed the occurrence of an increasing number of crises since the 1980s ranging from the Asian financial crisis in 1997-1998, the subsequent Russian bond market crisis, the Mexican crisis, Argentinian crisis, and most recently the GFC.

We therefore address this highly important issue. We re-examine the issue of market efficiency based on newly-developed and powerful autocorrelation tests which have been proven to be robust to heteroskedasticity - the Escanciano and Lobato (2009)'s automatic Box-Pierce Q_k test and Nankervis and Savin (2010)'s generalised Andrews-Ploberger test. We undertake our investigation in relation to sixteen Asian stock markets - 5 developed (Australia, Hong Kong, Japan, New Zealand and Singapore), 9 emerging (China A & B, India, Malaysia, Philippines, S. Korea, Thailand, Taiwan and Thailand) and 2 frontier (Pakistan and Sri Lanka) over the period 2001 to 2011. We examine the efficiency of each market across time based on rolling subsamples for each of the two tests. We also investigate the effect of the GFC on the level of efficiency of each of these markets through a pre and post GFC period analysis.

The sixteen Asian markets provide an interesting laboratory for the investigation of market efficiency. The Asian region has been the bulwark of economic growth since the 1980s and continues to be so even after the GFC. The Asian financial markets have witnessed substantial growth since the late 1980s which has attracted international investors making these markets regular components of international portfolios. However, it is claimed that these financial markets lag behind in development as compared to their respective economies, and are therefore thought to be inefficient. On the other hand, a number of major policies were implemented in these markets in the late 1980s and early 1990s (Kim and Shamsuddin, 2008) which paved the way for deregulation and liberalisation. After the Asian crisis of 1997, many of these markets underwent further reforms to strengthen the governance mechanisms as well as reporting standards in their financial markets, although some markets, as in the case of Malaysia, implemented a policy of restricting capital inflows for a short period of time immediately after the Asian crisis of 1997.

Thus, given all the major developments, it may be expected that these markets, overall, would have become more efficient over the years. A substantial number of studies have been conducted on this issue based on autocorrelation tests. The results from these studies, however, are mixed and these studies could have suffered from the problems with autocorrelation tests associated with heteroskedasticity-induced biases that have been mentioned earlier.

The present study therefore provides new evidence on market efficiency in general and, particularly in relation to Asian financial markets efficiency. This is achieved through the use of autocorrelation tests which overcome the weaknesses of tests used in the existing literature arising from heteroskedasticity-induced biases As far as we know, our paper is the first to apply the two tests (the Escanciano & Lobato (2009)'s automatic Box-Pierce Q_k test and Nankervis & Savin (2010)'s generalised Andrews-Ploberger test) in the investigation of the issue of stock market efficiency. Furthermore, our paper takes into account the GFC; this has been absent in prior studies unlike which have only analysed the effect of the Asian crisis. We also cover more markets (16 markets) than previous studies on Asian stock market efficiency.

Our results show that, over the full sample period of 2001 to 2011, all the five developed markets (Australia, Hong Kong, Japan, New Zealand and Singapore) are efficient, while among the nine emerging markets only three are efficient (China_A, S. Korea and Thailand) and the other six (China_B, India, Indonesia, Malaysia, Philippines and Taiwan) are not. With regards to the two frontier markets (Pakistan and Sri Lank), both are inefficient. For each market, we also find that the level of efficiency and inefficiency varies across time; however, as a whole, the markets have become more efficient over time. Our results reveal that during the GFC, the markets as a whole became inefficient but after the GFC, they recovered and even became more efficient than they were before the GFC.

The next section presents review of the literature on Asian stock market efficiency while Section 3 discusses the methodology of the study. Section 4 presents the empirical results while Section 5 concludes the study.

2. Literature review

There have been a number of studies on the issue of efficiency of Asian stock markets. However, these studies have come up with mixed results. Among these studies are those which examine the random walk behaviour of the South Asian stock markets. Cooray and Wickremasinghe (2008) and Islam and Khaled (2005) use unit root tests and the variance-ratio tests while Cooray and Wickremasinghe (2008) apply the Ng and Perron tests and the Zivot and Andrew test to detect unit root components. They find that the stock markets of India, Pakistan and Sri Lanka follow a random walk. Islam and Khaled (2005) make use of the Augmented Dickey-Fuller (ADF) and the Philips-Perron (PP) unit root tests and Lo and MacKinlay (1988) the variance ratio tests to analyse the random walk behaviour of the Dhaka Stock Exchange (DSE). They find that the DSE follows the random walk behaviour. Another study, Gupta (1990) also finds evidence of random walk behaviour for the Bombay Stock Exchange.

[Insert Table 1]

Crises have a way of shaking up things; they can become a wake up call or they can also worsen things. The Crises can trigger the implementation of new policies which can either make markets more efficient or less efficient. For example, as an aftermath of the Asian crises, Malaysia implemented short term controls on inflow and outflow of capital. In the existing literature on Asian market efficiency, there are a number of papers which have examined the effect of crisis on market efficiency. However, they mostly focus on the Asian crisis. They also yield conflicting results as regards the impact of crises on market efficiency**.** Lim, Brooks and Kim (2008) examine the effects of the 1997 financial crisis on the efficiency of eight Asian stock markets with the use of rolling bicorrelation test statistics for the three sub-periods of pre-crisis, crisis, and post-crisis. Their results show that the crisis has a negative effect on the efficiency of most Asian stock markets, with Hong Kong being the most negatively affected followed by the Philippines, Malaysia, Singapore, Thailand and Korea. However, they find that the efficiency of these markets improved after the crisis. Hoque, Kim and Pyun (2007) investigate the efficiency of eight emerging Asian stock markets during the pre-Asian crisis (1990–1997) and post-Asian crisis (1998–2004) periods. They discover that the crisis did not significantly affect the efficiency of Asian markets. Markets that were inefficient (Hong Kong, Indonesia, Malaysia, Philippines, Singapore and Thailand) and efficient (S. Korea) continued to be so after the crisis. The only exception was Taiwan which showed improvement in its efficiency. Kim and Shamsuddin (2008), using multiple variance ratio tests, more or less arrived at the same conclusion. The efficient markets (Hong Kong, Japan, S. Korea and Taiwan) and inefficient ones (Indonesia, Malaysia and Philippines) remained in the same state after the Asian crisis. The exceptions were

Singapore and Thailand which became more efficient after the crisis. Although it is well-known that the GFC is different from previous crises, to our knowledge, there has been no study of its impact on Asian market efficiency.

Due to changes occurring in financial markets across time, market efficiency therefore could be time varying. However, only a few studies have considered the time varying nature of market efficiency. Kim and Shamsuddin (2008) investigated the efficiency of nine Asian stock markets - Hong Kong, Indonesia, Japan, S. Korea, Malaysia, Philippines, Singapore, Taiwan and Thailand across the period 1990 to 2005. They find that Hong Kong, Japan, S. Korea and Taiwan markets are efficient while the markets of Indonesia, Malaysia and Philippines continued to be inefficient, despite financial liberalisation policies implemented in the 1980s which were intended to improve the efficiency of these markets. Cajueiro and Tabak (2004a,b) find the level of market efficiency to vary across periods, with inefficiency at its peak during crisis , followed by pre-crisis, then post-crisis.

Thus, it is evident that there is a need for more studies relating to the issue of efficiency of Asian stock markets, particularly those that focus on the effect of the GFC and on the time varying level of efficiency**.** We therefore address this gap in the literature. As stated previously, we examine the issue of market efficiency in relation to a larger set (sixteen) of Asian stock markets. We apply two newly-developed autocorrelation tests which are robust to heteroskedasticity across the period 2001 to 2011. We take into account the effect of the GFC by dividing the period into two sub-periods: pre-GFC and post GFC. We conduct the two tests over rolling periods to determine the time varying nature of the (in)efficiency of each market.

3. Data

This study employs the MSCI daily data derived from Datastream dataset expressed in US dollars. The sample period is from 1 January 2001 to 9 September 2011. In order to capture the effect of the GFC on market efficiency, the period is subdivided into two sub-periods: pre-GFC (1 January 2001 to 31 December 2007) and post GFC (1 January 2008 to 9 September 2011). There are 2,789 observations in the complete dataset pertaining to 16 Asian markets: Australia, China A, China B, Hong Kong, India, Indonesia, Japan, Malaysia, New Zealand, Pakistan, Philippines, Singapore, S. Korea, Sri Lanka, Taiwan, Thailand. These countries are classified by MSCI into developed markets, emerging markets, and frontier markets. (Please visit http://www.msci.com/products/indices/market_classification.html for details of the classification.) Based on the MSCI 2011 classification, among the 16 markets, 5 are developed Markets (Australia, Hong Kong, Japan, New Zealand and Singapore), 9 are emerging markets (China A & B, India, Malaysia, Philippines, S. Korea, Thailand, Taiwan and Thailand) and 2 are frontier markets (Pakistan and Sri Lanka).

Figure 1 presents the movement of the MSCI index for each of the 16 markets while Table 2 gives the descriptive statistics of daily market returns for each market. Figure 1 shows that all markets exhibit a significant inverted U-turn around the beginning of 2008 after a period of enduring growth. The impact of the GFC lasts about a year or so and then most of the indices mount again. As a matter of fact, markets such as China_B, Indonesia, Malaysia, Philippines, S. Korea, Sri Lanka, and Thailand even reach a level in 2010/2011 that is higher than the pre-GFC peak.

Table 2(a) shows that over 2001~2011, the average daily market return is 0.035% with Sri Lanka the highest (0.099%) and Japan the lowest and the only negative (-0.016%). In general, these markets are volatile, left-sewed, and all leptokurtic. Also, according to the Jargue-Bera statistic, none of the markets is normally-distributed. Comparing with the results before and after the GFC in Table 2(b) and Table 2(c), it is found the post-GFC daily returns are generally lower (the average return drops from 0.05% to -0.01%) and the stock markets become more volatile (the average standard deviation rises from 1.289 to 1.563).

[Insert Figure 1 here]

[Insert Table 2 here]

4. Methodology

This section describes the statistical tests used in this study, which includes Escanciano and Lobato (2009)'s automatic Box-Pierce Q test (hereafter, the AQ test) and Nankervis and Savin (2010)'s generalised Andrews-Ploberger test (hereafter, the GAP test). The procedures of these two tests are described as follows.

Let Z_t be the stock price for t=1,...,n and $Y_t = \ln(Z_t) - \ln(Z_{t-1})$ be its log return. Define the j[th] sample autocorrelation $\hat{\rho}_j = \hat{\gamma}_j / \hat{\gamma}_0$ where $\hat{\gamma}_j = (n-j)^{-1} \sum_{t=1+j}^{n} (Y_t - \overline{Y})(Y_{t+j} - \overline{Y})$ and $\overline{Y} = n^{-1} \sum_{t=1+j}^{n} Y_t$.

Tests used for market efficiency are typically constructed from a fixed number of autocorrelations. The leading example is the Box-Peirce Q_k test (cf. Box and Peirce, 1970), defined as $Q_k = n \sum_{j=1}^{k} \hat{\rho}_j^2$, which examines serial correlations up to k lags. In practice, the Q_k test requires the choice of a fixed lag number (k). On the one hand, choosing a small k might lead to an inconsistent result as the test may fail to detect serial correlation at lags higher than k; on the other hand, choosing a large k could cost the power of the test as many unnecessary lags may be taken in. Hence, the outcome of the Q_k test could be rather sensitive to the choice of k.[2] Apart from the lag choice issue, tests for market efficiency could suffer from substantial size distortion if they were applied to series that are actually serially uncorrelated but with some kind of non-linear dependence, such as conditional heteroskedasticity. As many economic and financial time series are well-recognized to exhibit conditional heteroskedasticity (GARCH or stochastic volatility) the testing result may not be creditable if the heteroskedasticity were not controlled.

Many tests are developed to fix these two issues. First, to deal with the size issues, modified tests are suggested building on autocorrelation measures that are robust to heteroskedasticity and other forms of non-linear dependence. See, for example, Lobato, Nankervis and Savin (2001, 2002), Guo and Phillips (2001) and Horowitz et al. (2006). In the paper, following Lobato, Nankervis and Savin (2001, 2002), two robust estimates for autocorrelation are considered:

$$\tilde{\rho}_j = \frac{\hat{\gamma}_j}{\sqrt{\hat{\tau}_j}} \text{ where } \hat{\tau}_j = \frac{1}{(n-j)} \sum_{t=1+j}^{n} (Y_t - \overline{Y})^2 (Y_{t+j} - \overline{Y})^2 , \tag{1a}$$

and

$$\tilde{\rho}_j^* \text{ in } \tilde{\rho}^* = \tilde{\rho}_1^*, \ldots, \tilde{\rho}_k^* \text{ where } \tilde{\rho}^* = \hat{L}\hat{r} \text{ with } \hat{V}^{-1} = \hat{L}'\hat{L} \text{ and } \hat{r} = \hat{r}_1, \ldots, \hat{r}_k . \tag{1b}$$

[2] Another commonly used test for market efficiency: the variance ratio (VR) test (cf. Cochrane, 1988 and Lo and MacKinlay, 1989), which is built on the variance ratio: $VR = \{(nk)^{-1} \sum_{t=k}^{n} (Y_t + Y_{t-1} + \ldots + Y_{t-k+1} - k\overline{Y})^2\} / \hat{\gamma}_0$, also bears the same problem as it requires the choice of a fixed number, *k*, known as the holding period.

Here, $\hat{V}$ is a consistent estimator of V, the variance-covariance of $\hat{r}$.[3]

To deal with the sensitivity of the testing outcome due to the choice of a lag parameter, the literature in general suggests taking into account a large number of autocorrelation lags to avoid inconsistency while dealing with the potential power loss with several different approaches. In this paper, two of these tests are considered. First, we consider the automatic Box-Peirce Q_k test of Escanciano and Lobato (2009):

$$AQ_{\bar{k}} = n\sum_{j=1}^{\bar{k}} \tilde{\rho}_j^2 \ . \qquad (2)$$

This test incorporates a data-driven rule in the choice of the lag parameter: $\bar{k} = \min\{m : 1 \leq m \leq d; L_m \geq L_h, h = 1,2,\ldots,d\}$ where $L_k = AQ_k - \pi(k,n,\lambda)$ and $\pi(k,n,\lambda) = k\ln(n)$ if $\max_{1\leq j\leq d}\sqrt{n}\,|\tilde{\rho}_j| \leq \sqrt{\lambda\ln(n)}$ and $\pi(k,n,\lambda) = 2k$ otherwise. Here, d is a large fixed upper bound and λ is a fixed number. Note that $\pi(k,n,\lambda)$ is a penalty term that is an increasing function of the included number of autocorrelations (k) and the penalty function is either based on the Akaike Information Criterion (AIC) (*2k*) or the Bayesian Information Criterion (BIC) ($k\ln(n)$) and which criterion is effectively used is determined by a data-driven rule that depends on whether "$\max_{1\leq j\leq d}\sqrt{n}\,|\tilde{\rho}_j| \leq \sqrt{\lambda\ln(n)}$" is true.[4] Unlike the usual Q_k test, the automatic test, as shown by the simulation of Escanciano and Lobato (2009), is completely

[3] In this paper, following Nankervis and Savin (2010), the VARHAC estimation procedure of den Haan and Levin (1997) is employed using the Bayesian Information Criterion (BIC) with the maximum lag 5.

[4] Escanciano and Lobato (2009) suggest set λ=2.4 which is motivated from an extensive simulation study. Small values of λ result in the Akaike's criterion choice, while a large λ leads to the Schwarz's criterion. Moderate values, such as 2.4, give a switching effect that combines the advantages of the two model selection criteria.

insensitive to the choice of d. In (2), when $\tilde{\rho}_j^*$ is used (in the place of $\tilde{\rho}_j$), the regarding test statistic is denoted as $AQ_{\bar{k}}^*$. Under the null hypothesis of market efficiency, $AQ_{\bar{k}}, AQ_{\bar{k}}^* \Rightarrow \chi^2(1)$ as $n \to \infty$ and the test reject the null hypothesis when $AQ_{\bar{k}}$ ($AQ_{\bar{k}}^*$) is large. Second, we consider a test suggested in Andrews and Ploberger (1996). In an ARMA(1,1) setting, a class of powerful tests for no serial correlation are derived by Andrews and Ploberger (1996) and these tests are recently modified by Nankervis and Savin (2010) to be robust to non-linear dependence. Among these tests, we consider the sup-LM test:

$$GAP = \ln \int \exp(LM_n(\theta)) dJ(\theta), \tag{3a}$$

where

$$LM_n(\theta) = n(1-\theta)^2 (\sum_{j=0}^{k_n} \theta^j \tilde{\rho}_j)^2 \tag{3b}$$

with $\theta = \{0, \pm.01, \ldots, 79, .80\}$ and k_n is set to be a large number (say, for example, $k_n = n^{1/2}$), and $J\theta$ is a probability measure (such as the uniform measure). In (3b), when $\tilde{\rho}_j^*$ is used in replacing $\tilde{\rho}_j$, the regarding test statistic is denoted as GAP*. Unlike the Box-Peirce test, the outcome of the test is insensitive to the choice of k_n. Under the null hypothesis of market efficiency, $GAP, GAP^* \Rightarrow \ln \int \exp(G(\theta)/2) dJ(\theta)$ as $n \to \infty$ where $G(\theta) = (1-\theta^2)(\sum_{i=0}^{\infty} \theta_i Z_i)^2$ and Z_i is a sequence of iid N(0,1) random variables. The GAP (GAP*) statistic rejects the null hypothesis in the right-tail.

5. Empirical Results

The results from the tests corresponding to the full sample are presented in Table 3(a) while those relating to the sub-period before and after the GFC are respectively shown in Tables 2(b) and 2(c). The testing results – the P-values of AQ, AQ*, GAP and GAP* – come out to be rather in agreement with each other, backing up that our overall results are robust. Note that, in this paper, a market is regarded efficient if the corresponding P-value is larger than 0.05 and inefficient otherwise.

In terms of the full sample, it can be seen from Table 3(a) that the five MSCI-classified developed markets (Australia, Hong Kong, Japan, New Zealand and Singapore) are all efficient while only three of the nine emerging markets (China_A, S. Korea and Thailand) are efficient leaving the remaining six (China_B, India, Indonesia, Malaysia, Philippines and Taiwan) inefficient. Neither of the two frontier markets (Pakistan and Sri Lank) is efficient. It appears therefore that the developed markets are efficient while the less developed ones might be not, which is in line with findings of prior studies. It is worth noting that among the developing economies, China A, South Korea and Thailand were found to be efficient. China A are generally only open for investment for Chinese citizens while Chinese B are open to both foreign and local investors. China A, unlike China B, has experienced very significant deregulations and therefore as a result of this, it has experienced very high growth since 2005. South Korea and Thailand are known to have actively implemented reforms which deregulated their financial markets and removed major restrictions in international capital flows. On the other hand, other less developed and more especially the frontier markets did not do so (Pan et al. 2007; Jongwanich, et al. 2011; Kanthavit and Arunsi, 2012)

[Insert Table 3 here]

Before the GFC, Table 3(b) shows that as a whole, the markets are efficient as indicated by the average p-values for all the markets which are all greater than 0.05. In terms of the developed markets sub-group, with the exception of Australia, all of them are efficient. In the case of the emerging markets, 4 markets are efficient – China A, South Korea, Taiwan and Thailand and 5 are not – China B, India, Indonesia, Malaysia, and the Philippines; however, as a whole, the emerging markets are efficient as their combined p-values still exceed 0.05. In relation to the frontier markets, one of them – Pakistan, is efficient but the other one - Sri Lanka, is inefficient. For the period after the GFC, it can be seen in Table 3(c) that the markets as a whole became more efficient as indicated by the higher average combined p-values of the markets. This result applies to both the developed and emerging markets but not for the frontier markets. After the GFC, Australia has now become efficient making all developed markets efficient. With regards to the emerging markets, there are now more (7) efficient markets as China B, India and Malaysia have become efficient. Both frontier markets became inefficient after the GFC.

Figure 2 reports the rolling subsample results based on the AQ and GAP tests. Each rolling window covers period "t to t+500" (so each subsample covers about 2 years) where t=1, 51, 101,… Note that, though the subsample results are based on much shorter sub-periods (500 observations) and hence the tests might be less powerful, they can provide an indication of the level of efficiency of each market across time. It is clear from Figure 2 that the level of market efficiency (inefficiency) for each market varies significantly across the period.[5] It can be seen from Figure 2 that China A, Japan and S. Korea are efficient all the time while Singapore, Australia, China B, Hong Kong, India, New Zealand, Taiwan, and Thailand are

[5] The evolving nature of market efficiency/inefficiency may be linked to the framework of Lo's (2004) adaptive market hypothesis.

generally efficient most of the time with short bouts of inefficiency. Interestingly, nearly the inefficiency bouts for these markets occurred before the GFC (except in the case of Taiwan). On the other hand, Malaysia, Indonesia, Sri Lanka and the Philippines are inefficient most of the time.

[Insert Figure 2 here]

We also compute the average P-values among 16 markets in each rolling subsamples and plot the result in Figure 3. Figure 3 shows a clear upward trend, particularly since the sub-period starting at 2006 – this might indicate a progress toward efficiency over the 16 studied stock market after the GFC. This figure confirms the findings shown in Table 3 – that the markets have become efficient over time. Figure 3 also shows that during the subsample periods that cover pre-GFC and early GFC observations (the shaded area), the markets as a whole became inefficient; however, the sub-periods with only post-GFC observations turned back to became even more efficient than they were before the GFC. During the GFC, the developed markets did not actually suffer a significant decrease in efficiency, it was the other markets that did, as can be gleaned from Figure 2. The markets that registered the most significant increase in efficiency after the GFC are Australia, Hong Kong, India, Indonesia, New Zealand Pakistan and Thailand.

[Insert Figure 3 here]

6. Conclusion

In this paper, provide fresh evidence on the issue of market efficiency in general and Asian market efficiency in particular. We note that the bulk of the literature on market efficiency relies on the use of autocorrelation tests which we believe could suffer from weaknesses arising from heteroskedasticity in the data. We examined the efficiency of 16 Asian stock markets across the period 2001 to 2011 based on two tests that are robust to heteroskedasticity – the Escanciano & Lobato (2009)'s automatic Box-Pierce Q_p test and Nankervis & Savin (2010)'s generalised Andrews-Ploberger test. We take into account the impact of the GFC by dividing the sample period into two sub-periods: pre-GFC (2001 to 2008) and post-GFC (2008 to 2010).

Inspite of the massive growth of their respective economies, their financial markets still lag behind in development which indicates that these markets could be inefficient. However, these markets have implemented liberalisation and deregulation policies since the 1980s which mean that these markets could be efficient. The existing literature, although significant in volume, does not provide clarity on this issue as their results are mixed. Moreover, as with the literature on market efficiency in general, these studies are based on autocorrelation tests which are plagued by problems arising from heteroskedasticity.

For the full sample period, we find that the markets which are more developed (Australia, China A, Hong Kong, Japan, New Zealand, Singapore and South Korea) are efficient while the ones that are less developed (China B, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka and Taiwan) are either less efficient or inefficient.

We also find the level of efficiency or inefficiency of each market to be time varying. The markets as a whole became more efficient over time. During the GFC, the markets became inefficient particularly the less-developed ones but the developed ones were not significantly affected; however, after the GFC, the markets even became more efficient than they were before the GFC. Thus, it appears that whether or not Asian markets are efficient depends on whether one is looking at developed or less developed markets and at what point in time one is focusing on.

In terms of future research, it would be fruitful to investigate as to what account for the differential effect of the GFC on the level of efficiency of the Asian markets.

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Table 1: Summary of Literature Review

Markets	Author(s)	Data Frequency	Sample period	Methodology
AUSTRALIA				
Efficient	Narayan & Smyth (2004)	Monthly	1960 - 2003	Two-regime TAR(k) model with an autoregressive unit root. ADF test, Nonlinearity test, Threshold unit root test
Inefficient	Hasanov (2008)	Monthly	1973 - 2006	Non-linear unit root test procedure developed by Kapetanios et al. (2003)
CHINA A				
Efficient	Liu & Liang (2007)	Daily	1990 - 2006	Wild Bootstrap method and R/S method
Inefficient	Lee et al. (2001)	Daily	1990 - 1997	VR, ADF
Inefficient	Araújo Lima & Tabak (2004)	Daily	1992 - 2000	MVR
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Niblock & Sloan (2007)	Daily & Weekly	2002 - 2005	Serial Correlation Coefficient Tests, Runs Tests, Variance Ratio Tests, Unit Root Tests, Engle-Granger cointegration tests, and Granger causality tests
Mixed	Hung (2009)	Daily	1996 - 2005	LOMAC variance ratio test, Ranks-based and signs-based variance ratio tests, Multiple variance ratio tests
CHINA B				
Inefficient	Hung (2009)	Daily	1996 - 2005	LOMAC variance ratio test, Ranks-based and signs-based variance ratio tests, Multiple variance ratio tests
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Niblock & Sloan (2007)	Daily & Weekly	2002 - 2005	Serial Correlation Coefficient Tests, Runs Tests, Variance Ratio Tests, Unit Root Tests, Engle-Granger cointegration tests, and Granger causality tests
HONG KONG				
Efficient	Coutts & Cheung (2001)	Daily	1985 - 1997	The Variance ratio (VR) test of Lo and MacKinlay (1988)
Efficient	Araújo Lima & Tabak (2004)	Daily	1992 - 2000	MVR
Efficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	The Variance ratio (VR) test (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests
Inefficient	Mun & Keen (1994)	Daily & Weekly	1982 - 1991	VR, Spectral shape test
Inefficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test

Table 1 (continued): Summary of Literature Review

Markets	Author(s)	Data Frequency	Sample period	Methodology
INDIA				
Efficient	Gupta (1990)	Daily	1979 - 1987	Serial correlation analysis and runs analysis
Efficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Gupta & Basu (2007)	Daily	1991 to 2006	ADF, PP, KPSS tests
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Islam & Khaled (2005)	Daily, Weekly, Monthly	1990 - 2001	Unit root test, VR
Mixed	Cooray & Wickramasighe (2007)	Monthly	1996 - 2005	Unit root tests (ADF, PP, DF-GLS & ERS), cointegration test, a multivariate Granger causality test or block causality test and impulse response analysis.
INDONESIA				
Inefficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	The Variance ratio (VR) test (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Inefficient	Guidia & Gupta (2013)	Daily	2000 - 2011	Unit root tests (ADF & KPSS tests), Variance ratio tests, MVR tests, Wright test, Runs test, cointegration test
JAPAN				
Efficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Efficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	The variance ratio (VR) test (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests)
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
MALAYSIA				
Inefficient	Mun & Keen (1994)	Daily & Weekly	1982 - 1991	VR, Spectral shape test
Inefficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Kawakatsu & Morey (1999)	Monthly	1976 - 1997	VR, MVR, ADF
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	The variance ratio (VR) test (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests)
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Inefficient	Guidia & Gupta (2013)	Daily	2000 - 2011	Unit root tests (ADF & KPSS tests), Variance ratio tests, MVR tests, Wright test, Runs test, cointegration test

Table 1 (continued): Summary of Literature Review

Markets	Author(s)	Data Frequency	Sample period	Methodology
NEW ZEALAND				
Efficient	Kumar Narayan (2005)	Monthly	1967 - 2003	Two-regime TAR(k) model with an autoregressive unit root. ADF test, Nonlinearity test, Threshold unit root test
Inefficient	Hasanov (2008)	Monthly	1988 - 2006	Non-linear unit root test procedure developed by Kapetanios et al. (2003)
PAKINSTAN				
Inefficient	Irfan, Irfan & Awais (2010)	Daily, Monthly	1999 - 2009	Unit root test, autocorrelation tests and ARIMA model
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Cooray & Wickramasighe (2007)	Monthly	1996 - 2005	Unit root tests (ADF, PP, DF-GLS & ERS), cointegration test, a multivariate Granger causality test or block causality test and impulse response analysis.
PHILIPPINES				
Efficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Kawakatsu & Morey (1999)	Monthly	1976 - 1997	VR, MVR, ADF
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	Variance ratio test, (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Inefficient	Guidia & Gupta (2013)	Daily	2000 - 2011	Unit root tests (ADF & KPSS tests), Variance ratio tests, MVR tests, Wright test, Runs test, cointegration test
SINGAPORE				
Efficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	Variance ratio test, (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests
Efficient	Guidia & Gupta (2013)	Daily	2000 - 2011	Unit root tests (ADF and KPSS), variance ratio tests, MVR tests, Wright test, Runs test, cointegration test
Inefficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Araújo Lima & Tabak (2004)	Daily	1992 - 2000	MVR
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test

Table 1 (continued): Summary of Literature Review

Markets	Author(s)	Data Frequency	Sample period	Methodology
SOUTH KOREA				
Efficient	Ryoo & Smith (2002)	Daily	1988 - 1998	MVR
Efficient	Narayan & Smyth (2004)	Monthly	1981 - 2003	ADF test, Zivot and Andrews test, Lumsdaine and Papell test
Efficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Efficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	Variance ratio test, (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests
Inefficient	Mun & Keen (1994)	Daily & Weekly	1982 - 1991	VR, Spectral shape test
Inefficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Kawakatsu & Morey (1999)	Monthly	1976 - 1997	VR, MVR, ADF
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	The generalized spectral martingale (EV-MDS) test
Mixed	Ayadi & Pyun (1994)	Daily, Weekly, Monthly, Quarterly	1984 - 1998	VR
SRI LANKA				
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Cooray & Wickramasighe (2007)	Monthly	1996 - 2005	Unit root tests (ADF, PP, DF-GLS & ERS). cointegration test, a multivariate Granger causality test or block causality test and impulse response analysis.
TAIWAN				
Efficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Efficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Efficient	Kim & Shamsuddin (2008)	Daily & Weekly	1990 - 2005	The variance ratio (VR) test (Chow and Denning (1993), Wild Bootstrap test, Joint Sign test, Small sample properties of joint VR tests)
Inefficient	Mun & Keen (1994)	Daily & Weekly	1982 - 1991	VR, Spectral shape test
Inefficient	Kawakatsu & Morey (1999)	Monthly	1976 - 1997	VR, MVR, ADF
Inefficient	Chang & Ting (2000)	Weekly, Monthly, Quarterly, Yearly	1971 - 1996	Variance Ratio
Inefficient	Peng et al. (2004)	Weekly	1993 - 2002	Chaos theory
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test
Mixed	Kung & Wong (2009)	Daily	1983 - 2005	Moving average and trading range break

Table 1 (continued): Summary of Literature Review

Markets	Author(s)	Data Frequency	Sample period	Methodology
THAILAND				
Efficient	Guidia & Gupta (2013)	Daily	2000 - 2011	Unit root tests (ADF & KPSS tests), Variance ratio tests, MVR tests, Wright test, Runs test, cointegration test
Inefficient	Mun & Keen (1994)	Daily & Weekly	1982 - 1991	VR, Spectral shape test
Inefficient	Huang (1995)	Weekly	1988 - 1992	VR, ADF
Inefficient	Kawakatsu & Morey (1999)	Monthly	1976 - 1997	VR, MVR, ADF
Inefficient	Hoque et al. (2007)	Weekly	1990 - 2004	MVR, Wright's sign test
Inefficient	Lim & Luo (2012)	Daily	1991 - 2007	Generalized spectral martingale (EV-MDS) test

Table 2: Descriptive statistics on stock returns

(a) Full Sample: 01/01/2001~09/09/2011 (2,789 observations)

	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Australia	0.010	1.047	-0.549	9.629	5246.987
China_A	0.006	1.643	-0.130	7.300	2156.010
China_B	0.056	1.990	-0.043	7.396	2246.153
Hong Kong	0.010	1.573	0.009	12.293	10035.428
India	0.053	1.642	-0.328	10.407	6425.463
Indonesia	0.081	1.452	-0.652	9.717	5441.651
Japan	-0.016	1.576	-0.408	10.418	6471.814
Malaysia	0.028	0.846	-1.033	15.089	17479.495
New Zealand	0.002	0.756	-0.483	8.304	3377.530
Pakistan	0.072	1.470	-0.301	6.252	1271.229
Philippines	0.038	1.347	0.099	16.780	22070.738
Singapore	0.013	1.267	-0.156	7.657	2531.087
S. Korea	0.046	1.607	-0.530	8.622	3803.869
Sri Lanka	0.099	1.299	0.367	31.070	91623.087
Taiwan	0.017	1.449	-0.181	5.373	669.645
Thailand	0.049	1.407	-0.816	14.514	15717.088
Average	0.035	1.398	-0.321	11.301	

(b) Pre-GFC Sample: 01/01/2001~31/12/2007 (1,825 observations)

	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Australia	0.038	0.741	-0.490	6.797	1169.217
China_A	0.051	1.459	0.003	8.116	1990.157
China_B	0.090	2.049	0.168	7.662	1661.419
Hong Kong	0.033	1.212	-0.244	6.543	972.803
India	0.094	1.459	-0.780	8.614	2582.086
Indonesia	0.103	1.313	-0.705	8.598	2534.169
Japan	0.006	1.330	-0.113	4.878	272.092
Malaysia	0.041	0.818	-0.669	10.545	4464.604
New Zealand	0.024	0.670	-0.546	7.690	1763.513
Pakistan	0.122	1.487	-0.407	6.401	930.065
Philippines	0.048	1.287	0.966	19.782	21700.746
Singapore	0.031	1.105	-0.167	5.885	641.351
S. Korea	0.073	1.567	-0.506	7.247	1449.037
Sri Lanka	0.095	1.392	0.399	34.459	75304.468
Taiwan	0.032	1.404	-0.092	5.189	366.893
Thailand	0.064	1.330	-0.844	18.291	17995.571
Average	0.059	1.289	-0.252	10.419	

(c) Post-GFC Sample: 01/01/2008~09/09/2011 (964 observations)

	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Australia	-0.043	1.459	-0.386	6.481	510.611
China_A	-0.077	1.943	-0.172	5.884	338.883
China_B	-0.008	1.873	-0.585	6.393	517.284
Hong Kong	-0.035	2.094	0.143	9.981	1960.524
India	-0.024	1.941	0.104	10.301	2142.655
Indonesia	0.039	1.684	-0.549	9.513	1752.409
Japan	-0.058	1.959	-0.514	10.639	2386.468
Malaysia	0.002	0.897	-1.535	20.658	12902.210
New Zealand	-0.041	0.895	-0.346	7.623	877.764
Pakistan	-0.023	1.433	-0.097	6.042	373.250
Philippines	0.019	1.455	-1.030	12.694	3944.602
Singapore	-0.021	1.527	-0.106	7.438	792.949
S. Korea	-0.005	1.679	-0.553	10.499	2307.733
Sri Lanka	0.105	1.102	0.227	7.459	806.912
Taiwan	-0.012	1.531	-0.301	5.515	268.580
Thailand	0.022	1.542	-0.756	9.927	2019.000
Average	-0.010	1.563	-0.404	9.190	

Table 3: Results (p-values) of statistical tests

(a) Full Sample: 01/01/2001~09/09/2011 (2,789 observations)

	AQ	AQ*	GAP	GAP*
Group 1: Developed Markets				
Australia	0.401	0.163	0.472	0.207
Hong Kong	0.493	0.196	0.619	0.246
Japan	0.641	0.483	0.576	0.265
New Zealand	0.123	0.091	0.06	0.028
Singapore	0.445	0.411	0.485	0.416
Average	0.421	0.269	0.442	0.232
Group 2: Emerging Markets				
China_A	0.948	0.902	0.898	0.902
China_B	0.008	0.062	0.001	0.001
India	0.021	0.002	0.039	0.003
Indonesia	0.000	0.000	0.000	0.001
Malaysia	0.000	0.000	0.000	0.000
Philippines	0.000	0.000	0.000	0.000
S. Korea	0.492	0.609	0.544	0.601
Taiwan	0.031	0.047	0.032	0.039
Thailand	0.752	0.751	0.524	0.41
Average	0.250	0.264	0.226	0.217
Group 3: Frontier Markets				
Pakistan	0.001	0.001	0.000	0.000
Sri Lanka	0.000	0.000	0.001	0.000
Average	0.001	0.001	0.001	0.000
All Markets Average	0.272	0.232	0.266	0.195

(b) Pre-GFC Sample: 01/01/2001~31/12/2007 (1,825 observations)

	AQ	AQ*	GAP	GAP*
Group 1: Developed Markets				
Australia	0.034	0.011	0.073	0.026
Hong Kong	0.598	0.697	0.263	0.362
Japan	0.345	0.300	0.377	0.339
New Zealand	0.490	0.541	0.35	0.379
Singapore	0.713	0.768	0.511	0.556
Average	0.436	0.463	0.315	0.332
Group 2: Emerging Markets				
China_A	0.820	0.791	0.754	0.734
China_B	0.012	0.075	0.001	0.001
India	0.042	0.001	0.058	0.001
Indonesia	0.000	0.000	0.001	0.001
Malaysia	0.000	0.000	0.000	0.000
Philippines	0.002	0.000	0.006	0.000
S. Korea	0.661	0.669	0.526	0.529
Taiwan	0.150	0.179	0.111	0.138
Thailand	0.986	0.970	0.702	0.664
Average	0.297	0.298	0.240	0.230
Group 3: Frontier Markets				
Pakistan	0.148	0.152	0.135	0.135
Sri Lanka	0.004	0.000	0.006	0.000
Average	0.076	0.076	0.071	0.068
All Markets Average	0.313	0.322	0.242	0.242

Table 3 (continued): Results (p-values) of statistical tests

(c) Post-GFC Sample: 01/01/2008~09/09/2011 (964 observations)

	AQ	AQ*	GAP	GAP*
Group 1: Developed Markets				
Australia	0.767	0.408	0.687	0.366
Hong Kong	0.397	0.142	0.424	0.117
Japan	0.896	0.799	0.766	0.474
New Zealand	0.181	0.162	0.136	0.061
Singapore	0.512	0.386	0.691	0.712
Average	0.551	0.379	0.541	0.346
Group 2: Emerging Markets				
China_A	0.748	0.693	0.960	0.934
China_B	0.403	0.506	0.446	0.517
India	0.252	0.261	0.390	0.394
Indonesia	0.009	0.014	0.017	0.027
Malaysia	0.060	0.149	0.059	0.105
Philippines	0.000	0.000	0.000	0.002
S. Korea	0.611	0.883	0.840	0.927
Taiwan	0.105	0.182	0.163	0.228
Thailand	0.600	0.361	0.608	0.264
Average	0.310	0.339	0.387	0.378
Group 3: Frontier Markets				
Pakistan	0.000	0.002	0.000	0.000
Sri Lanka	0.001	0.000	0.000	0.000
Average	0.001	0.001	0.000	0.000
All Markets Average	0.346	0.309	0.387	0.321

Fig 1 Movements of the Asian stock markets

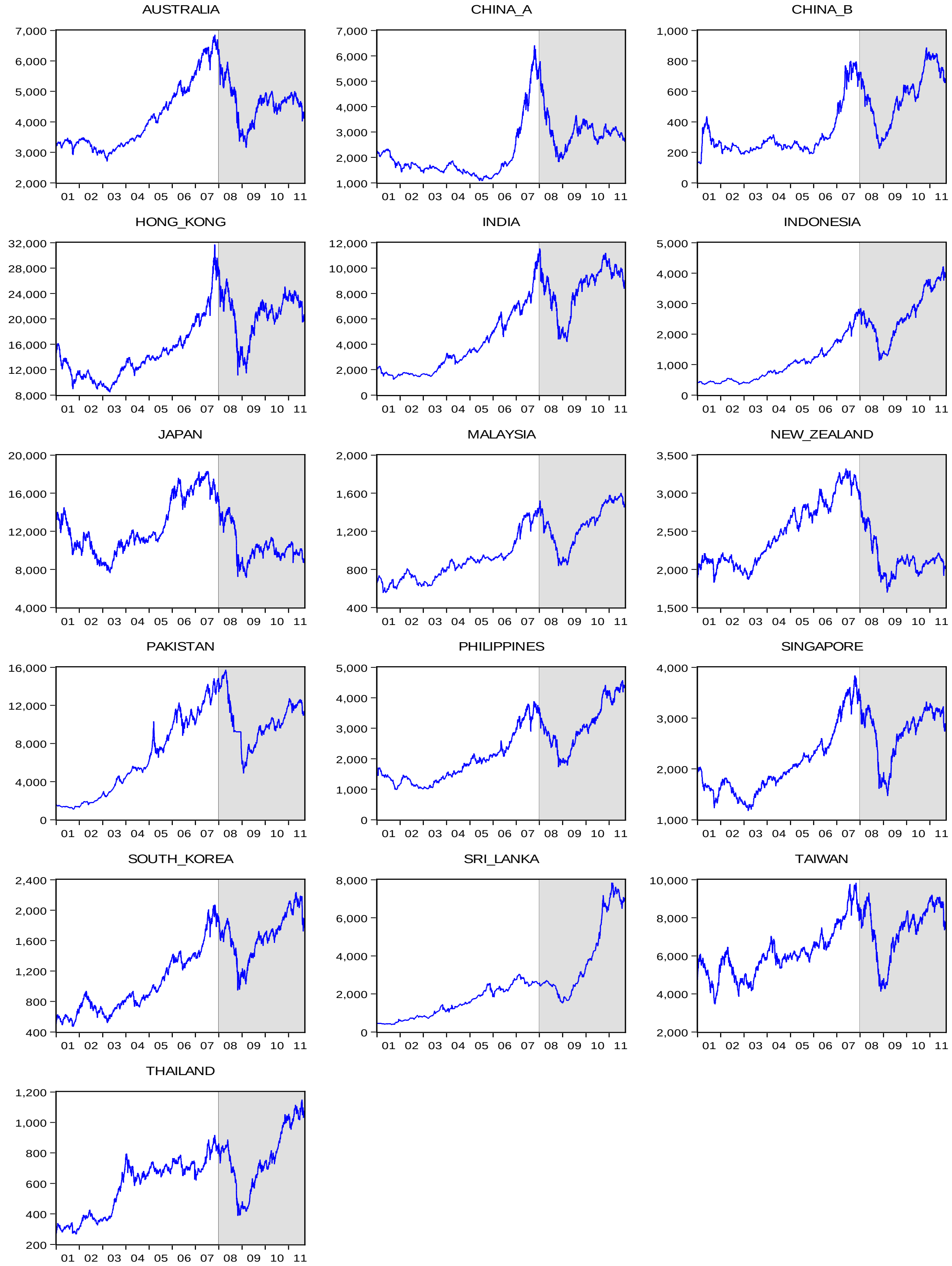

Fig 2 Rolling P-Values with AQ and GAP tests

Note: Each rolling window covers period "t to t+500" where t=1, 51, 101,… In each graph, the horizontal line gives the starting year and the shaded area represents the periods mixed with pre- and post-GFC observations.

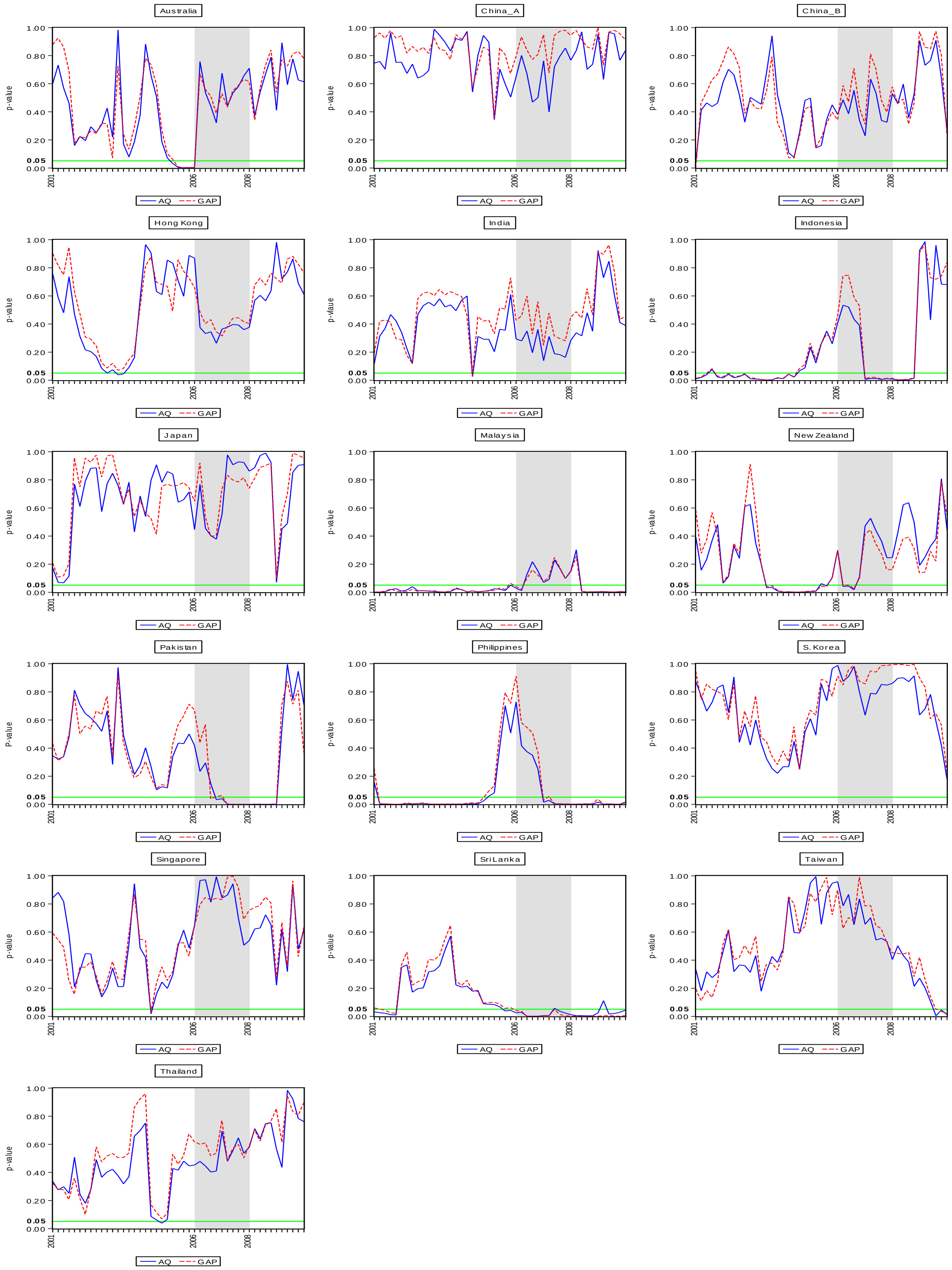

Fig 3 Average P-values across 16 markets (over each rolling subsamples)