Market Efficiency of Asian Stocks: Evidence based on Narayan-Liu-Westerlund GARCH-based Unit root test

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Abstract

This study uses the recently developed Generalized Autoregressive Conditional Heteroscedasticity (GARCH) model-based unit root test of Narayan et al. (2016) to examine the stock market efficiency of 19 Asian countries, using daily prices. The model flexibly accounts for heteroskedasticity and two structural breaks, the presence of which can lead to inaccurate results if neglected. Our results disclose the stock markets of 14 countries as inefficient following the rejection of the unit root null hypothesis. However, the stock markets of China, Hong Kong, Japan and the Korea Republic are adjudged efficient. We further extend the model to accommodate a maximum of five breaks to check the robustness of our results to higher breaks. We observe that the results are largely consistent except for Lebanon and Singapore. For completeness, we compare the results with those of conventional GARCH models that do not account for structural breaks and discover differing results for some countries. Hence, the role of structural breaks is not negligible in assessing market efficiency. Future studies should also incorporate heteroskedasticity and structural breaks in their modelling framework to obtain accurate results.

Keywords: Stock market efficiency; GARCH; Unit root; Structural breaks; Asia.
JEL Classification: C22, G01; G15

1. Introduction

One of the oldest traditional hypotheses in Financial Economics is the Efficient Market Hypothesis (EMH). According to Samuelson (1965), it is expected that, in an efficient market, stock price movement follows random walk path. Thus, stock returns are unpredictable, and investors' strategies cannot allow them to make arbitrage profits, that is, the absence of economic profit opportunities (see Fama, 1970; Jensen, 1978; Timmermann and Granger, 2004). Obviously, the issue surrounding stock market efficiency requires no formal introduction following the increasing level of empirical concentration on the subject matter in the literature. However, it requires constant and regular updates following developments in the modern stock markets, as well as the development of different techniques to tackle inherent market innovations or structural factors in the time series, such as the presence of structural breaks, nonlinearities, time variation and regime changes, in order to provide more accurate results.[1] This is also true for other financial markets.

Mensi et al. (2018) put it more succinctly when they disclose that despite the use of different empirical techniques, determining market efficiency level remains valid till date. We connect this assertion with the recurring turbulences in the various financial markets as caused by various factors which frequently change the degree of efficiency. In particular, a few studies have noted that time-varying abnormal returns, which is usually a common characteristic of an inefficient market regime, could result from changing market conditions (see Kim et al., 2014; Lim and Brooks, 2011), while others attribute the inefficiency to many other factors including structural shifts, market manipulation, information asymmetry, market frictions and market uncertainties (see Comerton-Forde and Putnins, 2014; Shamsuddin and Kim, 2010;

[1] Thus, time-varying efficiency in the context of the Adaptive Market Hypothesis (Lo, 2004) can also be applied but this can be of a rational nature and lead to spurious detection of efficiency in the context of time-varying risk and/or other factors.

Shleifer and Vishny, 1997). This has resulted in the controversial evidences of the stock market of efficiency at different times, and across different techniques (Ali et al., 2018).

In recent years, the Asian community seems to be pushing significantly and rising to prominence in the global economy. For instance, Rizvi and Arshad (2014) reveal that instead of the global economic and financial expansions, East Asia alone contributes 40% of the global GDP growth. They note further that such immense growth can be attributed to the formulation of trade and investment liberalization policies in the region. Consequently, this has resulted in the emergence of its stock markets. To confirm this, while the Chinese stock market has claimed significant high gain over 25 years (see Hu and Prigent, 2019), Kim et al. (2014) disclose that the Asian stock markets have been exhibiting varying and interesting degrees of maturity and development over time. The region has also been said to be attracting huge capital inflow from foreign sources, with Singapore developing into a global financial focal point, especially in terms of financial and banking services (see Rizvi and Arshad, 2016).

Yet, these markets are also well associated with many structural factors that continue to pose challenges as to their efficiency. For instance, the Chinese stock market has been adjudged to be faced with complex nonlinear features (see Han et al., 2019a) and multi-level market dynamics since the 1990s (see Han et al., 2019b). Besides, their efficiency sensitivity to information asymmetry and financial crises which frequently occurs either within the market or from exogenous sources seems to be high (see Hu and Prigent, 2019; Rivzi and Arshad, 2015). While the nonlinear movement could be caused by the presence of structural breaks along the time path, the information asymmetry and financial crises could in turn lead to significant structural shifts in the stock indices. It is important to put structural breaks into consideration with regards to determining if the stock markets of these countries can still be adjudged efficient to attract further investments and developments. Not considering these structural factors could result in unreliable conclusions being drawn.

Our first objective in this study is to test the stock market efficiency of the Asian countries using the newly proposed GARCH-based unit root model of Narayan et al. (2016). They note that the technique is superior to other unit root-based techniques for testing market efficiency due to its ability to account for two endogenous structural breaks and nonlinearity. The unit root test is found to be robust to GARCH orders and asymmetric conditional volatility.

Our second contribution relates to the expanse of countries considered. We are not oblivion of the notable studies that have been conducted for the region. However, the majority of these studies have been largely concentrated on the prominent countries in the region, such as China, Japan, Korea, Singapore, Pakistan and a few others(see Han, et al., 2019a; Han et al., 2019b; Kim et al., 2014; Jin, 2016; Lingaraja et al., 2014; Rivzi and Arshad, 2016). Little evidence is available for a few other countries including Kazakhstan, Oman, Jordan, Lebanon, Taiwan, Qatar, Vietnam, etc. Even the studies on the prominent countries did not largely put the inevitable effect of structural breaks into consideration. Hence, this study considers 19 Asian countries (including the prominent and unpopular, but emerging countries) into consideration, thus making the study with the largest consideration of Asian countries so far in the literature.

This remainder part of this paper is therefore structured as follows: Section 2 presents available literature on the topic. In section 3 and 4, methodology and empirical results are presented, while section 5 concludes the findings.

2. Review of Literature

As earlier noted, the rising prominence of the Asian economy, as well as its stock markets, has resulted in the flow of empirical analyses on stock market efficiency in that region, although more developed markets have been largely considered. Also, the empirical studies for the region have varied in scope, focus and methodology. This has resulted into a lack of consensus on empirical findings discovered over time, just as is observed in stock markets of other regions, including those of the world's most developed countries.

Using the runs test and serial correlation coefficient to examine the weak-form market efficiency of stock indices of five developed and 10 emerging Asian markets, Worthington and Higgs (2006) find no evidence of market inefficiency for the emerging stock markets. Hu and Prigent (2019) make consideration for the influencing role of information asymmetry on stock market efficiency, and they reveal that asymmetry in market information and illiquidity resulting from cluster trading impose an adverse effect on the Chinese stock market efficiency. In fact, they additionally disclose that there is a dominance of the effect of information asymmetry during the informational period, while the effect of illiquidity is prominent in other periods when trading has a lower concentration. The unit root tests employed by Mishra (2012) reveal that the Asian stock markets do not observe

weak form of market efficiency, and this conclusion is later corroborated by Amer (2014) and Paulo (2013) for South Asian countries using similar techniques in addition to variance ratio test. For the ASEAN countries, Shaik and Maheswaran (2017) employ various variance ratio tests due to different authors.[2] For five of the countries namely Viet Nam, Indonesia, Philippines, Malaysia and Thailand, they reject the efficient market hypothesis but establish a weak form of market efficiency for Singapore, Lao and Cambodia.

A few other studies have concentrated on the unavoidable impacts of financial crises on the efficiency of the stock markets of Asian countries. Notably identified in the literature are two prominent financial crises that strictly influenced the Asian stock markets, and they are the 1997 Asian financial crisis and the 2008 global financial crisis. For eight Asian countries, Hogue et al. (2007) examine the stock market efficiency for the periods before and after the Asian financial crisis and discover that the crisis did not alter the degree of efficiency of most of the stock markets. In particular, inefficiency still resulted after the crisis in Thailand, Malaysia, the Philippines, Hong-Kong, Singapore and Indonesia. This seems to be corroborated by the conclusion of Kim and Abdul (2008) which indicates the insignificance of the Asian

[2] The Association of Southeast Asian Nations (ASEAN) is a regional organization of 10 countries in the Southeast Asia that promote intergovernmental cooperation in order to facilitate economic, political, educational and sociocultural integration among member countries.

crisis on the market efficiency level of most of the East Asian countries, except Singapore and Thailand that observed efficiency during the post-crisis period.

Rizvi and Arshad (2016) assess the daunting impacts of the Asian financial crisis and the sub-prime crisis. They note that the impact of the former crisis was generally deteriorating and negative on the stock market efficiency of the countries considered, while the impact of the later varies, depending on the economic structure of the countries. The findings of Faiq et al. (2010) relatively contradict those of Rivzi and Arshad (2016) about the sub-prime crisis as they disclose insignificance on the informational efficiency of the Chinese stock market. The effect of the most notable financial crisis of 2008 has also been uncovered. Jin (2016) finds that the crisis had an adverse impact on the efficiency of the Asian stock markets as most stock returns observed long memory during the crisis period, but otherwise during the periods of tranquillity.

The most recent strand of the stock market efficiency literature appears to be connected to the determination of multi-fractal behaviour of stock market efficiency through the Multifractal detrended fluctuation analysis (MF-DFA) technique and its variants. Concerning Asia, studies that have engaged this technique include Rizvi and Arshad (2016), Han et al. (2019a), Han et al. (2019b), Wang and Wang (2018); Zhu and Zhang (2018) and Hasan and Mohammad (2015), among others. Virtually all the studies show evidence of the presence of multifractality in stock returns and different degrees of market efficiency at different phases. For instance, Han et al. (2019a) show that the returns series of the various Chinese stock indices showcase significant strong multifractal characteristics on the entire time scale, with ChiNext revealing the lowest multifractal behaviour, thus achieving the highest efficiency. On the other hand, Han et al. (2019a) come from the statistical and fractal angles to examine how market efficiency was affected by the 2015 stock market crash. They establish that SSE index returns exhibit a weaker multifractal structure than the SZSE index returns, suggesting that the Shenzhen stock market has a lower efficiency than the Shanghai stock market.

From the foregoing, assessment of stock market efficiency has been followed with different methodologies, ranging from the traditional methods, like the conventional unit root tests to variance ratio tests, and then to other advanced ones like the fractional integration and multifractal-based approaches. Obviously, the recently developed GARCH-based unit root method which flexibly accounts for structural breaks within nonlinear modelling has been rarely employed in the literature for the assessment of Asian stock markets efficiency.

3. Data and Pre-tests

Daily close indices of 19 Asian stocks were used. These datasets, spanning 28/07/2000 to 18/05/2020 were obtained from Bloomberg terminals. The lists of Asian stock indices used are listed in Table 1.We offer some preliminary analyses on the selected stock indices, including descriptive statistics, stationarity tests and graphical illustrations. Salient features of the descriptive statistics reported in Table 2. We observe that the stock prices swing widely apart for certain countries. For instance, Hong Kong records the highest average stock price index of 20,019 while Viet Nam has the least with a very low value of 527.30. We further assess the volatility of the series through the coefficient of variation. Depending on the level of market development and susceptibility to various market conditions and exogenous factors, we expect volatility to vary across the countries. Another notable empirical practice in time series analysis is the evaluation of the distribution properties of the series under consideration. In a large number of cases (12 countries), the stock indices are positively skewed, indicating a long thick tail to the right. This suggests that the stocks of these countries are underscored by recurrent small losses and a reduced chance of wide gains. The remaining indices are leftwardly or negatively skewed, implying that they exhibit regular minute gains and a few excessive losses. Turning to the kurtosis statistic, different behaviour is also established, with most of the series being platykurtic since their values are found below the threshold of 3. Supporting the conclusion from the skewness, these small values of kurtosis in most of the countries signal the tendency of a moderate degree of risk since the likelihood of extreme returns is reasonably low. It is thus seen from this brief statistical description of the series that the stock markets behave differently, as expected of countries with different levels of financial development. This further motivates the need to examine the degree of efficiency performance of the stock markets to determine their viability for future investments.

Based on the GARCH approach being employed to evaluate market efficiency, it is important to additionally consider the presence of autocorrelation in the series. We prove this with the Ljung-Box serial correlation test. Regardless of whether the residuals or their squared values are considered, the null hypothesis of no serial correlation is soundly rejected in all cases, thus suggesting that there is significant evidence of serial correlation in all the stock markets. The graphical plots provided in

Figure 1 shows that the stock indices exhibit significant fluctuations, thus giving credence to their high volatilities as established by the test of the coefficient of variation.

[Insert Table 2 about here]

[Insert Figure 1 about here]

Lastly, we decided to have a pre-test concerning the stationarity properties of the series ahead of the main analysis. This is important as the conventional unit root test is a traditional method of testing for market efficiency, although its power function could be weak to address inherent market innovations. This is the basis of the development of modern advanced tests. Notwithstanding, the results from the unit root test will give foresight to what should be expected upfront, and will further help to make a suitable comparison between these results and those of our proposed model. For robustness, we employ two unit root tests, namely the Augmented Dickey-Fuller (ADF) test, and its other version that accounts for structural breaks (ADF-SB). We observe from Table 3 that the unit root null hypothesis cannot be rejected for the stock market indices for virtually all the countries. The two exceptions of stationarity are found for Hong Kong when no structural breaks are accounted for and Taiwan regardless of the unit root model. Based on this then, the stock indices of the Asian countries can largely be adjudged nonstationary.

[Insert Table 3 about here]

4. Econometric Model and Empirical Findings

4.1 Econometric Model

We rely on the proposition of Narayan, Liu and Westerlund (2016) for the GARCH-based unit root test, with the regression model,[3]

$$X_t = \alpha_0 + \beta X_{t-1} + \sum_{i=1}^{k} D_i B_{it} + \varepsilon_t; \quad i = 1,\ldots,k \tag{1}$$

where X_t is the time series of stock price index under investigation such that X_{t-1} is the one lag of the dependent variable. The parameters α_0 and β are the intercept and the time trend coefficients, respectively; β is the autocorrelation coefficient at lag 1 between X_t and X_{t-1} with β = 1 implying unit root in the series under investigation. The dummy $B_{it} = 1$ if $t \geq T_{Bi}$ and $B_{it} = 0$, otherwise, where T_{Bi} is the break point with i=1,…,5 (i.e., k = 5), and D_i are the dummy variable coefficients.[4] The model residual ε_t in (1), which is a sequence of independently and identically distributed random variables with mean zero and variance unity, is then modelled using the simplest volatility model, that is the GARCH(1,1) process,

$$\varepsilon_t = z_t \sigma_t^2; \qquad z_t = N(0,1); \quad \sigma_t^2 = \omega + \theta \varepsilon_{t-1}^2 + \phi \sigma_{t-1}^2 \tag{2}$$

where model parameters $\omega > 0$; $\theta \geq 0$ and $\phi \geq 0$, conditioned such as to ensure positive definite and stationary conditional variances σ_t^2.[5]

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[3]Note, model in (1) is specified using first difference of X_t since this is applied on stock prices in this paper, while Narayan, Liu and Westerlund (2016) has applied their model on log-returns which requires no series difference.

[4] Note, Narayan, Liu and Westerlund (2016) originally restricted their model to two breaks, while in this work, we have extended the model to testing for up to maximum of five breaks as detected by Bai-Perron test. See results in Table 3.

[5] Details of regularity and existence condition as well as the estimation of this model is found in Bollerslev (1994).

For the convenience of application, and conformity with other unit root tests (such as the ADF test, and others), an alternative specification analysed in this paper is the test regression,

$$\Delta X_t = \alpha_0 + \rho X_{t-1} + \sum_{i=1}^{k} D_i B_{it} + \varepsilon_t ; \quad i = 1,...,k \tag{3}$$

where $\rho = \beta - 1$ and Δ denotes change, that is, $\Delta X_t = X_t - X_{t-1}$, the first difference of the price series.[6] Thus, in (1), the null hypothesis is $H_0 : \beta = 1$ which is equivalent to $H_0 : \rho = 1$.

The breakdates, T_{Bi} in (1) are unknown and are endogenously determined by conducting Bai and Perron (2003) multiple structural break tests, with the number of breaks earlier reported in Table 3. The actual breakdates are then recorded and used to form subsamples in the unit root testing. The Bai-Perron test uses a sequential sampling approach in the determination of the breakdates. For example, the first structural break l = 1 for T_{B1} is determined based on the significance of the F-statistic, sup $F_T\left(l+1/l\right)$ at a certain α-level. This selection of the first breakdate is equivalent to maximizing the absolute t-value of the break dummy coefficient D_1 as:

$$\hat{T}_{B1} = \arg\max_{\hat{T}_{B1}} \left| t_{\hat{D}1}\left(T_{B1}\right) \right| \tag{3}$$

To select the second breakdate, $\hat{T}_{B2}$, one imposes the first break $\hat{T}_{B1}$ in the Bai-Perron testing model and then estimate the second break as,

$$\hat{T}_{B2} = \arg\max_{\hat{T}_{B2}} \left| t_{\hat{D}2}\left(\hat{T}_{B1}, T_{B2}\right) \right| \tag{4}$$

[6] First difference of stock price gives the returns series, as log-returns series are equivalent stationary processes prices. The Logarithmic transformation is to obey Box-Cox transformation rule.

This goes on and on until the last fifth break $\hat{T}_{B5}$ is estimated by imposing the fourth break $\hat{T}_{B4}$ as,

$$\hat{T}_{B5} = \arg\max_{\hat{T}_{B5}} \left| \hat{t}_{\hat{D}5} \left(\hat{T}_{B4} - T_{B5} \right) \right| \quad (5)$$

4.2 Empirical Findings

The results of the model with just two breaks are presented in Table 4. The two identified break dates are precisely reported in the second and third columns, while the last column is devoted to the t-test statistic through which the unit root null hypothesis is tested. Out of the stock markets of 19 countries considered, the null hypothesis is rejected for as high as 15 countries, with the exceptions being China, Hong Kong, Korea Republic and Singapore. By implications, mean reversion, which is also associated with market inefficiency, is exhibited by the stock markets of these 15 countries, whereas nonstationarity and efficiency are at best inferred for the rest.

This study further answers the poser: can the stock market efficiency of the countries under consideration be altered by the consideration of more than two breaks? This is a noble extension to the two breaks consideration of the work of Narayan et al. (2016) that pioneered this testing model. Justifying the need to put structural breaks into consideration when testing market efficiency, financial markets are frequently fraught with turbulence and various domestic and external shocks (Adekoya and Oliyide, 2020a; Adekoya et al., 2020). These create structural shifts along the time path of the series such as that empirical models that fail to account for them can result in spurious results. However, for data series spanning across many years, there could be more structural shifts than the two implied by the technique of

Narayan et al. (2016). More so, the Asian markets are largely developing, compared to that of the U.S., indicating that the former could be more sensitive to various shocks than the former. Therefore, we follow the approach of Bai and Perron (2003) to identify a maximum of five breaks in each of the stock indices which are consequently included in the GARCH-based unit root model.

The results are shown in Table 5 alongside the t-test statistic for the test of the hypothesis of unit root for market efficiency. Interestingly, our extended model identifies break dates over two in all the countries. Although the exact break dates expectedly vary across the countries, it can be observed that some years are more pronounced. They include 2003-2004, 2007-2009, 2010-2012, 2014-2015 and 2015-2016 which respectively coincide with the Iraq War, the U.S. subprime mortgage crisis, the European sovereign debt crisis, the global oil price crash and the Chinese stock market crash. Considering the t-statistics, the results give credence to those in Table 4 when only two breaks are included, as the findings appear to be sustained not minding the increased number of breaks. Only Singapore seems to deviate from the initial pattern. Singapore gains significance, symbolizing the rejection of the null hypothesis of stock market efficiency. At best, the findings from the GARCH-based unit root models to measuring market efficiency are robust to a higher number of structural breaks. As revealed by Narayan et al. (2016) that two breaks are sufficient to determine the alteration of structural shifts to market efficiency, we prove the same in this study.

For robustness, we consider the asymmetric GARCH variant to check our results are robust o leverage effect in stock prices. We applied the Exponential GARCH (EGARCH) model of Nelson (1991) in this regard. These models are also estimated at different lag orders as seen in the results presented in Table 6. It is seen that the level of market efficiency changes for some countries. The results from the symmetric GARCH, for instance, reveal that Lebanon and Singapore lose their significance. On the other hand, the results from the EGARCH model seem to be inconsistent for Hong Kong and Malaysia as significance is only established at higher lag orders, while Lebanon remains insignificant still. Summarily, these results suggest that the market efficiency hypothesis may be rejected, or otherwise, in certain instances when correct GARCH variants are not specified such as the case of Asian stocks.

As rightly noted by Narayan et al. (2016), financial indices are often associated with the problem of heteroskedasticity which consequently makes conventional unit root models that cannot account for heteroscedasticity to produce spurious results. Therefore, our GARCH-based model which does not only correct for the possible heteroskedasticity bias, but also accounts for endogenous breaks in the modelling process, is adjudged to produce more reliable results. Besides, as far as we know, the findings on stock market efficiency of the Asian countries are diverse following different objectives of the authors including the impact of the financial crisis on efficiency (see Rivzi and Arshad, 2016; Jin, 2016, etc.), multifractal behaviour (see Han et al., 2019a; Wang and Wang, 2018; Zhu and Zhang, 2018, etc.) and the role of information asymmetry (see Hu and Prigent, 2019). There seems to be none that have a similar focus as ours, thus making a comparison of findings to appear difficult, although Lingaraja et al. (2014) merely consider the GARCH(1,1) model (without structural breaks) to establish that the emerging stock markets in the region tend to be efficient.

[Insert Table 4 about here]

[Insert Table 5 about here]

[Insert Table 6 about here]

5. Conclusion

Due to the evolving nature of some stock markets, especially in the developing countries such as in Asia, the development of many market innovations and the frequent emergence of financial turbulences which altogether affect the level of market operations, the empirical idea of the assessment of the degree of stock market efficiency is ever a valid one. This is because these market characteristics have the tendency of changing the degree of market efficiency from time to time, thereby often requiring advanced statistical or econometric techniques to arrive at accurate results. Thus, this study addresses a major feature of financial time series in modelling stock market efficiency. As noted by Narayan et al. (2016), unit root models that fail to put the problem of heteroskedasticity into consideration in the modelling process would likely produce spurious results as the null hypothesis could be over-rejected. Besides, even the heteroskedasticity-based model may not also produce optimal results in the presence of structural breaks which are also a notable feature of financial series. Obviating these, therefore, we take a different turn from most of the approaches in the literature on stock market efficiency by employing the recently developed

Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model of Narayan et al. (2016) which does not only account for the problem of heteroskedasticity but incorporates also two endogenously determined structural breaks in the series. This model is used for the stock markets of 19 Asian countries, most of whose efficiency has not been extensively investigated.

Summarily, our proposed methodology discloses that the unit root null hypothesis, which is associated with market efficiency, is rejected for 14 countries, while China, Hong Kong, Japan and the Korea Republic are the exceptions. We further extend the model to account for a maximum of five structural breaks as suggested by the Bai and Perron (2003) test. The results seem consistent with the original model in a large number of cases, except for Lebanon and Singapore. For completeness, we compare our results with an asymmetry GARCH-type model (the EGARCH model), both model with varying orders, and find that the results are different for some countries. Hence, not accounting for structural breaks may sometimes yield untrue results. Besides, since most governments strive to ensure an efficient stock market, factors inducing inefficiency such as information asymmetry should be checked policymakersers. Lastly, the effects of heteroskedasticity and structural breaks in modelling stock market efficiency cannot be jettisoned. Thus, future studies should pay close attention to these in their empirical framework.

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Compliance with Ethical Standards:

Conflict of Interest: Author A, OlaOluwa S. Yaya declares that he has no conflict of interest. Author B, Xuan V. Vo declares that he has no conflict of interest. Author C, Oluwasegun B. Adekoya declares that he has no conflict of interest.

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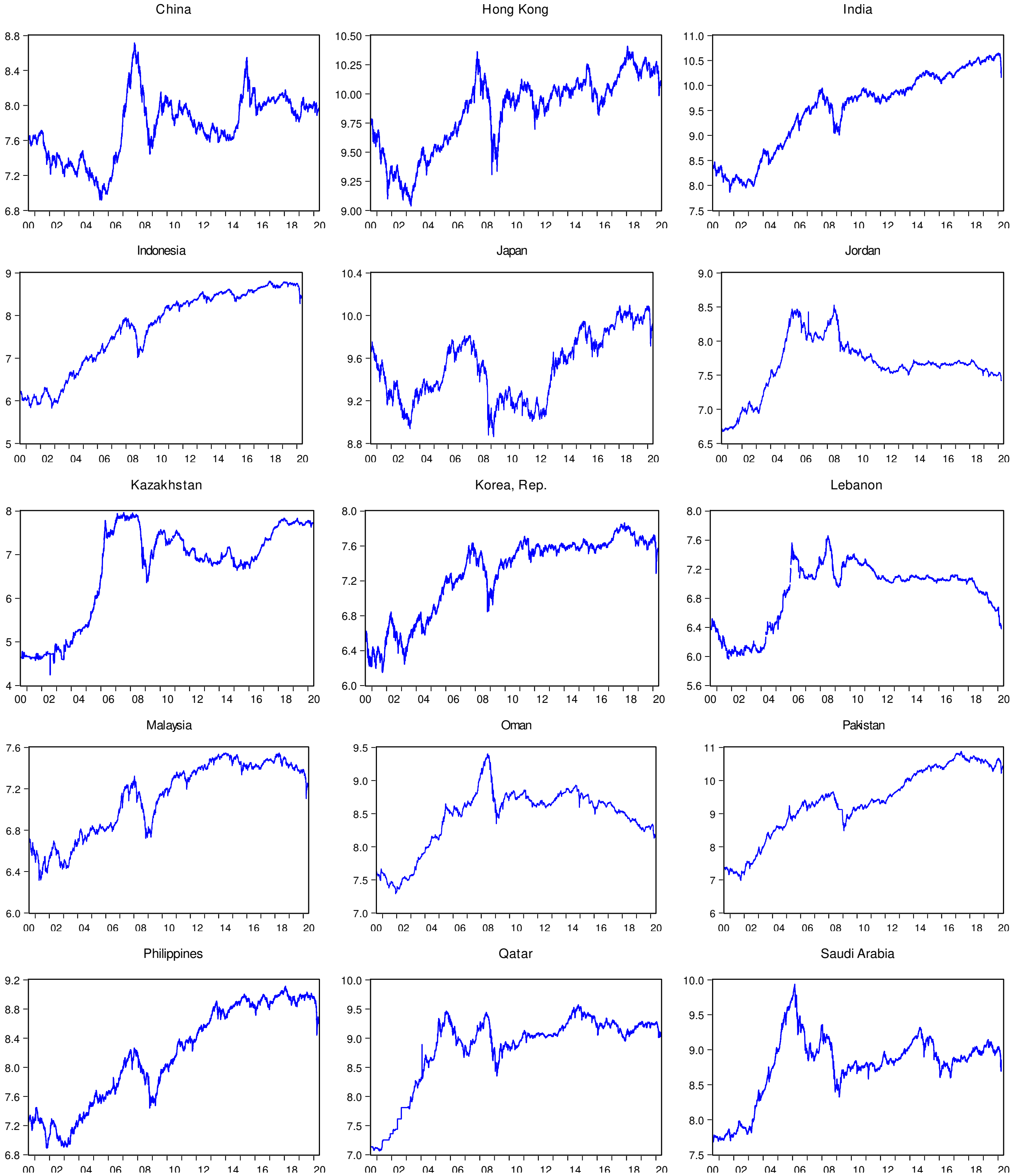
Table 1: List of Stock markets/indices

Country	Abbreviation	Name of Stock index
China	SSEC	Shanghai SE Composite Index
Hong Kong	HSI	Hang Seng Index
India	BSESN	S&P BSE Sensex Index
Indonesia	JKSE	Jakarta Composite Index
Japan	N225	Nikkei 225 Index
Jordan	AMGNRLX	Amman Stock Exchange General Index
Kazakhstan	KASE	KASE Index
Korea, Rep.	KS11	Korea SE Kospi Index
Lebanon	BLSI	Banque du Liban et d'Outre-Mer SAL Stock Index
Malaysia	KLSE	FTSE Bursa Malaysia KLCI Index
Oman	MSI	Muscat SE General Index
Pakistan	KSE	KSE 100 Index
Philippines	PSI	The Philippine Stock Exchange PSEi Index
Qatar	QSI	Qatar Exchange General Index
Saudi Arabia	TASI	Tadawul FF Index
Singapore	STI	FTSE Straits Times Index
Taiwan	TWII	Taiwan SE Weighted Index
Thailand	SETI	SET Index
Vietnam	VNI	Vietnam Index


China
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Saudi Arabia

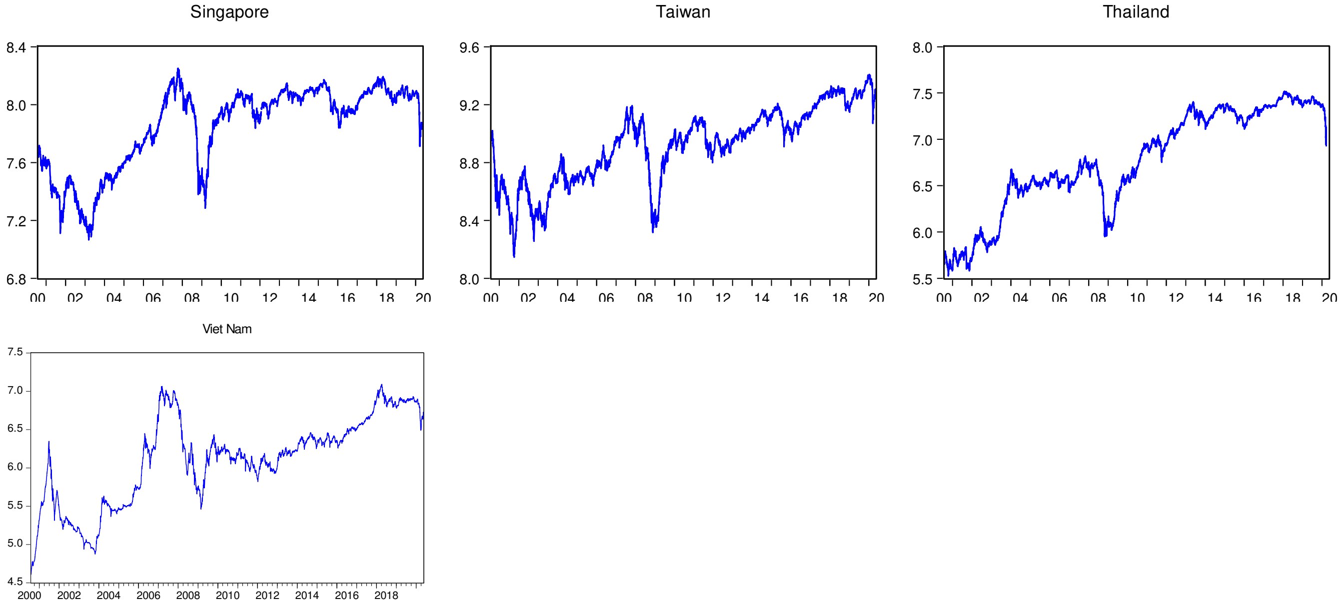

Figure 1: Trends in logged stock price indices

Table 2: Descriptive Statistics of Daily Stock indices

Country	Mean	CoV	Skewness	Kurtosis	BP
China	2499.5	35.3	0.790	4.129	4
Hong Kong	20019.0	28.7	-0.197	2.110	5
India	17944.5	60.4	0.326	2.112	4
Indonesia	3156.8	64.6	0.051	1.547	4
Japan	14331.8	31.4	0.407	1.981	4
Jordan	2274.4	38.7	0.845	3.684	4
Kazakhstan	1216.5	67.6	0.176	1.844	4
Korea Rep.	1595.4	35.8	-0.529	1.963	5
Lebanon	1052.7	35.0	-0.211	2.479	4
Malaysia	1312.3	31.4	-0.302	1.579	4
Oman	5109.1	38.8	0.289	3.894	4
Pakistan	18438.2	78.4	0.625	1.987	4
Philippines	4384.1	57.9	0.193	1.453	4
Qatar	7933.3	40.5	-0.673	2.658	4
Saudi Arabia	7160.6	41.4	0.869	5.360	5
Singapore	2672.1	24.5	-0.636	2.080	3
Taiwan	7775.0	24.4	0.005	2.235	4
Thailand	1009.1	46.5	0.068	1.602	4
Viet Nam	527.3	50.8	0.527	2.380	4

Note, CoV is the coefficient of variation while BP denotes the number of detected breakpoints by Bai-Perron test.

Table 3: Unit root tests results

Countries	ADF		ADF-SB	
	Level	**1st difference**	**Level**	**1st difference**
China	-1.9276	-71.2023***	-3.6188	-71.6818***
Hong Kong	-3.1359*	------------	-4.3149	-74.6377***
India	-1.6212	-68.8295***	-4.1325	-69.9426***
Indonesia	-0.6135	-64.8219***	-3.3607	-65.5559***
Japan	-2.5192	-73.5775***	-4.4250	-74.3589***
Jordan	-1.6617	-46.5095***	-4.4906	-74.6705***
Kazakhstan	-1.0599	-92.6304***	-3.8484	-96.8915***
Korea, Rep.	-2.0291	-71.0893***	-4.6516	-71.9507***
Lebanon	-0.1612	-46.6885***	-4.5327	-63.0002***
Malaysia	-1.2108	-63.1950***	-3.6885	-64.3881***
Oman	-0.3849	-45.0315***	-3.9866	-64.1370***
Pakistan	-1.0424	-63.4730***	-2.9107	-63.8725***
Philippines	-1.3809	-66.2592***	-3.0390	-67.4190***
Qatar	-1.7369	-84.0412***	-4.0691	-94.7737***
Saudi Arabia	-1.6846	-71.0195***	-4.3718	-71.9589***
Singapore	-1.7879	-70.7292***	-3.3579	-71.5424***
Taiwan	-4.3152**	-------------	-5.6053**	------------
Thailand	-1.8097	-47.7622***	-2.7571	-48.7327***
Viet Nam	-2.5264	-30.4818***	-3.7326	-31.2895***

*** and * respectively denote significance at 1% and 10% critical levels.

Table 4: Results of the two break GARCH-based Unit root model

Country	TB_1	TB_2	t-statistic
China	14/12/2006	26/01/2010	1.085
Hong Kong	13/10/2006	09/05/2017	1.242
India	01/03/2006	06/03/2014	4.451***
Indonesia	01/09/2006	03/09/2010	5.089***
Japan	29/09/2008	31/10/2014	-1.289
Jordan	05/01/2004	06/07/2009	5.661***
Kazakhstan	06/02/2006	30/05/2017	-7.381***
Korea Rep.	09/11/2006	17/09/2010	0.676
Lebanon	22/06/2005	16/09/2011	4.482***
Malaysia	26/10/2006	05/03/2010	8.817***
Oman	21/03/2005	30/05/2017	11.722***
Pakistan	11/02/2005	09/07/2013	7.445***
Philippines	14/09/2006	01/02/2012	5.023***
Qatar	06/12/2004	16/07/2013	2.778***
Saudi Arabia	03/05/2004	23/04/2007	2.107***
Singapore	24/02/2006	13/07/2010	1.033
Taiwan	03/01/2006	16/09/2013	2.459***
Thailand	05/09/2003	26/01/2012	3.513***
Viet Nam	17/03/2006	30/05/2017	13.613***

Note, two breakdates $TB_1$and TB_2based on Narayan, Liu and Westerlund (2016) are reported with the t statistics for testing the null of unit roots.

*** indicates significance of t test at 5% level.

Table 5: Results of the five breaks GARCH-based Unit root model

Country	TB_1	TB_2	TB_3	TB_4	TB_5	t-statistic
China	18/07/2003	14/12/2006	26/01/2010	03/12/2014	------	0.372
Hong Kong	24/10/2003	13/10/2006	07/10/2009	05/12/2012	09/05/2017	1.202
India	01/03/2006	07/09/2009	06/03/2014	30/05/2017	------	4.434***
Indonesia	12/09/2003	01/09/2006	03/09/2010	19/07/2016	------	4.987***
Japan	28/09/2005	29/09/2008	11/11/2011	31/10/2014	------	-1.302
Jordan	05/01/2004	06/07/2009	25/06/2012	30/05/2017	------	5.579***
Kazakhstan	27/01/2003	06/02/2006	07/05/2012	02/06/2017	------	-7.307***
Korea Rep.	20/11/2003	09/11/2006	17/09/2010	10/09/2013	13/03/2017	0.643
Lebanon	22/06/2005	25/06/2008	16/09/2011	21/06/2017	------	2.188***
Malaysia	21/10/2003	26/10/2006	05/03/2010	22/02/2013	12/02/2016	8.709***
Oman	21/03/2005	12/11/2008	08/04/2013	30/05/2017	------	11.569***
Pakistan	11/02/2005	20/07/2010	09/07/2013	28/06/2016	------	7.642***
Philippines	25/09/2003	14/09/2006	01/02/2012	21/01/2015	------	4.924***
Qatar	06/12/2004	06/10/2008	16/07/2013	08/09/2016	------	2.748***
Saudi Arabia	03/05/2004	23/04/2007	12/04/2010	03/06/2013	23/05/2016	2.060***
Singapore	24/02/2006	13/07/2010	28/03/2017	------	------	1.071***
Taiwan	03/01/2006	06/10/2009	16/09/2013	16/03/2017	------	2.455***
Thailand	05/09/2003	05/02/2009	26/01/2012	06/12/2016	------	3.465***
Viet Nam	17/03/2006	06/03/2009	16/01/2014	30/05/2017	------	13.339***

Note, five breakdates TB_1, …, TB_5 based modification of Narayan, Liu and Westerlund (2016) test. *** indicates significance of the *t* test at 5% level.

Table 6: Further Estimation based on differing GARCH and EGARCH orders

Country	GARCH(1,2)	GARCH(2,1)	GARCH(2,2)	EGARCH(1,1)	EGARCH(1,2)	EGARCH(2,1)	EGARCH(2,2)
China	0.383	0.384	0.382	-0.313	0.075	-0.266	-0.045
Hong Kong	1.314	1.421	1.427	1.712	1.671	2.309***	2.293***
India	4.470***	4.486***	4.486***	5.361***	5.312***	5.608***	5.372***
Indonesia	4.807***	4.619***	4.667***	4.713***	4.593***	4.334***	4.656***
Japan	-1.293	-1.295	-1.268	-1.190	-1.203	-1.411	-1.437
Jordan	5.606***	6.648***	5.780***	5.579***	5.606***	6.648***	5.780***
Kazakhstan	-7.071***	-6.901***	-6.960***	-6.092***	-5.508***	-4.922***	-5.465***
Korea Rep.	0.561	0.495	0.501	0.643	0.439	0.439	0.202
Lebanon	1.533	0.808	0.805	1.242	-0.138	0.187	1.022
Malaysia	8.337***	7.973***	8.414***	0.582	0.551	8.878***	9.885***
Oman	12.451***	12.232***	12.089***	12.349***	13.555***	13.173***	12.738***
Pakistan	7.361***	8.061***	8.411***	8.698***	8.199***	8.225***	8.217***
Philippines	4.649***	4.629***	4.521***	4.457***	4.392***	4.450***	4.389***
Qatar	2.252***	2.622***	5.397***	-2.000***	5.988***	5.402***	2.255***
Saudi Arabia	2.670***	2.345***	2.639***	2.422***	3.436***	2.356***	2.584***
Singapore	1.141	1.114	1.115	1.550	1.563***	1.705***	1.653***
Taiwan	2.424***	2.497***	2.488***	2.820***	2.626***	3.278***	3.206***
Thailand	3.401***	3.399***	3.89***	4.025***	3.856***	3.969***	2.872***
Viet Nam	12.888***	12.662***	12.594***	14.652***	14.111***	14.066***	14.476***

*** indicates significance of the *t* test at 5% level.