Weak form market efficiency: A case study of Asia-Pacific markets

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***Abstract*—This study aims to test the weak form market efficiency for five developed markets, nine emerging markets and three frontier markets in the Asia-Pacific region. The tools applied in the test of this form of market efficiency are serial correlation test, runs test and unit root test. The analysis is performed by using logarithm return for the period of 2008 to 2018. For all markets in our research, the results strongly reject the weak form efficiency when the unit root tests are carried out, while the results from the Durbin-Watson test are in complete contrast. However, in the runs test and variance ratio test, the results provide mixed evidences of weak form efficiency of the markets.**

***Keywords*—Asia-Pacific markets, jnvestment, stock markets, weak form market efficiency**

I. Introduction

OVER the last two decades, the Asia-Pacific region has achieved remarkable economic success. This region has one of the most active markets in the world with GDP volume of 19.43 trillion US dollars which is approximately around 22% of the world's. As a result, in growth terms, the Asia-Pacific markets have become leading performers in the global economy projected to grow 5.4 percent in 2019. The theory of weak form market efficiency, one of the foundation theories in traditional finance literature, has been utilized in many markets by many researchers to indicate the arbitrage opportunity for investors. In order to study the weak form market efficiency in the Asia-Pacific region, we consider some effective methods for testing the weak form market efficiency. One of the popular tests is to study the movement of asset prices. If asset prices tend to have random walk patterns, this may imply that the market return is unpredictable; in other words, we cannot deny that the market is efficient. Conversely, if the returns form of the market is predictable and the movement of asset price is not random, we can conclude that the market is inefficient and investors can derive profits from the market [1]. Previous studies on testing weak form market efficiency utilized several test methods. Fama, in 1965, studied the movement of asset prices and applied the random walk theory to investigate the movement of Dow-Jones Industrial stock by using daily prices during 1957-1962. The methods applied to test this were the serial correlation and the runs tests. It was shown that the serial correlation was too small to cover transaction costs of trading [2]. Lo and Mackinlay utilized the test of multiple variance ratio on the United States stock data. The results indicated that the market was not under an environment of weak-form market efficiency [3]. Later, in 1993, Chow and Denning applied the method of Lo and MacKinlay to develop the multiple variance ratio that focused on joint probability [4]. Higgs examined the weak form of market efficiency in Asian equity markets for five developed stock markets and ten emerging stock markets. With the methods of serial correlation and runs tests, the conclusion is that all the markets are not efficient markets. However, by the method of variance ratio test, it is indicated that only developed markets, such as those of Japan, Hong Kong and New Zealand, are efficient markets [5]. Smith and Ryoo performed a study on the random walk pattern test. Five European emerging markets were tested by using the multiple variance ratio test. It was found that some of the markets rejected the random walk hypothesis [6]. Smith, Jefferis and Ryoo tested seven stock markets in Africa by using the multiple variance ratio test. Weak form efficiency was found for the stock markets across Africa [7]. It can be seen that many current researchers apply some statistical methods to test weak form market efficiency [8-16]. Hence, this study emphasizes testing the Random walk hypothesis of movements of asset prices in stock market indices in relations to weak form efficiency testing in Asia-Pacific markets.

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II. Data

The data in this research has been acquired on the Asia-Pacific markets composed of five developed markets, which are those of Australia, Hong Kong, Japan, New Zealand and Singapore, nine emerging markets, which are those of China, India, Indonesia, Korea, Malaysia, Pakistan, Philippines,

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Taiwan and Thailand, and three frontier markets, which are those of Bangladesh, Sri Lanka and Vietnam, a total of seventeen markets of countries in the Asia-Pacific region. The data are daily closed price of the stock index in local currency from January 2008 to December 2018. The log-return applied in the daily prices is given by:

$$R_t = \ln \frac{P_t}{P_{t-1}} \tag{1}$$

where R_t is the log-return, P_t is the price at time *t* and P_{t-1} is the price at time *t* – 1.

III. Methodology

This research utilizes the well-known statistical tests, Durbin-Watson test, runs test and unit root test, to test the weak form of market efficiency so that the result should help investors to make investment decisions.

A. Durbin-Watson Test

A test for autocorrelation is the simplest way to test random walks. The uncorrelatedness of all lags for all returns implies a random walk property. On the other hand, if the returns have either a positive or negative correlation, this does not imply a random walk environment. In this study, we apply the Durbin-Watson test for autocorrelation. This method is one of most well-known serial correlation tests used for random walk testing. It is given by

$$R_t = \alpha + \rho R_{t-1} + \varepsilon_t \tag{2}$$

where R_t is the return at time *t*, R_{t-1} is the return at time *t* – 1, α is a constant, ς_t represents an error at time *t*, and ρ is a parameter which has the value between -1 to 1. The formula for Durbin−Watson test is

$$d = \frac{\sum_{t=2}^{T} (e_t - e_{t-1})^2}{\sum_{t=1}^{T} e_t^{\,2}} \tag{3}$$

where T is the observation numbers, e_t is the residual associated with the observation at time *t*, *d* is Durbin-Watson statistic value which is approximately equal to 2(1 – ρ) where ρ is autocorrelation of the residual. The value of *d* is between 0 and 4. A positive serial correlation is indicated if the value of *d* is less than 2. Conversely, there exists a negative serial correlation if the value of *d* is more than 2.

B. Runs Test

The method to be utilized for the non-parametric case is the runs test. This test applies the method of binary data which allows the return to be converted to either a case of positive sign (+) or negative sign (−). Any consecutive returns of either sign of positive (+) or negative (−) is treated as a run. This runs test follows the following relation.

$$Z = \frac{R - \mu}{\sigma} \tag{4}$$

where

$$\mu = \frac{2N_+N_-}{N} - 1$$

$$\sigma^2 = \frac{N_+N_-(2N_+N_- - N)}{N^2(N-1)} = \frac{(\mu-1)(\mu-2)}{N-1}$$

$$N = N_+ - N_-$$

N_+ is positive runs number

N_- is negative runs number

R is the total number of counting runs.

C. Unit Root Test

Unit root test is a tool for non-stationary case that has been applied in random walk testing and it has also generally been applied to test the weak form market efficiency in an investment analysis. This method was first introduced by Dicky and Fuller in 1981 and used particularly to test for the stationary state of the data. In this study, the Augmented Dickey-Fuller (ADF) method was applied to test for the weak form efficiency of the market. In the ADF test, it is assumed that the autoregressive model of order *q* or AR(*q*) is given by

$$\Delta P_t = \alpha + \delta P_{t-1} + \sum_{i=1}^{q} \gamma_i P_{t-1} + \beta t + u_t \tag{4}$$

where $\Delta P_t = P_t - P_{t-1}$, u_t is a sequence of random variable in each time which is independent and identical distribution (iid) with zero mean and σ^2 variance. The parameter γ_i is a coefficient on a time trend. If the testing value is greater than the critical value or δ is equal to zero, then the null hypothesis is accepted which implies that the returns are non-stationary.

D. Variance Ratio Test

This method of the variance ratio test was proposed by Lo and Mackinlay (1989) which is based on the property of the variance of increments of a random walk [3]. Therefore, if a time series follows a random walk process, the variance of its *q*-differences should be *q* times the variance of its first differences. The variance-ratio, $VR(q)$, is defined as:

$$Var\left(P_t - P_{t-q}\right) = qVar\left(P_t - P_{t-1}\right) \tag{5}$$

where *q* is any positive integer. The variance ratio is then estimated as follows

$$VR(q) = \frac{\frac{1}{q} Var\left(P_t - P_{t-q}\right)}{Var\left(P_t - P_{t-1}\right)} \tag{6}$$

If the value of $VR(q)$ is equal to 1, the null hypothesis will be accepted which means the time series data is a random walk.

According to Lo and MacKinlay, formulae for the calculation of $\sigma^2(q)$ and $\sigma^2(1)$ are as follows:

$$\hat{\sigma}^2(1) = \frac{\sum_{k=1}^{nq}\left(P_k - P_{k-1} - \hat{\mu}\right)^2}{(nq-1)} \tag{7}$$

where

$$\hat{\mu} = \frac{1}{nq}\sum_{k=1}^{nq}(P_k - P_{k-1}) = \frac{1}{nq}(P_{nq} - P_0)$$

and

$$\hat{\sigma}^2(q) = \frac{\sum_{k=1}^{nq}\left(P_k - P_{k-1} - q\hat{\mu}\right)^2}{(nq-1)} \tag{8}$$

where

$$h = q(nq+1-q)\left(1 - \frac{q}{nq}\right).$$

The test is performed under both homoscedastic and heteroskedastic specifications. Under homoscedasticity, the asymptotic variance of the variance ratio is expressed as follows:

$$Z(q) = \frac{VR(q)(q-1)}{\hat{\sigma}_0(q)} \tag{9}$$

where

$$\hat{\sigma}_0(q) = [(2(2q-1)(q-1))/(3q(nq))]^{(1/2)}.$$

Under heteroscedasticity, the asymptotic variance can be expressed as:

$$Z^*(q) = \frac{VR(q)(q-1)}{\hat{\sigma}_e(q)} \tag{10}$$

where

$$\hat{\sigma}_e(q) = \left[4\sum_{k=1}^{q-1}\left(1 - \frac{K}{q}\right)^2 \hat{\delta}_k^2\right]^{1/2}$$

and

$$\hat{\delta}_k^2 = \frac{\sum_{j=k+1}^{nq}\left(\rho_j - \rho_{j-1} - \hat{\mu}\right)^2\left(\rho_{j-k} - \rho_{j-k-1} - \hat{\mu}\right)^2}{\sum_{j=1}^{nq}\left\{\left(\rho_j - \rho_{j-1} - \hat{\mu}\right)^2\right\}^2} \tag{11}$$

However, the Lo and Mackinlay approach focuses on testing individual variance ratios for a specific aggregation interval, q, but the random walk hypothesis requires that $VR(q) = 1$ for all q. The multiple variance ratio test provides a joint test through controlling the size of the test. Chow and Denning presented in 1993 a procedure for the multiple comparison of the set of variance ratio estimates [4]. For a single variance ratio test, under the null hypothesis,

$$M_r(q) = VR(q) - 1 = 0.$$

We consider a set of m tests $\{M_r(q_i) \mid i = 1,2,...,m\}$ associated with the set of aggregation intervals $\{q_i \mid i = 1, 2, ..., m\}$. Under the random walk null hypothesis there are multiple sub-hypotheses

$$H_{0i} : M_r(q) = 0 \quad \text{for} \quad i = 1,2,\ldots,m$$

$$H_{1i} : M_r(q) \neq 0 \quad \text{for} \quad i = 1,2,\ldots,m$$

Rejection of any one or more H_{0i} rejects the random walk null hypothesis. By considering a set of Lo and MacKinlay's test statistics $\{Z(q_i) \mid i = 1,2,...,m\}$, since the random walk null hypothesis is rejected if any of the variance ratios is significantly different from one, it is necessary to emphasize the maximum absolute value in the set of test statistics. The core of Chow and Denning's MVR test is based on

$$PR\left[\max\left(|Z(q_i)|,\ldots,|Z(q_m)|\right) \leq SMM(\alpha; m; N)\right] \geq 1 - \alpha$$

in which $SMM(\alpha; m; N)$ is the upper α point of the Studentized Maximum Modulus (SMM) distribution with parameters m and N (sample size) degrees of freedom. Asymptotically, when N is infinite,

$$SMM(\alpha; m; \infty) = Z_{\alpha^*/2}$$

where $Z_{\alpha^*/2}$ is standard normal with $\alpha^* = 1 - (1-\alpha)^{1/m}$. With our sample size, we can use this last result and apply the standard normal distribution to calculate the critical values. The size of the MVR test is controlled for multiple comparisons by comparing the calculated values of the standardized test statistics, either $Z(q_i)$ or $Z^*(q_i)$ with the SMM critical values. If the maximum absolute value $Z(q_i)$ is greater than the critical value at a predetermined significance level then the random walk hypothesis is rejected.

IV. Empirical Results

The analysis of the stock market returns in the Asia-Pacific region is performed by descriptive statistics, the Durbin-Watson test, the unit root test and the variance ratio test. The results are described in the followings.

A. Descriptive Statistics

By using statistical tools, the empirical results are shown in

Table I The descriptive statistics

Market	Mean	Median	Maximum	Minimum	S.D.	Skewness
Australia	-0.00004	0.00037	0.05628	-0.08704	0.01094	-0.42238
Hong Kong	-0.00002	0.00038	0.13407	-0.13582	0.01553	0.02793
Japan	-0.00011	0.00058	0.13234	-0.12111	0.01582	-0.51212
New Zealand	-0.00004	0.00012	0.07531	-0.08696	0.01095	-0.49142
Singapore	0.00241	0.00012	0.09778	-0.07919	0.02106	-0.18145
China	-0.00028	0.00055	0.09034	-0.08873	0.01632	-0.55466
India	0.00025	0.00055	0.15990	-0.11604	0.01375	0.24174
Indonesia	0.00030	0.00098	0.07623	-0.10954	0.01313	-0.65842
Korea	0.00003	0.00034	0.11284	-0.11172	0.01227	-0.59100
Malaysia	0.00012	0.00024	0.03322	-0.03237	0.00570	-0.38794
Pakistan	0.00027	0.00054	0.07056	-0.13089	0.01226	-0.25447
Philippines	0.00027	0.00054	0.00054	-0.13089	0.01226	-0.86815
Taiwan	0.00005	0.00067	0.06525	-0.06735	0.01169	-0.39057
Thailand	0.00023	0.00067	0.07548	-0.11090	0.01198	-0.70262
Bangladesh	0.00019	0.00013	0.03685	-0.05358	0.00806	-0.10326
Sri Lanka	0.00032	-0.00002	0.09980	-0.10732	0.00877	0.13094
Vietnam	-0.00001	0.00072	0.04647	-0.06051	0.01420	-0.30411

Table I, where the descriptive statistics of log-returns is presented to show the basic information of the data. The results show that the markets that provide positive mean returns are the markets in Singapore, India, Indonesia, Korea, Malaysia, Pakistan, Philippines, Taiwan, Thailand, Bangladesh and Sri Lanka with the highest mean returns in Singapore. The medians are not that significantly different on comparing between markets; however, the market in Sri Lanka is the only market that has a negative median return. The market that provides the highest maximum return is the market in India and the lowest minimum return is that in Hong Kong. Nevertheless, as expected, the highest returns market in Singapore comes with the highest risk with respect to the standard deviation. Finally, the descriptive statistics of skewness shows that all of the markets are not under the normal distribution.

B. Durbin-Watson Test

Table II contains the results of the Durbin-Watson (DW) test of the logarithm returns of stock indices showing the DW statistic values and the p-values. The results indicate that all of markets fail to reject null hypothesis at .01 level or higher which clearly implies that there is no evidence of autocorrelation. Hence, we conclude that all markets are under the weak-form efficiency environment according to the Durbin-Watson test over the sample periods.

C. Runs Test

In this section, the runs test on each country of the Asia-Pacific region is studied for the null hypothesis of weak-form efficiency. The nonparametric statistics results are tabulated in Table III, in which it can be seen that most developed markets fail to reject our null hypothesis, with the exception of New Zealand. For the emerging markets, only China, Indonesia, Korea and Thailand fail to reject the null hypothesis as well. Likewise, all frontier countries fail to reject our null hypothesis. This implies that markets of Australia, Hong Kong, Japan, Singapore, China, Indonesia, Korea and Thailand are under the environment of weak-form efficiency.

Table II Results of Durbin-Watson test

Market	DW value	*p*-value
Australia	2.000	0.491
Hong Kong	1.995	0.452
Japan	2.000	0.496
New Zealand	1.996	0.458
Singapore	2.003	0.504
China	1.999	0.492
India	1.992	0.415
Indonesia	2.002	0.522
Korea	2.000	0.500
Malaysia	2.002	0.521
Pakistan	1.998	0.477
Philippines	1.992	0.417
Taiwan	2.001	0.511
Thailand	2.005	0.553
Bangladesh	2.003	0.521
Sri Lanka	2.019	0.682
Vietnam	2.007	0.568

Table III Results of runs test

Market	Above mean	Below mean	Number of runs	Runs Z-values	*p*-value
Australia	1469	1362	1421	0.245	0.806
Hong Kong	1408	1317	1350	-0.459	0.645
Japan	1412	1309	1389	1.131	0.258
New Zealand	1439	1245	1248	-3.415	0.000*
Singapore	1398	1359	1372	-0.275	0.783
China	1424	1253	1343	0.347	0.728
India	1362	1311	1277	-2.322	0.020*
Indonesia	1439	1247	1314	-0.898	0.369
Korea	1407	1314	1366	0.234	0.815
Malaysia	1097	1034	989	-3.321	0.000*
Pakistan	1368	1357	1135	-8.755	0.000*
Philippines	1377	1313	1235	-4.254	0.000*
Taiwan	1434	1271	1296	-2.030	0.042*
Thailand	1414	1272	1298	-1.635	0.102
Bangladesh	708	719	589	-6.645	0.000*
Sri Lanka	1240	1413	1106	-8.419	0.000*
Vietnam	1449	1289	1221	-5.536	0.000*

Table IV Results of Augmented Dickey-Fuller test

Market	ADF t-test	*p*-value	PP t-test	*p*-value
Australia	-15.154	0.000*	-54.612	0.000*
Hong Kong	-15.494	0.000*	-53.802	0.000*
Japan	-13.844	0.000*	-54.999	0.000*
New Zealand	-13.721	0.000*	-49.056	0.000*
Singapore	-12.721	0.000*	-50.761	0.000*
China	1253	0.000*	-50.717	0.000*
India	1311	0.000*	-47.633	0.000*
Indonesia	1247	0.000*	-46.596	0.000*
Korea	1314	0.000*	-51.509	0.000*
Malaysia	1034	0.000*	-42.098	0.000*
Pakistan	1357	0.000*	-43.833	0.000*
Philippines	1313	0.000*	-45.732	0.000*
Taiwan	1271	0.000*	-49.331	0.000*
Thailand	1272	0.000*	-49.149	0.000*
Bangladesh	719	0.000*	-33.576	0.000*
Sri Lanka	1413	0.000*	-45.519	0.000*
Vietnam	1289	0.000*	-42.564	0.000*

D. Unit Root test

The unit root test is performed and the results are shown in Table IV, comparing between the Augmented Dickey-Fuller (ADF) t-statistical hypothesis test and the Phillips-Perron (PP) t-statistical hypothesis test in each country. It can be obviously seen from Table IV that the null hypotheses are rejected at the 0.01 significant level for all markets; therefore, it indicates that all of the log-returns in the sample data are stationary. Consequently, we conclude that markets in all these countries do not reflect weak form efficiency. Surprisingly, the output of the unit root test is completely contradictory to that of the Durbin-Watson test. As a result, further discussion may be necessary in order to find the most appropriate approach to test the weak form efficient market hypothesis.

E. Variance Ratio Test

In this section variance ratio tests are employed to test the null hypothesis, namely homoscedastic and heteroskedastic increments random-walk, which are computed for intervals of 2, 5, 10, and 30 days. For each interval, we report the estimate of the variance ratio, $VR(q)$, and the statistical test for the null hypotheses of homoscedastic, $Z(q)$, and heteroscedastic, $Z^*(q)$. Using the multiple variance ratio procedure, we mainly focus only on the maximum absolute value of the test statistics. With our sample size and $m=4$, the 0.05 critical

Table V Results of Lo-MacKinlay Variance Ratio Estimates and Test Statistics of developed markets

Market		$q = 2$	$q = 5$	$q = 10$	$q = 30$
Australia	$VR(q)$	0.98	0.92	0.86	0.75
	$Z(q)$	-1.256	-2.011	-2.226	-2.202
	$Z^*(q)$	-1.740	-1.149	-1.272	-1.313
Hong Kong	$VR(q)$	0.97	0.93	0.89	0.84
	$Z(q)$	-1.532	-1.761	-1.754	-1.337
	$Z^*(q)$	-0.649	0.753	-0.799	-0.672
Japan	$VR(q)$	0.95	0.89	-0.83	0.81
	$Z(q)$	2.596	-2.602	-2.642*	-1.609
	$Z^*(q)$	-1.304	-1.247	-1.297	-0.854
New Zealand	$VR(q)$	1.06	1.08	1.13	1.22
	$Z(q)$	2.900*	1.791	1.943	1.852
	$Z^*(q)$	1.827	0.985	1.074	1.089
Singapore	$VR(q)$	1.03	1.05	1.09	1.25
	$Z(q)$	1.766	1.229	1.390	2.098
	$Z^*(q)$	0.914	0.599	0.679	1.074

The 0.05 critical value of $Z(q)$ and $Z^*(q)$ is 2.491. Sampling intervals (q) are in days.

Table VI Results of Lo-MacKinlay Variance Ratio Estimates and Test Statistics of emerging markets

Market		$q = 2$	$q = 5$	$q = 10$	$q = 30$
China	$VR(q)$	1.20	1.05	1.08	1.16
	$Z(q)$	1.045	1.066	1.185	1.324
	$Z^*(q)$	0.681	0.701	0.784	0.910
India	$VR(q)$	0.97	1.03	0.97	1.08
	$Z(q)$	5.212*	0.729	-0.426	0.678
	$Z^*(q)$	2.867*	0.401	-0.229	0.368
Indonesia	$VR(q)$	1.10	1.12	1.03	1.19
	$Z(q)$	2.596*	2.861	0.453	1.560
	$Z^*(q)$	-1.304	1.500	0.245	0.907
Malaysia	$VR(q)$	1.01	1.14	1.09	1.29
	$Z(q)$	4.144*	3.018	1.203	0.644
	$Z^*(q)$	2.853*	2.149	0.898	0.515
Pakistan	$VR(q)$	1.19	1.43	1.60	1.99
	$Z(q)$	9.725*	10.172*	9.287*	8.437*
	$Z^*(q)$	5.798*	6.261*	5.916*	5.702*
Philippines	$VR(q)$	1.12	1.09	0.99	1.03
	$Z(q)$	6.105*	2.134	-0.229	0.221
	$Z^*(q)$	4.131*	1.264	-0.138	0.142
Taiwan	$VR(q)$	1.05	1.07	1.00	1.15
	$Z(q)$	2.634*	1.567	0.051	1.252
	$Z^*(q)$	1.833	1.081	0.034	0.859
Thailand	$VR(q)$	1.05	1.12	1.08	1.27
	$Z(q)$	2.680*	2.935*	1.265	2.288
	$Z^*(q)$	1.327	1.455	0.657	1.280

The 0.05 critical value of $Z(q)$ and $Z^*(q)$ is 2.491. Sampling intervals (q) are in days.

Table VII Results of Lo-MacKinlay Variance Ratio Estimates and Test Statistics of frontier markets

Market		$q = 2$	$q = 5$	$q = 10$	$q = 30$
Bangladesh	$VR(q)$	1.13	1.32	1.48	1.61
	$Z(q)$	4.836	5.599*	5.388*	3.736
	$Z^*(q)$	2.971	3.563*	3.585*	2.695
Sri Lanka	$VR(q)$	1.15	1.43	1.69	2.51
	$Z(q)$	7.663*	10.025*	10.620*	12.572*
	$Z^*(q)$	2.411	3.818*	4.814*	7.178*
Vietnam	$VR(q)$	1.22	1.47	1.65	1.88
	$Z(q)$	11.303*	11.332*	10.132*	7.476*
	$Z^*(q)$	7.407*	7.586*	6.925*	5.311*

The 0.05 critical value of $Z(q)$ and $Z^*(q)$ is 2.491. Sampling intervals (q) are in days.

Table VIII Results of Chow and Denning Multiple Variance Ratio test and Test Statistics

Market	$Z(q)$	$Z^*(q)$
Australia	2.226	1.313
Hong Kong	1.760	0.799
Japan	2.642*	1.304
New Zealand	2.901*	1.827
Singapore	2.098	1.074
China	1.324	0.909
India	4.046*	2.327*
Indonesia	5.212*	0.867*
Korea	1.114	0.543*
Malaysia	4.114*	2.853*
Pakistan	10.171*	6.261*
Philippines	6.105*	4.131*
Taiwan	2.634*	1.833
Thailand	2.935*	1.455
Bangladesh	5.600*	3.586*
Sri Lanka	12.573*	7.178*
Vietnam	11.332*	7.586*

The 0.05 critical value of $Z(q)$ and $Z^*(q)$ is 2.491. Sampling intervals (q) are in days.

value is 2.491. For each statistical value $Z(q)$ or $Z^*(q)$, we indicate by an asterisk when the maximum absolute value of the test statistics exceeds the critical value, which rejects our null hypothesis of a random walk. By considering the statistical results for Japan in Table V, the null hypothesis that returns follow a homoscedastic random walk is rejected at $Z(10) = -2.642$. The rejection of the null hypothesis of a random walk under homoscedasticity for a ten days period is also a test of the null hypothesis of a homoscedastic random walk under the other sampling periods. Therefore, Japan returns do not follow a random walk. From this evidence we may conclude that the Japan equity market is not of the weak form market efficiency. However, the other developed markets are weak form efficient since all maximum absolute statistic values do not exceed critical values at 0.05 level of significance. Among the results of emerging markets in Table VI, we observe that the statistical values of homoscedastic and heteroscedastic increments exceed the critical value at 2-day intervals in India, Malaysia, Philippines and Pakistan. We can notice that Pakistan has the statistical values of homoscedastic and heteroscedastic increments that exceed the critical value in all the tested intervals. Furthermore, the evidence of homoscedastic increments statistical values in Indonesia and Taiwan at 2-day intervals and Thailand has homoscedastic increments statistical values for both 2-day and 5-day intervals; the null hypothesis is also rejected. So we may conclude that all of above markets do not reflect weak form market efficiency. According to table VII, the null hypothesis of a random walk under assumptions of both homoscedasticity and heteroscedasticity is rejected for all three frontier markets. We may then conclude that none of these markets are weak form efficient. Considering the result of Chow and Denning Multiple Variance Ratio test in Table VIII, we reject the null hypothesis of weak-form efficiency for Japan, New Zealand, India, Taiwan and Thailand in the homoscedastic case. Also, we reject the null hypothesis, in both homoscedastic and heteroscedastic cases, for Indonesia, Malaysia, Pakistan, Philippines and all three frontier markets.

V. Conclusion

The goal of this research is to investigate weak-form efficient market hypothesis of seventeen Asia-Pacific markets. Three different statistical tools are applied to test for the random walk property in stock index returns. The serial correlation results of the Durbin-Watson test suggest that all indicated markets are weak-form efficient. While the unit root tests, ADF and PP tests, indicate the absolute contrary. The results of the non-parametric method of runs test indicate that all developed markets are weak-form efficient with the exception of New Zealand. For the emerging markets, we accept the presence of random walks or the weak-form efficiency of the markets in China, Indonesia, Korea and Thailand. However, the test rejects the presence of random walks in stock index returns in all frontier markets. In conclusion, from the results of the sample data, it is suggested that investors who believe the existence of weak-form efficient markets may make investments by using the active trading technique, which is based on short-term movement, and not applying the technical analysis method, which is based on historical data, in order to gain some profit from the markets of Australia, Hong Kong, Japan, Singapore, China, Indonesia, Korea and Thailand based on the results of the runs test. However, if the consideration is based on the variance-ratio test, Australia, Hong Kong, Singapore, China and Korea may be the candidate choice for the investor. It should be noted that we may exclude the results of Durbin-Watson test and the unit root test for the decision making of investors since these two tests yield completely contradictory outcomes. It is suggested that we make investment decisions based on the results that most positively reflect weak-form efficiency among all statistical tests. Following this approach, the most attractive countries are Australia, Hong Kong, Singapore, China and Korea. For the investors who need to pick a country in which to invest, the descriptive statistics is suggested as an accompanying tool to help the investors to make a decision on investment based on the characteristics and market behavior when investing in the financial markets. It is also recommended that the decision of investment relies on the belief in the Efficient Market Hypothesis (EMH). Moreover, due to the completely different results of the Durbin-Watson test and the unit root test, in our future work, more statistical tools may be applied in order to find more reliable results. In addition, it is suggested that, if possible, big data usage should be employed in future research and some big data processing software may be useful in the implementation of various statistical tools. This may yield more reliable conclusions. For further studies, more countries should be taken into account, and more varied testing techniques could be considered, in order to make a more extensive conclusion, useful for the investor who is a believer of EMH.

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