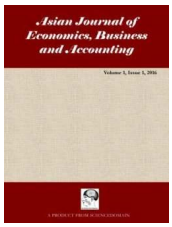

Asian Journal of Economics, Business and Accounting
1(1): 1-9, 2016, Article no.AJEBA.28347

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Asian Stock Markets' Efficiency: An Econophysics Approach

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Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

Article Information

DOI: 10.9734/AJEBA/2016/28347
Editor(s):
(1) Chen Zhan-Ming, Associate Professor, Department of Energy Economics, School of Economics, Renmin University of China, China.
Reviewers:
(1) Der-Jang Chi, Chinese Culture University, Taiwan.
(2) Shih-Wei Wu, National Taipei University of Technology, Taipei, Taiwan.
(3) Rebecca Abraham, Nova Southeastern University, Fort Lauderdale, USA.
Complete Peer review History: http://www.sciencedomain.org/review-history/15725

Original Research Article

Received 15th July 2016
Accepted 1st August 2016
Published 9th August 2016

ABSTRACT

Studying the efficiency in stock markets remains of importance as it can provide information about the possibility to make predictions concerning those markets. This paper's purpose is to study the behavior of 17 Asian stock markets, divided in three different groups: developed, emergent and frontier markets. The results point towards a deviation from the random walk of almost all indexes - the exceptions are the Japanese and the Korean markets. Surprisingly, developed markets show less efficiency than emerging markets. The fact that those markets suffered in the last years from severe economic problems (including contagion) could explain such results. Frontier markets, which are less developed and less liquid, have higher evidence of inefficiency.

Keywords: Detrended fluctuation analysis; efficiency; inefficiency; Asian stock markets; random walk.

1. INTRODUCTION

The financial markets' efficiency continues to be a topic often analyzed in financial literature, because it is important both for the issuers of financial assets as it is for the actual and potential investors. The importance of the efficiency is due to the fact that it could give some information about the evolution of those assets to agents.

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Despite not being a novelty, this kind of analysis still attracts researchers, as it could be performed using several methodologies. In fact, in the early 1970's, [1] stated that the returns of financial assets have no memory, implying that return rates should not have any kind of dependence. This hypothesis is called the Efficient Market Hypothesis (EMH) and it is designed in its weak form.

The literature is rich on EMH's analysis. It is possible to find analysis that use linear methodologies (which, generally, point for the efficiency) as well non-linear ones (in this case, the results are mixed). In particular, some physicists begun trying to explain some economical phenomena, using measures from statistical physics. Arguing that some economic theories could be founded on simplified models, they started to apply those methodologies, mainly to financial markets. Their interest in financial markets grew so much that Econophysics were created, as an interdisciplinary research field which applies statistical physics methods in order to solve problems in economics and management. The main advantage is that those methods are the preferential way of studying the non-linear dynamics of variables.

One of the methodologies used to analyze this non-linear dependence in data is the detrended fluctuation analysis (DFA), which is designed to detect long-range dependences in time series. Created by [2], a group of statistical physics, it was originally used to study the behavior of DNA. It has subsequent applications in other research fields: climatology (see, for example, [3]), heart beating (see, for example, [4]) or solid state physics (see [5]). It is also possible to find several applications of the DFA in economics and finance, that mainly analyze financial assets, has we will see in next two sections. These clearly exemplify that Econophysics is now a solid research field. For a more in-depth review about Econophysics, you can see, for example, the work of [6].

Returning to efficiency, in case EMH is verified, the return rates should behave like a random walk and have no memory. If, however, some persistence pattern is found in a given asset, it could be interpreted as a sign of inefficiency.

In this paper, we will use DFA to analyze the behavior of the 17 Asian MSCI (Morgan Stanley Capital International) stock markets: Australia, Hong Kong, Japan, New Zealand, and Singapore (developed markets); China, India, Indonesia, Korea, Malaysia, Philippines, Taiwan and Thailand (emerging markets); Bangladesh, Pakistan, Sri Lanka and Vietnam (frontier markets). Our main results point towards the efficiency of only two of this markets: the Japanese and the Korean. The other 15 indexes show a behavior that is different from expectations, which could be seen as a sign of inefficiency.

The remainder of the paper is organized as follows: Section 2 presents a brief literature review about the efficiency in stock markets as a whole, with a particular focus on Asian markets; Section 3 presents the data and the methodology used; Section 4 shows the results; Section 5 concludes and discusses such results.

2. LITERATURE REVIEW

It is possible to find in the literature several studies that analyze the behavior of financial assets. The first work on this subject is, probably, the one done by [7], which analyzes stock prices and concludes about the normality of those prices, as expected. The use of linear autocorrelations applied to financial data generally allows researchers to conclude favorably on the random walk behavior. Such results are found in older studies (as in, for example, [8,9,10], amongst others) but also in more recent works (see, for example, [11,12]). Even when any kind of linear autocorrelation is indeed present, it disappears in the short run (see, for example, [13]).

However, when non-linear techniques are applied, the results are somehow different. Firstly, it is possible to find that financial markets suffer from stylized facts: common facts which appear in several financial assets. Works as those of [14,15] survey these facts and find that the most usually stylized facts are the existence of fat tails in returns, asymmetries between gains and losses, volatility clustering, leverage effect, correlation between trading volumes and volatility or autocorrelation in the variance.

The crescent use of non-linear approaches has allowed researchers to extend their analysis. In the context of EMH this is very important, given that the existence of any kind of dependence (not only the linear one) could have an effect on the capability of predicting return rates, which violates the referred hypothesis.

In this context, it is possible to find different types of analysis, some of them running Econophysics analysis which are not restrained to linear approaches: [16,17,18,19,20,21] use different methodologies such as fractional analysis, mutual information, measures of entropy, cointegration or scaling analysis. All of these share the evidence about long-range dependence of financial markets. The efficiency claims the inexistence of dependence in data, and, as such, the existence of long-range dependence could be a signal of inefficiency.

We can also find some works using DFA applied to financial markets: [11], which analyzes G7 stock indexes (plus 3 other countries); [22], which analyzes Apple and Samsung stocks; [23], which studied Chinese and American stock markets; or [24], which studies the index of 12 Eurozone countries – these are just some examples of works applying DFA to stock markets. Once again, the evidence points to the existence of long-term dependence, and, as so, these could be seen as deviations of the weak form efficiency.

Please note that our main objective is not to make a deep literature review of the EMH, as our objective is to analyze Asian stock markets in particular. For a more in-depth survey on the EMH see, for example, [25].

Regarding the Asian stock markets, we can also find some studies that analyze the efficiency of some indexes [1]. As we can notice, no work involving such a long number of countries and using DFA has yet been published. It is possible to find a relatively large amount of studies using some of our indexes, with a number of methodologies: unit root tests (linear and non-linear), spectral analysis, serial correlation, variance ratio tests, or even with chaos theory, amongst others.

In our study, we analyze the indexes of 17 countries. According to our source, we can find developed, emerging and frontier markets. In this review of literature, for a better understanding, we will also divide the analysis in those same three groups.

The first group is composed by developed markets: Australia, Hong Kong, Japan, New Zealand, and Singapore. The studies for Australia, show mixed results: both [27,28] use non-linear unit root tests - but as the first identifies that the stock market is efficient, the later has found different evidence. The different sample could explain such contrary results. Similar results are found for New Zealand.

In the Hong Kong and Singapore stock indexes case, [29,30,31] found efficiency in the index (using the variance ratio test). However, [32,33,34,35] found the stock to be inefficient. They used different methodologies and samples.

For the Japanese stocks, most of the studies found evidence of efficiency: [33], which used linear tests, [31] using the variance ratio test and [11] which used DFA - the same procedure that we use in this paper.

Regarding emerging markets, our analysis covers the following countries: China, India, Indonesia, Korea, Malaysia, Philippines, Taiwan and Thailand. For these countries, most of the studies find that their markets are inefficient. In the Chinese case, [36,30,37,38,35], all found evidence pointing towards the inefficiency of the indexes analyzed. [39], however, find evidence of efficiency. Curiously, this is the only work that uses an Econophysics approach: the R/S method, which has some similarities with the DFA. All the others use, mainly, linear approaches.

The analysis of the Indian index, in previous literature, is almost completely based on unit root tests and serial correlation analysis. Note that these are linear approaches, which are normally more likely to show efficiency in its results. Even so, most of the studies have found evidence of inefficiency: see, for example, the studies of [40,41,34,35]. [42,33] found evidence of efficiency, but with older samples.

The Indonesian, Malaysian, Filipino and Thai indexes are normally inefficient: [31,35,43] have studies comprising all of these indexes. The indexes of Malaysia and Phillipines were studied by other authors, such as, for example, [44,33,45,34].

The Korean and Taiwanese indexes show some mixed results for different studies (which are, mainly, based, in linear approaches). [46,27,34, 31] found evidence of efficiency, whilst [32,33,45,35] found opposite results regarding Korea. In the case of the Taiwanese index, the

[1] *In the work of [26], you may find a complete review of literature on this topic.*

efficiency is found by [33,34,31] whilst [32,47,35] found evidence of inefficiency. Once again, most of these analysis are based on linear approaches.

Regarding emerging markets, the group is formed by 4 indexes: Bangladesh, Pakistan, Sri Lanka and Vietnam. Pertaining Bangladesh and Vietnam, we cannot find such kind of studies. The fact that these countries are listed in our source more recently could explain this. As for Pakistan and Sri Lanka, the studies are also sparse, and none of them could find clear evidence of efficiency (see [48,35] for both indexes, and [49], for the Pakistanese one).

The innovation on this paper lies on the fact that, as it is noticeable, this is the first study applying DFA to a large sample of Asian markets. [11] apply the DFA for 10 countries, but just one of them is from our database (the Japanese one).

3. DATA AND METHODOLOGY

The objective of this paper is to analyze the efficiency of Asian markets by applying DFA. We retrieved information for 17 countries: Australia, Hong Kong, Japan, New Zealand, and Singapore (developed markets); China, India, Indonesia, Korea, Malaysia, Philippines, Taiwan and Thailand (emerging markets); Bangladesh, Pakistan, Sri Lanka and Vietnam (frontier markets)[2]. We chose to study MSCI indexes rather than the national ones because they are more comparable. The data was retrieved from Datastream. The return rates were calculated by the traditional difference of natural logarithms, i.e., $r_t = ln(S_t) - ln(S_{t-1})$, with S being the information of the stock index.

In order to make interpretations comparable, we leveled the number of the indexes' observations. So, we retrieved the information from the 1st January 1993 until the 30th June 2016, in a total of 6130 observations. The starting date is due to the fact that some indexes only have information from that date onwards. Despite this, we have two exceptions: Bangladesh, whose sample starts in the 30th November 2009 (1719 observations) and Vietnam, with the sample being started on the 30th November 2006 (2501 observations). We chose to keep these two indexes for two reasons: first, it allows us to study the entire database of Asian indexes; secondly, they could provide a way to analyze if smaller samples may have some effect on the conclusions about efficiency.

The detrended fluctuation analysis (DFA) is a methodology used to analyze the dependence of time series, based is the concept of the Hurst exponent: a measure to distinguish between the random or the not-random behavior of a process. Initially used to determine the randomness of the Nile River, it was generalized as a form to study other phenomena (as occurs with other statistical physics methods). Regarding the DFA, it was developed by [2] and used originally to study the behavior of the DNA. The objective of DFA is to analyze how xt and xt+s relate in different moments in time, which allows the extension to financial markets.

Considering different equidistant observations described by xk, from k = 1 to t, firstly, the DFA integrates time series, calculating $x(t) = \sum_{k=1}^{t} x_k - \langle k \rangle$ ($\langle k \rangle$ is the average of the observations – the subtraction of $\langle k \rangle$ is not mandatory because is eliminated in the third step). The second step consists on dividing x(t) in N/s mutual exclusive boxes of equal dimension s. The third step calculates a trend z(t) for each segment, with ordinary least squares, and the time series is detrended, i.e., performing the following calculation: $x_s(t) = x(t) - z(t)$.[3] For each box, the DFA function given by $F(s) = \sqrt{\frac{1}{2N} \sum_{k=1}^{2N} [x_s(t)]^2}$ is then calculated. After this, it is averaged F(s) for all the centered boxes in s, generating the fluctuation $\langle F(s) \rangle$, which is a function of s. This method is repeated for all the different values of s and it is expected a power-law behavior of $\langle F(s) \rangle \sim s^{\alpha}$.

This α is equivalent to the Hurst exponent. If α = 0.5, a given time series is represented by a random walk, and it is possible to conclude that the referred time series has no long memory. If α ≠ 0.5, it means that the time series shows evidence of long-term correlation. That long-

[2] *For further information about the division and composition of the indexes, see www.msci.com*

[3] *The original application is made with a linear trend. Later applications include other polynomial trends (see, for example, Kantelhardt et al. 2001). In this study, we use the linear trend.*

range dependence is positive if $0.5 < \alpha < 1$ (that series exhibits a persistent behavior) and negative if $\alpha < 0.5$ (meaning anti-persistence).

Most of the DFAs applied to financial markets find evidence of long-term dependence: [50] for S&P500, [51,52] for exchange rates, [53] for Latin American stock indexes, [54] for oil prices, [55] for individual NYSE stocks and [11] for G7 countries plus Greece, Portugal and Spain – all of them found evidences of long-term dependence in the studied financial assets.

As previously referred, and as noticeable, there are no published works using DFA on Asian stock markets, which makes this the innovative feature of this paper.

4. RESULTS

The objective of this paper is to analyze the efficiency of Asian stock markets. First of all, we made some preliminary analysis, with the results shown in Table 1. The dashed lines of the table separate, firstly, the developed from the emergent markets and, then, the emergent markets from the frontier markets.

Firstly, since 1993 to 2016, the Japanese and the Chinese were the only two markets with a decrease on the value of the respective indexes. We can find another two stocks with a negative mean of their return rates: Bangladesh and Vietnam. Nevertheless, it is necessary to have in mind that these two markets have smaller samples. World economies in general and stock markets in particular faced some turbulent periods recently, which can explain these results. Another interesting feature of the results, is the fact that all indexes have relatively high values of kurtosis. This means that return rates of these stock markets are leptokurtic, consistent with the existence of fat tails. This feature is identified as a stylized fact of the financial markets (see, for example, [14]).

After descriptive statistics, we applied the DFA to all indexes' returns. Those results are presented in Table 2. In the second column of the table, it is possible to find the DFA exponent and the respective standard deviation. As referred in methodology's section, the return rates are expected to have an exponent of 0.5. With our results, it is possible to test statistically, with a simple t-test, if a given exponent is equal to 0.5 or not. The p-value of that test is presented, for each country, in the last column of Table 2.

In the developed markets' case, the Japanese index is the only one which shows evidence of behaving like a random walk. This result is coherent with other works such as, for example, [11,56]. The index of Hong Kong has a non-zero p-value, but at the 1% significant level we reject the hypothesis that return rates behave like a random walk. The same conclusion is reached for the other developed markets: Australia, New Zealand and Singapore have significant deviations from the 0.5 level, with the particularity that Australia and New Zealand share the fact that their return rates have an anti-persistent pattern.

Table 1. Descriptive statistics for return rates of the Asian stock markets. Mean, maximum and minimum are percentages

Index	Mean	Std. Dev.	Kurtosis	Maximum	Minimum
Australia	0,000185	0,0099	8,01	0,0610	-0,0868
Hong Kong	0,000195	0,0152	12,13	0,1598	-0,1379
Japan	-0,000005	0,0135	8,99	0,1306	-0,1044
New Zealand	0,000094	0,0106	16,83	0,1114	-0,1634
Singapore	0,000100	0,0125	9,79	0,1097	-0,0983
China	-0,000096	0,0190	8,84	0,1404	-0,1446
India	0,000377	0,0153	9,53	0,1642	-0,1205
Indonesia	0,000440	0,0185	13,63	0,1683	-0,1915
Korea	0,000251	0,0182	8,41	0,1172	-0,1310
Malaysia	0,000163	0,0136	54,66	0,2326	-0,2416
Philippines	0,000222	0,0146	13,08	0,1629	-0,1367
Taiwan	0,000144	0,0153	5,97	0,0917	-0,1031
Thailand	0,000069	0,0180	15,19	0,2143	-0,1808
Bangladesh	-0,000016	0,0160	26,00	0,1539	-0,1654
Pakistan	0,000262	0,0171	10,22	0,1420	-0,1573
Sri Lanka	0,000284	0,0141	40,91	0,2756	-0,1605
Vietnam	-0,000016	0,0170	3,99	0,0521	-0,0613

In the case of the emerging markets, the Korean index is the only one showing evidence of a random walk behavior (some previous works also found this same evidence). All the other six indexes show evidence of non-random walk behaviors (an exponent statistically significantly different from 0.5). The other two conclusions arise from those results: firstly, all indexes have a persistent behavior - which means that if an index has an upward (downward), it is expected that, in the future, it will have the same pattern; secondly, and probably more important, with the exception being the Malaysian case, all the other indexes have exponents nearer to the 0.5 level when compared with the developed markets, i.e., are more efficient. It was expected that more developed markets should be nearer from the efficiency level. Although the turbulence of the last years, mainly in the most developed markets, could explain such effects. Emerging markets are having a growing weight in the financial markets presently. This implies that they are also more liquid markets, and it could explain our results.

Table 2. DFA results

Stock market	DFA exponent	P-value
Australia	0.4689±0.0058	0.0000
Hong Kong	0.5149±0.0040	0.0007
Japan	0.4915±0.0067	0.2127
New Zealand	0.4456±0.0027	0.0000
Singapore	0.5518±0.0073	0.0000
China	0.5157±0.0031	0.0000
India	0.5255±0.0034	0.0000
Indonesia	0.5118±0.0034	0.0013
Korea	0.5120±0.0066	0.0772
Malaysia	0.5480±0.0064	0.0000
Philippines	0.5146±0.0029	0.0000
Taiwan	0.5131±0.0045	0.0059
Thailand	0.5155±0.0018	0.0000
Bangladesh	0.4523±0.0036	0.0000
Pakistan	0.5400±0.0026	0.0000
Sri Lanka	0.5817±0.0020	0.0000
Vietnam	0.5313±0.0046	0.0000

Finally, for the frontier markets we always reject the random walk behavior. Furthermore, the distance from the 0.5 level is relatively high. These are less developed and less liquid markets, when compared with the previous markets, and their behavior is somehow expected.

5. CONCLUSIONS

Despite the large amount of literature devoted to the analysis of the financial markets' efficiency, this topic remains of interest, because it may allow investors to know if the markets where they want to invest behave as theoretically expected. In the specific case of stock markets, the evidence of inefficiency is very important, because it could imply that an investor could predict asset prices and, as a result, have abnormal profits. In this paper, we pursue the objective of studying the Efficient Market Hypothesis in its weak form with an Econophysics approach, using a detrended fluctuation analysis. This methodology allows us to analyze the possibility of long-term dependence in financial markets.

Our sample is divided in three different groups: developed, emergent and frontier markets. In the developed markets group, the Japanese index is the only one which is consistent with the random walk behavior and, consequently, the only showing evidence of efficiency. All the other markets show evidence of inefficiency.

Regarding the emerging markets group, we again found only one index showing evidence of efficiency: Korea. All the other indexes show a persistent behavior, which could be seen as inefficiency. Despite this, the fact that the deviations from the random walk are smaller than the deviations of developed markets remains as an interesting result. One possible explanation to this is the fact that developed markets suffered severe economic problems in the last years. Because developed markets are very integrated, they may be affected from a contagion effect, whilst emerging markets show a more stable behavior.

Finally, the frontier markets - which are less developed and less liquid - show worse results on their efficiency. The fact that some of these markets are relatively young and that two of them have a smaller sized sample could also explain these results.

The results of the DFA allow us to conclude that most of these markets show evidence of long-range dependence, i.e., they are affected by a non-linear behavior. This is a long memory process, which means that the effects of events persist in time. This persistence could imply the existence of inefficiency, although it is necessary to prove that they allow the investor to gain abnormal systematic profits. It is necessary to state that we do not explore the possibility of predicting return rates. For this purpose, it would be necessary to distinguish between

deterministic and stochastic behaviors of the studied time series, and this is not the purpose of this paper. But, it is possible to conclude that most of the Asian markets do not follow a random walk, which may be synonymous of inefficiency.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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