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# Is CSX Index a Random Walk?

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## ABSTRACT

*The growth or decline in stock value depends on information. The Efficiency Market Hypothesis (EMH) consists of three different forms: strong-form, semi-strong-form, and weak-form states that stock price reflects its true value properly, and thus includes all information, public and private. If market inefficiency is discovered, an abnormal return may be created via risk-adjusted technical analysis. The Random Walk Hypothesis (RWH) argued that the price of stock tomorrow is computed based on the price of stock today, and the price of stock cannot be anticipated when a random number is consistent with weak-form efficiency. The empirical findings from this research have shown that the CSX index is not a random walk or weak-form inefficient, as indicated by the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, and the Variance Ratio (VR) test.*

***Keywords: CSX, EMH, RWH, Unit Root test, VR test***

## INTRODUCTION

Market efficiency means that the values of assets represent all information, public and private. Thus, by employing particular investment skills or techniques, no-one could beat the market or generate risk-adjusted excess return because all relevant information related to asset pricing was already taken into account, while asset prices, in accordance with Efficient Market Hypothesis (EMH), are fairly traded in the markets, Fama (1970). Three different types of market formats exist—strong form, semi strong form and weak form. An asset price, as indicated by the strong form efficiency, includes public and private information in the market. Referring to semi-strong form efficiency, price of an asset is determined only by publicly available information in a market. All previous asset prices subject to current reference are represented in the current asset price based on the availability of historical asset values as claimed by the weak form efficiency of EMH. The notion of the Random Walk Hypothesis (RWH) is closely connected with the term of weak form efficiency. Therefore, it is impossible to utilize technical analysis to anticipate and beat the market. The RWH is a well-known financial theory to examine stock price or stock index behavior. The theory of RWH mentions that changes in stock price are alleged, which means that today's stock price is determined by the sum between yesterday's stock price and a random number, thus, the movement of stock price is not predictable, Malkiel (1973).

The Cambodia Securities Exchange (CSX), known as Cambodia's stock market, is a joint venture operated between the Royal Government of Cambodia and the Korea Exchange. CSX has been operating its business in Cambodia for more than 10 years, and currently, there are seven listed firms. Two best-known financial theories, Efficient Market Hypothesis and Random Walk Hypothesis, are nevertheless unjustified in Cambodia's stock market. The main aim of this study is to find out a response to a research question: "Is CSX index a random walk?" Similarly, this research is attempting to examine whether or not there is a weak form efficiency of the EMH with the return of the CSX index. In the light of this study, two random walk tests are employed, unit root tests and variance ratio (VR) tests. The Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) are two of the most popular unit root tests on offer. The null hypothesis of ADF, PP and VR test stated that the return of CSX index is random walk. These tests are conducted on a continuous daily return of CSX index within the time span between 18 April 2012 and 20 July 2021.

## LITERATURE REVIEW

Numerous empirical studies were undertaken to examine the weak-form market efficiency in different financial markets of developed economies. Lee (1992) investigated if the weekly stock returns of ten industrialized countries, which include Austria, Belgium, Canada, France, West Germany, Italy,

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Japan, Netherland, Switzerland, and the United Kingdom followed a random walk process between 1967 and 1988. Using a variance ratio test, the research confirmed the existence of the weak-form efficiency in most selected markets where the random walk hypothesis was not rejected. Another study by Choudhry (1994), investigated the efficient market hypothesis (EMH) and the stochastic trends of stock indices in seven OECD markets between 1953 and 1989. The study employed several tests, such as means of the augmented Dickey-Fuller test (ADF), the KPSS test, the Cochrane variance ratio test (CVR), Lo-MacKinlay test, and the Campbell-Mankiw Decomposition test (CMD), in addition to Johansen's cointegration test. The study indicated that the selected stock markets are efficient during the sample studied period. Al-Loughani and Chappell (1997) found that the Financial Times Stock Exchange (FTSE) 30 share index of the UK stock markets did not follow a random walk during the investigation period between 1983 and 1989. Worthington and Higgs (2004) conducted a test on the weak-form EMH for sixteen developed markets and four emerging economies using the daily returns between 1995 and 2003. The analysis illustrated that most emerging markets were not associated with the random walk hypothesis, while five developed countries met the most stringent random walk criteria.

Several other studies were conducted on the emerging economies, including Karemera et al. (1999). The study adopted the multiple variance-ratio test to analyze the random walk hypothesis for fifteen emerging capital markets in terms of both the US dollar and local currency. The results demonstrated that most emerging markets' equity returns followed a random walk. A similar study by Smith and Ryoo (2003) indicated that the Turkey stock market, the only market among five European emerging economies in the study, followed a random walk under the variance ratio test. Applying autocorrelation analysis, runs test, and variance ratio test, Guidi et al. (2011) found that stock markets of the Central and Eastern Europe did not follow a random walk. Gilmore and McManus (2003) studied three main Central European markets, particularly the Czech Republic, Hungry, and Poland, using an array of tests and the analysis rejected the random walk hypothesis. Other studies on the individual stock market were also identified. The studies on the Russian capital market by Abrosimova et al. (2002) and later by Darushin and Lvova (2015) illustrated the existence of weak-form market efficiency. Borges (2009) assessed the Lisbon Stock Market between 1993 and 2006 by conducting a serial correlation test, a runs test, an augmented Dickey Fuller test and the multiple variance ratio test. The results suggested that the stock market index followed a random walk model. Panas (1990)'s research presented the weak-form efficient market in the case of Athens stock market, which contradicted the results from Dockery and Kavussanos (1996). Similarly, Zychowicz et al. (1995), Antoniou et al. (1997) and Tas and Atac (2019) rejected the random walk hypothesis for the Istanbul stock market, whereas Buguk and Brorsen (2003) suggested that the Turkey market was weak-form efficient.

In addition, the African stock markets also attract significant interests from the researchers. Smith evaluated 11 African markets in 2008 and the random walk hypothesis was rejected in the selected markets. Smith et al. (2002) used multiple variance ratio tests to investigate eight African equity markets and found that the South African market was the only market that followed a random walk. Similarly, according to Enowbi et al. (2009), weak-form efficiency was evidenced in the South African capital market, while other three stock markets in the study, such as Egypt, Morocco, and Tunisia, did not follow a random walk. The evaluation of weak-form EMH for the Nigerian Stock Exchange (NSE) presented a mixed result.

Olowe (1999) indicated that the NSE was efficient in weak-form using the monthly data between 1981 and 1992. It was later supported by further research from Ajao and Osayuwu (2012), and Ogundina and Omah (2013). However, Gimba (2012), Ogbulu (2016), Falaye et al. (2018), and Ejem et al. (2020) found that the NSE did not follow a random walk model, and thus was not weak-form efficient.

Several empirical studies pointed out the invalidity of the weak-form efficient market hypothesis for the Latin American stock markets (Charles & Darné, 2009; Worthington & Higgs, 2004). However, Ojah and Karemera (1999) identified the presence of random walk-in stock return for the Latin American emerging equity markets, employing multiple variance ratio and auto-regressive tests. According to Urrutia (1995), the variance ratio tests rejected the random walk hypothesis for the equity markets of Argentina, Brazil, Chile, and Mexico, while the runs tests indicated the selected stock markets are weak-form efficient.

Likewise, an impressive number of empirical studies assessed for the weak-form efficient market hypothesis on the Asian stock markets. Hoque et al. (2006) tested the eight Asian equity markets using alternative variance ratio tests, namely Hong Kong, Indonesia, South Korea, Malaysia, the Philippines, Singapore, Taiwan and Thailand. The results showed that stock prices of the eight Asian markets did not follow a random walk with the possible exception of Taiwan and South Korea.

The research by Poshakwale (1996) showed a non-random behavior in Bombay Stock Exchange between 1987 and 1994 and hence, the Indian stock market was not weak-form efficient. Later, Gupta and Basu (2007) and Gupta and Yang (2011) found that the Indian stock markets were weak-form inefficient between 1991 and 2007 and met the criteria of weak-form EMH between 2007 and 2011. However, Nisar and Hanif (2012) investigated four South Asian capital markets, including India, Pakistan, Bangladesh, and Sri Lanka. The result showed no evidence of random walk hypothesis between 1997 and 2011, and as such, the four selected markets were not weak-form efficient.

Caporale et al. (2020) employed Engle and Granger (1987) co-integrated technique to investigate whether the index of five European stocks such as IBEX35, FTSE100, DAX30, FTSE MIB40, and CAC40 in Spain, United Kingdom, Germany, Italy, and France, respectively, consist of weak-form inefficiency or not. The daily time frame of all stock indexes were taken under consideration beginning from January 2011 to January 2019. The empirical result of this research indicated that the five stock market indexes' presence of long memories or market is inefficient under the weak-form efficiency hypothesis of the EMH.

To assess the degree of market efficiency of some nations of the European Union: Bulgaria, Croatia, Czech Republic, Hungary, Romania, Poland, and Slovenia and seven countries in Central and Eastern Europe, Milos et al. (2020) developed a method known as Multifractal Detrended Fluctuation Analysis (MF-DFA) to examine the dynamic resources of multifractality. MF-DFA is carried out in three main stages: calculating stock index return, seasonal and trend decomposition using loess and MF-DFA. The research started at various times, but ended in August 2018. The result of the study indicated that stock markets under investigation were neither efficient, nor the progression of each market reached the mature stage.

Hari and Pratil (2021) performed three types of random walk tests: autocorrelation, run, and ADF tests on daily return of NEPSE Index in Nepalese Stock Markets. The study concluded that the Nepalese stock market is inefficient in weak form indicating that future price movements can be predicted based on their past price movements.

## METHODOLOGY

A deterministic trend with stationary first autoregressive, AR(1), component of time series data, $Y_t$, is written as follows:

$$Y_t = \beta_1 + \beta_2 t + \beta_3 Y_{t-1} + u_t \qquad (1)$$

where $\beta_1$ is a drift, t is time trend, $\beta_2$ is coefficient of time trend, $\beta_3$ is slope parameter of the first lag of Y and $u_t$ is assumed to be white noise ~$(0,\sigma^2)$. A restriction that impose on any of the three parameters: $\beta_1$, $\beta_2$ and $\beta_3$, in Equation (1) would create many types of random walk models in Table I below,

Table I. Random Walk Models

| Models | Equations | Restrictions |
|---|---|---|
| Pure random walk | $Y_t = Y_{t-1} + u_t$ | $\beta_1 = 0, \beta_2 = 0, \beta_3 = 1$ |
| Random walk with drift | $Y_t = \beta_1 + Y_{t-1} + u_t$ | $\beta_1 \neq 0, \beta_2 = 0, \beta_3 = 1$ |
| Deterministic trend | $Y_t = \beta_1 + \beta_2 t + u_t$ | $\beta_1 \neq 0, \beta_2 \neq 0, \beta_3 = 0$ |
| Random walk with drift and deterministic trend | $Y_t = \beta_1 + \beta_2 t + Y_{t-1} + u_t$ | $\beta_1 \neq 0, \beta_2 \neq 0, \beta_3 = 1$ |

Three most famous unit root tests were conducted to evaluate if time series data represent a random walk process: Augmented Dickey-Fuller (ADF), Phillips-Perron (PP) and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) tests. The theory of econometrics relating to the unit root tests are discussed below.

### *Augmented Dickey-Fuller (ADF) test*

In 1979, Dickey and Fuller conducted many unit root tests to determine if the selected time series data under study had a unit root or non-stationary device or no unit root or stationary unit. A stationary data shows a mean reverting process. An assessment of the first order autoregressive (AR) model of the form is a fundamental estimate for the Dickey-Fuller (DF) test:

$$y_t = \beta_1 + \beta_2 t + \beta_3 y_{t-1} + \varepsilon_t \qquad (2)$$

Where y is time series variable, $\beta_i$ are parameters or coefficients, i=1,2,3, t is time trend, ε is residual or error term which is assumed to be i.i.d. In a different way, equation (2) may be written as:

$$\Delta y_t = \beta_1 + \beta_2 t + \beta_3^* y_{t-1} + \varepsilon_t \qquad (3)$$

where $\beta_3{*}=\beta_3-1$. In the DF test, the DF had presumed that the remaining conditions were not linked in serial form. In the event of a serial relationship between the error components anticipated in equation (3) in violation of the DF test assumption, the estimated test result is inconsistent. It is worth noting that the Dickey-Fuller test hypothesis is $\beta_3=1$ and the alternative $|\beta_3| < 1$. If you cannot reject the null hypothesis, the $y_t$ has a root unit or a non-stationary one. By contrast, if a zero hypothesis is rejected, the $y_t$ has either stationary or no unit root (Dickey & Fuller, 1979). Dickey and Fuller created a different test known as the Augmented Dickey-Fuller (ADF) test to overcome the serial correlation problem of the error term. The ADF test will be conducted in a regression form. The null hypothesis is that the series has a unit root versus the alternative hypothesis is that the series has no unit root or stationary. This test is performed in the following form of a regression.

$$\Delta y_t = \beta_1 + \beta_2 t + \delta y_{t-1} + \sum^{p}_{j=1} \beta_j \Delta y_{t-j} + \varepsilon_t \qquad (4)$$

Where y is time series data, Δ is first difference operator, $\beta_1$, $\beta_2$, $\delta$ and $\beta_j$ are parameters or coefficients, t is time trend, ε is error term or residual term, i.i.d. The optimal lag length determination of the regression model (4) is the most important task in completing the ADF test since it does not result in a small lag length or a residual noise error, and it also fails to estimate the standard error in any of the respected parameters. The optimal lag length is established by utilizing information criteria such as the Akaike Information Criterion (AIC) or the Schwarz Information Criterion (SIC). The following hypotheses are provided of the ADF test, null and alternative:

$$H_0: \ \delta=0$$

$$H_1: \ \delta<0$$

The null hypothesis of δ=0 can't be dismissed when the critical value of t-tests retrieved from the DF table is lower than t-statistics, implying that a unit root or non-stationary for the time series under study is present. If t-statistic is higher than the critical t-test that can be comprehended that the time series is stationary or has no unit root, the null hypothesis is rejected or the alternative δ<0 hypothesis is accepted (Dickey & Fuller, 1979).

***Phillips-Perron (PP) test***

In order to resolve the serial correlation problem of the residual or error term, the lags of the first different terms of the regressors were introduced to the regression models (2), which led to the incoherence of the estimated result as carried out by Dickey and Fuller. In 1988, Phillips and Peron created a more completed notion of unit root testing later on. In the PP test, exactly the same regression model form as the DF test is used, as seen in the following equation (5).

$$\Delta q_t = \beta_1 + \beta_2 t + \delta q_{t-1} + \varepsilon_t \qquad (5)$$

Despite the regression of the two tests, PP and DF, the t-statistic adjustments, assumed in a DF test, are transformed instead into a Philips-Peron Z-statistic rather than a lag of the first difference terms of the regressors, to eliminate the serial correlation of the residual term problem (Phillips & Perron, 1988).

In this research, a different sort of test known as the Variance Ratio Test (VR) is also carried out, along with unit root tests such as ADF and PP for a random walk process. Below is a description of the VR testing method.

***Variance Ratio test***

Considering a vector of time series

$$[Y_t] = (Y_0, Y_1, Y_2, \ldots, Y_T) \text{ satisfying}$$

$$\Delta Y_t = \mu + \epsilon_t \qquad (6)$$

where μ is a parameter of arbitrary drift. Two crucial tests must be carried out, $E(\epsilon_t)=0$ for all t and $E(\epsilon_t \, \epsilon_{t-j})$ =0 for any positive j, as each of the test is a property of a random walk. Lo and MacKinlay (1988 & 1989) compile two random-walking properties test statistics, which apply in distinct sets of null hypotheses on $\epsilon_t$. First, Lo and MacKinlay assume strongly that $\epsilon_t$ is i.i.d. Gaussian with variance $\sigma^2$ (though the normality assumption is not strictly necessary). This is the homoskedastic random walk hypothesis, while some refer to it as the i.i.d. null. On the other hand, outline the heteroskedastic random walk hypothesis where i.i.d. assumptions are weak and enable very wide types of dependency and conditional heteroskedastic. Sometimes, this hypothesis is called the martingale null since it provides a number of enough (but not essential) criteria for $\epsilon_t$ to be a martingale sequence (m.d.s.). The mean of first difference and the scaled variance of the q-th difference estimators are defined:

$$\hat{\mu} = \frac{1}{T}\sum_{t=1}^{T}(Y_t - Y_{t-1})$$

$$\hat{\sigma}^2(q) = \frac{1}{T_q}\sum_{t=1}^{T}\left(Y_t - Y_{t-q} - q\hat{\mu}\right)^2 \qquad (7)$$

and the relevant variance ratio $VR(q)=(\hat{\sigma}^2(q)/(\hat{\sigma}^2(1)$. In the event of no-drift, T in equation (7) can be substituted for the variance estimators for bias by (T-q+1) or (T-q+1)(1-q/T) in the case of a drift. The VR z-statistic is defined as follows:

$$z(q) = [VR(q)-1]\cdot[s^2(q)]^{-1/2} \qquad (8)$$

where the z is asymptotically N(0,1) for optimal estimator choice $s^2$ (q). The sample estimator is defined as follows based on the i.i.d. hypothesis:

$$\hat{s}^2(q) = \frac{2(2q-1)(q-1)}{3qT} \qquad (9)$$

In the m.d.s. assumption, the kernel estimator is employed as follows:

$$\hat{s}^2(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \cdot \hat{\delta}_j \qquad (10)$$

where

$$\hat{\delta}_j = \left\{\sum_{t=j+1}^{T}(y_{t-j}-\hat{\mu})^2(y_t-\hat{\mu})^2\right\} \Big/ \left\{\sum_{t=j+1}^{T}(y_{t-j}-\hat{\mu})^2\right\}^2 \qquad (11)$$

Because the variance ratio restrict is applicable for every q>1 difference, the statistics upon several selected q values are often evaluated. Chow and Denning (1993) propose to check the joint test size a (coherent) testing statistics that evaluate a set of maximum Variation Ratio statistics with the highest absolute value. The p-value of the Chow-Denning statistics is limited from above by the probability of the parameter m and T-degree-freedom distribution with the Studentized Maximum Modulus (SMM). The bound is estimated via the asymptotic ($T=\infty$) SMM distribution. For i.i.d. null, variance ratio testing a second technique is offered. Under this set of assumptions, the joint covariance matrix of the variance ratio test statistics is formed as in Richardson and Smith (1991), and calculate Wald standard statistics on a joint hypothesis that all variance ratios statistics is 1. The statistics on Wald are asymptotic chi-squares under the null, with m degrees of freedom.

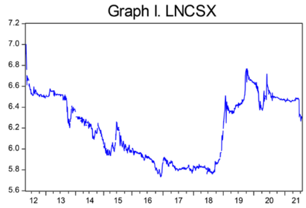
Three distinct types of random walk tests, such as the ADF, PP and VR, are performed on the daily continuous return of CSX index to examine the weak-form efficiency of the EMH in the Cambodia Securities Exchange. The duration of the study is between 18 April 2012 and 20 July 2021. Natural log return of CSX index is calculated as follows:

$$RCSX_t = LN\left({CSX_t}/{CSX_{t-1}}\right) \times 100$$

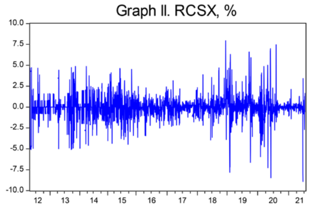
## EMPIRICAL RESULT

From April 2012 to the beginning of April 2015 the CSX series has been declining. The index value continued to decrease again until mid-December 2016 when the peak on 1 July 2015 was raised. The volatility of the Index series remains steady from January 2017 and October 2018, however, at the end of January 2019, it has risen to a higher and halt. The CSX index hit the maximum position in early October 2019 over the research process. A large movement of the series is portrayed between that time and the end of July 2020. The volatility of the index is relatively minimal between August 2020 and early July 2021.

Graph I. LNCSX



Graph II. RCSX, %



The average daily return of CSX is -0.0287 percent throughout this research period. The highest and lowest returns are 7.9528 percent and -8.9565, respectively. The volatility of the index return is 1.4512 percent. Regarding the result of the normality test, Jarque-Bera, the null hypothesis that the return of the index is distributed as normal distribution is highly rejected at 1 percent significance level. The total number of observations is 2,133. The histogram and Kernel distribution of the return is presented in Graph III.

**Table I. Descriptive Statistics, RCSX**

| | RCSX |
|---|---|
| Mean | -0.028796 |
| Maximum | 7.952889 |
| Minimum | -8.956559 |
| Std. Dev. | 1.451248 |
| Jarque-Bera (JB) | 3834.501 |
| Probability of JB | 0.000000 |
| Observations | 2133 |

Graph III. Histogram and Kernel of RCSX

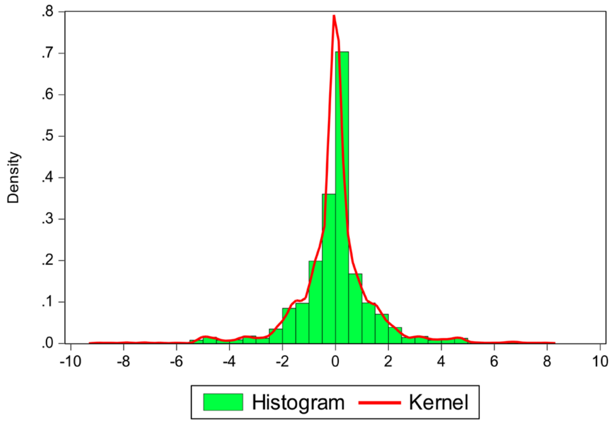



Table II. ADF and PP Unit Root Test of RCSX

Null Hypothesis: The variable has a unit root

| | | ADF test | PP test |
|---|---|---|---|
| With Constant | t-Statistic | -29.1436 | -41.5183 |
| | Prob. | 0.0000 *** | 0.0000 *** |
| With Constant & Trend | t-Statistic Prob. | -29.2287 0.0000 *** | -41.5566 0.0000 *** |
| Without Constant & Trend | t-Statistic Prob. | -29.1307 0.0000 *** | -29.1307 0.0000 *** |

Notes:

a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant

b: Lag Length based on SIC

c: Probability based on MacKinnon (1996) one-sided p-values.

Two different types of unit root tests, ADF and PP, are applied on the return of the CSX index. Each test is performed on three random walk models: model with drift, model with drift and trend, and model without drift and trend. The null hypothesis of the test stated that the return of the index is a random walk. Results from stationary unit root testing under the three models have shown that the change in the CSX index is not a random walk since the null hypothesis is highly rejected at 1 percent significance level as indicated in Table III. In addition to ADF and PP tests, the variance ratio test at 2, 4, 8, and 16 days is also conducted to investigate the RWH. According to joint tests presented in Table IV, the probabilities of studentized maximum modulus and Wald (Chi-Square) are close to zero which are less than 1 percent significance level, thus the null hypothesis that RCSX is a random walk is highly rejected. Under period 2, 4, 8, and 16 days, the hypothesis is also rejected at 1 percent significance level. The result of the Variance Ratio test is consistent with ADF and PP tests.

**Table III. Variance Ratio Test of RCSX**

Null Hypothesis: RCSX is a random walk

Sample: 4/18/2012- 7/20/2021

Included observations: 2132 (after adjustments)

Standard error estimates assume no heteroskedasticity

Use biased variance estimates

User-specified lags: 2 4 8 16

| Joint Tests | Value | df | Probability |
|---|---|---|---|
| Max \|z\| (at period 2)* | 22.26078 | 2132 | 0.0000 |
| Wald (Chi-Square) | 498.0351 | 4 | 0.0000 |

| Individual Tests | | | | |
|---|---|---|---|---|
| Period | Var. Ratio | Std. Error | z-Statistic | Probability |
| 2 | 0.517889 | 0.021657 | -22.26078 | 0.0000 |
| 4 | 0.292193 | 0.040517 | -17.46926 | 0.0000 |
| 8 | 0.139210 | 0.064063 | -13.43652 | 0.0000 |
| 16 | 0.067396 | 0.095329 | -9.782958 | 0.0000 |

*Probability approximation using studentized maximum modulus with parameter value 4 and infinite degrees of freedom

## CONCLUSION

This research shows no evidence of the existence of random walk in the Cambodia Securities Exchange using the ADF and PP unit root tests and the VR test. The unit root and variance ratio tests consistently show that the null hypothesis stating that the change of CSX index is random walk is rejected at 1 percent significance level. Under the Efficiency Market Hypothesis, the Cambodia Securities Exchange is regarded as a weak-form inefficient or CSX index that does not accurately reflect its true value. Therefore, an abnormal return can be achieved by examining the behavior of previous pricing using some technical analysis.

In general, there are several specific reasons for market inefficiency: illiquid market, high transaction costs, asymmetric information, etc. All of these reasons might have taken part or all into consideration to explain the weak-form inefficient in the stock market of Cambodia. Based on the results of this research, there is a doubt that might generate different results from this study, a structural break seems to be depicted on the natural log return of CSX index as indicated in Graph I, thus, applying unit root tests, ADF or PP, alone without taking into account this break might not adequate to justify weak-form efficiency in the Cambodia Securities Exchange. This research provides an opportunity for future scholars who are willing to conduct studies related to EMH in the stock exchange of Cambodia. In addition, the other tests like Run test and Multifractal Detrended Fluctuation Analysis should also be employed notwithstanding ADF, PP, and VR tests.

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