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Variance Ratio Test and Weak-Form Efficiency of Bahrain Bourse

Mohamed Khaled Al-Jafari

Dean of Postgraduate Studies

The Arab Academy for Banking and Financial Sciences, Damascus, Syria

E-mail: aljafarimohamedkhaled@yahoo.com

Tel: ++963932951695

Hatem Hatef Abdulkadhim

Department of Finance and Banking, University of Kalamoon

Former Dean at Al-Qadisiya and Al-Kufa Universities, Iraq, Deratiyah, Syria

E-mail: hatem.altaee@uok.edu.sy

Tel: ++963932354432

Abstract

The main objective of this study is to investigate whether stock prices in Bahrain Bourse follow a random walk process as required by the efficient market hypothesis. Therefore, this study investigates the weak-form of market efficiency in Bahrain stock market by testing the Random Walk Hypothesis (RWH) through multi-approaches specifically unit root, runs and variance ratio tests on the daily price of all share index of Bahrain from February 2003 to November 2010. The empirical results reject the RWH at weak-form level, indicating that stock prices do not fully reflect all historical information and that prudent investors will realize abnormal returns by using past historical data of stock prices and trading volume.

Keywords: Bahrain Bourse, Weak-Form, Efficient Market Hypothesis, Run Test, Unit Root Tests, Variance Ratio Test.

JEL Classification Codes: C12, D53, G12, G14

1. Introduction

The subject of market efficiency and random walk theory is considered one of the most researched topics in finance literature. An efficient market can be described as the one which security prices adjust rapidly to new information. On the other hand, the random walk theory indicates that stock price movements are unpredictable and it follows a random erratic behavior. Kendall (1953) and Fama (1965) are considered one of the earlier scholars who concluded that stock prices move randomly and past movements were of no use in predicting future movements. Later on, Fama (1970) divided the overall efficient market hypothesis (EMH) into three forms: the weak-form EMH, the semi-strong-form EMH, and the strong-form EMH. The Weak-Form of the EMH is the least restrictive form and assumes that current stock prices reflect all security market information, including the historical sequence of prices, rates of return, trading volumes, and other market generated information. Therefore, we should gain little from using any trading rules that decides whether to buy or sell a security based on past rates of return, or any other past market data. On the other hand, the semi-strong

form of the EMH asserts that security prices adjust rapidly to the release of all public information. Therefore, it implies that investors who base their decisions on any important new information after it is public should not derive above-average risk-adjusted profits from their transactions. However, the strong-form of the EMH is the most extreme form. It states that security prices fully reflect all information from public and private sources. This means that no investor has a monopolistic access to information relevant to the formation of prices. Therefore, no investor will be able to consistently derive above-average risk-adjusted rates of return.

The objective of this study is to test the random walk hypothesis on the behavior of Bahrain securities market. It utilizes unit root tests (Augmented Dickey-Fuller test, the Phillips-Perron test and the Kwiatkowski, Phillips, Schmidt and Shin test), run tests and variance ratio test.

This study is organized into six sections as follows: Section 2 describes the Bahrain securities market, while section 3 addresses the literature review. On the other hand, section 4 illustrates data and research methodology. The empirical results and statistical interpretations are presented in chapter 5. Finally, section 6 provides the concluding remarks.

2. The Bahrain Bourse

The Bahrain Stock Exchange was established in 1987 and commenced its operation in June of 1989 with 29 Bahraini listed shareholding companies. In recent years, the exchange invested in modernizing its operations by providing direct online trading services to its member brokers and expands listings and improved listed company information for exchange investors. In 2002, the Central Bank of Bahrain became the regulatory and supervisory authority for the exchange activities instead of the Ministry of Commerce. However, in 2010, Bahrain Bourse was established as a shareholding company replacing Bahrain Stock Exchange. Currently, Bahrain Bourse has 50 listed companies classified according to their activities and dominated by commercial banks and investments sectors. The Bahrain Bourse has three indices that track its performance, Bahrain All Share Index, Dow Jones Bahrain Index, and Esterad Index. Bahrain All Share Index is a capitalization-weighted index of all Bahraini public shareholding companies listed on Bahrain Stock Exchange.

3. Literature Review

There are several studies that were performed on the Middle Eastern stock markets. For instance, Jaradat and Al-Zeaud (2011) found that Amman stock exchange (ASE) is inconsistent with the RWH and is not weak-form efficient. Similar results were obtained by Maghyreh (2003) who found that ASE does not conform to random walk model and informationally inefficient. This contradicts Civelek (1991) who found that the industrial sector of ASE is weak-form efficient. On the other hand, Al-Jafari (2011) examined the RWH of Kuwait equity market (KSE) using parametric and nonparametric tests. He found that KSE is informationally inefficient at the weak-form level. Also, Al-Jafari and Altaee (2011) concluded similar results when testing the Egyptian equity market and found it to be inefficient and stock prices do not fully reflect all historical information. Salameh et al., (2011) tested the weak-form efficiency of twelve Arab stock exchanges. The empirical results showed that all twelve Arab stock markets did not behave randomly under the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) unit root test. Also, Awad and Daraghma (2009) concluded that the Palestinian securities market is inefficient at the weak-form level. On the other hand, Omran and Farrar (2006) investigated the RWH for five Middle Eastern countries. Their finding rejected the RWH for all markets. Also, Abdmoulah (2010) tested the weak-form efficiency for 11 Arab stock markets using GARCH-M (1,1) and found that all markets are weak-form efficient. Similarly, Marasheh and Shrestha (2008) examined the United Arab Emirates securities market. They found that data contains unit root and follow a random walk, meeting the criterion of weak-form market efficiency. Similar results were obtained by Mustafa (2004) who concluded that the UAE market is weak-form efficient. Butler and Malaikah (1992) examined stock returns behavior in Saudi Arabia and Kuwait during 1985-1989. They

found that the Saudi stock market is inefficient, while the Kuwaiti stock market is efficient. This is contrary to Hassan et al., (2003) who found that Kuwaiti stock exchange is weak-form inefficient. Similarly, Abraham et al., (2002) examined the weak-form efficiency for Kuwait, Saudi Arabia and Bahrain markets using the variance ratio test and the runs test for the period October 1992 to December 1998. Results of both tests rejected the RWH in all three markets concluding that they are weakly inefficient markets.

4. Data and Methodology

Lo and MacKinlay (1988) suggest the use of a variance-ratio (VR) statistic to test the random walk hypothesis. However, this procedure is not sufficient on its own to assess weak-form efficiency. In fact, when the random walk hypothesis is rejected, the alternative hypotheses are that the series analyzed are serially correlated. Therefore, further testing must be completed to provide an accurate assessment of weak-form efficiency. This has been commonly done with a runs test.

This section describes the data and comments on the descriptive statistics. It also illustrates briefly the utilized methodology tests in this study.

4.1. Data

Daily data for Bahrain All Share Index were obtained from the Monthly Bulletin and reports found on the Web site of Bahrain Bourse (www.bahrainbourse.com.bh). The data covers the period from February 2003 till the end of November 2010.

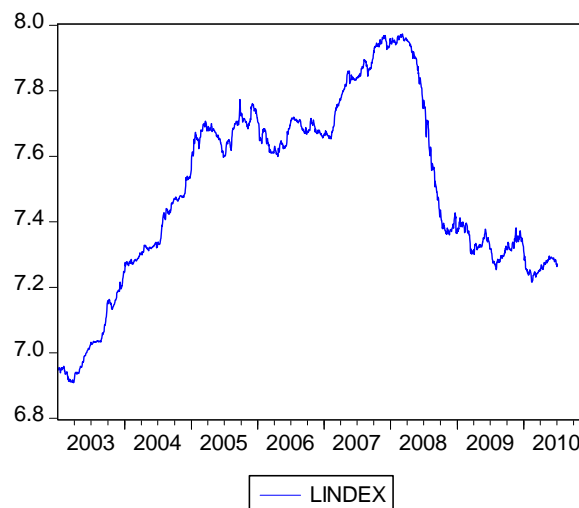
The returns are calculated on closing to closing prices as follows:

$$R_t = \ln \left[\frac{P_t}{P_{t-1}} \right] \quad (1)$$

Where P_t and P_{t-1} are the closing prices of stock index at time t and $t - 1$, respectively and \ln is natural logarithm.

In order to obtain a better understanding of the behavior of stock prices, a preliminary analysis of the data is carried out in this section. Figure (1) shows the plot of the return data based on the index covering the aforesaid period.

Figure 1: Time Series Plots of Bahrain Stock Market Index in Logarithm



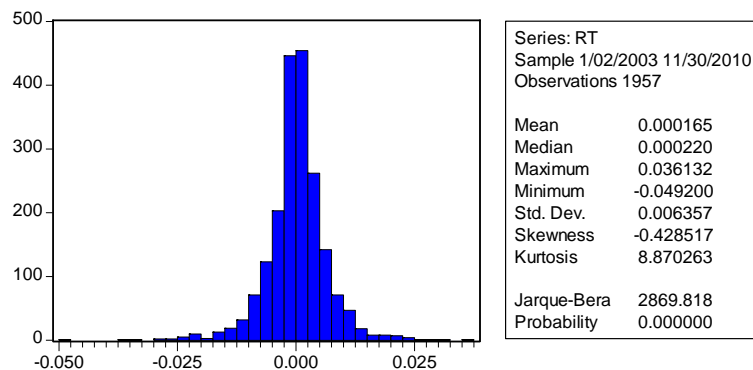
It is clear from this plot that the data exhibited strong volatility. The market experienced positive return until the second half of the year 2008, after that the index experienced high downward movement. In fact, all of GCC countries including Bahrain exhibited a sharp rising trend fueled by increased liquidity resulting from high energy prices. The increase of petrodollars led to irrational investment enthusiasm and speculative behavior among investors causing high increase in the equity prices (Ariss et al., 2011, p.982). The inequilibrium between the supply of and the demand for stocks caused by high liquidity, as a result most of the GCC indices exhibited a sharp decline. The estimated growth rates for the whole period and sub periods might shed lights on the behavior of the index during the period 2003 to 2010.

Table 1: Annual Growth Rates of the Index

Period	Rate of growth	t-statistics	p-value
2003-2006	0.001229	155.5459	0.00000
2006-2008	-0.00047	-32.6708	1.9E-168
2003-2010	0.000137	12.72555	1.06E-35

Descriptive statistics on the weekly index returns of Bahrain Bourse, using Eviews7, are reported in Table (2). These include the mean, maximum, minimum, standard deviation, skewness, kurtosis, Jarque-Bera, and probability value. N denotes the number of observations. Estimates are given for the full sample period 2003-2010.

Table 2: Summary Statistics of Bahrain Daily Price Index



In general, values for skewness equal to zero and kurtosis value of three represents that observed distribution is normally distributed. From the figures, it's clear that there is strong departure from normality in the unconditional distribution of the return with negative skewness. The negative skewness implies that the stock index returns are flatter to the left compared to the normal distribution. The Jarque-Bera statistic rejects the hypothesis of a normal distribution of returns at 1% significant level.

4.2. Statistical Methods

As mentioned earlier, this paper utilizes unit root tests, run tests and variance ratio tests. Therefore, a brief illustration of these tests is provided in this section.

4.2.1. Unit Root Tests

Unit root tests are commonly used to test the stationary property of a time series data. In this study three different unit root tests are employed to test the null hypothesis of a unit root. These tests are: the Augmented Dickey-Fuller (ADF) test, the Phillips-Perron (PP) test and the Kwiatkowski, Phillips,

Schmidt and Shin (KPSS) test. However, under the assumption of the random walk, the price series must have a unit root while the return series must not.

4.2.1.1. Augmented Dickey-Fuller (ADF) Test

The ADF tests assumes that y series follows an AR(p) process and add p lagged difference terms of the dependent variable y to the right side of the test regression. ADF test uses the following three regressions models:

$$\text{Model I : } \Delta y_t = \delta y_{t-1} + \beta \sum_{i=1}^p \Delta y_{t-i} + \mu_t \quad (2)$$

$$\text{Model II : } \Delta y_t = c_0 + \delta y_{t-1} + \beta \sum_{i=1}^p \Delta y_{t-i} + \mu_t \quad (3)$$

$$\text{Model III : } \Delta y_t = c_0 + c_1 t + \delta y_{t-1} + \beta \sum_{i=1}^p \Delta y_{t-i} + \mu_t \quad (4)$$

Model I, does not include intercept (drift) and trend terms. Model II includes constant term c_0 , while model III include constant term and a trend term c_1 . For all models, p is the number of lagged variables terms and μ_t is white noise.

The hypotheses in Augmented Dickey-Fuller (ADF) test are stated as follows:

H_0 : there is a unit root in the series.

H_1 : there is no unit root in the series (stationary).

4.2.1.2. Phillips-Perron Test

Phillips and Perron (1988) propose to estimate the long-run variance by the Newey-West (1987) estimator. This test is perhaps the most common test used next to the ADF-tests. PP tests are similar to ADF tests. The difference between the PP and the ADF tests in how they deal with serial correlation and heteroskedasticity in the errors. The idea of the Phillips-Perron test is to run a non Augmented Dickey-Fuller regression, and then to adjust for the bias that might occur due to correlation in the innovation term. Phillips-Perron test is a non parametric test with the following specifications:

$$P_t = \mu + \delta P_{t-1} + \varepsilon_t \quad (5)$$

$$P_t = \mu + \beta \left(t - \frac{1}{2}T\right) + \alpha P_{t-1} + \varepsilon_t \quad (6)$$

Where P_t is the natural logarithm of the price index at time t , μ is a constant, α and β are parameters to be estimated and ε_t is the error term. Equation (5) includes only the constant term, whereas equation (6) contains a constant term μ and a linear trend term $\beta \left(t - \frac{1}{2}T\right)$. The hypotheses of

Phillips-Perron (PP) tests are stated as follows:

H_0 : there is a unit root in the series.

H_1 : there is no unit root in the series (stationary).

4.2.1.3. The Kwiatkowski, Phillips, Schmidt and Shin Test (KPSS)

A useful alternative test is that introduced by Kwiatkowski, Phillips, Schmidt and Shin (1992). The KPSS test represents a useful alternative to hypothesis, and may conflict with tests that assume nonstationarity as a null hypothesis, thus indicating that there may be real doubt as to the properties of the time series. The KPSS test accounts for the problem of autocorrelation in a similar, although parametric, way to PP test.

In the KPSS model, series of observations is represented as a sum of three components, namely deterministic trend, a random walk, and a stationary error term. To perform the test, we first obtain the residual ε from the regression of y on a constant and a trend. It assumes that the process for y :

$$y_t = \delta t + Y_t + \varepsilon_t \quad (7)$$

With auxiliary equation for γ_t

$$\gamma_t = \gamma_{t-1} + \mu_t \quad (8)$$

where y_t denotes series of observations of variable of interest, τ -deterministic trend, γ_t – random walk process, ε_t – error term of equation (7), by assumption is stationary, μ_t denotes the error term of equation (8), and by assumption is a series of identically distributed independent random variables of $E(\mu_t) = 0$, and constant variance, $\hat{\sigma}_\mu^2$. A test for $\hat{\sigma}_\mu^2 = 0$ is a test for stationarity (Maddala and Kim, 1998).

The KPSS statistic is based on the residuals et from the OLS regression of γ_t on the exogenous variables. The test statistic is defined as:

$$KPSS = T^{-2} \sum_{i=1}^T S_t^2 / \sigma_T^2 \quad (9)$$

Where $S_t = \sum_{i=1}^t \varepsilon_i$ the partial sum of residuals, T is the number of observations, and the σ_T^2 represent an estimate of the long run variance of residuals. Large value of KPSS lead to rejection of the stationarity null hypothesis, since that means the series deviate from its mean. In the (KPSS) unit root test hypotheses are stated as follows:

H_0 : there is no unit root in the series (stationary).

H_1 : there is a unit root in the series.

4.2.2. The Run Test

In order to test for weak-form efficiency, we use the run test as it does not require returns to be normally distributed. This provides a solid alternative to parametric serial correlation tests in which distributions are assumed to be normally distributed.

To perform this test, let, n_a and n_b respectively represent observations above and below the sample mean (or median), and r represents the observed number of runs, with $n = n_a + n_b$.

$$Z(r) = \frac{r - E(r)}{\sigma(r)} \quad (10)$$

The expected number of runs can therefore be calculating by the following formula:

$$E(r) = \frac{n - 2n_a n_b}{n} \quad (11)$$

The standard error is represented by:

$$\sigma E(r) = \left[\frac{2n_a n_b (2n_a n_b - n)}{n^2 (n - 1)} \right]^{1/2} \quad (12)$$

Because returns are not normally distributed, the presence of structural breaks or outliers in the series can bias the test results. To control for such issues, we complete the runs test using a mean and a median as a base. However, using the median can yield more reliable results when there are outliers.

4.2.3. Variance Ratio Test (VR)

This test developed by Cochrane, (1988) and Lo and MacKinlay (1988, 1989) for testing the randomness of stock prices. The VR approach has gained popularity and has become the standard tool in random-walk testing. We can apply the test to both, the stock price index and to the individual stocks (Urrutia, 1995). Lo and MacKinlay (1988) show that the variance ratio test is more powerful than the unit root tests. Also, Ayadi and Pyun (1994) argue that the variance ratio has more appealing features than other procedures. We use overlapping (as opposed to non-overlapping) q -period returns in estimating the variances in order to obtain “a more efficient estimator and hence a more powerful test,” Campbell et al., (1997, p. 52).

The test is based on one of the properties of the random walk process, namely that the variance of the random walk increments must be a linear function of a time interval (q). That is, returns will follow a random walk when the variance of the (q^{th}) difference is equal to (q) times the variance of the first difference. The VR test is calculated as follows:

Variance ratio test under homoscedasticity, using overlapping observations is:

$$VAR(q) = \frac{\sigma_c^2(q)}{\sigma_a^2(q)} \quad (13)$$

Where $\sigma_c^2(q)$ is an unbiased estimator of $1/q$ of the variance of the q^{th} – difference and $\sigma_a^2(q)$ is an unbiased estimator of the variance of the 1st-difference.

The standard normal test-statistics under homoscedasticity, $Z(q)$ is:

$$Z(q) = \frac{VAR(q) - 1}{[\emptyset(q)]^{1/2}} \sim N(0,1) \quad (14)$$

Where:

$$\emptyset(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \sim N(0,1) \quad (15)$$

Variance ratio test under heteroscedasticity is:

$$Z^*(q) = \frac{VAR(q) - 1}{[\emptyset^*(q)]^{1/2}} \sim N(0,1) \quad (16)$$

Where:

$$\emptyset^*(q) = \sum_{j=1}^{q-1} \left[\frac{2(q-j)^2}{q} \right] \hat{\sigma}(j) \quad (17)$$

$$\text{with } \hat{\sigma}(j) = \frac{\sum_{t=j+1}^{nq} (p_t + p_{t-1} - \hat{\mu})^2 (p_{t-j} - p_{t-j-1} - \hat{\mu})^2}{\sum_{k=1}^{nq} (p_t - p_{t-1} - \hat{\mu})^2} \quad (18)$$

For performing this test, we first calculate the compounded daily returns on the Bahrain all share index, find its variance and repeat the procedure for 2, 4, 8, 10, 16 and 32-day returns. We then calculate the variance ratios for all five times intervals, and test the following null hypothesis:

H₀: The variance ratio for all the choosing aggregate intervals, q is unity.

An estimated variance ratio less than one implies negative serial correlation, while a variance ratio greater than one, or high Z value implies positive serial correlation. The rejection of single or more therefore rejects null hypothesis of the random walk. To assist contrast with preceding researches, Lo and MacKinlay, (1988), and Campbell, Lo, and Mackinlay, (1997), on other equity markets, the q is chosen as 2, 4, 8, 10, 16, and 32.

5. The Empirical Results

5.1. Results of the Unit Root Tests

ADF, PP, and KPSS tests were carried on the log of the index using the package Eviews7. The tests were performed at level and first difference. The results of ADF and PP tests are reported in Tables (3) and (4), while the results of KPSS are reported in Table (5).

Table 3: ADF and PP Unit root tests results on the logarithm of Bahrain stock market index at level

Type of test	t-statistics	Critical value at 1%	Critical value at 5%	Inference
ADF without intercept	1.070485	-2.566144	-1.940986	Do not reject
ADF with intercept	-2.118919	-3.433492	-2.862814	Do not reject
ADF with intercept and trend	-0.813473	-3.433492	-2.862814	Do not reject
PP without intercept	0.732577	-3.962738	-3.412106	Do not reject
PP with intercept	-1.849949	-3.433492	-2.862814	Do not reject
PP with intercept and trend	-0.915278	-3.962738	-3.412106	Do not reject

Table 4: ADF and PP Unit root tests results on the logarithm of Bahrain stock market index at first difference

Type of test	t-statistics	Critical value at 1%	Critical value at 5%	Inference
ADF without intercept	-36.31295	-2.566145	-1.940986	reject
ADF with intercept	-36.32399	-3.433493	-2.862815	reject
ADF with intercept and trend	-36.68215	-3.962740	-3.412107	reject
PP without intercept	-37.61213	-2.566145	-1.940986	reject
PP with intercept	-37.60129	-3.433493	-2.862815	reject
PP with intercept and trend	-37.26290	-3.962740	-3.412107	reject

The empirical results of the KPSS test on logarithm of Bahrain stock market index at level and first difference are reported in Table (5).

Table 5: KPSS Unit Root Test Results on the logarithm of Bahrain stock market index at level and first difference.

KPSS tests	LM-STAT	Critical value at 1%	Critical value at 5%	Inference
<i>Level</i>				
with intercept	1.559153	0.739000	0.463000	reject
with intercept and trend	1.214517	0.216000	0.146000	reject
<i>first difference</i>				
with intercept	1.390188	0.739000	0.463000	reject
with intercept and trend	0.123541	0.216000	0.146000	do not reject

The results in Table (5) indicate that all the null hypothesis of stationary in the daily Bahrain stock price index at level is rejected. Whereas stationary of stock prices series is confirmed at first difference. In other words, the empirical results from KPSS unit root test at first difference imply the difference stationary process in Bahrain stock market index in the trend and intercept only.

The results of ADF, PP, as well as that of KPSS provide evidence that the Bahrain all share index are nonstationary at level and stationary for the first difference. Therefore, the results are consistent with the random walk hypothesis. The KPSS tests offer conflicting results with those of ADF and PP only in the trend and intercept specification at the first difference. However, this result is true at the 5% confidence level but not at the 1% confidence level.

5.2. Results of the Run Tests

As evidenced in Tables (6) and (7). The run tests clearly show that Bahrain stock market is weak-form inefficient. The estimated Z-values are significant at the 1% level.

Table 6: Run Test with the Mean as a Base

n	n_a	n_b	$E(r)$	r	σ_r	$Z(r)$	Sig (2 tailed)
1957	993	963	.000165	844	0.00636	-6.119	0.000

SPSS19 software is used to obtain the results in this table as well as those in Table (7).

Table 7: Run Test with the Median as a Base

n	n_a	n_b	$E(r)$	r	σ_r	$Z(r)$	Sig (2 tailed)
1957	979	978	.00021	834	0.00636	-6.580	0.0000

5.3. Results of the Variance Ratio Test

Table (8) reports the test results of the variance ratio test.

Table 8: Variance Ratio Test at Return Series for the 2,4,8,10,16 and 32Day Returns

Data period	Test stat.	Time horizon q						
		$q = 2$	$q = 4$	$q = 8$	$q = 10$	$q = 16$	$q = 32$	
Feb. 2003- Nov. 2010	VR_q	1.1951	1.3595	1.5197	1.6162	1.9852	2.7483	12.125*
	Zq	8.6293*	8.4999*	7.7725*	8.0740*	9.9011*	9.1960*	
	Zq^*	5.3037*	5.4559*	5.3871*	5.7361*	5.7461*		

Notes: q is the number of daily intervals aggregated to compute the variance ratios. The variance ratios, $VR(q)$, are reported in the first rows, and Zq ; statistics are the asymptotic normal test statistics under homoscedasticity; Zq^* statistics are the asymptotic normal test statistics under heteroscedasticity. Test statistics marked with * indicate that the corresponding variance ratios are statistically different from 1 at the 1 percent level of significance.

Table (8) presents the variance ratios based on daily values of the index, as well as the corresponding Z and Zq^* statistics for the null hypothesis is that the variance ratios equal one, which means that the stock index prices follow a random walk. Results indicate that almost all of the test statistics for either assuming homoskedasticity or heteroskedasticity-consistent at any number of q are significant: this means that stock markets returns show predictability. In other words the random walk hypothesis is rejected. This would lead to the conclusion that the Bahraini stock market could be inefficient for all investment horizons up to 32 days.

6. Conclusion

This study examined the random walk behavior and efficiency of the Bahraini stock market using unit root tests, run test and variance ratio test. The empirical results reject the random walk hypothesis at the weak-form level, implying that stock prices do not fully reflect all historical information. The results of this paper conform to the results of most previous studies that were performed on Middle Eastern stock markets. They are similar to those found in Jaradat and Al-Zeaud (2011), Al-Jafari (2011), Al-Jafari and Altaee (2011), Abdmoulah (2010), Awad and Daraghma (2009), Marasheh and Shrestha (2008) Omran and Farrar (2006), Mustafa (2004), Maghyereh (2003), Hassan et al., (2003), and Abraham et al., (2002).

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