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A Generalized Autoregressive Conditional Heteroscedastic Approach for the Assessment of Weak-form-efficiency and Seasonality Effect: Evidence from Mauritius

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ABSTRACT

During the past decades, the efficient market hypothesis (EMH) has been at the heart of the debate in the financial literature. Ultimately, the consequence of the efficiency of a market is that prices always fully reflect all available information. The objective of this study is to test whether the stock exchange of Mauritius (SEM) and development and enterprise market (DEM) are weak form efficient. The autocorrelation test, variance ratio test, run test and calendar effects testing, made under ordinary least squares (OLS) regression and generalized autoregressive conditional heteroscedastic (GARCH)-M were used to examine weak-form EMH. Two indices namely the DEMEX and SEMDEX are tested by using both daily and monthly return data for the period from 1st January 2007 to 31st October 2012. Results obtained are mixed. For instance, from the autocorrelation test shows evidence to reject the null hypothesis of random walk for both daily and monthly returns. On the other hand, the run test indicates that the null hypothesis of random walk is rejected only for daily returns of SEMDEX and DEMEX while not rejected for the monthly series. The Lo and McKinley's variance ratio test fails to support weak-form-efficiency. Under both a daily perspective as well as on a monthly one, the returns of DEMEX has consistently proven to follow a random walk by using OLS and GARCH. While SEMDEX proved otherwise.

Keywords: Weak form Efficiency, Seasonality Effect, Generalized Autoregressive Conditional Heteroscedastic Model
JEL Classifications: C1, G14

1. INTRODUCTION

The role of bubbles in financial markets is intricately connected to the question of informational efficiency. The reason is both that bubbles above and below fundamental values are a violation of market efficiency, and that the fundamental value itself and deviations from it can only be defined with reference to a framework of informational efficiency in a market (Roll, 1977).

"*If there is to be one "father" of the efficient market hypothesis, this man is Eugene Fama, who remains an outspoken proponent of the hypothesis to this day*" (Palan, 2009).

According to Fama (1970), he defined an efficient market as "A market in which prices always 'fully reflect' available information," and proposed the classifications of weak-form, semi strong form, and strong-form market efficiency to concretize the "available information." These three categories have by now become the standard in descriptions of market efficiency. Fama (1970) was the first scholar who defined three types of efficient markets among which is weak-form market efficiency whereby the information subset of interest is past price histories.

Following the work of Fama, several studies have focused on the weak-form because if the evidence fails to support the weak-form of market efficiency, it is not necessary to examine the efficient market hypothesis (EMH) at the stricter levels of semi-strong and strong form. One of the earliest papers on weak-form market efficiency is that of Robert (1959), he concluded that stock prices follow random walk. However, the day-of-the-week effect refers to the existence of a pattern on the part of stock returns, whereby they are linked to the particular day-of-the-week. According to Harris (1986), the last trading days of the-week are characterized by substantially positive returns while the first trading even produce negative returns. The presence of such an effect would be evidence against random walk theory.

The hypothesis that is tested in this research is whether the stock exchange of Mauritius (SEM) and development and enterprise market (DEM) are weak form efficient. Also to test whether there is any day of the week effect or month of the year effect in the Mauritian stock market.

The rest of this paper is organized as follows: The existing theoretical and empirical literature is provided in section 2. Section 3 discusses the objectives of the research and the methodology used in the study. In section 4, the results derived from the implementation of the selected research methodology are demonstrated. It also encompasses a critical analysis of the results compared to conclusions drawn by researchers as pointed in the literature review. Finally, based on the results obtained, conclusions are drawn in the last section.

2. LITERATURE REVIEW

2.1. Theory of EMH

The EMH tries to explain why stock market prices appear to follow a random walk, i.e., that their daily variation is a random value following the Gaussian distribution. The theoretical groundwork of the EMH was first laid by Bachelier (1900). Half a century later this hypothesis was postulated by Maurice Kendall. According to Kendall (1953), he found that stock prices were random and that future price movement could not be predicted with the data he used. The academic community found this explanation for the EMH counterintuitive. However, this theory was embraced by various scholars. Its validity in the real-world markets was documented by studying empirical data. To do so, they developed different frameworks to model the characteristics of market prices. The first type of framework-based on expected return efficient markets – includes such well-known models as the fair game model, the random walk and the submartingale models, as well as the market model and the famous capital asset pricing model of Sharpe (1964); Lintner (1965); Mossin (1996).

2.1.1. Testing for weak form efficiency

Kim and Shamsuddin (2008) examined whether a group of Asian stock market returns (Hong Kong, Indonesia, Japan, Korea, Malaysia, Philippines, Taiwan, Thailand and Singapore) follow the random walk model. They used both daily and weekly price indices from 1990 to 2005 and adopted the new variance ratio test which was based on the wild bootstrap and signs.

It was found that the developed markets like Hong Kong, Japanese, Korean and Taiwanese markets show weak form efficiency while that of the emerging markets of Indonesia, Malaysia and Philippines were proved to be weak-form-inefficient. Also evidence was found that the Singaporean and Thai markets became efficient after the Asian crisis in 1997.

Using both the multiple variance-ratio (MVR) and the auto-regressive fractionally integrated moving-average tests, Kalu and Karemera (1999) documented evidence showing that equity prices in major Latin American emerging equity markets namely Argentina, Brazil, Chile and Mexico are random walk.

A study undertaken by Al-Khazali et al. (2008) tried to find evidence of the weak-form EMH in eight emerging markets in the Middle-East and North Africa namely Bahrain, Egypt, Jordan, Kuwait, Morocco, Oman, Saudi Arabia, and Tunisia. Using the new Wright (2000) variance-ratio as well as the classical VR test and the runs test, all three testing methods used gave consistent result that the equity markets follow the random-walk model.

There are other instances where the markets for both developed and emerging countries are found to be inefficient. This implies stock markets are not weak form efficient thus excess profits can be earned by exploiting trading opportunities.

For instance, random walk of Latin American equity markets was studied by Higgs and Worthington (2008). It constituted of seven emerging markets namely Brazil, Argentina, Chile, Colombia, Mexico, Peru and Venezuela. The daily returns for these countries were examined for random walk using the serial correlation, runs tests, Augmented Dickey-Fuller (ADF), Phillips-Perron and Kwiatkowski, Phillips, Schmidt and Shin unit root tests and MVR tests.

The results from the three different procedures employed concluded that none of these markets are observed to follow the random walk model and hence are not weak-form efficient.

2.2. Return Seasonality

Return seasonality are characterized by patterns in stock returns. Seasonality has been found in intraday, weekly, monthly and annual return data. Fama (1991) claimed that this may be caused by seasonal in the probabilities that measured whether prices are at ask or bid, due to seasonal in investors' trading patterns.

Several studies were carried out in order to test for the presence of the day of the week anomaly in stock returns. Some studies discovered that stock returns are random while others obtained significant presence of the market anomaly on some specific days of the week. Aly et al. (2004) examined the Egyptian stock market using the capital market authority index (CMA), in order to test for daily stock anomaly in an emerging capital market where trading takes place on only 4 days of the week compared to the traditional 5-day week. The daily returns for the CMA index from 1998-2001 was used. The results showed that the Egyptian stock market return on Monday are positive and significant on average however it was not significantly different from the returns of the other trading days. Thus, indicating that the stock market is weak-form efficient.

In the same spirit, Suliman and Suliman (2012) studied the daily stock anomaly on the Khartoum stock exchange (KSE) from Sudan. They examined this anomaly on both the stock market returns and the conditional volatility over the period of 2nd January 2006 to 30th October 2011 using daily observations. Three different models have been used to test for possible existence of day of the week namely the ordinary least squares (OLS) and two different generalized autoregressive conditional heteroscedastic (GARCH) model.

A dummy variable approach based on a linear regression with 5 dummy variables was employed in the first model. The author included lagged values of the return variable to eliminate the possibility of having auto correlated errors.

The empirical findings from the OLS and GARCH models indicated the absence of the day of the week effect in both returns and volatility equations for the KSE. Thus, during that period of study the KSE was not affected by the day of the week effect.

Faryad et al. (2011) analyses the day of the week effect on the equity market in Pakistan. This research consists of daily stock prices of the KSE-100 Index, for the period January 2006 to December 2010. The result obtained suggested that the Tuesday returns are quite significant and positive. The Tuesday return on average are greater compared to the other days of the week. Hence, it can be concluded that there exists day of the week effect in the Pakistan stock market. Likewise, the Kuwait stock exchange index was studied by Al-Loughani and Chappel (2001) for evidence of a day-of-the-week effect. The daily stock return for the period 1993 to 1997 was investigated. A nonlinear GARCH (1,1) was employed to test day-of-the-week anomaly. The findings obtained significantly showed that the returns on the five different trading days were not similar. Hence, it can be concluded that the Kuwait stock market face the day of the week effect.

On the other hand, the day of the week effect was investigated by Choudhry (2000) on seven emerging Asian stock markets returns. Daily stock prices from Indonesia, India, Malaysia, Philippines, South Korea, Taiwan, and Thailand was used from January 1990 to June 1995. The research was done using the GARCH model. Empirical results obtained indicate that both the mean and conditional variance (volatility) of stock return exhibited significant presence of the day of the week effect.

2.2.1. Testing month-of-the year effect

In several research papers, evidence was found of statistically significant differences in stock returns during particular months of the year. The "January effect" is the most researched anomaly but in the recent years the month of the year effect could be found in the other months as well.

2.2.1.1. Evidence of efficiency

Al-Jarrah et al. (2011) investigated the presence of the month of the year effect on the Amman stock exchange (ASE). The daily stock return for a sample period from 1992 to 2007 was examined. They employed the methodologies followed by Jaffe et al.(1989), Boudreaux (1995) and Floros (2008). The procedure used is the Cochrane-Orcutt method. The difference between mean returns for the beginning of the month and at the end of the month is tested in this particular regression model.

The results obtained indicate that the month of the year anomaly is not present in the ASE. These findings may have favorable impact on attracting foreign investment also these results have important implications for investors and traders who base their investment strategies on how the ASE index move overtime.

The impact of the global financial crisis on the monthly returns of Bahrain Bourse was examined by Al-Jafari (2011). The sample period consisted of daily returns from 1 January 2003 until 31 July 2011 which was divided into two different sub periods. The first period from 1 January 2003 to 30 November 2007 characterized the period before the global financial crisis while the second one is the crisis period and spanned from 1 December 2007 to 31 July 2011. The equality for mean tests which include F-test, Chi-square test and Kruskal-Wallis test were employed. Also the equality for variance tests were used which include the following; Bartlett test, Levene test, and Brown-Forsythe test. The empirical findings demonstrated that there were no significant differences of the monthly effect for daily returns of the Bahrain stock market in the two sub periods.

2.2.1.2. Evidence of inefficiency

Wyème and Olfa (2011) focused on the existence on the month of the year anomaly in the Tunis stock exchange (TSE). Using regression analysis of dummy variable (Gultekin and Gultekin, 1983), they investigated the month of the year effect on the daily stock return of TSE over the period January 2003 to December 2008. The authors found evidence of the month of the anomaly in the stock market of Tunis for the whole sample period. Furthermore, they documented an April effect, meaning that the mean daily market returns were significantly higher in the month of April than the remaining months.

After analyzing numerous research papers from the literature, certain issues can be clearly spotted. Some markets were found to be weak form efficient while others did not satisfy the random walk model. With respect to the presence of a certain trend in stock market returns, being the day of the week effect and month of the year effect, mixed conclusion were reached.

3. DATA AND METHODOLOGY

3.1. Research Objectives

The objective of this study is to test whether the SEM is weak form efficient. More specifically, to test whether there is any day of the week effect or month of the year effect in the Mauritian stock market. These results will therefore help to determine whether some investors can earn positive abnormal returns in the presence of such anomalies, if any.

3.2. Sources of Data

The time series data used in this study consist of daily and monthly returns of the SEMDEX and DEMEX. All price data are obtained from the SEM and cover the period from January 2007 to October 2012 resulting in total daily observation of 1523 and total monthly observation of 72 for the SEMDEX and DEMEX.

3.3. Return Calculation

Moreover, daily and monthly returns are calculated for that period. Then, a natural-logarithmic transformation is performed on the data to obtain logarithmic returns. This is-mainly due to its benefits of being time additive, mathematically convenient and approximately good. Importantly, the data has not been adjusted for dividends as its exclusion will still provide valid results under any study of calendar anomalies. To obtain a time series of continuously compounded returns, daily returns are calculated as follows:

$$R_t = \log(p_t) - \log(p_{t-1}) = \log(p_t/p_{t-1}) \quad (1)$$

Where p_t and p_{t-1} are the stock prices at time t and t−1

3.4. Research Instrument

Many techniques have been used in empirical studies in order to test for the weak-form of EMH. A set of complementary tests are used to detect the random walk in the observed series of the SEMDEX and DEMEX as mentioned below:

3.4.1. Autocorrelation test

Firstly, the autocorrelation test has been undertaken to measure the relationship between the stock return at current period and its value in the previous period aiming to determine whether the serial correlation coefficients are significantly different from zero.

Statistically, the hypothesis of weak-form efficiency should be rejected if stock returns are serially correlated. To test the joint hypothesis that all autocorrelations are simultaneously equal to zero, the Ljung-Box statistic is used.

3.4.2. Run test

Secondly the run test is being undertaken. It is a non-parametric test which analyze the serial independence in the returns stream and search out whether succeeding price variations are independent to each other as it happens under the random walk null hypothesis. It is argued that if price changes or returns are random then actual number of runs must be near to the expected number of runs. A run can be defined as a sequence of consecutive price changes with the same sign. In a series of consecutive price variations the null hypothesis can be tested.

3.4.3. Unit root tests

The unit root test is mostly used to test the stationarity of the time series. Therefore to test for the presence of unit root in the time series of stock price changes in the indices the ADF test is undertaken.

3.4.4. Variance ratio test

Finally, the variance ratio test, proposed by Lo and McKinlay (1988) is being employed. It is based on the assumption that the variance of increments in the random walk series is linear in the sample interval.

3.4.5. Testing for seasonality effects

In order to test whether the data shows any seasonal effects over days of the week, the following regression is being run;

$$R_t = \gamma_{Mon}D1_t + \gamma_{Tue}D2_t + \gamma_{Wed}D3_t + \gamma_{Thu}D4_t + \gamma_{Fri}D5_t + \varepsilon_t \quad (2)$$

Where,
$D1_t$=1 if it is a Monday return or otherwise zero for all other days
$D2_t$=1 if it is a Tuesday return or otherwise zero for all other days and so forth

The dependent variable R_t is the daily returns and $D1_t$, $D2_t$, $D3_t$, $D4_t$ and $D5_t$ are dummy variables from Monday to Friday. The random error term is ε_t and the mean return from Monday to Friday is indicated by the OLS coefficient γ_{Mon} to γ_{Fri}.

Similarly, to test for any seasonal effects over months of the year, the following regression is being used;

$$R_t = \gamma_{Jan}D1_t + \gamma_{Feb}D2_t + \gamma_{Mar}D3_t + \ldots + \gamma_{Nov}D11_t + \gamma_{Dec}D12_t + \varepsilon_t \quad (3)$$

Where,
$D1_t$=1 if it is a January return or otherwise zero for all other months
$D2_t$=1 if it is a February return or otherwise zero for all other months and so forth

The dependent variable R_t is the monthly returns and $D1_t$, $D2_t$, $D3_t$ until $D12_t$ are dummy variables from January to December. The random error term is ε_t and the mean return from January to December is indicated by the OLS coefficient γ_{Jan} to γ_{Dec}.

Furthermore, as employed by Lim et al. (2008), to account for the volatility brought by the global financial crisis, based on the sample period chosen, another regression with the incorporation of a crisis dummy is being used for both calendar effects as follows:

$$R_t = \gamma_{Mon}D1_t + \gamma_{Tue}D2_t + \gamma_{Wed}D3_t + \gamma_{Thu}D4_t + \gamma_{Fri}D5_t + \gamma_{Crisis}D6_t + \varepsilon_t \quad (4)$$

$$R_t = \gamma_{Jan}D1_t + \gamma_{Feb}D2_t + \gamma_{Mar}D3_t + \ldots + \gamma_{Nov}D11_t + \gamma_{Dec}D12_t + \gamma_{Crisis}D13_t + \varepsilon_t \quad (5)$$

Where,
$D6_t$ is a dummy variable taking the value of 1 for crisis or otherwise 0.

and,
$D13_t$ is a dummy variable taking the value of 1 for crisis or otherwise 0.

To safeguard against the dummy variable trap, the above regressions exclude intercept terms.

3.5. Volatility-modeling

The secondary approach is an estimation of GARCH models. The OLS regressions mentioned earlier assumes the existence of a constant variance, which may result in inefficient estimates, if there is a time varying variance. The GARCH model is used to look at the variance of the return more closely. Connolly (1989) stated that the GARCH model provides several advantages over OLS. It incorporates heteroscedasticity into the estimation procedure and can be expanded to include other relevant variables in the conditional variance equation. Moreover, the GARCH model offers more flexibility in robust modeling of stock returns. The GARCH (1,1) model is characterized by two equations which are conditional mean (mean return) and conditional variance (risk or volatility of returns) equations.

A modified GARCH (1,1) specification with added dummy variables for each day-of-the-week and month-of-the-year in the conditional variance equation is used to include the calendar effects for both the return and volatility equations.

To avoid collinearity problem in the regression model, only 4 out of 5 days in the week are included in the conditional variance equation as follows:

$$R_t=\gamma_{Mon}D1_t+\gamma_{Tue}D2_t+\gamma_{Wed}D3_t+\gamma_{Thu}D4_t+\gamma_{Fri}D5_t+\varepsilon_t \quad (6)$$

$$\sigma_t^2=\alpha_0+\gamma_{Tue}D2_t+\gamma_{Wed}D3_t+\gamma_{Thu}D4_t+\gamma_{Fri}D5_t+\sum_{j=1}^{p}\beta_j\sigma^2_{t-j}+\sum_{j=1}^{p}\alpha_j\varepsilon^2_{t-j} \quad (7)$$

The same technique was applied for the month-of-the-year effect as follows:

$$R_t=\gamma_{Jan}D1_t+\gamma_{Feb}D2_t+\gamma_{Mar}D3_t+\ldots+\gamma_{Nov}D11_t+\gamma_{Dec}D12_t+\varepsilon_t \quad (8)$$

$$\sigma_t^2=\alpha_0+\gamma_{Feb}D1_t+\gamma_{Mar}D2_t+\ldots+\gamma_{Nov}D11_t+\gamma_{Dec}D12_t+\sum_{j=1}^{p}\beta_j\sigma^2_{t-j}+\sum_{j=1}^{p}\alpha_j\varepsilon^2_{t-j} \quad (9)$$

Likewise, a financial crisis dummy has been included in both equations and run at the same time as follows:

$$R_t=\gamma_{Mon}D1_t+\gamma_{Tue}D2_t+\gamma_{Wed}D3_t+\gamma_{Thu}D4_t+\gamma_{Fri}D5_t+\gamma_{Crisis}D6_t+\varepsilon_t \quad (10)$$

$$\sigma_t^2=\alpha_0+\gamma_{Tue}D2_t+\gamma_{Wed}D3_t+\gamma_{Thu}D4_t+\gamma_{Fri}D5_t+\gamma_{Crisis}D6_t+\sum_{j=1}^{p}\beta_j\sigma^2_{t-1}+\sum_{j=1}^{p}\alpha_j\varepsilon^2_{t-j} \quad (11)$$

$$R_t=\gamma_{Jan}D1_t+\gamma_{Feb}D2_t+\gamma_{Mar}D3_t+\ldots+\gamma_{Nov}D11_t+\gamma_{Dec}D12_t+\gamma_{Crisis}D13_t+\varepsilon_t \quad (12)$$

$$\sigma_t^2=\alpha_0+\gamma_{Feb}D1_t+\gamma_{Mar}D2_t+\ldots+\gamma_{Nov}D11_t+\gamma_{Dec}D12_t+\gamma_{Crisis}D13_t+\sum_{j=1}^{p}\beta_j\sigma^2_{t-j}+\sum_{j=1}^{p}\alpha_j\varepsilon^2_{t-j} \quad (13)$$

4. FINDINGS AND ANALYSIS

This chapter is divided into two main parts. The first section illustrates the results obtained from the weak form efficiency tests. Then, the second part presents the results obtained from volatility modeling.

4.1. Autocorrelation Test

4.1.1. Daily returns

For Daily returns, it is found that the null hypothesis of random walk is rejected for all studied series using daily returns. Specifically, for DEMEX, it is evident that autocorrelation coefficients are significant with a positive sign up to the 7th lag. It is observed that serial correlation coefficients are significant at lag 1, 4, 7, 8, and 11 for SEMDEX. Furthermore, the positive sign of the autocorrelation coefficients obtained indicates that consecutive daily returns tend to have the same sign, so that a positive (negative) return in the current day tends to be followed by an increase (decrease) of return in the next several days.

The results of the Ljung-Box reveal that the autocorrelation coefficients of all 10 lags are jointly significant at 1% and 5% level. Notably, the results of Q-test fail to support the joint null hypothesis that all autocorrelation coefficients of 10 lags are equal to zero for the two indices at 5% level. Therefore, here it can be concluded that SEMDEX and DEMEX are not weak-form efficient.

4.1.2. Monthly returns

Unlike the results for the daily returns, it is found that autocorrelation coefficients of the monthly returns for DEMEX is significant with a positive sign only at the 3rd, 5th, 8th, 11th, and 12th lag. However, based on the Q-statistics, the null hypothesis of no autocorrelation on the DEMEX returns for all the 10 lags is strongly rejected at the 1% level concluding that DEMEX still seems to be affected by past return information to some extent.

Furthermore, results of the autocorrelation tests on monthly returns for SEMDEX show significant autocorrelation coefficient at the first 4th lag and at 8th, 9th, 11th, and 12th and hence does not contribute towards weak-form efficiency. Also, the results of Q-test fail to support the joint null hypothesis that all autocorrelation coefficients of 10 lags are equal to zero 5% level. Thus, the result of the Ljung-Box reveals that the autocorrelation coefficients of all 10 lags are jointly significant at 1% and 5% level.

4.2. Run Test

The run test is a non-parametric test approach to test and detect statistical dependencies (randomness). It is considered to be more useful than the parametric auto-correlation test since all observed series do not follow the normal distribution. In order to prove random walk, the run test is widely used because it ignores the statistical properties of the distribution.

4.2.1. Daily returns

In terms of the runs tests, the negative Z-values for both indices indicates that the actual number of runs falls short of the expected number of runs under the null hypothesis of return independence at the 0.01 level or lower for all markets. These indicate positive serial correlation. We likewise reject the null hypothesis of weak-form efficiency when employing the nonparametric assumptions entailed in runs tests.

For monthly returns of both indices the Z statistics is within ±1.96. This indicates that the actual runs of all series are greater than their corresponding expected runs, so that the null hypothesis of independence among stock returns is not rejected for these series.

4.3. Unit Root Test

The ADF unit root test is performed to check for stationarity of the time series which is a necessary condition for Random walk. The results show that the time series of the indices are stationary at order I (0) as well as for order I (1) at 5% level of significance.

4.4. Variance-ratio-tests

This study employs variance ratio tests for both null hypotheses, namely the homoscedastic and heteroscedastic increments random walk and calculated for intervals of 2, 4, 8, and 16 observations.

4.4.1. Daily-variance-ratio-tests

The empirical evidence obtained from the variance ratio tests for daily log prices indicates that the random walk hypothesis under the assumption of homoscedasticity is rejected for all series. In the case of SEMDEX and DEMEX, for instance, the Z-statistics suggest that the variance ratios are significantly different from one for all intervals at the 5% level. Therefore, the null hypothesis of random walk is strongly rejected for these series.

Additionally, the heteroscedasticity variance ratio test provides consistent evidence that the null hypothesis of random walk cannot be accepted for all daily return series. DEMEX as well as SEMDEX again reject the random walk hypothesis under all lag.

Results of the variance ratio tests on the monthly log prices, confirm again that the null hypothesis of random walk under the assumption of homoscedasticity is rejected for the indices at all cases of q. Under the heteroscedasticity variance ratio test DEMEX again reject the random walk hypothesis under all lags while SEMDEX fail to reject the null at 5% level hence proving to follow a random walk under such circumstances.

4.5. OLS Regression Results for Day-of-the-week Effect

The regression results testing for the presence of day-of-the-week effect are shown in Table 1.

As reported in Panel A, all the coefficients of SEMDEX are insignificant at the 5% level except for that of Friday. This shows a positive Friday effect meaning that Fridays tend to be always positive. As it can be seen the return on Fridays are the highest. According to Lenkkeri et al. (2006), Fridays are known to experience positive returns. The coefficient value of 0.000502, suggests that on average, SEMDEX returns are around 0.005% higher on Fridays than the average for other days of the week. Apart from the Friday effect, the result indicates that the average daily returns for SEMDEX are independent for the other days of the week. However we conclude that SEMDEX is weak-form inefficient because of the Friday effect. On the other hand, all the t-statistics for DEMEX are negative and statistically insignificant for all days of the week. This means that no day-of-the-week effect is observed for that index.

Furthermore, when a dummy is included for the crisis, as reported in Panel B in Table 2, the results change considerably and is better explained, proven by the increased adjusted R^2. The crisis variable is noted to be significant for DEMEX. Remarkably, this explains 0.027% of the variations in the daily returns of DEMEX. However, the coefficients of the other days of the week variables are proven to be statistically insignificant, hence suggesting that return from the other days of the week are independent. Despite, after accounting for the volatility caused by the crisis in the stock market, both SEMDEX and DEMEX are at the conclusion that they are weak-form efficient.

4.6. OLS Regression Results for Month of the Year Effect

The regression results testing for the presence of the month-of-the-year effect are shown in Table 3.

As reported in Panel A, none of the coefficients are significant at the 5% level. Economically, this means that no such anomaly is observed in those indices.

Likewise, the regression was run a second time with the inclusion of a variable for the event of the crisis. The results are shown Table 4.

The crisis variable has reported to be significant for SEMDEX, with a negative coefficient of −2.2%. However SEMDEX did not show any seasonal effects therefore it can be concluded being weak-form efficient. On the other hand DEMEX exhibited a positive month-of-the-year effect. It reported a positive significant coefficient for June at 1.4% therefore we can conclude that DEMEX has a positive month of the year effect. This may be due

Table 1: Panel A - Results of regression without the "Crisis" dummy variable

	SEMDEX	DEMEX
Monday	−0.0000674 (−0.29)	−0.000111 (−0.827)
Tuesday	0.00000179 (0.00774)	−0.0000765 (−0.572)
Wednesday	0.000056 (0.241)	0.000236 (1.763)
Thursday	−0.0000297 (−0.128)	−0.000118 (−0.882)
Friday	0.000502 (2.16)*	0.000172 (1.282)
R^2	0.00265	0.00421
Adjusted R^2	0.000022	0.00159

Coefficients are given in each cell followed by t-ratios in parentheses; *denotes significance at the 5% level

Table 2: Panel B - Results of regression with the "Crisis" dummy variable

	SEMDEX	DEMEX
Monday	−0.000240 (−0.901)	−0.000273 (−1.78)
Tuesday	−0.000171 (−0.641)	−0.000239 (−1.557)
Wednesday	−0.000117 (−0.44)	0.0000726 (0.473)
Thursday	−0.000203 (−0.76)	−0.000281 (−1.829)
Friday	0.000329 (1.233)	0.00000884 (0.0575)
Crisis	0.000281 (1.319)	0.000265 (2.156)*
R^2	0.00379	0.00726
Adjusted R^2	0.000509	0.00398

Coefficients are given in each cell followed by t-statistics in parentheses; *denotes significance at the 5% level

Table 3: Panel A - Results of regression without the "Crisis" dummy variable

	SEMDEX	DEMEX
January	0.00461 (0.444)	−0.00166 (−0.270)
February	−0.0168 (−1.622)	−0.000874 (−0.143)
March	0.00861 (0.83)	−0.0000977 (−0.016)
April	0.00815 (0.786)	0.00166 (0.272)
May	0.00637 (0.614)	−0.000111 (−0.0181)
June	0.00114 (1.0979)	0.0122 (1.991)
July	0.000104 (0.0101)	−0.00426 (−0.696)
August	−0.00907 (−0.875)	−0.00582 (−0.949)
September	0.00814 (0.785)	0.00174 (0.283)
October	−0.00117 (−0.1128)	0.000476 (0.0777)
November	−0.00694 (−0.611)	−0.00945 (−1.407)
December	0.00737 (0.649)	0.00399 (0.595)
R^2	0.115	0.12
Adjusted R^2	−0.0524	−0.0465

Coefficients are given in each cell followed by t-ratios in parentheses; *denotes significance at the 5% level to the disclosure of interim reports around that period of the year causing a June effect.

4.7. Diagnosing-for-ARCH-effects

Table 5 shows the results of ARCH tests performed on the residuals under two different model estimation methods. The tests included will help to assess the suitability of each methodology in modeling for the day-of-the-week. Presence of significant ARCH effects are denoted by an * tested at the 5% significance level which will undermine the validity of the coefficient estimates of that model. AC stands for autocorrelation and PAC stands for partial autocorrelation.

Conversely, these ARCH effects are reduced when they are modeled under regressions that take into account volatility. This holds true under the GARCH model, some autocorrelation remains up to lag 1 for SEMDEX. However, given this autocorrelation is low, the selection of a GARCH-(1,1) is-quite-satisfactory.

Likewise, the LM-ARCH test proves to be significant under the OLS estimation but disappears under the GARCH except for SEMDEX. Additionally, the Jarque-Bera statistics is rejected under all models, concluding that the residuals do not follow normal distribution, but it improves under GARCH models. Therefore, the GARCH model assesses the day-of-the-week effect better than the linear estimation whereby several misspecifications are found.

Observed in Table 6, the month-of-the-year models show different results. The residuals from the OLS regression, used to diagnose ARCH effects for the daily returns, exhibits significant autocorrelation at lag 2 for SEMDEX and the Ljung-Box test also proves to be jointly significant at all lags. However the ARCH effects are reduced under the GARCH model.

This Table 6 shows the results of ARCH tests performed on the residuals under two different model estimation methods. The tests included will help to assess the suitability of each methodology in modeling for the month-of-the-year. Presence of significant ARCH effects are denoted by an * tested at the 5% significance level which will undermine the validity of the coefficient estimates of that model. AC stands for autocorrelation and PAC stands for partial autocorrelation.

From Table 6, it is shown that the residuals from the OLS regression, used to diagnose ARCH effects for the daily returns, reports significant autocorrelation for SEMDEX at all lags while for DEMEX autocorrelation is significant at the 1st and 3rd lag only. Additionally, the Ljung-Box test proves to be significant at all lags for both indices.

On the other hand, DEMEX reports insignificant autocorrelation and the Ljung-Box test prove the same. Likewise, the LM-ARCH

Table 4: Panel A - Results of regression with the "Crisis" dummy variable

	SEMDEX	DEMEX
January	0.012 (1.214)	0.00216 (0.361)
February	−0.0094 (−0.948)	0.00294 (0.492)
March	0.016 (1.617)	0.00372 (0.622)
April	0.0119 (1.222)	0.00357 (0.61)
May	0.0101 (1.0389)	0.0018 (0.307)
June	0.0151 (1.555)	0.0141 (2.409)*
July	0.00382 (0.393)	−0.00235 (−0.402)
August	−0.00536 (−0.552)	−0.00391 (−0.667)
September	0.0119 (1.221)	0.00365 (0.623)
October	0.00254 (0.262)	0.00239 (0.407)
November	−0.00249 (−0.234)	−0.00715 (−1.114)
December	0.0118 (1.11)	0.00628 (0.978)
Crisis	−0.0223 (−3.19)**	−0.0115 (−2.72)
R^2	0.249	0.221
Adjusted R^2	0.0914	0.0574

Coefficients are given in each cell followed by t-ratios in parentheses; * and ** denote significance at the 5% and 1%, levels respectively

Table 5: Diagnosing ARCH effects under different regression approaches for the day-of-the-week

	Lag	OLS			GARCH		
		ACF	PACF	PROB	ACF	PACF	PROB
SEMDEX							
Autocorrelation of squared standardized residuals	1	0.426*	0.426	0.000	0.111*	0.111	0.000
	2	0.178*	−0.004	0.000	0.020	0.008	0.000
	3	0.146*	0.087	0.000	−0.043	−0.047	0.000
	4	0.086*	−0.008	0.000	−0.022	−0.012	0.000
	5	0.076*	0.040	0.000	−0.023	−0.018	0.000
Heteroskedasticity		**F statistics**	**P**			**F statistics**	**P**
Test: ARCH		336.768	0.000			19.0265	0.000
Normality test of residuals		**Jarque-Bera**	**JB-stat**			**Jarque-Bera**	**JB-stat**
		18368.25	0.000			1021.897	0.000
DEMEX							
Autocorrelation of squared standardized residuals	1	0.226*	0.226	0.000	0.008	0.008	0.741
	2	0.051	−0.001	0.000	−0.028	−0.028	0.531
	3	0.067*	0.059	0.000	0.002	0.003	0.735
	4	−0.000	−0.030	0.000	−0.035	−0.036	0.530
	5	0.040	0.047	0.000	0.008	0.009	0.658
Heteroskedasticity		**F statistics**	**P**			**F statistics**	**P**
Test: ARCH		81.884	0.000			0.109	0.742
Normality test of residuals		**Jarque-Bera**	**JB-stat**			**Jarque-Bera**	**JB-stat**
		5553.236	0.000			2981.730	0.000

OLS: Ordinary least squares, GARCH: Generalized autoregressive conditional heteroscedastic, * and ** denote significance at the 5% and 1%, levels respectively test proves to be insignificant under both the OLS estimation as well as GARCH for both SEMDEX and DEMEX. Importantly, normality of the residuals is respected under the GARCH modeling approach for both indices.

4.8. Modified-GARCH-model

4.8.1. Day-of-the-week-effect

The results are presented in Table 7 and two regressions were run, one with the crisis variable and one without it. It can be seen that the log-likelihood of the regression increases when the crisis variable is included.

On this Table 7, the column **X** shows the results for the regression which was run on the daily log returns by applying the mean formula and variance formula for the two indices over the period January 2007 to October 2012. Column **X*** shows the regression results which was run for the same sample data and over the same time period, but including a dummy variable representing the crisis period.

Surprisingly, the Friday effect noted for SEMDEX has disappeared under the volatility model and is showing significant negative return on Monday instead, indicating that the returns on Monday are lowest than the other days. This pattern of negative Monday returns is consistent to Coutts et al. (2000). Remarkably, no such anomaly was reported for DEMEX under OLS as well as the GARCH model.

However when the dummy for crisis is included in the model, both SEMDEX and DEMEX showed considerable day-of-the-

Table 6: Diagnosing ARCH effects under different regression approaches for the month-of-the-year

	Lag	OLS			GARCH		
		ACF	PACF	PROB	ACF	PACF	PROB
SEMDEX							
Autocorrelation of squared standardized residuals	1	0.236	0.236	0.048	0.152	0.152	0.194
	2	0.300*	0.259	0.006	−0.128	−0.155	0.234
	3	0.268	0.175	0.001	0.236	0.295	0.069
	4	0.145	0.000	0.002	0.404*	0.323	0.001
	5	0.159	0.031	0.002	0.064	0.033	0.001
Heteroskedasticity		**F statistics**	**P**			**F statistics**	**P**
Test: ARCH		3.791	0.0559			1.601	0.21
Normality test of Residuals		**Jarque-Bera**	**JB-stat**			**Jarque-Bera**	**JB-stat**
		50.362	0.000			1.769	0.413
DEMEX							
Autocorrelation of squared standardized residuals	1	0.030	0.030	0.805	−0.039	−0.039	0.737
	2	−0.078	−0.079	0.781	−0.086	−0.088	0.716
	3	0.070	0.075	0.838	0.189	0.183	0.341
	4	−0.013	−0.025	0.930	0.111	0.121	0.369
	5	0.034	0.048	0.967	−0.004	0.038	0.510
Heteroskedasticity		**F statistics**	**P**			**F statistics**	**P**
Test: ARCH		0.0561	0.814			0.105	0.746
Normality test of residuals		**Jarque-Bera**	**JB-stat**			**Jarque-Bera**	**JB-stat**
		19.729	0.000052			1.02	0.6

OLS: Ordinary least squares, GARCH: Generalized autoregressive conditional heteroscedastic, * and ** denote significance at the 5% and 1%, levels respectively

Table 7: GARCH regression results for day of the week

Panel A: Results of GARCH regression without the 'Crisis' dummy variable				
	SEMDEX		DEMEX	
	X	X*	X	X*
Mean				
Monday	−0.000264*	0.000131	−0.0000606	−0.000326*
Tuesday	0.0000229	0.000306	−0.0002	−0.000390*
Wednesday	0.000128	0.000364**	0.000157	−0.0000707
Thursday	0.0000103	0.000393*	−0.00014	−0.000353*
Friday	0.000212	0.000503*	0.0000681	−0.00012
Crisis		−0.000415*		0.000303*
Variance				
Constant	0.000000190	0.0000032*	0.00000217*	0.00000339*
Tuesday	0.0000000425	0.000000183	−0.00000102*	−0.00000107*
Wednesday	0.000000713	0.000000501	0.000000647**	0.00000132*
Thursday	−0.000000806**	−0.000000941*	−0.00000159*	−0.00000138*
Friday	−0.000000175	0.000000392	−0.0000017*	−0.00000141*
Crisis		−0.00000259*		−0.00000151*
ARCH	0.242*	0.54*	0.305*	0.253*
GARCH	0.792*	0.462*	0.469*	0.402*
Log likelihood	6768.533	6814.771	7205.936	7237.321

* and ** denote significance at the 5% and 1%, levels respectively. GARCH: Generalized autoregressive conditional heteroscedastic

week effect, unlike reported under the OLS model. SEMDEX has significant positive returns on Wednesday, Thursday and Friday as well with a negative significant return for the crisis. On the other hand, DEMEX exhibits significant negative return on Monday, Tuesday, Thursday and a positive significant return for the crisis.

Considering the variance equation, the ARCH and GARCH coefficients are significant at 5% level for all constituents proving that the GARCH model is valid. The sum of these two coefficients, being nearly 1, reports the momentum effects that existed during the crisis. It is vital to understand that when the sum of the significant coefficients on the lagged squared error-(ARCH) and lagged conditional variance-(GARCH) is close to 1, it implies that there is volatility clustering-whereby shocks-will-be persistent (Cont and Voltchkova, 2005). Furthermore, both SEMDEX and DEMEX exhibit volatility on the different days of the week. However, the volatility is very small, being close to zero.

The highest volatility occurs on Thursday for SEMDEX while for that of DEMEX it occurs on Wednesday when the crisis variable is not included. Furthermore, the lowest volatility occurs on Thursday for DEMEX.

Likewise when the crisis dummy is introduced, the highest volatility is reported on Monday for both SEMDEX and DEMEX. The lowest volatility is reported on Thursday for SEMDEX and on Tuesday for DEMEX. The crisis variable is proved to be negatively significant for both SEMDEX and DEMEX.

4.8.2. Month-of-the-year-effect

On this Table 8, the column **X** shows the results for the regression which was run on the daily log returns by applying the mean formula and variance formula for the two indices over the period January 2007 to October 2012. Column **X*** shows the regression results which was run for the same sample data and over the same time period, but including a dummy variable representing the crisis period.

As reported in Table 8, it is clear the DEMEX exhibits negative month of the year effect which is consistent with the OLS result. However, some results not shown under OLS model is that there is significant positive return in April and December while significant negative return in August for SEMDEX.

On the other hand, when the crisis dummy is included DEMEX showed a positive significant return for August. While SEMDEX had again a significant positive return in April and December while significant negative return in August. Moreover, no volatility is experienced for any indices as expected for low frequency data.

Table 8: GARCH regression results for month-of-the-year

Panel A: Results of GARCH regression				
	SEMDEX		DEMEX	
	X	X*	X	X*
Mean				
January	0.00830	0.0134	−0.000687	0.000942
February	−0.0102	−0.000761	0.00175	0.00366
March	−0.000633	0.00231	−0.00330	−0.00165
April	0.00697**	0.0108*	0.00102	0.00363
May	−0.00156	−0.00195	−0.000698	0.000766
June	0.00838	0.0109	0.0126	0.0139
July	−0.000745	0.00153	−0.00668	−0.00367
August	−0.0103*	−0.00917*	−0.00629	−0.00631*
September	0.0106	0.0110	−0.000604	−0.000162
October	0.00561	0.00406	0.00263	0.00481
November	0.00144	0.000512	−0.00358	−0.00455
December	0.00883*	0.00799*	0.00386	0.00453
Crisis		−0.0168		−0.00809
Variance				
Constant	0.000453	0.000387	0.000169	0.000145
February	−0.000176	−0.000173	−0.000167	−0.000150
March	−0.000639	−0.000501	−0.000222	−0.000184
April	−0.000503	−0.000449	−0.0000999	−0.000108
May	−0.000333	−0.000275	−0.0000755	−0.0000158
June	−0.000385	−0.000314	−0.0000788	−0.0000638
July	−0.000352	−0.000325	−0.000136	−0.000148
August	−0.000543	−0.000452	−0.000250	−0.000208
September	−0.000130	−0.000197	−0.000159	−0.000127
October	−0.0000266	0.000118	0.000174	0.0000564
November	−0.000685	−0.000705	−0.000368	−0.000253
December	−0.000542	−0.000416	−0.000122	−0.000119
Crisis		0.000151		0.0000771
ARCH	0.186	0.168	0.0975	0.0862
GARCH	0.545	0.521	0.576	0.581
Log likelihood	185.746	191.167	218.995	219.419

*Significant at the 5% level. GARCH: Generalized autoregressive conditional heteroscedastic

5. CONCLUSION

This study attempts to test the findings of Roberts (1959) who concluded that stocks follow a random walk. In order to test the weak form of EMH the autocorrelation testing, variance ratio tests, run test and calendar effects testing, made under OLS regression as well as the GARCH were used. Two indices namely the DEMEX and SEMDEX are tested by using both daily and monthly return data for the period from 1st January 2007 to 31st October 2012. The empirical evidence obtained from these studies is mixed. While some studies show empirical results that reject the null hypothesis of weak form market efficiency, the others report evidence to support the weak form of EMH.

The autocorrelation test shows evidence to reject the null hypothesis of random walk for all studied series using both daily and monthly returns. Additionally, the run test indicates that the null hypothesis of random walk is rejected for daily returns of SEMDEX and DEMEX while not rejected for the monthly series. The results of the Lo and McKinley's variance ratio test under both homoscedasticity and heteroscedaticity assumptions for both SEMDEX and DEMEX fails to support weak-form-efficiency for the daily returns. Additionally, when the monthly returns are used, random walk under the assumption of homoscedasticity is rejected for both indices however under the heteroscedasticity variance ratio test only DEMEX rejected random walk while SEMDEX proved to be weak form efficient.

Validated under both a daily perspective as well as on a monthly one, the returns of DEMEX has consistently proven to follow a random walk while SEMDEX has shown the contrary. It showcased a day-of-the-week effect as well as a month-of-the-year effect. SEMDEX showed evidence that it does follow a random walk when tested using monthly data but these effects vanished under the GARCH-M monthly perspective. Also under OLS, it had positive significant Friday effect while under the GARCH-M model it displayed positive Monday effect.

However when the crisis dummy was introduced under OLS, DEMEX which earlier proved to be weak-form efficient now exhibits positive return of around 1.4% in June. While under the GARCH-M, it showed positive significant returns in August. On the other hand, under the GARCH-M SEMDEX reported positive return on Wednesday, Thursday and Friday. Moreover it exhibited positive return in April and December while negative return in August. Both SEMDEX and DEMEX may possibly have exhibited such trend due to the crisis where fear and lack of confidence among investors were governing the market.

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