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1 Introduction

The concept of 'efficient' stock market has been hotly debated ever since Eugene Fama first introduced it around some thirty years ago. Under the weak form of market efficiency, the price of a security reflects all the available information about the economy, the market and the specific security, and that prices adjust immediately to new information. For a long time the conformation of random walk is considered to be a sufficient condition for market efficiency. However, rejection of random walk model does not necessarily imply the inefficiency of stock-price formation.

Random walk is the path of a variable over time that exhibits no predictable patterns at all. If a price, p, moves in a random walk, the value of p in any period will be equal to the value of p in the period before, plus or minus some random variable. The random walk hypothesis states that the present market price is the best indicator of the future market prices with an error term that is stochastic in nature. Hence the next time period price is anybody's guess. In an efficient market it is not possible to make profit based on the past information hence the prediction of the future price conditional on the past prices on an average should be zero. The more efficient a market is the more random and unpredictable the market returns would be. In the most efficient market the future prices will be totally random and the prices formation can be assumed to be a stochastic process with mean in price change equal to zero.

The objective of this project is to investigate whether prices in stock markets follow a weak form efficient process. The presence or absence of such a process in the stock markets is evaluated using stock market indices and returns. The study is made comprehensive by including three stock market indices and another three indices of individual stocks belonging to the respective stock markets under examination. The observations are tested using the methodologies which are common for this area of study.

2 Data and Methodology

There are various indices available that are widely used as the indicator of the performance of the stock markets in the world. These indices are constructed based on different methods and hence are expected to behave differently. Three different stock market indices and three individual company indices each from their respective stock markets are used in this paper. The market indices are:

1. Dow-Jones Industrial Average Index (United States of America)
2. TOPIX (Japan)
3. CAC40 (France)

The company stock indices include:

1. General Electric (United States of America)
2. Honda Motors (Japan)
3. L'Oreal (France)

The above mentioned market and company indices seem to be some natural choices for including in this report, as they are relatively popular and widely used by market players for benchmarking. Considering their substantial sizes and relatively large shares in local and world equity markets, one can exhibit very large volumes, high liquidity, comprehensive measures of stock price changes and instantaneous information distribution. TOPIX. For instance, includes all first section listed shares in the Tokyo Stock Exchange (TSE) which comprises some 1500 companies of all kind from all over Japan and the world. The index is computed and published every 60 seconds via TSE's Market Information System. It is reported to securities companies across Japan and is available worldwide through computerized information networks. Moreover, existence of available data on the indices for a large period of time is an added advantage for the study. The study spans more than 12 years, starting from 31 December 1989 till 31 December 2001 for monthly data; and begins from 29 December 1989, extending till 31 December 2001 for daily data. All the factors mentioned provide a relatively ideal 'condition' for testing weak form efficiency.

Of the three market indices, only the DJIA runs as a simple price average mechanism (in fancy definition is a price weighted index). The rest two indices are based on a more popular value weighted procedure.

To give a rough idea how the indices are calculated. Each stock in the Dow Jones Industrial Average represents $1/30^{th}$ of the overall average. The way the average is calculated is simply by adding up each stock price and divides by 30 (or the amount of stocks that were in the index at that time). Because of stock splits, they had to adjust the divisor. Today, with respect to the Industrial Average, the way to figure out how a one point move in any one stock affects the amount of points up or down the index moves, divide one by the current divisor. For example, if Philip Morris (MO) is down 4 points, divide 4 by 0.33098002 (the current divisor) = 12.085. Therefore, if the Dow Jones Industrials were down 20 points today, and Philip Morris was down 4 points, 12.085 of the 20 point decline would be attributed to Philip Morris.

For the value weighted indices (also known as market weighted indices), the market value of a stock is computed as the closing price times the number of shares outstanding. This expression is often called the stock's capitalisation or 'cap'. As a result, the value-weighted indices are biased toward the companies with the highest stock market value: a move in Honda will affect the TOPIX more than a move in Japan Wind Development.

Both daily and monthly prices are collected for this report, and based on the prices, return can be calculated as the logarithmic difference between two consecutive prices in a series. With the index levels and returns handy, various statistics can be carried out.

2.1 Jarque-Bera Statistics for Normality

The test for normality is carried out with the Jarque-Bera statistics provided by the EViews package. This is a test statistic for testing whether the series is normally distributed using skewness and kurtosis based on least squares residuals. The test statistic measures the difference of the skewness and kurtosis of the series with those from the normal distribution and is computed as:

$$JB = n\left[\frac{SK^2}{6} + \frac{(k-3)^2}{24}\right] \sim \chi_2^2 \text{ for \underline{large} samples}$$

Where SK is the skewness, k is the kurtosis, and n represents the number of estimated coefficients used to create the series.

Under the null hypothesis of a normal distribution[1] (i.e. H_0: JB = 0), the Jarque-Bera statistic is distributed as χ^2 with 2 degrees of freedom. The reported Probability is the probability that a Jarque-Bera statistic exceeds (in absolute value) the observed value under the null. Therefore, a small probability value leads to the rejection of the null hypothesis of a normal distribution.

[1] A normal distribution should have a skewness of 0 and kurtosis of 3

2.2 Ljung-Box Statistics for Serial Correlation

Ljung and Box[2] (1978) gave Q-statistic as an alternative to various hypotheses of autocorrelation with different time lags. As a fundamental test for market efficiency, the LB test is computed as follows:

$$Q(LB) = T(T+2)\sum_{j=1}^{k}\frac{\rho_j^2}{T-j} \sim \chi_k^2$$

Where, ρ_j is autocorrelation with j lags and T is the sample size.

To test the validity of market efficiency the Q-statistic is tested for various values of k, for the following null hypothesis:

$$H_0 : Q_k \sim \chi_k^2$$

Q-statistics can capture departures from no autocorrelation in either direction and at all time lags (governed by k). It follows a chi-square distribution with k degrees of freedom. Here k is the number of autocorrelations included in the Q-statistic. In EViews, Ljung-Box Q-statistics and their p-values are reported in the last two columns of the correlogram. In this work, correlograms were computed up to lags 30 and 36 for daily and monthly series respectively. Together with the autocorrelation and partial autocorrelation statistics, we are able to justify if the series obeys stationary, white noise, or random walk characteristics.

2.3 Augmented Dickey-Fuller Test of Unit Root

The early and pioneering work on testing for a unit root in time series was done by Dickey and Fuller. The basic objective of the test is to examine the null hypothesis that $\phi=1$ in

$$y_t = \phi y_{t-1} + u_t$$

against the one-sided alternative $\phi < 1$. Thus the hypotheses of interest are:

H_0 : series contains a unit root Vs H_1 : series is stationary.

In practice, the following regression is employed, for ease of computation and interpretation

$$\Delta y_t = \psi y_{t-1} + u_t$$

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[2] G. M. Ljung and G. E. P. Box, "On a Measure of Lack of Fit in Times Series Models," *Biometrika*, Vol. 65, 1978, pp. 297 – 303.

so that a test of $\phi = 1$ is equivalent to a test of $\psi = 0$ (since $\phi - 1 = \psi$).

However, the validity of the tests is based on u_t being a white noise. In particular, u_t is assumed not to be autocorrelated, but would be so if there was autocorrelation in the dependent variable of the regression (Δy_t) which has not been modelled. To avoid the test of being 'oversized' (the proportion of times a correct null hypothesis is incorrectly rejected), the solution is to 'augment' the test using p lags of the dependent variable, and the alternative model is written as[3]:

$$\Delta y_t = \psi y_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta y_{t-i} + u_t$$

To ensure that u_t is not autocorrelated, the lags of Δy_t now adjust any dynamic structure present in the dependent variable. The test is known as augmented Dickey-Fuller (ADF) test and the same critical values from the DF tables are used as before.

The ADF test is incorporated in EViews package. With the help of newer versions, the optimal numbers of lags of the dependent variables were chosen automatically by the package based on the Akaike's information criterion (AIC).

2.4 Runs Test for Randomness

The Runs Test is developed to test for randomness in time series. It is a nonparametric test that is particularly easy to perform. The basic idea of Runs Test is that if a series was random, then its performance on one day would be independent of the performance on any other day. For instance, a high-price day would be no more than likely to be followed by another high-price day than would any other day. The Runs Test developed in Minitab separates the observed number of runs with the expected number of runs and states:

H_0: series is a set of random variables (expected number of runs observed)

H_1: series non-random (observed runs either more or less than expected runs)

A new run is counted whenever an observation changes sign around its series mean.

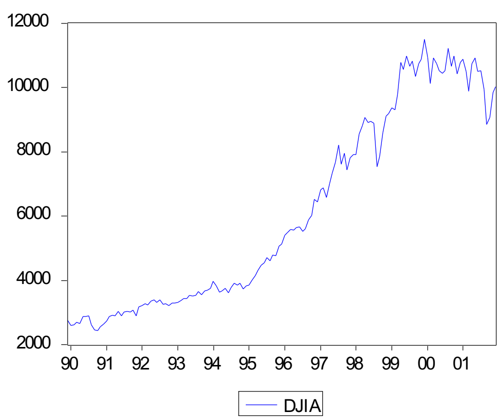
[3] For more detailed reference, see C. Brooks, "Introductory Econometrics for Finance," Cambridge University Press (2002), Chapter 7.

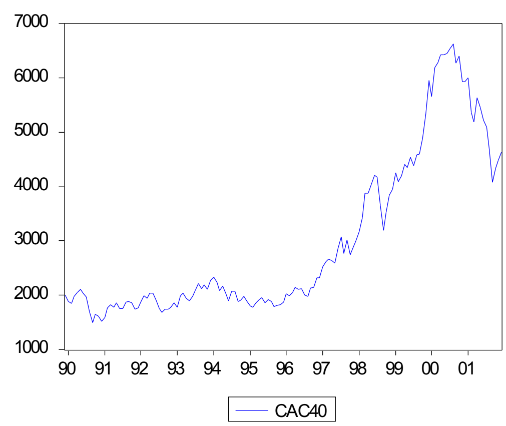
3 Results and Data Analysis

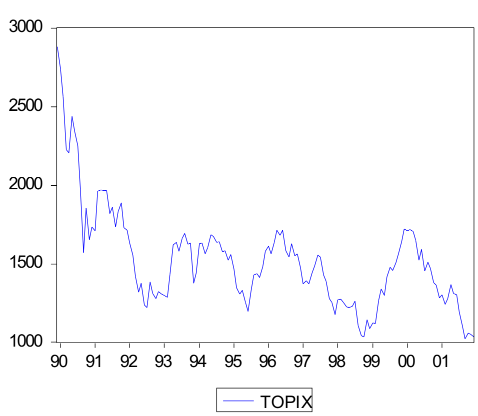
In this part I will first present a brief descriptive statistics regarding the index levels and returns. The normality test will be reported and analysed in section 3.2. It is then followed by Ljung-Box Q-statistics for serial correlation in section 3.3. In section 3.4 I will analyse the three ADF unit root test and the last section of this part will be devoted to the Runs test.

3.1 Descriptive Statistics

<u>Figures 1. Monthly index levels of DJIA, CAC40 and TOPIX</u>



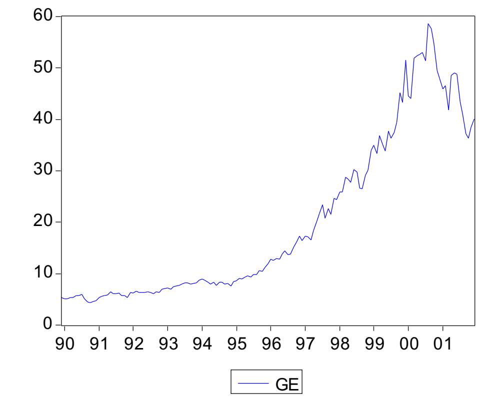


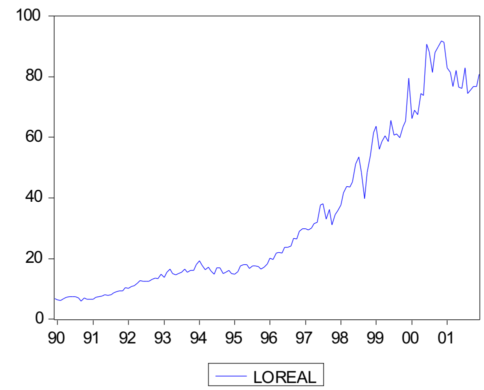


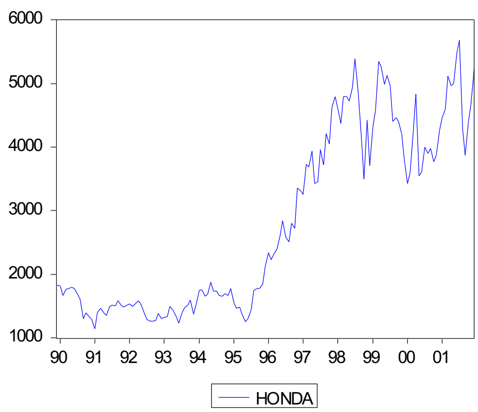
Figures 1 show the monthly index levels for the three markets under examination. Of the market indices, DJIA and CAC40 exhibit relatively similar patterns. In general the two indices rise over time with relatively flat slope (fluctuating around a constant mean) observed till mid 1990s, and from mid 90s onwards they took steeper slopes and greater fluctuations. Such a behaviour which exhibits a ‘long swing’ away from the mean value is best described as a random-walk with drift process. The effect of the drift on the series becomes greater and greater the further the two processes are tracked.

TOPIX shows a relatively peculiar behaviour, with its index level dropped gradually since the beginning of our observation. While the presence of a drift is not very clear compared to the other two market indices, we can, however, argue it obeys a random-walk process as well.

Figures 2. Monthly company index levels of General Electric, Honda and L'Oreal



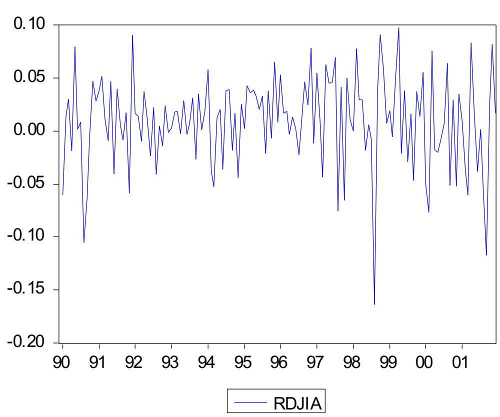




Figures 2 show the monthly index levels for the three companies under our examination. All three observations obey quite strictly the random-walk with drift characteristics.

All in all, by observing the line graphs in figures 1 and 2, we can say that the monthly levels do not obey a stationary process.

Figures 3. Monthly index returns for DJIA, CAC40, TOPIX, GE, L'Oreal and Honda



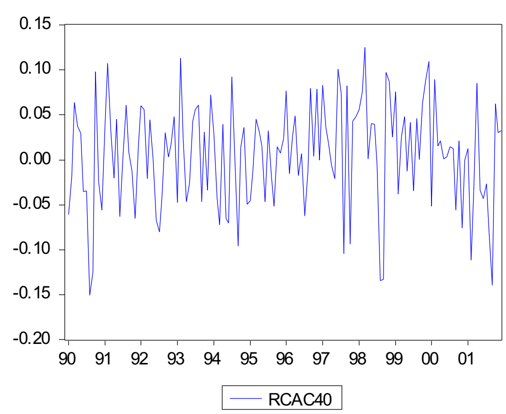
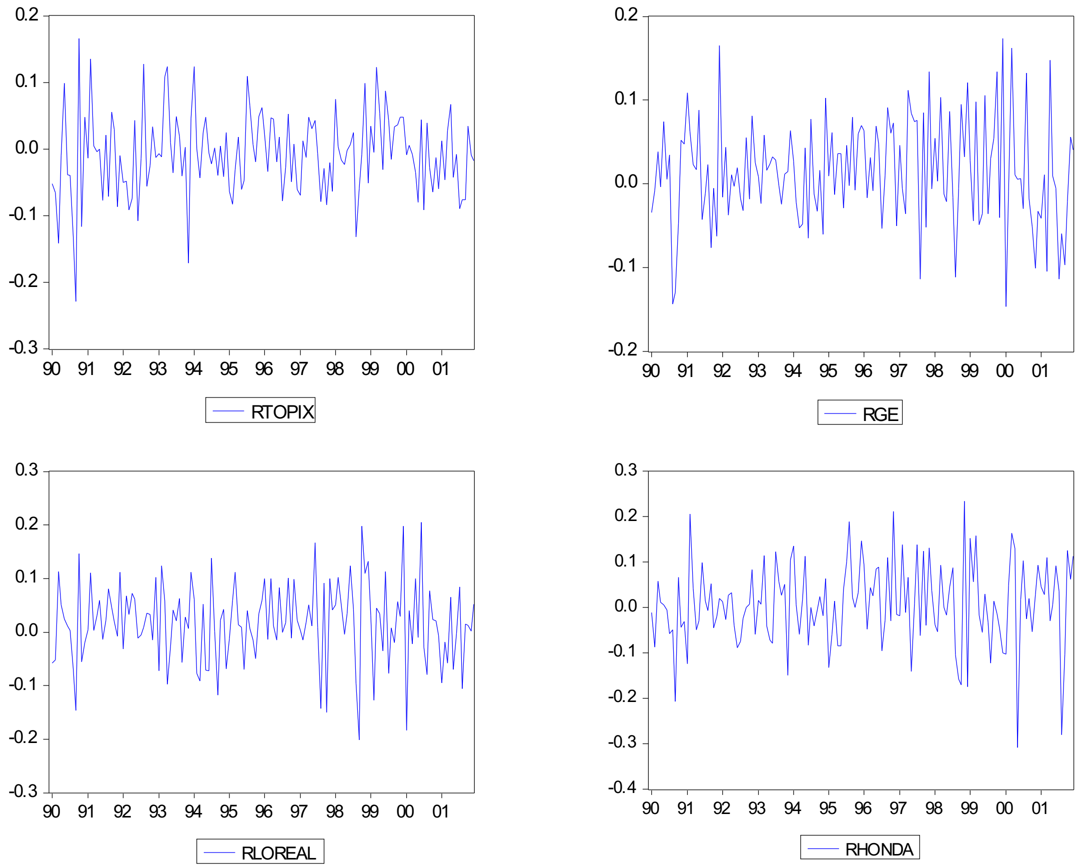


Figure 3. cont.



Comparing figures 3 with the index level figures, we clearly observe a white noise process for the monthly returns. In figures 3, a white noise process visibly has no trending or drifting behaviour, and the series frequently crosses their mean values which are very close to zero.

Tables 1 and 2[4] further confirm the above observation. For both daily and monthly returns we observe a similar pattern in which the series are centred around mean and median values very close to zero. While the monthly returns have their kurtosis values relatively close to 3, daily returns exhitibt rather high kurtosis values. This may indicate a leptokurtic behaviour which represents a tendency for daily returns to have distributions that exhibit fat tails and excess peakedness at the mean. We can thus conclude from such an observation that monthly returns follow distributions more closely to normal than daily returns.

[4] Refer section 3.2 for data

3.2 Results from Jarque-Bera Normality Test

Table 1. Summary of daily and monthly market index returns

	DJIA		TOPIX		CAC40	
	Daily	*Monthly*	*Daily*	*Monthly*	*Daily*	*Monthly*
Mean	0.000	0.009	0.000	-0.007	0.000	0.006
Median	0.000	0.014	0.000	-0.008	0.000	0.013
Maximum	0.049	0.098	0.091	0.167	0.068	0.125
Minimum	-0.075	-0.164	-0.074	-0.228	-0.077	-0.151
Std. Dev.	0.010	0.043	0.013	0.062	0.013	0.058
Variance	0.000	0.002	0.000	0.004	0.000	0.003
Skewness	-0.475	-0.746	0.187	-0.082	-0.176	-0.392
Kurtosis	8.348	4.436	7.232	3.838	5.429	2.795
JB	**3849.079**	**25.726**	**2354.870**	**4.381**	**785.866**	**3.941**
P-Value	**0.000**	**0.000**	**0.000**	**0.112**	**0.000**	**0.139**

Table 2. summary of daily and monthly company index returns

	GE		Honda		L'Oreal	
	Daily	*Monthly*	*Daily*	*Monthly*	*Daily*	*Monthly*
Mean	0.001	0.014	0.000	0.007	0.001	0.017
Median	0.000	0.010	0.000	0.008	0.000	0.019
Maximum	0.117	0.173	0.150	0.233	0.093	0.206
Minimum	-0.113	-0.147	-0.150	-0.308	-0.118	-0.201
Std. Dev.	0.016	0.063	0.022	0.091	0.020	0.074
Variance	0.000	0.004	0.000	0.008	0.000	0.005
Skewness	-0.012	0.029	-0.039	-0.324	-0.016	-0.208
Kurtosis	7.102	3.053	7.023	3.861	5.100	3.411
JB	**2195.684**	**0.036**	**2111.908**	**6.969**	**575.608**	**2.055**
P-Value	**0.000**	**0.982**	**0.000**	**0.031**	**0.000**	**0.358**

From the Jarque-Bera normality test, we can observe some contrary results between daily and monthly returns. Of all the daily returns, the null hypothesis which supports a normal distribution was rejected. However, this is not so for monthly returns. As we can see from the tables, except from the monthly Dow Jones and Honda returns, the JB test failed to reject the null for normality at 5% significance level. And if we set the significance level at 1 %, even monthly returns for Honda obeys are normal distribution.

Reasons rendering such contrary results between daily and monthly returns could be multiple. In my view this can be due to the much higher frequency of the daily returns which might has distorted the normal distribution of the test. Also, the 12-year span of our observations is just a small subset from the history of the stock markets and exhibiting normal distributions or not from our test does not necessarily represent the actual behaviour of the indices. Still, based on the JB results that we obtained, extra caution should be taken when conducting further tests which are based on the assumption of normal distribution.

3.3 Results from Ljung-Box Statistics for Serial Correlation

Table 3. Summary of serial correlation on daily and monthly market index levels

MONTHLY									
	DJIA			**CAC40**			**TOPIX**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.985	0.97	0.956	0.985	0.968	0.953	0.895	0.796	0.703
PAC	0.985	-0.025	0.04	0.985	-0.052	0.047	0.895	-0.022	-0.026
Q-STAT	143.69	283.94	421.16	143.56	283.31	419.74	118.54	213.08	287.36
P-VALUE	0	0	0	0	0	0	0	0	0
DAILY									
DL	**DJIA**			**CAC40**			**TOPIX**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.999	0.999	0.998	0.999	0.999	0.998	0.995	0.99	0.985
PAC	0.999	-0.015	0.022	0.999	-0.02	0.017	0.995	-0.045	0.019
Q-STAT	3130.7	6257.9	9381.9	3130.5	6257.4	9380.7	3104.9	6178.4	9221.8
P-VALUE	0	0	0	0	0	0	0	0	0

Table 4. Summary of serial correlation on daily and monthly company index levels

MONTHLY									
	GE			**L'OREAL**			**HONDA**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.986	0.973	0.959	0.98	0.962	0.942	0.976	0.956	0.941
PAC	0.986	0.009	-0.023	0.98	0.014	-0.019	0.976	0.073	0.09
Q-STAT	143.94	284.95	422.93	142.24	280.04	413.33	141.01	277.27	410.05
P-VALUE	0	0	0	0	0	0	0	0	0
DAILY									
	GE			**L'OREAL**			**HONDA**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.999	0.999	0.998	0.999	0.998	0.997	0.999	0.997	0.996
PAC	0.999	-0.007	0.025	0.999	0.012	0.02	0.999	0.013	0.023
Q-STAT	3130.6	6257.9	9381.9	3128.5	6251.8	9370	3126.8	6246.7	9360.1
P-VALUE	0	0	0	0	0	0	0	0	0

Tables 3 and 4 present the test results on serial correlation for monthly and daily index levels based on the Ljung-Box statistics. We see that for autocorrelation (AC) the coefficients have some very high values. This suggests a highly significant level and can be justified by the Q-statistics and P-values of the test. The partial autocorrelation coefficients are also high and significant at lag one and drop off substantially at the rest of lags.

The results generated in tables 3 and 4 may further confirm our random-walk with drift observation about stock indices. This is because when one suggests that stock prices follow a random walk, he is implying that the price changes are independent of one another. That is to say how the prices changed yesterday has nothing to do with how the prices change today; they are following a random walk process. However, over a certain time horizon, the price level itself tend to follow a drift, and this may explain why we observe high AC values for monthly and daily index levels.

Table 5. Summary of serial correlation on daily and monthly market index returns

MONTHLY									
	DJIA			**CAC40**			**TOPIX**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	-0.087	-0.011	-0.093	0.068	-0.083	0.048	-0.004	0.017	0.014
PAC	-0.087	-0.019	-0.097	0.068	-0.088	0.061	-0.004	0.017	0.014
Q-STAT	1.1239	1.1426	2.4426	0.677	1.688	2.0284	0.0028	0.0451	0.0734
P-VALUE	0.289	0.565	0.486	0.411	0.43	0.567	0.958	0.978	0.995
DAILY									
	DJIA			**CAC40**			**TOPIX**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.03	-0.038	-0.028	0.035	-0.026	-0.031	0.089	-0.056	-0.022
PAC	0.03	-0.039	-0.026	0.035	-0.028	-0.029	0.089	-0.065	-0.011
Q-STAT	2.8687	7.2907	9.7818	3.8681	6.0643	9.0939	25	34.93	36.517
P-VALUE	0.09	0.026	0.021	0.049	0.048	0.028	0	0	0

Table 6. Summary of serial correlation on daily and monthly company index returns

MONTHLY									
	GE			**L'OREAL**			**HONDA**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	-0.108	0.112	-0.126	-0.188	-0.087	-0.059	-0.067	-0.131	-0.083
PAC	-0.108	0.102	-0.106	-0.188	-0.127	-0.107	-0.067	-0.136	-0.105
Q-STAT	1.7179	3.5773	5.9395	5.1813	6.301	6.8194	0.6584	3.2028	4.2338
P-VALUE	0.19	0.167	0.115	0.023	0.043	0.078	0.417	0.202	0.237
DAILY									
	GE			**L'OREAL**			**HONDA**		
LAGS	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
AC	0.001	-0.053	-0.02	-0.044	-0.063	-0.031	-0.02	-0.025	-0.036
PAC	0.001	-0.053	-0.02	-0.044	-0.065	-0.037	-0.02	-0.026	-0.037
Q-STAT	0.0016	8.7723	10.08	6.1048	18.441	21.513	1.3108	3.2867	7.4427
P-VALUE	0.968	0.012	0.018	0.013	0	0	0.252	0.193	0.059

We now turn to index returns. Both daily and monthly index returns exhibit autocorrelation coefficients close to zero, this conforms to the white noise behaviour which index returns should obey. It can also be shown that for monthly returns there are rather strong supports for the null hypothesis of no serial correlation. With the exception of L'Oreal, one cannot reject the null of no serial correlation at around 5% significance level for all monthly index returns. This is further confirmed by comparing the autocorrelation coefficients with the band of the observations (0.163, -0.163). For daily index returns, however, the story is less apparent. But we can still conclude that with the exception of TOPIX and L'Oreal, one fails to reject the null at 1% significance level for all other daily returns.

To sum up, for the monthly returns none of the indices show significant autocorrelation of first-order. This could be due superiority of monthly figures over daily figures, which may contain sampling problems of biases due to bid-ask spreads and non-trading.

3.4 Results of ADF Test for Unit Root

The descriptive statistics and results of Augmented Dickey-Fuller tests for the daily and monthly indices (in logs) are presented in Table 7. Each row corresponds to a particular index. The last three columns present the results of ADF test for no drift and no trend model, drift and no trend model and drift and trend model respectively. The first entry is the value generated by the test, which is equal to zero under null hypothesis. The value below this statistic in italic is the corresponding McKinnon critical value at 1% significance level. As can be observed, the unit root tests strongly accept the null hypothesis of random walk for all the indices.

Table 7. Results of ADF Test for daily and monthly indices

DAILY MARKET INDICES								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
DJIA	3132	8.598	0.511	0.093	1.439	2.4545	-0.7646	-1.9947
						-2.5657	*-3.4323*	*-3.9610*
CAC40	3132	7.893	0.443	0.730	2.031	1.2678	-0.3938	-2.0656
						-2.5657	*-3.4323*	*-3.9610*
TOPIX	3132	7.306	0.189	0.566	3.928	-1.4346	-2.9859	-3.2946
						-2.5657	*-3.4323*	*-3.9610*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								
MONTHLY MARKET INDICES								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
DJIA	145	8.595	0.511	0.094	1.443	2.7693	-0.8009	-2.0889
						-2.5812	*-3.4765*	*-4.0230*
CAC40	145	7.896	0.446	0.721	2.018	1.1753	-0.4386	-2.1591
						-2.5811	*-3.4761*	*-4.0230*
TOPIX	145	7.309	0.194	0.646	4.021	-1.4480	-3.0758	-2.8253
						-2.5811	*-3.4761*	*-4.0296*

Table 7. cont.

DAILY COMPANY INDICES								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
GE	3132	2.672511	0.806854	0.28935	1.578534	2.3418	-0.4729	-2.0811
						-2.5657	*-3.4322*	*-3.9610*
L'OREAL	3132	3.184572	0.813648	0.097609	1.769032	2.8112	-0.6232	-2.8113
						-2.5657	*-3.4323*	*-3.9610*
HONDA	3132	7.802467	0.517245	0.168218	1.356617	0.9594	-0.5604	-2.7866
						-2.5657	*-3.4323*	*-3.9610*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

MONTHLY COMPANY INDICES								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
GE	145	2.670	0.809	0.291	1.576	2.6418	-0.4430	-1.8066
						-2.5812	*-3.4765*	*-4.0235*
L'OREAL	145	3.188	0.825	0.097	1.775	3.0220	-0.6894	-2.4805
						-2.5812	*-3.4771*	*-4.0235*
HONDA	145	7.804	0.517	0.164	1.352	1.2636	-0.4175	-2.8322
						-2.5815	*-3.4768*	*-4.0230*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

Table 8. Results of ADF Tests for daily and monthly index returns

DAILY MARKET INDEX RETURNS								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
DJIA	3131	0.000	0.010	-0.475	8.348	-14.9231	-15.1442	-15.1452
						-2.5657	*-3.4323*	*-3.9610*
CAC40	3131	0.000	0.013	-0.176	5.429	-22.5276	-22.5670	-22.5734
						-2.5657	*-3.4323*	*-3.9610*
TOPIX	3131	0.000	0.013	0.187	7.232	-17.8439	-17.8979	-17.9078
						-2.5657	*-3.4323*	*-3.9610*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

MONTHLY MARKET INDEX RETURNS								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
DJIA	144	0.009	0.043	-0.746	4.436	-12.4747	-13.0856	-13.0547
						-2.5812	*-3.4765*	*-4.0235*
CAC40	144	0.006	0.058	-0.392	2.795	-11.0534	-11.1364	-11.1117
						-2.5812	*-3.4765*	*-4.0235*
TOPIX	144	-0.007	0.062	-0.082	3.838	-11.8475	-11.9463	-11.9311
						-2.5812	*-3.4765*	*-4.0235*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

Table 8. cont.

DAILY COMPANY INDEX RETURNS								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
GE	3131	0.001	0.016	-0.012	7.102	-15.8641	-16.0890	-16.0864
						-2.5657	*-3.4323*	*-3.9610*
L'OREAL	3131	0.001	0.020	-0.016	5.100	-24.8554	-25.0766	-25.0731
						-2.5657	*-3.4323*	*-3.9610*
HONDA	3131	0.000	0.022	-0.039	7.023	-25.2840	-25.3037	-25.3138
						-2.5657	*-3.4323*	*-3.9610*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

MONTHLY COMPANY INDEX RETURNS								
	N	MEAN	STD. DEV.	SKEWNESS	KURTOSIS	NDNT	DNT	DT
GE	144	0.014	0.063	0.029	3.053	-7.3519	-13.2561	-13.2090
						-2.5813	*-3.4765*	*-4.0235*
L'OREAL	144	0.017	0.074	-0.208	3.411	-13.5441	-14.4063	-7.5374
						-2.5812	*-3.4765*	*-4.0249*
HONDA	144	0.007	0.091	-0.324	3.861	-9.7813	-9.8751	-9.8809
						-2.5813	*-3.4768*	*-4.0240*
NDNT - NO DRIFT & NO TREND, DNT - DRIFT & NO TREND, DT - DRIFT & TREND								

Table 8 presents the ADF test results on daily and monthly index returns for both market and company indices. The ADF statistics are substantially smaller (more negative) than the McKinnon critical values, indicating and strong rejection of the unit root hypothesis. In another word, index returns do not show random-walk behaviour, this is further confirmed by our previous test on serial correlation which indicates that index returns conform more to a white noise characteristic.

To conclude this section, it is shown that the tests for unit roots are strongly in favour of weak form efficiency based on the data generated. We can observe a random walk process for the index levels while the return conforms closely to white noise behaviour.

3.5 Results of Runs Test for Random Walks

Runs test results are presented in tables 9 and 10 for daily and monthly index returns respectively. The null for this test states that the expected number of runs should be observed in the sample, meaning that the series move randomly. The first rows of the tables present the mean value of the series and the second and third rows show the numbers of observed runs and expected runs computed by the test statistics. By comparing these two figures, we can infer if the series obeys an oscillating behaviour or trend behaviour.

Table 9. Runs test for daily index returns

	DAILY MARKET RETURNS			DAILY COMPANY RETURNS		
	DJIA	CAC40	TOPIX	GE	L'OREAL	HONDA
MEAN	0.0004	0.0003	-0.0003	0.0006	0.0008	0.0003
OBSERVED RUNS	1587	1529	1431	1565	1605	1483
EXPECTED RUNS	1565.981	1564.461	1565.1188	1561.721	1563.142	1533.73
P-VALUE	0.4523	0.2043	0	0.9064	0.1337	0.064

Table 10. Runs test for monthly index returns

	MONTHLY MARKET RETURNS			MONTHLY COMPANY RETURNS		
	DJIA	CAC40	TOPIX	GE	L'OREAL	HONDA
MEAN	0.009	0.0058	-0.0071	0.014	0.0171	0.0073
OBSERVED RUNS	84	78	79	80	78	74
EXPECTED RUNS	72.1111	72.6528	72.875	72.7778	72.944	72.9861
P-VALUE	0.0441	0.3688	0.3048	0.2256	0.3974	0.8653

In general none of the series observes great divergence between its numbers of observed and expected runs. At 5% significance level only nulls of daily TOPIX and monthly DJIA returns are rejected, and for the rest of the series the p-values are quite high.

It is worth mentioning that the Runs Test is constructed based on the assumption of normal distribution. According to the Normality test that was executed in section 3.2, however, the daily index returns do not follow a normal distribution. This may explain for the fact that the daily TOPIX returns having a p-value of 0 and it further distorts the credibility of the Runs Test results for the whole daily returns series.

By observing the monthly returns' results, which may obey more concretely a normal distribution, all series have their observed runs slightly more than the expected runs. And according to the p-values which in general quite strongly support the null hypothesis of a random behaviour, we can conclude that the Runs Test provides evidence for random walk behaviour for the index returns series and we some oscillating behaviour can also be observed from the series.

4 Conclusion

This project is constructed to examine if weak form efficiency can be observed from the six market and company stock indices. In theory, indices following weak form efficiency should follow a random-walk process over its price level changes and its returns should be some white noise. According to the samples under this work's examination, weak form efficiency can generally be firmed.

First, from the normality test we have shown that monthly stock returns tend to follow normal distribution better than daily returns. Such an observation, while a common case for many other similar academic works, should lead us to rely more on monthly series in determining the presence of weak form efficiency. Academics in general also tend to stand in favour for monthly and weekly data rather than daily ones due to the more reasonable frequency levels of the former two series.

The test for serial correlation provides evidence for supporting the presence of random-walk with drift behaviour in index levels. For index returns there exhibits autocorrelation coefficients very close to zero at all lags and conforms to the white noise behavious which index returns should obey. Theses observations were then supported by the Unit Root test stating the presence of random walk process in index levels and rejection of random walk process in index returns series.

Last but not least, none of the series observes great divergence between its numbers of observed and expected runs for the Runs Test. Moreover, from the monthly series which follow more concretely a normal distribution, random walk behaviour for index returns is strongly supported.

According to the results generated, it can be concluded that weak form efficiency exists in the stock markets of Dow-Jones, CAC40 and TOPIX, while for company stocks, weak form efficiency presents in General Electric, L'Oreal and Honda.