TESTING INFORMATIONAL EFFICIENCY: THE CASE OF U.E. AND BRIC EMERGENT MARKETS

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Abstract:
Empirical finance has brought together a considerable number of studies in determining the market efficiency in terms of information in the case of an emerging financial market. Conflicting results have been generated by these researches in efficient market hypothesis (EMH), so efficiency tests in the emerging financial markets are rarely definitive in reaching a conclusion about the existence of informational efficiency. This paper tests weak-form market efficiency of eight emerging markets: four U.E emerging markets: Romania, Hungary, Czech Republic, Slovakia, Estonia and BRIC emerging markets: Brazil, Russia, India and China. The random walk hypothesis of stock exchange indices is tested using statistical tests. To test for the existence of the normality hypothesis of distributed instantaneous yields (logarithmic) of stock index are employed Jarque-Bera and QQ-plot tests. The stationary tests for instantaneous yields (logarithmic) of stock exchange indexed that are used in this article are unit root tests, run tests and variance ratio test. Because the analysis determined empirically the presence of linear dependences for the returns series, it can be concluded that most of these emerging equity markets are not weak-form efficient.

Key words: *efficient market hypothesis, information, tests, emergent, random walk*

1. Introduction

There are two main theories that considerations concerning the efficiency of financial markets lay under: the theory of efficient markets and the random walk theory. In his famous study, which will definitively mark the theory of efficient markets, *Efficient Capital Markets: A Review of Theory and Empirical Work,* written by Fama in 1970, he gives the following definition: "A market in which prices always reflect the available information is called an efficient market". The **market efficiency hypothesis (EMH)** is a statement about:

- the theory that stock prices reflect the true value of stocks;

- the absence of arbitrage opportunities in an economy populated by rational, profit-maximizing agents;
- the hypothesis that market prices always fully reflect available information (Fama 1970).

Therefore the rational expectations of the returns for a particular stock according to the EMH may be represented as:

$$P_{t+1} = E_t P_{t+1} + \varepsilon_{t+1}$$

where P_t is the stock price; and ε_{t+1} is the forecast error. $P_{t+1} - E_t P_{t+1}$ should therefore be zero on average and should be uncorrelated with any information Φ_t. Also $E(x_{j,t+1} \mid \Phi_t) = 0$ when the random variable (good or bad news), the expected value of the forecast error, is zero:

$$E_t \varepsilon_{t+1} = E_t (P_{t+1} - E_t P_{t+1}) = E_t P_{t+1} - E_t P_{t+1} = 0$$

The **Random Walk Model (RWM)** is the model which assumes that subsequent price changes are sovereign and homogeneously distributed random variables and concludes that changes in assets prices cannot be forecasted through historical price changes and movements. The Random Walk Model is generally used to test the weak-form Efficient Market Hypothesis (Hamid K. et all, 2010).

Random walk theory claims that stock market can be analyzed as random walk according to the next three facts (Vulic, 2010):

- efficient markets respond very fast to new information;
- if the share price is a reflection of all available information, it is impossible to use that information for market predictions;
- it is impossible to predict market movement other than randomly.

The empirical evidences show that the random walk hypothesis is "almost approximately true". More precisely, if the financial assets returns are partial predictable, both on the short time, and on the medium and long time, the degree of predictability is generally low comparative with the high volatility of these returns.

A random walk is a usual example of a non-stationary series:

$$y_t = y_{t-1} + \varepsilon_t$$

where ε_t is a casual perturbation with stationary character. The series y_t present an upward variance in time, while its 1st difference is stationary because:

$$y_t - y_{t-1} = (1 - L)y_t = \varepsilon_t$$

Emerging equity markets are widely thought to be places of substantial trading profits and weak and semi-strong form market inefficiencies when compared to developed markets. In their article, Griffin, Kelly and Nardari, 2009, examine the extent to which this is true using a variety of methodologies and data from 28 developed and 28 emerging markets. Emerging markets exhibit similar autocorrelation in firm returns, suggesting that they are not under or overreacting to news contained in past returns any more than in developed markets. Emerging markets incorporate past market and portfolio returns into prices slightly better than developed markets.

Using the article of Basu and Morey (2005), who developed a theoretical model that explores the effect of trade openness on stock return autocorrelation patterns, the paper of Lim and Kim, 2008, brings their proposition to the data, examining the impact of liberalization policies, both trade and financial, on the informational efficiency of 23 emerging stock markets. In general, the key results from fixed effects panel regressions support their prediction that trade liberalization, rather than financial openness, matters the most for informational efficiency.

Islam, Watanapalachaikul, Clark (2007) proposed a theory-free paradigm of non-parametric tests of market efficiency for an emerging stock market, the Thai stock market, consisting of two tests which are run-test and autocorrelation function tests (ACF), to establish a more definitive conclusion about EMH in emerging financial markets. The result of this research demonstrates that an autocorrelation on Thai stock market returns exists particularly during the post-crisis period.

Regarding Romanian capital market, it has been investigated rationality of Romanian investors, and efficiency market hypothesis represented a useful tool in order to achieve this goal (Dragotă, Mitrica, 2004). The tests suggested by Fama [1970] have been successfully applied by many authors. Therefore, for many Romanian researchers it was incentive to proceed on investigating informational efficiency of Romanian capital market. Most of these studies have focused on the weak form of informational market efficiency using in that sense autocorrelation coefficients, normality and stationarity tests (Augmented Dickey-Fuller and Phillips-Perron) in order to test random walk pattern for stock returns.

Lazăr and Ureche (2007) tested weak-form market efficiency of eight emerging markets: Romania, Hungary, Czech Republic, Lithuania, Poland, Slovakia, Slovenia, Turkey. The used tests determined empirically the presence of linear and nonlinear dependences, for most of the returns series. Most of these emerging equity markets were not weak-form efficient.

This paper is structured as follows: section 2 presents the data and empirical methodology used for testing the weak-form of informational efficiency of the eight emerging capital markets. The empirical results of these tests are presented in section 3. The conclusions are given in the last section 4.

2. Data and methodology

The data used for this study is the market value-weighted equity indices (BET for Romania, SAX Index for Slovakia, OMX Tallinn for Estonia, PX for Czech Republic, BUX for Hungary, IBOVESPA for Brazil, RTSI for Russia, SENSEX for India and Shanghai Composite Index for China). In the past years, the stock markets have witnessed heightened activity in terms of various bull and bear runs. The reason for which we used in our study the stock markets indices is that usually the indices have the ability to capture all these happenings on the markets in the most judicious manner. One can identify the booms and busts of the equity markets through indices. Their brief description is given in table 1:

Table 1 – Description of the emergent stock exchange indices

Index	Description
BET Index – Bucharest Stock Exchange	the first index developed by BVB, is the reference index for the BVB market. BET is a free float weighted capitalization index of the most liquid 10 companies listed on the BVB regulated market. The index methodology allows BET to be a good underlying for derivatives and structured products.
PX Index – Prague Stock Exchange	the official index of the Prague Stock Exchange. It is a capitalization weighted price index and is made up of the most traded blue chips at the Stock Exchange. It is designed as a tradable index to be used as an underlying asset for structured products and for standardized derivatives (future).
OMX Tallinn Index – Tallinn Stock Exchange	an all-share index which includes all the shares listed on the Main and Secondary lists on the NASDAQ OMX Tallinn (the Tallinn Stock Exchange is the only regulated exchange in Estonia) with exception of the shares of the companies where a single shareholder controls at least 90% of the outstanding shares.
BUX Index – Budapest Stock Exchange	the official index of blue-chip shares listed on the Budapest Stock Exchange Ltd. The index shows the average price changing of the shares with the biggest market value and turnover in the equity section.
Bovespa Index – BM&FBOVESPA Stock Exchange	the main indicator of the Brazilian stock market's average performance. Ibovespa's relevance comes from two facts: it reflects the variation of BM&FBOVESPA's most traded stocks and it has tradition, having maintained the integrity of its historical series without any methodological change since its inception in 1968.
RTS Index – "Russian Trading System" Stock Exchange	the composite index of the Russian stock market calculated by Moscow Interbank Currency Exchange ("ZAO MICEX").
SENSEX Index – Bombay Stock Exchange	first compiled in 1986, was calculated on a "Market Capitalization-Weighted" methodology of 30 component stocks representing large, well-established and financially sound companies across key sectors. Since September 1, 2003, SENSEX is being calculated on a free-float market capitalization methodology. As the oldest index in the country, it provides the time series data over a fairly long period of time (from 1979 onwards).
SSE Composite Index – Shanghai Stock Exchange	was launched on July 15, 1991. Constituents are all listed stocks (A shares and B shares) at Shanghai Stock Exchange.The Base Day for SSE Composite Index is December 19, 1990. The Base period is the total market capitalization of all stocks of that day.

The time series cover a period of 10 years, from october 2002 to october 2012. The data consist of around 2500 daily values of every index. The returns have been measured using the first difference of monthly logarithmic price index:

$$R_t = d\log_e(C_t) = \log_e(C_t) - \log_e(C_{t-1})$$

Our empiric test followed the research of the random walk hypothesis of every index, using the following tests:

- Tests looking for the existance of the normality hypothesis of distributed instantaneous returns (logarithmic) of stock indices: we use the graphical analysis, Jarque-Bera test and QQ-plot test;
- Stationary tests for instantaneous returns (logarithmic) of stock indices: unit root tests (Augmented Dickey-Fulle test, Phillips-Perron test, autocorrelation coefficients and Ljung-Box test), run test and variance ratio test.

3. Empirical results

I. Tests on the hypothesis of normality of instantaneous returns of indices

In order to test the normality distribution hypothesis of the logarithmic (or continuously compounded) returns of indices it is used the Jarque-Bera test and QQ-plot test.

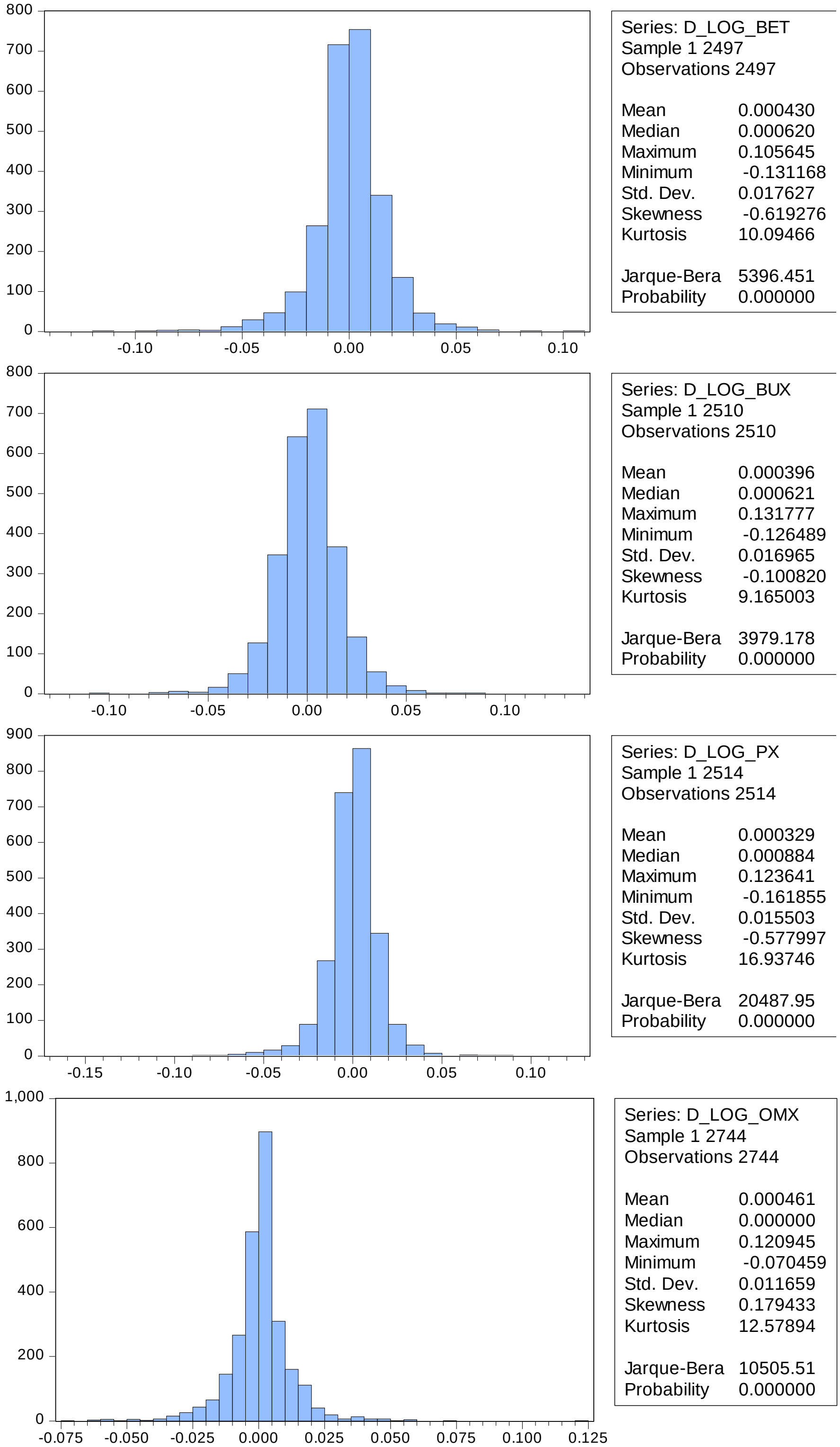
To study the normality, there are used the following indicators: Kurtosis, Skewness and Jarque-Bera.

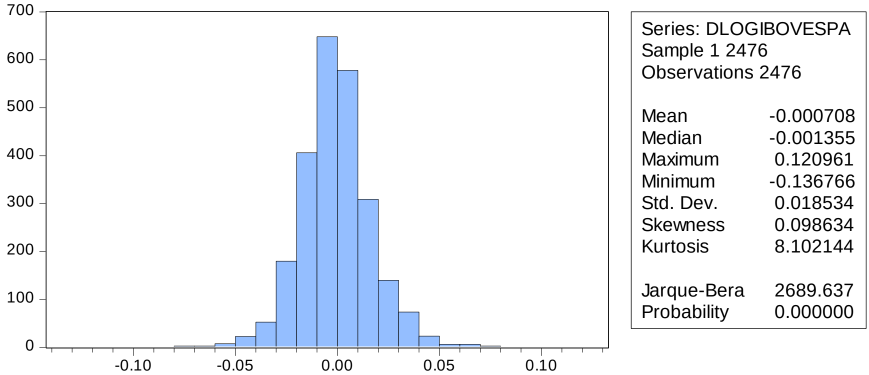
The Jarque–Bera test is a test of whether sample data of returns have the skewness and kurtosis matching a normal distribution. Samples from a normal distribution have an expected skewness of 0 and an expected excess kurtosis of 0 (which is the same as a kurtosis of 3). As the definition of JB shows, any deviation from this increases the JB statistic. If kurtosis is bigger than 3, the distribution is called leptokurtotic and if it is less than 3, platykurtotic.

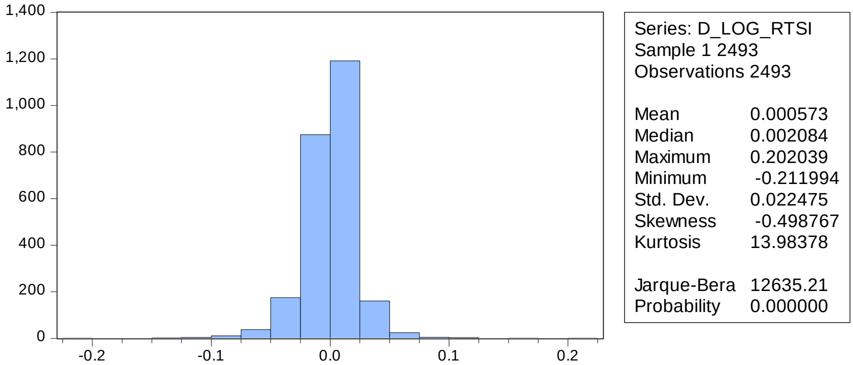
Also, to test the hypothesis of normality of instantaneous returns of indices, we used QQ-plot test. Theoretical quantile-quantile plots are used to assess whether the data in a single series follow a specified theoretical distribution. If the two distributions are the same, the QQ-plot should lie on a straight line. If the QQ-plot does not lie on a straight line, the two distributions differ along some dimension. The pattern of deviation from linearity provides an indication of the nature of the mismatch.

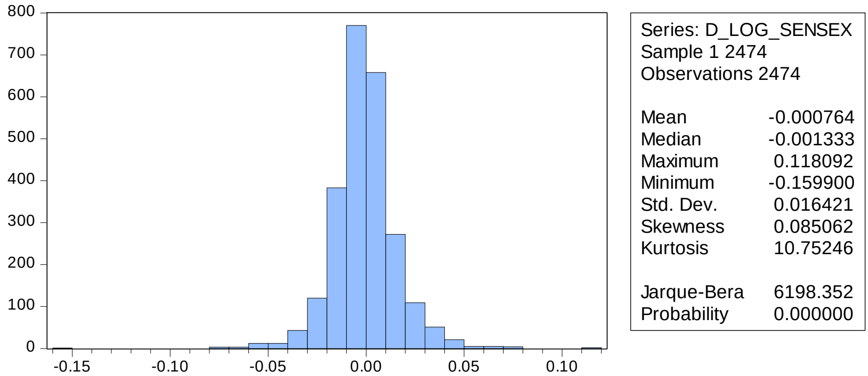
The graphics of the Jarque-Bera and QQ-plot tests for every index are presented below:

Figure 1 – Jarque-Bera test




Series: DLOGIBOVESPA
Sample 1 2476
Observations 2476
Mean -0.000708
Median -0.001355
Maximum 0.120961
Minimum -0.136766
Std. Dev. 0.018534
Skewness 0.098634
Kurtosis 8.102144
Jarque-Bera 2689.637
Probability 0.000000


Series: D_LOG_RTSI
Sample 1 2493
Observations 2493
Mean 0.000573
Median 0.002084
Maximum 0.202039
Minimum -0.211994
Std. Dev. 0.022475
Skewness -0.498767
Kurtosis 13.98378
Jarque-Bera 12635.21
Probability 0.000000


Series: D_LOG_SENSEX
Sample 1 2474
Observations 2474
Mean -0.000764
Median -0.001333
Maximum 0.118092
Minimum -0.159900
Std. Dev. 0.016421
Skewness 0.085062
Kurtosis 10.75246
Jarque-Bera 6198.352
Probability 0.000000

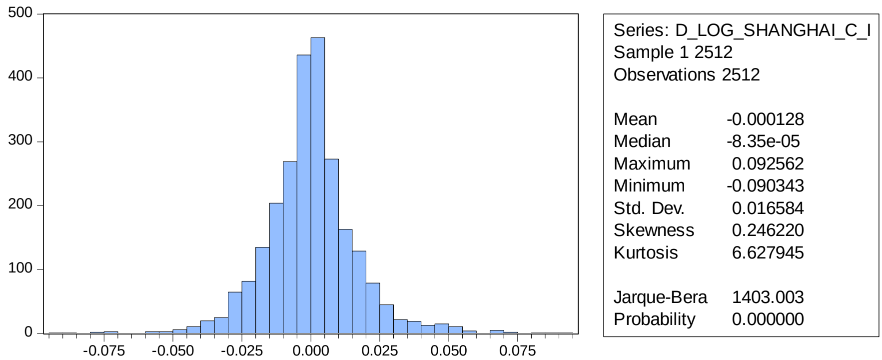
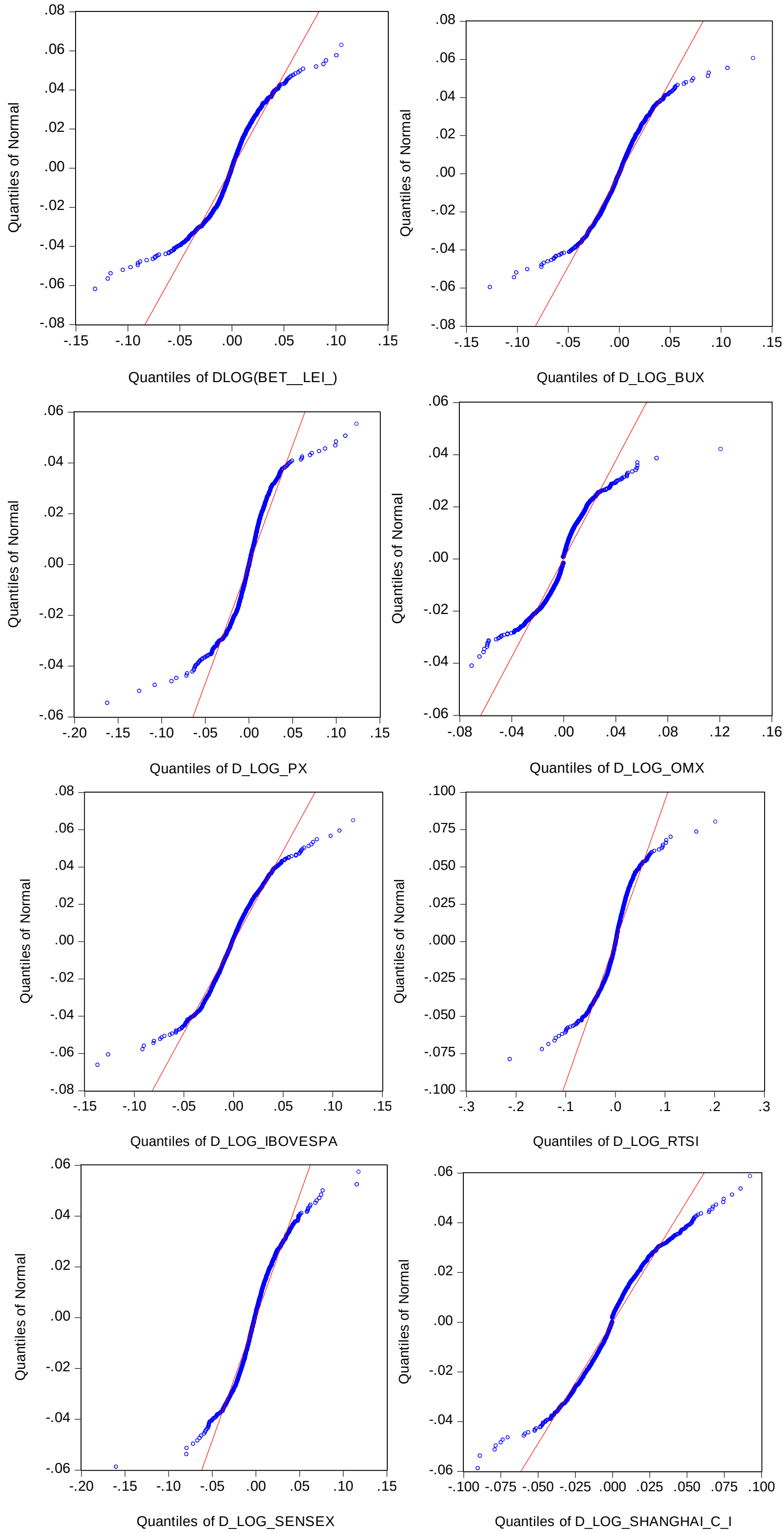

Series: D_LOG_SHANGHAI_C_I
Sample 1 2512
Observations 2512
Mean -0.000128
Median -8.35e-05
Maximum 0.092562
Minimum -0.090343
Std. Dev. 0.016584
Skewness 0.246220
Kurtosis 6.627945
Jarque-Bera 1403.003
Probability 0.000000

Figure 2 – Quantile-Quantile plot



The main results from the upper histograms and QQ-plots are presented as follows:

- The lowest mean returns is observed in India, with a value of -0.076% and in Brazil (-0.07%) and the highest mean returns are for the Russian index returns (0.057%). The market risk measured using standard deviation is higher in Russia, this capital market being characterised by a higher volatility and lower in Estonia.
- A negative skewness shows that the lower deviations from the mean are larger than the upper deviations, indicating a greater probability of large deceases than rises. The BET, BUX, PX and RTSI series are asymmetric on the left, because the Skewness indicator (the asymmetry coefficient) is negative. Also, the OMX, IBOVESPA, SENSEX and Shanghai_C_I are asymmetric on the right, because the Skewness indicator (the asymmetry coefficient) is positive. The Kurtosis indicator (the flattening coefficient) shows us that the series have a vaulting superior to the one specific to the normal distribution (k=3), the distribution of the daily instantaneous returns of all the eight indices being leptokurtosis. If the associated probability of the test is bigger than the chosen relevance level (1, 5, 10%), the null hypothesis of normal distribution is accepted. In our study, because the value of the associated probability is zero, the null hypothesis of normal distribution of indices is rejected.
- As it can be noticed from the analyzed data, the QQ-plot charts for all the indices highlight the fact that the daily yields are not normally distributed. Also, we cannot conclude that the series distributions are normal based on the Jarque-Bera test. Almost all markets exhibits significant deviations from normality. Because of the correlation existing between yields, and because they do not have a normal distribution, we reject the hypothesis that these time series are random walk type and so, serious question marks are raised regarding the existence of weak form informational efficiency on the these eight emergent capital markets.

The further analysis requires that whether the time series are non-stationary or stationary.

II. Stationary tests for instantaneous returns of BET index

The stationary tests for instantaneous yields (logarithmic) of stock index used are: unit root tests, run test and variance ratio test.

a. Unit root tests

To test the stationary for instantaneous returns, daily calculated, of the stock indices we use Augmented Dickey-Fuller (ADF) and Phillips-Perron tests. Also, the autocorrelation coefficients are calculated and the Ljung-Box test is used.

Augmented Dickey-Fuller is the most popular stationary test. It was presented by the statisticians David Alan Dickey and Wayne Arthur Fuller in 1979 and

1981. ADF test is used to test the unit root hypothesis. If one time series has unit root that means it is nonstationary and it follows random walk. ADF Test Statistic and PP Test Statistic represent the t test for accepting or rejecting the null hypothesis of the Dickey-Fuller and Phillips Perron tests. To reject the null hypothesis (series is unit root), if the value of the t statistic test is less than the critical value for the significant level chosen. ADF test implies that the series of natural logarithms of indices, analyzed by us, follow the stochastic process1, type AR(1). Phillips-Perron test is a test that does not include in the tested equation differences between the past series and is using the method of least squares in a simple form. The test itself is a t-statistic for regression coefficient, but adjusted to remove errors.

After the data adaptation using EViews 7, the results of ADF test for the level and for the first difference are shown below:

Table 2 - Augmented Dickey-Fuller Unit-Root Test for UE emergent countries

	Augmented Dickey-Fuller Unit-Root Test Test at level (UE emergent countries)			
	Romania (BET)	Hungary (BUX)	Czech Republic (PX)	Estonia (OMX)
t-Statistic	-2.108449	-2.400883	-2.660694	-2.048444
1% level	-3.432776	-3.432764	-3.432760	-3.432542
5% level	-2.862498	-2.862492	-2.862490	-2.862394
10% level	-2.567325	-2.567322	-2.567321	-2.567269
	Augmented Dickey-Fuller Unit-Root Test Test at first difference (UE emergent countries)			
	Romania (BET)	Hungary (BUX)	Czech Republic (PX)	Estonia (OMX)
t-Statistic	-45.05436	-37.16422	-37.30376	-44.89769
1% level	-3.432776	-3.432764	-3.432760	-3.432542
5% level	-2.862498	-2.862492	-2.862490	-2.862394
10% level	-2.567325	-2.567322	-2.567321	-2.567269

Table 3 - Augmented Dickey-Fuller Unit-Root Test for BRIC emergent countries

	Augmented Dickey-Fuller Unit-Root Test Test at level (BRIC emergent countries)			
	Brazilia (IBOVESPA)	Rusia (RTSI)	India (SENSEX)	China (Shanghai_C_I)
t-Statistic	0.868842	-2.116637	0.717162	-0.823768
1% level	-3.432797	-3.432780	-3.432800	-3.432760
5% level	-2.862507	-2.862500	-2.862508	-2.862490
10% level	-2.567330	-2.567326	-2.567331	-2.567321
	Augmented Dickey-Fuller Unit-Root Test Test at first difference (BRIC emergent countries)			
	Brazilia (IBOVESPA)	Rusia (RTSI)	India (SENSEX)	China (Shanghai_C_I)

t-Statistic	-49.73613	-44.31588	-46.37489	-0.847005
1% level	-3.432798	-3.432780	-3.432800	-3.432760
5% level	-2.862507	-2.862500	-2.862508	-2.862490
10% level	-2.567330	-2.567326	-2.567331	-2.567321

The first part of the test displays the results of the test and the critical values for every relevance level (1,5,10%). If the test value is bigger than the critical one, the null hypothesis is not rejected (the series has one unit root, it is non-stationary). In our case the null hypothesis is not rejected in almost all cases. All BRIC countries have non-stationary indices series for the level. Romania, Hungary and Estonia present non-stationary indices series for the level, and also Czech Republic but only for 1% and 5% relevance level. These results don't admit the rejection of the null hypothesis of random walk evolution of the returns, implying an important probability that the weak-form of informational efficiency exists in these emergent capital markets. But still these tests are not sufficient in order to assert certainly that the capital markets are weak efficient in terms of information.

According to tables above, the time series of indices is non-stationary at order I(0). In order to determine the order of integration of the series, we test the stationarity of the first difference of indices series. The value of ADF statistics is significantly smaller than the critical values at 1%, 5% and 10% significance level. The null hypothesis is rejected. Time series of all indices are stationary and they don't have a unit root nor they follow random walk. At the same time we reject the hypothesis of weak for efficiency for the capital markets in the eight countries we have studied.

Phillips-Perron test operates using the same principle as ADF. The obtained results are similar using P-P test:

Table 5 - Phillips-Perron Unit-Root Test for UE emergent countries

	Phillips-Perron Unit-Root Test Test at level (UE emergent countries)			
	Romania (BET)	Hungary (BUX)	Czech Republic (PX)	Estonia (OMX)
t-Statistic	-2.095866	-2.421191	-2.615938	-2.006146
1% level	-3.432775	-3.432762	-3.432757	-3.432541
5% level	-2.862497	-2.862491	-2.862489	-2.862394
10% level	-2.567325	-2.567322	-2.567321	-2.567269
	Phillips-Perron Unit-Root Test Test at first difference (UE emergent countries)			
	Romania (BET)	Hungary (BUX)	Czech Republic (PX)	Estonia (OMX)
t-Statistic	-45.09237	-47.15599	-46.83056	-47.59733
1% level	-3.432776	-3.432763	-3.432759	-3.432542
5% level	-2.862498	-2.862492	-2.862490	-2.862394
10% level	-2.567325	-2.567322	-2.567321	-2.567269

Table 6 – Phillips-Perron Unit-Root Test for BRIC emergent countries

	Phillips-Perron Unit-Root Test Test at level (BRIC emergent countries)			
	Brazilia (IBOVESPA)	Rusia (RTSI)	India (SENSEX)	China (Shanghai_C_I)
t-Statistic	1.159058	-2.129833	0.814556	-0.847005
1% level	-3.432797	-3.432779	-3.432799	-3.432760
5% level	-2.862507	-2.862499	-2.862508	-2.862490
10% level	-2.567330	-2.567326	-2.567330	-2.567321
	Phillips-Perron Unit-Root Test Test at first difference (BRIC emergent countries)			
	Brazilia (IBOVESPA)	Rusia (RTSI)	India (SENSEX)	China (Shanghai_C_I)
t-Statistic	-49.97014	-44.20696	-46.31083	-50.16873
1% level	-3.432798	-3.432780	-3.432800	-3.432761
5% level	-2.862507	-2.862500	-2.862508	-2.862491
10% level	-2.567330	-2.567326	-2.567331	-2.567321

By putting into practice the two methodologies of testing we can conclude: the null hypothesis is accepted for level, and for the difference it is not accepted, therefore all the indices are of 1 order (with 1% level of significance).

To further analyze the randomness of the return series we used **serial autocorrelation and Ljung-Box Q-statistics**. As a test on independence of the instantaneous returns distributions, we calculated the autocorrelation between the instantaneous yields with a lag of k according to the formula:

$$\rho_k = \frac{\operatorname{cov}ar(d\ln S_t, d\ln S_{t-k})}{\operatorname{var}(d\ln S_t)}$$

The autocorrelation function test is examined to identify the degree of autocorrelation in a time series. It measures the correlation between the current and lagged observations of the time series of stock returns. If time series has unit root, than the autocorrelation function (ACF) slowly decrease starting from the value of one and the partial correlation function (PACF) has only first value which differs from zero. If one time series has two unit roots, ACF act the same way as for the one unit root series, but the PACF has only first two nonzero values. In order for a time series to be integrable by order 1, the autocorrelation coefficients must be close to 1, and the autocorrelation coefficients for the first difference must be (statistically significant) less than 1.

Another technique that will be used for testing the autocorrelation is Ljung-Box (1979), for autocorrelations with lag more or equal to 1. The Ljung–Box test is a type of statistical test of whether any of a group of autocorrelations of a time series are different from zero. Instead of testing randomness at each distinct lag, it tests the "overall" randomness based on a number of lags, and is therefore a portmanteau test. This test is sometimes known as the Ljung–Box Q test, and it is closely connected to the Box–Pierce test.

The autocorrelation coefficients for 12 lags and the partial correlation coefficients of the series for the level and for the first difference are analysed. The following results regarding these tests are obtained:

Table 7 - Autocorrelation and Q-Statistics for Returns (values for the first difference)

	IBOVESPA			RTSI			SENSEX			Shanghai_C_I		
	AC	Q-stat	Prob	AC	Q-stat	Prob	AC	Q-stat	Prob	AC	Q-stat	Prob
1	-0.001	0.0042	0.949	0.118	34.846	0.000	0.069	11.819	0.001	-0.001	0.0049	0.944
2	-0.038	3.5367	0.171	0.009	35.065	0.000	-0.044	16.568	0.000	-0.011	0.3055	0.858
3	-0.066	14.283	0.003	-0.042	39.510	0.000	-0.009	16.768	0.001	0.046	5.6100	0.132
4	-0.007	14.407	0.006	0.023	40.876	0.000	0.004	16.800	0.002	0.046	10.883	0.028
5	-0.010	14.660	0.012	-0.001	40.881	0.000	-0.033	19.469	0.002	-0.022	12.106	0.033
6	-0.015	15.209	0.019	0.009	41.079	0.000	-0.043	24.064	0.001	-0.037	15.632	0.016
7	-0.036	18.443	0.010	0.032	43.632	0.000	0.013	24.456	0.001	0.012	16.001	0.025
8	0.034	21.372	0.006	-0.073	56.948	0.000	0.058	32.908	0.000	-0.018	16.791	0.032
9	-0.008	21.547	0.010	-0.016	57.602	0.000	0.028	34.913	0.000	0.002	16.798	0.052
10	0.044	26.314	0.003	-0.008	57.753	0.000	0.026	36.595	0.000	0.032	19.408	0.035
11	-0.012	26.688	0.005	0.025	59.382	0.000	-0.020	37.564	0.000	0.025	21.013	0.033
12	0.013	27.089	0.008	0.024	60.779	0.000	0.003	37.579	0.000	0.022	22.263	0.035

	BET			BUX			OMX			PX		
	AC	Q-stat	Prob	AC	Q-stat	Prob	AC	Q-stat	Prob	AC	Q-stat	Prob
1	0.089	19.717	0.000	0.058	8.5991	0.003	0.152	63.832	0.000	0.065	10.782	0.001
2	-0.000	19.718	0.000	-0.075	22.835	0.000	0.059	73.298	0.000	-0.081	27.200	0.000
3	0.011	20.024	0.000	-0.027	24.647	0.000	0.067	85.766	0.000	-0.049	33.149	0.000
4	-0.033	22.750	0.000	0.068	36.390	0.000	0.017	86.554	0.000	0.033	35.970	0.000
5	0.008	22.893	0.000	0.045	41.507	0.000	0.057	95.602	0.000	0.053	43.133	0.000
6	-0.010	23.123	0.001	-0.038	45.150	0.000	0.044	100.97	0.000	-0.015	43.689	0.000
7	0.035	26.111	0.000	-0.069	57.204	0.000	0.019	101.93	0.000	-0.023	45.056	0.000
8	0.043	30.830	0.000	0.012	57.595	0.000	0.060	111.91	0.000	0.003	45.078	0.000
9	0.012	31.211	0.000	0.056	65.501	0.000	0.072	126.17	0.000	0.012	45.444	0.000
10	-0.021	32.356	0.000	0.003	65.524	0.000	0.051	133.24	0.000	0.033	48.269	0.000
11	0.064	42.511	0.000	-0.032	68.042	0.000	0.043	138.37	0.000	-0.008	48.427	0.000
12	0.019	43.424	0.000	-0.024	69.454	0.000	0.050	145.32	0.000	0.019	49.349	0.000

Based on the obtained results, we can conclude that the indices represent stationary time series. The values of ACF and PACF decrease slowly and ACF and PACF have very small values which all implies that the analyzed series are stationary. Stationary goes hand in hand with inefficiency of these emergent capital markets. Also, the linear dependence of the returns is highlighted by the significant values of the autocorrelation coefficients for the level (e.g. for AC for BET lag 1 – 0,998). Also, by applying the Ljung-Box test we determined the fact that there are linear dependencies, the p values being smaller that the critical value of 0.05. If p-value < 0.05 of the Q-

Statistics, the null hypothesis of the entire autocorrelation coefficients together equal to zero may be rejected at 0.05 level of significance. Therefore it is inferred that the historical returns can be used to predict future returns and this element indicates that the weak form of market efficiency does not hold. The P-values in table above at first difference indicates that the null is rejected for all markets. From lag 1 to lag 3 and for lag 9 the equity market of China shows little efficiency (a weak-form efficiency). This is the case of Brasil, which also shows proof of little efficiency from lag 1 to 2.

b. Run test

The run test is a non-parametric test whereby the number of sequences of consecutive positive and negative returns is tabulated and compared against its sampling distribution under the random walk hypothesis. In the stock market, run test of randomness is applied to know if the stock price of a particular company is behaving randomly, or if there is any pattern. Run test of randomness is basically based on the run. Run is basically a sequence of one symbol such as + or -. A run is defined as the repeated occurrence of the same value or category of a variable. The procedure first classifies each value of the variable as falling above or below a cut point and then tests to ensure that there is no order to the resulting sequence. Because it is a function of the number of positive and negative cases, the expected number of runs always depends on the cut point. The results of the runs test may depend on the choice of cut point.

Under the null hypothesis that successive outcomes are independent, the total expected number of runs is distributed as normal with the following mean and the following standard deviation:

$$E(R) = \frac{n + 2n_A n_B}{n}$$

$$\sigma_R = \sqrt{\frac{2n_A n_B (2n_A n_B - n)}{n^2 (n-1)}}$$

where n is the total number of observations, n_A is the number of first run cycle, and n_B is the number of second run cycle. Number of runs is marked with R. The test for serial dependence is carried out by comparing the actual number of runs, to the expected number. The null proposition is: H_0 : E(runs) = E(R).. and checks a randomness hypothesis for a two-valued data sequence. The H0 elucidates that the succeeding price changes are not dependent and moves randomly. If the number of observations is large its distribution is almost equal to normal distribution. That is why we can use standard normal Z distribution for implementing Run test. The formula for standard score is:

$$Z = \frac{R - E(R)}{\sigma_R}$$

If calculated Z value is different than critical value with appropriate significance level, than we can reject null hypothesis and conclude that analyzed stock index can be predicted. In that case capital market will not satisfy weak form of market efficiency.

The results of basic parameters for the Run test applied on time series indices are given in the tables bellow (performed in SPSS):

Table 8 – Run test for UE emergent countries

	Run Test BET		Run Test BUX		Run Test PX		Run Test OMX	
	1: Median dl	2: Mode dlog	1: Median dlog	2: Mode dlog	1: Median dlog	2: Mode dlog	1: Median dlog	2: Mode dlog
n_A	1248	1149	1255	904	1257	1165	1170	1170
n_B	1249	1348	1255	1606	1257	1349	1574	1574
n	2497	2497	2510	2510	2514	2514	2744	2744
R	1135	1152	1271	1147	1264	1245	1145	1145
E(R)	1249,5	1241,57	1256	1157,832	1258	1251,267	1343,259	1343,259
σ_R	24,979	24,8212	25,04496	23,08512	25,06491	24,93059	25,61897	25,61897
Z	-4,584	-3,609	0,599	-0,469	0,239	-0,251	-7,739	-7,739
Z_α=0,05	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96
Hypoth.	H_1	H_1	H_0	H_0	H_0	H_0	H_1	H_1

Note: for these nonparametric runs tests it was used SPSS 11.0; own computations

Table 9 – Run test for BRIC emergent countries

	Run Test IBOVESPA		Run Test RTSI		Run Test SENSEX		Run Test Shanghai_C_I	
	1: Median dlog	2: Mode dlog	1: Median dlog	2: Mode dlog	1: Median dlog	2: Mode dlog	1: Median dlog	2: Mode dlog
n_A	1238	1329	1246	1013	1237	2473	1256	1266
n_B	1238	1147	1247	1480	1237	1	1256	1246
n	2476	2476	2493	2493	2474	2474	2512	2512
R	1236	1230	1214	1152	1179	3	1231	1227
E(R)	1239	1232,31	1247,4997	1203,76	1238	2,9991	1257	1256,92
σ_R	24,8746	24,7402	24,9599	24,0837	24,86463	0,028421	25,05494	25,05335
Z	-0,121	-0,093	-1,342	-2,149	-2,373	0,028	-1,038	-1,194
Z_α=0,05	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96	±1,96
Hypoth.	H_0	H_0	H_0	H_1	H_1	H_0	H_0	H_0

Note: for these nonparametric runs tests it was used SPSS 11.0; own computations

The number of runs represents the observed runs in the test variable. We performed two run tests: in the first one, the cut point is the sample median and in the second one, the cut point is the mode. The distribution of ratings is actually bimodal. If the order of the ratings is purely random with respect to the median value, for BET index you would expect about 1250 runs across these 2497 cases. Because they are observed only 1135 runs, the Z statistic is negative (-4,584). The second run test, with respect to the median value, you would expect about 1242 runs across these 2497 cases. Because they are observed only 1152 runs, the Z statistic is also negative (-

3,609). So the final conclusion would be that the Romanian capital market doesn't satisfy the weak form of efficiency. It is inefficient because movement of the stock prices can be predicted.

During the period 2002-2012, the results for the eight emergent countries are different, in the sense that for 2 countries, Romania and Estonia, the total cases of runs is significantly less than the expected number of runs. Also Russia at cut point = mode as well as India at cut point = median have less expected number of runs against total cases so these markets clearly reject the random walk hypothesis. According to results, during the 10-years period, all the other capital markets, in Hungary, Czech Republic, Brazil, China, Russia (at cut point = median) and India (at cut point = mode) are weak-form efficient.

However, these results must be testified by using the more modern Variance Ratio test introduced by to Lo and MacKinlay (1988). If the Variance Ratio test statistic > 1, then the series is positively correlated.

c. Variance ratio test

The question of whether asset prices are predictable has long been the subject of considerable interest. One popular approach to answering this question, the Lo and MacKinlay (1988, 1989) overlapping variance ratio test, examines the predictability of time series data by comparing variances of differences of the data (returns) calculated over different intervals. A significant assumption of the random walk theory is investigated through variance ratio test. If we assume the data follow a random walk, the variance of a q-period difference should be q times the variance of the one-period difference. Evaluating the empirical evidence for or against this restriction is the basis of the variance ratio test.

EViews 7 application was used to perform the Lo and MacKinlay variance ratio test, in order to determine whether differences in indices series are uncorrelated, or follow a random walk or martingale property. We performed the test using the log differences data in indices series (we assumeed that the data follow an **Exponential** random walk so that the innovations are obtained by taking log differences). We analized the basic Lo and MacKinlay variance ratio statistic assuming heteroskedastic increments to the random walk. We identified four test periods (2, 5, 10, 30), as the intervals whose variances we wished to compare to the variance of the one-period innovations.

Of interest for our analysis is whether the indices returns, as measured by the log differences of the prices, are *i.i.d.* or martingale difference, or alternately, whether the indices returns themselves follow an exponential random walk.

The results are shown in table 10 and 11:

Table 10 – Variance ratio test UE emergent countries

	BET		BUX		OMX		PX	
Period (J)	Var. ratio	Probability	Var. ratio	Probability	Var. ratio	Probability	Var. ratio	Probability
2	1.102589	0.0000	1.058123	0.0036	1.152422	0.0000	1.065435	0.0010
5	1.124450	0.0045	1.007950	0.8557	1.374668	0.0000	0.982064	0.6815
10	1.173494	0.0102	1.015966	0.8127	1.624794	0.0000	0.991122	0.8951
30	1.565846	0.0000	1.098608	0.4230	2.272197	0.0000	1.172380	0.1610

Table 11 – Variance ratio test BRIC emergent countries

	IBOVESPA		RTSI		SENSEX		Shanghai_C_I	
Period (J)	Var. ratio	Probability	Var. ratio	Probability	Var. ratio	Probability	Var. ratio	Probability
2	0.997402	0.8971	1.118105	0.0000	1.068856	0.0006	0.998425	0.9371
5	0.895974	0.0181	1.175489	0.0001	1.051226	0.2448	1.039410	0.3673
10	0.803383	0.0038	1.188420	0.0053	1.013538	0.8419	1.046720	0.4880
30	0.842307	0.2032	1.354500	0.0041	1.177990	0.1511	1.240921	0.0502

If the Variance Ratio test statistic > 1, then the series is positively correlated. In our study it does not holds true for all countries. In the case of Brazil, Czech Republic (at period = 5, 10) and China (for period = 2) the test shows that the indices series are not positively correlated. The standardized VR test statistics is significant ($p<0.05$) at J = 2 for all countries except Brazil and China. At J=5 and 10 it is significant in all cases except Hungary, Czech Republic, India and China. At J=30 the Variance Ratio test is significant only in the case of Romania, Estonia and Russia. For Romania, Estonia and Russia it is significant for all periods, but in China it is not significant at all.

The individual statistics generally reject the null hypothesis, so the series cannot be fairly treated as random walks. It suggests that the indexes are imperfectly adjusted under the impact of informational shocks and displays some rigidities in their formation mechanisms.

4. Conclusions

This empirical study investigates the weak form of market efficiency in the emergent capital markets. The sample size consists of eight equity markets from UE and BRIC countries. The purpose of the applied statistical tests was whether the selected equity markets follow the random walk model at individual level or not. No arbitrage profits can be earned if the equity markets are efficient at individual level.

To verify the normality distribution hypothesis of the logarithmic (or continuously compounded) returns of indices we used Jarque-Bera test and QQ-plot test. The results reveal that the Jarque-Bera test rejects the hypothesis of a normal distribution for almost all markets. Because of the correlation existing between yields, and because they do not have a normal distribution, we reject the hypothesis that these time series are random walk type.

To test the stationary for instantaneous returns, daily calculated, of the stock indexes on the eight emergent capital markets, we used Augmented Dickey-Fuller (ADF) and Phillips-Perron tests. Also, the autocorrelation coefficients were calculated and the Ljung-Box test was used. All BRIC countries have non-stationary indices series for the level. Romania, Hungary and Estonia present non-stationary indices series for the level, and also Czech Republic but only for 1% and 5% relevance level. These results don't admit the rejection of the null hypothesis of random walk evolution of the returns, implying an important probability that the weak-form of informational efficiency exists in these emergent capital markets.

Based on the obtained results, the indices represent stationary time series. Stationary goes hand in hand with inefficiency of these emergent capital markets. Also, the linear dependence of the returns is highlighted by the significant values of the autocorrelation coefficients for the level. Also, by applying the Ljung-Box test we determined the fact that there are linear dependencies. Even in cases when the normality hypothesis of the instantaneous returns cannot be dismissed, the statistical tests performed for indices indicate the fact that the evolution of returns is dependent from one period to another (autocorrelation coefficients are significantly different from zero), which invalidates the efficiency hypothesis of weak form market. They may suggest using past information to obtain abnormal returns. Under these conditions, using models based on the efficiency hypothesis seems unspecified in order to obtain useful results.

To verify the weak form of efficiency, also runs test and variance ratio tests were applied for this purpose. Emerging markets are typically characterized by a non-linear information behavior in stock prices. In these conditions we will use in the future studies BDS Independence Test in order to test for time based dependence in a series. It can be used for testing against a variety of possible deviations from independence including linear dependence, non-linear dependence, or chaos.

The research of emergent markets efficiency will have new dynamics because, beside the classical analysis instruments, new research models will be applied based on the technical progress and on the high speed of incorporating the information. As a conclusion, all the efficiency tests, the scientific identification of markets inefficiencies help the improvement of our knowledge regarding the assets behavior and the returns evolution in time. They help to improve the assets evaluation models, but also the practices and the vision of professionals in the capital markets.

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