TESTING THE WEAK-FORM EFFICIENCY OF THE ROMANIAN CAPITAL MARKET BY ASSESSING THE RANDOM WALK-LIKE BEHAVIOUR OF STOCK PRICES

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Abstract

This paper attempts to test the efficiency of the Romanian Capital Market by assessing some basic statistical properties of prices for the ten most liquid stocks listed on the Bucharest Stock Exchange. More specifically, by testing if stock price series exhibit a random walk-like behaviour. For robustness of the results, two unit root tests—the Augmented Dickey-Fuller and the Kwiatkowski-Phillips-Schmidt-Shin—are used to measure stationarity for both prices and returns, and determine if price dynamics is determined by an order one integrated process (a proxy for the random walk). Further Lo and MacKinley's Variance Ratio Test is applied to study if the variance of returns is a linear time-dependent function (a well-known property of a random variable). The analysis is done for a period between 15 October 1997, or the listing date on the stock exchange, respectively, and 10 April 2013, for both daily and weekly observations. Furthermore, to take into account the distortive effects of the financial turmoil from 2007-2009 on market efficiency, a separate analysis has been conducted for two sub-periods, pre- and post-recession, respectively.

Keywords: *Financial Markets, Random Walk, Stationarity, Unit Root Test, Variance Ratio Test*

JEL Classification: *G12, G14, G17, C58*

1. Introduction

According to Fama (1970:383) „a market in which prices fully reflect all available information is called efficient." Nevertheless, efficiency is a relative term and can be measured only against certain hypothesis. Fama (1991:1575) highlights that „market efficiency per se is not testable. It must be tested jointly of some model of equilibrium, an asset-pricing model." It is generally accepted that there exist three levels of efficiency which a market might have—weak, semi-strong and strong—depending on the type of information embedded in stock prices. However, the focus of this paper is only on the weak form efficiency of capital markets, as this is the level of efficiency that characterises emerging markets such as the Bucharest Stock Exchange. The weak-form efficiency asserts that the only relevant information set to determine current security prices is the historical price series of that particular security. In most of the empirical literature, the presumed random walk behaviour of stock prices is used as the basis hypothesis to test for weak-form efficiency, since new information is deemed to come in a random fashion in an efficient market. The market efficiency hypothesis is assessed by testing if price time series follow a random walk-like behaviour. In order to accomplish this, two important properties of a random walk are assessed, namely stationarity of price return and linear time-dependence of price return variance.

Although a number of studies on the efficiency of the Romanian capital market have been conducted, no clear results emerged. Todea (2002) tested the stationarity and autocorrelation of daily stock price return sequences for ten companies listed on the Bucharest Stock Exchange (for the period 1997-2000), and concluded that the market is efficient in its weak form. Dragota et al. (2009) applied a series of statistical tests (Cowles-Jones, binary cycles, Variance Ratio Test) to a set of 19 stocks and 4 indexes and arrived at the same conclusion. Dima and Milos (2009) tested the random walk hypothesis on the BET daily series between 2000 and 2009 by performing stationarity tests (ADF, KPSS and ERS) and found some empirical evidence of informational efficiency (in its weak-form). On the other hand, Barna et al. (2003) tested the stationarity of the daily price series for the BET and BET-C indexes, between January 1999 and March 2003, by performing unit root tests (ADF) for both level and first order difference and rejected the hypothesis of market efficiency. Dragota and Mitrica (2004) studied a sample of 6 companies listed on the first category of the Bucharest Stock Exchange for the period 1998-2000 and concluded that the market is not efficient in its weak form. These findings are reinforced by those of Stanculescu and Mitrica (2012) who analysed the stationarity of the 10 most liquid securities on the Bucharest Stock Exchange by performing unit root tests (ADF and Phillips-Perron).

2. Methodology and data

2.1. Data set

The analysis is conducted on a sample of ten of the most liquid stocks traded on the first category of the Bucharest Stock Exchange (TLV, BRD, BIO, SNP, BKR, SIF1, SIF2, SIF3, SIF4 and SIF5) and comprises daily and weekly price series. The data was collected from the online portal kmarket.ro on 10 April 2013. The observation period for each stock is from its listing date on the Bucharest Stock Exchange until 10 April 2013. To take into consideration the distortive effects of the 2007-2009 financial crises on the local capital market, a sub-period analysis has also been conducted. The reference date for the pre- and post-crisis analysis has been set to 31 August 2007. As the analysis is done for relatively low frequencies (daily and weekly observations) one can omit gains attributable to owning stocks (e.g., dividends). Furthermore, financial intermediation commissions, management commissions and slippage costs can also be neglected. Hence, the return of stocks can be approximated through the first order difference of prices.

2.2. Random walk model

As discussed above, the standard method for assessing the market efficiency is testing the random behaviour of price changes. This is accomplished by assessing if price movements are determined by stochastic processes described by the following relation:

$$P_t=\mu+P_{t-1}+\varepsilon_t \qquad (1)$$

Where P_t is the price at period t, μ is the expected price change (the drift) and ε_t represents white noise ($\varepsilon_t \sim N(0,\sigma^2)$). According to relation (1), the best price estimate for $t+1$ is the price in t. As a consequence, the historical analysis of prices is senseless as future price changes are purely random.

If relation (1) holds, the expected value of the price ($E[P_t]=P_0+\mu t$) and its associated risk ($Var[P_t]= t\sigma^2$) can be estimated, for any given moment in the future. Also, two important characteristics of a random walk can be derived—the underlying process that generates the random walk is not stationary in level (i.e., its mean and variance are not constants) and that its variance is a linear function of time. If $Var[P_t]$ is considered to be the squared risk of price volatility, it results that this variable increases in time by a constant factor (σ).

To derive the next property relation (1) has to be rewritten in the following form:

$$r_t=\mu+\varepsilon_t \qquad (2)$$

Where $r_t=P_t-P_{t-1}$ is the change in price at moment t. As $\varepsilon_t \sim N(0,\sigma^2)$ it follows that rt is also normally distributed, with mean $E[r_t]=\mu$ and variance $Var[r_t]=\sigma^2$. It can be easily deducted that the price change (the return) is stationary. A necessary condition for a time series to follow a random walk process is for its first order difference to be stationary. It can be considered that a market shows informational efficiency if prices are non-stationary in level but stationary in the first order difference. The economic implication is that investors cannot obtain above market returns on a regular basis, and that any such gains are purely random.

From a statistical modelling perspective, the main implication of the random walk hypothesis for price dynamics is that it provides an estimation for the evolution of stock returns (assumed to be zero on average) and the evaluation of the risk associated with the price (its square increases linearly with time). However, if price changes do not exhibit a random walk-like behaviour, there is no relation between current and future price change and risk, and the time dimension regains its relevance. Such examples are emerging markets which present a considerable short term risk for investors. However, if investments in such regions are held for sufficiently long periods (such as for the risk-return trade-off to reach an equilibrium), the pay-off can be high. To assess if the movement of stock prices on the Romanian Capital Market is determined by stochastic processes, a set of statistical tests are used to evaluated stationarity (ADF and KPSS) and the time dependence of return variance (Variance Ratio Test).

2.3. Unit root test

The stationarity of a financial time series does not mean that the series remains unchanged over time rather that its evolution is determined by a set of rules that are fairly stable (e.g., its distribution). Consequently, even if the price of a certain security follows a trend, the series is stationary in its first order difference if the distribution of the price change is stable over time.

$$P_t-P_{t-1}=(1-L)P=\mu+\varepsilon_t \qquad (3)$$

According to relation (3) a random walk is stationary in its first order difference (it has a unit root). A superior order stationary series is called integrated of order d, and noted as *I(d)*, if the series becomes stationary after d successive differentiation operations. The integration order gives the number of unit roots. As a random walk is integrated of order one, an *I(1)* process can be used as a proxy measurement for random behaviour. To verify if the price of a stock is determined by an *I(1)* process, the ADF test is used to check for unit roots, while the KPSS test will assess the stationarity. These two tests are complementary instruments and strengthen the results if their outcomes are compatible.

Stationarity of the time series will be verified at both level and first order difference to study if the stock price series describe a *I(1)* process. Confirming the hypothesis of unit root at a price level and stationarity at a return level will be interpreted as a random walk, consequently a proof of informational efficiency. A series is considered to be described by an *I(1)* process if the ADK and KPSS test statistics for the price are above the significance level threshold and for return are below the significance level threshold.

2.4. Variance ratio test

The Variance Ratio Test was developed by Lo and MacKinley (1988) to assess if the variance of the residual variable (first order difference) is a linear function of time (common characteristic of a random variable). This can be formalized as described in relation (4):

$$VR(q) = \frac{\sigma^2(q)}{q\sigma^2(1)} \quad (4)$$

Where $\sigma^2(q)=Var[P_{t+q}-P_t]$ is the variance of the q^{th} order difference. In the case of a random walk, the q^{th} order difference can be expressed as a sum of q consecutive returns and relation (4) becomes $VR(q)=1$.

The null hypothesis verifies if the ratio given by relation (4) is significantly close to *1* (H_0: $VR(q)=1$). The rejection of the null hypothesis at a statistical significance level implies that the analysed series presents autocorrelation (if $VR(q)>1$, the series presents positive autocorrelation and if $VR(q)<1$, it presents negative autocorrelation), hence, does not describe a random walk process.

3. Results

For the entire period, the test statistics for both the daily and the weekly series show that price movements are described by *I(1)* processes (Table 1.a.). The price stationarity hypothesis is rejected at a statistically significant level for the entire data set and the unit root hypothesis cannot be rejected at a significant level for any of the analysed stocks showing that the time series have a unit root. Furthermore, return stationarity cannot be rejected for any of the analysed series, while the unit root hypothesis is rejected for all data sets, showing that the return is stationary.

Table 1.a. Stationarity Test Results – Entire Period

Frequency	Daily Series				Weekly Series			
Level	Price		Return		Price		Return	
Test	ADF	KPSS	ADF	KPSS	ADF	KPSS	ADF	KPSS
TLV	-0.811 (0.815)	6.639***	-13.845*** (0.000)	0.079	-0.597 (0.869)	2.729***	-5.672*** (0.000)	0.076
BRD	-1.455 (0.557)	2.005***	-11.418*** (0.000)	0.236	-1.620 (0.472)	0.920***	-4.279*** (0.001)	0.198
BIO	-1.394 (0.587)	1.814***	-10.704*** (0.000)	0.112	-1.373 (0.596)	0.780***	-3.123** (0.026)	0.126
SNP	-1.738 (0.412)	1.722***	-8.684*** (0.000)	0.134	-1.876 (0.344)	0.768***	-8.216*** (0.000)	0.136
BKR	-1.479 (0.663)	2.669992	-13.093*** (0.000)	0.11	-1.298 (0.631)	1.123***	-3.544*** (0.007)	0.086
SIF1	-1.479 (0.544)	2.315***	-13.093*** (0.000)	0.172	-1.401 (0.583)	0.938***	-5.159*** (0.000)	0.18
SIF2	-1.425 (0.572)	2.605***	-10.557*** (0.000)	0.162	-1.347 (0.609)	1.061***	-4.863*** (0.000)	0.147
SIF3	-1.554 (0.506)	2.088***	-10.797*** (0.000)	0.167	-1.822 (0.370)	0.964***	-4.924*** (0.000)	0.157
SIF4	-1.472 (0.548)	2.237***	-12.578*** (0.000)	0.17	-1.360 (0.603)	1.024***	-3.753*** (0.004)	0.221
SIF5	-1.342 (0.612)	2.450***	-10.485*** (0.000)	0.201	-1.080 (0.725)	1.142***	-3.199** (0.021)	0.211

Note: The test results are presented in the main row, while the probabilities associated to the null hypothesis are presented in parentheses; ***,** and * denote the rejection of the null hypothesis at a significance level of 1%, 5% and 10%, respectively

(Source: Author's Calculations)

However, when the analysis is done on sub-periods, the results are no longer consistent. Pre-crises analysis shows that the KPSS test for return stationarity reject the null hypothesis for 8 of the analysed stocks at both frequencies (Table 1.b.). Only the prices of BIO and SNP seem to be describing an I(1) process for both daily and weekly series.

Table 1.b. Stationarity Test Results – Pre-crises Period

Frequency	Daily Series				Weekly Series			
Level	**Price**		**Return**		**Level**		**Price**	
Test	**ADF**	**KPSS**	**ADF**	**KPSS**	**ADF**	**KPSS**	**ADF**	**KPSS**
TLV	3.399 (1)	4.364***	-8.011*** (0.000)	1.649***	3.116 (1)	1.988***	-4.009*** (0.002)	1.365***
BRD	1.285 (0.999)	4.365***	-37.319*** (0.000)	0.527**	1.856 (1)	1.874***	-5.411*** (0.000)	0.542**
BIO	0.165 (0.97)	1.974***	-6.437*** (0.000)	0.212	0.646 (0.990)	1.054***	-7.097*** (0.000)	0.238
SNP	-0.785 (0.822)	4.311***	-6.395*** (0.000)	0.07	-0.876 (0.795)	1.996***	-5.356*** (0.000)	0.054
BKR	0.595 (0.990)	0.655**	-4.657*** (0.000)	0.512**	-0.261 (0.926)	0.337	-2.174 (0.217)	0.354*
SIF1	1.814 (1)	4.685***	-7.392*** (0.000)	0.596**	1.953 (1)	1.966***	-4.376*** (0.000)	0.637**
SIF2	1.028 (0.997)	4.508***	-7.353*** (0.000)	0.485**	1.407 (0.999)	1.900***	-4.035*** (0.001)	0.424*
SIF3	2.983 (1)	4.348***	-7.548*** (0.000)	1.107***	2.655 (1)	1.868***	-3.881*** (0.002)	0.981***
SIF4	1.693 (1)	4.690***	-7.78*** (0.000)	0.528**	2.164 (1)	2.017***	-7.032*** (0.000)	0.582**
SIF5	1.938 (1)	4.516***	-7.189*** (0.000)	0.659**	1.923 (1)	1.902***	-1.376 (0.594)	0.960***

Note: The test results are presented in the main row, while the probabilities associated to the null hypothesis are presented in parentheses; ***,** and * denote the rejection of the null hypothesis at a significance level of 1%, 5% and 10%, respectively

(Source: Author's Calculations)

In the post-crises period only BRD stock price movements describe an I(1) process for both frequencies (see Table 1.c.). None of the stock price series presents a random walk-like behaviour for all three periods and both frequencies.

Table 1.c. Stationarity Test Results – Post-crises Period

Frequency	Daily Series				Weekly Series			
Level	**Price**		**Return**		**Level**		**Price**	
Test	**ADF**	**KPSS**	**ADF**	**KPSS**	**ADF**	**KPSS**	**ADF**	**KPSS**
TLV	-2.118 (0.238)	0.226	-8.195*** (0.000)	0.157	-2.080 (0.253)	0.114	-3.18** (0.023)	0.205
BRD	-2.361 (0.153)	1.810***	-7.363*** (0.000)	0.245	-2.378 (0.149)	0.910***	-2.979** (0.038)	0.244
BIO	-2.555 (0.103)	1.224***	-9.178*** (0.000)	0.364*	-2.319 (0.167)	0.634**	-3.001** (0.036)	0.336
SNP	-1.907 (0.329)	0.625**	-6.866*** (0.000)	0.331	-1.997 (0.288)	0.317	-3.528*** (0.008)	0.267
BKR	-3.653*** (0.005)	2.084***	-9.532*** (0.000)	0.759***	-3.69*** (0.005)	0.968***	-1.755 (0.402)	0.624**
SIF1	-3.089** (0.028)	1.776***	-10.764*** (0.000)	0.767***	-3.332** (0.014)	0.878***	-2.810* (0.058)	0.657**
SIF2	-3.109** (0.026)	1.314***	-8.399*** (0.000)	0.710**	-2.674* (0.080)	0.665**	-2.702* (0.075)	0.740***
SIF3	-3.329** (0.014)	1.878***	-11.413*** (0.000)	0.749	-3.352** (0.014)	0.913***	-2.984** (0.038)	0.663**
SIF4	-3.38** (0.012)	2.032***	-12.365*** (0.000)	0.85	-3.403** (0.012)	0.998***	-2.275 (0.181)	0.733**

SIF5	-1.342 (0.612)	1.600***	-7.027*** (0.000)	0.644**	-2.868* (0.051)	0.797***	-1.734 (0.413)	0.586**

Note: The test results are presented in the main row, while the probabilities associated to the null hypothesis are presented in parentheses; ***,** and * denote the rejection of the null hypothesis at a significance level of 1%, 5% and 10%, respectively

(Source: Author's Calculations)

Results of the Variance Ratio Test are more consistent across the analysed periods in the sense that the null hypothesis is rejected (for at least one of its time series) for the majority of stocks (see Table 2). When analysing the entire period, only TLV, BRD and SNP price series seem to present the characteristics of a random walk, if the martingale hypothesis is taken into consideration.

Table 2. Variance Ratio Test Results – Values of statistics |z| max

Frequency	**Daily Series**			**Weekly Series**		
Symbol	**Entire Period**	**Pre-crisis**	**Post-crisis**	**Entire Period**	**Pre-crisis**	**Post-crisis**
TLV	0.567	0.655	2.68**	1.197	1.032	1.141
	1.171	1.75	15.34***	1.871	2.748**	1.214
BRD	0.923	1.079	0.878	1.534	2.611**	1.211
	1.779	1.815	1.433	2.391*	3.539***	1.636
BIO	2.981**	1.262	2.58**	1.752	0.557	1.006
	4.871***	1.888	4.561***	2.743**	0.831	1.559
SNP	0.546	0.781	0.951	2.036	1.267	1.616
	0.79	1.228	1.32	2.612**	1.732	1.894
BKR	3.432***	3.538***	2.225*	4.273***	2.265*	3.285***
	8.152***	5.268***	6.359***	6.068***	2.296*	5.777***
SIF1	3.345***	1.475	3.416***	1.56	0.998	0.927
	6.544***	3.38***	5.813***	2.294*	1.592	1.175
SIF2	2.269*	1.07	2.195	2.307*	0.921	1.958
	4.227***	2.198	3.647***	3.543***	1.573	2.454*
SIF3	2.28*	0.318	3.285***	1.585	0.688	1.425
	6.114***	1.136	6.393***	3.199***	2.512**	1.906
SIF4	3.248***	2.167	2.615**	1.624	1.164	0.506
	6.069***	4.722***	4.29***	2.677**	1.939	0.697
SIF5	2.323*	1.042	2.227*	2.345*	0.717	2.359*
	4.386***	2.282	3.604***	3.729***	1.219	2.99**

Note: The values in the table represent the z-statistics absolute |z| in conditions of heteroscedasticity and homoscedasticity, respectively; ***,** and * denote the rejection of the null hypothesis at a significance level of 1%, 5% and 10%, respectively

(Source: Author's Calculations)

A comparative analysis of the pre- and post-crisis periods suggests a deterioration of the daily efficiency of the market, while the weekly series implies a slight improvement in efficiency (measured through the probability acceptance of the null hypothesis). The rejection of the null hypothesis increased significantly from 11 in the pre-crises period to 20 in the post-crises period, proof of deteriorating informational efficiency from a period to the other. The rejection of the Variance Ratio Test null hypothesis is significantly higher at the daily series, suggesting that markets tend to become more efficient over longer periods of time. One of the possible explanations is that investors change their behaviour as the risk associated with the selection of a certain portfolio structure increases over time. Due to the high uncertainty associated with the local capital market, especially after the events of 2007, long term portfolios bear greater risks. As a consequence, investors track stock price volatility more attentively and try to secure their portfolios by including assets with lower volatility. Furthermore, they also tend to close their positions at the end of a weekly cycle to avoid potential volatility commonly observed at the beginning of a new cycle.

4. Conclusions

Although the Romanian capital market presents signs of informational efficiency in its weak form for certain classes of stocks, it is not sufficient to generalize to the entire Bucharest Stock Exchange. Different results obtained for the analysed periods and stocks may suggest that the domestic capital market has been undergoing relatively important and quick changes in its structure and operating mechanisms—accelerated by the 2007-2009 financial crises. As the Romanian economy is interconnected with the global economy, its capital market was affected by the financial shock wave and hysteresis effects started building as investors departed from rationality. Mimetic behaviour of individuals determined the emergence of patterns in stock price changes (mostly downwards). As uncertainty increased, such patterns got stronger and the magnitude of price changes could not anymore be balanced-out by arbitrageurs. This led to the deterioration of the transmission mechanism of prices and finally to the decline in market efficiency in the period following the outbreak of the financial crisis. A possible explanation for the difference in efficiency between stock classes is that the SIFs (as financial investment vehicles) are more sensitive to market changes, while companies in the energy (SNP) and financial services (TLV, BRD) sectors present a lower risk for investors. This is because of the strategically importance of the sectors in general, and these companies are of systemic importance to the national economy and present a low default risk, in particular. Furthermore, the result must be regarded in the context of an emerging turbulent capital market, in a non-entirely crystallized stage of development, with asymmetric and imperfect information flows, and non-accurate rules of functioning.

This work was supported from the European Social Fund through Sectorial Operational Programme Human Resources Development 2007–2013, project number POSDRU/159/1.5/S/134197, project title "Performance and Excellence in Doctoral and Postdoctoral Research in Romanian Economics Science Domain"

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