Facultatea de Științe Economice și Gestiunea Afacerilor

PhD THESIS
ABSTRACT

STATISTICAL INVESTIGATIONS OF THE BEHAVIOR OF FINANCIAL ASSET PRICES- CAPITAL MARKET CASE STUDY

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SUMMARY OF THE THESIS

INTRODUCTION

Financial market represents one of the most fascinating mechanisms of a functional market economy. This is a constantly moving and changing market, freely regulated by the level of supply and demand. As part of the financial market, capital market reflects, perhaps, in the best way the relation between supply and demand, providing a continuously updated framework with all available information. In the context of capital markets, of main interest is how the new information is integrated in the asset prices.

Statistics and quantitative analysis techniques come to support the capital market investors, allowing them to understand, compare or predict phenomena in the market. H.G. Wells prediction that "Statistical thinking will one day be as necessary for efficient citizens as the ability to read and write" has arrived to be true. The purpose of performing statistical analysis on financial data is to identify and develop models that capture the market behavior. In general terms, a model is a simplified description of the reality, while in economics, a model describes the prices or the returns empirical behavior, specifically, it explain a process through a set of variables and the quantitative and qualitative relationships between them. In this thesis, the empirical approach seeks to identify the main statistical characteristics of financial data, using an appropriate and highly recommended, in the recent literature, research methodology.

Capital markets theory is governed by the efficient market hypothesis, introduced by Fama (1970), and it describes a market in which prices fully reflect all available information. As simple as it seems, Fama's definition is abstract and comprehensive because it assumes a perfect market, governed by a rational behavior of the investors. In an efficient market, one can not make predictions based on historical prices or achieve sustained profits. Capital markets literature is divided among studies that support the efficient market theory while other empirical studies show proofs of the inefficiency of several capital markets.

In the context of this research, the analysis of market efficiency has a double relevance. On one side, it can reveal a mechanism that incorporates immediately all available information in the price generating process, such that the best prediction based on historical prices is today's price. On the other side, it can offer informations regarding the market inefficiency, which can be used to exploit technical analysis strategies in order to earn profits. The two concepts, of market efficiency and profitability based on technical analysis strategies are in contradiction, the reason for which the first step in the empirical investigation is to assess the degree of market efficiency.

The first objective in understanding the phenomena that take place on the capital markets is to identify the statistical properties that characterize the asset returns. Because asset/market indices returns can be used as indicators of the performance, are mainly investigated the properties of the returns and not of the prices. The main properties of the returns are highlighted in Engle (2004), among which of highly interest in this research are the ones regarding the distribution of the returns, risk and predictability.

The second objective is to understand the processes that describe the price/ returns evolution. In this regard, we are going to focus on two directions: the analysis of market efficiency, respectively the study of technical analysis profitability, for the Romanian market. The two approaches are in contradiction, the reason for which a preliminary step of the analysis is to investigate the market efficiency (Romanian capital market). The efficiency is regarded in the relative form, which allows us to place the Romanian market relatively to other European stock markets.

Technical analysis, used to predict future prices based on the historical values, becomes useless in an efficient market, because the price changes are independent, and in a restrictive manner, identically distributed. Over the time, the performance of technical analysis has been frequently questioned, although there are consistent empirical studies that support the efficiency of technical analysis strategies on important markets. Technical analysis theory is based on the assumption of predictability, respectively the study of historical behavior leads to patterns that are expected to be observed in the future prices.

The requirements of an efficient market are difficult to be realized in the financial practice because they impose a perfect competition, a framework in which prices incorporate fully and immediately all available information and allow all participants equal and fair access to information. Due to this facts, were introduced alternative theories of the efficient market hypothesis, that focus on the investor's behavior and the factors that determine the price changes. Giving up the restrictive form of the absolute efficiency and considering the efficiency in the relative form (Campbell et al., 1997) represents an important step in the efficient market theory. The updated theory regards the efficiency as a dynamic component, meaning that it allows the markets to have periods with different degrees of efficiency.

Regarding the statistical methodology, it is difficult to invalidate the efficient market hypothesis as long as there is no widely recognized methodology in this purpose. Mainly, are applied statistical tests that focus on the particular forms of the deviations from efficiency. So, the approach of the relative efficiency allows us to identify those potential factors that lead to a change in the efficiency level over time.

The aim of the empirical analysis performed in this study is not to classify the Romanian stock market as efficient or not, but to identify the degree of efficiency in time and relatively to other stock markets. This objective is achieved under a more general framework, by placing the Romanian capital market in report to the degree of efficiency of 20 European markets, both developed and emerging markets; based on three indicators of efficiency are constructed capital market rankings of the efficiency.

In a capital market that exhibits deviations from efficiency, it becomes important to investigate to what extent the causes of deviations are potential sources of profitability. Usually, these sources can be exploited through means of technical analysis strategies which are based on the concept of statistical smoothing and therefore, detecting local trends in price series. One of the most used strategies is the moving average, a strategy that offers trading signals when a short term moving average intersects a long term moving average.

The particularities that ensure the originality of this study consist mainly in the use of an appropriate research methodology in terms of statistical properties of the data. Regarding the distribution of the returns, we focused mainly on the family of the generalized hyperbolic distributions, that has similar properties to financial returns. The fatter tails (due to the high frequency of the extreme values) suggest the use of statistical tests and measures, in order to detect the dependency structure, that takes into account this behavior. Regarding the previous, we have used statistical methods and efficiency indicators (such as the Automatic portmanteau test, Hurst exponent, fractal dimension) that facilitate the detection of the main types of dependencies that might occur in the returns, measures that are robust to the heroscedastic behavior of the returns. These measures are applied over the whole period of time and/or on rolling windows.

In the context of technical analysis we point out the necessity of using a research methodology that accounts for data-snooping, useful when on the same data set are applied several strategies in order to identify that strategy that returns the highest profitability. Using an improper methodology could lead to misleading results. Fama (1998) points out that many of the anomalies are due to the applied methodology and they disappear once an appropriate methodology is used.

In this research, the empirical analyzes of the behavior of stock returns are performed on a portfolio of assets traded at Bucharest Stock Exchange, which brings additional results to the existing literature, that generally focuses on market indices. The Romanian capital market, BSE is a young market, operating since 1997 and evolving in a transition economy. Therefore, the historical prices are not long enough to allow long term pattern analysis.

The paper is structured in four chapters, preceded by introduction and is concluded with final remarks and perspectives of future research.

First chapter includes an overview of the concepts conveyed in this paper, respectively an analysis of the stochastic processes used to describe the evolution of the financial assets. In this chapter is introduced the notion of efficient market and the main forms of efficiency, together with a literature review of the studies that contributes to the theoretical development of the notion or highlights empirical evidence in the field. Classical theoretical models used to describe the price evolution of stock market prices under the hypothesis of efficiency are the ones of random walk, respectively the martingale model. Also, since the stock returns have certain specific characteristics, are introduced the main statistical properties of the returns and the dynamic models identified in the related literature.

Market efficiency represents one of the most controversial subjects in the financial literature because it implies requirements that are difficult to assess in the practical framework, specifically it requires a rational behavior of the investors and a perfect and total transparency on any new information. Thus, over time were introduced alternative theories of efficiency, such as adaptive markets hypothesis or fractal markets. The adaptive markets theory is an approach of the capital markets from an evolutionary perspective, which focuses on the financial behavior of the investors and their reactions to market changes. On the other side, the central point of the fractal markets theory is the market liquidity and the impact of the investment horizon on the investors behavior.

The **second chapter** is dedicated to the study of the main statistical properties of stock returns in terms of statistical distribution; they usually show a leptokurtic distribution and fatter tails than the normal distribution. The financial literature mentions several distributions that model adequately the returns distribution, but does not designate a specific distribution as the most suitable. In this section are highlighted the main studies that develop the research on the topic, but also the studies that introduce and support the utility of the generalized hyperbolic distribution. The analyzed sub-classes of the generalized hyperbolic distribution are: Normal Inverse Gauss, asymmetric t-Student, Variance- Gamma, hyperbolic and generalized hyperbolic.

In the empirical study of this chapter are estimated the parameters of all five distributions using the maximum likelihood estimation method and are used the goodness-of-fit measures and specific graphics to compare and select the distribution that offers a well approximation of the returns. Special attention is given to modeling the left tail of the distribution, where is found the value-at-risk. It is of main importance to identify a distribution that describes accurately the behavior of stock returns when estimating the Value-at-Risk, an essential tool in risk management. Value-at-risk is estimated by means of parametric methods, based on the specific distribution of the returns, and nonparametric methods. The analyzed period is divided into a period of analysis and a test one, and the values are estimated based on the rolling windows approach. Such an approach allows a statistical comparison of the estimated values to the ones recorded on the real market. The performance of the VaR estimation methods, and therefore of the statistical distribution, is verified through backtesting tests; we have tested here the hypothesis that the number of cases in which the loss exceeds the estimated risk is the one expected according to selected probability level.

In **chapter three** are introduced the main statistical methodologies used to analyze the degree of informational efficiency. Are emphasized here the predictability tests that focus both on short and long-term memory in returns. This chapter provides an empirical research on the efficiency of the Romanian stock market in the context of 20 European stock markets. The issue of efficiency is addressed through means of the departure from the hypothesis of efficiency and are created rankings, of the investigated markets, based on these departures. Thus, by investigating the efficiency in the relative approach, the restrictive barrier of “all or nothing”, imposed by the hypothesis of efficiency, is overrun.

Are applied here, as measures of efficiency, the Hurst exponent, fractal dimension and the efficiency index that takes into account both the short-term dependencies and the long-term ones. Based on these three measures of efficiency are created rankings of the stock markets for the whole investigated period of 15 years but also for three sub-periods delimited by the changes in the economical environment. The empirical results place the Romanian market among the stock markets with the highest deviation from the concept of informational efficiency in the weak form and identifies different degrees of efficiency on the investigated periods.

Chapter four reviews the main studies in the literature of technical analysis and are introduced here the most used trading strategies. Technical analysis encompasses a large variety of strategies, but the empirical studies conducted over the time have concluded the profitability and the investor’s preference to certain strategies, such as the moving average strategy.

The main studies that address the issue of technical analysis performance are characterized based on the methodological approach. One of the main issues in the empirical literature consists in the lack of statistical testing of the profitability of the investigated strategy. In order to prevent this methodological drawback, are recommended the data-snooping tests, specifically, in the empirical study performed in this chapter is used the Hansen Superior Predictive Ability Test

(2005). It is tested here the null hypothesis that the best model in terms of the profitability, from the entire universe of models, has no superior predictive ability compared to the reference strategy.

The empirical study of this chapter concludes the empirical research of the previous chapter, by investigating technical's analysis profitability, namely the profitability of the moving average strategies on the Romanian stock market. It is analyzed the impact of the dependency pattern on the return excess of the most profitable strategy over the buy-and-hold strategy, in the informational efficiency framework.

SUMMARY OF CHAPTER I

Theoretical aspects regarding the evolution and statistical properties of financial assets

In the first chapter is developed the theoretical framework that underlies the stock market theory and the processes that describe the stock price evolution, in contrast with the main alternative theories. The foundations of the modern theory were developed around the assumption of efficient market, introduced and defined by Fama (1965, 1970) as “a market in which prices always fully reflect all available information”. The assumption that prices incorporate all available information, at any time, determine random price changes in time, influenced only by the new available information, which is unpredictable. Informational efficiency hypothesis implies a perfect market, which provides completely transparency and equal access to information, and is governed by a rational behavior of the investors. One can notice the abstract character of the definition, which raises serious difficulties in constructing the testing methodology.

Under the assumption of efficiency, the evolution of the stock market prices follow a random walk model, applied to the logarithm of the price, $p_t = \mu + p_{t-1} + \varepsilon_t$, where p_t is the price logarithm, $lnY_t \equiv p_t$, μ is the expected price change and (ε_t)~IID(0,σ^2) denotes independent and identically distributed increments with mean zero and finite variance σ^2. In Campbell et al. (1997) terminology, this stochastic process describes a random walk 1model, RW1, which is the most restrictive form due to the IID assumption of the increments. Under the RW1 framework, any series resulted by applying a linear or nonlinear function on returns is uncorrelated. Nevertheless, in financial practice, there are significant positive correlations in the returns series resulted when applying nonlinear transformations, such as absolute value or squared returns, which makes the RW1 assumption unlikely to hold in the empirical evidence.

Random walk II (RW2) is a less restrictive model compared to RW1, which preserves the assumption of independent price changes but waves the condition that they follow the same distribution (identically distributed) $p_t = \mu + p_{t-1} + \varepsilon_t$, where ε_t is a sequence of independent random variables. The hypothesis of random walk III (RW3) is the least restrictive type of random walk processes, which allows price changes to be dependent but linearly uncorrelated $Cov(\varepsilon_t, \varepsilon_{t+k}) = 0,\ \forall k \neq 0$. This form allows heteroscedasticity in returns, which is tested in most empirical studies.

The martingale model is formulated in terms of conditional expectation $E(p_{t+1}|p_t, p_{t-1}, \dots) = p_t$, namely, the expected value of the price in the next period, conditioned by its past values, is the current price. In terms of predictability, the best prediction of tomorrow’s price is today’s price. The martingale hypothesis applied to prices is equivalent to the type II random walk hypothesis (Escanciano & Lobato, 2009). Thus, a random walk model with the error term consisting of a succession of independent variables (which are not necessarily identically distributed) is equivalent to a martingale process.

The hypothesis of informational efficiency was one of the most investigated assumptions in the economic field, as Jensen (1978) said "I believe there is no other proposition in economics which has more solid empirical evidence supporting it than the Efficient Market Hypothesis". In the efficiency framework, the stock markets are characterized either as efficient or inefficient, a characteristic that holds in time.

The existing statistical methodology investigates to what extent, under the hypothesis of efficiency, prices reflect all available information but they do not address the behavior and the preferences of the investors. The following steps in the evolution of efficient market theory capture its evolutionary character, materialized in the adaptive markets hypothesis (Lo, 2005). According to the new theory, the investors act based on their own interest, make mistakes, learn and adapt, competition leads to innovation and adaptation, natural selection shapes the market ecology and the evolution determine the market dynamics in time (Lo, 2005). In order to remain on the market, investors have to adapt and become more competitive, otherwise they will be eliminated. The evolutionary process of the market is reflected in its effectiveness, which varies over time. The expected returns, respectively the prices are affected by the changes that take place in the market ecology, such that, occasionally, may occur profit opportunities.

Fractal markets hypothesis focuses on market liquidity and the impact of the investment period on the balance of the market. Unlike in the efficient market theory, where the emphasis is on market efficiency, in the fractal market theory, the emphasis is on market stability. In such a market, investors assume the same level of risk, leading to similarities in the distribution of the returns, regardless the investment allocated timeframe.

Most of the empirical studies regarding the stock market investigate the behavior of the returns series because it presents more attractive properties, both from a practical or statistical approach. In this thesis, the returns are computed in logarithmic form, $R_t = \ln\left(\frac{Y_t}{Y_{t-1}}\right) = \Delta lnY_t$, where Y_t is the asset price and R_t is the return, at moment *t*.

Regarding the statistical behavior, the empirical literature outlines a set of common characteristics, which were synthesized, among others, in Cont (2001):

- generally, there are no significant linear correlations in the asset returns. This property is related to the hypothesis of informational efficiency and imposes the use of a statistical methodology that accounts for nonlinear dependencies;
- unconditional distribution of the returns has higher tails than the normal distribution. In particular, the normal law or any stable law with infinite variance is not suitable to approximate the distribution of asset returns;
- usually, the unconditional distribution of returns is negatively skewed, suggesting a higher probability of extreme negative returns than positive ones;
- the distribution of returns looks gets closer to the normal distribution as the time scale increases;
- volatility clustering: the volatility measures of the returns display positive autocorrelations, which tend to cluster in time, meaning that extreme negative (positive) returns tend to be followed by negative (positive) returns;
- volume is correlated with all measures of volatility;
- leverage effect: most measures of volatility are negatively correlated with the asset returns. After a price decrease, volatility tends to increase stronger than after

the same sized price increase, which indicates a different reaction of investors to the bad or good new arrived information;

In this thesis we focus primarily on the first three properties, which regards the informational efficiency hypothesis, respectively the distribution of the asset returns.

Regarding the time series typology, are identified the following processes used to model the generating process of financial data:

- stationary processes (integrated processes, $d=0$), described by an autocorrelation function that decreases exponentially, corresponding to a time series with short-memory. The observations that are far apart in time, are independent;
- first order integrated processes ($d=1$), when the autocorrelation function decreases linearly and the observations that are far apart in time are not independent;
- fractionally integrated processes (Baillie, 1996), characterized by nonzero correlations between observations that are far apart in time, namely the autocorrelation function decreases slowly towards zero. $d \in (0, 0.5)$ describes a stationary process that exhibits a persistent long term behavior, while for $d \in (-0.5, 0)$ it is described a stationary process with an anti-persistent behavior. When $d \in (0.5, 1)$, the process is non-stationary with a persistent long-term behavior.

Most of the stock market time series show small dependencies between observations that are far apart in time, which suggest persistence of the analyzed phenomenon, namely long memory. The statistical methodology used to model such a behavior focuses on two aspects: first, developing models for fractionally integrated processes and secondly, developing estimation methods of the Hurst coefficient (Hurst, 1951), which is related to the order of fractionally integration, d, through $H = d + 0.5$. In self-similar processes, long memory is a reflection of the local smoothness of the series, quantified by the fractal dimension, described through the relation $D+H=2$.

Considering the type of the dependencies that might occur in the asset returns, the main econometric models developed are the ARMA models (for stationary processes), ARFIMA (for fractionally integrated processes) or SETAR (used to capture the nonlinear dependencies).When referring to model the variance, used as proxies for volatility and risk, are recommended GARCH type models. Depending on the different characteristics of the financial series, in the literature are suggested particular models derived from the GARCH framework, such as IGARCH, TGARCH, GJR-GARCH or EGARCH.

SUMMARY OF CHAPTER II

Distribution of the financial returns: theoretical considerations and empirical results

From a stock market to another are observed specific features in the distribution of the returns, but essentially, is outlined a set of common statistical properties. Mainly for daily or weekly data, returns exhibit fatter tails compared to the normal distribution due to the higher frequency of the extreme values, and a slight asymmetry to the left.

Over time there have been proposed several theoretical distributions as possible alternatives to modeling the distribution of stock returns. Usually, the probability laws that describe power functions are good approximations of the distribution of the returns, but the adequacy level depends on the investigated market (Haas & Pigorsch, 2011). The family of generalized hyperbolic distributions is mention in the recent literature as a good candidate for modeling the distribution of financial returns,

The generalized hyperbolic distribution is a mixture distribution, of the type normal variance-mean mixture, resulted from the generalized inverse Gaussian GIG (Barndorff- Nielsen & Blaesild, 1981):

$$X = \mu + \beta Z + \sqrt{Z}Y$$

with Y being normally distributed N(0,1), $Z \sim GIG(\lambda, \delta, \gamma)$, $\gamma = \sqrt{\alpha^2 - \beta^2}$ and Y and Z are independent variables. The conditional distribution of X, conditioned by Z, is normal. Such a distribution is adequate when the data sample is not homogeneous, but there are several sub-samples in which the variable follows a normal distribution.

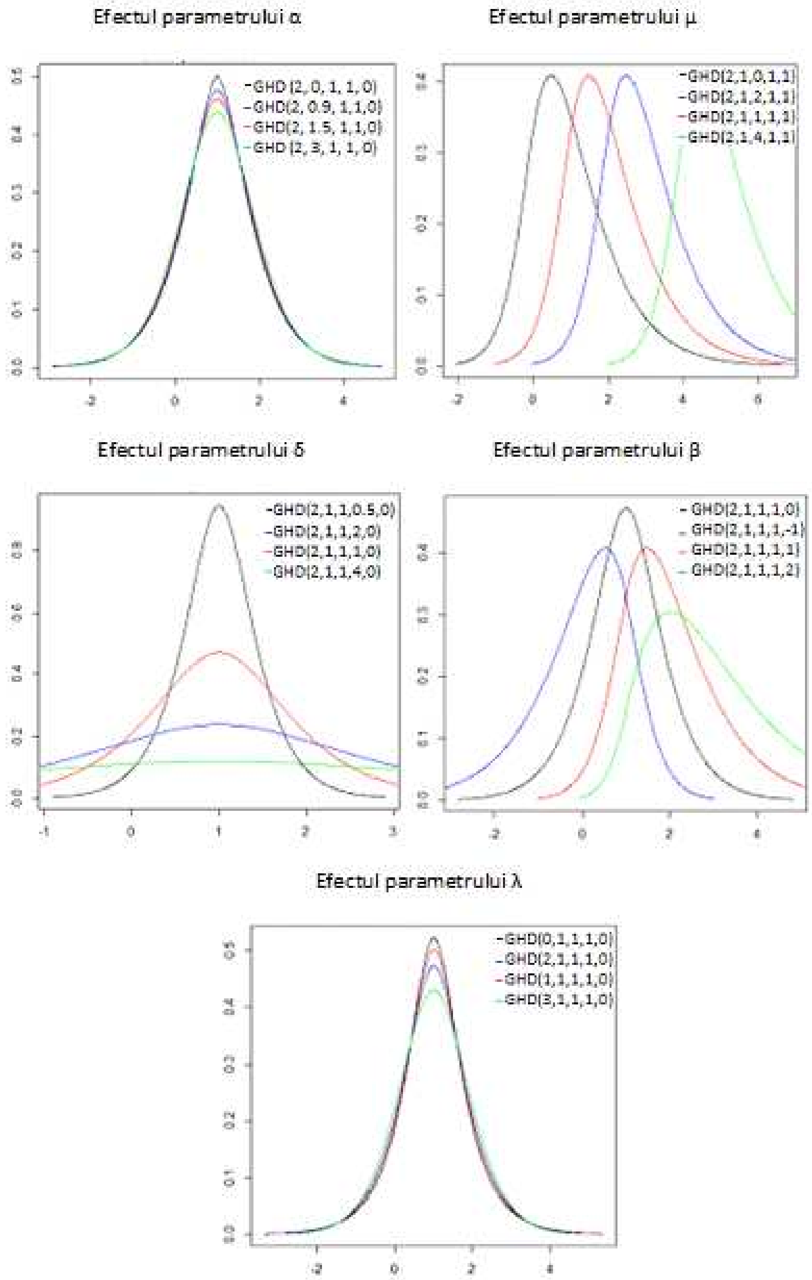
The probability density function of the univariate generalized hyperbolic distribution, in Prause's (1999) parameterization is defined as:

$$f_{GHD}(x; \alpha, \beta, \delta, \mu, \lambda) = a(\lambda, \alpha, \beta, \delta)(\delta^2 + (x-\mu)^2)^{\frac{\lambda - \frac{1}{2}}{2}} K(\lambda, \alpha, \beta, \delta, \mu),$$

where, $K(\lambda, \alpha, \beta, \delta, \mu) = K_{\lambda - \frac{1}{2}}(\alpha\sqrt{\delta^2 + (x-\mu)^2}\exp(\beta(x-\mu))$ is the modified Bessel function and $a(\lambda, \alpha, \beta, \delta) = \frac{(\alpha^2 - \beta^2)^{\frac{\lambda}{2}}}{\sqrt{2\pi}\alpha^{\left(\lambda - \frac{1}{2}\right)}\delta^\lambda K_\lambda(\delta\sqrt{\alpha^2 - \beta^2})}$ is the norming factor. The parameters are defined on the following domains: $\delta \geq 0, |\beta| < \alpha \ for \ \lambda > 0, \delta > 0, |\beta| < \alpha \ for \ \lambda = 0$ and $\delta > 0, |\beta| \leq \alpha \ for \ \lambda < 0$.

Figure 1 show the effect of each parameter on the shape of the distribution, when the other parameters are hold constant.

Figure 1. Generalized hyperbolic distribution- the effect of the parameters



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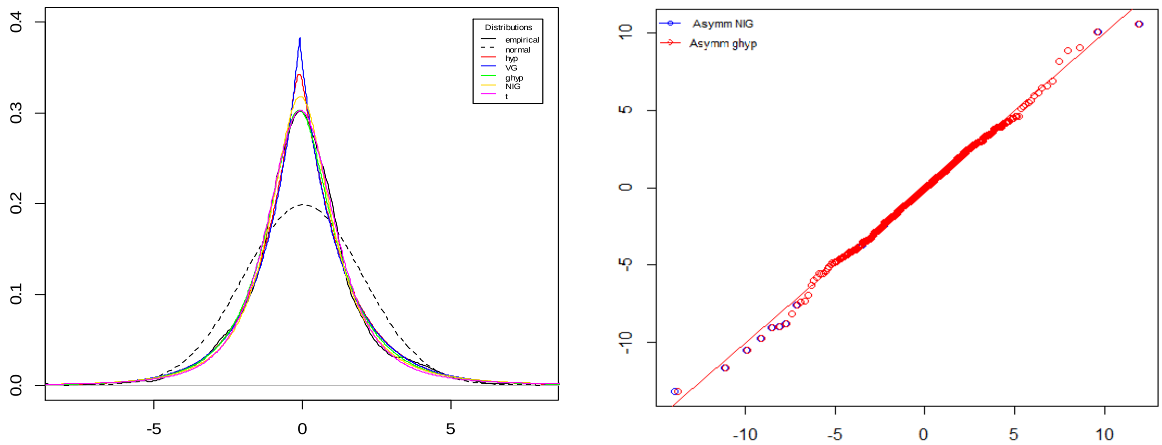
In the empirical study conducted in this chapter is analyzed the fit of five sub-classes of the generalized hyperbolic distribution on five assets traded at Bucharest Stock Exchange, together with the market index, BET. Namely, are investigated here the generalized hyperbolic distribution, the Normal Inverse Gaussian, the hyperbolic distribution, Variance- Gamma and asymmetric t-Student. The investigated assets are the Investment Funds, analyzed between 2007 and 2012. Figure 2 presents a comparison between the fit of the analyzed laws and the empirical distribution and the Q-Q plot for the Normal Inverse Gaussian distribution and generalized hyperbolic, for the market index, BET.

Figure 2. The distribution of BET returns. Q-Q plot for Normal Inverse Gaussian and generalized hyperbolic distributions



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The selection criterias of the most adequate distribution of the asset returns were considered the goodness-of-fit measures and the ability to estimate the Value-at-Risk (VaR). In the financial practice, it is of main importance the ability of the distribution to model the left tail, where are the extreme negative values.

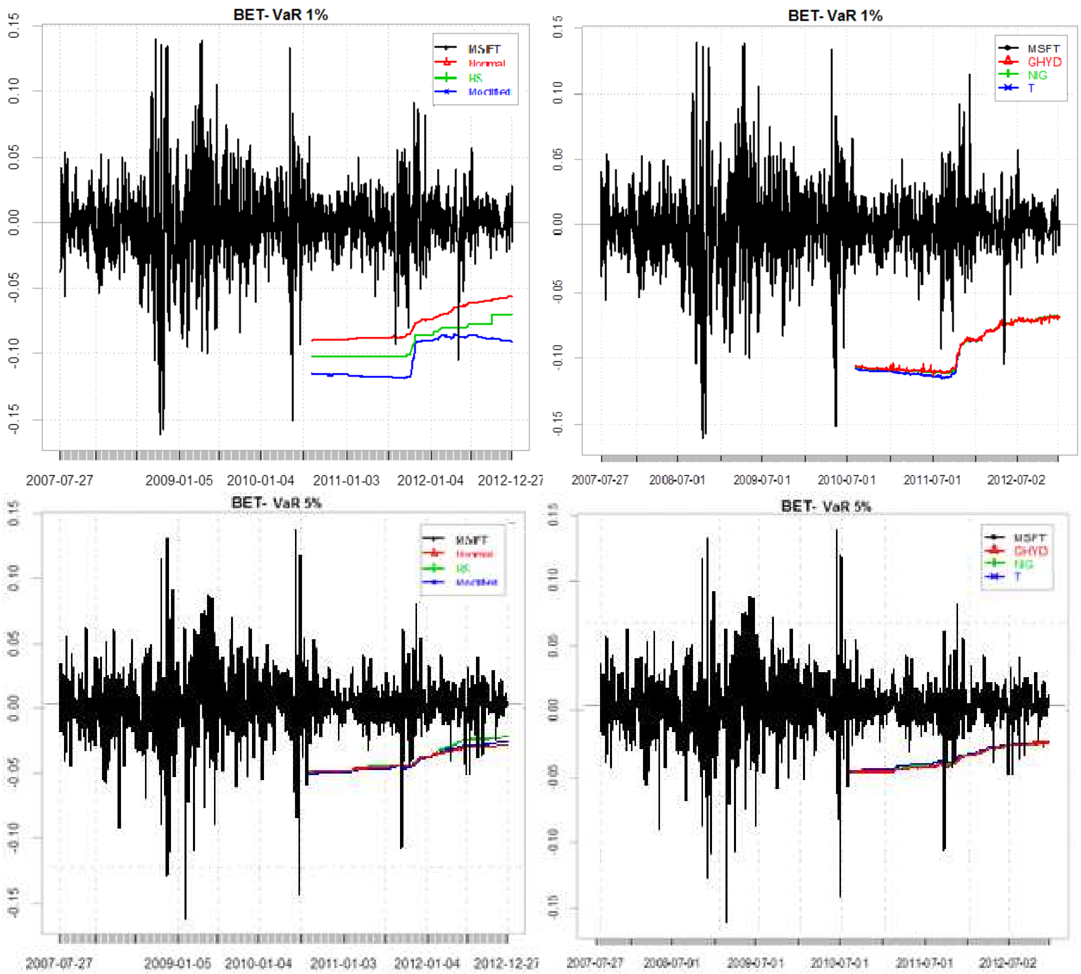
Value-at-Risk quantifies the potential risk of loss of an asset or portfolio over a considered time horizon and a fixed probability. When the distribution law is known, for a fixed probability p, VaR is defined by the quantile value , $F_X(VaR_p) = p$, where F_X is the corresponding distribution function of the returns.

VaR estimation accuracy is tested, in the empirical study, through the use of a backtest. Data is divided into an analyze period and a testing one, based on the rolling windows approach. Since there is no consensus in the literature regarding the length of the windows, we have used 750 observations in each window, equivalent to three years of daily trading data. Based on each window returns is estimated the Value-at-Risk for the following day. The estimated values are the ones from the testing period, and they are compared statistically with the real looses that occur on the market, based on Kupiec's test (Kupiec, 1995).

Kupiec's test null hypothesis states that the percentage of the cases in which the actual loss is greater than the estimated VaR is equal to the level expected by selecting a certain probability, $H_0: \hat{p} = p$, where, $\hat{p} = x/n$ and x is the number of cases in which the loss is greater than the estimated VaR, n is the number of observations and p is the percentage corresponding to the selected probability. The test statistic is constructed as a likelihood ratio, $LR = -2\ln\left(\frac{p^x(1-p)^{n-x}}{(\frac{n-x}{n})^{n-x}(\frac{x}{n})^x}\right)$. Under the null hypothesis, the test statistic follows LR~ $\chi^2_{(1)}$.

Figure 3 shows the estimated VaR values for the BET index through normal method, historical and Cornish-Fisher, but also through parametric methods in which it is considered that the returns follow specific distributions, other than the normal; in this case were considered the generalized hyperbolic distribution, Normal Invere Gaussian and asymmetric t-Student.

Figur3 3. Value-at-Risk for BET



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The empirical study developed for the Romanian stock market provides additional results to the existing literature, as follows: a) are considered distribution laws that have not been studied before, such as Normal Inverse Gaussian distribution, Variance- Gamma, hyperbolic or asymmetric t-Student, b) is analyzed the ability of the mentioned distributions to fit adequately the left tail, by estimating the Value-at-Risk and backtesting the results, c) the analysis is performed on individual assets traded on the Romanian stock market.

Regarding the adequacy of the investigated probability laws in modeling the distribution of the returns, over the whole domain, we synthesize the following remarks:

- KS test leads to rejecting the null hypothesis that the returns follow any of the normal distribution or Variance- Gamma;
- KS test and the plots of the distributions suggest that the generalized hyperbolic distribution, Normal Inverse Gaussian and asymmetric t-Student are proper fits of the empirical law of returns. KS test does not reject the null hypothesis at a 1% significance level. KS test provides close values for all previously mentioned distributions and the plots of the theoretical distributions are closed to the empirical one;
- in terms of most criteria, the generalized hyperbolic distribution seems slightly more adequate in modeling the distribution of the returns.

Regarding the Value-at-Risk estimation, namely the ability of the five classes of theoretical distributions to model the left tail of the empirical returns, we synthesize the following results:

- VaR estimated at 5% level of probability (9% significance level) through the normal, historical or Cornish- Fisher methods returns similar values;
- there are significant differences between VaR estimated at 1%, when are compared the values estimated through the normal, historical and Cornish- Fisher methods. The smallest losses are returned under the assumption of normal distribution while the highest are returned by the Cornish- Fisher method;
- under the assumption that the returns follow the generalized hyperbolic distribution, Normal Inverse Gaussian or t-Student, are estimated similar values for the VaR quantile.

Kupiec test rejects the null hypothesis that the percentage of cases in which the actual loss is greater than the estimated VaR is equal to the percentage expected, when VaR is estimated at 5%. When VaR is estimated at 1%, Kupiec test does not reject the null hypothesis. In all the observed situations, but mainly for VaR at 5%, in the test period were fewer cases where the returns were lower than the estimated VaR, compared to the expected number. The test period (August 2010 to December 2012) was characterized by a certain level of stability on the stock market, that returns less frequent negative extreme values, compared to the analysis period (2007- August 2010). Therefore, the VaR estimation methods are sensitive to the investigated period of time.

SUMMARY OF CHAPTER III

Investigation of the weak form efficiency: the case of the European stock market

Even Fama (1970) admits that the efficiency in the absolute form remains an ideal difficult to achieve in the stock markets and that empirical studies can only establish how close a market is to this ideal. Based on the empirical evidence that support the hypothesis of informational efficiency, a step forward in developing the theory of the efficient markets is the relative efficiency approach.

The main contribution of this chapter is the empirical analysis of the degree of the relative efficiency of 20 European stock markets, both, in terms of the evolution in time and by using several measures to quantify the deviations from the assumption of efficiency. Some of the measures used to quantify the degree of efficiency were computed over the whole period of time but also on rolling windows, to ensure a better robustness of the estimated values.

Among the considered measures is used a generalized measure of efficiency that was recently proposed in the literature and it accounts for both long and short-term dependencies. The rankings of the considered stock markets were made based on three measures, namely the Hurst exponent, fractal dimension and the generalized measure. Hurst exponent accounts for the long-term memory in returns, fractal dimension is an indicator of the local memory and the generalized measure includes, besides the two previous indicators, the first order autocorrelation coefficient (accounts for the short-term memory).

In the empirical study is investigated the predictability of the stock returns based on the deviations from the random walk model, generated by short-term dependencies, linear or nonlinear or long-term dependency. Are included here tests that were developed under the theory of fractal markets because, after Peters (1994) introduced this theory, it was outlined a new approach of the deviations from efficiency. Mainly, long memory can be described, based on the self-similarity property through fractal dimension, which is a local characteristic of the time series. In time, multifractality became an appropriate scientific framework for the study of efficiency.

Beran et al. (2013) classifies the tests designed to investigate the long memory into three categories: heuristic, parametric and nonparametric tests. Among heuristic methods are mentioned: R/S analysis introduced in Hurst (1951), KPSS statistic (Kwiatkowski et al., 1992), V/S analysis (Giraitis et al., 2003), DFA analysis (Peng et al., 1994) or parameter estimate-on methods for *d* based on temporal aggregation (Beran et al., 1995). For parametric estimation methods is mentioned the Whittle estimator (Fox & Taqqu, 1986). The category of semi-parametric methods can be divided into estimation methods from the spectral analysis domain, like GPH estimator (Geweke & Porter- Hudak, 1983), Whittle estimator (Kunsch, 1987) and estimation methods of the wavelet analysis (Abry & Veitch, 1998, 1999). To estimate the Hurst exponent, in this chapter, it has been used the rescaled range method, R/S. The R/S statistic is computed as a difference between the maximum and the minimum deviation from the mean, divided by the standard deviation, and it can be described through a power function of the form $(R/S)_\tau = c\tau^H$.

In the context of the stock markets, fractal dimension quantifies the degree of the smoothness in the time series, being a measure of the local memory, which is reflected, based on the self-similarity property, in the global one. The estimation methodology used in this chapter focuses on Hall- Wood (1993) and Genton (1998) estimators. Hall- Wood method involves dividing the time series into smaller series, similar to a zooming process, in order to notice if there is a pattern in the chart series. Genton method uses the estimator $\widehat{D}_G = 2 - \frac{log\widehat{V}(\frac{2}{n}) - \log\widehat{V}(\frac{l}{n})}{2log2}$, based on the squared average of the return differences that are separated by $\frac{l}{n}$ moments of time.

From a methodological point of view, to identifying if the analyzed European stock markets show deviations from the weak form efficiency, are used, as efficiency measures, the Hurst exponent, fractal dimension and the generalized measure of efficiency introduced in Kristoufek & Vosvrda (2013). Long-term dependencies are estimated based on Hurst exponent, computed over the whole period of time and on rolling windows. The rolling windows approach assumes, at each step, the use of overlapping windows of the same length. In this case were used windows of 300 observations and the Hurst exponent was estimated on every window. Because this approach returns several values of the estimated measure, it is considered in the analysis the median value of the estimated Hurst exponents. Finally, the long-term measure used to rank the stock markets is the average between the Hurst exponent estimated on the whole period of time and the median value of the information set estimated on rolling windows. Fractal dimension is computed as the average of the two estimators, Hall-Wood and Genton.

The generalized measure is based on long-term dependencies, short-term dependencies and measures of fractality. In computing the generalized measure are considered the following merasures: the average of Hurst exponent estimated on the whole period of time and on rolling windows, the average of fractal dimension estimated through the methods of Hall-Wood and Genton and the first order correlation coefficient.

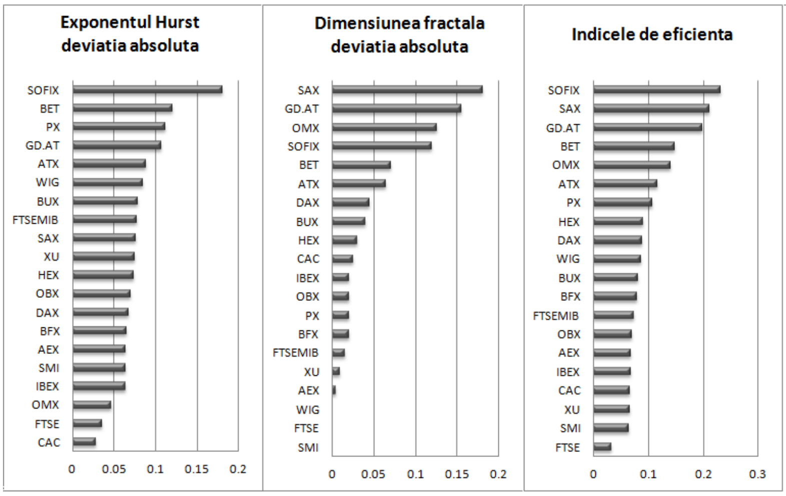
The generalized measure is described by:

$$EI = \sqrt{\sum_{i=1}^{n} (\frac{\widehat{M}_i - M_i^*}{R_i})^2},$$

where, $\widehat{M}_i$ is an estimate of the i^{th} measure of efficiency, M_i^* is the expected value of the i^{th} measure under the assumption of efficiency and R_i is the range of each measure. The generalized measure takes values between 0 and $\frac{\sqrt{n}}{2}$, where *n* is the number of the included measures. Under efficiency, $EI = 0$ and $EI = \frac{\sqrt{n}}{2}$ corresponds to the highest degree of inefficiency.

In computing the rankings were considered the absolute deviations of each measure from the efficiency value (0.5 for Hurst exponent and 1.5 for fractal dimension). The analysis is performed on a set of market indices corresponding to 20 European stock markets, both from developed or emerging markets. We have considered daily data between January 1999- December 2013. The whole period was divided into three sub-periods, as follows: pre-financial crisis period (1999- 2006), financial crisis period (2007-2008) and the years 2009-2013, when the market was under a slight stability but still affected by the financial crisis effects. Figure 4 shows the rankings of the investigated European stock market indices based on three measures of efficiency, for the whole period of 1999- 2013.

Figura 4. Clasamentul indicilor conform exponentului Hurst, Dimensiunea Fractală şi Măsura Generalizată a eficienţei pentru perioada 1999- 2013



Source: Baciu (2014a)

For the whole covered period, 1999- 2013, are drawn the following conclusions:

- based on the generalized measure, the most efficient markets are the mature ones, from countries like United Kingdom, France or Switzerland. On the other side, a high degree of inefficiency affects the markets of Bulgaria, Slovakia, Greece or Romania;
- based on the Hurst exponent, are noticed high deviations, that suggest long memory in returns rather than short memory;
- compared to the generalized measure, the Romanian stock market is ranked top four inefficient markets. The Hurst exponent suggest that the returns are affected by long memory, the market being ranked as the second market with the highest long-term dependencies.

In Europe, the years 1999-2013 were affected by events that lead to a different market behavior. For this reason, we have conducted empirical studies for each of the three delimited sub-periods: 2003-2007, 2007-2008 and 2009-2013, that concludes the following results:

- between 1999-2006, the rankings of the relative markets efficiency were similar to the rankings for the overall period, in terms of the three efficiency measures;
- for the years affected by the financial crisis, 2007- 2008, the rankings do not change significantly compared to the previous period, but is noticed a higher deviation of the fractal dimension measure for the SAX index (Slovakia) relatively to the other markets;
- for the years 2009-2013, all the markets exhibit deviations from the hypothesis of informational efficiency, with the highest deviations for Finland and Poland, that are caused mainly by the presence of a local memory identified through significant deviations of the fractal dimension from the expected value. In the previous periods, the degree of efficiency on the two markets, of Finland and Poland, was average.

Overall, the markets of Bulgaria, Slovakia, Greece or Romania exhibit higher deviations from efficiency, while, on the mature stock markets, like United Kingdom, France, Sweden or Switzerland is identified a higher level of efficiency.

The empirical study on the Romanian stock market concludes a low level of efficiency, which evolves positively in time. Compared to the existing literature on the Romanian stock market, this study provides a more comprehensive approach in terms of the methodology, as follows: a) were used efficiency measures recently suggested in the literature to identify the main types of dependencies (fractal dimension, generalized measure), b) it was considered the evolution in time by using the rolling windows approach, c) the degree of the deviation from efficiency was analyzed relatively to the main European stock markets. Romanian stock market, characterized by the market index, BET, is classified as a market with a low degree of efficiency, a result that allows the assumption of a potential predictability on the market. This remark is a first hint that statistical forecasting methods or technical analysis strategies could be used to return profits.

SUMMARY OF CHAPTER IV

Investigation of the weak form efficiency: technical analysis

In the context of informational efficiency, where the price evolution is described by random walk or martingale models, technical analysis can not return constant profits (profits can exist occasionally) because prices fully and immediately incorporates all available information such that there are no arbitrage opportunities. The presence of a dependence structure in the returns contradicts the efficient market theory and allows technical analysis strategies to return profits, with a success that depends mostly on the analyzed market and the selected period of time. Although the financial theory of stock markets supports the efficiency hypothesis, the fact that stock markets work until nowadays suggest the traders interest in this institution, an interest that would not hold in time without a potential financial reward. From a practical perspective, it is considered that stock markets exhibit potential predictability of the price changes, an approach that comes into the detriment of informational efficiency.

The studies regarding the profitability of technical analysis strategies were conducted primarily on the United States stock market, but as with the developing of stock markets, other markets, both, developed or emerging markets, began to present theoretical or empirical interest. Park & Irwin (2007) classify the technical analysis literature into early studies (1960- 1987) and modern studies (1988-2004). Compared to the early studies, modern studies bring an improved approach by considering several strategies in the analysis of the profitability instead of a single strategy, incorporating transaction costs and considering the risk level assumed but also by using an appropriate research methodology, based on bootstrap methods or genetic programming and testing the robustness of the results with the use of data-snooping tests.

The empirical study developed in this chapter is focused on two main ideas: first, the performance of technical analysis strategies is tested on the Romanian market, under the assumption of time dependencies in returns and secondly, is analyzed the relation between the excess return and informational efficiency. This approach is justified under the previous chapter results, that concludes the deviation of the Romanian stock market from informational efficiency.

In light of the statistical methodology, we mention the following contributions. First, we applied a recent statistical methodology for estimating the dependency structure in the returns. Short-term dependencies are estimated based on the Automatic Portmanteau test of Escanciano & Velasco (2009). This enhanced version of the Box-Pierce test was selected because it is robust to heteroskedasticity of unknown type. The test is based on the null hypothesis of random walk, $H_0\colon \rho_j = 0, \forall j \geq 1$, where ρ_j is the j^{th} order autocorrelation coefficient. The portmanteau statistic is improved to allowing the automatic selection of the lags, p. The automatic selection is realized based on the Akaike Informational Criterion or the Bayesian Information Criterion, depending on the type of the autocorrelations in returns. The test is applied using the rolling windows approach, in order to capture the persistence of the dependencies in time. The test statistic is computed for each window and is made a decision on rejecting or not the random walk hypothesis. Finally, is quantified the number of windows in which the null hypothesis is rejected. The percentage of windows that fail to reject the null hypothesis is an efficiency indicator (Todea & Rusu, 2014); a higher value implies a more efficient market.

Long-term dependencies are quantified using Hurst exponent. A drawback of the R/S estimation method is the fact that is sensitive to the presence of the short term dependencies (Lo, 1991). To overcome this drawback, the Hurst exponent was estimated on non-overlapping blocks of shuffled data, besides the estimation on whole period (Cajueiro & Tabak, 2005a). The blocks consist of a fixed number of observations, without overlapping. This methodology removes any existing dependency structure inside the blocks, but due to the length of the blocks, long-term dependencies remain unaffected.

The second contribution consists in the use of a robustness test to check the performance of the trading strategy. Hansen's Superior Predictive Ability test (Hansen, 2004) was applied recently in the empirical literature of the profitability of trading strategies and, regarding the Romanian stock market, this study is to our knowledge, among the first studies that applies this test. The null hypothesis states that the benchmark strategy is not inferior to any alternative forecast, $H_0: \mu \leq 0$, where μ is the vector of the expected values in terms of the excess return of the best trading rule compared to the benchmark strategy. The benchmark strategy was considered the buy-and-hold strategy. The test statistic is $T_n^{SPA} = \max(max_{k=1,..,m} \frac{\sqrt{n}\bar{d_k}}{\widehat{\omega_k}}, 0)$, where $\widehat{\omega_k^2} = var(n^{\frac{1}{2}}\overline{d_k})$ is an estimator for the variance of the excess return. In order to obtain the asymptotical values for p-value, are applied bootstrap simulations based on the stationary bootstrap of Politis & Romano (1994).

Thirdly, is used a selection mechanism of the best performing trading rule out of the entire universe of moving average trading rules (Brock et al., 1992), in terms of profitability. The moving average that was used in the empirical analysis is composed of a short-term moving average for a time period that is varying between 1 and 10 days, a long-term moving average between 50 and 200 days and a fixed band between 0 and 1%, with an increment of 0.1%, used to avoid the insignificant differences between the two moving averages. The sell/ buy signals are generated only when the differences between the short-term moving average and the long term one are higher that the considered level of the band. All the combinations that can be generated between the short-term moving average, the long-term moving average and the band determine the entire universe of trading rules, respectively 16500 strategies.

The empirical study performed in the first part of this chapter aims to assess the performance of technical analysis on the Romanian stock market, under the assumption that the returns exhibit short and long-term dependency structures. The moving average strategy, in the form proposed in this paper, exploits both short and long-term dependencies. Moving average strategy is applied on a portfolio of 21 independent assets traded at Bucharest Stock Exchange between 2003-2012. The period under review is divided into two sub-samples defined, for each asset, by the highest closing price reached in 2007; due to the impact of the financial crisis, that moment corresponds to a structural break.

Table 1 presents, for each asset, the empirical results regarding the best trading strategy in the second period, 2007-2012.

Table 1. Best trading strategy for 2007-2012

Activ	*VMA*	*Rentabilitatea VMA (%)*	*Rentabilitatea Buy&Hold (%)*	*Data-snooping p-value*
ALR	MA(8,51,0.1)	2.7052	-1.1985	0.08
ATB	MA(1,88,0.4)	2.3359	-0.9512	0.1
BRK	MA(6,62,0.3)	1.9661	-0.0026	0.12
OIL	MA(9,52,0.1)	3.015	-1.2528	0.09
PREH	MA(5,50,0.5)	1.9384	-0.9557	0.16
SIF1	MA(5,51,0.9)	2.9679	-0.7269	0.31
SIF2	MA(2,51,1)	4.3103	-0.4394	0.41
SIF3	MA(3,50,0.1)	3.8919	-0.6839	0.3
SIF4	MA(1,99,0.8)	1.4652	-0.7253	0.23
SIF5	MA(10,50,0.7)	4.3319	-0.7648	0.28
SNP	MA(5,66,0.5)	1.9907	-0.1759	0.55
DAFR	MA(2,50,0.3)	4.448	-2.2484	0.03
SCD	MA(7,91,0.7)	2.3132	-0.0495	0.21
UAM	MA(10,145,0.2)	0.7707	-0.7946	0.15
SPCU	MA(8,78,0.7)	2.4725	-0.6522	0.13
BRD	MA(8,68,0.6)	2.8881	-1.0473	0.11
EFO	MA(8,57,0.5)	2.503	-1.255	0.17
STZ	MA(9,103,0.1)	0.164	-0.2853	0.31
ELMA	MA(4,62,0.2)	1.3759	0.2493	0.23
ART	MA(8,184,0.9)	1.1143	-1.0592	0.05
IMP	MA(3,68,0.4)	4.3192	-2.7053	0.05

Source: own processing

The first part of the study identifies, for each of the two sub-periods, the moving average that returns the highest profitability out of the entire universe of trading rules. The robustness of the results is tested through means of data-snooping tests. For 2003- 2007, the excess return is not statistically significant for any of the considered assets. For 2007-2012, although the return of the most profitable strategy exceeds the return of the buy-and-hold, only 6 out of 21 strategies are significantly superior at 10% level of significance.

The second part of this chapter is dedicated to the study of the relationship between excess return and informational efficiency, on the Romanian stock market in the two sub-periods of time. The excess return is explained through a linear regression model, using the independent variables that quantify the deviations from efficiency but also micro-economic factors, respectively the associated risk and the return of the equities. The deviations from efficiency are quantified through Hurst exponent and the percentage of windows in which the random walk hypothesis is rejected. Standard deviation of the returns is used as a proxy for risk (Nelson, 1991; Glonsten et al., 1993) and ROE (return on equity) is the micro-economic indicator of the profitability of equity. ROE is one of the most important indicators of the company's performance (Cajueiro & Tabak, 2004).

Table 2 presents the variables estimated values for 2007-2012, namely the Hurst exponent estimated on the whole period of time, Hurst exponent estimated on blocks of shuffled data, the percentage of windows that reject the random walk hypothesis and the excess return of the moving average strategy compared to buy-and-hold.

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Tabel 2. Recorded values for the analyzed variables between 2007-2012

Activ	*Exponentul Hurst*	*Memoria lungă*	*Memoria scurtă (%)*	*Exces de rentabilitate*
ALR	0.6413	0.6552	0.23	3.9037
ATB	0.5964	0.596	0.21	3.2871
BRK	0.6421	0.6393	0.28	1.9687
OIL	0.6021	0.5984	0.02	4.2678
PREH	0.59	0.5541	0.15	2.8941
SIF1	0.6172	0.6243	0.45	3.6948
SIF2	0.6549	0.6624	0.35	4.7497
SIF3	0.6258	0.6376	0.3	4.5758
SIF4	0.5821	0.5864	0.1	2.1905
SIF5	0.6465	0.6578	0.3	5.0967
SNP	0.609	0.6118	0.16	2.1666
DAFR	0.6765	0.6778	0.18	6.6964
SCD	0.6519	0.6397	0.25	2.3627
UAM	0.4541	0.4641	1	1.5653
SBCU	0.5944	0.5802	0.25	3.1247
BRD	0.653	0.6338	0.03	3.9354
EFO	0.5474	0.5136	0.86	3.7580
STZ	0.5149	0.5098	1	0.4493
ELMA	0.5969	0.5948	1	1.1266
ART	0.573	0.55	0.51	2.1735
IMP	0.6237	0.6085	0.48	7.0245

Source: own processing

The fact that the return series allow dependencies is a first hint that technical analysis strategies could return profits. Under this framework, a fair question is to what extent the dependence structure could lead to possible financial benefits. Empirical results identify a positive and statistically significant influence of the long memory in the excess return. On the other side, short memory does not have a significant influence. Excess return is positively associated with firm-specific variables, the risk being statistically significant in both sub-periods while the return of equities only in the second sub-period. Similar results are drawn when the transaction cost is considered (0.3% one way). Therefore, regarding the relationship between the excess return and the dependencies in return series, the empirical evidence support the conclusion that the profitability of the moving average strategy is due to long memory instead of the short one.

GENERAL CONCLUSIONS AND RECOMMENDATIONS FOR FURURE RESEARCH

Through this paper we aimed to contribute to the knowledge of the appropriate statistical methodology used for modeling the behavior of stock market prices. Achieving this goal requires a good understanding of the economical theories that govern the financial markets but also, it requires the ability to identify, from the broad spectrum of applied statistics, the statistical tools that are suitable for delimiting the specific statistical properties of the returns and for the analysis of the dynamics of financial asset prices.

The fundamental concept of financial theory of stock markets is the hypothesis of efficiency, built on the assumption of a market in which all participants behave rationally and have equal, unlimited and immediately access to any information. Recent studies are emphasizing a possible irrational and unexpected behavior of the market participants as a reaction to market information. Also, equal access to any information is questionable and also the immediate reflection of the information in the prices, aspects that lead to deviations from market efficiency if they are not accomplished. The most known altenative/ complementary theories of the informational efficiency are the behavioral finance, adaptive markets theory and fractal markets theory.

By using the appropriate research methodology, we have focused to identifying the main statistical properties of the stock prices/ returns, mainly we were interested in the characteristics regarding the distribution of the returns, risk and predictability. Based on financial literature, it was assumed that financial returns follow a leptokurtic distribution, with fatter tails than the normal distribution. Although the existing literature do not identify the most appropriate distribution, the family of the generalized hyperbolic distributions contains distributions, that may be, in our opinion, potential candidates because of their theoretical properties.

Based on the results of the empirical study conducted on a set of assets traded on the Romanian stock market, the hyperbolic distribution, Normal Inverse Gaussian and Assymetric t-Student are identified as good approximations of the empirical distribution. It was paid a special attention to modeling the left tail of the empirical distribution due to the occurrence of the extreme negative values. An immediate practical utility that results from knowing the probability law that describes the behavior of the stock returns is the estimation of the Value-at-Risk, an important tool in the risk management area. Value-at-risk was estimated through parametrical and non-parametrical methods, but we considered important to test the ability of the methods to anticipate VaR. The ability of the estimation methods to predict correctly the maximum potential loss, at a specific confidence level, is statistically tested through a backtest, applied based on the rolling windows approach. Regarding the family of the generalized hyperbolic distributions, the generalized hyperbolic law, Normal Inverse Gaussian and asymmetric t-Student, all lead to similar results for the quantile value VaR.

The empirical research of the stock price predictability enrolls in recent research trends, which regards the efficiency from an evolutionary perspective and accepts periods with different degree of efficiency. Such an approach allows us to identify factors that have a significant influence in the change of the degree of efficiency and thereby, become potential sources of predictability in the stock market. In terms of the statistical approach, we aimed here to apply a suitable methodology to detecting the several types of dependencies in returns (short memory, long memory and local memory). In this regard, were considered measures that take into account the statistical characteristics of the financial returns (mainly the heteroscedasticity and non- normal distribution).

According to recent literature recommendations, the empirical results were refined through the rolling windows approach and estimation on non-overlapping blocks of shuffled data. Using this methodology allows building measures that characterize the degree of deviation from informational efficiency and place the stock markets relatively to each other's degree of efficiency. The empirical analysis is performed under the assumption of relative efficiency, an approach that allows us to construct efficiency rankings of the most important European stock markets. However, these efficiency measures were used as explanatory variables in the econometric models that address the excess return of the moving average strategies. The empirical results regarding the efficiency of the Romanian stock market, places this market on the top of the most inefficient (along with the stock markets from Bulgaria, Slovakia or Greece) markets in Europe.

In the framework of the previous empirical results regarding the deviation from efficiency of the Romanian stock market, we considered appropriate to analyze the profitability of the moving average strategy on this market and to what extent this strategy could lead to a significant excess return compared to the buy-and-hold strategy. It was selected, for each asset, the moving average strategy that returns the highest excess return.

The study was conducted for two periods of time, characterized by a different economical environment, namely before and after the beginning of the financial crisis. We considered important to provide robust statistical results by applying a data-snooping test (Hansen's Superior Predictive Ability test), which was rarely used in the literature. The data-snooping test null hypothesis states that the best trading rule (moving average, in this case) is not superior to the benchmark strategy. For 2003-2007, the excess return is not statistically significant, while between 2007-2012, although the returns of the most profitable rules exceed the returns of the buy-and-hold, the null hypothesis is rejected for only 6 out of the total of 21 assets.

The fact that the returns exhibit short and long-term dependencies, quantified through Hurst exponent and Escanciano & Lobato (2009) test, is a first hint that technical analysis strategies could return profits. The second part of the empirical research regarding the profitability of the moving average strategy concludes that excess return is positively associated with the long-term memory and micro-economic indicators, like risk. Therefore, the long-term dependency structure can be exploited in order to earn profits.

In addition to the empirical studies performed over the three out of four chapters of this thesis, we paid a special attention to defining the theoretical concepts and the statistical methodology applied, but also to frame the financial theories that motivate the empirical research. Each study is framed in the context of the recent literature by highlighting the main empirical results and theoretical contributions.

The keywords that describe this research are those of returns and profitability, basic notions that materializes in a financial gain as an effect of a complex combination of microeconomic, macroeconomic and even psychological factors. Turning the information into profits is conditioned by the use of an appropriate statistical methodology.

The main purpose of the empirical studies is to analyze the statistical properties and the dynamic of the asset prices/ returns on the Romanian stock market. Although the results of the empirical research bring valuable contributions to the existing literature on the Romanian market, there are several aspects that deserve attention on future research.

A first aspect regards the probability laws that model the financial returns and consists in extending the analysis to a larger portfolio of independent assets both from Romanian and foreign stock market. As an alternative to the goodness-of-fit measures applied, Anderson-Darling could be used as an appropriate alternative to KS test as it focuses specially on the fit of the theoretical distribution on the tails of the empirical data. Regarding the relative efficiency, we have used in the empirical study the deviations from the informational efficiency reference, but from a statistical approach, it would be of main interest to test the significance of these deviations, an approach that could consist in a future research.

The profitability of the moving average strategy was investigated relative to buy-and-hold, but, as it could be noticed from the empirical results, the buy-and-hold strategy leads to positive returns under periods affected by a positive and increasing trend. In this regard, on a future research we can extend these results by considering trading strategies that account for specific market indicators.

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