Portfolio creation and stocks evaluation with chaos theory

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Abstract

Purpose of this dissertation is to investigate as well as to evaluate the behavior of stock prices in Athens Stock Exchange (ASE) based on chaos theory. More specifically, this dissertation evolves Greek stocks from the bank sector for the period 1986-2007. Note that for two (2) of the banks (Bank of Cyprus and Agricultural Bank of Greece) involved in the sample the data for the period 2001-2007 are restricted because these corporations have only recently entered the ASE.

A methodology similar to that of Kai Du (2004), Theriou et al, (2005), Ayandi and Kryzanowski, (2004) and Oh et al, (2005) is employed; the constraints imposed by a smaller sample both in time and in terms of the number of stocks are taken into account.

The findings of this research have showed that the Greek Stock Market, and more specifically the bank sector, is characterized from a chaotic behavior. Nevertheless, an allusion is made to these findings for a future research in the whole Greek Stock Market.
1. Introduction

Chaos theory has been extensively used by many researchers like Opong et al. (1999), Fama and French (1992) and Kai Du (2004) in many different Stock Markets (e.g. Chinese Stock Market, London Financial Times Stock Exchange (FTSE)) in order to investigate if any of those markets is characterized from a chaotic behavior.

The present research has been inspired by four (4) older chaotic methods. These methods were introduced from Ayandi and Kryzanowski in 2004, Kai Du in 2004, Theriou et al, in 2005, and Oh et al, in 2005, respectively. The methodology adopted in this thesis is based on the above mentioned methods. In addition to this, it has been reformed in order to fit Greek Stock Market. The area under investigation is the Athens Stock Exchange during the period 1986 – 2007. More specifically, it focuses on the Bank Sector of the Greek Stock Market during this particular period. The stock prices of ten (10) Greek Banks from the private and the public sector are gathered and analyzed.

Scope of this dissertation is the creation of portfolio as well as the stocks evaluation with the use of chaos theory. More specifically, it attempts to show that both an existing investor and/or a future one should create one’s own portfolio based on chaos theory. This will give one a more precise picture of what is really taking place in the Greek Stock Market. In this way, one will be able to succeed the best result possible that is the maximization of one’s investment.

The present dissertation is consisting of the following ten (10) sections, which also include the appendixes.

The first section is concerned with: (a) the technical analysis and its basic tools (charts and cycle analysis, moving averages etc); (b) the segregation of technical analysis studies in two (2) different groups (early and modern studies) by Park and Irwin in 2006; (c) the researchers’ principal allegations about it.
The second section, the so-called “literature review”, deals with portfolio, chaos theory, chaos game, fractal and fractal dimension, fractal market hypothesis and Capital Market Hypothesis (CMT). In this section, a small introduction as well as a definition of the terms “portfolio”, “chaos theory”, “fractal market hypothesis” and “Capital Market Hypothesis (CMT)” are given.

In the third section eleven (11) different traditional and modern methods from several stocks markets like the Chinese, the Greek, the Norwegian and the US one are briefly mentioned. These methods focus on the existence and/or the absence of chaotic behavior in the above mentioned stock markets. Most of them attest the existence of a kind of chaotic behavior in each one of those markets. This attestation is worth to be investigated in order for the implications and the effects on those markets’ behavior through years to be evaluated and calculated.

The fourth and fifth section respectively present and analyze the following points: the hypothesis and the main target of the dissertation; the methodologies along with the equations to be used as basic elements, which will be enriched in order to create a new portfolio. There are four (4) different methodologies. The first one is a portfolio algorithm known as $\beta$-G portfolio algorithm, “that selects stocks based on their market capitalization and optimizes them in terms of its standard deviation from $\beta$” (Oh et al, 2005). The second one is an asset-pricing model (APM) -free measure, and especially the APM-free kernel model which is used to evaluate the performance of actively managed portfolios (Ayandi and Kryzanowski, 2004). The third one intends to explicate the cross-sectional relationship between average stock returns and risk in Athens Stock Exchange (ASE)” based in the Fama and French research in 1992 introduced by Theriou et al., in 2005. The last one is a research on the Chinese Stock Market; more specifically, on the daily and monthly returns of Shanghai Stock, Shenzhen Stock A&B Index and their composite based on the rescaled range (R/S) analysis discovered by Hurst in 1951 and the Confidence Test introduced by Peters in 1991.
The sixth section presents the results of this dissertation as they are given through a variety of graphs. There are four (4) different graphs for each one of the ten (10) banks that were involved in the sample. These graphs basically represent the profile of daily returns of every single mentioned bank, their frequency distributions of daily returns and their fractal dimensions as well.

The seventh section shows the main conclusions of this dissertation grouped in four (4) categories. It further presents some limitations that have to do with the size of the sample along with suggestions for future researches. These suggestions stress emphasis on the fact that there should be a broader investigation in the most companies possible in order for a rounder view of what actually affects the Greek Stock Market to be acquired.

Finally, the last three sections are the appendixes. In the first one, a brief analysis of its bank progress through years is held. Ten (10) different banks compose the sample to be used in the methodology part. The Agricultural Bank of Greece, the Bank of Cyprus, the Bank of Greece and the Ethniki Bank are among these. In the second one, all the graphs and tables created for each one of those ten (10) banks involved in the sample are presented. In the third Appendix, the C++ program created through the research in order to drop the results of the R/S analysis is presented.
2. Literature Review

2.1. Technical analysis

Before the creating a portfolio and evaluating stocks, a brief allusion to the technical analysis will be held. The term technical analysis refers to the method of evaluating stocks by analyzing statistics generated by market activity, such as past prices and volume. In technical analysis a variety of forecasting methods such as chart analysis, cycle analysis, and computerized technical trading systems (Park and Irwin, 2006) are used to depict certain price-volume factors that repeat themselves. Most of the technical trading systems include moving averages, channels and momentum oscillators. According to Pring (2002), “The technical analysis is a reflection of the idea that prices move in trends that are determined by the changing attitudes of investors toward a variety of economic, monetary, political, and psychological forces. The art of technical analysis is to identify a trend reversal at a relatively early stage and ride on that trend until the weight of the evidence shows or proves that the trend has reversed”.

Technical analysts believe that the historical performance of stocks and markets can show what will probably happen in future. By diagramming a market’s movement, they can determine market swings in advance. According to the theory, the best time to sell (take a short position) is the start of a major downtrend; the best time to buy is when prices, and trends, are heading upward.

Park and Irwin (2006) segregate all the technical analysis studies in two (2) different groups: the “early studies” (1960-1987) and the “modern” studies. Modern studies are classified into seven (7) groups based on their main characteristics:

1. Standard studies
2. Model-based bootstrap studies
3. Reality check studies
4. Genetic programming studies
5. Non-linear studies
6. Chart patterns studies
7. Others studies, studies that do not fit in any of the above mentioned categories.

It is worth mention that as far as the technical analysis is concerned, researchers are divided into two (2) different groups: those considering technical analysis as very important when one wants to create a portfolio (Neely, 1997; Allen and Karjalainen’s, 1999; Hudson et al., 1996; Oberlechner, 2001; Doura and Siy, 2002) and, those arguing that technical analysis is not the proper way to do it since they consider it as an unreliable method (Mills, 1997; Bessimbinde and Chan, 1995; Fernandez et al., 2000).

Brock et al. (1992) research on the Dow Jones Industrial average (DJIA) over 1897-1986, for instance, display mixed results. In this case, Brock et al. (1992) applied two technical trading systems: a moving average and a trading range break-out in order to report gross returns without taking under consideration the transactions’ costs. As a result, their results were not adequate in order to prove that technical trading rules generate economics profits (Park and Irwin, 2006).

Contrary to this, Allen and Karjalainen’s (1999) proved the importance of technical analysis. In their research a genetic algorithm was used in order to “learn” the technical trading rules for the S&P 500 index for the period from 1928 to 1995. The daily prices were transformed from no-stationary to stationary by dividing them with a 250-day moving average. Also the daily returns were sensitive to transaction costs but were robust to the impact of the 1987 stock market crash.

In 1997 Neely also used technical analysis in his investigation on the U.S. foreign exchange intervention about the importance of the relationship between trading-rules and central bank intervention. Neely (1997) argued that this relationship is very important since “it might shed light on the source of technical trading rule profits that seem to contradict the efficient-market hypothesis”.

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Finally, in 2001 Oberlechner showed the importance of the technical analysis among foreign exchange traders and financial journalists in Frankfurt, London, Vienna and Zurich through a questionnaire, an interview survey and forecasting methods. According to Oberlechner and Hocking (1997) forecasting methods depict the relationship between trading decision-makers and financial new providers in the foreign exchange market.

2.2. Portfolio and chaos theory

2.2.1. What do we mean when we refer to portfolio term?

In finance, a portfolio is an assortment of investments held by an institution or a citizen. In establishing an investment portfolio a financial institution will typically carry out its own investment analysis. On the contrary, a citizen may turn to the services of a financial advisor or a financial institution which offers portfolio management services (Tobin, 1958). Holding a portfolio is part of an investment and a risk-limiting strategy called diversification, “where an investor can reduce his portfolio risk by holding a diversified portfolio of assets that are not perfectly correlated” (Markowitz, 1952). The assets in the portfolio can include stocks, bonds, options, distress warrants, gold certificates, real estate, futures contracts or even production facilities.

In management, a portfolio involves deciding which assets are to be included in the portfolio given the goals of the portfolio owner and changing economic conditions (Sharpe, 1964). “Selection involves deciding what assets to purchase, how many to purchase, when to purchase them, and what assets to divest” (Lintner, 1965). These decisions always involve some sort of performance measurement; most of the time expected return on the portfolio, and the risk associated with this return, for example the standard deviation.
The graph above illustrates that the market portfolio depends on the expected return, where all investors, companies or private individuals expect the maximization of their profits, as well as the every type of risk an investor accepts to take. The efficient frontier depicts every attainable combination that maximizes expected return at each level of portfolio risk. There are three types of combinations: (a) the ones with high risk, (b) those with medium and (c) with low risk. Usually, investors that take high risks combinations earn more money than others that take lower ones.

The following diagram gives a more precise picture of how the efficient frontier curve is. The curve in a portfolio is not feasible to happen since the risk is too high and the returns are not exactly what one should expect to gain from such risk. On the contrary, combinations that are below the frontier curve are not worth to be taken by any investor as long as an investor is able to achieve more profits, if one chooses to take a combination that is on the frontier curve.
2.3. Chaos theory

The term "chaos theory" refers to systems visibly disordered. In reality, though, it finds out the underlying order in apparently random data (Devaney, 2003). “The chaos theory phenomenon is also known as sensitive dependence on initial conditions. Just a small change in the initial conditions can drastically change the long-term behaviour of a system such a small amount of difference in a measurement might be considered experimental noise, background noise, or an inaccuracy of the equipment” (Ott, 2002; Strogatz, 2000).

Chaos theory has been related to many different things, from predicting weather changes to the stock market changes. Based on Clyde and Osler (1997), chaos theory is an effort to see and understand the original order of complex systems that may appear to be without order at first look. Related to financial markets, researchers like the supporters of chaos theory believe that price is the very last thing to change for a stock, bond, or some other security. Price changes can be determined through severe mathematical equations predicting the following factors:

1) A trader's own personal motives, needs, desires, hopes, fears and beliefs are complex and nonlinear.
2) Volume changes
3) Acceleration of the changes
4) Momentum behind the changes
2.4. The Chaos game

In 1998 Barnesley introduced a mathematical experiment, the so called chaos game. The experiment showed the infinite number of triangles enclosed within a triangle. The self-similarity of this experiment according to Barnesley was one of the most important characteristics of fractals. He also mentioned “that even the plots of the experiment different every time one plays it, the Sierpinski triangle always appears because the system responds to the random events in a deterministic way and that local randomness and global determinism produce a steady structure”. Those local randomness and global determinism are called fractals.

According to Barnesley (1998), the prediction of that actual sequence of points is unattainable and so is the position of the next point which totally depends on the current point. The empty spaces within each triangle have a zero (0) percent probability of being planned. The ends outlining each triangle have a higher possibility of taking place. This is why local randomness is not alike with equal probability of all potential solutions and independence as well.

Barnesley (1998), colligated all the above with markets potentially at a local random and at the same time with a statistical structure at non-random.

2.5. What is a fractal?

Fractals do not have certain measurable features or properties desirable for modelling purposes. The self-similarity can only be mathematically described. It is ”qualitative”, which means that the method is similar at different scales and statistically spatial or temporal. Each of these scales resembles to other scales, but they are not identical.

The logarithmic spiral is an example of a characteristic scaling function. Here \( z \) presents the generation number and \( d_z \) is the average of branch generation \( z \): 
\[
d_z = q \cdot d_{z-1} \cdot d_0
\]

According to Weibel and Gomez (1962) \( q = 2^{-1/3} \) so 
\[
d_z = d_0 \cdot 2^{-z/3}
\]
where \( d_0 \) is the diameter of the main branch of the lung.
In a more general form, the $d_z = q \ast d_{z-d} \ast d_0$ equation can be rewritten as: $d_{z,a} = d_0 \ast e^{-a z}$ where $a = -\ln(q) > 0$.

### 2.6. Fractal dimension

The fractal dimension depicts how the object fills its space. It also describes the structure of the object while the magnification factor is changed. A fractal time series statistically scales in time. One method for calculating the fractal dimension involves covering the curve with circles of a radius, $r$. The number of scales can be measured by the following equation:

$$N \ast (2 \ast r)^d = 1$$

Where:

- $N$ is the number of circles
- $r$ is radius
- $d$ is the fractal dimension

Using logarithms, the above equation can be transformed into:

$$d = \log(N) / \log\left(\frac{1}{2 \ast r}\right)$$

The fractal dimension of time series is important since it recognises that a process can be somewhere between deterministic and random.

### 2.7. Capital Market Theory (CMT)

According to Markowitz (1952, 1959) and Peters (1991a) the Capital Market Theory sets the environment in which securities analysis is performed. Without a well-made view of modern capital markets, securities analysis can be useless. A great debate, and great separation, divides the academics, with their efficient market hypothesis, and the practitioners, with their views of market inefficiency. Even though, the debate appears unreal and insignificant at times, its resolution is greatly critical to accomplishing useful securities analysis and achieving successful investing.

Markowitz (1959) also mentioned that the securities prices and their associated returns should better be viewed from the speculators’ side since they have the ability “to profit on a security by anticipating its future value
before other speculators do”. Usually, speculators bet whether the current price of a security is above or below its future value, and sell or buy according to the current price of a security.

Different speculation theories like Modern Portfolio Theory (MPT) - a theory on how risk-averse investors can create portfolios in order to optimize market risk for expected returns with emphasis on the risk as a natural part of higher reward- did not differentiate between short-term speculators and long-term investors.

Market was assumed to be “efficient”, which means that prices already reflected all current information that could expect future events. Therefore, only the speculative, stochastic component could be modelled; but not the change in prices owed to changes in value. If markets returns are normally distributed, then they are the same at all investment horizons.

As far as risks are concerned, they are the same for every investor at a specific investment horizon. Risk and return are supposed to grow at a commiserative rate over time meaning that there is not any advantage of being a long-term investor or a sort one.

2.8. Fractal market hypothesis

The fractal market hypothesis emphasises the impact of liquidity and investment horizons on the behaviour of investments. It states that:

1. The market is stable and consists of many investors with different investment horizons which certify the presence of liquidity for traders.
2. The information set that is important to each investment horizon is different and it is more related to market reaction and technical factors in the short term than in the longer term.
3. If a security has no tie to the economic cycle, then there will be no long-term trend. Trading, liquidity and short-term information will dominate.
4. If something happens, for example elections, long term-investors either stop participating in the market or being trading based in the short-term information set. This has as a result, market to become
unstable since there are no long-term investors to stabilize it by offering liquidity to sort-term investors.

5. Prices reflect a combination of short-term technical trading and long-term fundamental valuation. Thus, short-term price changes are likely to be more volatile than long-term traders.

Unlike the Efficient Market Hypothesis (EMH), the Fractal Market Hypothesis (FMH) argues that information is valued according to the investment horizon of the investor and that some times prices may not reflect all available information but only the information considered as important for that specific investment horizon.

Letamendia (2007) also professed that the Fractal Market Hypothesis (FMH) is based on the Coherent Market Hypothesis (CMH) of Vaga (1991) where the market is supposed to assume different states and can shift between stable and unstable regimes and the K-Z model of Larrain (1991) where the chaotic regime occurs when investors lose faith in long-term fundamental information.

Likewise the above mentioned models, the Fractal Market Hypothesis (FMH) specifies when the regime changes and why the markets become unstable when fundamental information looses its value. It is also based on the fact that the market is stable when it has no characteristic time scale or investment horizon and that instability occurs when the market loses its fractal structure and assumes a fairly uniform investment horizon.

In our case these changes have to do with the changes happening during a year period in the stock market and especially in the Greek market; how the listed companies react to those changes and how a new portfolio might help them to weather a possible crisis.
3. Methods of stock prices analysis based on chaos theory

3.1. How the agents in the market behave

The first method was proposed by Ogino and Nagao in 2004. It is basically “an examination of the way that the agents in the market behave, when the stock price change in artificial markets resembles that in the real market”. In order to analyze the agents’ behavior, a tree-shaped program is used. The stock price changes rate with a stock Price (t) at time t is given by the following equation:

\[ \text{Change (t)} = \frac{\text{Price (t)} - \text{Price (t - 1)}}{\text{Price (t - 1)}} \]

When the number of agents is a, the number of stocks is a/2. The agent i calculates the forecast change rate \( c_i(t) \) from the own forecast tree that uses past changes. The \( p_i(t + 1) \) is calculated by:

\[ p_i(t + 1) = (1.0 + c_i(t)) \times \text{Price (t)} \]

The Automatically Defined Groups (ADG) method is also used in order to “optimize both grouping for agents and program of each group at the same time in the process of evolution” as well as to utilize the analysis of the mechanisms of price changes.

The Hurst exponent (H) used to distinguish fractal from random times series and a nonparametric model when the probability distributions of the system is not normal has been taken into consideration. If \( (H_i < H_{i,i}) \), the time series are reverting. When \( (H_i > H_{i,i}) \), the time is persistent. According to Ogino and Nagao (2004), the lower the H value is, the more jagged the time series is. Also the Hurst algorithm that obtains the exponent from a time series is used:
\[ \bar{x}(\tau) = \frac{1}{\tau} \sum_{i=1}^{\tau} x_i \]

\[ X(t, \tau) = \sum_{i=1}^{\tau} (x_i - \bar{x}(\tau)), \tau = 1, 2, ..., \tau \]

\[ S(\tau) = \sqrt{\frac{1}{\tau} \sum_{i=1}^{\tau} (x_i - \bar{x}(\tau))^2} \]

\[ R(\tau) = \max_{1 \leq p \leq \tau} X(t, \tau) - \min_{1 \leq p \leq \tau} X(t, \tau) \]

\[ H(\tau) = \log \left( \frac{R(\tau)}{(S(\tau) \cdot c))} / \log(\tau) \right) \]

### 3.2. A portfolio algorithm based on the market capitalization

The second method was proposed by Kyong Joo Oh, TaeYoon Kim, Sung-Hwan Min and Hyoung Yong Lee in 2005. It is basically "a portfolio algorithm" known as "β-G portfolio algorithm" which is used in order to select stocks based on their market capitalization and to optimize them in terms of its standard deviation from \( \beta_p \) "(Oh et al, 2005). This exact algorithm depends on market volatility. It is more efficacious when the market is stable since short purchasing period with small \( T \) tends to be more stable than long purchasing period with large \( T \), rather than when phenomena like bullish or bearish (Liu, Wang and Lai, 2000). It also tends to signify outstanding performance for short-term applications especially with small \( I \) and small \( T \) strategy.

The equation of the portfolio beta \( \beta_p \) is the following one:

\[ \beta_p = \frac{Cov(r_p, I_m)}{\text{Var}(I_m)} \]

\( r_p \): It is the return rate of a portfolio

\( I_m \): It is the return rate of the benchmark index or the capital market m.
This equation can also be used to calculate the beta of just one stock. The result of that calculation will show the sensitivity of this specific stock to market fluctuations.

There are two steps to be followed in this algorithm. In the first step an industry sector $i_k$ with the largest amount of market capitalization is selected. For this industry sector $i_k$ the priority is calculated with the following equation:

$$P_{i_k(j)} = \frac{\left\{ \sum_{t \in E} (I_m(t) - \overline{I_m})^2 \right\}^{1/2}}{\left\{ \sum_{t \in E} (r_{i_k(j)}(t) - \overline{I_{i_k}}(j))^2 / (T - 2) \right\}^{1/2}}$$

Where $P_{i_k(j)}$ is the priority for $k$th stock of $i_k$th industry sector, $j=1,2,...,d_{i(k)}$ and $\overline{X}$ is defined by $\overline{X} = \sum_{c \in E} X(t)/T$. Then the stock with the highest priority is chosen and added to the portfolio as well as removed from the selected industry sector $i_k$. After this, the market capitalization is updated and return to the starting point of this step.

For $\Phi_\rho = \{c_1, c_2, \ldots, c_l\}$ established by the step 1, let $w_k^m (k = 1,2,\ldots,l)$ be the market capitalization of $c_k \in \Phi_\rho$ scaled by the entire market capitalization. Note that $\sum_{k=1}^l w_k^m < 1$ if $l < n$. Where $n$ is the number of stocks for the benchmark index, $l$ is the number of stocks for the portfolio ($l<n$), $c_k$ is the serial code of $k$th stock to be included in the portfolio ($k=1,2,\ldots,l$) and $\Phi_\rho$ is a portfolio set $\{c_1, c_2, \ldots, c_l\}$ selected from all $n$ stocks.

In the second step the optimal weight is assigned $\{w_1^p, w_2^p, \ldots, w_l^p\}$ to each of the selected stocks by minimizing
through the algorithm $Q(w_1, w_2, \ldots, w_l) = \sum_{k=1}^{l} (w_k^m - w_k^l)^2 P_k^{-2}$ where $P_k^{-2}$ is given by the priority equation. Further analysis of this method is held in the methodology part of this assignment.

3.3. An asset-pricing model (APM) -free measure.

The third method is an Asset- Pricing Model (APM) -free measure, and especially the APM-free kernel model used in order to evaluate the performance of actively managed portfolios (Ayandi and Kryzanowski, 2004). This measure is a result of the failure of previous model like CAPM and APT to turn over reliable measures of performance sometimes generating misleading conclusions (Dydvig and Ross, 1985; Admati and Ross, 1985; and Grinblatt and Titman, 1989).

The kernels method consists of two stages: first the appropriate normalized pricing is calculated through a system of momentum equations including only passively handled portfolios; second the risk-settled fund performance is gauged by multiplying the gross cash return through the counted or fitted pricing kernel and taking off the gross return on the risk-free asset (Chen and Knez, 1996).

In this method the basic asset pricing equation used is:

$$E_t(M_{t+1} R_{i,t+1}) = 1 \text{ where } i=1, 2, \ldots, N.$$ 

When there are opportunities that time-varying, the stochastic factors can be described by a power utility function that exhibits constant relative risk aversion, (Cochrane, 2002) given by the following equation:

$$U(w_t) = \frac{1}{1 - \gamma} W_t^{1 - \gamma},$$

where $W_t$, is the level of the wealth at $t$, and $\gamma$ is the relative risk aversion coefficient. In a single-period model when an investor, an industry or even a private individual, holds a portfolio his terminal wealth is given by $E[U(W_{t+1}) | \Omega_t ]$, $\Omega_t$ is the information set. The return on wealth is given by
\[ R_{w,t+1} = a_t R_{b,t+1} + (1-a_t)R_{f,t+1} = a_t (R_{b,t+1} - R_{f,t+1}) + R_{f,t+1} = a_t r_{b,t+1} + R_{f,t+1} \]

Where \( R_{b,t+1} \) is the gross return on the benchmark portfolio from \( t \) to \( t+1 \).

\( r_{b,t+1} \) is the excess return on the benchmark portfolio from \( t \) to \( t+1 \).

\( R_{f,t+1} \) is the gross risk-free rate from \( t \) to \( t+1 \) that is known one period in advance at time \( t \).

\( a_t \) is the proportion of tool wealth invested in the benchmark portfolio.

More particularly \( \theta \equiv (\alpha \gamma)' \) is the vector of unknown parameters and the model has to comply with the following conditional moment restriction:

\[ E_t[Q^c (r_{b,t+1}, Z_t, \theta_0) r_{p,t+1}] = 0_N \] such that \( E_t[Q^c (r_{b,t+1}, Z_t, \theta_0)] = 1 \)

and the pricing errors are given by:

\[ u_{t+1}^c = Q^c (r_{b,t+1}, Z_t, \theta) r_{p,t+1} \equiv u(r_{b,t+1}, r_{p,t+1}, Z_t, \theta) \]

There will be further analysis of this method in the methodology part.

3.4. A contraction of random walk hypothesis to chaotic dynamics.

This method was introduced by Serletis and Shintani in 2002. It is an effort to contrast the random walk hypothesis to chaotic dynamics based on the researches of Whang and Linton (1999) and Nychka et al. (1992).

In order to find out the level of non-stationary data and at the same time “estimate the memory parameter \( d \) of fractional integration”, (Serletis and Shintani, 2002), the modified log periodogram regression by Kim and Phillips (2000) is used.

More specifically:

\[ \text{InP}_t = \beta_1 + \beta_2 t + \epsilon_t, \quad t = 1,2,\ldots \]

\[ (1 - L)^d \epsilon_t = X_t, \quad t = 1,2,\ldots \]
The BDS test \( W(N, m, \varepsilon) = \sqrt{N} \frac{C(N, m, \varepsilon) - C(N, 1, \varepsilon)^m}{\hat{\sigma}(N, m, \varepsilon)} \) that was introduced by Brock at al. in 1996 “testing the null hypothesis of whiteness-independent and identically distributed (i.i.d.) observations against a variety of possible deviations from independence including linear and nonlinear dependence and chaos” (Serletis and Shintani, 2002) is also used in order to test for serial independence of \( X_t \).

According to of Whang and Linton (1999) and Nychka et al. (1992) \( \{X_t\}_{t=1}^T \) is a random scalar sequence generated by:

\[
X_t = \theta(X_{t-1}, \ldots, X_{t-m+1}) + u_t \quad \text{where} \quad \theta : \mathbb{R}^m \rightarrow \mathbb{R}
\]

is a nonlinear dynamic map and \( \{u_t\}_{t=1}^T \) is a random sequence of i.i.d disturbances with \( E(u_t) = 0 \) and \( E(u_t^2) = \sigma^2 < \infty \). \( \Theta \) is also assumed to satisfy a smoothness condition and \( Z_t = (X_t, \ldots, X_{t-m+1})' \in \mathbb{R}^m \) is strictly stationary and satisfies a class of mixing conditions.

\[
F(Z_t) = (\theta(X_{t-1}, \ldots, X_{t-m}), X_{t-1}, \ldots, X_{t-m+1})'
\]

With \( U_t = (u_t, 0, \ldots, 0)' \) such that \( Z_t = F(Z_{t-1}) + U_t \) and

\[
\hat{\lambda} = \lim_{M \rightarrow \infty} \frac{1}{2M} \ln \nu_1(T_M' T_M), \quad T_M = \prod_{i=1}^M J_{i-M+1} J_{i-M+2} \ldots J_0 \quad \text{where} \quad u_i(A) \text{ is the } i\text{th largest value of a matrix } A
\]

It is also has to be mentioned that the exponent estimator \( \hat{\lambda} \) can be obtained by

\[
\hat{\lambda}_M = \frac{1}{2M} \ln \nu_1(\tilde{T}_M' \tilde{T}_M), \quad \tilde{T}_M = \prod_{i=1}^M \tilde{J}_{i-M+1} = \tilde{J}_{M-1} \tilde{J}_{M-2} \ldots \tilde{J}_0
\]

where \( \tilde{J}_i = \frac{\partial F(Z_i)}{\partial Z'} \) and the neural network estimator \( \hat{\theta} \) can be obtained by minimizing the least square criterion

\[
S_t(\hat{\theta}_T) = \frac{1}{T} \sum_{t=1}^T (X_t - \hat{\theta}_T(Z_{t-1}))^2,
\]
Where the neural network sieve \( \theta_r(z) = \beta_0 + \sum_{j=1}^{k} \beta_j \psi(a'_j z + b_j) \), \( \psi \) is an activation function \( \psi(u) = \frac{u^{(1+|u|/2)}}{2+|u|+u^2/2} \) and \( k \) is the number of hidden units.

On the contrary, Serletis and Shintani, (2002) mentioned that under some reasonable condition the \( \hat{\lambda}_M \) estimator according to Whang and Linton (1999) is asymptotically normal and its standard error can be obtained by

\[
\Phi = \sum_{j=-M+1}^{M-1} w(j / S_M) \tilde{\gamma}(j) \quad \text{and} \quad \tilde{\gamma}(j) = \frac{1}{M} \sum_{|t-j|=|\xi|} \eta_t \eta_{t-j}
\]

Where \( \hat{\eta}_t = \tilde{\xi}_t - \hat{\lambda}_M \) with

\[
\tilde{\xi}_t = \frac{1}{2} \ln \left( \frac{v_1(T_t, \tilde{T}_t)}{v_1(T_{t-1}, \tilde{T}_{t-1})} \right) \quad \text{for} \quad t \geq 2 \quad \text{and} \quad \tilde{\xi}'_t = \frac{1}{2} \ln v_1(T_{t'}, \tilde{T}_{t'})
\]

3.5. Random walk type behavior in stock market

The fifth method is an extension of the model suggested by Serletis and Shintani in 2002 for random walk type behavior in stock market. It tests the random walk hypothesis by using a parametric statistical model called randomly modulated periodicity (RMP) (Hinich and Serletis, 2006).

The randomly modulated periodicity (RMP) model allows the capture of the intrinsic variability of a cycle (Hinich, 2000). A discrete-time random process \( x(t_n) \) with period \( T = N \tau \) has the following form:

\[
x(t_n) = s_0 + \frac{2}{N} \sum_{k=1}^{N/2} [(s_1 + u_{1k}(t_n)) \cos(2\pi f_k t_n) + (s_2 + u_{2k}(t)) \sin(2\pi f_k t_n)]
\]

Where:
- \( t_n = nt \)
- \( \tau \) is the sampling interval
- \( f_k = k/T \) is the \( k \) th Fourier frequency
for each period the period
\{u_1(t_1),...,u_{N/2}(t_n),u_2(t_n),...,u_{2N}(t_n)\} are random variables
with zero means and a joint distribution that has the following finite
dependence property: \{u_{jr}(s_1),...,u_{jr}(s_m)\} and \{u_{ks}(t_1),...,u_{ks}(t_n)\}
are independent if \(s_m + D < t_i\) for some \(D>0\) and all \(j,k=1,2\) and
\(r,s=1,...,N/2\) and all times \(s_1 <...< s_m\) and \(t_1 <...< t_n\).
\(u_{k1}(i)\) and \(u_{k2}(i)\), are called 'modulations' and when \(D<<N\) they are
approximately stationary within each period. The process \(x(t_n)\) is:

\[x(t_n) = s(t_n) + u(t_n)\]

Where

\[s(t_n) = E[x(t_n)] = s_0 + \frac{N}{2} \sum_{k=1}^{N/2} [s_{1k} \cos(2\pi f_k t_n) + s_{2k} \sin(2\pi f_k t_n)]\]

And \(u(t_n) = \frac{2}{N} \sum_{k=1}^{N/2} [u_{1k} \cos(2\pi f_k t_n) + u_{2k} \sin(2\pi f_k t_n)]\)

A measure of the modulation relative to the underlying periodicity
called signal coherence spectrum (SIGGOH) that was introduced by Hinich
(2000) is also used. For each \(G=\text{Fourier frequency } f_k/T\) the value of
SIGGOH is:

\[\gamma_x(k) = \sqrt{\frac{|s_k|^2}{|s_k|^2 + \sigma_n^2(k)}}\]

Where \(s_k = s_{1k} + is_{2k}\) is the amplitude of the \(k\)th sinusoid written in
complex variable form, \(i=\sqrt{-1}\), \(s_n^2(k) = E|U(k)|^2\) and
\(U(k) = \sum_{n=0}^{N-1} u_k(t_n) \exp(-i2\pi f_k t_n)\) is the discrete Fourier transform (DFT) of
the modulation process \(u_k(t_n) = u_{1k}(t_n) + iu_{2k}(t_n)\) written in complex
variable form.

The amplitude-to-modulation standard deviation (AMS) is:

\[\rho_x(k) = \frac{|s_k|}{\sigma_n(k)}\]

for frequency \(f_k\) and the estimator \(\gamma_k\) is:
\[
\hat{y}(k) = \frac{|\tilde{X}(k)|^2}{\sqrt{|\tilde{X}(k)|^2 + \hat{\sigma}_n^2(k)}}, \quad \text{where} \quad \tilde{X}(k) = \frac{1}{M} \sum_{m=1}^{M} X_m(k) \text{ is the sample mean of the DFT,}
\]

\[
X_m(k) = \sum_{n=0}^{N-1} x_t \exp(-i 2 \pi \frac{m}{N} n),
\]

And \(\hat{\sigma}_n^2(k) = \frac{1}{M} \sum_{m=1}^{M} |X_m(k) - \tilde{X}(k)|^2\) is the sample variance of the residual discrete Fourier transform, \(X_m(k) - \tilde{X}(k)\).

### 3.6. The independent and identically distributed (IID) behavior in London Financial Time Stock Exchange (FTSE).

The sixth method based on the linear modeling examines the independent and identically distributed (IID) behavior of London Financial Times Stock Exchange (FTSE) (Opong et al. 1999). More specifically, all four FTSE Indices (FTSE All Share Index, FTSE 100 Index, FTSE 250 Index and FTSE 350) and the daily price data for a specific time period are used.

In this method, the calculation of the independent and identically distributed (IID) behavior consists of several different steps.

Where:
- \(S_t\) is the logarithm return at time period \(t\)
- \(S_{t-1}\) is the logarithm return at time period \(t-1\)
- \(\beta\) are the parameters to be estimated
- \(\varepsilon_t\) is the residual form the regression which is analyzed in the study.

According to Peters (1994), the time period is divided into \(A\) contiguous sub-periods of length \(n\), such that \(A \times n = N\) where \(N\) is the length of the series \(N_t\). Each sub-period is \(I_a\), \(a=1,2,3,...,A\). Each element in \(I_a\) is labeled \(N_{k,a}\) such that \(k=1,2,3,...,n\). For each \(I_a\) of length \(n\), the average value, \(e_a\) is defined as

\[
e_a = \left(\frac{1}{n}\right) \times \sum_{k=1}^{n} N_{k,a}
\]
The rage $R_{I_a}$ is defined as the maximum less the minimum value, $X_{k,a}$, within each sup-period $I_a$ given by $R_{I_a} = \max(X_{k,a})$, where $1 \leq k \leq n$, $1 \leq a \leq A$.

Where the time series of accumulated departures for each sub-period is:

$$X_{k,a} = \sum_{i=1}^{k} (N_{i,a} - e_a), \quad k = 1, 2, 3, \ldots, n$$

The standard deviation $S_{I_a}$ of each range $R_{I_a}$ is:

$$S_{I_a} = \left[ \left( \frac{1}{n} \right) \times \sum_{k=1}^{n} (N_{k,a} - e_a)^2 \right]^{0.50}$$

The average $R/S$ value for length $n$ is defined as:

$$\left( \frac{R}{S} \right) = \left( \frac{1}{A} \right) \times \sum_{a=1}^{A} \left( \frac{R_{I_a}}{S_{I_a}} \right)$$

The Expected $(R/S)$ is given by:

$$E(R/S) = \left[ \left( \frac{n - 0.5}{n} \right) \times \left( \frac{n \times \pi}{2} \right) \right]^{-0.5} \times \sum_{r=1}^{n-1} \sqrt{\frac{(n-r)}{r}}$$

The variance of the Hurst exponent is given by: $Var(H) = \frac{1}{T}$, where $T$ is the total number of observations in the sample.

$V$ statistic is also used in order the break in a series to be detected. It is given by:

$$V_n = \frac{(R/S)_n}{\sqrt{n}}$$

Opong et al. (1999) also used a test based on Brock et al. (1996) BDS test in order to examine the behavior of the FTSE indexes. "The BDS statistical measures the statistical significance of the correlation dimension calculations. The correlation integral is the profitability that any two points are within a certain length, $e$, apart in phase space" Opong et al. (1999). The equation of the correlation integral is:

$$C_m(e) = \left( \frac{1}{N^2} \right) \times \sum_{i,j=1}^{T} Z(e - |X_i - X_j|), \; i \neq j$$
Z(e)=1 \text{ if } e \mid X_i - X_j \mid > 0,0, \text{ otherwise:}

T is the number of observations
e is the distance
C_m is the correlation integral for dimension m
X is the index series

Finally, when the DBS is normally distributed the equation has the following form:

\[ W_N (e, T) = | C_n(e, T) - C_1(e, T) | \times \frac{T}{\sqrt{S_N(e, T)}} \]

3.7. An investigation of the existence of nonlinear structure in the Greek stock market returns.

This method was introduced by Barkoulas and Travlos in 1998. It is an investigation of the existence of nonlinear structure in the Greek stock market returns based on the closing prices of the value-weighted index comprising the 30 most marketable stocks during the period 1988-1990. The existence of nonlinear structure is very common in developing economies like the Greek one.

Barkoulas and Travlos used the correlation dimension and the Kolmogorov entropy in order to examine the presence of chaotic dynamics.

At the beginning, the discrete-time autonomous dynamics systems (Mayfield and Mrach, 1992) were used. The exact equation is the following one:

\[ x_i = F(x_{i-1}), x \in \mathbb{R}^n \text{, where } F: U \to \mathbb{R}^n \text{ with } U \text{ an open subset of } \mathbb{R}^n \]

As far as the correlation dimension is concerned, the Grassberger and Procaccia (1983, 1984) algorithm in order to define a sequence of m-histories of the ASE index: \( y_m^i = (y_j, \ldots, y_{j+m-1}) \) was used.

The correlation was measured by the number of vectors within an \( \varepsilon \) distance from one another and is given by:
\[ C_m(\varepsilon) = \lim_{N \to \infty} \frac{1}{N^2} \times \# \{ (j, k) \mid \|y_j^m - y_k^m\| < \varepsilon \} \quad m = 2, 3, \ldots, \]

Where \( \{\Lambda\}, \| \|, N, \) and \( m \) denote the cardinality of the set \( \Lambda \).

The Kolmogorov entropy on the other hand was used since Barkoulas and Travlos (1999) consider it very important in order to find out “how chaotic” a system is. They use the \( K_{2,m}(\varepsilon) = \frac{1}{\tau} \ln \frac{C_m(\varepsilon)}{C_{m+1}(\varepsilon)} \) equation.

According to Grassberger and Procaccia (1983, 1984) the Kolmogorov entropy is zero for a stable process, infinite for a completely random process, and finite for the chaotic process.

### 3.8. An investigation of the validity of the much-used assumptions that the stock market returns follow a random walk and are normally distributed.

The eighth method was proposed in 2000 as a means to “investigate the validity of the much-used assumptions that the stock market returns follow a random walk and are normally distributed”. For this reason Skjeltrop (2000) applied the concepts of chaos, fractals and “new” analytical techniques to explore the possibility that scaling phenomena occur in the stock market returns. More specifically, two independent models were used for the examination of the price variations in the two stock markets (Norwegian and US market).

Skjeltrop (2000) also took for granted the Fama (1970) capital market efficiency, where the efficient market hypothesis depends in the specification of the information set \( \Phi \).

Earlier, Fama (1970) had claimed that there are three versions if the efficient market hypothesis:

- Weak-form efficiency
- Semistrong-form efficiency
- Strong-form efficiency
Where the calculation of tomorrow’s discounted price plus dividend is given by:

\[ P_t = E \left[ \frac{P_{t+1}^*}{1 + \rho} | \Phi_t \right], \quad P_{t+1}^* = P_{t+1} + d_{t+1}, \quad d_{t+1} \]

the expected dividends, \( \Phi_t \) the current information set \( t \), \( \rho \) the discount rate.

And the frequency of returns with no kurtosis is given by:

\[ f(r) = \frac{1}{\sigma_i \sqrt{2\pi}} \exp \left[ - \frac{1}{2} \left( \frac{r - E(r)}{\sigma_i} \right)^2 \right] \]

The first method that Skjeltrop (2000) used was the Rescaled Range Analysis (R/S analysis) which was further developed by Hurst in 1951. This method “uses the rescaled range analysis to estimate the fractal dimension and the degree of persistence or anti-persistence of a time series” Skjeltrop (2000).

At the beginning, a time series in price of length \( M \), is converted into a times series of logarithmic ratios \( N = M - 1 \) such that

\[ N_i = \log \left( \frac{M_{i+1}}{M_i} \right), \quad i = 1, 2, \ldots, (M - 1). \]

Then the time series of accumulated departures from the mean \((X_{k,a})\) for each sub-period \( I_a \), \( a = 1, 2, \ldots, A \) is defined as:

\[ X_{k,a} = \sum_{i=1}^{k} (N_{i,a} - e_a), \quad k = 1, 2, \ldots, n. \]

The standard deviation of each sub-period \( I_a \) is given by:

\[ S_{I_a} = \sqrt{\frac{1}{n} \sum_{k=1}^{n} (N_{k,a} - e^2_a)} \]

and the average R/S value for the length is:

\[ (R / S)_n = \frac{1}{A} \sum_{a=1}^{A} \left( \frac{R_{I_a}}{S_{I_a}} \right) \]

At this point it is proper to mention that Skjeltrop (2000) stated that the R/S analysis has some serious weakness likewise the Scaling Range, small
sample sizes and the short-term dependencies in the data. Thus, in order to
eliminate those problems, he started his method by using a series of
logarithmic returns \( S_t = \log \left( \frac{P_t}{P_{t-1}} \right) \) where \( S_t \) is the logarithmic return \( t \) time \( t \),
\( P_t \) the price at time \( t \). He also obtains the intercept, \( a \), and slope, \( b \) and uses
the \( X_t = S_t - (a + b \cdot S_{t-1}) \) in order to show the dependence of \( S_t \) on \( S_{t-1} \).

The second method that Skjeltrop (2000) followed was a distributional
scaling approach proposed by Mandelbrot in 1997 for the investigation of the
scaling behavior of the distribution of returns for different time horizons.

Here, the representation of the stable distribution was given
by: \[ L_a(Z, \Delta t) = \frac{1}{\pi} \int_0^\infty \exp(-\gamma \Delta t q^a) \cos(qZ) dq \]

Where \( a \) is the characteristic exponent \( 0 < a < 2 \), \( Z \) the return, \( \gamma \) the
scale factor and \( \Delta t \) the time interval. The stable distribution according to
Skjeltrop (2000) rescaled under the following transformations:

\[
Z_s = \frac{Z \Delta t}{(\Delta t)^{1/a}} \quad \text{and} \quad L_a(Z_s, 1) = \frac{L_a(Z, \Delta t)}{(\Delta t)^{-1/a}}
\]


This method was proposed by Koutmos and Phillipatos in 2007 in order
to test the hypothesis that stock returns in the Athens Stock Exchange (ASE)
adjust asymmetrically to past information due to the differential adjustment
costs.

It was basically based on the Koutmos (1998 and 1999) research.
According to it, the current stock price was given by:
\[ C_t = a(P_t - V_t)^2 + b(P_t - P_{t-1})^2 \]
\( P_t \) is the observed stock price and \( V_t \), the
The intrinsic value $V_t$ according to Koutmos and Phillipatos (2007) follows a martingale process given by $V_t = c + V_{t-1} + u_t$, where $c$ is the drift and $u_t$ is a zero mean possibly conditionally heteroskedastic process.

The adjustment process is given by:

$$P_t - P_{t-1} = (1 - \theta^+)(V_t - P_{t-1})^+ + (1 - \theta^-)(V_t - P_{t-1})^-$$

where,

$$(V_t - P_{t-1})^+ = \text{Max\{}(V_t - P_{t-1}),0\}$$ and $$(V_t - P_{t-1})^- = \text{Min\{}(V_t - P_{t-1}),0\}$$

The asymmetric autoregressive model that according to Koutmos and Phillipatos (2007) the stock returns follow is given by:

$$R_t = \beta + \theta^+ R_{t-1}^+ + \theta^- R_{t-1}^- + \varepsilon_t$$

Based on the aforementioned equation the optimal one-step forecast will depend on the sign $R_{t-1}$.

For $R_{t-1} \geq 0$, $E(R_t \mid I_{t-1}) = \beta + \theta^+ R_{t-1}^+$

For $R_{t-1} \leq 0$, $E(R_t \mid I_{t-1}) = \beta + \theta^- R_{t-1}^-$

According to Bollerselev (1992) the conditionally heteroscedastic is modeled as an asymmetric GARCH process given by:

$$\sigma_t^2 = a_0 + a_1 \varepsilon_{t-1}^2 + \phi \sigma_{t-1}^2 + \delta S_{t-1} \varepsilon_{t-1}^2$$

where $\sigma_t^2$ is the conditional variance of the returns at time $t$, $\varepsilon_t$ is the innovation at time $t$ and $a_o, a_1, \phi$ and $\delta$ are nonnegative fixed parameters.

Finally, Koutmos and Phillipatos (2007) use the Laplace distribution whose density is given by:

$$f(\mu_t, \sigma_t) = \frac{1}{2\sigma_t^2} \exp \left\{ - \left| \frac{\varepsilon_t}{\sigma_t^2} \right| \right\}$$

since they believe that the Laplace distribution is more peaked and has flatter tails than the normal distribution and the latter that can be expressed as:
\[
L(\theta) = \sum_{i=1}^{T} \log f(\mu_i, \sigma_i)
\]

where, \(\mu_i\) is the conditional mean and \(\sigma_i\) the conditional standard deviation.

3.10. A cross-sectional relationship between average stock returns and risk in Athens Stock Exchange (ASE).

The tenth method “basically explores the ability of the capital asset pricing model, as well as the firm specific factors in order to explain the cross-sectional relationship between average stock returns and risk in Athens Stock Exchange (ASE)” Theriou et al., 2005.

The main characteristics of this method are similar to those that Fama and French (1992) have followed in their research. Potential constraints being imposed by a smaller sample both in time and in terms of the number of stocks as well anomalies found by other researchers like Keim (1983, 1986) and Roll (1982-1983) that would probably effect the results of this method are also taken under consideration.

All the stocks involved in this method were selected according to a specific procedure. This procedure included eleven (11) different steps.

Theriou et al, (2005) adopted the Fama-MacBeth (1973) procedure in order to estimate the relationship between size, beta and market to book value. They followed the following empirical model:

\[
R_{it} - R_{jt} = \gamma_0 + \gamma_1 \beta_{it} + \gamma_2 \ln(ME)_{it} + \gamma_3 \ln(BE / ME)_{it} + e_{it}
\]

At the same time they “produced” seven (7) specifications in order to assess the explanatory power of each individual variable, as well as its interrelationship with other independent variables.

- \(R_i - R_f = \gamma_0 + \gamma_1 \beta_i + e_i\)
- \(R_i - R_f = \gamma_0 + \gamma_2 \ln(ME) + e_i\)
- \(R_i - R_f = \gamma_0 + \gamma_3 \ln(BE / ME) + e_i\)
- \(R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(BE / ME) + e_i\)

- \(R_i - R_f = \gamma_0 + \gamma_3 \ln(BE / ME) + e_i\)
- \(R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(BE / ME) + e_i\)
- \(R_i - R_f = \gamma_0 + \gamma_3 \ln(BE / ME) + e_i\)
\[
R_i - R_f = \gamma_0 + \gamma_2 \ln(ME)_t + \gamma_3 \ln(BE / ME)_t + e_i
\]
\[
R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(ME)_t + \gamma_3 \ln(BE / ME)_t + e_i
\]
Where \(R_i\) is the monthly returns on asset \(i\) and \(R_f\) the risk free rate on month \(t\), \(\beta_i\) is the yearly-allocated beta estimated for stock \(I\), \(\ln(ME)\) is the log of the market capitalization, \(\ln(BE / ME)\) is the log of the book-to-market equity ratio.

Theriou et al. (2005) also test the following four (4) hypotheses:

1. \(H_0 : \gamma_0 = 0 \) \( \quad H_1 : \gamma_0 \neq 0 \)
2. \(H_0 : \gamma_1 = 0 \) \( \quad H_1 : \gamma_1 > 0 \)
3. \(H_0 : \gamma_2 = 0 \) \( \quad H_1 : \gamma_2 < 0 \)
4. \(H_0 : \gamma_3 = 0 \) \( \quad H_1 : \gamma_3 > 0 \)

There will be further analysis of this method in the methodology part.

### 3.11. Fractal analysis of Chinese Stock Market

This method was introduced by Kai Du in 2004. It was basically a research on the Chinese Stock Market, and more specifically on the daily and monthly returns of Shanghai Stock, Shenzhen Stock A&B Index and their composite. In order to certify that the frequency distributions of the Chinese Stock Market returns were characterized by strict deviations from normal distribution, Kai Du (2004) used the rescaled range (R/S) analysis discovered by Hurst in 1951 and the Confidence Test introduced by Peters in 1991 too.

Based on his research, Kai Du (2004) showed that the frequency distributions of the Chinese Stock Market daily or monthly returns are characterized not only by systematic deviations from normal distributions but also they deviate from the normal once both in its leptokurtic and fat-tailed features and in its asymmetry. He also mentioned that the time series of the volatility and trading volume also exhibit high persistence. Finally, the results also from the rescaled analysis (R/S analysis) showed that the Chinese financial data are characterized by large value of Hurst exponent (\(H>0.5\)). Further analysis of the Kai Du’s research will be held in the methodology part.
4. Hypothesis

The hypothesis used to initiate the portfolio creation is based on the chaos theory which describes better and more radically the stocks series. Special attention is motivated “by the fact that nonlinearities are presumably quite different depending on the whether nominal or real variables are involved” (Mullineux and Peng, 1993). Usually, prices fluctuate easily. A market recession equals with a large negative change and a recovery equals with a large positive change; a price rigidity would also have similar results (Greedy and Martin, 1993).

The daily stocks prices are used as data. More specifically, the present dissertation focuses in ten (10) different stocks from the Greek bank sector (Agricultural Bank of Greece, Emporiki Bank, Bank of Cyprus, Eurobank, Piraeus Bank, Alpha Bank, , Bank of Greece, Ethniki Bank and Geniki Bank). Data from 1986 to the present day are use for eight (8) of the above mentioned banks. On the contrary, data from 2001 till today are used for Bank of Cyprus and Agricultural Bank of Greece on the basis that these two (2) banks are new in the Greek Stock Market.
5. Methodology part

In order to create a new portfolio, according to the literature review, four (4) major methods will be used. These are enriched with some other important criteria, as the stocks price and ratios.

The first method was introduced by Kyong Joo Oh, TaeYoon Kim, Sung-Hwan Min and Hyoung Yong Lee in 2005. It is basically "a portfolio algorithm; with the name β-G portfolio algorithm, that selects stocks based on their market capitalization and optimizes them in terms of its standard deviation from $\beta_p$ "(Oh et al, 2005). This exact algorithm depends on market volatility. It becomes more efficacious when the market is stable since short purchasing period with small $T$ tends to be more stable than long purchasing period with large $T$, rather than when phenomena like bullish or bearish (Liu, Wang and Lai, 2000). It also tends to signify outstanding performance for short-term applications especially with small $I$ and small $T$ strategy.

The equation of the portfolio beta $\beta_p$ is the following one:

$$\beta_p = \frac{Cov(r_\rho, I_m)}{Var(I_m)}$$

$r_\rho$: It is the return rate of a portfolio

$I_m$: It is the return rate of the benchmark index or the capital market m.

This equation can also be used to calculate the beta of just one stock. The result of that calculation will show the sensitivity of this specific stock to market fluctuations.

Before analyzing ad detailing the β-G portfolio algorithm some very important quantities should be defined. These are as follows:

- $n$ that is the number of stocks for the benchmark index
- $l$ that is the number of stocks for the portfolio ($l<n$)
- $c_k$ that is the serial code of $k$th to be included in the portfolio ($k=1,2,...,l$)
that is a portfolio set \( \{c_1, c_2, \ldots, c_l\} \) selected form all \( n \) stocks

- \( s \) that is the number of industry sectors comprising the benchmark index
- \( d_i \) that is the number of stocks comprising \( i \)th industry sectors
- \( \beta_{i(j)} \) that is the individual beta for each \( j \)th stock of \( i \)th industry sector
  
  \( (j = 1, 2, \ldots, d_i) \) and \( (i = 1, 2, \ldots, s) \) where the subscript \( i(j) \) is used to stress dependence of \( j \) on \( i \).
- \( r_{i(j)}(t) \) is the rate of return for \( j \)th stock of \( i \)th industry sector at time \( t \)
- \( I_m(t) \) is the rate of benchmark index \( m \) at time \( t \) E training period given by \( \{a_0, a_0 + 1, \ldots, a_0 + T - 1\} \) with starting point \( a_0 \) and size \( T \)

There are two steps to be followed in this algorithm. In the first one, an industry sector \( i_k \) with the largest amount of market capitalization is selected. For this industry sector \( i_k \) the priority is calculated with the following equation:

\[
P_{i_k(j)} = \frac{\left\{ \sum_{t \in E} (I_m(t) - \overline{I_m})^2 \right\}^{1/2}}{\left\{ \sum_{t \in E} \left( r_{i_k(j)}(t) - r_{i_k(j)} \right)^2 / (T - 2) \right\}^{1/2}}
\]

Where \( P_{i_k(j)} \) is the priority for \( k \)th stock of \( i_k \)th industry sector, \( j = 1, 2, \ldots, d_{i(k)} \) and \( \overline{X} \) is defined by \( \overline{X} = \sum_{t \in E} X(t) / T \). Then the stock with the highest priority is chosen and added to the portfolio as well as removed from the selected industry sector \( i_k \). After this, the market capitalization is updated and return to the starting point of this step.

For \( \Phi_p = \{c_1, c_2, \ldots, c_l\} \) established by the step 1, let \( w_k^n (k = 1, 2, \ldots, l) \) be the market capitalization of \( c_k \in \Phi_p \) scaled by the entire market capitalization. Note that \( \sum_{k=1}^{l} w_k^n < 1 \) if \( l < n \). Where \( n \) is the number of stocks for the benchmark index, \( l \) is the number of stocks for the portfolio \( (l < n) \), \( c_i \) is the serial code of \( k \)th stock to be included in the portfolio \( (k = 1, 2, \ldots, l) \) and \( \Phi_p \) is a portfolio set \( \{c_1, c_2, \ldots, c_l\} \) selected from all \( n \) stocks.
In the second step the optimal weight will be assigned
\{w_1^p, w_2^p, ..., w_l^p\} (\sum_{k=1}^{l} w_k^m = 1) to each of the selected stocks by minimizing
through the algorithm \(Q(w_1, w_2, ..., w_l) = \sum_{k=1}^{l} (w_k - w_k^m)^2 P_k^{-2}\) where \(P_k^{-2}\) is given
by the priority equation.

Kyong Joo Oh et al., (2005) noted that even though this specific \(\beta\)-G portfolio algorithm could work both for bullish and bearish markets, for practical short-term applications of it, risk aversion and transaction costs have also to be included.

When Kyong Joo Oh et al., (2005) referred to risk aversion they talked about the way that consumers and investors behaved under uncertainty. It is the reluctance of a person to accept a bargain with an uncertain payoff rather than a bargain with a more certain but possibly lower expected payoff. The inverse of a person's risk aversion is sometimes called their risk tolerance.

The risk aversion is measured as the marginal reward an investor wants to receive if he takes for a new amount of risk. In Portfolio Theory (Alvarez and Koskela, 2004), risk aversion is being measured as standard deviation of the return on investment, i.e. the square root of its variance. The symbol used for risk aversion is \(A\) or \(A_n\) and it can be calculated by the following equations:

\[
A = \frac{dE(r)}{d\sigma} \quad A_n = \frac{dE(r)}{dn\sqrt{\mu_n}} = \frac{1}{n} \frac{dE(r)}{d\mu_n}
\]

According to Diacon (2002) and Fidich et al., (2006) there are two (2) measures of risk aversion:

- The absolute risk aversion, where the higher the curve of \(u(c)\), the higher the risk aversion is.
- And the relative risk aversion (RRA) or coefficient of relative risk aversion is defined as: \(R_u (c) = cr_u (c) = -cu''(c) / u'(c)\)

When Kyong Joo Oh et al., (2005) refers to transaction costs they meant a cost that is incurred in making an economic exchange. Transaction
costs are considered very important for a potential transaction (Mawah, 2007; Iyengar, 2004 and Bielecki et al., 2005). There are also a number of kinds of transaction cost like:

- “Search and information costs, costs that a people take under consideration when they want to make a future transaction” (Mawah, 2007). These costs may involve the price of a specific good, its quality or even its availability in the market.
- “Bargain costs, costs required to come to an acceptable agreement with the other party to the transaction, drawing up an appropriate contract and so on” (Bielecki et al., 2005).

The second method that will be used was introduced by Kai Du in 2004. It is basically a research on the Chinese Stock Market, and more specifically on the daily and monthly returns of Shanghai Stock, Shenzhen Stock A&B Index and their composite. In order to certify that the frequency distributions of the Chinese Stock Market, returns are characterized by strict deviations from normal distribution Kai Du (2004) used the rescaled range (R/S) analysis discovered by Hurst in 1951 and the Confidence Test introduced by Peters in 1991 as well.

Based on Hurst (1951), the R/S analysis or Hurst exponent is a nonparametric methodology that can distinguish random time series from fractal time series. This statistical measure can be measured by: 

\[(R/S)_n = c \cdot n^H\]

where \((R/S)_n\) refers to the rescaled range of a time series, and \(c\) is a constant. In a more logarithmic way the above equation can be transformed into:

\[\log(R/S) = \log(c) + H \log(n).\]

Hurst (1951) has divided the rescaled range (R/S) analysis in seven (7) different steps:

1. In the first step \(M\) is the length of the of time series, then these time series are converted into time series of length \(N=M-1\) of logarithmic ratios;

\[N_i = \log\left(\frac{M_{i+1}}{M_i}\right)\text{ for } i=1,2,\ldots, M-1;\]
2. Then the above time series are divided into A contiguous subperiods of length n, such that N=An and with a superiod I_a, with a=1,..., A. Define \( e_a \frac{1}{n} \sum_{k=1}^{n} N_{k,a} \)

3. Define \( X_{k,a} = \sum_{i=1}^{n} \left( N_{i,a} - e_a \right) \), where k=1,...,n;

4. Define the range as \( R_{I_a} = \max X_{k,a} - \min X_{k,a} \), where k=1,...,n;

5. The standard deviation for each subperiod is:

\[
S_{I_a} = \sqrt{\frac{1}{n} \sum_{k=1}^{n} (N_{k,a} - e_a)^2}
\]

6. The rescaled range for each \( I_a \) subperiod is equal to \( R_{I_a} / S_{I_a} \). The average R/S value is defined as

\[
(R / S)_n = \frac{1}{A} \sum_{a=1}^{A} \frac{R_{I_a}}{S_{I_a}}
\]

7. The length n is increased to the next higher value, and \( \frac{M-1}{n} \) is an integer value. The steps one (1) to six (6) are repeated until \( n = \frac{M-1}{2} \) then the regression with \( \log(R / S) = \log(c) + H \log(n) \)

Kai Du (2004) used the Confidence Test, in order to certify that the results of the rescaled range (R/S) analysis have significance (Peters, 1991). This test is based on the following equation (Anis and Lloyd, 1976):

\[
E(R / S_n) = \left\{ \frac{\Gamma\left(\frac{n-1}{2}\right)}{\sqrt{\pi}} \right\} \left\{ \frac{\Gamma\left(\frac{n}{2}\right)}{\sqrt{\pi}} \right\} \sum_{r=1}^{n-1} \sqrt{\frac{n-r}{r}}
\]

or its simpler form (Peters, 1991):

\[
E(R / S_n) = \frac{n - 0.5}{n} \left( \frac{n\pi}{2} \right)^{-0.5} \sum_{r=1}^{n-1} \sqrt{\frac{n-r}{r}}
\]
The results of this test showed that “the frequency distributions if daily and monthly trading volume deviate from the normal one not only in its leptokurtic and fuit-tailed features, but also in its asymmetry” (Kai Du, 2004).

The third method is an asset-pricing model (APM)-free measure, and especially the APM-free kernel model in order to evaluate the performance of actively managed portfolios (Ayandi and Kryzanowski, 2004). This measure is a result of the failure of previous model like CAPM and APT to turn over reliable measures of performance and sometimes generating misleading conclusions (Dydvig and Ross, 1985; Admati and Ross, 1985; and Grinblatt and Titman, 1989).

The Capital Asset Pricing Model (CAPM) according to (Bartholdy and Peare, 2003; Bohm, 2002; Ang and Chen, 2005 and Bossaerts, 2003) is a model that describes the relationship between risk and expected return and that is used in the pricing of risky securities. It can be calculated by the following equation:

$$ r_a = r_f + \beta_a (r_m - r_f) $$

Where:
- $r_f$ is the risk free rate
- $\beta_a$ is the beta of the security
- $r_m$ is the expected market return

The general idea behind Capital Asset Pricing Model (CAPM) is that investors need to be rewarded in two ways: time value of money and risk. The time value of money is represented by the risk-free ($r_f$) rate in the formula and compensates the investors for placing money in any investment over a period of time (Ang and Chen, 2005; Bohm, 2002). The other half of the formula represents risk and calculates the sum of return the investor needs for taking on extra risk. This is calculated by taking a risk measure (beta) that compares the returns of the asset to the market over a period of time and to the market premium ($r_m - r_f$).

Fama, E. and French, K. (1992) and French, C. W. (2003) also mentioned that it is very important when someone uses the CAPM model to
take under consideration some assumptions that will help him calculate it accurately. These assumptions are the following once:

- All investors have reasonable expectations.
- There are no arbitrage opportunities.
- Returns are normally distributed.
- Fixed quantity of assets.
- Perfectly efficient capital markets.
- Separation of financial and production sectors.
- Risk-free rates exist with unlimited borrowing capacity and universal access.
- The Risk-free borrowing and lending rates are equal.
- No inflation and no change in the level of interest rate exist.

Arbitrage Pricing Theory (APT) (Iqbal et al., 2007; Balduzzi and Robotti, 2007), on the contrary, is considered to be a relatively new theory. It predicts a relationship between the returns of portfolio and the returns of a single asset through a linear combination of variables. It differs from CAPM in its assumptions and explanation of risk factors associated with the risk of an asset.

According to Dydvig and Ross (1985); Admati and Ross (1985), if Arbitrage Pricing Theory (APT) holds, then the risky asset can be described by the following relation:

\[
E(r_j) = r_f + b_{j1}RP_1 + b_{j2}RP_2 + ... + b_{jn}RP_n
\]

\[
r_j = E(r_j) + b_{j1}F_1 + b_{j2}F_2 + ... + b_{jn}F_n + \epsilon_j
\]

Where:

- \( E(r_j) \) is the risky asset’s expected return
- \( RP_k \) is the risk premium of the factor
- \( r_f \) is the risk free rate
- \( F_k \) is the macroeconomic factor
- \( b_{jk} \) is the sensitivity of the asset factor k, also called factor loading
- \( \epsilon_j \) is the risky asset’s idiosyncratic random shock with mean zero
According to Dybvig and Ross, 1985; Admati and Ross, 1985; and Grinblatt and Titman, 1989; Coën, 2000) the APT along with the Capital Asset Pricing Model (CAPM) is one of two influential theories on asset pricing. The APT differs from the CAPM in that it is less restrictive in its assumptions. It allows for an explanatory (as opposed to statistical) model of asset returns. It takes for granted that each investor will hold a unique portfolio with its own particular range of betas. In some ways, the CAPM can be considered a "special case" of the APT in that the securities market line represents a single-factor model of the asset price, where Beta is exposure to changes in value of the Market.

Additionally, the APT can be seen as a "supply side" model, since its beta coefficients reflect the sensitivity of the underlying asset to economic factors. Thus, factor shocks would cause structural changes in the asset's expected return, or in the case of stocks, in the firm's profitability (Balduzzi and Robotti, 2007).

The kernels method consists of two steps: first it calculates the appropriate normalized pricing using a system of momentum equations including only passively handled portfolios; second it gauges the risk-settled fund performance by multiplying the gross cash return by the counted or fitted pricing kernel and taking off the gross return on the risk-free asset (Chen and Knez, 1996).

In this method the basic asset pricing equation that is used is:

\[ E_i(M_{t+1} R_{i,t+1}) = 1 \] where i=1, 2,..., N.

Where:
- \( R_{i,t+1} \) is a gross return or payoff divided by price on asset i at time t+1
- \( M_{t+1} \) is the stochastic discount factor or the pricing kernel.

According to Luttmer (1996), if \( r_{i,t+1} = R_{i,t+1} - R_{f,t+1} \) is defined as an excess return, it has a zero price. The price equation then becomes:

\[ E_i(M_{t+1} r_{i,t+1}) = 0 \] where i=1, 2,..., N.
Ayandi and Kryzanowski, 2004 also followed the Campbell and Viceira (1999) and Brandt (2001) works that had to do with the optimal portfolio weight. They stressed out that the optimal portfolio weight is a random variable measure with respect to conditioning variables and with a conditional Euler equation: \( a_t = a(\Omega_t) \). Here the conditional optimization problem for a uniformed investor is given by: 
\[
\begin{align*}
E[a_t r_{b,t+1} + R_{f,t+1} | \Omega_t] = 0
\end{align*}
\]

Where the \( E[a_t r_{b,t+1} + R_{f,t+1} | \Omega_t] = 0 \) is the conditional Euler equation.

By defining the positive conditional stochastic discount factor with the no-arbitrage principle (Grinblatt and Titman, 1989; and Chen and Knez, 1996)
\[
M^c_{t+1} = (a_t r_{b,t+1} + R_{f,t+1})^\gamma
\]
the \( M^c_{t+1} \) can be normalized such that:
\[
Q^c_{t+1} = \frac{M^c_{t+1}}{E_t(M^c_{t+1})} = M^c_{t+1} R_{f,t+1}, \quad Q^c_{t+1} = 1
\]
The unconditional normalized pricing kernel is given by:
\[
Q^u_{t+1} = \frac{M^u_{t+1}}{E_t(M^u_{t+1})} = M^u_{t+1} R_{f,t+1}, \quad Q^u_{t+1} = 1
\]

The (un)conditional portfolio measure depending on the use of the appropriate SDF according to Ayandi and Kryzanowski, (2004) is \( \lambda_i, i = (u, c) \).

If the excess return on any portfolio \( y \) is \( r_{y,t+1} \) then:
\[
\begin{align*}
\lambda^u_i &= E(Q^u_{t+1} r_{y,t+1}) = E(r_{y,t+1}) + Cov(Q^u_{t+1}, r_{y,t+1}) \\
\lambda^c_i &= E(Q^c_{t+1} r_{y,t+1}) = E(r_{y,t+1}) + Cov(Q^c_{t+1}, r_{y,t+1})
\end{align*}
\]

The unconditional and the conditional framework are also taken into consideration. As far as the unconditional framework is concerned, the unconditional performance measure is given by:
\[
\begin{align*}
\lambda^u_i &= E(Q^u_{t+1} r_{p,t+1}) = E(Q^u_{t+1} R_{p,t+1}) - R_{f,t+1} = 0 \\
Q^u_{t+1} &= Q(r_{b,t+1}, a)
\end{align*}
\]

Nevertheless, the unconditional performance measure for an actively managed portfolio with a \( R_{a,t+1} \) (Ayandi and Kryzanowski, 2004) is given by
\[ \lambda^\alpha_t = E(Q^\alpha_{t+1} r_{p,t+1}) = E(Q^\alpha_{t+1} R_{a,t+1}) - R_{f,t+1} = E\left( w(\Omega^\alpha_t) Q^\alpha_{t+1} R_{a,t+1} \right) - R_{f,t+1} \]

Where \( \Omega^\alpha \) represents the private information set.

Furthermore, according to Ayandi and Kryzanowski, (2004) when uniformed investors use publicly known information, \( \Omega^p \), in constructing their portfolio, the gross return is given by

\[ R_{p,t+1} = w(\Omega^p_t) R_{a,t+1} \text{ with } w(\Omega^p_t) 1_N = 1 \text{ and } \Omega^p \subset \Omega^a \]

The conditional performance measure according to Ayandi and Kryzanowski, (2004) can be written as:

\[ \lambda^c_t = E_t(Q^c_{t+1} R_{a,t+1}) \otimes Z_t - R_{f,t+1} 1_N \otimes Z_t = 0 \]

\[ E_t(Q^c_{t+1}) Z_t = Z_t \]

Here, the conditional performance for the actively managed portfolio (Ayandi and Kryzanowski, 2004) is given by

\[ \lambda^c_t = E_t(Q^c_{t+1} r_{a,t+1}) = E_t(Q^c_{t+1} R_{a,t+1}) - R_{f,t+1} \]

At this point it is important to mention that Ferson and Schadt (1996), Dahlquist and Soderlind (1999) and Ayandi and Kryzanowski (2004) claimed that “the parameterization of the conditional normalized pricing kernel differs from the one associated with the conditional evaluation” based on the following two (2) moment conditions:

\[ E(Q^c_{t+1} R_{a,t+1}) = R_{f,t+1} 1_N \]

\[ E(Q^c_{t+1}) = 1 \]

When there are opportunities that time-varying the stochastic factors can be described by a power utility function that exhibits constant relative risk aversion, (Cochrane, 2002) given by the following equation:

\[ U(w_t) = \frac{1}{1 - \gamma} W_t^{1-\gamma} \]

where \( W_t \) is the level of the wealth at \( t \), and \( \gamma \) is the relative risk aversion coefficient. In a single-period model when an investor, an industry or even a private individual, holds a portfolio his terminal wealth is given by \( E[U(W_{t+1}) | \Omega_t] \), \( \Omega_t \) is the information set. The return on wealth is given by:

- 40 -
\[ R_{w,t+1} = a_t R_{b,t+1} + (1 - a_t) R_{f,t+1} = a_t (R_{b,t+1} - R_{f,t+1}) + R_{f,t+1} = a_t r_{b,t+1} + R_{f,t+1} \]

Where:

- \( R_{b,t+1} \) is the gross return on the benchmark portfolio from t to t+1.
- \( r'_{b,t+1} \) is the excess return on the benchmark portfolio from t to t+1.
- \( R_{f,t+1} \) is the gross risk-free rate from t to t+1 that is known one period in advance at time t.
- \( a_t \) is the proportion of tool wealth invested in the benchmark portfolio.

More particularly, \( \theta \equiv (\alpha \gamma)' \) is the vector of unknown parameters and the model has to comply with the following conditional moment restriction:

\[ E_t[Q^c(r_{b,t+1}, Z_t, \theta_0)r_{p,t+1}] = 0_N \quad \text{such that} \quad E_t[Q^c(r_{b,t+1}, Z_t, \theta_0)] = 1 \]

The pricing errors are given by:

\[ u^c_{t+1} = Q^c(r_{b,t+1}, Z_t, \theta)r_{p,t+1} \equiv u(r_{b,t+1}, r_{p,t+1}, Z_t, \theta) \]

The dimension of this vector (KL+1) of unknown parameters with an excess return K and conditioning variables L is given by:

\[ E_t[u(r_{b,t+1}, r_{p,t+1}, Z_t, \theta_0)] = E[u(r_{b,t+1}, r_{p,t+1}, Z_t, \theta)] = 0_N \]

Where the conditional and unconditional moment restrictions can be written as:

\[ E_t[u(r_{b,t+1}, r_{p,t+1}, Z_t, \theta_0)] = E[u(r_{b,t+1}, Z_t, \theta_0)] = 0_N \quad \text{and} \quad E_t[Q^c(r_{b,t+1}, Z_t, \theta_0)] = E[Q^c(r_{b,t+1}, Z_t, \theta_0)Z_t - Z_t] = 0_L \]

The third method was introduced by Theriou et al., in 2005. It “basically explores the ability of the capital asset pricing model, as well as the firm specific factors in order to explain the cross-sectional relationship between average stock returns and risk in Athens Stock Exchange (ASE)”.

The main characteristics of this method are similar to those that Fama and French (1992) followed in their research. Constraints imposed by a smaller sample both in time and in terms of the number of stocks along with some anomalies found by other researchers like Keim (1983, 1986) and Roll
(1980) that would probably effect the results of this method are also taken into consideration.


The first one is the “size effect” anomaly. According to Banz (1981), the Capital Asset Pricing Model (CAPM) can not explicate the appearance of higher average returns from low market value stocks rather from others with bigger market value. Keim (1983 and 1986) and Roll (1980) have both included the “January effect” in this type of anomaly. It is basically a “calendar effect wherein stocks, especially small-cap stocks, have historically tended to rise noticeably in price during the period starting on the last day of December and ending on the fifth trading day of January. This effect is owed to year-end selling to create tax losses, recognize capital gains, effect portfolio window dressing, or raise holiday cash. Because such selling depresses the stocks but has nothing to do with their fundamental worth, bargain hunters quickly buy in, causing the January rally” Keim (1983 and 1986).

The second basic category is the so-called “value effect” anomaly. Luu and Kennedy (2007) have claimed that the value effect suggests that portfolios of firms with high book to market ratios will also perform higher than the average market return in the long run. Theriou et al, (2005) have argued that the that the stock returns can be predicted by ratios of market value to accounting measures like book-to-market-ratio, payout ratio, share of equity in new finance and yield spreads between long-term and short-term interest rates.

The last one is the “momentum effect” anomaly. According to Jegadeesh and Titman (1993) the stocks that appear to have high returns for the last three (3) to twelve (12) months tend to outperform in the future.

Theriou et al, (2005) have also taken into account the result of date snooping. Earlier, White, H., (2000) claimed that data snooping happens when a given set of data is used more than once since there are considered
to be very important and useful in conclusions or model selection. Nevertheless, it is important that any possible “satisfied” results achieved by these data may be simply by chance should be considered. White (2000) has also mentioned that “the use of data snooping may cause problem due to the lack of sufficiently simple practical methods capable of assessing the potential dangers of data snooping in a given situation”. According to White (2000), data snooping is also known as data mining, a powerful tool in the examination and analysis of huge databases. The formulas used in data mining are known as algorithms. The most known data mining algorithms are regression analysis used with quantitative data and classification analysis.

Lo and Mackinlay (1990) have used the data snooping technique in statistics tests since they claim that "tests of financial asset pricing models may yield misleading inferences when properties of the data are used to construct those tests”. More specifically, it is mentioned “that most of the time statistic tests are based on returns to portfolios of common stock, where portfolios are constructed by sorting on some empirically motivated characteristic of the securities such as market value of equity”.

All the stocks that are involved in this method have been selected according to a specific procedure. This procedure involved eleven (11) different steps. Some of those steps deal with issues like:

- All the stocks that are involved in this method have at least values for the last twenty-four (24) monthly returns.
- The first three (3) months of the new stocks are deleted, so the returns to become more stable.
- The size and the book-to-market ratio are estimated with algorithmic approximation.
- The estimated variables were performed by the cross-section regression analysis.

Note that all those eleven (11) steps and especially the creation of time series were based on the Fama and McBeth research (1973).
Theriou et al. (2005) have adopted the Fama-MacBeth (1973) procedure in order to estimate the relationship between size, beta and market to book value. They followed the following empirical model:

\[ R_{it} - R_{jt} = \gamma_0 + \gamma_1 \beta_{it} + \gamma_2 \ln(ME) + \gamma_3 \ln(BE / ME) + e_{it} \]

At the same time they "produced" seven (7) specifications in order to assess the explanatory power of each individual variable, as well as its interrelationship with other independent variables.

- \[ R_i - R_f = \gamma_0 + \gamma_1 \beta_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_2 \ln(ME)_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_3 \ln(BE / ME)_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(ME)_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(ME)_i + \gamma_3 \ln(BE / ME)_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_3 \ln(BE / ME)_i + e_i \]
- \[ R_i - R_f = \gamma_0 + \gamma_1 \beta_i + \gamma_2 \ln(ME)_i + \gamma_3 \ln(BE / ME)_i + e_i \]

Where \( R_i \) is the monthly returns on asset i and \( R_f \) the risk free rate on month \( t \), \( \beta_i \) is the yearly-allocated beta estimated for stock I, \( \ln(ME) \) is the log of the market capitalization, \( \ln(BE / ME) \) is the log of the book-to-market equity ratio.

Theriou et al. (2005) also test the following four (4) hypotheses:

5. \( H_0: \gamma_0 = 0 \quad H_1: \gamma_0 \neq 0 \)
6. \( H_0: \gamma_1 = 0 \quad H_1: \gamma_1 > 0 \)
7. \( H_0: \gamma_2 = 0 \quad H_1: \gamma_2 < 0 \)
8. \( H_0: \gamma_3 = 0 \quad H_1: \gamma_3 > 0 \)

The first two (2) hypotheses deal with the term \( \gamma_0 \) which according to Theriou et al. (2005) should be zero, while the coefficient on the beta \( \gamma_1 \) should be positive and expected to equal the excess return on the market.

The last two (2) hypotheses refer to the empirical evidence on the size and book-to-market effects.
6. Findings

The stock prices of ten (10) different banks have been analyzed in this dissertation. These banks cover almost the whole Greek Bank sector. The analysis starts with two (2) figures which present the stock prices (figure 6.1) as well as the returns of those stocks (figure 6.2).

The analysis of two (2) of the aforementioned banks is presented in this chapter: the Agricultural Bank of Greece and Alpha Bank. The choice of those two (2) banks made has been based on two (2) important criteria. First, the Agricultural bank is a public bank which entered the Greek Stock Market in 2001 and has recently been privatized. Moreover, Alpha bank is considered to be one of the biggest private banks. Second, the observations for Agricultural bank cover the years from 2001 till today; for Alpha bank from 1986 till today. All the figures for each of the ten (10) banks included in the sample are presented in the Appendix 2.

As it can be seen from figure 6.6 but also from 6.1, the general index and the stock prices are moving in the same way. This can be explained by on the fact that banks contribute in a great manner to the way that general index is moving.

In figure 6.7 where the returns for the Alpha Bank are presented, some variances characterising the two (2) periods of the Greek Stock Market can be observed. The first period extends till 1997 and the second one covers a period from 1997 till today. The same can be observed as far as the Agricultural bank is concerned. The only difference lies on the fact that there is only one period: the first half of 2005 approximately. The two (2) periods that can be observed in figure 6.6 are 1999 and 2006-7. Two (2) maximum points appear in all banks for the second period of the Greek Stock Market.

Figure 6.3 presents the standard distribution of returns. Here, a non normal variance of returns can be seen. The observations made are as follows: (a) the symmetry of the normal distribution is missing; (b) there are many high picks; (c) the tails are very long. Taking into consideration the above, the doubt, about the reliability of the standard- classic methods as far
as it concerns the results and how adequate those are, is made. The same results can be seen in figure 6.8 despite the fact that the number of the observations is at least four (4) times larger.

Figure 6.4 refers to stock’s fractal dimension. The dimension is moving around 2 although this is not very characteristic in figure 6.9. The average of the fractal dimension is presented in table 6.11. Here, the average for the Agricultural Bank is the biggest one; the next bigger is that of Cyprus Bank. These two (2) banks have the fewer observations, they entered the Greek Stock Market in 2001-the smaller one refers to the Bank of Greece which is a public one. The fractal dimension average for Alpha bank is one of the biggest. The base 2 for the fractal dimension average implies that the banks returns are characterized by a chaotic structure.

Although the above mentioned conclusion is a characteristic one of chaotic behaviors, it is not cogent enough so to say that the stocks prices used in this research are chaotic ones. A further analysis of those stock prices was made for this reason. The Agricultural bank’s results of the correlation analysis are presented in table 6.1, while the histogram normality test of the same bank is given in figure 6.5. Observing that (a) the Jarque Bera that is bigger than zero (0), (b) the Alpha bank’s coefficient indicator that is huge, (c) the coefficient skewness and the kurtosis one, it is obvious that the stock returns of the sample can not be analyzed by a traditional statistic analysis.

In tables 6.2 and 6.7, where the ARCH test is taking place, the coefficient F-statistic is too big while the probability of F-statistic is zero (0). This means that the results of this test have some “problems”. The aggregated results of the above indicators for all banks are presented in table 6.12.

The R/S analysis for the ten (10) banks is also held through taking all the aforementioned factors into consideration. Tables 6.3 and 6.8 respectively present the results of the R/S analysis. In order to drop all these results a program in C++ was also created. This program is in Appendix 3. The values of the Hurst Exponent (H-Exponent) are calculated using table 6.4. The values that the Hurst Exponent takes characterize the banks’ returns. A value
equal to 0.5 (H=0.5) implies an independent process, a value between 0.5 and 1 (0.5<H≤1) means that a time series has “long memory” while, a value between 0 and 0.5 (0<H≤0.5) characterize an anti-persistence process which cover less distance than a random one.

Table 6.13 gives the results of the R/S analysis of all banks. In table 6.4 the H-Exponent is 0.3, this means that the data of this research (stocks prices) are anti-persistence. It should be mentioned that the coefficient F-statistic indicator and the Probability (F-statistic) indicator are very small. This means that the results of the H-exponent test are correct.

The above show that the traditional analysis methods can not be implemented in the Greek Stock Market, and more specifically in the Bank sector. It is also “unsafe” to generalize the capability of analyzing the stock prices with R/S analysis, if there will not be a further analysis in all stocks that exist in the Greek Stock Market or even in a representative sample of stocks from all sectors.
Agricultural Bank of Greece

Fig. 6. 1 Stock price and General index of Agricultural Bank of Greece

Fig. 6. 2 of Agricultural Bank of Greece
Fig. 6. 3 Standard Deviations of Agricultural Bank of Greece

Fig. 6. 4 Fractal Dimension of Agricultural Bank of Greece
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 1690
Included observations: 1690

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
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<td>1.65E-05</td>
<td>9.910966</td>
<td>0.0000</td>
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</tbody>
</table>

R-squared: 0.054991
Mean dependent var: 4.054923
Adjusted R-squared: 0.054432
S.D. dependent var: 0.675963
S.E. of regression: 0.657309
Akaike info criterion: 1.999857
Sum squared resid: 729.3085
Schwarz criterion: 2.006286
Log likelihood: -1687.879
F-statistic: 98.22725
Durbin-Watson stat: 0.013662
Prob(F-statistic): 0.000000

Table 6.1 Correlation Analysis of Agricultural Bank of Greece

Fig. 6.5 Histogram Normality test of Agricultural Bank of Greece
### Table 6.2 ARCH Test of Agricultural Bank of Greece

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
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<td>2.508950</td>
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<td>RESID^2(-1)</td>
<td>0.977426</td>
<td>0.005029</td>
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<th>Value</th>
<th>Probability</th>
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<tr>
<td>F-statistic</td>
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<tr>
<td>Obs*R-squared</td>
<td>1616.799</td>
<td>0.000000</td>
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</table>

### Table 6.3 R/S Analysis Results of Agricultural Bank of Greece

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<th>n</th>
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<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
</tr>
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<td>0.426077</td>
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<td>1.113943</td>
<td>3.75555</td>
<td>0.574674</td>
<td>4.51889</td>
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<td>13</td>
<td>1.414973</td>
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<td>209.18</td>
</tr>
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<td>26</td>
<td>1.812913</td>
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</tr>
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<td>11614.9</td>
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<tr>
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### Table 6.4 Correlation Analysis of R/S Results of Agricultural Bank of Greece

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<th>Prob.</th>
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<th>Component</th>
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</thead>
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<tr>
<td>R-squared</td>
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<tr>
<td>Adjusted R-squared</td>
<td>0.998306</td>
<td>0.238800</td>
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<td>S.E. of regression</td>
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<td>Log likelihood</td>
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<tr>
<td>Durbin-Watson stat</td>
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ARCH Test:

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<th>Probability</th>
<th>Obs*R-squared</th>
<th>Probability</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>0.145954</td>
<td>0.715598</td>
<td>0.189984</td>
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Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 9
Included observations: 8 after adjusting endpoints

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R-squared                  0.023748  Mean dependent var 6.03E-05
Adjusted R-squared         -0.138961  S.D. dependent var 8.03E-05
S.E. of regression         8.57E-05   Akaike info criterion -15.67897
Sum squared resid          4.41E-08   Schwarz criterion -15.65911
Log likelihood             64.71588   F-statistic 0.145954
Durbin-Watson stat         1.175293   Prob(F-statistic) 0.715598

Table 6. 5 ARCH test of R/S results of Agricultural Bank of Greece
Alpha Bank

Alpha Bank

Fig. 6. 6 Stock price and General index of Alpha Bank.

Profile of daily returns

Fig. 6. 7 Profile of daily returns of Alpha Bank.
**Fig. 6. 8 Standard Deviations of Alpha Bank.**

**Fig. 6. 9 Fractal Dimension of Alpha Bank.**
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<td>0.005240</td>
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R-squared: 0.966758
Mean dependent var: 8.224502
Adjusted R-squared: 0.966752
S.D. dependent var: 7.799314
S.E. of regression: 1.422126
Akaike info criterion: 3.542551
Schwarz criterion: 3.544982
F-statistic: 157889.9
Prob(F-statistic): 0.000000

Table 6. 6 Correlation Analysis of Alpha Bank.

Fig. 6. 10 Histogram Normality test of Alpha Bank.
ARCH Test:

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<tr>
<td>Obs*R-squared</td>
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Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5431
Included observations: 5430 after adjusting endpoints

<table>
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R-squared: 0.955878 Mean dependent var: 2.021810
Adjusted R-squared: 0.955870 S.D. dependent var: 3.338609
S.E. of regression: 0.701344 Akaike info criterion: 2.128732
Sum squared resid: 2669.943 Schwarz criterion: 2.131162
Log likelihood: -5777.506 F-statistic: 117595.7
Durbin-Watson stat: 1.837455 Prob(F-statistic): 0.000000

Table 6.7 ARCH test of Alpha Bank.

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<th>R/S</th>
<th>log(R/S)</th>
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Table 6.8 R/S Analysis results of Alpha Bank.

Dependent Variable: LOG_R_S_01
Method: Least Squares
Date: 10/26/07 Time: 10:19
Sample: 1 12
Included observations: 12

<table>
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<th>Variable</th>
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<td>LOG_N_01</td>
<td>0.261240</td>
<td>0.007155</td>
<td>36.51009</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.992554 Mean dependent var: 0.814627
Adjusted R-squared: 0.991809 S.D. dependent var: 0.268420
S.E. of regression: 0.024293 Akaike info criterion: -4.446274
Sum squared resid: 0.005901 Schwarz criterion: -4.365456
Log likelihood: -26.66733 F-statistic: 1332.987
Durbin-Watson stat: 0.748899 Prob(F-statistic): 0.000000

Table 6.9 Correlation analysis of R/S results of Alpha Bank.
ARCH Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>0.027073</th>
<th>Probability</th>
<th>0.872942</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obs*R-squared</td>
<td>0.032991</td>
<td>Probability</td>
<td>0.855871</td>
</tr>
</tbody>
</table>

Test Equation:

Dependent Variable: RESID^2
Method: Least Squares
Date: 10/26/07  Time: 10:19
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000455</td>
<td>0.000239</td>
<td>1.902888</td>
<td>0.0895</td>
</tr>
<tr>
<td>RESID^2(-1)</td>
<td>0.056191</td>
<td>0.341504</td>
<td>0.164540</td>
<td>0.8729</td>
</tr>
</tbody>
</table>

R-squared          | 0.002999    | Mean dependent var | 0.000485 |
Adjusted R-squared | -0.107779   | S.D. dependent var  | 0.000501 |
S.E. of regression | 0.000528    | Akaike info criterion | -12.09388 |
Sum squared resid  | 2.50E-06    | Schwarz criterion   | -12.02153 |
Log likelihood     | 68.51632    | F-statistic         | 0.027073 |
Durbin-Watson stat | 1.872556    | Prob(F-statistic)   | 0.872942 |

Table 6. 10 ARCH test of R/S results of Alpha Bank.

<table>
<thead>
<tr>
<th>Banks</th>
<th>Averages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural Bank of Greece</td>
<td>1.991767</td>
</tr>
<tr>
<td>Emporiki Bank</td>
<td>1.972267</td>
</tr>
<tr>
<td>Bank of Cyprus</td>
<td>1.988175</td>
</tr>
<tr>
<td>Eurobank</td>
<td>1.952738</td>
</tr>
<tr>
<td>Piraeus Bank</td>
<td>1.966284</td>
</tr>
<tr>
<td>Alpha Bank</td>
<td>1.986913</td>
</tr>
<tr>
<td>Attica Bank</td>
<td>1.975595</td>
</tr>
<tr>
<td>Bank of Greece</td>
<td>1.963546</td>
</tr>
<tr>
<td>Ethniki Bank</td>
<td>1.969531</td>
</tr>
<tr>
<td>Geniki Bank</td>
<td>1.967964</td>
</tr>
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</table>

Table 6. 11 Average of Fractal Dimensions
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural bank</td>
<td>98.22725</td>
<td>0.000000</td>
<td>13.76</td>
<td>0.001</td>
<td>-0.1806</td>
<td>2.745</td>
<td>37777.19</td>
<td>0.000000</td>
</tr>
<tr>
<td>Emporiki Bank</td>
<td>23634.94</td>
<td>0.000000</td>
<td>3051.144</td>
<td>0.000000</td>
<td>0.226811</td>
<td>6.643825</td>
<td>580306.8</td>
<td>0.000000</td>
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<tr>
<td>Bank of Cyprus</td>
<td>11260.55</td>
<td>0.000000</td>
<td>47.40424</td>
<td>0.000000</td>
<td>-0.135470</td>
<td>2.237144</td>
<td>46751.13</td>
<td>0.000000</td>
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<tr>
<td>Eurobank</td>
<td>32678.46</td>
<td>0.000000</td>
<td>2050.440</td>
<td>0.000000</td>
<td>0.543212</td>
<td>5.813821</td>
<td>171064.0</td>
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<tr>
<td>Piraeus Bank</td>
<td>48787.41</td>
<td>0.000000</td>
<td>1367.739</td>
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<td>0.845037</td>
<td>4.785037</td>
<td>221744.2</td>
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<tr>
<td>Alpha Bank</td>
<td>157889.9</td>
<td>0.000000</td>
<td>366.5073</td>
<td>0.000000</td>
<td>-0.522591</td>
<td>3.726097</td>
<td>117595.7</td>
<td>0.000000</td>
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<tr>
<td>Attica Bank</td>
<td>12656.29</td>
<td>0.000000</td>
<td>11357.25</td>
<td>0.000000</td>
<td>1.193584</td>
<td>9.670081</td>
<td>201637.3</td>
<td>0.000000</td>
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<tr>
<td>Bank of Greece</td>
<td>16595.22</td>
<td>0.000000</td>
<td>130.2709</td>
<td>0.000000</td>
<td>0.358656</td>
<td>3.247266</td>
<td>479526.6</td>
<td>0.000000</td>
</tr>
<tr>
<td>Ethniki Bank</td>
<td>87564.21</td>
<td>0.000000</td>
<td>2145.876</td>
<td>0.000000</td>
<td>-0.570431</td>
<td>5.860284</td>
<td>286030.8</td>
<td>0.000000</td>
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<tr>
<td>Geniki Bank</td>
<td>12562.59</td>
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<td>11059.70</td>
<td>0.000000</td>
<td>1.063602</td>
<td>9.674386</td>
<td>400940.3</td>
<td>0.000000</td>
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</tbody>
</table>

Table 6. 12 Basics indicator of all banks
<table>
<thead>
<tr>
<th>Banks</th>
<th>Hurst Exponent</th>
<th>ARCH Test: F-statistic</th>
<th>ARCH Test: Prob(F-statistic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agricultural bank</td>
<td>0.316773</td>
<td>0.145954</td>
<td>0.715598</td>
</tr>
<tr>
<td>Emporiki Bank</td>
<td>0.228836</td>
<td>0.235254</td>
<td>0.235254</td>
</tr>
<tr>
<td>Bank of Cyprus</td>
<td>0.264300</td>
<td>0.688507</td>
<td>0.493944</td>
</tr>
<tr>
<td>Eurobank</td>
<td>0.245546</td>
<td>17.45212</td>
<td>0.000155</td>
</tr>
<tr>
<td>Piraeus Bank</td>
<td>0.284215</td>
<td>0.227374</td>
<td>0.644843</td>
</tr>
<tr>
<td>Alpha Bank</td>
<td>0.261240</td>
<td>0.027073</td>
<td>0.872942</td>
</tr>
<tr>
<td>Attica Bank</td>
<td>0.317727</td>
<td>0.228838</td>
<td>0.643794</td>
</tr>
<tr>
<td>Bank of Greece</td>
<td>0.240756</td>
<td>1.004989</td>
<td>0.342296</td>
</tr>
<tr>
<td>Ethniki Bank</td>
<td>0.240976</td>
<td>0.709476</td>
<td>0.421436</td>
</tr>
<tr>
<td>Geniki Bank</td>
<td>0.265486</td>
<td>2.729427</td>
<td>0.106545</td>
</tr>
</tbody>
</table>
7. Conclusions

This dissertation attempted to investigate the cross-section of average stock returns in the Greek Stock Market (ASE) and particularly in ten (10) different Greek Banks. The methodology adopted was similar to Kai Du (2004), Theriou et al, (2005), Ayandi and Kryzanowski, (2004) and Oh et al, (2005). All the above mentioned methodologies use or adopt part/s of the Fama and French’ model (1992) which analyze/s the relation of systematic and unsystematic risk as well as average returns of portfolios according to their size, with the use of book-to-market equity ratio and average returns.

The basic purpose of this dissertation was to provide a further insight of anomalies present in the Greek Stock Market with the use of fractal analysis, R/S analysis, and other important methods as well.

The basic findings of this dissertation can be grouped in the following ones:

1. Variables like the book-to-market equity and average returns can explain and at the same time investigate in a better way the relation between systematic and unsystematic risk and average stock returns than beta.

2. The frequency distributions of the Athens Stock Exchange (ASE) returns are characterized by systematic deviations from normal distribution.

3. The frequency distributions of daily trading volume deviate from the normal one in its asymmetry, in its leptokurtic and fat-tailed features as well.

4. The time series of volatility and trading volume appear to have high persistence.

It is should be mentioned that this dissertation has worked on and analyzed only stocks from the bank sector. In this respect, the same analysis should be done for all the sectors of the Stock Market, in order to generalize the results found for the whole Greek Stock Market and for all the stocks; and
if not possible then it should feasible for a great amount of stocks from each sector.

A basic and general conclusion of this dissertation could be that the stock prices of the Greek banks involved in the sample are characterized by a chaotic structure with a fractal dimension around two (2). Furthermore, the basic conclusion of the R/S analysis is that the time series are anti-persistence, element that has to be carefully taken into account through the creation of a new portfolio.

The statistical analysis of the banks’ stock prices from the Greek Stock Market proved their chaotic structure as well as that traditional methods can not be used on them. The need, however, of an analysis of those stocks based on other chaotic methods is needed. The results that came out through the present research prove that the chaotic analysis is a powerful and at the same time reliable “tool” for the Greek Stock Market analysis. Thus, through the chaotic analysis an investor will be able to evaluate and at the same time to follow the trend of the Greek Stock Market more precisely. This will help one know of what will probably affect its trend which might cause one important future loses (wrong investments or financial moves).

Finally, the implications that have to be taken into account are as follows. First, this dissertation has only focused in a specific sector of the Greek Stock Market, the bank sector. Second, it should be useful to compare the already found results with the ones that will come out from other chaotic methods in order to verify the pertinence of them.
References

Articles:


Ang, Andrew and Joseph Chen (2005), ‘CAPM over the Long Run: 1926-2001’.


Bielecki, Tomas Z. R., Jean-Philippe Chancelier, Stanley R. Pliska and Agnes Sulem (2005), ‘Risk sensitive portfolio optimization with transaction costs’.


Hurst, H. E. (1951), ‘The long-Term Storage Capacity of Reservoirs’, *Transactions of the American Society of Civil Engineers*, 116 (1), 70-99


Kim, Chang Sik and Peter C.B. Phillips (2000), 'Modified Log Periodogram Regression’ Mimeo, Department of Economics, University of British Columbia


Markowitz, Harry M. (1952), 'Portfolio Selection', *Journal of Finance*, 7 (1), pp. 77-91

Mawah, Bernard (2007), 'Option pricing with transaction costs and non-linear Black-Scholes equation' Department of Mathematics, Uppsala University


Skjeltorp, Johannes A. (2000), 'Scaling in the Norwegian stock market', Research Department, Norges Bank (Central Bank of Norway), pp. 486-528

Strogatz, Steven (2000), 'Nonlinear Dynamics and Chaos', Perseus Publishing


Books:


**Websites:**


Official Website of Geniki Bank: http://www.geniki.gr

Official Website of Investopedia: http://www.investopedia.com
Appendix 1

Ten (10) different banks from the Greek Exchange Market will be used in the portfolio creation:

1. Agricultural Bank of Greece
2. Emporiki Bank
3. Bank of Cyprus
4. Eurobank
5. Piraeus Bank
6. Alpha Bank
7. Attica Bank
8. Bank of Greece
9. Ethniki Bank
10. Geniki Bank

All the following information are taken from the official websites of those ten (10) Greek Banks and they are trying to show briefly the foundation and the evolution of each one of them through years.

The Agricultural Bank of Greece was founded in 1929 as a non-profit organisation, provider of credit to the agricultural sector. Its main aims were:

(a) The implementation of programmes for financing both the activities of the primary sector of the economy,
(b) The processing and marketing of agricultural products,
(c) The enhancing of rural development.

Nevertheless, in 1990 it expanded its activities in the non-agricultural sector by developing both a broad branch network all over Greece and a variety of new financial products and services.

In 1991 the Agricultural Bank became S.A., broadened the spectrum of banking and financial services and acquired participating interests in specialised financial companies. It, therefore, expanded the ABG group of companies. In 2000 it entered the Athens Stock Exchange Market.

Between 2004 and 2006 the Bank strengthened its position by implementing a wide range of reforms and restructuring programs. It also developed its branch network competitiveness and productivity, managed to
achieve high growth rates which are depicted in the financial statements of both the Bank and the Group (source: http://www.atebank.gr).

Emporiki Bank with branches in Greece, London, Cyprus, Romania, Bulgaria and Albania is considered to be one as one of the largest banking institutions in Greece, with a continuous, constructive and energetic participation in the development of the Greek economy and in the modernisation of the country's banking market. It was established in 1907 and entered the Athens Stock Exchange Market in 1909. The Group of Emporiki is one of the most dynamic Groups in the financial sector, and offers an extensive range of products and services, such as:

- Investment banking and leasing,
- Factoring,
- Insurance,
- Banc assurance,
- Asset management for institutional investors,
- Mutual fund management,
- Securities portfolio management,
- Real estate development and management,
- Consumer credit

It is also active in the foreign and domestic capital and money markets offering a comprehensive range of traditional and modern banking services and products that meet the savings, financing and investment needs of its customers (source: http://www.atebank.gr).

The Bank of Cyprus Group, Greece is part of the Bank of Cyprus Group that was founded in Cyprus in 1899, where it holds the largest market share. The Group provides full banking services in Cyprus, Greece, Great Britain and Australia and has representation offices in all continents.

Greece is the centre of the Group's international expansion, since a Group parallel to that in Cyprus has already been completed. During its 16 years activity in Greece, Bank of Cyprus has been expanding rapidly and steadily.
The Bank of Cyprus Group Greece provides a full range of financial services:

- Banking services,
- Easing,
- Asset management,
- Stock broking services,
- Factoring,
- Insurance services (general insurance / life insurance).

In order to provide the best customer service, activities have been organized in three sectors:

1. Corporate
2. Retail
3. Consumer

At the same time, branches are flexible, so as to provide high quality service and specialized products that cover customer needs.

Bank of Cyprus aims primarily at offering each customer products that will provide added value and at ensuring a long-lasting cooperation based on mutual trust and transparency. Bank of Cyprus Greece also invests in technology (source: http://www.bankofcyprus.gr).

In the year 2000 the Bank of Cyprus Group was listed at the Athens Exchange. Thus, new prospects for the Bank of Cyprus Group Greece were created and everyone was granted the opportunity to participate at its development.

The Bank of Cyprus Group has the following subsidiaries:

- Bank of Cyprus Ltd
- Kyprou Leasing S.A.
- Kyprou Securities S.A.
- Kyprou Insurance Services Ltd
- Kyprou Life (source: http://www.bankofcyprus.gr)

Eurobank was established in December 1990 under the name of "Euromerchant Bank S.A.", offering mainly investment and private banking services. The Bank changed its strategic focus in the mid-1990s, in view of
the deregulation of the Greek retail banking sector. Since then, EFG Eurobank Ergasias has followed a successful course based on dynamic organic growth and has engaged in a series of mergers and acquisitions (Cretabank, Ergobank, Post Bank Bulgaria, Banc Post S.A. Romania, Post Banka AD Serbia Merger, Eurocredit Retail Services of Cyprus, INTERTRUST Mutual Fund Management Company, Tekfenbank of Turkey, Universal Bank of Ukraine, DZI Bank in Bulgaria). Today, EFG Eurobank Ergasias holds the leading position in the fastest growing and most profitable banking segments in Greece.

In 1999 the EFG Eurobank entered the Athens Stock Market with an initial public offering of its shares (source: http://www.eurobank.gr/online/home).

Piraeus Bank Group was founded in 1916. Nowadays, it is one of the most dynamic and active financial organisations in Greece. At the beginning of 1999, the Bank acquired Xiosbank and absorbed the activities of National Westminster Bank Plc in Greece. In June 2000, the Bank unified its three commercial banks in Greece (Piraeus Bank, Macedonia-Thrace Bank and Xiosbank), creating one of the three largest private sector banks in Greece. In early 2002, Piraeus Bank acquired the Hellenic Industrial Development Bank (ETBAbank). Except Greece, it has also branches in New York, London, Albania, Romania Bulgaria, Serbia and Egypt.

The main strategic targets of Piraeus Bank Group are:

- Further enhancing market shares in Greece and abroad wherever it operates,
- Improving service quality and customer satisfaction,
- Creating innovative products,
- Further enhancing the Group’s position in retail banking and small and medium-sized enterprises financing,
- Strengthening the Group in the areas of asset management and bancassurance.

The Group’s fundamental policy direction for human resources development is based on the efficient management of human resources, leading to the creation of skilful and dedicated personnel able to function
within the framework of the competitive EU banking market (source: http://www.piraeusbank.gr).

Alpha Bank that was founded in 1879 is one of the largest banks in Greece. It is also active in the international banking market, with presence in Cyprus and Southeastern Europe as well as in New York, London and Jersey in the Channel Islands.

- The Bank grew considerably in the last decades. Beyond providing banking services and products, it has developed into a major Group offering a wide range of financial services in Greece and in Southeastern Europe. In 1999 the bank acquired 51% of the shares of the Ionian Bank (source: http://www.alpha.gr/page).

The Bank's activities cover the entire range of financial services including shipping services as well as a wide range of deposits and loan accounts. Together with the companies that comprise the Alpha Bank Group, it provides services like:

- Financing services, through the companies Alpha Leasing and ABC Factors, Alpha Finance U.S, Alpha Asset Management A.E.D.A.K. and the European Development Programs Management Company of Thessaly and Sterea Hellas
- Investment services, through Alpha Ventures and Ionian Holdings
- Information and other services, through Evremathia
- Real estate, through Alpha Astika Akinita (source: http://www.alpha.gr/page)

Attica Bank operates as a Banking Societe Anonyme. The main object of this banking company is to act in the area of banking industry on its own behalf and on behalf of others. Attica Bank became a member of the Commercial Bank of Greece Group in 1964. It has been listed at the Athens Stock Exchange since 1964.

In 1997 the Group handed a portion of its stake over the TSMEDE (the Engineers and Public Works Contractors and Pension Fund) and the Loans and Consignements Fund. Finally in 2002 Commercial Bank of Greece Group
handed all of the remained shares over the Tahydromiko Tamieftirio (Greek Postal Savings Bank) (source: http://www.atticabank.gr/index.asp?a_id=46).

The Bank of Greece that was founded in 1927 is the central bank of the country. The profile of Greece has changed dramatically during the 1928-2003 period, as these seventy-five years have seen the transformation of a developing country into a Member State of the European Economic and Monetary Union. The country's national currency, the drachma, has followed a similar course, until it was finally replaced with the euro at the beginning of 2002 (source: http://www.bankofgreece.gr).

The National Bank of Greece S.A. was founded in 1841 and has been listed on the Athens Stock Exchange since 1880. In over 160 years of successful operation, the Bank has expanded into a modern diversified financial group that today services its clients’ constantly growing needs. As part of this diversification, the Bank founded Ethiniki Hellenic General Insurance Company in 1891 and National Mortgage Bank in 1927.

Until the establishment of the Bank of Greece in 1928, NBG was responsible for issuing currency in Greece in addition to its commercial banking services. The Bank expanded its business further when, in 1953, it merged with the Bank of Athens S.A. In 1998, the Bank merged through absorption with its subsidiary "National Mortgage Bank of Greece S.A.", formed as a result of the merger of two former subsidiaries "National Mortgage Bank" and "National Housing Bank of Greece S.A.", in order to provide integrated mortgage lending services to its customers.

Since 1999, NBG has been listed on the New York Stock Exchange. At the end of 2002, the Bank merged through absorption with its subsidiary "National Bank for Industrial Development SA". In the context of its strategic orientation towards SE Europe, NBG acquired Finansbank in Turkey and Vojvodjanska Banka in Serbia (source: http://www.nbg.gr).

Geniki Bank, a member of Societe Generale is one of the largest financial groups in the euro-zone, with more than 90,000 employees, serving more than 16 million clients worldwide. The Bank was founded in 1937 in order to provide financial services for the personnel of the Greek Armed
forces; nowadays its range of products includes private and corporate banking services, e-banking, as well as financial, insurance and leasing services via its subsidiaries. It offers a range of deposit/investment accounts and products, consumer and mortgage loans, credit and debit cards and mutual funds in the area of private banking. In the corporate banking sector, it offers deposit/investment products and loans for small, medium and large enterprises, current accounts and custodianship services for institutional investors. Today the bank operates 140 branches in Greece, while the group is also consisted by four subsidiary companies, that provide specialised banking, financing and insurance services (source: http://www.geniki.gr).
Appendix 2

Emporiki Bank

Fig. Appendix 2. 1 Stock price and General index of Emporiki Bank

Fig. Appendix 2. 2 Profile of daily returns of Emporiki Bank
Fig. Appendix 2. 3 Standard Deviations of Emporiki Bank

Fig. Appendix 2. 4 Fractal Dimension of Emporiki Bank
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
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<tbody>
<tr>
<td>C</td>
<td>-2.312628</td>
<td>0.128485</td>
<td>-17.99926</td>
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<td>GENERAL_INDEX01</td>
<td>0.008402</td>
<td>5.46E-05</td>
<td>153.7366</td>
<td>0.0000</td>
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</tbody>
</table>

R-squared 0.813205
Adjusted R-squared 0.813171
S.E. of regression 5.892929
Sum squared resid 188530.8
Log likelihood -17338.51
Durbin-Watson stat 0.002810

Table Appendix 2.1 Correlation Analysis of Emporiki Bank

Series: Residuals
Sample 1 5431
Observations 5431
Mean -1.44E-14
Median -0.355429
Maximum 28.76280
Minimum -21.80341
Std. Dev. 5.892386
Skewness 0.226811
Kurtosis 6.643825
Jarque-Bera 3051.144
Probability 0.000000

Fig. Appendix 2.5 Histogram Normality test of Emporiki Bank
ARCH Test:

<table>
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<tr>
<th></th>
<th>F-statistic</th>
<th>Probability</th>
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<tr>
<td>Obs*R-squared</td>
<td>5379.680</td>
<td>Probability</td>
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Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5431
Included observations: 5430 after adjusting endpoints

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<th>t-Statistic</th>
<th>Prob.</th>
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<tr>
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<td>1.430217</td>
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<td>RESID^2(-1)</td>
<td>0.997416</td>
<td>0.001309</td>
<td>761.7787</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.990733
Adjusted R-squared: 0.990731
S.E. of regression: 7.940963
Sum squared resid: 342283.6
Log likelihood: -18954.98
F-statistic: 580306.8
Durbin-Watson stat: 1.544567
Prob(F-statistic): 0.000000

Table Appendix 2. 2 ARCH test of Emporiki Bank

<table>
<thead>
<tr>
<th>n</th>
<th>log(n)</th>
<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
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<tbody>
<tr>
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<td>0.440605</td>
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<tr>
<td>6</td>
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<td>0.465061</td>
<td>3.06998</td>
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<tr>
<td>10</td>
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<tr>
<td>15</td>
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<td>4.59447</td>
<td>0.662235</td>
<td>263.977</td>
</tr>
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<td>30</td>
<td>2.257679</td>
<td>7.13439</td>
<td>0.853357</td>
<td>4450.26</td>
</tr>
<tr>
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<td>0.930694</td>
<td>12896.8</td>
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<td>0.969399</td>
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<td>3.03583</td>
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<td>0.984461</td>
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<td>1.010321</td>
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<td>2715</td>
<td>3.43377</td>
<td>11.7956</td>
<td>1.07172</td>
<td>273537</td>
</tr>
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</table>

Table Appendix 2. 3 R/S Analysis results of Emporiki Bank

Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 12
Included observations: 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.306439</td>
<td>0.018979</td>
<td>16.14616</td>
<td>0.0000</td>
</tr>
<tr>
<td>LOG_N_01</td>
<td>0.228836</td>
<td>0.008146</td>
<td>28.09275</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.987488
Adjusted R-squared: 0.986236
S.E. of regression: 0.027655
Sum squared resid: 0.007648
Log likelihood: 27.12193
Durbin-Watson stat: 0.477201

Table Appendix 2. 4 Correlation analysis of R/S results of Emporiki Bank
ARCH Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>0.235254</th>
<th>Probability</th>
<th>0.639242</th>
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</thead>
<tbody>
<tr>
<td>Obs*R-squared</td>
<td>0.280209</td>
<td>Probability</td>
<td>0.596565</td>
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</tbody>
</table>

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
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<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000529</td>
<td>0.000295</td>
<td>1.792150</td>
<td>0.1067</td>
</tr>
<tr>
<td>RESID^2(-1)</td>
<td>0.160615</td>
<td>0.331144</td>
<td>0.485030</td>
<td>0.6392</td>
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</tbody>
</table>

R-squared                | 0.025474    | Mean dependent var | 0.000635 |
Adjusted R-squared        | -0.082807   | S.D. dependent var  | 0.000636 |
S.E. of regression        | 0.000662    | Akaike info criterion | -11.63867|
Sum squared resid         | 3.95E-06    | Schwarz criterion   | -11.56632|
Log likelihood            | 66.01267    | F-statistic         | 0.235254 |
Durbin-Watson stat        | 1.822535    | Prob(F-statistic)   | 0.235254 |

Table Appendix 2.5 ARCH test of R/S results of Emporiki Bank
Bank of Cyprus

Fig. Appendix 2. 6 Stock price and General index of Bank of Cyprus

Fig. Appendix 2. 7 Profile of daily returns of Bank of Cyprus
Fig. Appendix 2. 8 Standard Deviations of Bank of Cyprus

Fig. Appendix 2. 9 Fractal Dimension of Bank of Cyprus
Table Appendix 2. 6 Correlation Analysis of Bank of Cyprus

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
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<td>GENERAL_INDEX01</td>
<td>0.003227</td>
<td>3.04E-05</td>
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<tr>
<td>R-squared</td>
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<td>4.651889</td>
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<td></td>
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<td>S.E. of regression</td>
<td>1.210653</td>
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<td></td>
<td>3.221348</td>
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<tr>
<td>Sum squared resid</td>
<td>2541.491</td>
<td></td>
<td></td>
<td>3.227638</td>
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<tr>
<td>Log likelihood</td>
<td>-2794.130</td>
<td></td>
<td></td>
<td>11260.55</td>
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<td>Durbin-Watson stat</td>
<td>0.009653</td>
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</table>

Fig. Appendix 2. 10 Histogram Normality test of Bank of Cyprus
### ARCH Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>46751.13</th>
<th>Probability</th>
<th>0.000000</th>
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</thead>
<tbody>
<tr>
<td>Obs^R-squared</td>
<td>1672.985</td>
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</table>

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 1736
Included observations: 1735 after adjusting endpoints

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<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<tbody>
<tr>
<td>C</td>
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<td>RESID^2(-1)</td>
<td>0.981798</td>
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</table>

R-squared: 0.964256  Mean dependent var: 1.464732
Adjusted R-squared: 0.964236  S.D. dependent var: 1.629002
S.E. of regression: 0.308068  Akaike info criterion: 0.484158
Sum squared resid: 164.4717  Schwarz criterion: 0.490451
Log likelihood: -418.0072  Prob(F-statistic): 46751.13

### Table Appendix 2.7 ARCH test of Bank of Cyprus

<table>
<thead>
<tr>
<th>n</th>
<th>log(n)</th>
<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.69897</td>
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<td>0.441271</td>
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<tr>
<td>10</td>
<td>1</td>
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### Table Appendix 2.8 R/S Analysis results of Bank of Cyprus
Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 5
Included observations: 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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</table>

R-squared   0.998664
Adjusted R-squared  0.998219
S.E. of regression  0.010950
Log likelihood  16.75459

<table>
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<tr>
<th>R-squared</th>
<th>Mean dependent var</th>
<th>Probability</th>
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<tbody>
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<th>S.D. dependent var</th>
<th>Probability</th>
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</thead>
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<table>
<thead>
<tr>
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<th>Probability</th>
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<tbody>
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</tbody>
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<table>
<thead>
<tr>
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<th>F-statistic</th>
<th>Probability</th>
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</thead>
<tbody>
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</table>

<table>
<thead>
<tr>
<th>Durbin-Watson stat</th>
<th>Prob(F-statistic)</th>
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<tbody>
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<td>1.637845</td>
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Table Appendix 2. 9 ARCH test of R/S results of Bank of Cyprus

ARCH Test:

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<th>F-statistic</th>
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<table>
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<th>Obs*R-squared</th>
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Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5
Included observations: 4 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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<tbody>
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</table>

R-squared   0.256093
Adjusted R-squared -0.115861
S.E. of regression  6.46E-05
Log likelihood  34.30178

<table>
<thead>
<tr>
<th>R-squared</th>
<th>Mean dependent var</th>
<th>Probability</th>
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<tbody>
<tr>
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<table>
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<th>Probability</th>
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<th>Prob(F-statistic)</th>
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Table Appendix 2. 10 ARCH test of R/S results of Bank of Cyprus
Fig. Appendix 2. 11 Stock price and General index of Eurobank.

Fig. Appendix 2. 12 Profile of daily returns of Eurobank.
Fig. Appendix 2. 13 Standard Deviations of Eurobank.

Fig. Appendix 2. 14 Fractal Dimension of Eurobank.
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5409
Included observations: 5409

<table>
<thead>
<tr>
<th>Variable</th>
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<th>t-Statistic</th>
<th>Prob.</th>
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R-squared                      0.858030     Mean dependent var 8.315006
Adjusted R-squared             0.858044     S.D. dependent var 7.406551
S.E. of regression             2.790967     Akaike info criterion 4.891023
Sum squared resid              42117.82     Schwarz criterion 4.893462
Log likelihood                 -13225.77    F-statistic 32678.46
Durbin-Watson stat             0.006666     Prob(F-statistic) 0.000000

Table Appendix 2. 11 Correlation Analysis of Eurobank.

Fig. Appendix 2. 15 Histogram Normality test of Eurobank.
ARCH Test:

| F-statistic | 171064.0 | Probability | 0.000000 |
| Obs*R-squared | 5242.331 | Probability | 0.000000 |

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5409
Included observations: 5408 after adjusting endpoints

<table>
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<th>Variable</th>
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<th>t-Statistic</th>
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R-squared: 0.969366
Adjusted R-squared: 0.969360
Mean dependent var: 7.787844
S.D. dependent var: 17.08709
S.E. of regression: 2.990962
Akaike info criterion: 5.029437
Sum squared resid: 48361.29
Schwarz criterion: 5.031876
Log likelihood: -13597.60
F-statistic: 171064.0
Durbin-Watson stat: 1.681992
Prob(F-statistic): 0.000000

Table Appendix 2. 12 ARCH test of Eurobank.

<table>
<thead>
<tr>
<th>n</th>
<th>log(n)</th>
<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
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<tr>
<td></td>
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<td>LOG_N_01</td>
<td>0.245546</td>
<td>0.006751</td>
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<tr>
<td></td>
<td>R-squared</td>
<td>0.969936</td>
<td>Mean dep var</td>
<td>0.759358</td>
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<tr>
<td></td>
<td>Adjusted R-squared</td>
<td>0.969203</td>
<td>S.D. dep var</td>
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<tr>
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<td>S.E. of regression</td>
<td>0.031212</td>
<td>Akaike info</td>
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<tr>
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<td>Sum squared resid</td>
<td>0.039943</td>
<td>Schwarz crit</td>
<td>-3.986896</td>
</tr>
<tr>
<td></td>
<td>Log likelihood</td>
<td>89.08816</td>
<td>F-statistic</td>
<td>1322.763</td>
</tr>
<tr>
<td></td>
<td>Durbin-Watson stat</td>
<td>0.249618</td>
<td>Prob(F-statistic)</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

Table Appendix 2. 14 Correlation analysis of R/S results of Eurobank.

**ARCH Test:**

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<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
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<td>0.000219</td>
<td>1.606881</td>
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<td>0.303768</td>
<td>Mean dep var</td>
<td>0.000800</td>
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<td>Adjusted R-squared</td>
<td>0.286362</td>
<td>S.D. dep var</td>
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<td>S.E. of regression</td>
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<td>Akaike info</td>
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</tr>
<tr>
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<td>Schwarz crit</td>
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<td>Log likelihood</td>
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<td>F-statistic</td>
<td>17.45212</td>
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</tr>
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<td></td>
<td>Durbin-Watson stat</td>
<td>1.956156</td>
<td>Prob(F-statistic)</td>
<td>0.000155</td>
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</table>

Table Appendix 2. 15 ARCH test of R/S results of Eurobank.
Fig. Appendix 2. 16 Stock price and General index of Piraeus Bank

Fig. Appendix 2. 17 Profile of daily returns of Piraeus Bank
Fig. Appendix 2. 18 Standard Deviations of Piraeus Bank

Fig. Appendix 2. 19 Fractal Dimension of Piraeus Bank
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>-2.740830</td>
<td>0.051986</td>
<td>-52.72238</td>
<td>0.0000</td>
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<td>GENERAL_INDEX01</td>
<td>0.004884</td>
<td>2.21E-05</td>
<td>220.8787</td>
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</tbody>
</table>

R-squared: 0.899864
Adjusted R-squared: 0.899846
S.D. of regression: 2.384403
Akaike info criterion: 4.576143
Schwarz criterion: 4.578573
F-statistic: 48787.41
Prob(F-statistic): 0.000000

Table Appendix 2. 16 Correlation Analysis of Piraeus Bank

Series: Residuals
Sample 1 5431
Observations 5431

Mean: -8.20E-15
Median: -0.533873
Maximum: 10.75563
Minimum: -7.965418
Std. Dev.: 2.384184
Skewness: 0.845037
Kurtosis: 4.785438
Jarque-Bera: 1367.739
Probability: 0.000000

Fig. Appendix 2. 20 Histogram Normality test of Piraeus Bank
ARCH Test:

<table>
<thead>
<tr>
<th>F-statistic</th>
<th>221744.2</th>
<th>Probability</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Obs*R-squared</td>
<td>5300.257</td>
<td>Probability</td>
<td>0.000000</td>
</tr>
</tbody>
</table>

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5431
Included observations: 5430 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.069868</td>
<td>0.026085</td>
<td>2.678518</td>
<td>0.0074</td>
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<tr>
<td>RESID^2(-1)</td>
<td>0.988120</td>
<td>0.002098</td>
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</table>

R-squared: 0.976106
Adjusted R-squared: 0.976102
S.E. of regression: 1.709699
Sum squared resid: 15866.43
Log likelihood: -10616.04
F-statistic: 221744.2
Durbin-Watson stat: 1.776842
Prob(F-statistic): 0.000000

Table Appendix 2. 17 ARCH test of Piraeus Bank

<table>
<thead>
<tr>
<th>n</th>
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<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.69897</td>
<td>2.22372</td>
<td>0.34708</td>
<td>2.8025</td>
</tr>
<tr>
<td>6</td>
<td>0.778151</td>
<td>2.39592</td>
<td>0.379472</td>
<td>3.06998</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>2.88815</td>
<td>0.457602</td>
<td>3.96333</td>
</tr>
<tr>
<td>15</td>
<td>1.176091</td>
<td>3.26001</td>
<td>0.513219</td>
<td>4.85406</td>
</tr>
<tr>
<td>30</td>
<td>1.477121</td>
<td>4.17179</td>
<td>0.620322</td>
<td>263.977</td>
</tr>
<tr>
<td>181</td>
<td>2.257679</td>
<td>8.47904</td>
<td>0.928347</td>
<td>4450.26</td>
</tr>
<tr>
<td>362</td>
<td>2.558709</td>
<td>9.43917</td>
<td>0.974934</td>
<td>12896.8</td>
</tr>
<tr>
<td>543</td>
<td>2.7348</td>
<td>10.1008</td>
<td>1.004356</td>
<td>23916.4</td>
</tr>
<tr>
<td>905</td>
<td>2.956649</td>
<td>10.8873</td>
<td>1.03692</td>
<td>51942</td>
</tr>
<tr>
<td>1086</td>
<td>3.03583</td>
<td>10.8224</td>
<td>1.034324</td>
<td>68469.2</td>
</tr>
<tr>
<td>1810</td>
<td>3.257679</td>
<td>11.1</td>
<td>1.045323</td>
<td>148287</td>
</tr>
<tr>
<td>2715</td>
<td>3.43377</td>
<td>12.4428</td>
<td>1.094918</td>
<td>273537</td>
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</table>

Table Appendix 2. 18 R/S Analysis results of Piraeus Bank

Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 12
Included observations: 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<td>5.160732</td>
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<tr>
<td>LOG_N_01</td>
<td>0.284215</td>
<td>0.015438</td>
<td>18.40984</td>
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</table>

R-squared: 0.971340
Adjusted R-squared: 0.968474
S.E. of regression: 0.052414
Sum squared resid: 0.027472
Log likelihood: 19.44970
F-statistic: 338.9222
Durbin-Watson stat: 0.526372
Prob(F-statistic): 0.000000

Table Appendix 2. 19 Correlation analysis of R/S results of Piraeus Bank
**ARCH Test:**

<table>
<thead>
<tr>
<th></th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0.002036</td>
<td>0.001216</td>
<td>1.674043</td>
<td>0.1284</td>
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<tr>
<td>RESID^2(-1)</td>
<td>0.160351</td>
<td>0.336281</td>
<td>0.476837</td>
<td>0.6448</td>
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Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
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<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>R-squared</td>
<td>0.024641</td>
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</tr>
<tr>
<td>Adjusted R-squared</td>
<td>-0.083732</td>
<td>0.001216</td>
<td>-0.83732</td>
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<td>S.E. of regression</td>
<td>0.003289</td>
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<td>Sum squared resid</td>
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<td>Log likelihood</td>
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<td>Durbin-Watson stat</td>
<td>1.885539</td>
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**Table Appendix 2. 20 ARCH test of R/S results of Piraeus Bank**
Attica Bank

Fig. Appendix 2. 21 Stock price and General index of Attica Bank

Fig. Appendix 2. 22 Profile of daily returns of Attica Bank.
Fig. Appendix 2. 23 Standard Deviations of Attica Bank.

Fig. Appendix 2. 24 Fractal Dimension of Attica Bank.
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<td>0.001730</td>
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R-squared: 0.699811  Mean dependent var: 3.162375
Adjusted R-squared: 0.699756  S.D. dependent var: 3.026475
S.E. of regression: 1.658343  Akaike info criterion: 3.849883
Sum squared resid: 14930.30  Schwarz criterion: 3.852313
Log likelihood: -10452.36  F-statistic: 12656.29
Durbin-Watson stat: 0.006069  Prob(F-statistic): 0.000000

Table Appendix 2. 21 Correlation Analysis of Attica Bank.

Fig. Appendix 2. 25 Histogram Normality test of Attica Bank.
ARCH Test:

F-statistic 201637.3 Probability 0.000000
Obs*R-squared 5287.658 Probability 0.000000

Test Equation:
Dependent Variable: RESID\(^2\)
Method: Least Squares
Sample(adj usted): 2 5431
Included observations: 5430 after adjusting endpoints

<table>
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<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>C</td>
<td>0.038256</td>
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<td>RESID(^2)(-1)</td>
<td>0.986938</td>
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R-squared 0.973786 Mean dependent var 2.749593
Adjusted R-squared 0.973781 S.D. dependent var 8.096096
S.E. of regression 1.310937 Akaike info criterion 3.379730
Sum squared resid 9328.325 Schwarz criterion 3.382161
Log likelihood -9173.967 F-statistic 201637.3
Durbin-Watson stat 1.665505 Prob(F-statistic) 0.000000

Table Appendix 2. 22 ARCH test of Attica Bank.

<table>
<thead>
<tr>
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<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
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<tr>
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<td>6</td>
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<td>4.85406</td>
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<td>263.977</td>
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<td>1.676091</td>
<td>4.0021</td>
<td>0.698305</td>
<td>3.06998</td>
</tr>
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<td>0.908363</td>
<td>4450.26</td>
</tr>
<tr>
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<td>2.457809</td>
<td>9.96568</td>
<td>0.998507</td>
<td>12896.8</td>
</tr>
<tr>
<td>543</td>
<td>2.7348</td>
<td>10.711</td>
<td>1.02983</td>
<td>23916.4</td>
</tr>
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<td>13.1782</td>
<td>1.119856</td>
<td>51942</td>
</tr>
<tr>
<td>1086</td>
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<td>1.131266</td>
<td>68469.2</td>
</tr>
<tr>
<td>1810</td>
<td>3.257679</td>
<td>13.7221</td>
<td>1.137421</td>
<td>148287</td>
</tr>
<tr>
<td>2715</td>
<td>3.43377</td>
<td>17.1858</td>
<td>1.23517</td>
<td>273537</td>
</tr>
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</table>

Table Appendix 2. 23 R/S Analysis results of Attica Bank.

Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 12
Included observations: 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<tr>
<td>LOG_N_01</td>
<td>0.317727</td>
<td>0.007175</td>
<td>44.28138</td>
<td>0.0000</td>
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</table>

R-squared 0.994926 Mean dependent var 0.829179
Adjusted R-squared 0.994419 S.D. dependent var 0.326070
S.E. of regression 0.024360 Akaike info criterion -4.440716
Sum squared resid 0.005934 Schwarz criterion -4.359899
Log likelihood 28.64430 F-statistic 1960.841
Durbin-Watson stat 1.403677 Prob(F-statistic) 0.000000

Table Appendix 2. 24 Correlation analysis of R/S results of Attica Bank.
ARCH Test:
F-statistic 0.228838  Probability 0.643794
Obs*R-squared 0.272755  Probability 0.601490

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>1.839535</td>
<td>0.0990</td>
</tr>
<tr>
<td>RESID^2(-1)</td>
<td>-0.156689</td>
<td>0.327548</td>
<td>-0.478370</td>
<td>0.6438</td>
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</tbody>
</table>

R-squared 0.024796  Mean dependent var 0.000533
Adjusted R-squared -0.083560  S.D. dependent var 0.000914
S.E. of regression 0.000951  Akaike info criterion -10.91477
Sum squared resid 8.14E-06  Schwarz criterion -10.84243
Log likelihood 62.03124  F-statistic 0.228838
Durbin-Watson stat 2.012406  Prob(F-statistic) 0.643794

Table Appendix 2. 25 ARCH test of R/S results of Attica Bank.
**Bank of Greece**

Fig. Appendix 2. 26 Stock price and General index of Bank of Greece.

**Profile of daily returns**

Fig. Appendix 2. 27 Profile of daily returns of Bank of Greece.
Fig. Appendix 2. 28 Standard Deviations of Bank of Greece

Fig. Appendix 2. 29 Fractal Dimension of Bank of Greece
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
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<td>0.0000</td>
</tr>
<tr>
<td>GENERAL_INDEX01</td>
<td>0.019829</td>
<td>0.000154</td>
<td>128.8224</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared 0.753499 Mean dependent var 30.44668
Adjusted R-squared 0.753453 S.D. dependent var 33.42746
S.E. of regression 16.59790 Akaike info criterion 8.456797
Sum squared resid 1495636. Schwarz criterion 8.459228
Log likelihood -22962.43 F-statistic 16595.22
Durbin-Watson stat 0.002918 Prob(F-statistic) 0.000000

Table Appendix 2. 26 Correlation Analysis of Bank of Greece

Fig. Appendix 2. 30 Histogram Normality test of Bank of Greece.

Series: Residuals
Sample 1 5431
Observations 5431

Mean -5.51E-15
Median -3.483899
Maximum 51.07816
Minimum -47.42912
Std. Dev. 16.59637
Skewness 0.358656
Kurtosis 3.247266
Jarque-Bera 130.2709
Probability 0.000000
ARCH Test:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>1.543513</td>
<td>0.712681</td>
<td>2.165783</td>
<td>0.0304</td>
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<tr>
<td>RESID^2(-1)</td>
<td>0.994390</td>
<td>0.001436</td>
<td>692.4786</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared: 0.988807
Adjusted R-squared: 0.988805
S.E. of regression: 43.68670
Sum squared resid: 10359489
Mean dependent var: 275.4329
S.D. dependent var: 412.8952
Akaike info criterion: 10.39233
Sum squared resid: 10359489
Mean dependent var: 275.4329
S.D. dependent var: 412.8952
Akaike info criterion: 10.39233

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5431
Included observations: 5430 after adjusting endpoints

Table Appendix 2. 27 ARCH test of Bank of Greece.

<table>
<thead>
<tr>
<th>n</th>
<th>log(n)</th>
<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.69897</td>
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<tr>
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<tr>
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<td>4.85406</td>
</tr>
<tr>
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</tr>
<tr>
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</tr>
<tr>
<td>362</td>
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<td>8.96538</td>
<td>0.952569</td>
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</tr>
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<td>0.985949</td>
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</tr>
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<td>12.0328</td>
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</tr>
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</table>

Table Appendix 2. 28 R/S Analysis results of Bank of Greece.

Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 12
Included observations: 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
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</thead>
<tbody>
<tr>
<td>C</td>
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<td>0.240756</td>
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</table>

R-squared: 0.988896
Adjusted R-squared: 0.988778
S.E. of regression: 0.027390
Sum squared resid: 0.007502
Log likelihood: 27.23766
Durbin-Watson stat: 1.766234

Table Appendix 2. 29 R/S Analysis results of Bank of Greece.
ARCH Test:

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<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>Probability</th>
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<tbody>
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<td>F-statistic</td>
<td>1.004989</td>
<td>0.342296</td>
</tr>
<tr>
<td>Obs*R-squared</td>
<td>1.104937</td>
<td>0.293185</td>
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</table>

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
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<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
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<tr>
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</tbody>
</table>

R-squared: 0.100449
Adjusted R-squared: 0.000499
S.E. of regression: 0.000682
Sum squared resid: 4.18E-06
Log likelihood: 65.69730
Durbin-Watson stat: 0.893830

Table Appendix 2. 30 ARCH test of R/S results of Bank of Greece.
Ethniki Bank

Fig. Appendix 2. 31 Stock price and General index of Ethniki Bank.

Profile of daily returns

Fig. Appendix 2. 32 Profile of daily returns of Ethniki Bank.
Fig. Appendix 2. 33 Standard Deviations of Ethniki Bank.

Fig. Appendix 2. 34 Fractal Dimension of Ethniki Bank.
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Date: 10/25/07   Time: 13:19
Sample: 1 5431
Included observations: 5431

<table>
<thead>
<tr>
<th>Variable</th>
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<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
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<tr>
<td>GENERAL_INDEX01</td>
<td>0.008213</td>
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</tr>
</tbody>
</table>

R-squared 0.941619   Mean dependent var 12.13636
Adjusted R-squared 0.941609   S.D. dependent var 12.38588
S.E. of regression 2.992962   Akaike info criterion 5.030772
Sum squared resid 48632.01   Schwarz criterion 5.033203
Log likelihood -13659.06   F-statistic 87564.21
Durbin-Watson stat 0.005703   Prob(F-statistic) 0.000000

Table Appendix 2. 31 Correlation Analysis of Ethniki Bank.

Fig. Appendix 2. 35 Histogram Normality test of Ethniki Bank.
ARCH Test:

<table>
<thead>
<tr>
<th></th>
<th>F-statistic</th>
<th>286030.8</th>
<th>Probability</th>
<th>0.000000</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obs*R-squared</td>
<td>5328.874</td>
<td>Probability</td>
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</tbody>
</table>

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5431
Included observations: 5430 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.086075</td>
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<td>0.0321</td>
</tr>
<tr>
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<td>0.001852</td>
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<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared          | 0.981376 Mean dependent var | 8.954668  |
Adjusted R-squared | 0.981373 S.D. dependent var | 19.74482 |
S.E. of regression | 2.694788 Akaike info criterion | 4.820884 |
Sum squared resid  | 39417.49 Schwarz criterion | 4.823315 |
Log likelihood     | -13086.70 F-statistic | 286030.8  |
Durbin-Watson stat | 1.383550 Prob(F-statistic) | 0.000000 |

Table Appendix 2. 32 ARCH test of of Ethniki Bank.

<table>
<thead>
<tr>
<th>n</th>
<th>log(n)</th>
<th>R/S</th>
<th>log(R/S)</th>
<th>E(R/S)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.69897</td>
<td>2.74051</td>
<td>0.437831</td>
<td>2.8025</td>
</tr>
<tr>
<td>6</td>
<td>0.778151</td>
<td>2.89868</td>
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<td>3.06998</td>
</tr>
<tr>
<td>10</td>
<td>1.176091</td>
<td>3.82513</td>
<td>0.582646</td>
<td>4.85406</td>
</tr>
<tr>
<td>15</td>
<td>1.477121</td>
<td>4.55817</td>
<td>0.658791</td>
<td>263.977</td>
</tr>
<tr>
<td>30</td>
<td>2.257679</td>
<td>7.02794</td>
<td>0.846828</td>
<td>4450.26</td>
</tr>
<tr>
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<td>8.35189</td>
<td>0.921785</td>
<td>12896.8</td>
</tr>
<tr>
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<td>2.7348</td>
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<td>0.973119</td>
<td>23916.4</td>
</tr>
<tr>
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<td>2.956649</td>
<td>10.0329</td>
<td>1.001426</td>
<td>51942</td>
</tr>
<tr>
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<td>10.2001</td>
<td>1.008604</td>
<td>68469.2</td>
</tr>
<tr>
<td>1810</td>
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<td>1.035542</td>
<td>148287</td>
</tr>
<tr>
<td>2715</td>
<td>3.43377</td>
<td>13.1364</td>
<td>1.118476</td>
<td>273537</td>
</tr>
</tbody>
</table>

Table Appendix 2. 33 R/S Analysis results of Ethniki Bank.

Dependent Variable: LOG_R_S_01
Method: Least Squares
Sample: 1 12
Included observations: 12

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.288793</td>
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</tr>
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<td>LOG_N_01</td>
<td>0.240976</td>
<td>0.005592</td>
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<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared        | 0.994644 Mean dependent var | 7.981666 |
Adjusted R-squared| 0.994109 S.D. dependent var | 0.247339 |
S.E. of regression| 0.018984 Akaike info criterion | -4.93937 |
Sum squared resid | 0.003604 Schwarz criterion | -4.858579 |
Log likelihood   | 31.63638 F-statistic | 1857.195 |
Durbin-Watson stat | 0.990592 Prob(F-statistic) | 0.000000 |

Table Appendix 2. 34 Correlation analysis of R/S results of Ethniki Bank.
**ARCH Test:**

<table>
<thead>
<tr>
<th>Test Statistic</th>
<th>Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-statistic</td>
<td>0.709476</td>
<td>0.421436</td>
</tr>
<tr>
<td>Obs*R-squared</td>
<td>0.803776</td>
<td>0.369967</td>
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</tbody>
</table>

**Test Equation:**

Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 12
Included observations: 11 after adjusting endpoints

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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<tr>
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<td>-0.277121</td>
<td>0.329004</td>
<td>-0.842304</td>
<td>0.4214</td>
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</table>

R-squared: 0.073071  Mean dependent var: 0.000293
Adjusted R-squared: -0.029922  S.D. dependent var: 0.000428
S.E. of regression: 0.000434  Akaike info criterion: -12.48217
Sum squared resid: 1.70E-06  Schwarz criterion: -12.40983
Log likelihood: 70.65195  F-statistic: 0.709476
Durbin-Watson stat: 2.111544  Prob(F-statistic): 0.421436

Table Appendix 2. 35 ARCH test of R/S results of Ethniki Bank.
Geniki Bank

Fig. Appendix 2. 36 Stock price and General index of Geniki Bank.

Fig. Appendix 2. 37 Profile of daily returns of Geniki Bank.
Fig. Appendix 2. 38 Standard Deviations of Geniki Bank.

Fig. Appendix 2. 39 Fractal Dimension of Geniki Bank.
Dependent Variable: STOCK_PRICE01
Method: Least Squares
Sample: 1 5409
Included observations: 5409

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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R-squared: 0.699103
Adjusted R-squared: 0.699047
S.E. of regression: 3.815817
Sum squared resid: 78728.39
Log likelihood: -14917.53
F-statistic: 12562.59
Durbin-Watson stat: 0.003661

Table Appendix 2. 36 Correlation Analysis of Geniki Bank.

Figure Appendix 2. 40 Histogram Normality test of Geniki Bank.
ARCH Test:

F-statistic 400940.3 Probability 0.000000
Obs*R-squared 5336.052 Probability 0.000000

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Sample(adjusted): 2 5409
Included observations: 5408 after adjusting endpoints

<table>
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<td>0.994386</td>
<td>0.001570</td>
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</table>

R-squared 0.986696 Mean dependent var 14.55755
Adjusted R-squared 0.986694 S.D. dependent var 42.87560
S.E. of regression 4.945842 Akaike info criterion 6.035341
Sum squared resid 132238.1 Schwarz criterion 6.037780
Log likelihood -16317.56 F-statistic 400940.3
Durbin-Watson stat 1.663131 Probi(F-statistic) 0.000000

Table Appendix 2. 37 ARCH test of Geniki Bank.

<table>
<thead>
<tr>
<th>n</th>
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<th>R/S</th>
<th>E(R/S)</th>
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<tr>
<td>300</td>
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</table>
Table Appendix 2. 38 R/S Analysis results of Geniki Bank.

Dependent Variable: LOG_R_S_01  
Method: Least Squares  
Sample: 1 42  
Included observations: 42

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
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<td>LOG_N_01</td>
<td>0.265486</td>
<td>0.003258</td>
<td>81.49714</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

R-squared 0.994014  
Mean dependent var 0.770618  
Adjusted R-squared 0.993864  
S.D. dependent var 0.182079  
S.E. of regression 0.014263  
Akaike info criterion -5.615869  
Schwarz criterion -5.53123  
Log likelihood 119.9332  
F-statistic 6641.783  
Prob(F-statistic) 0.000000  

Table Appendix 2. 39 Correlation analysis of R/S results of Geniki Bank.

ARCH Test:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>Prob.</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.000146</td>
<td>7.20E-05</td>
<td>2.023318</td>
<td>0.0499</td>
</tr>
<tr>
<td>RESID^2(-1)</td>
<td>0.263088</td>
<td>0.159245</td>
<td>1.652098</td>
<td>0.1065</td>
</tr>
</tbody>
</table>

R-squared 0.065408  
Mean dependent var 0.000192  
Adjusted R-squared 0.041444  
S.D. dependent var 0.000432  
S.E. of regression -12.64883  
Akaike info criterion -12.56524  
Schwarz criterion 2.729427  
F-statistic 261.3011  
Prob(F-statistic) 0.010506  

Table Appendix 2. 40 ARCH test of R/S results of Geniki Bank.
Appendix 3

#include <iostream.h>
#include <fstream.h>
#include <math.h>
void main ()
{
    double stockTable[7000];
    double stockTableLN[7000];
    double epsilon[7000];
    double stockTableX[7000];
    double stockTableR[7000];
    double stockTableSI[7000];
    double stockTableI[7000];
    double sum, maxX, minX;
    double RSAverage[700];
    long double finaleTableRS[700][6];
    int i=1, index, j, k, plithos, endTable, endTableEpsilon,endTableR,endTableSI,I=1,r;
    int endTableLN,endFinaleTableRS;
    long double apotelesmaRS,pi,sumR;
    pi=4*atan(1);
    ifstream infile;
    ofstream outfile;
    ofstream outfileln;
    ofstream outfileepsilon;
    ofstream outfileX;
    ofstream outfileR;
    ofstream outfileSI;
    ofstream outfileRSA;
    ofstream finaleResult;
    ofstream outfileFRSA;
    infile.open("trapeza.dta");
    outfile.open("result.dta");
    outfileln.open("resultln.dta");
    outfileepsilon.open("resulte.dta");
    outfileX.open("resultX.dta");
    outfileR.open("resultR.dta");
    outfileSI.open("resultSI.dta");
    outfileRSA.open("resultRSA.dta");
    finaleResult.open("filaleresult.dta");
    outfileFRSA.open("filaleanalysis.dta");
    cout<<"---- >> start of programm <<---- "<<endl;
    while (!infile.eof())
    {
        infile>>stockTable[i];
        i++;
    }
    endTable=i-1;
    cout<<"---------------------------------"<<endl;
}
cout<<"--- amount of data : "<endTable<< "-----"<<endl;
cout<<"----------------------------------"<<endl;
for (i=1;i<endTable;i++)
    outfile<<stockTable[i]<<endl;
outfile.close();

for (i=1;i<endTable-1;i++)
    stockTableLN[i]=logl( stockTable[i+1]/stockTable[i]);
for (i=1;i<endTable-1;i++)
    outfileLn<<stockTableLN[i]<<endl;
outfileLn.close();

endTableLN=endTable-1;
plithos=5;
while (plithos <= (endTableLN/2))
    if ((endTableLN%plithos)==0)
    {
        cout<<endl;
cout<<" number of observations -- "<plithos<<endl;
i=1; j=1; sum=0;
while (i<=endTableLN)
    {
        sum+=stockTableLN[i];
        if ((i%plithos)==0)
        {
            epsilon[j]=sum/static_cast<double>(plithos);
            sum=0;
            j++;
        }
i++;
    }
    endTableEpsilon=j-1;
    outfileepsilon<<"--- "<plithos<<"--"<<endl;
for (k=1; k<=endTableEpsilon; k++)
    outfileepsilon<<epsilon[k]<<endl;
    j=1;
stockTableX[1]=stockTableLN[1]-epsilon[j];
maxX=minX=stockTableX[1];
sum=stockTableX[1]*stockTableX[1];
for (k=2; k<=endTableLN; k++)
    {
        stockTableX[k]=stockTableLN[k]-epsilon[j];
        sum+=stockTableX[k]*stockTableX[k];
        if(maxX<stockTableX[k])maxX=stockTableX[k];
        if(minX>stockTableX[k])minX=stockTableX[k];
        if ((k%plithos)==0)
        {
            stockTableR[j]=maxX-minX;
            stockTableSI[j]=sum / static_cast<double> (plithos);
            j++; k++;
}
stockTableX[k]=stockTableLN[k]-epsilon[j];
maxX=minX=stockTableX[k];
sum=stockTableX[k]*stockTableX[k];
}
}
outfileR<<""""<<plithos"""" """"""<<endl;
outfileSI<<""""<<plithos"""" """"""<<endl;
outfileX<<""""<<plithos"""" """"""<<endl;
for (k=1; k<=endTableEpsilon; k++)
{
    outfileX<<stockTableX[k]<<endl;
}
for (k=1; k<=endTableEpsilon; k++)
{
    stockTableSI[k]=sqrt(stockTableSI[k]);
    outfileR<<stockTableR[k]<<endl;
    outfileSI<<stockTableSI[k]<<endl;
}
sum=0;
outfileRSA<<""""<<plithos"""" """"""<<endl;
for (k=1; k<=endTableEpsilon; k++)
{
    if(stockTableSI[k]==0)stockTableSI[k]=1e-18;
    stockTableI[k]=stockTableR[k]/stockTableSI[k];
    sum+=stockTableI[k];
    outfileRSA<<stockTableI[k]<<endl;
}
RSAverage[I]=sum/static_cast<double>(endTableEpsilon);
finaleResult<<plithos"""" """"""<<endl;
finaleTableRS[I][0]=plithos;
finaleTableRS[I][2]=RSAverage[I];
plithos++;
I++;
}
else
{
    plithos++;
}
endFinaleTableRS=I-1;
infile.close();
outfile.close();
outfileepsilon.close();
outfileX.close();
outfileR.close();
outfileSI.close();
outfileRSA.close();
finaleResult.close();
cout<<endl<<"-""- end of first calculation """"""<<endl;
for (k=1; k<=endFinaleTableRS; k++)
if (finaleTableRS[k][0]<=20)
    apotelesmaRS=powl((finaleTableRS[k][0]*pi/2),0.5);
else
    if(finaleTableRS[k][0]<=300)
    {
        sumR=0;
        for (r=1;r<=(finaleTableRS[k][0]-1);r++)sumR+=sqrtl((finaleTableRS[k][0]-r)/r);
        apotelesmaRS=((finaleTableRS[k][0]-0.5)/finaleTableRS[k][0]) * powl((finaleTableRS[k][0]*pi/2),0.5)*sumR;
    }
    else
    {
        sumR=0;
        for (r=1;r<=(finaleTableRS[k][0]-1);r++)sumR+=sqrtl((finaleTableRS[k][0]-r)/r);
        apotelesmaRS=powl((finaleTableRS[k][0]*pi/2),0.5)*sumR;
    }
finaleTableRS[k][1]=logl(finaleTableRS[k][0]);
finaleTableRS[k][3]=apotelesmaRS;
finaleTableRS[k][4]=finaleTableRS[k][2]/sqrtl(finaleTableRS[k][0]);
finaleTableRS[k][5]=finaleTableRS[k][3]/sqrtl(finaleTableRS[k][0]);
cout<<"<finaleTableRS[k][0]<<<" | "<finaleTableRS[k][1]<<< | "<finaleTableRS[k][2]<<< | "<finaleTableRS[k][3]<<< | "<finaleTableRS[k][4]<<< | "<finaleTableRS[k][5]<<< endl;
outfileFRSA<<finaleTableRS[k][0]<<"<finaleTableRS[k][1]<<< | "<finaleTableRS[k][2]<<< | "<finaleTableRS[k][3]<<< | "<finaleTableRS[k][4]<<< | "<finaleTableRS[k][5]<<< endl;
}