Correlation of Returns in Stock Market Prices:

Evidence from Nordic Countries

Author: Amin S. Sofla

Supervisor: Catherine Lions
Correlation of Returns in Stock Market Prices: Evidence from Nordic Countries

Amin Salimi Sofla

Supervisor: Catherine Lions

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Amin S. Sofla
Abstract

This paper tests a version of efficient market hypothesis on new sets of daily, weekly and monthly data for the Nordic countries stock market. Author used correlation test AR (1) and AR (2) for testing hypothesis. The results suggest that returns in Nordic stock market do not have the correlation in weekly and monthly data; therefore, a weak version of efficient market hypothesis cannot be rejected. Since findings of prior researches are mix, the findings of this thesis is inconsistence with some and consistent with others and shows that the possibility of earning abnormal returns during period (2007-2009) was low.

Key words: Efficient Market Hypothesis, Random Walk, Correlation of Returns
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Introduction

In this chapter, author introduces this thesis. First, short background will be reviewed. Then, author will state the research problem, purpose, and hypothesis. Afterwards, methodology, previous studies, limitations and structure of research will be presented.

Background

Random walk hypothesis states that stock prices move randomly; as a result, expected profit for the speculator is zero. Many economists believe that random walk can be applied to test the efficient market hypothesis in the weak level. “The efficient markets hypothesis (EMH) maintains that market prices fully reflect all available information” (Lo A. , 2007, p. 1). Early literature used stochastic processes to test whether prices precluded everyone from easy profit and whether prices followed those processes or not. Basic conclusion of those studies was that prices cannot and should not reflect information known to everyone. What is more , “Efficient Market Hypothesis is one the most controversial and well-studied propositions in all the social sciences, yet is surprisingly resilient to empirical proof or refutation “ (p. xiii).“Recent advances in evolutionary psychology and the cognitive neuroscience may be able to reconcile the EMH with behavioral anomalies” (Lo A. , 2007, p. 1).

Statement of Problem

When stock prices do not fluctuate randomly, some investors can use past stock prices to gain abnormal return. Doing regular test is necessary to see the evolving conditions of earning abnormal returns in the stock market. Besides, it is important to know whether market is efficient or not because market efficiency is fundamental characteristics of capitalist economy; it improves capital allocation and enhances market confidence. Especially, during recent financial crisis, many criticized the efficient market hypothesis (Nocera, 2009, p. 1). Since with some assumptions correlation test can show the efficiency of financial market in a weak level, we can test whether market during financial crisis was efficient or not. One common and intuitive test of the random walk is to check serial correlations (Borges M. , 2008, p. 4). Assuming rationality and risk neutrality, a version “of the efficient market hypothesis states that information observable to the market prior to week t should not help to predict the return during week t“ (Wooldridge, 2009, p. 385). In other words, stock returns are not correlated to one another; consequently, statistical model of the efficient market hypothesis ((E(y_t |y_{t-1} , y_{t-2} , y_{t-3}, ... ) = E(y_t ), where y_t is a return in time i) holds and changes in returns are independent from one another.

Purpose

The purpose of this paper is to examine whether Nordic stock market is efficient in the weak form or not. This purpose will be fulfilled by finding any correlation of returns for the Nordic stock market prices using a new set of data for the period 2007-2009. The presence or absence of this correlation in the returns is examined using stock market index. Testing of correlation in
returns can be done in any time dimension. The most common time dimension is daily one. Since market index is daily, it is logical to choose daily dimension. Besides, to avoid day of the week effect, author added weekly test to this research. In some cases, the results of statistical tests are different for lower frequency data; therefore, author makes a study more comprehensive by adding monthly data. Finally, in almost all cases, previous studies in random walk have focused on one or combination of these time dimensions.

**Research Hypothesis and Methodology**

“A strict form of the efficient market hypothesis states that information observable to the market prior to week t should not help to predict the return during week t. If we use only past information on y, the EMH is stated as \( E(\text{y}_t | \text{y}_{t-1}, \text{y}_{t-2}, \text{y}_{t-3}, ...) = E(\text{y}_t) \)“ (Wooldridge, 2009, p. 385). Following research question has constructed to comply with the purpose of this research:

Does the expected value of stock returns in Nordic Stock Exchanges depends on past stock returns?

Then, following research Hypothesis is constructed to answer statistically the research question:

*Expected value of stock prices returns in Nordic Stock Exchanges does not depend on past stock prices returns.*

If the hypothesis is rejected, it means that there was a possibility of earning abnormal returns during given period (2007-2009). However, if there is not any correlation among returns, “future returns cannot be forecasted by using information on historical prices” (Chancharat & Valadkhani, 2007, p. 2).

One common way to test this equation is autoregressive process of order one known as AR (1), where the null hypothesis is \( H_0 : \beta_1 = 0 \). Since this model sometimes, fail to find correlation among returns that are more than one lag apart, author uses autoregressive model of order two known as AR (2). AR (2)’s equation is this case would be:

\[
y_t = \beta_0 + \beta_1 \text{y}_{t-1} + \beta_2 \text{y}_{t-2} + u_t
\]

where \( E(u_t | \text{y}_{t-1}, \text{y}_{t-2}, \text{y}_{t-3}, ...) = 0 \) and the null hypothesis is \( H_0 : \beta_0 = \beta_1 = 0 \) (Wooldridge, 2009, p. 386).

**Previous Researches**

Huge body of financial studies has focused on the random walk and efficient market hypothesis. More specifically, in the random walk and market efficiency in the weak form, some of the newly done researches are as follow:

In the study that compared random walk among some European countries, Borges (2008) has found mix finding based on different kind of tests among countries. In all, Borges research showed that France, Germany and Spain stock prices followed random walk. In a comprehensive work by Worthington and Higgs in which they test random walk in sixteen European countries such as Sweden, Norway and Finland, they rejected random walk hypothesis in many of the countries (Worthington & Higgs, 2004). Gilmore and McManus (2003) tested random walk in some eastern European stock markets and found random walk movement in Hungry, Czech
Republic and Poland’s stock markets. Smith and Ryoo checked the random walk in Greece, hungry, Poland, Portugal and turkey and rejected random walk in four of the markets (Smith & Ryoo, 2003). In another study, Worthington and Higgs rejected random walk in some of the Latin American countries (Worthington & Higgs, 2003). Besides, Grieb and Reyes studied the random walk in Mexican and Brazilian securities and showed that only Brazil’s market had a tendency toward random walk (Grieb & Reyes, 1999). In the study of random walk in some Asian equity markets, Worthington and Higgs (2006) rejected random walk in all the studied markets by serial correlation test. Finally, Karemera, Ojah, & Cole (1999) tested the random walk in some emerging market and found random walk movement contrary to other tests.

Limitations
This paper uses the OMX Nordic 40 index for the period January 2007 to December 2009. The index is a market capitalization weighted stock index with a daily turnover amounting about 1.2 billion Euros at 21th December 2009. It consists of 40 most-traded classes of stocks from the four stock markets in the Nordic countries. Due to the probable existence of abnormalities within one year, the period of more than one year is chosen. For designing the tests, author assume rationality and risk neutrality and does not take in to account any transaction cost and taxes. Furthermore, study uses only test of correlation to see whether prices follow random processes or not. Finally, author did not try to find which time dimension is more suitable for test and did not try to compare given period to other periods.

Structure of the Thesis
This thesis is divided in to five chapters. The brief explanation of each chapter follows:

Introduction
This chapter mainly reviews the problem, research hypothesis, methodology, previous researches and limitations of the study.

Methodology
In this chapter, author discusses the methods chosen for the study, the process of data collection and processing and the way study was conducted.

Review of the Literature and Conceptual Framework
Following methodology chapter, this chapter discusses the random walk hypothesis, efficient market hypothesis, and their relationship, previous studies in both fields and current state of them.

Result and Analysis
This chapter represents the result of study and discusses findings.

Conclusion
This chapter contains final words about this thesis and shows how the purpose of the research is fulfilled. Besides, author recommends some suggestion for future studies.
Methodology

Introduction
In this chapter, author reviews the characteristics of this research and methods he uses for testing hypothesis.

Author Understanding and Knowledge
When researcher wants to start the research, it is important to know what directs his attention and what he expects to find (Gilje & Grimen, 1992). There is no doubt that market efficiency and random walk theories are one of the most considerable theories in economics and finance. “If, as Paul Samuelson has suggested, financial economics is the crown jewel of the social sciences, then the efficient market hypothesis must account for half the facets” (Lo, 1997, p. xix). Author, as a finance student, was encountered with different cases and questions in random walk and efficient market hypothesis during his studies; as a result, he was curious to know more about these issues. Furthermore, reading more outstanding articles, author expect to find non-random walk movement in prices. Since for random walk and EMH, knowledge and theories have been already developed, researcher proposed hypotheses and test them. Author tries to reduce the risk of not-stated items in the hypothesis and use a method for collecting, processing and testing of data that gives better information.

Research Characteristic

Introduction
Having dissimilar assumptions, individuals see their own surrounding differently and interpret what they received through their own knowledge in a non-equal manner. Even in the case that phenomenon is the same, researchers can draw different conclusions. Therefore, it is important to show what choices author made in the study and on what ground he made them.

Quantitative or Qualitative
In each research, the researcher for fulfilling the research purpose and testing the hypothesis or answering to the research question, might choose qualitative method, quantitative methods or combination of them. In qualitative research, data are not numbers; however, in quantitative research are. In quantitative research, researcher tries to transform information to quantities and investigate quantitative data and their relationships. In other words, researcher in quantitative research uses experimental method and quantitative measures to test hypothesis (Golafshani, 2003, p. 597). Since in this research, author uses historical stock prices and investigates the relationship among their changes, he uses quantitative method.

Hermeneutics and Positivism
There are two main scientific points of view: Hermeneutics and positivistic. In hermeneutics approach, researcher tries to explain and interpret context in a broad meaning (Wallén, 1993). In the case that we encounter with false and wrong questions or we are not aware of mechanism, hermeneutics approach does not work (Eriksson & Wiedersheim-Paul, 2001). In other side, positivistic researcher studies observable phenomena and uses scientific method. Usually positivistic researcher uses quantitative method because she works on measurable evidence. Positivism claims that knowledge is gained by two sources: five senses and what we can arrive at.
our reasons (Eriksson & Wiedersheim-Paul, 2001). In this research, author follows a positivistic research and choose testable method that usually must be proved only by empirical tests and not by argument. Besides, positivistic approach is used in this research because author follows scientific method: started with Hypothesis, examined them empirically and finally drawn conclusion from the result obtained. These conclusions are refutable and verifiable by other researches.

**Deductive or Inductive**
Deductive, inductive and abductive approaches are three main methods used for conducting research (Halvorsen, 1992). When researcher uses a theory and gets the problem from theory in order to test hypothesis, she uses deductive approach. In this research, author gathers data and analyzes them using statistical method in order to accept or reject hypothesis (Muller, 2005). The interpretations are objective and researcher uses a positivistic approach for testing hypothesis. This research follows deductive approach; author gathers data and uses statistical methods for testing hypothesis. Besides, author does not aim at understanding new phenomenon and does not gather data through interview and observation to develop a theory. Since abductive research is a combination of deductive and inductive research and author focused only on the deductive approach, he does not use abductive method.

**Reliability**
Joppe (2000) defined reliability as “the extent to which results are consistent over time and an accurate representation of the total population under study is referred to as reliability and if the results of a study can be reproduced under a similar methodology, then the research instrument is considered to be reliable” (2000, p. 1). In other words, reliability is the matter of consistency. This consistency has two main aspects: consistency over time and internal consistency. Consistency over time refers to the stability of measurement over time and internal consistency refers to consistency among items. (Punch, 1998, p. 99)

In this thesis, data are collected from their original and are publicly available for everyone to reproduce the test in the future. Author’s chosen methodology is considered to be reliable because the methodology is presented clearly and everyone in future research can reuse it. Therefore, if someone else wants to repeat this study during the same period, she or he has access to the same data and can use the same methodology, reaching to the same results as author’s. Finally, other sources used in this thesis are reliable too. Theorists are well known and the articles and books are leader in their fields and were published in high rank academic journals.

**Validity**
“Validity determines whether the research truly measures what it was intended to measure or how truthful the research results are” (Joppe, 2000). In other words, “validity refers to the degree to which evidence and theory support the interpretations of test scores entailed by proposed uses of tests” (AERA, 1999). Validity is important in each research because it concerns the meaning placed on test results (Messick, 1995). “Insofar, as the definitions of reliability and validity in quantitative research reveal two strands: First, concerning reliability, the results are replicable. Second, with regards to validity, the means of measurement are accurate and they are actually measuring what they are intended to measure” (Golafshani, 2003, p. 599)
In order to test the hypothesis, author has chosen the AR model that will be represented in details later. This model was mathematically proven and has used by many scholars and researchers which will be represented in the background section. Therefore, this model is highly valid and accurate and actually measures what is intended to measure.

In this research, data are stock prices that are accurate measure of the stock values because many researchers and professionals use them to value shares and there is not any other reliable approach to value shares. Moreover, OMX index is used as a representative of a market that is highly accurate and reliable. Many scholars and professionals use indexes and especially OMX index in Nordic’s context to report the whole market and majority of capital market researchers have used this index for their studies in Nordic countries. Furthermore, the chosen methodology is valid, and tests accurately what intends to measure because it was mathematically proven, and many scholars consider it as a method for testing the thesis hypothesis.

**Period of Research, Data Selection, Collection and Processing**

Author has chosen the period January 2007 to November 2009 for doing this research. Many researchers have already tested random walk in Nordic countries stock exchanges. Newer period is chosen by author to add more scientific meaning to this research.

Data used in this thesis are secondary data. Secondary data are data that are gathered from other data sources and databases. The secondary data chosen for this study is OMX Nordic 40. This “index consists of the 40 largest and most actively traded stocks on the Nordic exchanges. The OMXN40 is a market-weighted price index. The base date for OMXN40 index is December 28, 2001, with a base value of 1000” (OMX Nordic Exchange). The composition of the OMXN40 index is revised twice a year. Author uses the price index data from Nasdaqomx Nordic website that are available in xls format and tests the random walk behavior in three time dimensions: Daily, weekly and monthly. This approach is common in these kinds of researches; however, he did not try to find which time dimension is more suitable for random walk test.

**Statistical Tests**

**AR (1) and AR (2)**

“A strict from of the efficient market hypothesis states that information observable to the market prior to week t should not help to predict the return during week t. If we use only past information on y, the EMH is stated as \(E(y_t | y_{t-1}, y_{t-2}, y_{t-3}, \ldots) = E(y_t)\)” (Wooldridge, 2009, p. 385). In this equation \(y_t\) are returns which can be calculated with using following formula:

\[
return_t = \log \frac{price_t}{price_{t-1}}
\]

One way for testing this equation is using autoregressive process of order one known as AR (1). Consider this AR (1) model,

\[
y_t = \beta_0 + \beta_1 y_{t-1} + u_t
\]
Where we have:
\[
E(u_t | y_{t-1}, y_{t-2}, y_{t-3}, \ldots) = 0
\]

If we combine these two equations, then we have,
\[
E(y_t | y_{t-1}, y_{t-2}, y_{t-3}, \ldots) = E(y_t | y_{t-1}) = \beta_0 + \beta_1 y_{t-1}
\]

This last equation has two important results. First, when we control \(y\) lagged one period, no other lags of \(y\) affect the expected value of \(y_t\). Actually, name of first order is originated in this idea. Second, we assume that the relationship is linear (Wooldridge, 2009, p. 384).

The null hypothesis is stated as \(H_0 : \beta_1 = 0\). Now, for testing \(H_1 : \beta_1 = 0\) against \(H_0 : \beta_1 \neq 0\), we use OLS’s t statistic.

In order to see whether there is a relationship among returns in time \(t\), \(t-1\) and \(t-2\), new model is presented. It is probable that AR (1) cannot find correlation among returns which are more than one period apart. For solving this problem, we must estimate model with more than one lag. One of the models of this estimation is autoregressive model of order two or AR (2) as follows:
\[
y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + u_t
\]

Where
\[
E(u_t | y_{t-1}, y_{t-2}, y_{t-3}, \ldots) = 0
\]

In term of parameters of our model, the null hypothesis states that efficient market hypothesis hold:
\[
H_0 : \beta_1 = 0, \beta_2 = 0
\]

Now we should create an alternative to \(H_0\):
\[
H_1 : H_0 \text{ is not true}
\]

For testing the \(H_0\) hypothesis, we cannot use t statistics because t statistics tests hypothesis that do not have restrictions on the other parameters. “If we add the homoskedasticity assumption \(Var(u_t | y_{t-1}, y_{t-2}) = \sigma^2\), we can calculate F statistics to test” the hypothesis (Wooldridge, 2009, p. 386). Formula for F statistics is:
\[
\frac{(SSR_r - SSR_{ur})/q}{SSR_{ur}/(n - k - 1)}
\]

Where \(SSR_{ur}\) is the sum of squared residuals from the unrestricted model and \(SSR_r\) is the sum of squared residuals from the restricted model.

**Testing for Heteroskedasticity**

Heteroskedasticity assumption indicates that, given the explanatory variables, the variance of the error term is constant. “Heteroskedasticity does not cause bias or inconsistency in OLS estimators” (Wooldridge, 2009, p. 265) but t statistics will not have t distribution. For checking whether heteroskedasticity assumption holds, author uses Breusch-Pagan test for heteroskedasticity. Consider the equation that is used in Breusch-Pagan test:
\[ \hat{u}_t^2 = \delta_0 + \delta_1 y_{t-1} + u_t \]

In this equation \( \hat{u}_t = y_t - \hat{y}_t \), where the null hypothesis is \( H_0 : \delta_1 = 0 \). Now, we use t statistics on return \( y_{t-1} \) to check whether there is heteroskedasticity or not. If heteroskedasticity exists, the variance of stock return would depend on the past returns. In this case, author will use heteroskedasticity-robust test statistics to solve the problem (Wooldridge, 2009, p. 433).

**Testing for Robust**

As we know, one of the main assumptions of OLS statistics is heteroskedasticity. Now, we should see what happens if this assumption does not hold. “It is important to remember that heteroskedasticity does not cause bias or inconsistency in the OLS estimators of the \( \beta_j \)” and “the interpretation of our goodness-of-fit measures is also unaffected by the presence of heteroskedasticity” (Wooldridge, 2009, p. 264), but OLS inference might be “faulty in the presence of heteroskedasticity” (p. 265). For solving this problem, heteroskedasticity-robust standard error for all \( \hat{\beta}_i \) must be calculated with following formula:

\[
\sqrt{\frac{\sum_{i=1}^{n} \hat{\epsilon}_{ij}^2 \hat{u}_i}{SSR_j}}
\]

“Where \( \hat{\epsilon}_{ij}^2 \) denotes the \( i^{th} \) residual from regressing \( x_j \) on all other independent variables, and \( SSR_j \) is the sum of squared residuals from this regression” (Wooldridge, 2009, p. 267).

**ARCH in Stock Returns**

Recently, economists are interested in dynamic forms of heteroskedasticity. Consider following simple static regression model with the assumption that Gauss-Markov assumptions holds:

\[ y_t = \beta_0 + \beta_1 z_t + u_t \]

We know from heteroskedasticity assumption that when \( Z \) is all n outcome of \( z_t \), \( \text{Var}(u_t | Z) \) is constant. However, heteroskedasticity might arise when the variance of \( u_t \) given \( Z \) is constant. For checking this problem, we can use autoregressive conditional heteroskedasticity (ARCH) model. The first order ARCH model is as follow:

\[
E(u_t^2 | u_{t-1}, u_{t-2}, \ldots) = E(u_t^2 | u_{t-1}) = \alpha_0 + \alpha_1 u_{t-1}^2
\]

Or in other words:

\[ u_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + v_t, \]

In this equation, the expected value of \( v_t \) given \( u_{t-1}, u_{t-2}, \ldots \) is zero. If above-mentioned equation is hold, it implies that “a larger error in the previous time period was associated with a larger error variance in the current period” (Wooldridge, 2009, p. 434).
Review of the Literature and Conceptual Framework

Introduction
In this, author briefly reviews the concepts of random walk and efficient market, the ways of testing them in financial market and their relationship. Then, author reviews behavioral finance, market anomalies and recent financial crisis.

Introduction to Random Walk and Efficient Market Hypotheses
A random walk is defined as a process in which the current value of a variable is composed of the past value plus an error term. A random walk model is as follows:

\[ y_t = y_{t-1} + e_t, \quad t = 1,2, \ldots \]

In financial theory, random walk hypothesis demonstrates that stock prices move randomly. In other words, changes in stock prices are independent from each other and more mathematically, there is no correlation among changes in stock prices in time t with changes in stock prices in time t+1. There are several methods to test random walk in financial market. For example, Correlation test, Runs test, Unit Root test and Variance Ratio test.

If we suppose investors, who participate in market to increase their own wealth, use all available information in the market, the prices will reflect all available information and eliminate profit arising from information-based trading. When market prices fully reflect all available information, market is informationally efficient. If market is efficient, then only newly arrived information creates volatility, it would be impossible to earn excess return for a long period, there is not any undervalued security, there would be impossible to forecast future prices in a long time and there will not be any rational winners and losers. Therefore, in this market, it would be impossible to outperform because all the participants know all the information. In the modern economic theory, economists assume that all the agents want to maximize their utility. Efficient Market Hypothesis has another assumption under the name of rational expectations, which asserts that investors’ reactions in average are updated appropriately in a normal distribution pattern. There is a fallacy that thinks rational expectation means agents are rational; however, updating expectation in a normal pattern does not necessarily mean agents are rational. The only consequence of rational expectation is that in markets that follow rational expectation pattern, nobody can earn abnormal profit. Besides, Leroy posited that “the martingale property will be satisfied only as an approximation and that no rigorous theoretical justification for it is available” (LeRoy S. F., 1973, p. 445) or Lucas claimed that “the outcomes of the tests as to whether actual price series have the martingale property do not in themselves shed light on the generally posed issue of market efficiency” (Lucas, 1978, p. 1441). Finally, Lo and Mackinlay explained that “Random walk Hypothesis is neither an necessary nor a sufficient condition for rationally determined security prices” (Lo & Mackinlay, 2002, p. 5). Therefore, it is possible to predict prices in efficient market and unpredictable prices in the market do not necessarily mean that market is efficient.

The main origin of Efficient Market Hypothesis came back to Paul Samuelson (Samuelson, 1965). In his article, he asserted that when the level of efficiency in a market increases,
randomness of price changes will increase and that when the price changes are completely random and unpredictable the profit must have been gained before. Market participants want to utilize their own information to increase their welfare in a market. When this happens, regularly no profit can be gained by participants because of the three p: prices, probabilities, and preferences; these three P have origin in supply and demand principles in economics (Lo A. W., 2004).

EMH has a controversy inside itself. In one side, theory claims that there is not any possibility to make excess return in a long term and in other side, it posits that all the market participants must continuously work to outperform in the market. However, EMH’s supporters argue that if market is efficient, nobody seeks excess return in the market; therefore, market after a while will be inefficient and when the market is inefficient, investors tempt to seek more return and then market will be efficient (Damodaran, 2002). In order to increase our understanding of the market, Brealey and Myers (2003) proposed six lessons from EMH: 1. Markets have no memory. 2. We should trust in market prices. 3. By studying market prices, we know many things about companies’ future such as theirs probability of bankruptcy. 4. There are no financial illusions. 5. If investors can do something by themselves, they do not pay someone else for doing that. 6. “Investors don’t buy a stock for its unique qualities” (p. 369).

**History of Random Walk and Efficient Market Hypothesis**

The idea of random walk was introduced in sixteenth century by Italian Mathematician, Girolamo Cardano in his book “The book of chance” in which he mentioned that equal condition is the fundamental principle of all gambles. If inequality exists in favor of you, you are unjust and if it is in favor of your opponent, you are fool. Many other scientists, especially mathematicians have contributed to this concept in later years. For the first application in stock markets, in 1863, a French stockbroker, Jules Regnault claimed that there is a direct relationship between the price deviation and the square root of time. Later, in 1889, Gibson introduced the concept of efficient market in his book ‘The Stock Markets of London, Paris and New York’ (Sewell, 2008).

Mathematical finance emerged with Bachelier in 1900. In his doctoral thesis, he mentioned:”The influences that determine fluctuations on the exchange are innumerable; past, present, and even discounted future events are reflected in market prices, but often show no apparent relation to price changes…. The determination of these fluctuations depends on infinite numbers of factors; therefore, it is impossible to aspire to mathematical prediction of prices” (Bachelier L., 1900, p. 17). In all, the main message of his work was that the expected profit for the speculator is zero.

Karl Pearson introduced random walk concept in 1905. In the year 1905, Albert Einstein unaware of Bachelier’s result, extended the equations for Brownian motion. Some years later, Keynes in 1923 mentioned that investors are rewarded based on their risk baring and not for knowing the future better and he concluded that this is a consequence of EMH. In 1925, Frederick McCauley found a similarity between the fluctuation of stock market and throwing a dice and Cowles, in 1933, after analyzing the performance of forecasters, pointed out that prices could not be forecast. Working, in 1934, found the same result and assert that the behavior of
stock returns look like numbers from lottery. In his book ‘The general theory of employment, interest and money’, John Maynard Keynes claimed that investors make decision in stock market based on ‘animal spirit’. Once again, in 1944, Cowles came to conclusion that forecasters did not beat the stock market and Working, in 1958 showed that forecasters could not predict price changes in an ideal future market. Working on 22 time series, Kendall (1953) has found that stock prices at weekly intervals were random. In 1962, Paul H. Cootner, perhaps for the first time, found that stock market prices did not follow random walk and Arnold B. Moore found a slight positive serial correlation for the index. Later, Granger and Morgenstern claimed that market prices followed the simple random walk in the short lag but did not obey the simple random walk in a long range (Sewell, 2008). These researches followed by Steiger (1954) paper in which he claimed that stock prices did not follow a random walk. Before 1965, many empirical works validated the random walk (Walter, 2003, p. 11). Later, interplays between academics and practitioners started around the predictability versus random walk and this clash is still not completely reduced. For example, Williams in his guidebook ‘the theory of investment value’ mentioned that for individual was possible to outperform when she had the superior information. In 1960’s, the first midterm solution brought by some studies. For example, Fama claimed “now in fact, we can probably never hope to find a time series that is characterized by perfect independence. Thus, strictly speaking, the random walk theory cannot be a completely accurate description of reality. For practical purposes, however, we may be willing to accept the independence assumption of the model as long as the dependence in the series of successive price changes is not above some “minimum acceptable” level. The independence assumption is an adequate description of reality as long as the actual degree of dependence in the series of price changes is not sufficient to allow the past history of the series to be used to predict the future in a way which makes expected profits greater than they would be under a naïve buy-and-hold model. The issue of predictability seemed closed, leaving behind two more or less opposing and irreconcilable concepts” (Fama E., 1965, p. 35). Besides, Firstly applying the random walk hypothesis, Samuelson (1965) provided economic argument for efficient market. Efficient market framework was built with underlying probabilistic assumptions. With these assumptions efficient marker hypothesis lost its general nature. For example, if we assume short period of compensation, efficiency will be rejected. Besides, the efficiency is limited by the specific restraining characteristics of probability laws (Walter, 2003, p. 27). Later, Harry Roberts (1967) divided the EMH’s tests to weak and strong form tests. Fama and his group continued doing research with event study and came to the conclusion that the stock market was efficient (Fama & al., 1969). In 1970, Fama (1970) defined the efficient market as a market in which available information is fully reflected in prices. Random walk testing continued with Kemp and Reid (1971) paper in which they claimed that stock prices were conspicuously nonrandom. Besides, in EMH tests, Beja (1977) found that real market was impossibly efficient; Sanford J. Grossman and Joseph E. Stiglitz (1980) showed that perfect informationally efficient market was impossible; LeRoy and Porter (1981) rejected market efficiency; Werner F. M. De Bondt and Richard Thaler (1986), in the first behavioral finance paper, found that stock prices overreact and that market is not efficient in a weak form.

In an outstanding article in random walk, Lo and MacKinlay (1988), using variance-ratio test for a weekly data, strongly rejected the random walk hypothesis. In an international context, Eun and Shim (1989) found that stock markets were not informationally efficient. Later, Fama concludes that, “market efficiency survives the challenge from the literature on long-term return
anomalies” (Fama E., 1998, p. 283) but later Shleifer in 2000, challenged the assumption of investor rationality and perfect arbitrage in EMH (Sewell, 2008).

Finally, Pesaran claims that “it is often argued that if stock markets are efficient then it should not be possible to predict stock returns, namely that none of the variables in the stock market regression (1) should be statistically significant. Some writers have even gone so far as to equate stock market efficiency with the non-predictability property. But this line of argument is not satisfactory and does not help in furthering our understanding of how markets operate…. In fact, it is easily seen that stock market returns will be non-predictable only if market efficiency is combined with risk neutrality (Pesaran, 2003, p. 4)”.

**Statistical Tests of Random Walk**

**Correlation test**

In this method, researcher analyses the correlation of share price changes in one period with their previous period. Perhaps, researcher can choose any period but usually economists prefer daily, weekly and monthly periods. Random walk theory states that this correlation is equal to zero meaning that the expected profit for speculator is zero. Since author uses correlation test in this research, this method will be explained in detail in chapter three.

**Runs Test**

Another statistical method for testing random walk hypothesis is run test. For example in the daily data, runs are the number of days in which prices move in the same direction. In other words, researcher considers number of runs in the price changes with the same sign. For Runs test, two methods can be used. In the first approach, two kinds of returns are defined: positive and negative. Positive returns are returns equal or greater than zero and negative returns are returns less than zero. In the second approach, researcher considers each return with the respect of mean and defines positive and negative returns. This approach is nonparametric; consequently, it does not assume normality. An important assumption in Runs test is that the real number of runs (R) must be close to the expected number of runs. Suppose that n_+ and n_- be the numbers of positive and negative returns when n= n_+ + n_- . For the large sample we have,

\[ Z = \frac{R - \mu_R}{\sigma_R} \approx N (0,1) \]

Which means that Z is a normally distributed variable and in this case \( \mu_R = \frac{2n_+ n_-}{n} + 1 \) and

\[ \sigma_R = \sqrt{\frac{2n_+ n_- (2n_+ n_- - n)}{(n-1)n^2}} \]

**Unit Root Tests**

In times series in which autoregressive parameter is one, we have unit root. By estimating the following equation through OLS, we will have Augmented Dickey-Fuller (ADF) unit root test. In this test, we will look for a unit root in the price changes series.

\[ \Delta P_t = \alpha_0 + \alpha_1 t + \rho_0 P_{t-1} + \sum_{i=1}^{q} \rho_i \Delta P_{t-i} + \epsilon_{it} \]
In this equation, \( P_t \) is the price at time \( t \), and \( \Delta P_t = P_t - P_{t-1} \) are estimated coefficients, \( q \) is the number of lagged terms, \( t \) is the trend term, \( \alpha_i \) is the coefficient to be estimated for the trend, \( \alpha_0 \) is the constant, and \( \varepsilon \) is white noise. The null hypothesis of a random walk is

\[
H_0 : \rho_0 = 0
\]

Then, Mackinnon (1994) approach is used to determine the significance of the \( t \)-statistic associated with \( \rho_0 \) (Borges M., 2008, p. 6).

**Variance Ratio Tests**

Suppose \( X_t \) is a stochastic process satisfying the following relation:

\[
X_t = \mu + \varepsilon_t , \quad E(\varepsilon_t) = 0 , \quad \text{for all } t
\]

In this equation, \( \mu \) is a drift with arbitrary parameter. In random walk hypothesis, \( \varepsilon_t \) are serially uncorrelated. Variance ratio test can be developed by two cases: First hypothesis in which Gaussian increments are identically and independently distributed; second, in more general case. In identically and independently distributed Gaussian increments, we have \( H_1 : \varepsilon_t \) IDD \( N \left( 0, \sigma^2 \right) \). Assume that we have \( nq+1 \) observations \( X_0 , X_1 , X_2 ,..., X_nq \) of \( X_t \), where \( q \) are arbitrary integer greater than one. Then the null hypothesis can be defined. Variance ratio test yields reliable inference in both null hypothesis and is more powerful than previously mentioned tests. However, we must be watchful when \( q \) is large relative to the sample size. In other words, test result depends on alternatives and there are cases that other tests have more properties (Lo & Mackinlay, 2002).

**Levels of Market Efficiency’s Tests and Their Degrees**

Roberts (1959, p. 8) gave a statistical suggestion in his paper to analyze price changes and price levels. Based on his work, Fama (1970) in his outstanding paper explained that “the empirical work itself can be divided into three categories depending on the nature of the information subset of interest. Strong-form tests are concerned with whether individual investors or groups have monopolistic access to any information relevant for price formation.[...]” In the less restrictive semi-strong form tests the information subset of interest includes all obviously publicly available information, while in the weak form tests the information subset is just historical price or return sequences” (p. 414). Later, LeRoy (1976) made a comment about Fama’s work and corrected some of his mistakes. In the beginning of his article, he mentioned that “Fama’s discussion of the theory of efficient capital markets, [...] contains several important passages that are, at best, very misleading (p. 139). [...]” “The problems noted in this comment are not minor, particularly for the students who seek an understanding of the theory underlying the empirical studies of capital market efficiency. However, corrections are easily made, and subject to these corrections, Fama’s summary article is valuable addition to the literature” (p. 141).

In the weak-form, today’s stock prices reflect all the past’s information. In other words, stock prices follow random walk and technical analysis cannot be used for earning excess return. In semi-strong form, both public information and future expectations are reflected in a stock’s current price. Therefore, neither technical nor fundamental analysis can find any pattern in the stock behavior. In order to make excess profit, market participants must have private information because all publicly available information is reflected in today’s prices.
In strong-form market efficiency, all information in a market, both public and private, are reflected in today’s stock prices. Therefore, in this form of efficiency, nobody can earn profit above normal. Fama put three conditions in which market can obtain strong-form market efficiency: (1) no transactions costs, (2) costless access to relevant information (3) similar way of valuing the stocks by all investors (1991). These condition are impossible to meet; therefore, strong-form market efficiency is a theoretical concept that cannot exist in the reality.

Many studies have been done to test market efficiency. The way that someone can categorize them would be enormous. For example, Lo (1997) categorized them in the following sections: random walk test, variance ratio tests, overreaction and under reaction, the winner-loser effect, price earnings ratios, the small firm effect, price book value ratios, the three-factor model, the January effect, the weekend effect, the earnings announcement drift, standardized unexpected earnings, the momentum effect, mean-reversion, calendar effects, the size effect and the value effect.

Keane (1983) divided each of Fama’s three levels of efficiency tests in three different degrees: inefficiency, near efficiency, perfect efficiency. For example in semi-strong form, perfect efficiency degree means prices are valued in a manner that even the most experts cannot outperform in this degree. In a near efficiency, only experts can outperform but all other investors do not. Finally, in an inefficiency level, non-experts can identify undervalued stock and they can earn excess return in a market.

Financial Market Anomalies
Kuhn (1970) proposed that a shift in the scientific paradigm might happen when anomalies appear. Market efficiency like any other scientific paradigm is not something completely true and unchangeable; as a result, it is predictable that many anomalies in financial market appear. Financial market anomalies are cross-sectional and time series patterns in security returns that are not predicted by a central paradigm or theory (Keim D. B., 2008, p. 1). In other words, market anomaly refers to price or return distortion from efficiency. Many believe that if EHM is true, there must not be any deviation from it in financial market; therefore, they contradict market anomalies with EMH. Fama & French believed that anomalies are pattern in a market not having any explanation by capital asset pricing model (Fama & French, 1996). Finding anomalies helps economists to recognize alternative sources of risk; however, “researchers must recognize that the existence of this anomalous evidence does not constitute proof that existing paradigms are wrong” (Keim D. B., 2008, p. 9). There are many anomalies in the financial market and number of them is growing. Keim classifies them based on their nature as being cross-sectional or time series (Keim D. B., 2008, p. 1).

Cross-Sectional Return Patterns
“Given certain simplifying assumptions, the CAPM states that the return on a security is linearly related to the security’s non-diversifiable risk (or beta) measured relative to the market portfolio of all marketable securities” (Keim D. B., 2008, p. 1). Risk usually defines as a standard deviation of returns (Womack & Zhang, 2003, p. 2). Risk of shares consists of two main parts: systematic risk and unsystematic. Systematic risk is a market risk that cannot be diversified. Unsystematic risk is related to specific stock; therefore, it can be diversified away. The Beta (β) of a stock or portfolio is a ratio which shows the relationship of their returns with that of the...
whole financial market (Levinson, 2006, p. 147). Positive beta means that stocks follow the market in price changes and zero beta means that stock prices are not correlated to the market. With this short background, some examples of the cross-sectional return pattern are as follows:

“The value effect refers to the positive relation between security returns and the ratio of accounting based measures of cash flow or value to the market price of the security” (Keim D. B., 2008, p. 2). For example, stocks with low P/BV ratio can earn higher return than stocks with high P/BV ratio. Fama and French (1996) have found negative relationship between P/BV ratio and stock return in the period 1963-1990. One explanation of these results is that stocks with low P/BV ratios are riskier because there is higher probability for them to going out of the business.

“The size effect refers to the negative relation between security returns and the market value of the common equity of a firm” (Keim D. B., 2008, p. 3). For example, there are some evidences that smaller firms earn higher return than bigger firms do with the same betas. In one explanation, Dimson (1988) tried to relate price earnings ratio anomalies to transaction cost. However, Damodaran (2002) believes that differences in transaction cost cannot explain small firm effect anomaly across time. In another explanation, theorists such as Damodaran (2002) relates this anomaly to capital asset pricing model’s problem in defining risk. Beta as an index for risk measurements may work malfunctioning; therefore, it underestimates the correct risk of small firms.

“Prior stock returns have been shown to have explanatory power in the cross section of common stock returns. Stocks with prices on an upward (downward) trajectory over a prior period of 3 to 12 months have a higher than expected probability of continuing on that upward (downward) trajectory over the subsequent 3 to 12 months. This temporal pattern in prices is referred to momentum” (Keim D. B., 2008, p. 5). For example, Jegadeesh and Titman (1993) (2001) investigated the portfolio of stocks and have found that those stocks that performed bad in one period had a tendency to perform well but poorly in the next 3-12 months. This finding is inconsistent with the efficient market hypothesis because this shows some level of non-random walks in stock market.

**Time Series Return Predictability**

While some models consider expected stock returns as a constant variable through time, many studies show the opposite. Following section represent some of the important findings in this area.

Studies that focuses on predicting returns with the help of past returns, show “that autocorrelations of higher-frequency (daily, weekly) individual stock returns are negative and that the autocorrelations are inversely related to the market capitalization of the stock” (Keim D. B., 2008, p. 6). For example, Niederhoffer and Osborne in 1966 found that there was a negative serial correlation in returns (Neiderhofer & Osborne., 1966, p. 897) or Jegadeesh and Titman documented trading strategies based on past price momentum over 3 to 12 months holding period (Jegadeesh & Titman, 1993, p. 65). Some researchers have found that there were winner and loser portfolios. In other words, we can have portfolios that outperform or that gain less than a market. These studies came to the hypothesis called overreaction hypothesis, which is related to market participants tending to overreact to short-term information in a market. For example De Bondt & Thaler’s finding shows that “portfolios of prior losers are found to outperform prior
winners” (De Bondt & Thaler, 1985, p. 804). However, there are some hints that should be considered in winner and loser effects finding. First, indicating January effect, many successful returns usually happened in the month of January. Second, showing asymmetric price correction, loser portfolio wins three times the amount that winner portfolios lose. Third, we should be aware of interpreting winner or loser portfolios since the winner-loser effect might be an example of the size anomaly (De Bondt & Thaler, 1987).

For having precise information about expected returns, some researchers use predetermined explanatory variables such as expected inflation, the dividend-to-price ratio, the earnings-to-price ratio, the book-to-price ratio, and the level of consumption relative to income (Keim D. B., 2008, p. 6). For example, there are some evidences that stocks with low (P/E) ratio are undervalued in some cases; therefore, market participants can earn excess return. These stocks usually have low growth rate and low risk, but they might have larger tax burden because they create more dividends. This is why stock buyers do not prefer to buy these stocks and consequently these stocks are undervalued. Gyllenhof and Johansson (1987) and Ohrn and Nilsson (1995) studied price earnings ratio anomalies in Sweden market. For the period 1977-1986, Gyllenhof and Johansson have found that this anomaly did not exist. In other side, Ohrn and Nilsson observed this anomaly in the period 1984-1993. Latane et al. proposed that, using unexpected earning forecast, investors could earn abnormal return in a market (Latané, Jones, & Rieke, 1974). In other side, Reinganum (1981) has found that unexpected earnings forecasts could not be used to obtain abnormal returns. Nowadays, there are many companies that produce more accurate data; consequently, investors rarely overestimate earnings.

Some researches studied patterns in daily return around weekend. Findings show that stocks create larger return on Fridays compared to Monday’s. However, because of risk matters, and due to longer period up to Monday, stocks should earn more return. For example, French (1980)'s study in United States confirms that Mondays have more negative returns than other days in the week. A day of the week effect is still present in many European countries (Rosa María Apolinario, Santana, Sales, & Caro, 2006, p. 61).

Some researchers showed that there are differences in returns during a year especially in the end of year. Market participants can buy stocks in January with lower prices and sell those stocks in next month with higher prices. Keim (1983) for the first time observed the January effect in the market in 1980. One explanation of this effect is tax loss hypothesis. Individual investors, who are tax sensitive, tend to sell stock at the end of the year to claim a capital loss. Another explanation for the January effect is institutional behavior in the year-end. There are some evidences that institutions’ number of buying decrease and their number of selling increase in the end of the year, pushing down the prices and later pushing up them (Damodaran, 2002).

**Behavioral Finance**

As Kuhn (1970) mentioned “new and unsuspected phenomena are repeatedly uncovered by scientific research, and radical new theories have again and again been invented by scientists” (Kuhn, 1970, p. 52). “Modern financial economic theory is based on the assumptions that the representative agent in the economy is rational in two ways: she makes decisions according to the axioms of expected utility theory and makes unbiased forecasts about the future” (Thaler,
1999, p. 12). The behavior in the real world does not necessarily follow these assumptions in some areas such as volume, volatility, dividends and predictability.

Earlier economists believed that future returns could not be predicted based on historical information. However, “now, everyone agrees that stock prices are at least partly predictable“ (Thaler, 1999, p. 14). Therefore, there are cases that financial economics’ assumptions do not work. Thaler suggest that “we can enrich our understanding of financial markets by adding a human element” (Thaler, 1999, p. 15). Many researchers have focused on preferences and behavior of market participants. Psychologists and some economists have found a number of departures from the preferences models’ paradigm. For example, in overconfidence issue, which believes that that overconfident investors trade excessively, Barber and Odean found that “men trade more than women and thereby reduce their returns more so than do women. Furthermore, these differences are most pronounced between single men and single women” (Barber & Odean, 2001, p. 289). Besides, Gervais and Odean claimed that “the expected future profits of a more successful trader may actually be lower than those of a less successful trader. Successful traders do tend to be good, but not as good as they think they are” (Geravais & Odean, 2001, p. 31). Overreaction suggests that “most people tend to overreact to unexpected and dramatic news events” (DeBondt & Thaler, 1986, p. 793). DeBondt and Thaler mentioned that “portfolios of prior losers outperform prior winners (Debondt & Thaler, 1986, p. 804). Furthermore, prospect theory, as an alternative to expected utility theory (Kahneman & Tversky, 1979, p. 263) was introduced by Kahneman and Tversky. Expected utility theory claims that individuals make decision based on expected theory that is taking to account sizes of payouts and their probabilities. Betting preferences in uncertain situations is described with mathematical model, which takes into account size of payouts, probability, risk and utility. In economics, Neumann and Morgenstern discuss expected utility hypothesis and mentioned some proofs for it in their article (PJH, 1982). Up to 70’s Neumann and Morgenstern model was a main economic theory for assessing individual behavior under risk. In 1979 two psychologists Kahneman and Tversky introduced new descriptive model under the name of prospect theory. They believed that decision-making process consists of two stages: Heuristic and utility. In heuristic stage, individuals use rules of thumb in assigning probabilities. In the utility stage, these individuals will choose alternatives that have a higher utility. For example, De Bondt and Thaler (1985) have found some reactions to unexpected and dramatic news. Their article is considered as one of the starters of behavioral finance. Besides, Shiller (Sandmann, 1992) has found some abnormal unexplained stock prices volatility in stock markets. In all, it can be concluded that for understanding price volatility in stock market, social psychology plays an important role because there are several cognitive biases such as mental accounting, informational cascades, herd behavior, representativeness, conservatism principle, disposition effect, overconfidence and forecasting errors.

Later, in loss aversion in which individuals strongly prefer to avoid loss in order to acquire gain, Shefrin and Statma, Odean made contribution or Odean tested “the disposition effect, the tendency of investors to hold losing investments too long and sell winning investments too soon “ (Odean, 1998, p. 1775 ). In herding or following the trend, Huberman and T. Regev analyzed non-event that made Stock Prices Soar. In their article, they concluded that “enthusiastic public attention induced a permanent rise in share prices, even though no genuinely new information had been presented “ (2001, p. 387). In psychological accounting, Tversky and Kahneman,
explained decision problems in the case that people systematically violate the requirements of consistency and coherence, and traced these violations to the psychological principles (Tversky & Kahneman, 1981, p. 453). In hyperbolic discounting, Laibson (1997) “analyzed the decisions of a hyperbolic consumer who has access to an imperfect commitment technology” (p. 443). In decision regret model, Bell (1982) identified two components of risk version: Decreasing marginal value and regret aversion. Some financial economists have tried answering these critiques by arguing that their impact and prevalence are limited because many forces adjust those opportunities. Whether forces are powerful enough or not is an issue that should be answered in a future.

Rational behavior is considered as a fundamental assumption in efficient market hypothesis. However, we know from many behavioral finance studies that this claim is not always true. Therefore, behavioral finance can help us to understand what is not considered in the model. Ritter (2003, p. 429) considered cognitive psychology (how people think) and the limits to arbitrage (when markets will be inefficient) as building blocks of behavioral finance. These realities are not precisely considered in the earlier financial economics researches. Bodie (2005) considered behavioral finance in early stage and claimed that it “is probably still too early to pass judgment on the behavioral approach, specifically, which behavior models will stick and become part of the standard toolkit of financial analysts” (p. 401). Finally, Thaler (1999) predicted that behavioral finance will be viewed as a redundant phrase because economists will routinely incorporate as much “behavior” into their models as they observe in the real world; after all, to do otherwise would be irrational” (p. 16).

For explanations of the EMH and its behavioral critics, we can focus on the differences between economics and psychology. In Psychology, many studies are based on experiment but in economics field, experiment is not common. In psychology, new theories come from empirical analysis; however, in economics, it is vice versa. What is more, in psychology, we do have many behavioral theories, but we do not have many in economics. Finally, there is more mutual consistency between theories in economics than in psychology. Samuelson (1947) in his PhD thesis developed a mathematical framework for economic analysis and many of economic and finance researchers follow his foundation thereafter. They usually start from a single or multiple postulates and then develop the research around them. Lo (2004) believes that this cultural bias in economics is the underlying reason behind the controversy of EMH and behavioral critics. Finally, it is interesting to know that Samuelson was aware of limitations of deductive approach and he mentioned these limitations in his foundation. Finally, “it is a striking fact that the world’s first professor of economics in a way founded modern biology. Both Darwin and Wallace, the two co-inventors of the evolutionary hypothesis specifically acknowledged their debt to Malthus. In spite of this close connection at the beginnings of modern biology, however, the two disciplines had very little contact with each other until about 1960 and in fact still have far less contact than” (Tullock, 1979, p. 1) economists think is desirable.
Current State of Efficient Market Hypothesis
As we saw earlier, many anomalies emerged against market efficiency; besides, many scientific researches try to use less assumption. Efficiency like other paradigm might shift and new paradigm might emerge. Currently,”efficiency is in a state of turmoil: questions have been raised concerning the validity of the efficiency concept, without any theoretical foundation appearing for the moment to replace it (Walter, 2003, p. 4)”.

The question is that it is possible to rationalize the Samuelson’s proof or not. Actually, Samuelson did not take in to account risk, and put some limitations on expected return. Later, some researchers such as Grossman claimed that “in an economy with complete markets, the price system does not act in such a way that individuals, observing only prices, and acting in self-interest, generate allocations which are efficient” (Grossman, 1976, p. 585). Besides, Grossman and Stiglitz posited that “if competitive equilibrium is defined as a situation in which prices are such that all arbitrage profits are eliminated, is it possible that a competitive economy always be in equilibrium? Clearly not“(Grossman & Stiglitz, 1980, p. 393).

After many researches, up to this moment, economics have not reached a consensus about efficient market hypothesis. There are some important reasons behind this matter. First, efficient market hypothesis is not defined precisely; therefore, it does not have falsifiability characteristic. A researcher who wants to test efficient market hypothesis must take into account additional structures. Therefore, several hypotheses must be tested; consequently, the test will have little contribution. Second, efficiency even in purer sciences is used to show a degree and not the hundred percent situations. Take an example of a piston, engineers always talks about the efficiency degree of piston. This point of view should be applied in to economics. We should talk about the degree of which market is efficient and even in proper words, we should talk about relative efficiency. In other words, talking about comparison of efficiency in different markets is more meaningful than talking about efficiency of one market (Lo A., 2007, p. 13).

Adaptive Market Hypothesis
When a paradigm such as efficient market hypothesis cannot answer to questions and many anomalies argue against it, we might need new paradigm. Andrew W. Lo (Lo, 2004) proposes adaptive market hypothesis as a new perspective to solve the problem of efficient market hypothesis. Involving human interactions, economic systems are more complex than any familiar system such as physical systems. “Because human behavior is heuristic, adaptive, and not completely predictable—at least not nearly to the same extent as physical phenomena—modeling the joint behavior of many individuals is far more challenging than modeling just one individual. Indeed, the behavior of even a single individual can be baffling at times, as we all know” (Lo, 2004, p. 21). From the above-mentioned discussion, we know that pure deductive approach cannot explain many economic systems. One of the possible ways to solve this problem comes from evolutionary psychology. For example, Farmer (2002) “develops an analogy between financial and biological ecologies“ (p. 57). Lo (1999), extends several advances in the modeling of financial markets and argued that “financial agents compete and adapt, but they do not necessarily do so in an optimal fashion. Evolutionary and ecological models of financial markets is truly a new frontier whose exploration has just begun” (p. 9991).
Becker (1976) posited that “the central problem of sociobiology, the natural selection of altruism, can be resolved by considering the interaction between the utility maximizing behavior of altruists and egoists” (p. 826). Hirshleifer (1977) surveyed “some of the main parallels and divergences in economic and sociobiological reasoning” (1977, p. 5). What is more, Luo (2003) used the evolutionary idea of natural selection in informational efficiency. Hodgson (1995) applied this issue in economics and Niederhoffer (1997) have proposed Darwanian approach to the EMH. Niederhoffer (1997) likens financial market to an ecosystem consisting of dealers as herbivores, speculators as carnivores, and floor traders and distressed investors as decomposers. Later, Bernstein (2003) mentioned that equilibrium is rarely realized in practice and evolutionary process can explain market dynamic better. Evolutionary perspective, in which individuals are viewed as organisms that want to maximize chance of survival through genetic material, have more modest claims than Samuelson’s (1947) point of view.

To sum up, it is a time to consider EMH with an evolutionary approach. Other scientists such as Simon (1955) made a doubt on traditional economic theory in which economic man either is rational or has knowledge of the relevant aspects of his environment (1955, p. 99). He operationalized this proposition many years ago with the idea of bounded rationality. He mentions that opposite to neoclassic economics, individuals, because of optimization’s cost and because of limitations in computation ability, hardly can optimize their own benefits (1955). However, because of this question “what determines the point at which an individual stops optimizing and reaches a satisfactory solution?” (Lo, 2004, p. 22), the classic optimization approach up to now is a de facto standard. An evolutionary perspective helps us to answer the critics’ questions. The answer is that individuals do not find satisfactory point with analytical analysis and instead they use trial and error. They use heuristic approach in which they use past experiences and guess about best outcome and learn through positive and negative consequences. Adaptive market hypothesis is new paradigm in the economics so it needs more researches to play more role in model making (Lo, 2004).

Recent Financial Crisis
This thesis’ intention is not making any relationship between random walk and financial crisis. However, since the period chosen for the study falls in recent financial crisis’ period, author would like to have a quick review on recent crisis and its relationship with stock price volatility.

Since the great depression of the 1930s, current financial crisis is considered as the worst (Pendery, 2009). Immediate trigger of this crisis was the US’s housing bubble around 2005-2006. As a result, interest rate has increased, encouraging borrowers to refinance their loan quickly. When housing prices started decreasing in 2006-2007, borrower could not refinance as easy as before, leading to increased default numbers. Resulting from flowing money from other countries, Federal Reserve kept interest rate too low from 2002-2006, contributing to easy credit condition. Besides, some financial innovations such as mortgage-backed securities and collateralized debt obligations helped foreign and national investors to invest in housing market. Housing prices started decreasing in 2006-2007 and investors and institutions losses. These events weakened the financial position of banking system in U.S. and transferred this erosion to other parts of economy. Besides, policymakers did not recognize the financial institutions role in the economy to prevent the growth of the problem. This crisis had a major effect on the wealth: U.S. stock index decreased 45 percent in November 2008 from its peak in 2007, housing prices
felt down about 20 percent from its peak, American’s retirement assets decreased 22 percent and saving and investment assets lost more than 1 trillion dollar.

As mentioned before, stock prices in U.S. decreased roughly 50 percent from October 2007 to March 2009. Figure 1 shows the (DJIA) index and the S&P 500 index from January 1990 to July 2009.

![Figure 1: Stock Prices since 1990](image)

These indices did not take in to account dividends. But, based on research has done by Center for Research in Security prices, even if we include dividends, stockholders did not receive any return for more than a decade from 1996 till 2007. Figure two shows the S&P 500 over a period 1926 to July 2009. As we can see, the 2007 crisis is the worst since 1930s (Center for Research in Security Prices).

![Figure 2: Historical Values of the S&P 500](image)
Financial crisis affected many countries worldwide. Except Norway, which suffered mildly, other Nordic countries experienced great impact from crisis. The empirical evidence shows that financial crisis produce a structural change in the markets’ volatility pattern (Dima & Murgea, 2008). Theoretically, not being able to assess the market and adjust to newly available information, investors during financial crisis will have irrational behavior, leading to non-random walk behavior of stock prices during crisis. Fama, many years before, pointed out one of the possibilities of this behavior: “Zero covariances are consistent with a fair game model, but as noted earlier, there are other types of nonlinear dependence that imply the existence of profitable trading systems, and yet do not imply nonzero serial covariances” (Fama E. F., 1970, p. 394).
Results and Analysis

Introduction
In this chapter, author reviews the results of returns correlation tests, heteroskedasticity and ARCH in three time dimensions. Then, discussion of result will be presented.

Descriptive Statistics
OMX Nordic 40 index data from January 2007 up to November 2009 was gathered from nasdaqomxnordic.com website. Table 1 in the appendix shows the list of companies that their instrument was used to produce this index:

Stock index movements during this period can be seen below.

![Figure 3: OMX Nordic 40 movement during 2007-2009. Source www.nasdaqomxnordic.com](image)

Maximum closing price was 1441.46 in 2007/10/11 and minimum one was 500.4 in 2009/3/6. During this period, average closing stock prices was 999.6 with the 275.14 standard deviation. Maximum daily return was 4.07%, minimum one was -3.78 and standard deviation of daily returns was about 0.0089. Maximum weekly return was 5.9%, minimum one was -9.3 and standard deviation of weekly returns was about 0.019. Maximum monthly return was 8.3% and minimum one was -8.3 and standard deviation of monthly returns was about 0.03. The graphs show the daily, weekly and monthly returns for OMX 40 index from 2007 to 2009. As the graphs show, we can hardly find any pattern in returns.
**Figure 4: Weekly Returns for Nordic Stock Market Prices from 2007 to 2009**

**Figure 5: Weekly Returns for Nordic Stock Market Prices from 2007 to 2009**

**Figure 6: Monthly Returns for Nordic Stock Market Prices from 2007 to 2009**
Serial Correlation of Daily Returns

**AR (1) and AR (2)**

In order to estimate AR (1) model, \( y_t = \beta_0 + \beta_1 y_{t-1} + u_t \), Where we have:

\[
E(u_t | y_{t-1}, y_{t-2}, y_{t-3}, ...) = 0
\]

and \( H_0 : \beta_1 = 0 \) against \( H_1 : \beta_1 \neq 0 \). OMX Nordic 40 index data from January 2007 (2007-01-04) up to November 2009 (2009-11-27) were gathered from nasdaqomxnordic.com website. Then daily returns were calculated for this period using following formula:

\[
return_t = \log \frac{price_t}{price_{t-1}}
\]

Author ran the regression and came to following equation:

\[
return_t = -0.0002 - 0.0234 \cdot return_{t-1}
\]

The number of observations is 739, SE for \( return_{t-1} \) is 0.037 and the t statistics for the coefficient on \( return_{t-1} \) is -0.64; therefore, \( H_0 : \beta_1 = 0 \) cannot be rejected against two-sided alternative in 5% significance level. The results show a very slight negative correlation in the OMX return from one day to the next, but this is not strong enough to reject the null hypothesis. Furthermore, heteroskedasticity-robust t statistics is -0.49, leading to same conclusion.

Taking to account \( E(u_t | y_{t-1}, y_{t-2}, ...) = 0 \) and \( Var(u_t | y_{t-1}, y_{t-2}) = \sigma^2 \), consider following AR (2) model as follow:

\[
y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + u_t
\]

In this model, we want to test whether a group of variables has effect on the dependant variable. The null hypothesis is stated as:

\( H_0 : \beta_1 = 0, \beta_2 = 0 \)

After running test, we have:

\[
return_t = -0.0003 - 0.0255 \cdot return_{t-1} - 0.0876 \cdot return_{t-2}
\]

The number of observations is 738, SE for \( return_{t-1} \) is 0.037, SE for \( return_{t-2} \) is 0.037, t statistics for \( return_{t-1} \) is -0.69 and t statistics for \( return_{t-2} \) is -2.38, indicating that one of the lags is significant at 5% level. Besides, \( R^2 = 0.008 \), the F statistics for 2 and 735 degrees of freedom is approximately 3.03 and p value for F statistics is 0.0486; therefore, we reject null hypothesis and as a result, two lags are jointly significant in 5% level. Heteroskedasticity-robust t statistics for \( return_{t-1} \) and \( return_{t-2} \) are -0.54 and -1.74 respectively; therefore, we can conclude two lags are individually insignificant at 5% level.
Testing for Heteroskedasticity
Consider the equation that is used for Breusch-Pagan test:

$$\hat{u}_t^2 = \delta_0 + \delta_1 y_{t-1} + \nu_t$$

where the null hypotheses are $H_0: \delta_1 = 0$ versus $H_1: \delta_1 \neq 0$. Now, we use t statistics on return $y_{t-1}$ to check whether there is heteroskedasticity or not.

After running test, we had following equation:

$$\hat{u}_t^2 = 0.00008 - 0.0014 return_{t-1} + residual_t$$

Where the number of observations is 739 and SE for $return_{t-1}$ is 0.0007. The t statistics for the coefficient on $return_{t-1}$ is -2.07, indicating evidence of heteroskedasticity in 1% significant level.

ARCH in Stock Returns
The first order ARCH model is as follow:

$$u_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \nu_t$$

with following hypotheses: $H_0: \alpha_1 = 0$ versus $H_1: \alpha_1 \neq 0$. After running regression, we calculate t statistics on $u_{t-1}^2$ to check the hypothesis.

$$u_t^2 = 0.00007 + 0.1468 u_{t-1}^2 + residual_t$$

Where the number of observations is 738 and SE for $u_{t-1}^2$ is 0.036. The t statistics for the coefficient on $u_{t-1}^2$ is 4.02, indicating that there is a strong ARCH.

Serial Correlation of Weekly Returns

AR (1) and AR (2)
Weekly returns were calculated using OMX Nordic 40 index data from January 2007 (2007-1-19) up, to November 2009 (2009-10-27). Author ran the regression and came to following equation:

$$\text{return}_t = -0.0012 - 0.0729 \text{return}_{t-1}$$

Where the number of observations is 150 and SE for $\text{return}_{t-1}$ is 0.082. The t statistics for the coefficient on $\text{return}_{t-1}$ is -0.89, so $H_0: \beta_1 = 0$ cannot be rejected against two-sided test in 5% significance level. The results show a very slight negative correlation in the OMX return from one week to the next, but it is not strong enough to reject the random walk of prices. Furthermore, heteroskedasticity-robust t statistics is -0.65, leading to same conclusion.

Taking to account $E(u_t | y_{t-1}, y_{t-2}, \ldots) = 0$ and $Var(u_t | y_{t-1}, y_{t-2}) = \sigma^2$, now consider following AR (2) model as follow:

$$y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + u_t$$
Here, we want to test whether a group of variables has effect on the dependant variable. The null hypothesis is stated as

$$H_0 : \beta_1 = 0, \beta_2 = 0$$

After running test we had:

$$\text{return}_t = -0.0012 - 0.0702 \text{return}_{t-1} + 0.0480 \text{return}_{t-2}$$

The number of observations is 149, SE for $\text{return}_{t-1}$ is -0.84 and SE for $\text{return}_{t-2}$ is 0.58, the t statistics for $\text{return}_{t-1}$ is 0.60 and t statistics for $\text{return}_{t-2}$ is 0.43, indicating two lags are individually insignificant at 5% level. The F statistics with 2 and 146 degrees of freedom is approximately 0.57, and $R^2 = 0.008$. P value for F statistics is 0.567; therefore, $H_0$ cannot be rejected and lags are jointly insignificant in 5% level. Heteroskedasticity-robust t statistics for $\text{return}_{t-1}$ and $\text{return}_{t-2}$ are -0.60 and 0.43 respectively, leading to same conclusion as above.

**Testing for Heteroskedasticity**

Consider the equation which is used in Breusch-Pagan test:

$$\hat{u}_t^2 = \delta_0 + \delta_1 y_{t-1} + \nu_t$$

where the null hypothesis is $H_0 : \delta_1 = 0$ versus $H_1 : \delta_1 \neq 0$. Then, we use t statistics on return $y_{t-1}$ to check whether there is heteroskedasticity or not. After running test we had following equation:

$$\hat{u}_t^2 = 0.0003 - 0.0117 \text{return}_{t-1} + \text{residual}_t$$

Where the number of observations is 150 and SE for $\text{return}_{t-1}$ is 0.0036. The t statistics for the coefficient on $\text{return}_{t-1}$ is -3.22, indicating evidence of heteroskedasticity. Besides, the interesting finding is that volatility in stock return is lower when $\text{return}_{t-1}$ was high, and vice versa.

**ARCH in Stock Returns**

The first order ARCH model is as follow:

$$u_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \nu_t$$

with following hypotheses: $H_0 : \alpha_1 = 0$ versus $H_1 : \alpha_1 \neq 0$. Then, after running regression, we can calculate t statistics on $u_{t-1}^2$ to check the hypothesis. After running regression, we have:

$$u_t^2 = 0.0003 + 0.1484 u_{t-1}^2 + \text{residual}_t$$

Where the number of observations is 149 and SE for $u_{t-1}^2$ is 0.0815. The t statistics for the coefficient on $u_{t-1}^2$ is 1.82, indicating that ARCH is low.
Serial Correlation of Monthly Returns

AR (1) and AR (2)
Using OMX Nordic 40 index data from March 2007 up to November 2009, monthly returns were calculated for this period. Author ran the regression and came to following equation:

\[ \text{return}_t = -0.0038 + 0.2928 \text{return}_{t-1} \]

Where the number of observations is 33 and SE for \( \text{return}_{t-1} \) is 0.1715, the t statistics for the coefficient on \( \text{return}_{t-1} \) is 1.71, so \( H_0 : \beta_1 = 0 \) cannot be rejected against two-sided alternative in 5% significance level. The results show a slight correlation in the OMX return from one month to the next, but it is not strong enough to reject the random walk of prices. Furthermore, heteroskedasticity-robust t statistics is 1.76, leading to same conclusion.

Taking to account \( E(\text{u}_t | y_{t-1}, y_{t-2}, ... ) = 0 \) and \( \text{Var}(\text{u}_t | y_{t-1}, y_{t-2}) = \sigma^2 \), Now consider following AR (2) model as follow:

\[ y_t = \beta_0 + \beta_1 y_{t-1} + \beta_2 y_{t-2} + \text{u}_t \]

Here we want to test whether a group of variables has effect on the dependant variable. The null hypothesis is stated as

\[ H_0 : \beta_1 = 0, \beta_2 = 0 \]

After running test we had:

\[ \text{return}_t = -0.0049 + 0.3271 \text{return}_{t-1} - 0.0913 \text{return}_{t-2} \]

The number of observations is 32 and SE for \( \text{return}_{t-1} \) is 0.183 and SE for \( \text{return}_{t-2} \) is 0.183; t statistics for \( \text{return}_{t-1} \) is 1.78 and t statistics for \( \text{return}_{t-2} \) is -0.50, indicating two lags are individually insignificant at 5% level. The F statistics for 2 and 29 degrees of freedom is approximately 1.6 and \( R^2 = 0.099 \). P value of F statistics is 0.221; therefore, we cannot reject null hypothesis and as a result two lags are jointly insignificant in 5% level. Heteroskedasticity-robust t statistics for \( \text{return}_{t-1} \) and \( \text{return}_{t-2} \) are 1.67 and -0.58 respectively, leading to same conclusion.

Testing for Heteroskedasticity
Consider the equation which is used in Breusch-Pagan test:

\[ \hat{\text{u}}^2_t = \delta_0 + \delta_1 y_{t-1} + v_t \]

where the null hypotheses are \( H_0 : \delta_1 = 0 \) versus \( H_1 : \delta_1 \neq 0 \). Now, we can use t statistics on return \( y_{t-1} \) to check whether there is heteroskedasticity or not. After running test we have following equation:

\[ \hat{\text{u}}^2_t = 0.0009 - 0.00056 \text{return}_{t-1} + \text{residual}_t \]

where the number of observations is 33 and SE for \( \text{return}_{t-1} \) is 0.0092. The t statistics for the coefficient on \( \text{return}_{t-1} \) is 0.061, indicating no evidence of heteroskedasticity.
ARCH in Stock Returns

The first order ARCH model is as follow:

\[ u_t^2 = \alpha_0 + \alpha_1 u_{t-1}^2 + \nu_t \]

with following hypotheses: \( H_0 : \alpha_1 = 0 \) versus \( H_1 : \alpha_1 \neq 0 \). Then, after running regression, we can calculate t statistics on \( u_{t-1}^2 \) to check the hypothesis. After running regression we have,

\[ u_t^2 = 0.0009 + 0.0284 u_{t-1}^2 + \text{residual}_t \]

Where the number of observations is 32 and SE for \( u_{t-1}^2 \) is 0.1833. The t statistics for the coefficient on \( u_{t-1}^2 \) is 0.15, indicating no ARCH.

Interpretation of the Results

Since P-value approach give an opportunity for comparing the test statistics against the different critical values, author presents the summary of p-values findings.

<table>
<thead>
<tr>
<th>Test</th>
<th>Daily Returns</th>
<th>Weekly Returns</th>
<th>Monthly Returns</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Return t-1</td>
<td>Return t-2</td>
<td>( u_{\cdot(t-1)}^\cdot \cdot^2 )</td>
</tr>
<tr>
<td>AR(1)</td>
<td>-0.63</td>
<td>-0.49</td>
<td>0.62</td>
</tr>
<tr>
<td>AR(2)</td>
<td>-0.69</td>
<td>-0.54</td>
<td>0.59</td>
</tr>
<tr>
<td>Heteroskedasticity</td>
<td>-2.07</td>
<td>-0.04</td>
<td></td>
</tr>
<tr>
<td>Arch</td>
<td></td>
<td></td>
<td>4.03</td>
</tr>
</tbody>
</table>

29
Implications of finding would be as follows:

<table>
<thead>
<tr>
<th>Tests</th>
<th>Time</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlation of Returns (Simple Regression)</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Correlation of Returns (Multiple Regression)</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Heteroskedasticity</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Arch In Stock Returns</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

As we can see in the table, AR (1) tests’ results for simple regression cannot reject weak version of efficient market hypothesis for daily, weekly and monthly data. However, it is probable that AR (1) cannot find correlation between returns which are more than one period apart; therefore, AR (2) test has been done. Results for this test also cannot reject efficient market hypothesis in weak level except for daily data. This rejection of correlation of returns is inconsistent with Worthington and Higgs (2004). One interpretation of this inconsistency is that Worthington and Higgs used variance-ratio test for doing their research. When financial economists did more precise tests on data belong to the studies with less complicated tests, they came to the contrary findings (Lo A. W., 1997).

After doing heteroskedasticity tests in analyzing weekly data, result indicates interesting finding: The returns are not correlated but volatility is lower when the previous return was high and vice versa; therefore “the expected value of stock returns does not depend on past returns but the variance of returns does” (Wooldridge, 2009, p. 433). Besides, for daily data, we have this dependence of volatility too.

In analyzing ARCH test, we can conclude that for daily data, “a larger error at time $t - 1$ implies a larger variance in stock returns today” (Wooldridge, 2009, p. 435).

Finally, since monthly tests have no heteroskedasticity and ARCH, we might relay on these data; however, we must be cautious in the interpretation of these results. They assume normality of stock returns (Borges M. , 2008, p. 13), which is not necessarily a valid assumption for the distribution of daily, monthly and weekly data and rationality of market participants and their neutrality toward risk.
Conclusions and Recommendations

Conclusions
EMH is one of the most influential and controversial theories in finance. The main idea behind this theory is that if market is efficient, then only newly arrived information causes volatility and it would be impossible to earn excess return in a long period; consequently, capital allocation will be improved and market confidence will be enhanced. Therefore, doing regular test of market efficiency is necessary to see the evolving condition of capital market. Assuming rationality and risk neutrality, one version “of the efficient market hypothesis states that information observable to the market prior to week t should not help to predict the return during Existence of market efficiency is the fundamental characteristics of capitalist economy; it week t“ (Wooldridge, 2009, p. 385).

Author’s purpose in this paper was to test market efficiency by doing correlation of returns for the Nordic stock market. Following research hypothesis was constructed to comply with the purpose of this research: The expected values of stock returns in Nordic Stock Exchanges depend on prior stock returns. This study cannot reject efficient market hypothesis in weak level except for daily data. One main implications of this result is that expected profit for the speculator is zero; consequently, there is not market participant who outperforms in the market. Since author assumed rationality and risk neutrality (limitations of this study), another implication of the result is that Nordic stock market is informationally efficient. However, without considering these limitations, not rejecting random walk has few implications for not rejecting some general model of market efficiency. The main reason behind this conclusion is that prices do not necessarily form a martingale sequence; as a result, random walk test does not work well; however, the results “can be interpreted as a non-rejection of some economic models of efficient price formation” (Lo A. W., 1997, p. 18)

While many of previous studies were unable to reject random walk hypothesis, some recent papers show that prices are predictable in stock market prices. In the European context, the result of this study is consistent with previous studies except Worthington and Higgs’s (2004). One interpretations of this inconsistency is that they used variance-ratio test for doing their research. If researcher uses complicated tests, he or she might come to the contrary findings with (Lo A. W., 1997).

Furthermore, this research had another finding, which is common in many random walks studies. Heteroskedasticity tests in analyzing weekly data indicates that returns are not correlated but volatility are; consequently, variances of stock returns depend on past returns. Moreover, ARCH test for daily data shows that “a larger error at time t – 1 implies a larger variance in stock returns today” (Wooldridge, 2009, p. 435).
Recommendations for Further Researches
During doing this thesis, author has found different approaches in defining random walk and market efficiency; as a result, author suggests doing theoretical researches to reconcile those conflicts. In other words, since market efficiency is not well-defined model, and there are many models with different implications, author recommends doing researches for defining a model which is more consistent with the reality of financial markets. What is more, doing other statistical tests are recommended since they had different findings in some researches.
### Tables

#### Table 1. OMX 40’s Companies

<table>
<thead>
<tr>
<th>Name of Companies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ABB Ltd</td>
<td>Nokia Oyj</td>
</tr>
<tr>
<td>Alfa Laval</td>
<td>Novo Nordisk B</td>
</tr>
<tr>
<td>ASSA ABLOY B</td>
<td>Outokumpu Oyj</td>
</tr>
<tr>
<td>Atlas Copco A</td>
<td>Sampo A</td>
</tr>
<tr>
<td>AstraZeneca</td>
<td>Sandvik</td>
</tr>
<tr>
<td>Boliden</td>
<td>SCA B</td>
</tr>
<tr>
<td>Carlsberg B</td>
<td>SEB A</td>
</tr>
<tr>
<td>Danske Bank</td>
<td>Sv. Handelsbanken A</td>
</tr>
<tr>
<td>DSV</td>
<td>Skanska B</td>
</tr>
<tr>
<td>Electrolux B</td>
<td>SKF B</td>
</tr>
<tr>
<td>Ericsson B</td>
<td>SSAB A</td>
</tr>
<tr>
<td>FLSmidth &amp; Co.</td>
<td>Stora Enso R</td>
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<tr>
<td>Fortum Oyj</td>
<td>Swedbank A</td>
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<tr>
<td>Getinge B</td>
<td>Swedish Match</td>
</tr>
<tr>
<td>Hennes &amp; Mauritz B</td>
<td>Tele2 B</td>
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<tr>
<td>Investor B</td>
<td>TeliaSonera</td>
</tr>
<tr>
<td>KONE Oyj</td>
<td>UPM-Kymmene Oyj</td>
</tr>
<tr>
<td>A.P. Møller - Mærsk B</td>
<td>Volvo B</td>
</tr>
<tr>
<td>Metso Oyj</td>
<td>Vestas Wind Systems</td>
</tr>
<tr>
<td>Nordea Bank</td>
<td>Wärtsilä Oyj Abp</td>
</tr>
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</table>
### Table 2. Summary of Statistics for Daily Data

#### AR (1)

<table>
<thead>
<tr>
<th>Regression Statistics for Return t</th>
<th>No. of obs.</th>
<th>SSR</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>F stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>739</td>
<td>0.0590851</td>
<td>0.008953752</td>
<td>0.0005498</td>
<td>0.4053968</td>
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<td>No. of missing obs.</td>
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<td>0.0591176</td>
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<tr>
<td>Mean of Dep Var</td>
<td>-0.000239223</td>
<td>0.0003295</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t Statistics</td>
<td>-0.636708</td>
<td>-0.491779</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### AR (2)

<table>
<thead>
<tr>
<th>Regression Statistics for Return t</th>
<th>No. of obs.</th>
<th>SSR</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>F stat.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td>t Statistics</td>
<td>-0.636708</td>
<td>-0.491779</td>
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#### Testing for Heteroskedasticity

<table>
<thead>
<tr>
<th>Regression Statistics for $u_{t-1}^2$</th>
<th>No. of obs.</th>
<th>SSR</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>F stat.</th>
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<td>-1.351553</td>
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</table>

#### Arch In Stock Returns

<table>
<thead>
<tr>
<th>Regression Statistics for $u_{t-1}^2$</th>
<th>No. of obs.</th>
<th>SSR</th>
<th>RMSE</th>
<th>$R^2$</th>
<th>F stat.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>738</td>
<td>2.097E-05</td>
<td>0.00016879</td>
<td>0.0215653</td>
<td>16.221916</td>
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<td>2.143E-05</td>
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<tr>
<td>Mean of Dep Var</td>
<td>0.0000800</td>
<td>0.0006997</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>t Statistics</td>
<td>-2.066023</td>
<td>-1.351553</td>
<td></td>
<td></td>
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### Table 3. Summary of Statistics for Weekly Data

<table>
<thead>
<tr>
<th>AR (1)</th>
<th>Regression Statistics for Return $t$</th>
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<tbody>
<tr>
<td>No. of obs.</td>
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<tr>
<td>Mean of Dep Var</td>
<td>-0.001144425</td>
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<tr>
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<td>0.018845943</td>
</tr>
<tr>
<td>Variable</td>
<td>Estimate</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.001224389</td>
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<tr>
<td>Return $t$-1</td>
<td>-0.0728982695</td>
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<tr>
<td>$t$ Statistics</td>
<td>-0.889332</td>
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<table>
<thead>
<tr>
<th>AR (2)</th>
<th>Regression Statistics for Return $t$</th>
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<tbody>
<tr>
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<td>149</td>
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<tr>
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<td>-0.001206781</td>
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<tr>
<td>RMSE</td>
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<tr>
<td>Variable</td>
<td>Estimate</td>
</tr>
<tr>
<td>Intercept</td>
<td>-0.001236179</td>
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<tr>
<td>Return $t$-1</td>
<td>-0.070208702</td>
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<td>Return $t$-2</td>
<td>0.0479743999</td>
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</tbody>
</table>

**Testing for Heteroskedasticity**

<table>
<thead>
<tr>
<th>Regression Statistics for $u_{t}^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of obs.</td>
</tr>
<tr>
<td>No. of missing obs.</td>
</tr>
<tr>
<td>Mean of Dep Var</td>
</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>$u_{(t-1)}^2$</td>
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<tr>
<td>$t$ Statistics</td>
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**Arch In Stock Returns**

<table>
<thead>
<tr>
<th>Regression Statistics for $u_{t}^2$</th>
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</thead>
<tbody>
<tr>
<td>No. of obs.</td>
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<tr>
<td>No. of missing obs.</td>
</tr>
<tr>
<td>Mean of Dep Var</td>
</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>$u_{(t-1)}^2$</td>
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<tr>
<td>$t$ Statistics</td>
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</tbody>
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Table 4. Summary of Statistics for Monthly Data

<table>
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</tr>
<tr>
<td>Mean of Dep Var</td>
</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>Return t-1</td>
</tr>
<tr>
<td>t Statistics</td>
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</tbody>
</table>

<table>
<thead>
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<th>AR (2) Regression Statistics for Return t</th>
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<tbody>
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<td>No. of missing obs.</td>
</tr>
<tr>
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</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>Return t-1</td>
</tr>
<tr>
<td>Return t-2</td>
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</tbody>
</table>

Testing for Heteroskedasticity

<table>
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<tr>
<th>Regression Statistics for uₜ²</th>
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<tbody>
<tr>
<td>No. of obs.</td>
</tr>
<tr>
<td>No. of missing obs.</td>
</tr>
<tr>
<td>Mean of Dep Var</td>
</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
</tr>
<tr>
<td>Intercept</td>
</tr>
<tr>
<td>Return t-1</td>
</tr>
<tr>
<td>t Statistics</td>
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Arch In Stock Returns

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<tr>
<th>Regression Statistics for uₜ²</th>
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<tr>
<td>No. of missing obs.</td>
</tr>
<tr>
<td>Mean of Dep Var</td>
</tr>
<tr>
<td>RMSE</td>
</tr>
<tr>
<td>Variable</td>
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<tr>
<td>Intercept</td>
</tr>
<tr>
<td>uₜ² (t-1)²</td>
</tr>
<tr>
<td>t Statistics</td>
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