ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΕΙΡΑΙΩΣ
ΤΜΗΜΑ ΧΡΗΜΑΤΟΟΙΚΟΝΟΜΙΚΗΣ ΚΑΙ ΤΡΑΠΕΖΙΚΗΣ ΔΙΟΙΚΗΤΙΚΗΣ
ΠΡΟΓΡΑΜΜΑ ΜΕΤΑΠΤΥΧΙΑΚΩΝ ΣΠΟΥΔΩΝ
ΣΤΗ ΧΡΗΜΑΤΟΟΙΚΟΝΟΜΙΚΗ ΚΑΙ ΤΡΑΠΕΖΙΚΗ ΔΙΟΙΚΗΤΙΚΗ

Οι Ιδιότητες των Αποδόσεων των Χρηματιστηριακών Δεικτών - Η Αποτελεσματικότητα των Αγορών

ΔΙΠΛΩΜΑΤΙΚΗ ΕΡΓΑΣΙΑ

Σταύρος Γρουτάς

2005

Acknowledgments

I would like to express my gratitude to my supervisor and professor Christina Christou, for the chance she gave me to work on such an interesting issue. Her invaluable help with expertise, understanding, and patience, added considerably to my thesis experience. She was always willing, guiding me thoughtfully and precisely.

Contents

Chapter1: INTRODUCTION…………………………………………………………..4

Chapter 2: EFFICIENT MARKET HYPOTHESIS…………………………………5

2.1 The significance of efficiency...…………………………….………….....6

2.2 Types of Efficiency…………………………………………………….....7

2.3 Forms of Efficiency……………………………………………………….8

2.4 Efficient Market Hypothesis and Bubbles…………………………..9

2.5 Anomalies: The Challenge to Efficiency……………………………9

2.6 What Market Efficiency does and does not imply……………...…10

2.7 Whether or not investors can make money…………..………...…11

2.8 Human behavior in financial system....……………….………….…12

2.9 Evaluation of market behavior……………………………………..13

Chapter 3: RANDOM WALK HYPOTHESIS………………………………...18

3.1 The meaning of Random Walk Hypothesis..………………………19

3.2 The importance Random Walk Hypothesis……………………….20

3.3 Market Efficiency and the Random Walk theory………………….21

3.4 Random Walk Hypothesis – Index 1………………………………..22

Chapter 4: VARIANCE RATIO TEST…………………………………………..23

4.1 A review of past studies on stock market efficiency…..…………...23

4.2 Important studies on various stock markets using Variance Ratio tests…………………………………………………………………26

4.3 Most Important Variance Ratio Tests……………………………...27

Chapter 5: EMPIRICAL RESULTS……………………………..…………………….33

5.1 Empirical results for developed countries………………………….34

5.2 Empirical results for emerging countries…………………….…41

5.3 Empirical results for frontier countries…………………………….50

5.4 Looking at the VR tests through a rolling window……………......56

Conclusion……………………………………………………….....62

References…………………………………………………………...63

CHAPTER 1

INTRODUCTION

Stock markets are strongly connected with the concept of market's efficiency. Most of the transactions and financial decisions are based on strategies that take into account that valuable information, "efficiency". A market is efficient when its stock returns exhibit random walk behavior. In this dissertation, that hypothesis is examined through Variance Ratio (VR) tests that are definitely the most widely used econometric tools for testing the random walk hypothesis (RWH). The notion of VR tests is that if a stock's return is purely random, the variance of k-period return is k times the variance of one-period return.

First was Lo and MacKinlay's (1988) VR test which introduce that econometric tool and then Chow and Denning (1993) who modified the conventional test in order to determine whether the multiple VRs are jointly equal to one. Lo and MacKinlay's VR test is an individual test while the multiple VR test of Chow and Denning is a joint test. Even though the multiple VR test is quite powerful testing for homoskedastic or heteroskedastic nulls, it should be mentioned that it is an asymptotic tests and that increases the possibility of inaccuracy. Furthermore Wright (2000) and Whang and Kim (2003), have proposed two alternatives to conventional asymptotic VR tests. The "rank and sign" VR tests from Wright and the "subsampling" test from Whang and Kim replaced the forerunner tests, since they are not affected by asymptotic approximations.

Three groups of countries are examined in this dissertation. Firstly, 7 developed countries, that are the core of the international stock market, may provide results useful for every investor. Moreover, 10 emerging markets are tested, which have become increasingly important to the safety and vitality of the global financial markets as shown in recent studies. Lastly, 5 frontier markets may possibly give valuable results for every contrarian investor, since that markets are mostly inefficient.

The main purpose of this paper is to compare outcomes of the mentioned VR test for the evaluation of the RWH in 22 equity markets. Secondly, is to ascertain any changes in the random walk patterns of stock prices at the ten emerging markets, taking into account significant crises with the VR tests of Wright (2000) through a rolling window. Our findings support that Wright's rank and sign and Whang-Kim's subsampling VR tests yield statistical results, which are less ambiguous as compared to the initial VR tests. That is clearer for relatively small sample sizes.

Moreover, Chapter 2 presents the concept of "Efficient Market Hypothesis", while section 3 provides the theory and the features of the "Random Walk Hypothesis". Section 4 reports in detail the most important VR tests, including past similar studies. Last but not least, chapter 5 discusses the empirical results of every single test and depicts them with a pivot table.

Keywords: Stock Market Efficiency, Random Walk Hypothesis, Variance Ratio Test, rollingdeveloped, emerging and frontier markets.

CHAPTER 2

EFFICIENT MARKET HYPOTHESIS

Efficient Market Hypothesis (EMH) not only has been an essential part of the development of modern financial economics, but also remains an influential intuition. It is a formal notion that has remarkable usefulness in financial economics. An unattributable old joke, not only amusing but intuitive also, says:

A finance professor and a student are walking down a street and the student sees a €100 bill lying on the pavement. As the student is reaches down to pick up the money the professor says "*Don't bother; if that really was a €100 bill it wouldn't be there.*"

It is not that €100 is impossible to be found in the street. The point is that €100 is a significant amount of money and it is unlikely that somebody would accidentally lose a bill of that size. But even if they did, one would have to be extremely lucky to be the first one to spot it. That explains why financial markets are so competitive and money-making opportunities are so rare. That shows how competitive are financial markets and cited what Eugene F. Fama means with the term "Efficient Market Hypothesis" (EMH).

The Efficient Market hypothesis (EMH) asserts that financial markets are "informationally efficient", which means that prices on traded assets, e.g., stocks, bonds, or property, already reflect all known information. The Efficient Market hypothesis states that it is impossible to consistently "beat" the market by using any already known information, except through luck. Is defined that information is anything, totally unpredicted that may affect stock prices in future.

In accordance with theoretical papers[1,2] questioning markets efficiency Professor Eugene Fama was firstly developed the Efficient Market Hypothesis at the University Of Chicago Booth School Of Business as an academic concept of his Ph.D. thesis in the early 1960s at the same school. As Burton Malkiels mention in his paper "It was widely accepted up until the 1990s, when behavioral finance economists, who were a fringe element, became mainstream. Empirical analyses have consistently found problems with the efficient markets hypothesis, the most consistent being that stocks with low price to earnings (and similarly, low price to cash-flow or book value) outperform other stocks". Alternative theories have proposed that these inefficiencies are result of some biases, which are able to force investors to purchase overpriced growth stocks rather than value stocks.[3] Although the efficient markets hypothesis has become controversial because substantial and lasting inefficiencies are

[1] The Efficient Market Hypothesis and its Critics (2003) - Burton G. Malkiel,

[2] Human Behavior and the Efficiency of the Financial System (1999) - Robert J. Shiller

[3] Is The Market Rational? No, say the experts. But neither are you - Fox J. (December 9, 2002)

observed, Beechey et. Al. (2000)[4] considers that it remains a worthwhile starting point.

Louis Bachelier was the pioneer of the Efficient Market hypothesis., throughout his dissertation, "The Theory of Speculation". His work took great popularity but not before 1950s, when some scattered, independent work corroborated his thesis. The Efficient Market hypothesis emerged as an important theory in the mid-1960s. Paul Samuelson had begun to circulate Bachelier's work among economists. In 1964 Bachelier's dissertation along with the empirical studies mentioned above were published in an anthology edited by Paul Cootner. In 1965 when Eugene Fama published his dissertation arguing for the random walk hypothesis, Paul Samuelson published a proof for a version of the Efficient Market hypothesis. Later in 1970 Fama published a review of both the theory and the evidence for the hypothesis. The paper extended and refined the theory, included the definitions for three forms of market efficiency: weak, semi-strong and strong.[5]

2.1 The significance of efficiency

Jones S. and Netter J. (2005) wonder how important is informational efficiency in markets[6]. In their journal is mentioned: "Nowadays, the capital markets channel funds from savers to firms, which use the funds to finance projects. Informational efficiency is necessary if funds are to flow to the highest-valued projects. Shareholders want managers to maximize stock prices and they will attempt to ensure that their managements undertake only projects(decisions) that increase the value of their stock. However, maximization of stock prices can result in the capital market directing funds to the most valuable projects only if stocks are efficiently priced, in the sense of accurately reflecting the fundamental value of all future cash flows". Hence, for inefficient capital markets, managers would not emphasize the short run at the expense of long-term projects. In addition, in efficient capital markets firms can easily increase their capital because the markets determine the prices such security holders are willing to exchange claims on a firm's future cash flows.

Market efficiency is also important for investors who do not have the time or the resources to do a thorough analysis, hence they are able to invest their money in the market if they know that the securities they trade are accurately priced. Due to this the capital market is able perform its function of translating savings into valuable projects. Finally, there are policy implications on market efficiency. If capital markets are efficient, then the government's role in capital markets should be very limited.

Jones S. and Netter J. point out that a large amount of empirical research has been done in order to answer whether capital markets are efficient. Hence to examine that issue, stock price data have been used, for two main reasons:

---

[4] Beechey M, Gruen D, Vickrey J. (2000) - The Efficient Markets Hypothesis: A Survey

[5] Fama, Eugene (1970). "Efficient Capital Markets: A Review of Theory and Empirical Work"

[6] Steven L. Jones and Jeffry M. Netter (2003) - Efficient Capital markets

a) Stock prices are available in data bases such as DataStream.

b) Stock market is likely to be less efficient than other securities markets (such as the bond market) because cash flows paid to stockholders are relatively uncertain, and there is no terminal payoff as in a bond.

Therefore, stocks are relatively difficult to value, and evidence of stock market efficiency would be an evidence of efficiency in securities markets in general.

A lot of empirical studies have proved that stock prices react quickly, in the expected direction, if an information is released. For example, ten minutes are enough to start modifying a stock price when an earnings announcement released. However, such evidence does not show that the amount of price reaction accurately reflects fundamentals or that security prices accurately reflect the fundamental value of the securities. Other evidence shows that profits trading have been earned by corporate insiders based on inside information. Nowadays, the empirical debate on market efficiency centers on whether future returns are predictable or not.

Before Eugene Fama, some other empirical tests examined market efficiency, trying to prove that stock returns remain statistically independent under certain circumstances.[7] Researchers found that stock returns follow the known notion of "Random Walk". That means that historical returns are useless for predicting future returns, which is consistent with weak form of efficiency.

2.2 Types of Efficiency

We have to establish some clarity for "Efficiency" because it is an ambiguous word. According to the book "Corporate Financial Management" of Glen Arnold, there are three types of efficiency[8]:

1) Operational Efficiency refers to the exchange cost that buyers and sellers have during a security transaction. It is desirable that the market carries out its operations at the lowest possible cost. This may be promoted by creating as much competition between market makers and brokers as possible so that they earn only normal profits and not extremely high profits. It may also be enhanced by competition between exchanges for secondary-market transactions.

2) In Allocation Efficiency society has not infinite resources and it is important to be found mechanisms, which allocate those resources to where they can be most useful. Those industrial and commercial firms with the greatest potential to use investment funds effectively need a method to channel funds their way. Stock markets help in the process of allocating society's resources between competing real investments. For example, an efficient market provides vast funds for fast-growth

[7] Steven L. Jones and Jeffry M. Netter (2003) - Efficient Capital markets

[8] Abstract from the book "Corporate Financial Management" (Third Edition) – Glen Arnold

sectors such as electronics, pharmaceuticals and biotechnology industries but allocates only small amounts for slow-growth industries.

3) Last but not least is Pricing Efficiency. In a pricing efficient market the investor can expect to earn merely a risk-adjusted return from an investment as prices move instantaneously and in an unbiased manner to any news. It is pricing efficiency that is the focus of this section and the term efficient market hypothesis applies to this form of efficiency only.

2.3 Forms of Efficiency

Furthermore the Efficient Market hypothesis requires that agents have rational expectations; that on average the population are correct and whenever new relevant information appear, the agents update their expectations appropriately. Note that it is not required that the agents be rational. EMH allows that when faced with new information, some investors may overreact and some may under-react. All that is required by the EMH is that investors' reactions be random and follow a normal distribution pattern so that the net effect on market prices cannot be reliably exploited to make an abnormal profit, especially when considering transaction costs (including commissions and spreads). Thus, any one person can be wrong about the market but the market as a whole is always right. There are three common forms in which the Efficient Market hypothesis is commonly stated: weak-form efficiency, semi-strong-form efficiency and strong-form efficiency, each of them has different implications for how markets work.

1) Weak-form efficiency. In that type of efficiency future prices cannot be predicted by taking into account price from the past. Excess returns cannot be earned in the long run by using investment strategies based on historical share prices or other historical data. Contrarian policies will not always be able to produce excess returns, though some forms of fundamental analysis may still provide excess returns.

Stock prices exhibit no serial dependencies, meaning that no patterns are available to asset prices. This implies that future price movements are determined entirely by information not contained in the price series. Hence, prices must follow a random walk. This EMH does not require that prices remain at or near equilibrium, but only that market participants are unable to systematically profit from market inefficiencies.

There are examples from past, indicating that the use of very sophisticated models of the market was able to accrue profits from the existence of small anomalies[9] in the market. However, while EMH predicts that all price movement is random many studies have shown an obvious tendency for the stock markets to trend over time periods of weeks or longer.

2) Semi-strong-form efficiency is the second form of efficiency and implies that share prices adjust to new information immediately and in such a way that no

[9] Reference to an Article in a web site: What is market efficiency? - Reem Heakal

excess returns can be earned by trading on that information. In semi-strong-form efficiency is impossible to produce excess returns reliably. To test for semi-strong-form efficiency, the adjustments to previously unknown news must be of a reasonable size and must be instant.

3) In strong-form efficiency, all information, public and private, are adjusted to share prices and no one can out-profit the market. If private information would become public by law, strong-form efficiency is impossible, except in the case that the law would totally ignored. To test for strong-form efficiency, a market needs to exist where investors cannot consistently earn excess returns over a long period of time.

2.4 Efficient Market Hypothesis and Bubbles

A consequence of the EMH is that asset prices are always at levels justified by their underlying fundamentals. However, many "episodes" in financial history suggest that during some periods asset prices move out-of-step with the underlying fundamentals, such as periods of bubbles and crashes. Such periods typically feature high volatility in real output. Continuing rises in asset prices, followed by crashes, apparently enigmatic by changes in fundamentals have been around since the time of the Dutch "Tulipmania"[10] of 1636-1637, and the South Sea bubble of 1720. Recent examples of bubbles include the late 1980s bubble in the Japanese property and equity market, and the late 1990s internet bubble in most major stock markets.

2.5 Anomalies: The Challenge to Efficiency

According to EMH, because all market participants have access to the same information and prices respond only to information available in the market then no one has the ability to out-profit anyone else. In efficient markets, prices become not predictable but random, so no contrarian strategies or arbitrage opportunities can be occurred. A planned approach to investment, therefore, cannot be successful. Because of the random walk of prices, any investment strategy that aims to beat the market consistently results in failure. Hence, the EMH suggests that it would be more profitable for an investor to put his or her money into an index fund.

The presence of some financial abnormalities in economic theory was a big contributor to the formation of behavioral finance. These so-called anomalies[11] directly violate modern financial and economic theories, which assume rational and logical behavior. In the real world of investment there are clear evidences against the EMH. There are investors who have beaten the market, whose investment strategy focuses on undervalued stocks, made millions and set an example for numerous followers. There are portfolio managers who have better track records than others, and there are investment houses with more renowned research analysis than others. Hence, anomalies generate a strong doubt against the random walk theory.

[10] Reference on the book "Famous First Bubbles: The Fundamentals of Early Manias"(2001) - Peter M. Garber

[11] Anomalies in finance: What are they and what are they good for? (2001) – G. Frankfurter and Elton McGoun

The most important examples against the EMH are:

- The January effect, which is a pattern that shows higher returns tend to be earned in the first month of the year.
- The "Blue Monday on Wall Street" which discourages buying on Friday and, with result on Monday morning the tendency for prices to be higher on the day before and after the weekend. That is due to the weekend effect and the "rest" from shopping during the week.

Professor Paul Krugman in MIT economics suggests: "Because of the mass mentality of the trendy, short-term shareholder, investors pull in and out of the latest and hottest stocks. These results in stock prices, distorted the market inefficiency. So prices reflect no longer all available information in the market. Prices are instead being manipulated by profit seekers".

Furthermore, the hypothesis argues that an investor who outperforms the market does so, not out of skill but out of luck. EMH followers say this is due to the laws of probability: at any given time in a market with a large number of investors, some will outperform while other will remain average.

To summarize, there exist two opposing schools of thought concerning the usefulness of public information in the investment process: First, the "efficient markets" theorists who claim that investors cannot benefit by using public information, and second the more traditional school which contents that investors who expend resources to obtain information can receive compensation for their efforts.[12]

2.6 What Market Efficiency does and does not imply

a) The first implication, as mentioned before, of an efficient market is that no group of investors should be able to consistently beat the market using a common investment strategy. Moreover, an efficient market would also carry very negative implications for many investment strategies and actions that are taken for granted.

In Aswaht Damodoran (2002) study n an efficient market, equity research and valuation would be a costly task that provided no benefits. The odds of finding an undervalued stock should be random. At best, the benefits from information collection and equity research would cover the costs of doing the research. Then, a strategy of randomly diversifying across stocks or indexing to the market, carrying little or no information cost and minimal execution costs, would be superior to any other strategy that created larger information and execution costs. There would be no value added by portfolio managers and investment strategists. Finally, in an efficient market, a strategy of minimizing trading, i.e., creating a portfolio and not trading unless cash was needed would be superior to a strategy that required frequent trading.[13]

[12] Contrarian Investment Strategy: The Next Generation.(1998) - Dreman D.

[13] Market Efficiency: Definitions, Tests and Evidence (2002)- Aswaht Damodoran

b) An efficient market does not imply that:

i) Stock prices are possible to take every value much different from true value. So the deviations should be random.

ii) No investor will outperform the market at any time period. That is fault, every investor should be able to beat the market in any period.

iii) No investor will earn money in the long term. That is obviously wrong, because to beat the market in long term, is rare but not unlikely.[14]

Markets are strongly affected by the actions of investors, sensing bargains and putting into effect methods to beat the market. The necessary conditions for a market inefficiency to be eliminated are as follows:

(a) The asset which is the source of the inefficiency has to be traded.

(b) The transactions costs of executing the scheme have to be smaller than the expected profits from the scheme.

(c) Recognize the 'potential for excess return'.

(d) Can replicate the beat the market scheme that earns the excess return.

(e) Have the resources to trade on the stock until the inefficiency disappears.

2.7 Whether or not investors can make money

At first glance it might appear that testing whether investors can make money in markets is unlikely for all arguments that mentioned before. This is largely true for most of the traditional tests of the EMH, but not at all.

There are many tests according to Jonathan Berk (2007)[15] that are concentrated on showing whether particular trading strategies can or cannot make money. Eugene Fama (1965) [16] mentioned:

"The main conclusion will be that the data seem to present consistent and strong support for the [random-walk] model. This implies, of course, that chart reading, though perhaps an interesting pastime, is of no real value to the stock market investor. This is an extreme statement and the chart reader is certainly free to take exception. We suggest, however, that this and other studies in support of the random walk model are now so voluminous, the counterarguments of the chart reader will be completely lacking in force if they are not equally well supported by empirical work."

---

[14] Market Efficiency: Definitions and Tests – Aswaht Damodoran

[15] A Critique of the Effcient Market Hypothesis (2007) - Jonathan B. Berk

[16] The Behavior of Stock-Market Prices. - Eugene F. Fama; *Journal of Business*, 1965.

This view assumes that if we knew the true asset pricing model and if a trading strategy that made money exists, it would be possible to identify it. But it is a fact, that if anybody such a trading strategy would never reveal this information, otherwise the opportunity would disappear.

We could say that although it is impossible to observe money making trading strategy while the strategy makes money, one should be able to observe whether the strategy made money ex post: Once enough people discover the strategy and drive profits to zero, the existence of the strategy will become public knowledge. One could then see whether indeed the strategy made money using historical prices. The problem with this approach is that mining data for profit making strategies is always possible. Hence it is not clear how one would differentiate a money making strategy that truly did exist as a profit opportunity in the past from a strategy that historically yielded above normal profits by pure chance. In both cases, the data would show that it was possible to use strategies to make money in the past, but going forward, neither strategy would be expected to keep make money.

The impression that money making strategies do not exist is perhaps one of the biggest misconceptions in financial economics. That happens because active portfolio managers as a group earn essentially the same return as passive strategies, which implies that active managers lack skill. As Jonathan Berk (2004) [17]show, the average return to investors in a mutual fund, cannot be used as a measure of managerial skill. If investors could earn abnormal returns simply by picking particular mutual funds, there would be excess demand to invest in these funds and so the market would not clear. Balance can only be sustained if investors cannot earn abnormal returns investing in funds, that is, at all times the expected excess return of mutual funds must be zero. That means that, on average, active and passive managers should earn the same return and there should be no predictability in performance of any fund, regardless of the skill level of managers. So the fact that active managers do not consistently make higher returns than passive managers is not evidence that active managers are unskilled, and more importantly, that money making strategies do not exist.

2.8 Human behavior in financial system

In that part of second chapter are developed human behaviors as imperfections in financial markets to a combination of cognitive biases such as overconfidence, overreaction, representative bias, information bias, an inability to use configured rather than linear reasoning, and various other predictable human errors in reasoning and information processing. Investors and researchers have disputed the efficient markets hypothesis empirically and theoretically. Not only economists but psychologists too, such as Daniel Kahneman, Amos Tversky, Richard Thaler, and Paul Slovic, have examined that phenomenon. These errors in reasoning lead most investors to avoid high-value stocks and buy growth stocks at expensive prices, which allow those who reason correctly to profit from bargains in neglected value stocks and the overreacted selling of growth stocks.

[17] Five Myths of Active Portfolio Management (2004) - Jonathan B. Berk

Empirical evidence has been mixed, but has generally not supported strong forms of the efficient markets hypothesis. According to Dreman, in a 1995 paper, low P/E stocks have greater returns. In an earlier paper he also refuted the assertion by Ray Ball that these higher returns could be attributed to higher beta, whose research had been accepted by efficient market theorists as explaining the anomaly in neat accordance with modern portfolio theory. Burton Malkiel (2007)[18], a well-known proponent of the general validity of EMH, has warned that certain emerging markets such as China are not empirically efficient; that the Shanghai and Shenzhen markets, unlike markets in United States, exhibit considerable serial correlation (price trends), non-random walk, and evidence of manipulation.

2.9 Evaluation of market behavior

a) There have been al lot of efforts of EMH proponents, such as Burton Malkiel with the book "A Random Walk Down Wall Street", to bequeath EMH's importance. However, people cannot appreciate this effort. Popular books and articles promoting various forms of stock-picking, such as the books by popular CNBC (Business Channel) or other specialists continue to examine the more appealing notion that investors can "beat the market."

EMH is commonly rejected by the general public due to a misconception about its meaning. Some believe that EMH says that a security's price is a correct representation of the value of that business, as calculated by what the business's future returns will actually be. In other words, they believe that EMH says a stock's price correctly predicts the underlying company's future results. Since stock prices clearly do not reflect company future results in many cases, many people reject EMH as clearly wrong.

b) The early tests focused primarily on whether prices of certain financial assets do fully reflect various types of information, and several tests have also considered the characteristics of probabilities implicit in asset prices.

But the most enduring critiques of the EMH revolve around the preferences and behavior of market participants. The standard approach to modeling preferences is to assert that investors optimize additive time-separable expected utility functions from certain parametric families, e.g., constant relative risk aversion. However, psychologists and experimental economists have documented a number of departures from this paradigm, in the form of specific behavioral biases that are ubiquitous to human decision-making under uncertainty, several of which lead to undesirable outcomes for an individual's economic welfare. e.g:

a) Over-confidence (Fischofi and Slovic, 1980; Barber and Odean,2001; Gervais and Odean,2001)

b) Overreaction (DeBondt and Thaler, 1986),

[18] Investment Opportunities in China. (2007) - Burton Malkiel

c) Loss aversion (Kahneman and Tversky, 1979; Shefrin and Statman, 1985; Odean, 1998)

d) Herding (Huberman and Regev, 2001),

e) Psychological accounting (Tversky and Kahneman, 1981),

f) Miscalibration of probabilities (Lichtenstein et al., 1982),

g) Hyperbolic discounting (Laibson, 1997), and regret (Bell, 1982; Clarke et al., 1994).

These critics of the EMH argue that investors are often (if not always) irrational, exhibiting predictable and financially ruinous behavior.[19]

To see just how pervasive such behavioral biases can be, consider the following example[20] which is a slightly modified version of an experiment conducted by two psychologists in 1979.

Suppose you are offered two investment opportunities, A and B: A yields a sure profit of €240,000 and B is a lottery ticket yielding €1 million with a 25% probability and €0 with 75% probability. If you had to choose between A and B, which would you prefer? Investment B has an expected value of €250,000, which is higher than A's payoff, but this may not be all that meaningful to you because you will receive either €1 million or zero. Clearly, there is no right or wrong choice here; it is simply a matter of personal preferences. Faced with this choice, most subjects prefer A, the sure profit, to B, despite the fact that B offers a significant probability of winning considerably more. This behavior is often characterized as "risk aversion" for obvious reasons. Now suppose you are faced with another two choices, C and D: C yields a sure loss of €750,000, and D is a lottery ticket yielding €0 with 25% probability and a loss of €1 million with 75% probability. Which would you prefer? This situation is not as absurd as it might seem at first glance; many financial decisions involve choosing between the lesser of two evils. In this case, most subjects choose D, despite the fact that D is more risky than C. When faced with two choices that both involve losses, individuals seem to be "risk seeking", not "risk averse" as in the case of A-versus-B.

The fact that individuals tend to be risk averse in the face of gains and risk seeking in the face of losses can lead to some very poor financial decisions. To see why, observe that the combination of choices A-and-D is equivalent to a single lottery ticket yielding €240,000 with 25% probability and €760,000 with 75% probability, whereas the combination of choices B-and-C is equivalent to a single lottery ticket yielding €250,000 with 25% probability and €750,000 with 75% probability. The B-and-C combination has the same probabilities of gains and losses, but the gain is €10,000 higher and the loss is €10,000 lower. In other words, B-and-C is formally

[19] Reference the journal: "The adaptive Markets Hypothesis: Market Efficiency from an evolutionary perspective" (2004) – Andrew W. Lo

[20] Kahneman and Tversky's Prospect Theory - Kahneman and Tversky (1979). The above example is an abstract of the journal "The adaptive Markets Hypothesis: Market Efficiency from an evolutionary perspective" – Andrew W. Lo (2004).

equivalent to A-and-D plus a sure profit of €10,000. In light of this analysis, would you still prefer A-and-D?

A common response to this example is that it is contrived because the two pairs of investment opportunities were presented sequentially, not simultaneously. However, in a typical global financial institution, the London office may be faced with choices A and B and the Tokyo office may be faced with choices C and D. Locally, it may seem as if there is no right or wrong answer (the choice between A and B or C and D seems to be simply a matter of personal risk preferences) but the globally consolidated financial statement for the entire institution will tell a very different story. From that perspective, there is a right and wrong answer, and the empirical and experimental evidence suggests that most individuals tend to select the wrong answer. Therefore, according to the behavioralists, quantitative models of efficient markets (all of which are predicated on rational choice) are likely to be wrong as well.

Grossman (1976) and Grossman and Stiglitz (1980) go even further. They argue that perfectly informationally efficient markets are impossibility, because if markets are perfectly efficient, there is no profit to gathering information, in which case there would be little reason to trade and markets would eventually collapse. Alternatively, the degree of market inefficiency determines the effort investors are willing to expend to gather and trade on information; hence a non-degenerate market equilibrium will arise only when there are sufficient profit opportunities, i.e., inefficiencies, to compensate investors for the costs of trading and information-gathering. The profits earned by these attentive investors may be viewed as \economic rents" that accrue to those willing to engage in such activities. Who are the providers of these rents? Black (1986) gave us a provocative answer: \noise traders", individuals who trade on what they consider to be information but which is, in fact, merely noise.

The supporters of the EMH have responded to these challenges by arguing that while behavioral biases and corresponding inefficiencies do exist from time to time, there is a limit to their prevalence and impact because of opposing forces dedicated to exploiting such opportunities. A simple example of such a limit is the so-called "Dutch Book", in which irrational probability beliefs give rise to guaranteed profits for the savvy investor. Consider, for example, an event E, defined as "the S&P 500 index drops by 5% or more next Monday", and suppose an individual has the following irrational beliefs: there is a 50% probability that E will occur, and a 75% probability that E will not occur. This is clearly a violation of one of the basic axioms of probability theory (the probabilities of two mutually exclusive and exhaustive events must sum to one) but many experimental studies have documented such violations among an overwhelming majority of human subjects.

These inconsistent subjective probability beliefs imply that the individual would be willing to take both of the following bets B1 and B2:

B1 equals to €1 if E occurs, otherwise B1 equals to - €1.

B2 equals to €1 if E^c occurs, otherwise B2 equals to - €3.

where E^c denotes the event "not E". Now suppose we take the opposite side of both bets, placing €50 on B1 and €25 on B2. If E occurs, we lose €50 on B1 but gain €75 on B2, yielding a profit of €25. If E^c occurs, we gain €50 on B1 and lose €25 on B2, also yielding a profit of €25. Regardless of the outcome, we have secured a profit of €25, an "arbitrage" that comes at the expense of the individual with inconsistent probability beliefs. Such beliefs are not sustainable, and market forces (namely, arbitrageurs such as hedge funds and proprietary trading groups) will take advantage of these opportunities until they no longer exist, i.e., until the odds are in line with the axioms of probability theory (Only when these axioms are satisfied is arbitrage ruled out. This was conjectured by Ramsey (1926) and proved rigorously by de Finetti (1937) and Savage (1954)). Therefore, proponents of the classical EMH argue that there are limits to the degree and persistence of behavioral biases such as inconsistent probability beliefs, and substantial incentives for those who can identify and exploit such occurrences. While all of us are subject to certain behavioral biases from time to time, according to EMH supporters market forces will always act to bring prices back to rational levels, implying that the impact of irrational behavior on financial markets is generally negligible and, therefore, irrelevant.

But this last conclusion relies on the assumption that market forces are sufficiently powerful to overcome any type of behavioral bias, or equivalently, that irrational beliefs are not so pervasive as to overwhelm the capacity of arbitrage capital dedicated to taking advantage of such irrationalities. This is an empirical issue that cannot be settled theoretically, but must be tested through careful measurement and statistical analysis.

One anecdotal piece of evidence is provided by the collapse of fixed-income relative-value hedge funds in 1998 such as Long-Term Capital Management (LTCM). The default by Russia on its government debt in August 1998 triggered a global flight to quality, widening credit spreads to record levels and causing massive dislocation in fixed-income and credit markets. During that period, bonds with virtually identical cash flows and supposedly little credit risk exhibited dramatically different prices, implying extraordinary profit opportunities to those who could afford to maintain "spread" positions in which the cheaper bonds were purchased and the richer bonds were shorted, yielding a positive carry at the outset. If held to maturity, these spread positions would have generated payments and obligations that offset each other exactly, hence they were structured as near-arbitrages. But as credit spreads widened, the gap between the long and the short side grew larger because illiquid bonds became cheaper and liquid bonds became more expensive, causing brokers and other creditors to require holders of these spread positions to either post additional margin or liquidate a portion of their positions to restore their margin levels. These margin calls caused many hedge funds to start unwinding some of their spread positions, which caused spreads to widen further, which led to more margin calls, more unwinding, and so on, creating a cascade effect that ended with the collapse of LTCM and several other notable hedge funds.

In retrospect, even the most ardent critics of LTCM and other fixed-income relative value investors now acknowledge that their spread positions were quite rational, and that their demise was largely due to an industry-wide underappreciation of the commonality of their positions and the degree of leverage being applied across the many hedge funds, investment banks, and proprietary trading groups engaged in these types of spread trades. This suggests that the forces of irrationality investors (flocking to safety and liquidity in the aftermath of the Russian default in August 1998) were stronger, at least for several months, than the forces of rationality.

This example and many similar anecdotes of speculative bubbles, panics, manias, and market crashes have cast reasonable doubt on the hypothesis that an aggregate rationality will always be imposed by market forces.

CHAPTER 3

RANDOM WALK HYPOTHESIS

Random walk theory is strongly connected with the notion of the efficient market. It is a mathematical formalization of a trajectory that consists of taking successive random steps. Random walk theory infer results valuable to computer science, physics, ecology, economics, and a number of other fields as a fundamental model for random processes in time. Such are, the path traced by a molecule as it travels in a liquid or a gas, the search path of a foraging animal, the price of a fluctuating stock and the financial status of a gambler can all be modeled as random walks.

The random walk theory states that market and securities prices are random and not influenced by past events. The idea is also referred to as the weak form efficient-market hypothesis. A Random Walk Down Wall Street, written by Burton Malkiel (1973)[21], a Princeton economist, is an influential book on the subject of stock markets. Malkiel argues that asset prices typically exhibit signs of random walk and that one cannot consistently outperform market averages. The book is frequently cited by those in favor of the efficient market hypothesis.

For educational and intuition reasons, Burton Malkiel performed a test where his students were given a hypothetical stock that was initially worth fifty dollars. That test was occurred randomly, since the closing stock price for each day was determined by a coin flip. If the result was heads, the price would close a half point higher, but if the result was tails, it would close a half point lower. Thus, each time, the price had a fifty-fifty chance of closing higher or lower than the previous day. Cycles or trends were determined from the tests. Malkiel then took the results in a chart and graph form to a man who was trying to predict future movements by seeking to interpret past patterns on the assumption that "history tends to repeat itself". The man told Malkiel that they needed to immediately buy the stock. When Malkiel told him it was based purely on a flipping coin, the chartist was disappointed. Malkiel argued that this indicates that the market and stocks could be just as random as flipping a coin.

Not only through an economic perspective, the random walk hypothesis were examined but for psychological reasons too. It was applied to NBA basketball players, by psychologists who examined every shot the Philadelphia 76ers made, over one and a half seasons of basketball. The psychologists found no positive correlation between the previous shots and the outcomes of the shots afterwards. Economists and believers in the random walk hypothesis apply this to the stock market. The actual lack of correlation of past and present can be easily seen. If a stock goes up one day, no stock market participant can accurately predict that it will rise again the next. Just as a basketball player with extremely luck or a "hot hand" can miss the next shot, the stock that seems to be on the rise can fall at any time, making it completely random.

[21] Reference in the book "A Random Walk Down Wall Street"(1973) - Burton G. Malkiel

There are other economists, professors, and investors who believe that the market is predictable to some degree. These people believe that prices may move in trends and that the study of past prices can be used to forecast future price direction. There have been some economic studies that support this view, and a book written by that tries to prove that random walk hypothesis is wrong.

3.1 The meaning of Random Walk Hypothesis

The most important notion behind the random walk theory is that the randomness of stock prices tries to find price patterns or take advantage of new information futile. In particular, the theory claims that day-to-day stock prices are independent of each other, meaning that momentum does not generally exist and calculations of past earnings growth does not predict future growth. The random walk theory also states that all methods of predicting stock prices are futile in the long term. Burton Malkiel in his book says: "The notion of intrinsic value is undependable because it relies on subjective estimates of future earnings using factors like expected growth rates, expected dividend payouts, estimated risk, and interest rates".

The random walk theory also considers technical analysis undependable because, according to Malkiel, chartists buy only after price trends are established and sell only after price trends are broken; essentially, the chartists buy or sell too late and miss the boat. According to the theory, this happens because stock prices already reflect the information by the time the analyst moves on the stock. Malkiel also notes that the widespread use of technical analysis reduces the advantages of the approach.

Further, Malkiel finds fundamental analysis flawed because analysts often collect bad or useless information and then poorly or incorrectly interpret that information when predicting stock values. Factors outside of a company or its industry may affect a stock price, rendering further the fundamental analysis irrelevant.

There are two forms of the random walk theory. In both forms, the rapid incorporation of information is disadvantageous for investors and analysts. The semi-strong form states that public information will not help an investor or analyst select undervalued securities because the market has already incorporated the information into the stock price. The strong form states that no information, public or private, will benefit an investor or analyst because even inside information is reflected in the current stock price

Not only in market efficiency, but also in the random walk theory there are statistical anomalies that reveal some exceptions:

1. High-dividend stocks tend to provide higher returns over time because during down markets the high dividend yields often create demand for these stocks and thus increases the price.

2. Stocks with low P/E ratios tend to outperform those with high P/Es, although the tendency is volatile over time.

3. There are seasonal trends in the stock market, especially at the beginning of the year and the end of the week.

4. Contrarian strategies tend to outperform other strategies because reversals are often based on economic facts rather than investor psychology.

5. Prices of small, less liquid stocks seem to have some serial price correlation in the short-term because they do not incorporate information into their prices as quickly.

In contrary to the above, professors Andrew W. Lo and Archie Craig MacKinlay (2001)[22], professors of Finance at the MIT Sloan School of Management and the University of Pennsylvania, respectively, have also tried to prove the random walk theory wrong. They wrote the book "A Non-Random Walk Down Wall Street", which goes through a number of tests and studies that try to prove there are trends in the stock market and that they are somewhat predictable.

They prove it with what is called the simple volatility-based specification test, which is an equation that states:

$$X_t = \mu + X_{t-1} + \varepsilon_t$$

where,

X_t is the price of the stock at time t

μ is an arbitrary drift parameter

ε_t is a random disturbance term.

With this equation, they have been able to put in stock prices over the last number of years, and figure out the trends that have unfolded. They have found small incremental changes in the stocks throughout the years. Through these changes, Lo and MacKinlay believe that the stock market is predictable, thus contradicting the random walk hypothesis. Lo and MacKinlay have authored a paper, the Adaptive Market Hypothesis[23], which puts forth another way of looking at predictability of price changes.

3.2 The importance of Random Walk Hypothesis

The random walk theory states that it is impossible to consistently outperform the market, particularly in the short-term, because it is impossible to predict stock prices. This may be controversial, but by far the most controversial aspect of the theory is its claim that analysts and professional advisors add little or no value to portfolios. As B. Malkiel mentions, "Investment advisory services, earnings predictions, and complicated chart patterns are useless...Taken to its logical extreme, it means that a blindfolded monkey throwing darts at a newspaper's financial pages

[22] A Non-Random Walk Down Wall Street.(2001) - Andrew W. Lo & A. Craig MacKinlay

[23] The *Adaptive Market Hypothesis*, as proposed by Andrew Lo (2004,2005), is a new framework that reconciles theories that imply that the markets are efficient with behavioral alternatives, by applying the principles of evolution - competition, adaptation, and natural selection - to financial interactions.

could select a portfolio that would do just as well as one carefully selected by the experts." He also provides considerable support to the intimidated individual investor, but in particular encourages investors to understand the theories and investment methods that the random walk theory challenges.

3.3 Market Efficiency and the Random Walk theory

The idea that security prices follow random walk was introduced by Bachelier in 1900. He used this term to refer to successive price changes which are independent of each other. In other words, tomorrow's price changes (and therefore tomorrow's price) cannot be predicted by looking at today's price change, $P_{t+1} - P_t$ is independent of $P_t - P_{t-1}$.

More recently, the first serious application of the Random Walk Hypothesis to financial markets can be traced back to Paul Samuelson (1965)[24], whose contribution is summarized by the title of his article: "Proof that Properly Anticipated Prices Fluctuate Randomly". Samuelson indicates that in informationally efficient market prices changes must be unforecastable if they fully incorporate the expectations and information of all market participants. Malkiel B. also indicates that the efficient market hypothesis is associated with the idea of "random walk". The random walk idea is that if the flow of information is immediately reflected in stock prices, then tomorrow's price change will reflect only tomorrow's news and will be independent of the price changes today. On the other hand, news is by definition unpredictable and, thus, price changes must be unpredictable and random. This leads to the fact that prices fully reflect all known information, and even uniformed investors buying a diversified portfolio will gain a rate of return as generous as that the experts will achieve. For Malkiel, efficiency means that investors are not allowed to earn above-average risk- adjusted returns.

Poshakwale S., among other analysts, also, recognizes that the efficient market hypothesis is inextricably related to the random walk theory. As with all tests of theories involving future expected prices or returns, past actual prices or returns are used for the tests. As far as the random walk theory concerns, sets of share price changes are tested for serial independence. Random walk theory for share prices reflects a securities market where new information is rapidly incorporated into prices and where "excess" returns cannot be made from spotting trends or from trading new information.

That share prices which appear to follow a random walk is an interesting result and either proving it or disproving it, occupied many analysts in the 1970s. What remained to be shown was why share prices followed a random walk. There was plenty of evidence, but a formal theory was missing. What was needed was a model of share price behavior to explain the random walk. The gap was filled by more general model based on the concept of the efficiency- the efficient market hypothesis (EMH). According to Andor G. and Ormos M. the random walk model assumes that successive returns are independent and that the returns are identically distributed over time. The random walk model is a restricted version of the efficient market theory.

[24] Proof that Properly Anticipated Prices Fluctuate Randomly.(1965) - Paul Samuelson

The efficient market hypothesis does not require identical return distribution in the various periods, furthermore it does not imply the returns independent through time. So the random walk is a sufficient but not necessary condition to fulfill the weak form of efficient market.

3.4 Random Walk Hypothesis - Index 1[25]

Stochastic process	Description	Applicability to real markets	Notes
iffusion Process	Satisfies the diffusion equation	poor	Regnault (1863) and Osborne (1959) discovered that price deviation is proportional to the square root of time, but the nonstationarity found by Kendall (1953), Houthakker (1961) and Osborne (1962) compromises the significance of the process.
aussian Process	Increments normally distributed	poor	Financial markets exhibit leptokurtosis (Mitchell (1915, 1921), Olivier (1926), Mills (1927), Osborne (1959), Larson (1960), Alexander (1961)).
Lévy Process	Stationary independent increments	poor	Kendall (1953), Houthakker (1961) and Osborne (1962) found nonstationarities in markets in the form of positive autocorrelation in the variance of returns.
Markov Process	Memoryless	poor	Kendall (1953), Houthakker (1961) and Osborne (1962) found positive autocorrelation in the variance of returns.
Martingale	Zero expected return	sub martingale: good for stock market	Bachelier (1900) and Samuelson (1965) recognized the importance of the martingale in relation to an efficient market. Whilst Cox and Ross (1976), Lucas (1978) and Harrison and Kreps (1979) pointed out that in practice investors are risk averse, so (presumably as compensation for the time value of money and systematic risk) they demand a positive expected return. In a long-only market like a stock market this implies that the price of a stock follows a sub martingale (a martingale being a special case when investors are risk-neutral).
Random walk	Discrete version of Brownian motion	poor	LeRoy (1973) and (especially) Lucas (1978) pointed out that a random walk is neither necessary nor sufficient for an efficient market.
Wiener rocess/Brownian motion	Continuous-time, Gaussian independent increments	poor	Bachelier (1900) developed the mathematics of Brownian motion and used it to model financial markets. Note that Brownian motion is a diffusion process, a Gaussian process, a Lévy process, a Markov process and a martingale. On the one hand this makes it a very strong condition (and therefore the least realistic), on the other hand it makes it a very important 'generic' stochastic process and is therefore used extensively for modeling financial markets (for example, see Black and Scholes (1973)).

[25] In the above index the information has been collected from the site: www.e-m-h.org. The purpose of that index is informative only and has nothing to do with personal research.

CHAPTER 4

VARIANCE RATIO TEST

4.1 A review of past studies on stock market efficiency

In several journals is referred that the first studies on weak-form market efficiency, primarily examined serial correlation of price changes. Specifically, the pioneering work of Kendall (1953)[26] and Fama (1965)[27] on the random walk hypothesis observed no serial correlation in returns, providing evidence in support of the weak-form efficient market hypothesis. Another comprehensive review of the early literature on market efficiency also provided overwhelming support for the efficient market hypothesis. The subsequent empirical work, however, has provided mixed results.

Testing for the random walk model proved to be essential for the empirical finance literature, since it is valuable of the weak-form efficient market hypothesis. The tests that performed are two: The unpredictable stock returns using past price information and the linearity of variance of return with holding period. There have been a lot of past studies but the latter using the variance ratio test proposed by Lo and MacKinlay (1988)[28].

The most important studies on the random walk hypothesis emerged in the 1980s. Most of these studies provided evidence against the random walk hypothesis with remarkable methodology. This evidence of market inefficiency was explained in terms of market overshooting (Dedondt and Thaler, 1985), noise trading (Black, 1986), time-varying risk and returns (Lo and MacKinlay, 1988) and fads (fads means that there is a tendency towards herding in the market) (Lehmann, 1990). Two major studies in the cohort of the second generation studies are Poterba and Summers (1988) and Fama and French (1988). Among competing statistical techniques of testing for the random walk hypothesis, Poterba and Summers (1988) preferred the variance ratio test. Investigating monthly returns for the US and 17 other stock markets, they observed negative serial correlation in the long horizon and positive serial correlation in the short horizon, which provided evidence in support of the mean reversion property, contrary to the random walk hypothesis. They concluded that serial correlation was attributed to noise trading, not fundamental factors. Their study highlighted the possibility that the finding on the random walk hypothesis might be sensitive to sampling intervals. This issue was examined comprehensively by Fama and French (1988). They used an adjusted OLS model to estimate autocorrelation

[26] The analysis of economic time series. Journal of the Royal Statistical Society Series A. (1953) - Kendall M.

[27] The behavior of stock market prices. (1965) - Fama, E.,

[28] Lo, A.W., MacKinlay, A.C., 1988. Stock market prices do not follow random walks: evidence from a simple specification test. The Review of Financial Studies

coefficients for 1 to 10 years of real returns. In general, their results indicated a U-shape pattern in autocorrelation coefficients with respect to investment horizons and provided some evidence against the random walk hypothesis. However, these results were primarily driven by data from pre-World War II period. The evidence of the U-shape and large autocorrelations was much weaker in the post-World War II period.

Following the works of Poterba and Summers (1988) and Fama and French (1988), many researchers attempted to use alternative tests for a random walk hypothesis and challenged the earlier findings. For example, Lo (1991) used modified rescaled range test (R/S test) to demonstrate absence of long-term memory in stock prices and support the random walk hypothesis. Further studies also reached the same conclusion using the joint test of modified R/S test and the variance ratio test (see Chow and Denning, 1993; Richardson, 1993). Using the variance ratio test and the modified rescaled range test, Coggin (1998) and Berneburg (2004) were also unable to reject the random walk hypothesis for the US and European equity indexes, respectively.

Numerous journals have been published during the last ten yaears in order to test the efficiency of stock markets. The table bellow presents a concise summary of the findings of selected studies in Asian stock markets, indicating the methodologies used and the types of applying data. Generally, the results were sensitive to the sampling frequency. The hypothesis of weak-form efficiency could be rejected using daily data, but not using lower frequency data (weekly, monthly, quarterly, etc.). This finding is consistent with the notion of slow price adjustment in response to a shock, which might be attributed to regulatory constraints such as the system of stock price limits and the extent of domestic financial market liberalization. Overall, the past studies on Asian stock market efficiency provide mixed results, although they tend to indicate that the emerging Asian markets are not efficient in the weak-form.

However, the results are scattered over numerous studies, and many of them are too outdated to reflect the impact of the Asian crisis and gradual effects of financial liberalization.

Past studies testing market efficiency of Asian countries applying Variance Ratio tests[29]

Studies	Data and methodology	Markets	RWH hypothesis
Mun and Kee (1994)	DW, 1982–1991 VR, Spectral shape test	HK, KOR, THA, MAL, TAW	Rejected for all countries with daily data Rejected only MAL and THA with weekly data
Ayadi and Pyun (1994)	D, W, M, 2M, Q, 1984–1998 VR	KOR	Rejected with daily data Not rejected with lower frequency data
Huang (1995)	W 1988–1992 VR, ADF	HK, IND, KOR, JAP PHI, SIN, THA, TAW	Rejected for KOR, MAL, HK, SIN, THA
Kawakatsu and Morey (1999)	M, 1976–1997 VR, MVR, ADF	KOR, MAL, PHI, TAW, THA	Find little evidence that financial market liberalization improves efficiency
Ryoo and Smith (2002)	D, 1988–1998 MVR	KOR	The market approaches RW as price limits are relaxed frequency data
Chang and Ting (2000)	W, M, Q, Y, 1971–1996 VR	TAW	Rejected with daily data Not rejected with lower frequency data
Peng et al. (2004)	W, 1993–2002 Chaos theory	TAW	Rejected
Lima and Tabak (2004)	D, 1992–2000 MVR	China, HK, SIN	Rejected for China and SIN
Lee et al. (2001)	D, 1990–1997 VR, ADF	China	Rejected
Hoque et al. (in press)	W, 1990–2004 VR, MVR, W	HK, IND, KOR, MAL PHI, SIN, THA, TAW	Rejected except for KOR and TAW

- D: daily, W: weekly, M: monthly, Q: quarterly, Y: annual;
- VR: Lo and MacKinlay variance ratio test; MVR: Chow and Denning multiple variance ratio test, W: Wright's sign test; ADF: Augmented Dickey and Fuller Test;
- HK: Hong Kong; JAP: Japan, KOR: Korea, TAW: Taiwan, IND: Indonesia, PHI: Philippines; MAL: Malaysia, THA: Thailand, SIN: Singapore;

All studies listed in this table used aggregate stock market indices to test market efficiency.

[29] Are Asian stock markets efficient? Evidence from new multiple variance ratio tests - Jae H. Kim & Abul Shamsuddin. The index provide results that have been collected from the mentioned journal. It is a pivot table and has nothing to do with personal research, but only with comparative reasons.

4.2 Important studies on various stock markets using Variance Ratio tests

Lo and MacKinlay's individual VR test is one of the most important early studies on the RWH in emerging markets. Ayadi and Pyun (1994) find the Korean equity market meanreverting while Huang (1995) rejects the RWH for the markets of Korea, Malaysia, Hong Kong, Singapore and Thailand. Interestingly, Chang and Ting (2000) show that the RWH is fairly accepted for the Taiwan Stock Exchange with monthly, quarterly and annual data, but it is rejected with weekly returns. Evaluating stock exchanges in China, Darrat and Zhong (2000) and Lee, Chen, and Rui (2001) reject the RWH.

For Latin American stock markets, Urrutia (1995) test the Argentine, Brazil, Chile and Mexico stock exchanges while Grieb and Reyes (1999) study the Brazil and Mexico exchanges. Both studies find that Latin American markets to follow the random walk behavior.

Many studies of Chow–Denning's multiple VR tests evaluate the RWH in emerging stock markets. For instance, Kawakatsu and Morey (1999) study 16 sample emerging markets using a battery of econometric tests. Their results from the Chow–Denning tests reveal that the random walk cannot be rejected before and after financial liberalization for most countries they investigated. Ryoo and Smith (2002) find that the Korean stock market as a whole follows a random walk, and Abraham, Seyyed, and Alsakran (2002) show that the RWH cannot be rejected for the Kuwaiti, Saudi Arabian, and Bahrain markets when observed index levels are used but the inferences are reversed with the index data corrected to take into account infrequent trading of small-firm stocks in the three markets.

Another investigation by Smith et al. (2002) performed for eight emerging stock markets in Africa (Egypt, South Africa, Zimbabwe, Morocco, Kenya, Nigeria, Botswana, and Mauritius) and find the RHW is rejected for all except the South African market. For emerging markets in Europe, Smith and Ryoo (2003) reject the RWH for the stock markets of Greece, Hungary, Poland, and Portugal, but they find the Turkey market following a random walk. For Asian emerging markets, Lima and Tabak (2004) report the existence of a random walk for Hong Kong and class A share (available only to domestic investors) and rejections of RWH for Singapore and class B share (available only to foreign investors) of the two Chinese stock exchanges. Lastly, Buguk and Brorsen (2003) apply both Chow–Denning multiple VR and Wright's (2000) rank and sign VR tests for the Istanbul stock exchange. The two tests give mixed results. Hence, while the multiple VR test finds a random walk, the Wright's nonparametric test shows some evidence against a random walk.

4.3 Most Important Variance Ratio Tests

1) Lo and MacKinlay Variance Ratio test.[30]

Central to the evaluation of the RWH is a mean-reverting pattern of stock returns. If the price of a stock is meanreverting, its return is predictable from before in the form of a systematic pattern in its dependence on past prices. On the other hand, if the stock price follows a random walk or martingale, the stock return is unpredictable from past price information.

Suppose that x_t is an asset return at time t, where t=1,...,T. Following Wright (2000), we write

$$VR(x;k) = \left\{\frac{1}{Tk}\sum_{t=k}^{T}(x_t + x_{t-1} + \cdots + x_{t-k+1} - k\hat{\mu})^2\right\} \div \left\{\frac{1}{T}\sum_{t=1}^{T}(x_t - \hat{\mu})^2\right\} \quad (1)$$

where, $\hat{\mu} = T^{-1}\sum_{t=1}^{T} x_t$. This is an estimator for the unknown population VR, denoted as V(k), which is the ratio of $1/k$ times the variance of the k -period return to the variance of the one-period return. Lo and MacKinlay (1988) showed that if x_t is independent and identically distributed (IID), then under the null hypothesis that $V(k)=1$,

$$M_1(x;k) = (VR(x;k) - 1)\left\{\frac{2(2k-1)(k-1)}{3kT}\right\}^{-1/2} \quad (2)$$

follows the standard normal distribution asymptotically. To accommodate x_t's exhibiting conditional heteroskedasticity, Lo and MacKinlay (1988) proposed an heteroskedasticity robust test statistic

$$M_2(x;k) = (VR(x;k) - 1)\left\{\sum_{j=1}^{k-1}\left[\frac{2(k-j)}{k}\right]^2 \delta_j\right\}^{-\frac{1}{2}} \quad (3)$$

which follows the standard normal distribution asymptotically under null hypothesis that V(k)=1, where

$$\delta_j = \left\{\sum_{t=j+1}^{T}(x_t - \hat{\mu})^2(x_{t-j} - \hat{\mu})^2\right\} \div \left\{\sum_{t=1}^{T}(x_t - \hat{\mu})^2\right\}^2$$

---

[30] Lo, A. W., & MacKinlay, A. C. (1988). Stock market prices do not follow random walks: Evidence from a simple specification test.

The M_2 test is applicable to x_t's generated from a martingale difference time series (see Assumption H* of Lo and MacKinlay, 1988). The usual decision rule for the standard normal distribution applies to both tests.

2) Multiple Variance Ratio Test By Chow And Denning (1993).

Chow and Denning (1993) provide a multiple VR test for the joint null hypothesis $V(k_i) = 1$ for i = 1,..., m against the alternative that $V(k_i) \neq 1$ for some holding period k_i. The (heteroscedasticity-robust) test statistic can be written as

$$MV_1 = \sqrt{T} \max_{1 \le i \le l} |M_1(x; k_i)| , \quad (4)$$

This is based on the idea that the decision regarding the null hypothesis can be made based on the maximum absolute value of the individual VR statistics. The statistic follows the studentized maximum modulus [SMM] distribution with m and T degrees of freedom, i.e., $SMM(a, l, T)$, where l is the number of k values, whose critical values are tabulated in Stoline and Ury (1979)[31]. When T is large, the null hypothesis is rejected at a level of significance if the $MV(x; ki)$ statistic is greater than the $[1-(\alpha^*/2)]$th percentile of the standard normal distribution where $\alpha^*=1-(1-\alpha)^{1/l}$. Similarly, the heteroskedasticity–robust version of the Chow and Denning test MV_2 can be written as

$$MV_2 = \sqrt{T} \max_{1 \le i \le l} |M_2(x; k_i)| , \quad (5)$$

which is a joint test using $M_2(x,k)$ given in (3), and it has the same critical values as MV_1.

3) Wright's rank and sign VR tests

As mentioned above both Lo and MacKinlay and Chow and Denning tests are asymptotic tests, whose sampling distributions are approximated based on their limiting distributions. Lo and MacKinlay (1988) find that the sampling distribution of the VR statistic can be far from normal in finite samples, showing severe bias and right skew. These finite sample deficiencies may give rise to serious size distortions or low power, which can lead to misleading inferences. This is especially true when the sample size is not large enough to justify asymptotic approximations. As Deo and Richardson (2003)[32] point out, the Lo and MacKinlay test is inconsistent with respect to the variety of meanreverting alternatives where the limiting power function is bounded by a number less than one. In this respect, Wright's (2000) tests have two advantages over Lo and MacKinlay and Chow and Denning tests when sample size is relatively small:

---

[31] Tables of the studentized maximum modulus distribution and an application to multiple comparisons among means. (1979) - Stoline, M.R., Ury, H.K.

[32] On the asymptotic power of the variance ratio test (2003) - Deo R. S., & Richardson, M.

(i) as the sign and rank tests have exact sampling distribution, there is no need to resort to asymptotic approximation and

(ii) the tests may be more powerful than the conventional VR tests when the data are highly non-normal (Wright, 2000).

Wright (2000) derives rank and sign statistics as follows. Let r(x_t) be the rank of x_t among x_t's. Consider the standardized rank r_{1t}=[(r(x_t)−0.5(T+1) / [(T−1)(T+1) / 12]. Under the null hypothesis that x_t is generated from an IID sequence, r(x_t) is a random permutation of the numbers of 1, …, T with equal probability. Wright (2000) suggests the

$$R_1 = \left(\frac{\frac{1}{Tk}\sum_{t=k+1}^{T}(r_{1t} + r_{1t-1} \dots + r_{1t-k})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{1t}^2} - 1 \right) \times \left(\frac{2(2k-1)(k-1)}{3kT} \right)^{-\frac{1}{2}} \quad (6)$$

and

$$R_2 = \left(\frac{\frac{1}{Tk}\sum_{t=k+1}^{T}(r_{2t} + r_{2t-1} \dots + r_{2t-k})^2}{\frac{1}{T}\sum_{t=1}^{T} r_{2t}^2} - 1 \right) \times \left(\frac{2(2k-1)(k-1)}{3kT} \right)^{-\frac{1}{2}} \quad (7)$$

where

$$r_{1t} = r(y_t) - \frac{T+1}{2} / \sqrt{\frac{(T-1)(T+1)}{12}} \qquad \text{and} \qquad r_{2t} = \Phi^{-1} r(y_t)/(T+1)),$$

where, $r(y_t)$ be the rank of y_t among $y_1, y_2, \dots, y_T$. Φ is the standard normal cumulative distribution function. The variance-ratio test based on the signs of increments rather than ranks can be defined as follows:

$$S_1 = \left(\frac{\frac{1}{Tk}\sum_{t=k+1}^{T}(s + s_{t-1} \dots + s_{t-k})^2}{\frac{1}{T}\sum_{t=1}^{T} s_t^2} - 1 \right) \times \left(\frac{2(2k-1)(k-1)}{3kT} \right)^{-\frac{1}{2}} \quad (8)$$

if μ=0, then S_1 has the same distribution as:

$$\left(\frac{\frac{1}{Tk}\sum_{t=k+1}^{T}(s_t^* + s_{t-1}^* \dots + s_{t-k}^*)^2}{\frac{1}{T}\sum_{t=1}^{T} s_t^{*2}} - 1 \right) \times \left(\frac{2(2k-1)(k-1)}{3kT} \right)^{-\frac{1}{2}}$$

where, $\{s^*{}_t\}_{t-1}^{T}$ is an *IID* sequence, each element of which is 1 with probability 0.5 and -1 otherwise. The test S_2, which is related to the conservative test that a series is a random walk with drift (see, Campbell and Dufour, 1997), controls for the probability of Type I error in finite samples and is robust to conditional heteroskedasticity.

As we see from the alternative variance-ratio tests proposed by Wright, his rank based variance-ratio tests simply substitute r_{1t} and r_{2t} in place of y_t as defined in M_1, noting that these ranks have mean 0 and variance 1. Wright (2000) claims that the rank tests R_1 and R_2 always have better power than either of the M_1 and M_2 tests of Lo and MacKinlay. Both R_1 and R_2 dominate the heteroskedasticity-robust test M_2 in power. Wright also shows that even though the sign-based tests generally have less power than the rank-based tests, they still have more power than the variance-ratio tests of Lo and MacKinlay. These ranks-and signs-based variance-ratio tests have substantially improved power with little or no risk of size distortions.

The critical values for Wright's (2000) R_1 and R_2 tests are calculated by simulating their exact sampling distributions. We do not consider Wright's (2000) S_1 and S_2 test, because in Monte Carlo simulation, Wright found that the size and power properties of S_2 are inferior to those of S_1. Index 2 shows the critical values for R_1 and R_2 test statistics associated with the sample sizes and holding periods.

The variance-ratio tests are examined for several values of k and T. The null hypothesis can be soundly rejected when the test statistics are rejected for all k. However, the hypothesis can be rejected if there are more than two rejections.

Index 2, Critical values for Wright's R1 and R2 tests

K	T=100	T=150	T=500	T=750	T=2500
R1					
2	-2.18, 1.68	-2.12,1.79	-2.06, 1.84	-2.02, 1.90	-1.97, 1.91
3	-2.09, 1.65	-2.08 1.76	-2.04, 1.87	-	-
4	-2.04, 1.62	-2.04 1.77	-2.05, 1.83	-1.99, 1.88	-1.99, 1.91
5	-2.02, 1.57	-2.02 1.75	-2.05, 1.84	-	-
8	-	-	-1.99, 1.83	-1.95, 1.89	-1.95, 1.92
16	-	-	-1.935 1.68	-1.93, 1.82	-1.97, 1.88
R2					
2	-2.17, 1.68	-2.11 1.75	-2.06, 1.86	-2.04, 1.89	-1.96, 1.91
3	-2.07, 1.65	-2.10 1.76	-2.05, 1.87	-	-
4	-2.05, 1.60	-2.08 1.77	-2.06, 1.86	-1.97, 1.85	-2.02, 1.93
5	-2.00, 1.60	-2.03 1.76	-2.05, 1.85	-	-
8	-	-	-1.98,1.81	-1.94, 1.85	-1.96, 1.91
16	-	-	-1.93, 1.71	-1.93, 1.76	-1.97, 1.85

4) Whang–Kim subsampling test.

The Whang and Kim test uses the subsampling technique of Politis, Romano, and Wolf (1997), which is a data-intensive method of approximating the sampling distribution. It can show better properties than the conventional VR tests when the sample size is relatively small. The Monte Carlo experiment results reported in Whang and Kim (2003) confirm that their new VR test shows excellent power in small samples, coupled with little or no serious size distortions.

To test the null hypothesis that $V(ki)=1$ (i=1, …, l), Whang and Kim (2003) consider the statistic

$$MV_3 = \sqrt{T} g_N(x_1, \dots, x_T), \quad (9)$$

Where $g_t(x_1, \dots x_T) = max_{1 \le i \le l} |VR(x; ki) - 1| and\ VR(x; k)$ is defined in (1). The sampling distribution function for the MV_3 statistic is written as

$$G_T(x) = P(\sqrt{T} g_T(x_1, \dots, x_T) \le x. \quad (10)$$

Since the distribution function given in (10) is unknown and analytically intractable, Whang and Kim (2003) use the following approximation. Consider a subsample $(x_t, \dots, x_{t-b+1})$ of size b for t=1, ..., T−b+1. The statistic MV_3 calculated from the subsample is denoted as $g_T, b, t = gb(x_t, \dots, x_{t-b+1})$. Then, GT(x) is approximated by the distribution function obtained by the collection of g_T,b,t's calculated from all individual subsamples. It can be written as

$$\hat{G}_{T,b}(x) = (T - b + 2)^{-1} \sum_{t=0}^{T-b+1} l(\sqrt{b} g_{T,b,t} \le x),$$

where $l(.)$ is the indicator function that takes 1 if the condition inside the bracket is satisfied and 0 otherwise.

The 100(1−α)% critical value for the test can be calculated as the (1−α)th percentile of $\hat{G}$b,T, while the p-value of the test is estimated as $1-\hat{G}_{T,b}(MV_3)$. The null hypothesis that V(ki)=1 (i=1,..., l) is rejected at the level of significance α if the observed MV_3 is greater than this critical value or if the p-value is less than α. To implement the subsampling technique, a choice of block length b should be made. Whang and Kim (2003) recommend that a number of block lengths from an equally spaced grid in the interval of $[2.5T^{0.3}, 3.5T^{0.6}]$ be taken. However, they find that the size and power properties of their test are not sensitive to the choice of block length.

Developed Markets

America	Europe	Pacific
Canada	Austria	Austria
United States	Belgium	Hong Kong
	Denmark	Japan
	Finland	New Zealand
	France	Singapore
	Germany	
	Greece	
	Ireland	
	Italy	
	Netherlands	
	Norway	
	Portugal	
	Spain	
	Sweden	
	Switzerland	
	United Kingdom	

Emerging Markets

America	Europe, Middle East & Africa	Asia
Brazil	Czech Republic	China
Chile	Egypt	India
Colombia	Hungary	Indonesia
Mexico	Israel	Korea
Peru	Morocco	Malaysia
	Poland	Philippines
	Russia	Taiwan
	South Africa	Thailand
	Turkey	

Frontier Markets

America	Central & Eastern Europe & CIS	Africa	Middle East	Asia
Argentina	Bulgaria	Botswana	Bahrain	Pakistan
Jamaica	Croatia	Ghana	Jordan	Sri Lanka
Trinidad & Tobago	Estonia	Kenya	Kuwait	Vietnam
	Lithuania	Mauritius	Lebanon	
	Kazakhstan	Nigeria	Oman	
	Romania	Tunisia	Qatar	
	Serbia		Saudi Arabia	
	Slovenia		UAE	
	Ukraine			

Source: MSCI (Morgan Stanley Capital International) - International Equity Indices, Market and Country coverage.

Chapter 5

EMPIRICAL RESULTS

The first group of indices demonstrates that variance ratio estimates and test statistics of RWH for 22 countries during the periods 1/1/1973 up to 14/5/2009 for some developed countries, 1/7/1994 up to 14/5/2009 for some emerging countries and 2/10/2000 up to 14/5/2009 for some frontier countries based on the methodology of conventional variance ratio test by Lo and MacKinlay (1988). The level of significance is considered to be 5% and the holding periods (*k*'s) are [10, 20, 40, 80] for daily results, [2, 4, 8, 16] for weekly results and [2, 3, 4, 5] for monthly results. It is considered functional the use of different periodical lags (*k*'s) and data with diverse seasonality because that will depict better the efficiency of each market and how reliable the test is. The critical value for 1%, 5%, and 10% of significance level is 2.576, 1.96 and 1.65 respectively. For that test the tested area is $-1.96 \leq Mi \leq 1.96$ for i=1,2.

Indices 3 report the results of Multiple Variance Ratio Test by Chow and Denning (1993), for the same countries using daily, weekly and monthly data. In that test the k period is 16. That is because there is not available bibliography for critical values with different k's. The critical value for *k*=16 and significance level 1%, 5%, and 10% is 3.022, 2.491 and 2.226 respectively. So for the examined significance level, if $MVi \geq 2.491$, for i=1,2, null hypothesis is rejected.

Indices number 4 show how efficient the 22 markets are, testing the random walk hypothesis under the Wright's (2000) R1 and R2 rank tests which always have better power than either of the M1 and M2 tests of Lo and MacKinlay. The data and the *k*-periods are the same as the first test. The critical values in 5% of significance level are given above in index 1.

The last group of indices displays the results of Whang and Kim's (2003) test for the same developed, emerging and frontier markets. For that test monthly data are too limited that results would be unreliable, hence only daily and weekly data have been used. The authors recommend that a number of block lengths from an equally spaced grid in the interval of $[2.5T^{0.3}, 3.5T^{0.6}]$ should be taken. So, different blocks (b) have been calculated for daily and weekly data, where T varies to each group of countries. To accept the null hypothesis PValue should be over 1%, 5% or 10% respectively to the desired significance level. So if PValue≤0.05 the null is rejected.

5.1 Empirical results for developed countries

In **Lo and MacKinlay**'s test the null of RWH is soundly accepted for the heteroskedastic M_2 test, using daily, weekly or monthly data for every country and every value of k. On the other hand, the results with homoskedastic M_1 test vary between countries and k-periods. Hence, applying daily data the null is accepted for France and Japan and rejected for Canada and Italy. Additionally U.S.A's and United Kingdom's market seems to be efficient for *k* equals to 40 and 80, while for Germany the null is rejected for that values. The results for weekly data are consistent for Germany, France, Japan, USA and United Kingdom, while for Italy and Canada the hypothesis is rejected. Finally, the results using monthly data show rejection for every country except Japan.

Index 3.1.1, Daily Data

Developed Markets

COUNTRY	k	M_1	M_2
GERMANY	10	0.7444	0.2639
	20	0.9750	0.3459
	40	2.1025**	0.7690
	80	2.5804***	1.0123
CANADA	10	3.8100***	0.9444
	20	2.7502***	0.6731
	40	3.8408***	0.9602
	80	4.2118***	1.1150
FRANCE	10	-1.6889*	-0.5692
	20	-0.7219	-0.2440
	40	0.8917	0.3095
	80	0.9804	0.3608
ITALY	10	2.2737**	1.0384
	20	3.3375***	1.5313
	40	3.4353***	1.6204
	80	2.8583***	1.4270
JAPAN	10	-0.6314	-0.3563
	20	0.1586	0.0950
	40	1.0771	0.6811
	80	1.3018	0.8673
U.S.A	10	-4.6259***	-1.6334
	20	-2.8704***	-1.0011
	40	-1.5429	-0.5487
	80	-0.8392	-0.3157
UNITED KINGDOM	10	-4.2811***	-1.4984
	20	-3.1431***	-1.1050
	40	-1.2573	-0.4555
	80	0.0144	0.0055

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 3.1.2, Weekly Data

Developed Markets

COUNTRY	k	M_1	M_2
GERMANY	2	-0.1660	-0.0508
	4	0.6123	0.1875
	8	1.8338*	0.5863
	16	2.0919**	0.7341
CANADA	2	0.2424	0.0506
	4	1.0502	0.2431
	8	2.5046**	0.6483
	16	2.7702***	0.7607
FRANCE	2	0.1726	0.0639
	4	0.9295	0.3525
	8	2.0916**	0.8154
	16	1.4797	0.5814
ITALY	2	2.0850**	0.9360
	4	3.7071***	1.7308*
	8	3.5072***	1.7509*
	16	2.5571**	1.3453
JAPAN	2	-1.6238	-1.0777
	4	0.1302	0.0896
	8	1.5601	1.0902
	16	1.8238*	1.2935
U.S.A	2	-3.1579***	-1.0222
	4	-1.0655	-0.3724
	8	-0.3261	-0.1225
	16	-0.2749	-0.1106
UNITED KINGDOM	2	-2.5198**	-1.0525
	4	-1.2335	-0.4781
	8	0.4537	0.1722
	16	0.8867	0.3422

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 3.1.3, Monthly Data

Developed Markets

COUNTRY	k	M_1	M_2
GERMANY	2	3.2149***	1.2431
	3	2.7309***	1.0741
	4	3.1946***	1.2767
	5	3.6391***	1.4736
CANADA	2	4.9578***	1.3384
	3	4.1350***	1.1848
	4	4.3870***	1.3308
	5	5.0047***	1.5852
FRANCE	2	3.5369***	1.4699

	3	2.4659**	1.0557
	4	2.6745***	1.1641
	5	3.2216***	1.4088
ITALY	2	2.7310***	1.4888
	3	2.2064**	1.2395
	4	2.6061***	1.4969
	5	3.1443***	1.8313*
JAPAN	2	1.6220	1.0184
	3	1.2173	0.7752
	4	1.3278	0.8639
	5	1.4100	0.9370
U.S.A	2	2.9659***	1.0762
	3	1.9090*	0.7215
	4	2.2912**	0.8988
	5	2.9092***	1.1725
UNITED KINGDOM	2	4.5503***	1.8157*
	3	4.5313***	1.9049*
	4	4.8562***	2.1390**
	5	5.4033***	2.4631**

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

The results using the variance ratio test of **Chow and Denning** are mixed. Under the conditions of heteroskedasticity the null hypothesis is strongly accepted for all data and every market, with the exception of United Kingdom's market for monthly data. In contrast, the MV_1 test provides the evidence of random walk behavior only for Germany and France for daily data, for Germany, France, Japan and United Kingdom for weekly data and Japan for monthly data.

Index 3.2.1, Daily Data | q=16

Developed Markets

COUNTRY	MV_1	MV_2
GERMANY	1.8433	0.6623
CANADA	6.7028***	1.7417
FRANCE	1.9712	0.6641
ITALY	3.5365***	1.7299
JAPAN	3.5792***	1.7239
U.S.A	4.6431***	1.6524
UNITED KINGDOM	4.7150***	1.6574

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 3.2.2, Weekly Data | q=16

Developed Markets

COUNTRY	MV_1	MV_2
GERMANY	2.2956*	0.7620
CANADA	3.0097**	0.8046
FRANCE	2.1581	0.8398
ITALY	3.7071***	1.7861
JAPAN	1.8882	1.3285
U.S.A	3.1579***	1.0222
UNITED KINGDOM	2.5198**	1.0525

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 3.2.3, Monthly Data | q=16

Developed Markets

COUNTRY	MV_1	MV_2
GERMANY	4.2685***	1.7873
CANADA	5.0047***	1.5977
FRANCE	4.1971***	1.8736
ITALY	3.8139***	2.3326*
JAPAN	2.2946*	1.5968
U.S.A	3.2293***	1.3410
UNITED KINGDOM	5.8174***	2.7777**

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Both **Wright**'s R_1 and R_2 test dominate the heteroskedasticity-robust M_2 test in power. However, the results are quite similar with those of our initial test. In detail, R_1 test gives fairly consistent results using weekly data for every country and every *k*, with the exception of United Kingdom, which is strongly rejected by both tests, and USA just for $k = 2$. On the contrary the results of R_2 test do not exhibit random walk behavior for Canada for lags *k*=2,8,16, for Japan for *k*=2,4,8 and for USA for any level of *k*. Using monthly data the null is soundly accepted for Italian, Japanese, USA's and United Kingdom's market by both tests, while results for the rest countries fail to reject the null.

Index 3.3.1, Weekly Data

Developed Markets (T=1901)

COUNTRY	k	R_1	R_2
GERMANY	2	-0.9882	-1.3339
	4	-1.4813	-2.4114**
	8	-1.6085	-1.2400
	16	-1.8658	-1.6450
CANADA	2	1.2609	-3.2103**
	4	1.3327	-1.5799
	8	0.4167	-2.2905**
	16	0.3753	-2.8911**
FRANCE	2	0.0005	-0.8676
	4	1.5673	-1.7178
	8	1.9016	-0.4408
	16	0.3457	-0.7852
ITALY	2	0.6087	-2.5436**
	4	1.6318	0.2935
	8	0.6269	-0.4174
	16	-0.8939	-1.7126
JAPAN	2	-0.8369	-4.4520**
	4	0.3888	-3.9760**
	8	1.0638	-2.7386**
	16	0.6496	-1.7136
U.S.A	2	-2.1727**	-5.3573**
	4	-1.1603	-3.8284**
	8	-1.1505	-3.9396**
	16	-1.6159	-3.4761**
UNITED KINGDOM	2	-2.4016**	-2.9288**
	4	-2.3546**	-2.5282**
	8	-2.0644**	-2.2060**
	16	-1.9158	-2.1644**

"**" indicate significance at the 5% level.

Index 3.3.2, Monthly Data

Developed Markets (T=437)

COUNTRY	k	R_1	R_2
GERMANY	2	-1.3940	-0.9549
	3	-2.2014**	-1.6248
	4	-1.8168	-1.4266
	5	-1.5096	-1.1666
CANADA	2	-0.4463	-2.6943**
	3	-0.3973	-3.4817**
	4	0.0267	-2.8152**
	5	-0.1181	-2.4852**
FRANCE	2	0.7883	3.1344**
	3	-0.6846	1.8967
	4	-0.1804	1.5238

	5	0.1841	1.1340
ITALY	2	0.1138	-0.0126
	3	-1.1938	-0.7044
	4	-1.0042	-1.2257
	5	-0.5839	-1.5059
JAPAN	2	0.9950	-1.6402
	3	-0.0468	-1.4603
	4	0.1388	-0.8990
	5	0.3362	-0.9924
U.S.A	2	0.5471	-0.4087
	3	-0.3652	-1.2861
	4	-0.3726	-1.1748
	5	-0.2881	-0.6752
UNITED KINGDOM	2	0.4723	1.7426
	3	0.3163	1.2335
	4	0.2366	0.8209
	5	0.5212	1.1095

"**" indicate significance at the 5% level.

In **Whang and Kim**'s test the results are mixed due to the different blocks (b). Hence, while for most developed countries the null RWH is rejected for small b, as that increases the PValue increases too. Particularly, applying daily data for France, USA and Japan the null is accepted for all b's, while the results for Germany and United Kingdom give fairly strong acceptance. Only for Canada and Italy the test fails to accept the null as the p-values are less than 5% for nearly all evaluated cases. Using monthly data, results are more precise. Only Japanese and USA's market seem to follow the Random Walk hypothesis, while results for the rest markets reject the null at some but not all values of b.

Index 3.4.1, Daily Data

Developed Markets (T=9481)

COUNTRY	b	MVn	P Value
GERMANY	41	15.0660	0.0320**
	447		0.1165
	852		0.2116
CANADA	41	27.5226	0.0061***
	447		0.0411**
	852		0.0989*
FRANCE	41	6.3898	0.3891
	447		0.4834**
	852		0.5387*
ITALY	41	24.6166	0.0023***
	447		0.0097***
	852		0.0617*

JAPAN	41	7.7185	0.1477
	447		0.5515
	852		0.6324
U.S.A	41	15.6189	0.0172**
	447		0.0166**
	852		0.0264**
UNITED KINGDOM	41	15.6209	0.0234**
	447		0.1280
	852		0.1771

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 3.4.2, Weekly Data

Developed Markets (T=1901)

COUNTRY	b	MVn	P Value
GERMANY	41	22.0506	0.0129**
	183		0.0349**
	325		0.0418**
CANADA	41	17.9193	0.0183**
	183		0.0651*
	325		0.0215**
FRANCE	41	22.5969	0.0091***
	183		0.0401**
	325		0.0913*
ITALY	41	25.6610	0.0048***
	183		0.0134**
	325		0.0241**
JAPAN	41	14.9001	0.0666*
	183		0.2023
	325		0.3200
U.S.A	41	6.4218	0.1224
	183		0.5657
	325		0.3809
UNITED KINGDOM	41	17.3047	0.0107**
	183		0.0105**
	325		0.0076***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

5.2 Empirical results for emerging countries

According to **Lo and MacKinlay**'s test the results provide for eight of ten emerging markets the evidence of the random walk behavior under the conditions of heteroskedasticity. For daily data, the M_2 test rejects the null hypothesis only for Poland and Russia, while the results for the rest of the countries indicate market efficiency. On the other hand the M_1 test, which relies on homoskedasticity, give mixed results. For Brazilian and Taiwanese markets the null is accepted only for *k* equals to 10 and 20, while for k=30 or 40 is rejected. This indicates that the markets are efficient in the short-horizon but not with the long holding periods. Moreover, for Hungary, Mexico, Poland and Russia the results are against the null hypothesis, while for South Africa, China, Czech Republic and Turkey are fairly consistent.

Index 4.1.1, Daily Data

Emerging Markets

COUNTRY	k	M_1	M_2
BRAZIL	10	-0.4611	-0.1711
	20	0.6260	0.2316
	40	2.5104**	0.9546
	80	4.1376***	1.6573*
HUNGARY	10	2.5943***	1.4075
	20	2.2625**	1.2745
	40	2.2165**	1.3035
	80	1.7142*	1.0811
MEXICO	10	3.2436***	1.2840
	20	4.0846***	1.6454
	40	3.9405***	1.6705*
	80	3.8509***	1.7819*
POLAND	10	4.2080***	2.2029**
	20	3.9910***	2.0709**
	40	3.5536***	1.8836*
	80	2.7687***	1.5339
SOUTH AFRICA	10	-0.3169	-0.1536
	20	0.6296	0.3046
	40	1.3199	0.6507
	80	0.8141	0.4176
TAIWAN	10	1.2063	0.8549
	20	1.9483*	1.4127
	40	2.0711**	1.5416
	80	2.4860**	1.9028*
CHINA	10	-0.6567	-0.2205
	20	-0.1222	-0.0427
	40	1.0411	0.3855
	80	1.0340	0.4035
CZECH REPUBLIC	10	-1.3602	-0.4020
	20	-0.9530	-0.2890

	40	0.4607	0.1472
	80	0.5366	0.1918
RUSSIA	10	6.2946***	2.3724***
	20	6.2820***	2.3833***
	40	8.2864***	3.2330***
	80	9.7878***	4.0795***
TURKEY	10	1.3670	0.8209
	20	2.2170**	1.3513
	40	1.6307	1.0229
	80	1.1858	0.7765

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 4.1.2, Weekly Data

Emerging Markets

COUNTRY	k	M_1	M_2
BRAZIL	2	-1.9156*	-0.7381
	4	0.9481	0.3805
	8	2.9055***	1.1823
	16	4.2364***	1.7710*
HUNGARY	2	0.9161	0.5965
	4	1.2739	0.8401
	8	1.4951	0.9924
	16	1.0858	0.7445
MEXICO	2	-0.3262	-0.1217
	4	2.2779**	0.8641
	8	2.4975**	0.9902
	16	2.4519**	1.0760
POLAND	2	1.1656	0.5838
	4	1.8901*	0.9591
	8	1.9660**	1.0304
	16	1.6079*	0.8957
SOUTH AFRICA	2	0.1705	0.0888
	4	1.6080	0.8583
	8	2.3147**	1.2391
	16	1.4254	0.7796
TAIWAN	2	0.1252	0.1020
	4	1.8388*	1.5026
	8	2.3565**	1.8809*
	16	2.7302***	2.2052**
CHINA	2	1.5963	0.6891
	4	1.8548*	0.8243
	8	2.6931***	1.2219
	16	2.1024**	0.9711
CZECH REPUBLIC	2	-0.4839	-0.2329
	4	0.0890	0.0410

	k	M_1	M_2
	8	1.6355	0.6903
	16	1.2466	0.5363
RUSSIA	2	4.9462***	2.1457**
	4	5.6000***	2.3825**
	8	7.7325***	3.2930***
	16	9.1196***	4.0326***
TURKEY	2	-0.4171	-0.2539
	4	1.6377	1.0415
	8	1.4996	0.9985
	16	1.0058	0.6998

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 4.1.3, Monthly Data

Emerging Markets

COUNTRY	k	M_1	M_2
BRAZIL	2	4.4598***	1.6898
	3	5.1854***	2.0516
	4	5.7657***	2.3709
	5	6.1203***	2.5921
HUNGARY	2	1.0733	0.9183
	3	0.7105	0.6080
	4	1.0976	0.9415
	5	1.3094	1.1202
MEXICO	2	2.5218**	1.3212
	3	2.8412***	1.5402
	4	3.4182***	1.9031
	5	3.9498***	2.2294
POLAND	2	0.8726	0.5829
	3	1.0881	0.7060
	4	1.1575	0.7323
	5	1.4282	0.8923
SOUTH AFRICA	2	2.0538**	1.3200
	3	1.4260	0.9219
	4	1.3443	0.8715
	5	1.4473	0.9395
TAIWAN	2	0.9170	0.7407
	3	1.7531*	1.4605
	4	1.6136	1.3681
	5	1.3576	1.1589
CHINA	2	2.7652***	1.0817
	3	2.6042***	1.0405
	4	2.0422	0.8326
	5	1.8523*	0.7718
CZECH REPUBLIC	2	2.4683**	1.0817
	3	2.1356**	1.3376
	4	2.1979**	1.2370
	5	2.2892**	1.3364

RUSSIA	2	4.9701***	1.8207*
	3	6.1729***	2.3169**
	4	6.8276***	2.6334***
	5	6.9127***	2.7363***
TURKEY	2	-0.3480	-0.2708
	3	0.0236	0.0189
	4	0.2593	0.2080
	5	0.2955	0.2346

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Applying weekly and monthly data results are quite similar. For the M_2 test the null is accepted for every market and almost every k-period apart from Russia for weekly and monthly data and Brazil for monthly data too. M_1 test exhibit random walk behavior for markets of Hungary, Poland, South Africa, Czech Republic and Turkey using weekly data and give fairly strong rejection for the Russian and Mexican market. Brazilian, Taiwanese and Chinese markets are efficient in the short-horizon for lags k=2 and 4. For monthly data Hungary, Poland, South Africa, Taiwan and Turkey follow the Random Walk hypothesis in contrast with Brazil, Mexico, China, Czech Republic and Russia where efficiency is strongly rejected using M_1 test.

Chow and Denning's test indicates findings that differ between MV_1 and MV_2. For daily data MV1 test give fairly strong rejections for all markets except for China's and Czech Republic's. For weekly and monthly data results different. The null of RWH is accepted for the homoskedastic M_1 for Hungary, Poland, South Africa, Czech Republic and Turkey for weekly data, plus Taiwan for monthly data. Conversely test M_2 show results that accept the null for almost every market. Only Mexican and Poland markets are against the null hypothesis for daily data and Russian market for any time period.

Index 4.2.1, Daily Data | q=16

Emerging Markets

COUNTRY	MV_1	MV_2
BRAZIL	2.9312**	1.2140
HUNGARY	5.4061***	2.6357**
MEXICO	7.5228***	3.0881***
POLAND	5.7834***	3.2853***
SOUTH AFRICA	3.0764***	1.5572
TAIWAN	2.9269**	2.0341
CHINA	1.3722	0.4608
CZECH REPUBLIC	2.4149*	0.6978
RUSSIA	7.1023***	2.7865**
TURKEY	3.1212***	1.8579

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 4.2.2, Weekly Data | q=16

Emerging Markets

COUNTRY	MV_1	MV_2
BRAZIL	4.2364***	1.7710
HUNGARY	1.8775	1.2408
MEXICO	2.8066**	1.1567
POLAND	2.1534	1.1070
SOUTH AFRICA	2.4082*	1.2868
TAIWAN	2.7637**	2.2276*
CHINA	2.7830**	1.2662
CZECH REPUBLIC	1.6355	0.6903
RUSSIA	9.1196***	4.0326***
TURKEY	1.9025	1.2419

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 4.2.3, Monthly Data | q=16

Emerging Markets

COUNTRY	MV_1	MV_2
BRAZIL	6.1203***	2.6053**
HUNGARY	1.9223	1.6612
MEXICO	4.0690***	2.3098*
POLAND	1.9022	1.1913
SOUTH AFRICA	2.0538	1.3200
TAIWAN	1.7531	1.4605
CHINA	2.7652**	1.0817
CZECH REPUBLIC	2.4683*	1.5040
RUSSIA	6.9127***	2.7363**
TURKEY	0.3480	0.2708

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

The results using the variance ratio test of **Wright** are mixed. Findings are quite confusing and in many countries ambiguous. For example for Brazil, Poland, Taiwan and China the null is accepted for almost every level of *k* and every test. On the other hand Hungary has two rejections for R_1 and R_2 tests with k=2, Mexico is rejected for k = 4 and the null for Russia is strongly rejected under the conditions of heteroskedasticity. Results are vague also for South African, Czech Republic's and Turkish market, where the Wright's test fail to accept the null hypothesis. Using monthly data the null RWH is accepted for almost every market. Only for Russia the findings are against the null. At last, results allow to conclude that the Poland and Hungarian markets seem to follow the random walk hypothesis.

Index 4.3.1, Weekly Data

Emerging Markets (T=780)

COUNTRY	k	R_1	R_2
BRAZIL	2	-0.3010	-1.4457
	4	1.6796	0.4458
	8	2.5059**	0.8136
	16	1.2173	-0.1027
HUNGARY	2	-2.9589**	-2.4796
	4	-0.9030	-0.4401
	8	-0.5954	-0.5349
	16	-1.4263	-1.2151
MEXICO	2	0.6539	1.2486
	4	2.0455**	2.3234
	8	1.9097	1.6622
	16	1.9410**	1.3994
POLAND	2	-1.2360	-1.5897
	4	0.0263	-0.3604
	8	0.2626	-0.6467
	16	-0.5688	-1.0157
SOUTH AFRICA	2	1.4354	-0.1617
	4	2.7409**	1.2818
	8	3.1650**	0.7675
	16	2.2744**	-0.2696
TAIWAN	2	-2.0487**	-1.3015
	4	-0.5616	-0.3562
	8	-0.0790	-0.4725
	16	0.4033	0.1438
CHINA	2	-2.0086	-3.4352**
	4	-1.1782	-0.6658
	8	-0.2549	0.2505
	16	0.1083	0.1183
CZECH REPUBLIC	2	2.2837**	0.1687
	4	3.6460**	0.1373
	8	3.0890**	0.4363
	16	1.4419	-0.2584
RUSSIA	2	-0.8070	2.3506**
	4	0.3364	2.6594**
	8	1.4869	2.8998**
	16	1.9469**	1.8809**
TURKEY	2	-2.9809**	-2.2886**
	4	-1.6209	-1.3638
	8	-1.0789	-1.4274
	16	-1.5071	-1.9216

"**" indicate significance at the 5% level.

Index 4.3.2, Monthly Data

Emerging Markets (T=179)

COUNTRY	k	R_1	R_2
BRAZIL	2	1.6401	0.0842
	3	0.5177	-0.4643
	4	0.0971	-0.7529
	5	0.0259	-0.6214
HUNGARY	2	-1.5066	-0.7216
	3	-2.8788**	-1.8059
	4	-2.1604**	-1.4598
	5	-1.8515	-1.3762
MEXICO	2	0.8826	0.8619
	3	1.4207	1.1894
	4	1.4285	1.1065
	5	1.1995	0.8006
POLAND	2	-0.7341	-1.6402
	3	-1.9155	-1.9274
	4	-1.9044	-1.9197
	5	-2.0462**	-2.1144**
SOUTH AFRICA	2	1.4426	0.8189
	3	1.2631	0.0323
	4	0.6629	-0.5160
	5	0.1419	-0.8826
TAIWAN	2	-0.0370	0.0181
	3	0.4835	0.4909
	4	0.4289	0.4334
	5	0.4973	0.4449
CHINA	2	0.3126	1.2739
	3	0.9272	1.3322
	4	0.7902	0.8470
	5	0.5184	0.3008
CZECH REPUBLIC	2	-1.1925	-1.6545
	3	-1.0825	-1.2310
	4	-0.9980	-0.9566
	5	-0.9614	-1.0714
RUSSIA	2	2.7365**	2.0687**
	3	2.4789**	1.3264
	4	2.2650**	0.8452
	5	2.2192**	0.2887
TURKEY	2	-0.7974	-0.5871
	3	-1.4605	-1.3655
	4	-1.4240	-1.5592
	5	-1.1462	-1.5761

"**" indicate significance at the 5% level.

Studying the **Whang and Kim**'s results is obvious that emerging markets are efficient by applying both daily and weekly data for almost every block-b. While in the first case Mexican, Poland, Russian and Turkish markets do not follow random walk, using weekly data the test gives fairly strong rejections only for Brazilian, Poland and Russian markets.

Index 4.4.1, Daily Data

Emerging Markets (T=3880)

COUNTRY	b	MVn	P Value
BRAZIL	41	17.9889	0.0190**
	270		0.1226
	498		0.2258
HUNGARY	41	17.0703	0.0234**
	270		0.1196
	498		0.0745*
MEXICO	41	28.2372	0.0016***
	270		0.0316**
	498		0.0304**
POLAND	41	25.4648	0.0021***
	270		0.0008***
	498		0.0006***
SOUTH AFRICA	41	9.4584	0.1109
	270		0.3904
	498		0.5160
TAIWAN	41	14.8409	0.0161**
	270		0.0880*
	498		0.0836*
CHINA	41	7.4603	0.1794
	270		0.4610
	498		0.5260
CZECH REPUBLIC	41	4.7363	0.9969
	270		0.6406
	498		0.6235
RUSSIA	41	59.3797	0.0006***
	270		0.0006***
	498		0.0005***
TURKEY	41	13.8391	0.0258**
	270		0.0739*
	498		0.0310**

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 4.4.2, Weekly Data

Emerging Markets (T=780)

COUNTRY	b	MVn	P Value
BRAZIL	41	26.6116	0.0054***
	116		0.0315**
	190		0.0034***
HUNGARY	41	13.6005	0.0567*
	116		0.0571*
	190		0.0034***
MEXICO	41	17.1265	0.0607*
	116		0.0826**
	190		0.0236**
POLAND	41	15.5943	0.0405**
	116		0.0030***
	190		0.0236**
SOUTH AFRICA	41	7.2926	0.3468
	116		0.2838
	190		0.3345
TAIWAN	41	13.0209	0.0513*
	116		0.2027
	190		0.1622
CHINA	41	9.8430	0.1457
	116		0.2688
	190		0.3378
CZECH REPUBLIC	41	12.1123	0.1444
	116		0.0826*
	190		0.0456**
RUSSIA	41	55.5824	0.0027***
	116		0.0030***
	190		0.0034***
TURKEY	41	5.0506	1.0000
	116		0.5976*
	190		0.4730**

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

5.3 Empirical results for frontier countries

The results for frontier markets applying **Lo and MacKinlay**'s tests are presumable. Using the homoskedastic M_1 test for daily data, the null RWH is rejected for every market and every value of k, while using weekly statistics only Argentina's market seems to follow random walk. Furthermore, studying monthly data, results for Argentina, Pakistan and Romania show efficiency for all *k* lags. For the markets namely, Argentina and Pakistan, M_2 test fails to reject the null using weekly and monthly data for all k's. On the contrary, for daily data test rejects all markets. Additionally, results do not exhibit random walk behavior for Slovenia and Bulgaria for monthly and weekly data. Finally, the null for Romania is rejected (for some but not all k) under the condition of homoskedasticity but not M_2 test too.

Index 5.1.1, Daily Data

Frontier Markets

COUNTRY	k	M_1	M_2
ARGENTINA	10	4.6161***	2.8653***
	20	3.5267***	2.1149**
	40	2.8546***	1.7949*
	80	2.8625***	2.0066**
BULGARIA	10	11.3626***	5.0950***
	20	13.3226***	6.1867***
	40	12.7168***	6.2488***
	80	13.9125***	7.0584***
PAKISTAN	10	4.9830***	2.7620***
	20	5.4571***	3.1473***
	40	4.5206***	2.7428***
	80	3.5467***	2.3130**
ROMANIA	10	3.2664***	1.8923**
	20	4.7040***	2.8712***
	40	4.5583***	2.9038***
	80	4.4753***	2.9923***
SLOVENIA	10	3.0904***	1.8923**
	20	4.7038***	2.8712***
	40	7.0541***	2.9038***
	80	10.7121***	2.9923***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 5.1.2, Weekly Data

Frontier Markets

COUNTRY	k	M_1	M_2
ARGENTINA	2	1.6709*	1.1065
	4	2.2459**	1.4803
	8	1.8929*	1.2858
	16	1.9069*	1.4327
BULGARIA	2	7.4869***	3.4818***
	4	10.3799***	4.8818***
	8	9.9216***	5.1029***
	16	10.9202***	5.7509***
PAKISTAN	2	2.5476**	1.5671
	4	3.2666***	1.9982**
	8	2.7921***	1.7610*
	16	2.2780**	1.5329
ROMANIA	2	1.7084*	1.3017
	4	4.0344***	2.7552***
	8	4.0121***	2.7216***
	16	3.9085***	2.7406***
SLOVENIA	2	2.5604**	1.3453
	4	4.7976***	2.622 0***
	8	7.2530***	3.9992***
	16	10.6785***	5.9674***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 5.1.3, Monthly Data

Frontier Markets

COUNTRY	k	M_1	M_2
ARGENTINA	2	1.5007	1.4744
	3	1.6052	1.5884
	4	1.7585*	1.7544*
	5	2.1597**	2.1666**
BULGARIA	2	2.2995**	1.9884**
	3	3.2127***	2.3205**
	4	3.8608***	2.6034***
	5	3.8985***	2.5139**
PAKISTAN	2	1.3732	1.5912
	3	1.3852	1.4339
	4	1.2782	1.2487
	5	1.1717	1.1227
ROMANIA	2	0.6735	0.5253
	3	1.1663	0.9129
	4	1.2419	0.9830
	5	1.3878	1.1003
SLOVENIA	2	5.0803***	3.0069***
	3	6.9775***	4.0710***

4	8.2591***	4.8190***
5	8.9992***	5.3194***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Applying **Chow and Denning**'s test, daily data result in strongly rejection of the null hypothesis for all countries. As the time period increases, findings of Argentina's market provide evidence of the random walk behavior for both MV_1 and MV_2, while results for Pakistan show efficiency only for MV_2 test. Using monthly data only for Pakistan and Romania both tests accept the null hypothesis.

Index 5.2.1, Dailly Data | q=16

Frontier Markets

COUNTRY	MV_1	MV_2
ARGENTINA	4.7654***	3.1246***
BULGARIA	12.6947***	5.8050***
PAKISTAN	5.8315***	3.0515***
ROMANIA	4.1646***	2.5041**
SLOVENIA	8.7086***	2.8195**

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 5.2.2, Weekly Data | q=16

Frontier Markets

COUNTRY	MV_1	MV_2
ARGENTINA	2.2459*	1.4803
BULGARIA	10.9202***	5.7509***
PAKISTAN	3.5484***	2.1833
ROMANIA	4.1497***	2.8024**
SLOVENIA	10.6785***	5.9674***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 5.2.3, Monthly Data | q=16

Frontier Markets

COUNTRY	MV_1	MV_2
ARGENTINA	2.9659**	2.9677**
BULGARIA	4.1356***	2.6034**
PAKISTAN	1.6489	1.5912
ROMANIA	2.0749	1.6181
SLOVENIA	10.1338***	6.2541***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

The null hypothesis, for **Wright**'s tests, seems to be accepted applying weekly data only for Argentina's and Romania's markets. The rest of the examined markets do not follow Random Walk hypothesis with more than two rejections. In contradiction to our expectations, results for monthly data indicate efficiency for all countries apart from Slovenia which is soundly rejected by both tests.

Index 5.3.1, Weekly Data

Frontier Markets (T=454)

COUNTRY	k	R_1	R_2
ARGENTINA	2	1.3274	-0.0080
	4	1.7053	0.8465
	8	0.7643	0.0369
	16	0.8765	-0.3637
BULGARIA	2	-2.5088**	-2.1686**
	4	-2.4700**	-2.9308**
	8	-2.1569**	-3.0549**
	16	-1.1591	-1.8446
PAKISTAN	2	2.4976**	1.5546
	4	2.7352**	2.2787**
	8	1.8476**	0.3698
	16	1.0897	-0.5170
ROMANIA	2	-0.9227	-3.9613**
	4	0.7074	-2.4797**
	8	0.7949	-2.6459**
	16	0.6516	-2.1886**
SLOVENIA	2	-1.4876	-2.4214**
	4	0.7094	-4.2301**
	8	1.3623	-1.9682**
	16	1.9445**	-1.0271

"**" indicate significance at the 5% level.

Index 5.3.2, Monthly Data

Frontier Markets (T=104)

COUNTRY	k	R_1	R_2
ARGENTINA	2	0.6866	0.5247
	3	0.6427	0.3002
	4	0.9962	0.2996
	5	1.3937	0.6359
BULGARIA	2	0.0126	-0.9719
	3	-0.0629	-0.3117
	4	0.4923	0.3267
	5	0.9549	0.5807
PAKISTAN	2	0.2291	-0.4523
	3	0.0706	-0.9495
	4	0.1229	-0.9438
	5	0.0410	-1.0330
ROMANIA	2	-0.0309	-1.2220
	3	-0.4115	-1.3687
	4	-0.4157	-1.4247
	5	-0.3218	-1.4652
SLOVENIA	2	3.1030**	2.1840**
	3	3.5067**	2.0693**
	4	3.8692**	1.9064**
	5	4.0484**	1.6771**

"**" indicate significance at the 5% level.

In **Whang and Kim**'s test findings assure us that most of the frontier markets do not follow the Random Walk hypothesis. It is more than apparent that apart from Argentina, which recently downgraded to frontier country, the null hypothesis is soundly rejected for every single market and by any block-b, as in most of the results the PValue slightly reaches the 1%.

Index 5.4.1, Weekly Data

Frontier Markets (T=2249)

COUNTRY	b	MVn	P Value
ARGENTINA	41	20.4559	0.0258**
	200		0.0892*
	359		0.1422
BULGARIA	41	91.1271	0.0009***
	200		0.0010***
	359		0.0011***
PAKISTAN	41	32.3938	0.0136**
	200		0.0122**

	359		0.0011***
ROMANIA	41	32.6645	0.0018***
	200		0.0215**
	359		0.0011***
SLOVENIA	41	50.5487	0.0009***
	200		0.0010***
	359		0.0011***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

Index 5.4.2, Weekly Data

Frontier Markets (T=454)

COUNTRY	b	MVn	P Value
ARGENTINA	41	21.5096	0.0072***
	89		0.0327**
	137		0.0251**
BULGARIA	41	78.5641	0.0048***
	89		0.0054***
	137		0.0063***
PAKISTAN	41	17.2965	0.0482**
	89		0.0218**
	137		0.0627*
ROMANIA	41	30.3036	0.0072***
	89		0.0054***
	137		0.0063***
SLOVENIA	41	101.9787	0.0048***
	89		0.0054***
	137		0.0063***

"*", "**"and "***" indicate significance at the 10%, 5% and the 1% levels, respectively.

5.4 Looking at the VR tests through a rolling window

To get additional information about the sources and implications of these results, we apply Wright's (2000) variance ratio tests on each emerging country, using fixed-size rolling windows of 300 observations and *k*-period equals to 16. For instance, the first window comprises the first 300 sample data points, the second window is composed by the observations running from observations 2 through 301, and so on. The last window is built with the last 300 observations.

Figure 1 displays the results for this procedure for **Brazilian** stock Market for R_1 and R_2 tests, and for lags k=16 with its corresponding 5% critical values and window width of 300 observations. The results exhibit random walk behavior for the majority of the examined windows with the exception of some consecutive rejected windows, under the condition of homoskedasticity, during the periods 2004-2005 and 2008-2009. The first shock is probably an evidence of the gradual depreciation process, culminating in the 1999 January Brazilian currency crisis, when the Real suffered a maxi-devaluation. Furthermore, the second shock possibly indicates the current world economic crisis.

Figure 1

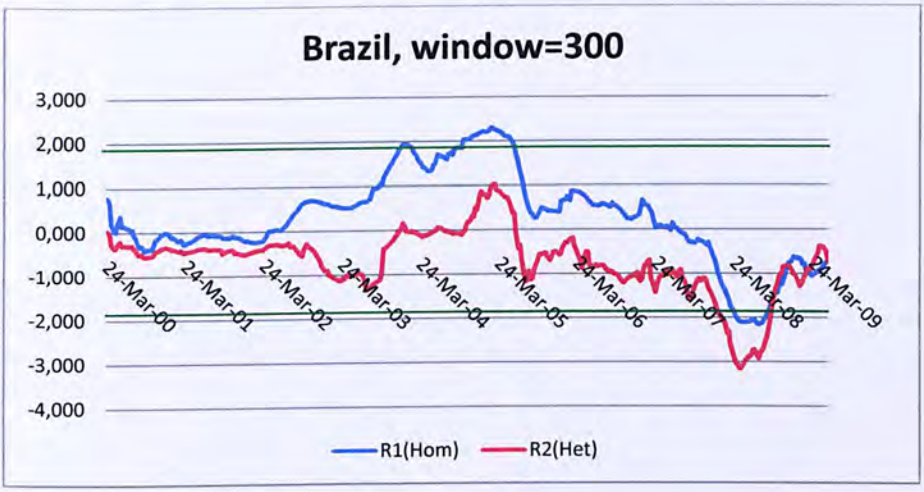
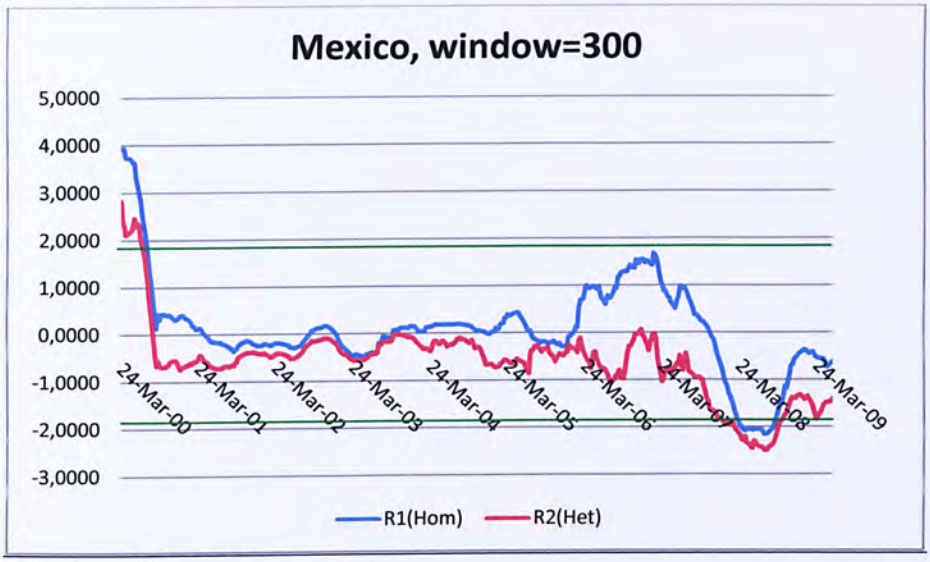


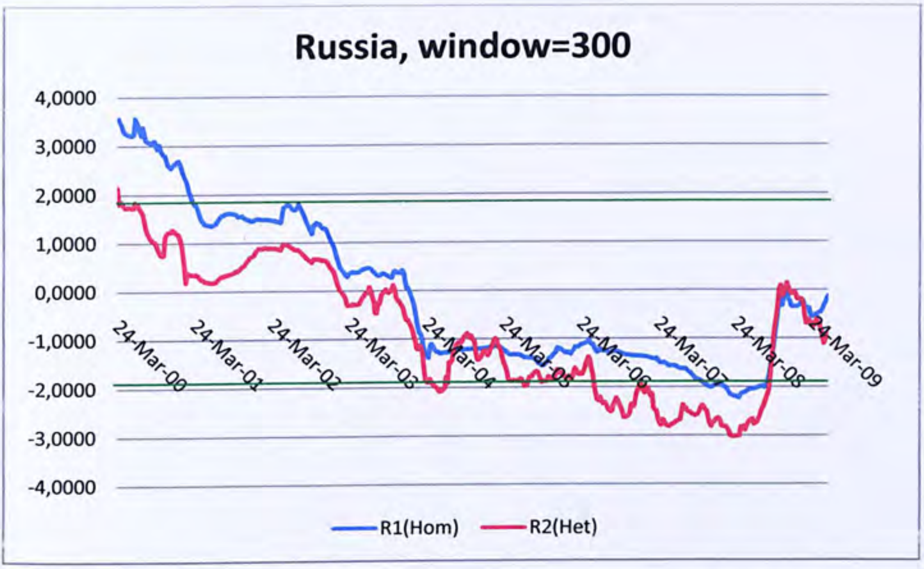
Figure 2 provide results that show the economic crisis in **Mexico**, widely known as the Mexican peso crisis or Tequila Effect. In December 1994, the sudden devaluation of the Mexican peso caused loss of confidence and credibility not only for investors but for consumers too. The impact of that crisis is clearly depicted in figure 3, since the null of random walk hypothesis during that period is strongly rejected. Similar assumptions can be inferred for the period 2008-2009, regarding the present world economic crisis, where another shock is figured.

Figure 2



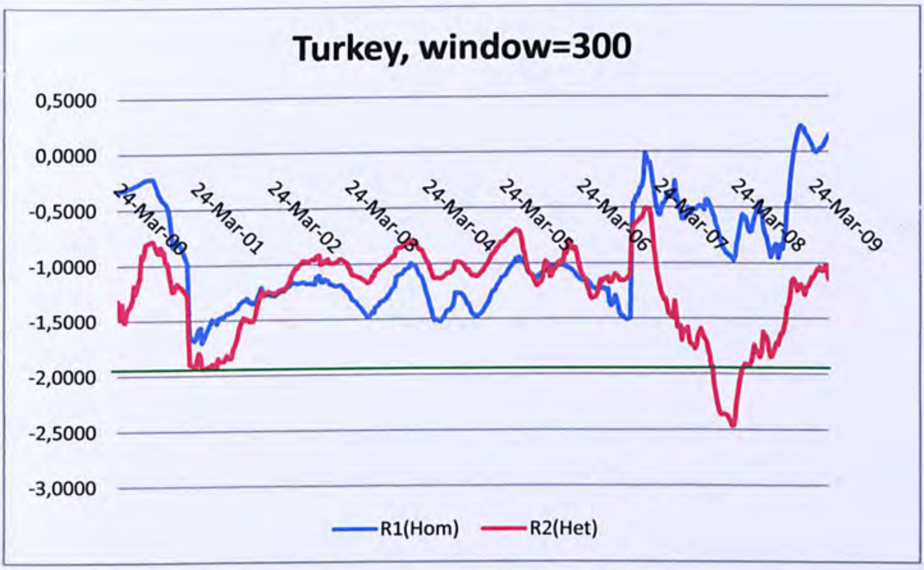
The Russian financial crisis (also called "Ruble crisis") hit **Russia** on 17 August 1998. It was triggered by the Asian financial crisis, which started in July 1997. In period 2008–2009 another Russian financial crisis, part of the world Economic crisis of 2008, blew up. It was an ongoing crisis in the Russian financial markets that has been compounded by political fears after the war with Georgia. Then a subsequent drop in ruble-to-dollar exchange rate and dollar-denominated prices of Russian corporate securities forced investors to crowd out, worsening Russian stock market. That is possibly the reason for the second evidence of market's inefficiency to our figure.

Figure 3

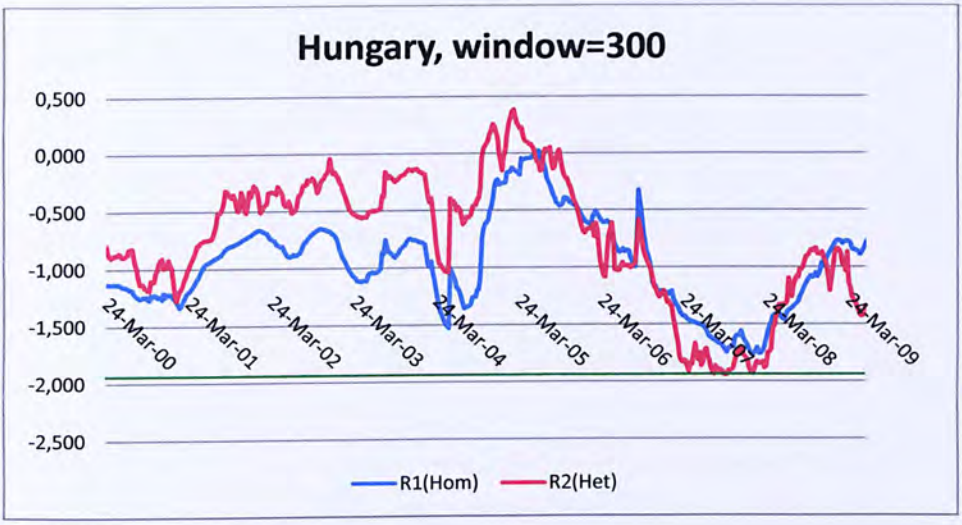


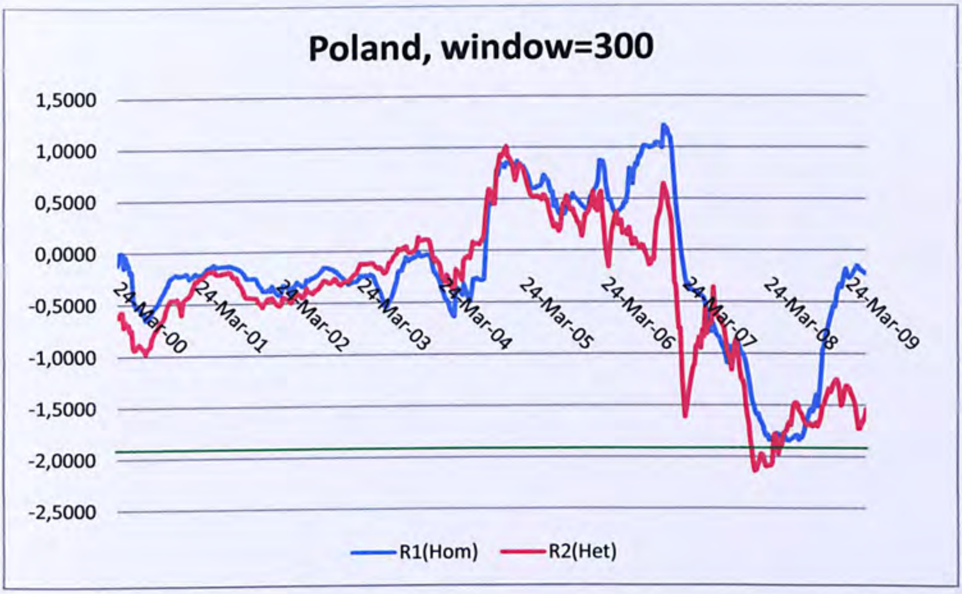
In February 2001, **Turkey** became another emerging market to experience a devastating crisis, following the collapse of its soft exchange rate peg (price/earnings to growth ratio). The crisis severely damaged the country's banking system and led to an unprecedented contraction in economic activity. In figure 4 the results allow to conclude that the Turkish market during that period does not follow the random walk theory.

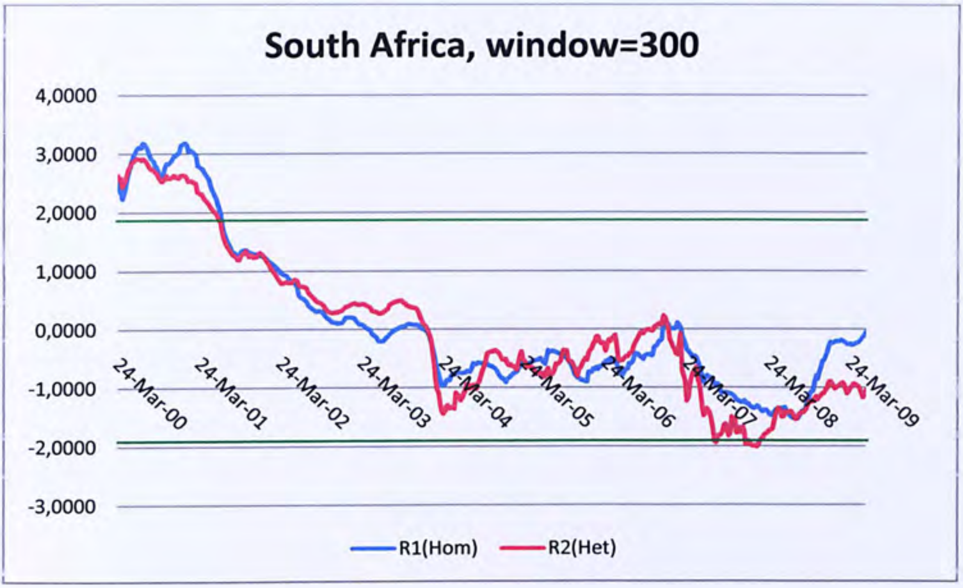
Figure 4

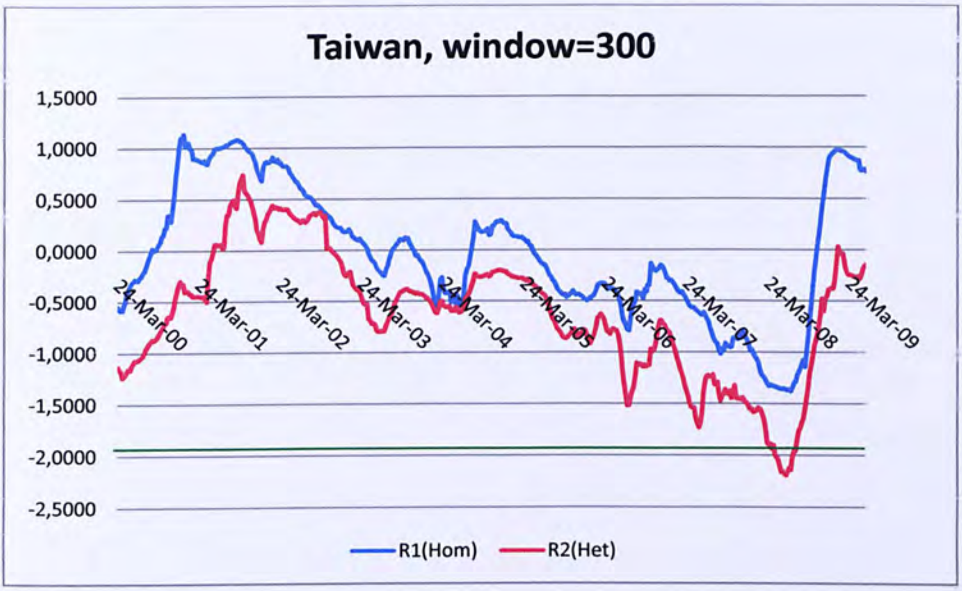


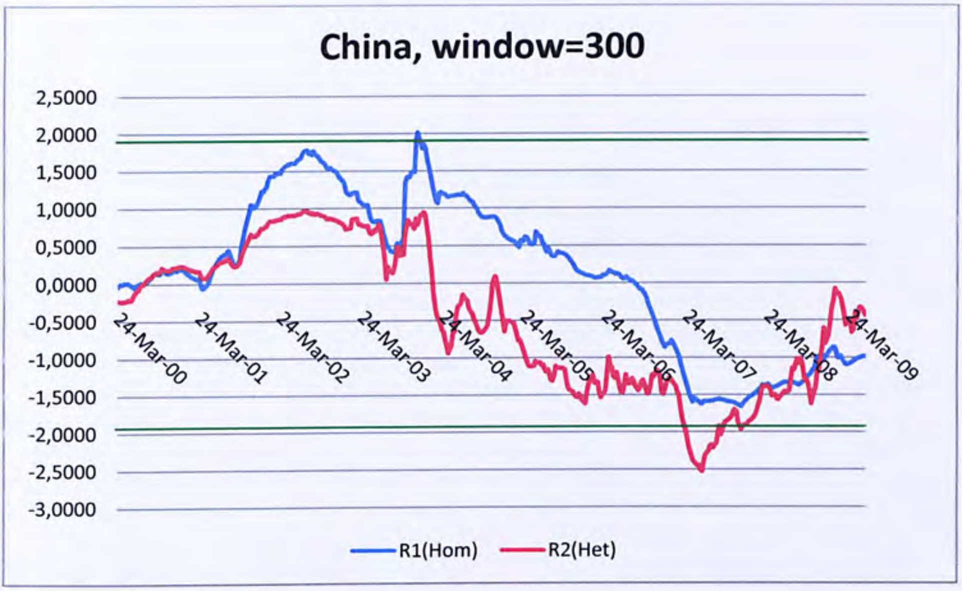
All other graphs indicate that, with the exception of period 2008-2009, all markets, apart from South Africa, lie wholly within the 95% confidence band. At this point it should be mentioned that the rejected period outline the world economic recession that obviously affects the market efficiency.

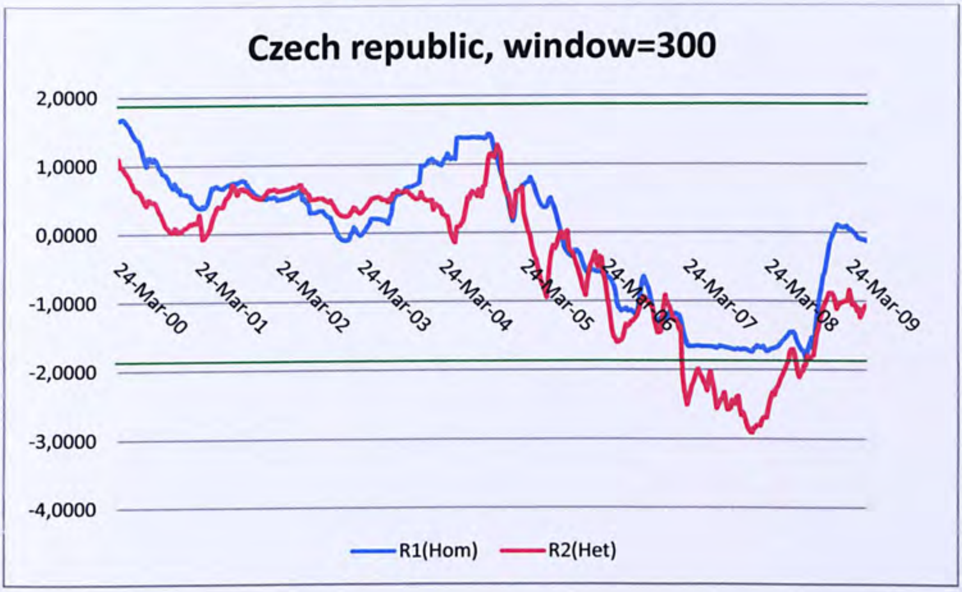





South Africa, window=300
4,0000
3,0000
2,0000
1,0000
0,0000
-1,0000
-2,0000
-3,0000
24-Mar-00
24-Mar-01
24-Mar-02
24-Mar-03
24-Mar-04
24-Mar-05
24-Mar-06
24-Mar-07
24-Mar-08
24-Mar-09
R1(Hom)
R2(Het)


Taiwan, window=300
1,5000
1,0000
0,5000
0,0000
-0,5000
-1,0000
-1,5000
-2,0000
-2,5000
24-Mar-00
24-Mar-01
24-Mar-02
24-Mar-03
24-Mar-04
24-Mar-05
24-Mar-06
24-Mar-07
24-Mar-08
24-Mar-09
R1(Hom)
R2(Het)


China, window=300
2,5000
2,0000
1,5000
1,0000
0,5000
0,0000
-0,5000
-1,0000
-1,5000
-2,0000
-2,5000
-3,0000
24-Mar-00
24-Mar-01
24-Mar-02
24-Mar-03
24-Mar-04
24-Mar-05
24-Mar-06
24-Mar-07
24-Mar-08
24-Mar-09
R1(Hom)
R2(Het)


Czech republic, window=300
2,0000
1,0000
0,0000
-1,0000
-2,0000
-3,0000
-4,0000
24-Mar-00
24-Mar-01
24-Mar-02
24-Mar-03
24-Mar-04
24-Mar-05
24-Mar-06
24-Mar-07
24-Mar-08
24-Mar-09
R1(Hom)
R2(Het)

CONCLUSION

To summarize, that dissertation examined the notion of market efficiency through the most important Variance Ratio tests – Lo and MacKinlay's, Chow and Denning's, Write's and Whang and Kim's – while an alternative way of testing – Rolling Window through Write's test – added significance to the results.

Before studying the empirical part, has been introduced the meaning of market efficiency and the Random Walk behavior. That research pays attention to the properties of the efficient markets and how people understand or react to that conception. Furthermore, intuitive examples are given with past efforts to bequeath the significance of random walk hypothesis.

Last but not least, are the results which prove that as powerful a country is, the more efficient market would have. From the results it is obvious that the most developed markets exhibit the random behavior, except from Italian which shows strongly rejections especially for short time periods and testing under the conditions of homoskedasticity.

Furthermore, in emerging markets yields are mostly attempting to efficiency. The most ambiguous markets are Poland and Hungary, which are strongly rejected for Lo and MacKinlay's and Whang and Kim's tests, especially for the R_2 test.

Finaly, frontier countries exhibit rejections for the most test and *k* lags. That is predictable and one could say that these markets may offer arbitrage or contrarian strategies.

References

- The Efficient Market Hypothesis and its Critics (2003) - Burton G. Malkiel,
- Human Behavior and the Efficiency of the Financial System (1999) - Robert J. Shiller
- Is The Market Rational? No, say the experts. But neither are you - Fox J. (December 9, 2002)
- The Efficient Markets Hypothesis: A Survey (2000) - Beechey M, Gruen D, Vickrey J.
- Efficient Capital Markets: A Review of Theory and Empirical Work (1970). - Fama, Eugene
- Efficient Capital markets - (2003) Steven L. Jones and Jeffry M. Netter
- Abstract from the book "Corporate Financial Management" (Third Edition) – Glen Arnold
- Reference to an Article in a web site: What is market efficiency? - Reem Heakal
- Reference on the book "Famous First Bubbles: The Fundamentals of Early Manias"(2001) - Peter M. Garber
- Anomalies in finance: What are they and what are they good for? (2001) – G. Frankfurter and Elton McGoun
- Contrarian Investment Strategy: The Next Generation.(1998) - Dreman D.
- Market Efficiency: Definitions, Tests and Evidence (2002)- Aswaht Damodoran
- A Critique of the Effcient Market Hypothesis (2007) - Jonathan B. Berk
- The Behavior of Stock-Market Prices. - Eugene F. Fama; Journal of Business, 1965.
- Five Myths of Active Portfolio Management (2004) - Jonathan B. Berk
- *Investment Opportunities in China. (2007) - Burton Malkiel
- Reference the journal: "The adaptive Markets Hypothesis: Market Efficiency from an evolutionary perspective" (2004) – Andrew W. Lo
- The adaptive Markets Hypothesis: Market Efficiency from an evolutionary perspective – Andrew W. Lo (2004).
- Does the stock market overreact? (1985) - Dedondt W., Thaler, R.
- Noise.(1986) - Black, F. Journal of Finance
- Fads, martingales and market efficiency. (1990). - Lehmann, B.M
- Mean reversion in stock returns: Evidence and Implications (1988) - Poterba, J.M., Summers L.H,
- Permanent and temporary components of stock prices.(1988) - Fama, E., French, K.
- The random walk hypothesis for Chinese stock markets: Evidence from variance ratio tests (2009) - Amelie Charles, Olivier Darne
- Variance ratio tests of Random Walk Hypothesis of the euro exchange rate (2008) - Jeng-Hong Chen
- A multiple variance ratio test using subsampling (2002) - Yoon-Jae Whanga, Jinho Kimb
- A note on the weak form efficiency of capital markets: The application of simple technical trading rules to UK stock prices – (1935 to 1994), (1995)- Robert Hudson, Michael Dempsey, Kevin Keasey
- A simple multiple variance ratio test (1992) - K. Victor Chow and Karen C. Denning

- *A Variance-Ratio Test of Random Walks in foreign exchange Rates Christina Y. Liu and Jia He
- *Index-Futures Arbitrage and the Behavior of Stock Index Futures Prices A. Craig MacKinlay Krishna Ramaswamy
- Learning, Asset-Pricing Tests, and Market Efficiency (2002) - Jonathan Lewellen and Jay Shanken
- On the Predictability of Stock Returns: An Asset-Allocation Perspective (1996) Shmuel Kandel and Robert F. Stamaugh
- Stock Market Prices Do Not Follow Random Walks: Evidence from a Simple Specification Test Andrew W. Lo A. Craig MacKinlay
- The size and power of the variance ratio test in finite samples: A monte Carlo Investigation (1988), - Andrew W. Lo and A. Craig MacKinlay
- The Taiwan stock market does follow a random walk (2007) - Dat Bue Lock
- Using Generalized Method of Moments to Test Mean (1991) -Variance Efficiency A. CRAIG MacKinlay and Matthew P. Richardson
- Variance ratio tests of the random walk hypothesis for European emerging stock markets (2003) – Graham Smith and Hyun-Jungryoo
- Weak-form Efficiency and Causality Tests in Chinese Stock Markets (1997) - Martin Laurence Francis Cai Sun Qian
- Alternative Variance RatioTests Using Ranks and Signs (2000) - Jonathan H. Wright
- *Liquidity and market efficiency (2006) - Tarun Chordiaa, Richard Rollb, Avanidhar Subrahmanyam
- Market efficiency of Brazilian exchange rate: Evidence from variance ratio statistics and technical trading rules (2008) - Benjamin M. Tabak, Eduardo J.A. Lima
- Non-linear predictability in stock and bond returns: When and where is it exploitable? (2009) - Massimo Guidolina, Stuart Hydea, David McMillanc, Sadayuki Ono
- Return predictability in African stock markets (2002) - Joe Appiah-Kusia, Kojo Menyah
- Testing for predictability in equity returns for European transition markets (2006) - Daniel O. Cajueiroa, Benjamin M. Tabak
- The Random Walk Hypothesis of stock Market Behavior – Granger and Morgenstern
- *Stock return predictability and model Uncertainty (2001) - Doron Avramov
- New Variance Ratio Tests to Identify Random Walk from the General Mean Reversion Model (2005) - Kin Lam, May Chun Mei Wong and Wing-Keung Wong
- A New Variance Ratio Test of Random Walk in Emerging Markets: A Revisit - Osamah M. Al-Khazali, David K. Ding, Chong Soo Pyun
- *Tables of the studentized maximum modulus distribution and an application to multiple comparisons among means. (1979) - Stoline, M.R., Ury, H.K.
- On the asymptotic power of the variance ratio test (2003) - Deo R. S., & Richardson, M.

- A Variance Ratio Test of the Behavior of Some FTSE Equity Indices using Ranks and Signs (2009) - Authors: Belaire-Franch, Jorge1 Opong, Kwaku (*In Press*)
- The Adaptive Markets Hypothesis: Market Effciency from an Evolutionary Perspective – (2004) Andrew W. Loy
- *New Variance Ratio Tests to indentify Random Walk from the General Mean Reversion Model (2005) - Kin Lam, May Chun Meiwong, and Wing- Keungwong
- Random Walk and Efficiency tests in the Asia-Pacific foreign exchange markets: Evidence from the post-Asian currency crisis (2008)- Sohel Azad- (*In press*)

Note: The references that mentioned with an asterisk (*) have been studied just for understanding specific notions and intuition.