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Ojdanic, Marija

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MARKET EFFICIENCY IN THE BELGRADE STOCK EXCHANGE

Marija Ojdanic

A research report submitted to the Faculty of Commerce, Law and Management, University of Witwatersrand, in partial fulfilment of the requirements for the degree of Master of Business Administration

Johannesburg
May, 2006

ABSTRACT

The Belgrade Stock Exchange is the capital market operating in Serbia and Montenegro. It was established in 1989, but active share trading began only in around 2004. The purpose of this research was to test whether the Belgrade Stock Exchange exhibits random walk characteristics (non-predictability of future returns based on past returns), which is considered the minimum hurdle of market efficiency. The runs test and the LOMAC test were used to conduct the statistical tests. The sample consisted of the composite index of the Belgrade Stock Exchange and a selection of the largest, most liquid shares with sufficient trading history. Weekly, local currency data was used.

Random walk hypothesis could not be rejected for the composite index nor for the majority of the selected shares, which lends support to the hypothesis that the Belgrade Stock Exchange is weak form efficient. This finding should increase international investors' confidence in the Belgrade Stock Exchange and attract capital towards the country.

DECLARATION

I, Marija Ojdanic, declare that this research report is my own, unaided work. It is submitted in partial fulfilment of the requirements for the degree of Master of Business Administration in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

Marija Ojdanic
26th May, 2006

ACKNOWLEDGEMENTS

I wish to express my sincere thanks to:

- Max MacKenzie, my supervisor, for making this research an enjoyable process.
- Hector, for all his love, help and support.
- Hector, Cathy and Jill, for all the hard work in proof-reading this research.

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1 Introduction

1.1 Context of Study

Stock market efficiency has been the topic of much research in both emerging and developed markets (see table 3). For emerging markets it is of particular importance to prove at least weak form efficiency in order to gain investor confidence and attract international capital (El-Erian & Kumar, 1995; Magnusson & Wydick, 2002).

There are a number of definitions of an emerging market. A single theme is common in most: an emerging market has a low to middle income economy (Hess, 1998; Platt, 1998; Richards, 1996). According to this definition, based on income level classification by the World Bank (2005), Serbia and Montenegro is an emerging market.

The stock exchange operating in Serbia and Montenegro is The Belgrade Stock Exchange, which was originally founded in 1894. Before the Second World War it provided a market for trading in securities, commodities and foreign currency and, in conjunction with countries from the Danube Region, created the Danube Contract for futures trading in grain. It served as one of the key factors for the regulation of the local economy. Its last session was held on 4 April 1941, when with the Second World War and the establishment of the communist regime, it ceased to trade. It was officially closed at the beginning of the fifties (Belgrade Stock Exchange, 2005).

The Belgrade Stock Exchange was re-established in 1989 in accordance with the Capital and Money Market Law and was initially called The Yugoslav Capital Market. In 1992 it resumed the name of The Belgrade Stock Exchange and is now operating in accordance with the Law on Securities and Other Financial Instruments Market (Belgrade Stock Exchange, 2005).

1.2 Problem Statement

The objective of this research is to determine whether the Belgrade Stock Exchange is weak form efficient.

1.3 Research Delimitations

The research will focus solely on stock trading.

The research will not investigate the efficiency of the original Belgrade Stock Exchange (pre Second World War).

The research will focus on weak form efficiency, testing whether future share prices can be predicted based on past prices. This research will not test whether abnormal profits can be made by exploiting potential inefficiencies, nor it will take into consideration existing trade conditions (e.g. trading costs).

1.4 Research Assumptions

In determining stock exchange efficiency, it is assumed that all publicly available information regarding stocks trading (such as stock prices and trading history) is true and accurate. The researcher acknowledges, however, that some information may not be based on accepted international standards and may not be completely reliable.

1.5 Research Importance

As Magnusson & Wydick (2002) explain, for developing countries, an efficient stock market channels much needed international capital towards the country. The more efficient the stock market is, the more confidence investors have, and the more they invest. Thus, if this study proves that the Belgrade Stock Exchange passes the lowest hurdle of efficiency, international investor confidence will be increased and capital attracted to Serbia and Montenegro.

2 Literature review

2.1 Market Efficiency

2.1.1 Origins of Efficient Market Hypothesis

The origins of the efficient market hypothesis can be traced back to the first studies on capital markets and returns made by investors, which indicated that future returns are independent of past returns and adhere to some probability distribution (Bachelier, 1900; Kendall, 1953; Mandelbrot, 1963). Bachelier (1900) suggested a normal distribution based on an analysis of rente (government bonds) data from the Paris Stock Exchange, which was supported in research by Kendall (1953) on a number of capital markets including the London Stock Exchange. Mandelbrot (1963) suggested the Paretian distribution as a better approximation.

Today, the literature on the efficient market hypothesis is vast, and the hypothesis has been examined and explained in detail. Of the numerous authors on the subject, Fama is probably the best known. His research on and summary of the efficient market hypothesis has appeared a number of times in the world's leading financial journals (Fama, 1970; Fama, 1991; Fama 1995).

2.1.2 Efficient Market and Random Walk Theory

In an efficient market a large number of intelligent profit-maximisers are actively competing, with each trying to predict future prices based on all available important current information (Fama 1995). This competition leads to a situation where securities prices fully and correctly reflect all relevant known information and are rapidly adjusting to any new available information (El-Erian & Kumar, 1995; Fama, 1995).

In such a market, securities are deemed to be efficiently priced; meaning that the current price of a security is a good estimate of its intrinsic value. This estimate can, however, never be exact as there is always room for disagreement about the implications of new information (Fama 1995). Therefore, actual security prices vary around its intrinsic value but competition among investors ensures that these variations are not significant (Fama 1995; El-Erian & Kumar, 1995). Thus, investors can expect appropriate risk-related returns, but not abnormal profits (Dockery, 2000).

Intrinsic values can change over time as a result of new information (Fama, 1995). New information is by definition unpredictable, therefore resulting price changes are also unpredictable and random (Malkiel, 1989). In an efficient market, actual prices can initially over-adjust or under-adjust to a change in intrinsic value, but the probability of over- and under-adjustment is the same (Fama, 1995). Furthermore, it is possible that in anticipation of a relevant event, adjustment in actual prices sometimes precedes occurrence of that event. This means that the lag in the complete adjustment is itself a random variable (Fama 1995).

In an efficient stock market, therefore, prices adjust almost instantaneously to newly available information and movements in the stock prices over the short period do not exhibit any systematic patterns, but resemble a random walk. This *random walk model* states that investment returns are serially independent and their probability distributions are constant over time. In other words, past stock market information is irrelevant for predicting future movements in stock prices. (El-Erian & Kumar, 1995; Fama 1991; Fama 1995; Magnusson & Wydick, 2002, Malkiel, 1989).

Elaborating on the topic, Dockery (2000:52) further explains: “in an efficient market, stock prices reflect the prevailing value of the future income stream that stocks generate, for stock prices also depend on future dividends, prices and interest rates. Should other factors, such as past prices and dividends, affect the value investors place on stocks, then of course, stock prices will

depart from their intrinsic value. When stock prices deviate from intrinsic values the market may be judged inefficient."

Dockery (2000) identifies other characteristics of an efficient market: market participants in an efficient market can obtain accurate and reliable information and conduct business in an orderly, ethical and professional manner. The market is basically a fair game with sets of rules, procedures and governance structures where investors cannot outperform each other based solely on available information (Fama, 1991).

2.1.3 Levels of Market Efficiency

As described by a number of authors (Fama, 1970; Fama, 1995; Malkiel, 1989; Thompson & Ward, 1995), it is possible to distinguish three levels of an efficient market, based on three types of information sets discounted in stock price. These levels of efficiency are: weak form, semi-strong form and strong form.

The weak form of the efficient market hypothesis states that future returns are non predictable based on past returns. In other words, prices fully reflect all information from the historical sequence of prices. Thus, no investment strategy based on analysis of past prices can give abnormal returns (Fama 1995; Thompson & Ward, 1995; Malkiel 1989). Weak form efficiency is generally considered to be a minimal hurdle that a market must pass to be deemed efficient. As Magnusson & Wydick (2002:142) explain, "weak form efficiency, although not implying that a market cannot be exploited through inside information, implies that systematic excess returns are not possible through exploitation of past movements in stock prices".

The semi-strong form of the hypothesis states that, in addition to historical price information, the equity market accurately converts all relevant publicly available information (Fama, 1970; Malkiel, 1989; Magnusson & Wydick, 2002). In this form of efficiency, public information is so rapidly discounted into stock prices, that analysis of financial statements, announcements on

dividends or stock splits etc (fundamental analysis) will not give abnormal returns.

The strong form of the efficient market hypothesis states that an equity market efficiently converts all information into accurate security prices. Therefore, no information, public or private, can help investors to achieve abnormal returns (Magnusson & Wydick, 2002; Fama 1970).

2.1.4 Implications of Random Walk Theory

A number of methods of describing and predicting stock market prices have been challenged by random walk theory. According to Fama (1995) market practitioners in general have two broad approaches to predicting stock prices: technical analysis and fundamental analysis. Technical analysts, also known as chartists, believe that past patterns of price behaviour tend to repeat in the future, thus the sequence of price changes is of importance in determining the following day's price. Fundamental or intrinsic value analysts assume that at any point in time each security has a certain intrinsic value which depends on a security's earning potential. If actual prices tend to move towards the intrinsic value, then estimating the intrinsic value helps predict security price movement.

Fama (1995) suggests that the random walk model challenges both approaches to predicting security price movement. For technical analysts, the challenge is straightforward – if prices move randomly it is not possible to identify patterns in price behaviour which would help predict future prices (Fama, 1995). For fundamental analysts, the challenge is more subtle. According to random walk theory, security prices at any time are a fair representation of intrinsic value, and additional fundamental analysis is of value only if the analyst is in possession of new information which has not been discounted in the share price, or if he/she has better insight than other traders into the effects of new information. Without either of these, the random selection of shares and a pure buy and hold strategy is as good as any strategy arrived at through fundamental analysis (Fama, 1995).

2.1.5 Returns over Long Horizons

Some returns predictability studies over long horizons (e.g. Fama & French, 1988; Poterba & Summers, 1988) find negative serial correlation. As Bodie, Kane & Marcus (2002) explain, such findings do not necessarily imply market inefficiency, and offer ways of interpreting them. One possible interpretation is that prices initially overreact to relevant news, giving positive serial correlation in the short term, but they later correct to fair levels, giving negative serial correlation in long run. In addition, market returns depend on market premiums or business cycles, which change over time.

2.2 Emerging Markets

2.2.1 Definition of an Emerging Market

There are a number of definitions of an emerging market. For example, Divecha, Drach & Stefek (1992) provided a now somewhat outdated or contemptuous definition of an emerging market as one that:

- is not developed according to Morgan Stanley Capital International or Financial Times indices;
- is of no interest to global institutional investors;
- has a reliable source of data; and
- has securities that trade publicly.

Some authors, however, simply use income level in classifying a market as emerging. For example, Platt (1998) considers the market of a country with a middle-income economy as emerging, while Richards (1996) considers a market with a low or middle income economy as emerging.

Hess (1998) poses a further condition: in addition to lower income level, there needs to be a general perception by the investment community that the country is making progress in a favourable direction (Hess, 1998). He also

finds a lax and/or corrupt regulatory environment, inefficient bank operations and greater perceived investment risk as attributes of an emerging market.

Based on income level, Serbia and Montenegro is classified by the World Bank (2005) as being in the lower-middle income economy, and thus can be called emerging. In addition, there is an expectation in the investment community that the region will prosper. For example, Mobius (2000) identifies broad areas of emerging markets expected to recover economically and attract international investment: “In Southern and Eastern Europe, the drive to converge with EU standards should continue to positively influence many markets. In addition, the continuation of privatisation efforts should see greater foreign interest in those markets. Political problems should move into the background and development should continue” (Mobius 2000:1).

2.2.2 Importance of Efficient Stock Market

A number of authors agree that an efficient stock market plays a critical role in the economy (Dockery, 2000; El-Erian & Kumar 1995; Fama, 1991; Magnusson & Wydick, 2002). A functional stock market effectively transfers capital from savings to a productive environment, allowing for efficient allocation of resources (Magnusson & Wydick, 2002; Dockery, 2000). Furthermore, an efficient capital market mitigates the cost of lending and trade risk, which ultimately results in a more productive economy (Dockery, 2000).

Developing markets are, in general, characterised by limited availability of domestic finance, relative to the development need, and competition for foreign sources of funding (El-Erian & Kumar, 1995). An equity market can channel international capital towards a country, allowing it to grow its economy. (El-Erian & Kumar, 1995; Gill & Trooper,1988; Magnusson & Wydick, 2002).

Standifird & Weinstein (2002) identify two important benefits of a well-functioning stock exchange for a developing country. Firstly, the regulatory regime of a stock exchange impacts on the ability of firms traded on the

exchange to establish organizational legitimacy (due to easier access to, and retention of, resources), which may be critical for a company's growth and sustainability. Secondly, a stock exchange facilitates the transition from a state-controlled to a free market economy and to the privatisation of companies (El-Erian & Kumar, 1995). This is demonstrated in the Eastern and Central European countries which achieved remarkable transformations from socialism to democracy.

Richards (1996) supports the case for liberalizing and opening financial markets in developing countries, as it allows more investors to share the risk and reduces the volatility of returns. Also, reductions in controls on capital flows lead to greater asset pricing efficiency and demand for higher standards of financial reporting and legal frameworks favourable to investment. The growth of the stock market increases the volume of long term investment as the liquidity of stock markets allows risk-averse savers to participate in long term investment projects. According to Levine and Zervos (1995), countries with more liquid stock markets experience above-average growth in investment and GDP in the long term.

Gill & Trooper (1988) identify additional benefits of a functional equity market for the country's economy. It reduces the vulnerability companies have to floating and high interest rates. This contributes to the stability of the country's financial system and economy. It also provides finance for small businesses, promotes democratic ownership of industry, establishes fair prices for securities and minimises transaction costs, all of which increase economic efficiency.

2.2.3 Factors That Encourage Market Efficiency

A number of studies have tried to determine factors which contribute to the development of an emerging stock market (Dockery, 2000; El-Erian & Kumar, 1995; Hess, 1998). They suggest the following:

- Economists and government need to understand that the equity market plays a significant positive role in the economic development of the country. Obtaining support from the government is necessary in securing other legislative, regulatory and political changes (Hess 1998).
- Macroeconomic reform that includes privatisation and encourages development and growth of private sector enterprises (El-Erian & Kumar, 1995; Hess, 1998).
- An appropriate legal system such as contract law, company law, banking law and a justice system able to enforce these. This legal framework encourages investor protection and increases their confidence.
- Deregulation and liberalisation of government controls that have in the past restricted access by foreigners, such as exchange controls, price controls, taxes, subsidies etc (Hess, 1998).
- Appropriate monetary and fiscal policy and other policies that stabilise inflation and exchange rates (Hess, 1998).
- An effective wading, clearing, settlement and custody system and transparent trading conditions (El-Erian & Kumar, 1995; Hess, 1998).
- Compliance with international standards and requirements such as accounting standards and financial requirements (El-Erian & Kumar, 1995; Hess, 1998).
- Market regulation and supervision and company information disclosure (Dockery, 2000; El-Erian & Kumar, 1995; Hess, 1998). As Hess explains “Good information is especially critical for foreign investors whose willingness to invest in an emerging market is largely driven by the ability to obtain and effectively analyse company information” (Hess 1998:27).
- Good quality education must be available to the population in order to develop the skills needed to provide the infrastructure and competitive environment for shares trading (Hess, 1998). Education and training for financial market participants, specifically brokers who must be able to provide professional service to both companies and investors is particularly important (El-Erian & Kumar,1995).

In addition to the above, Dockery (2000) identifies other factors that influence market efficiency, related to the quantitative properties of the market. These include: market thinness and supply of stocks, frequency of trading and liquidity and shortage/supply of market professionals.

2.2.4 Stages of Development

Papaioannou & Duke (1993) suggest four stages of development of an emerging equity market. The first stage is after a country has achieved a degree of economic and political stability and has begun implementing growth-oriented policies. Equity prices rise, encouraging the confidence of the domestic investors who accept investment in stock as an alternative to bank deposits and government bonds.

In the second stage, the market gets some credibility and pressures from both international investors and local companies lead to the loosening of regulations in the market (particularly exchange controls) and an attraction of international investors. Market liquidity grows.

In the third stage, the market becomes even more stable and investors easily absorb new issues of stocks and bonds. Typically, companies are increasing the number of new issues, and are tending to rely on equity to a greater extent.

Finally, in the fourth stage, the market is perceived as having similar risks and stability as one in a mature or developed country, leading to a fall in risk premiums to international levels.

2.2.5 Reasons for Investing in an Emerging Market

The eighties and nineties brought rapid growth to emerging equity markets. This growth was much higher than in some developed markets (Richards, 1996; Gill & Trooper, 1988).

Even in the eighties, the potential benefits of investment in emerging equity markets were recognised. Gill & Trooper (1988) suggest that, although volatile, emerging markets provide an opportunity to diversify investment portfolios. DeFusco, Geppert & Tsetsekos (1996) find that correlations in returns between the major emerging regions are low and occasionally negative, which provides a case for diversification of a portfolio across the main emerging regions. Wilcox (1992) suggests that the wealth being created through investment in an emerging market is high, while offering risk reduction via diversification.

Patel & Sarkar (1998), conclude that developed market crises have become less severe over time, both in terms of price decline and duration, while crises in emerging markets have not. However, even in time of crisis, international stocks continue to provide diversification benefits for US investors with long-term horizons.

2.2.6 Characteristics of Market Efficiency in an Emerging Market

There seems to be a consensus amongst researchers that, in general, the efficiency of stock markets in emerging economies is lower than the efficiency in developed economies (Butler & Malaikah, 1991; Darrat & Zhong, 2000; Dockery & Vergari, 2001; Errunza & Losq, 1985; Gillmore & McManus, 2003; Karemera, Ojah & Cole, 1999; Magnusson & Wydick, 2002; Muller, 1999; Samanta & Bordoloi, 2005; Song, Liu & Romilly, 1998). Similarly, a number of authors agree that emerging markets exhibit higher volatility than developed markets (Karemera, Ojah & Cole, 1999; Michelfelder & Pandya, 2005; Richards, 1996), and find non-normality of emerging market stock returns (Claessens, Dasgupta & Glen, 1995; Harvey, 1995; Song, Liu & Romilly, 1998; Urrutia, 1995). Therefore, emerging stock markets are often viewed as subject to manipulation by insiders at the expense of other investors (Magnusson & Wydick, 2002).

Emerging markets are less likely to exhibit random walk in stock prices. As El-Erian & Kumar (1995) suggest, dependence in prices may occur for the following reasons: companies disclose less information to investors (compared to developed markets); there is less investment research; investors are less sophisticated; markets are smaller and are fragmented; emerging markets are less organised and investors have shorter horizons because of greater political and economic uncertainties.

There seems, however, to be no consensus regarding the correlation between the returns of separate emerging markets. Divecha, Drach & Stefek (1992) suggest that emerging markets are relatively uncorrelated with each other and with developed markets, because of very few economic and trading interlinkages and severe restrictions on outsider participation. DeFusco, Geppert & Tsetsekos (1996) also find that correlations in returns between the main emerging regions are low and occasionally negative. A publication by the IMF (1995), however, suggests that returns in emerging equity markets are more likely to be correlated, as investors sometimes perceive all emerging markets as a single asset class and events in one country may affect other emerging markets with little economic rationale (IMF, 1995; Richards, 1996).

Michelfelder & Pandya (2005) find that the effect of non-trading days in an emerging market is more significant than in mature markets. This may be a consequence of inefficient networks and accumulation of information during non-trading days to the extent that it impacts the market. Also, Michelfelder & Pandya (2005) find that US shocks are rapidly transmitted to the rest of the world.

Divecha *et al* (1992) find that stock returns in the emerging markets tend to be more homogenous than in developed markets for a number of reasons. They find higher asset and sector concentration in emerging markets, meaning that few large companies or few main industries dominate the market and determine its behaviour. After adjusting for this effect, correlation between stocks is still high and indicates that a single market force tends to have a significant impact on the movement of stock prices. Finally, volatility itself and

R squared (percentage of observations explained by the model) are likely to be positively correlated (if the market moves 50% a month, it is likely that the majority of stock will have moved in the same direction).

Dockery E. *et al* (2001) explain that the size of the market is related to its efficiency. Small markets have both supply and demand limitations and this prevents investors from forming well-balanced portfolios. Small changes in investor demand can lead to large price swings and significant deviation of share prices from intrinsic value.

Patel & Sarkar (1998), based on an empirical analysis of stock index data for a number of developed and emerging markets through nine stock market crises in period 1970-1997, conclude that developed market crises have become less severe over time, both in terms of price decline and duration, while crises in emerging markets have not. Aggarwal, Inclan & Leal (1999) find that periods of increased volatility in emerging stock markets are due more to local political events than world factors.

2.3 Tests of Market Efficiency

2.3.1 Classification

There are numerous techniques used by researchers to determine levels of market efficiency. Fama (1991, 1995) classifies these tests into three main groups:

1. Tests of return predictability, encompassing both statistical tools and model comparison tests
2. Event studies
3. Tests for private information

Tests of return predictability are the biggest group. They revolve around the random walk hypothesis and are used mainly to test weak form efficiency. Within this group Fama (1995) further identifies two main approaches.

In the first approach, statistical tools, such as serial correlation coefficients and analysis of runs of consecutive price changes, are used.

In the second approach a certain model for prediction of future prices, based on mechanical trading rules (technical analysis) is tested to see if it can provide profits greater than those obtained through buy and hold. Some of these models are relatively complex such as ARIMA, GARCH, ANN etc (Song, Liu & Romilly, 1998; Darrat & Zhong, 2000; Gillmore & McManus, 2003; Samanta & Bordoloi, 2005), while others are fairly simple and are usually described as anomalies. This latter group include the weekend effect, the Monday effect (Sullivan & Liano, 2002), the January effect (Robins, Sandler & Durand, 1999) and mean reversion due to investor overreaction (Muller, 1999).

Event studies analyse the speed of price adjustment to various public announcements. These are tests for semi-strong efficiency (Fama, 1991).

Event studies have been examined in research by the likes of Dodd (1981), Fama, Fisher, Jensen & Roll (1969), and Patell & Wolfson (1984).

Tests for private information involve testing whether specific investors have information that is not discounted in market prices. Fama (1991) considers these as tests of strong form efficiency. First, possible parties with access to private information are identified (the most obvious candidates are professional portfolio managers or company directors). Second, the evidence that these parties can use this information to achieve abnormal returns (above passive buy and hold strategy) is tested. Any significant and sustained result, however, may be due to the exceptional ability of the investor or to insider information. The distinction is fairly difficult to determine. Data to analyse the performance of insider traders is not easily available for research, as insider trading is illegal (Thompson & Ward, 1995).

Fama's classification and the main tests used are presented in Table 1, below.

Table 1

Classification (as per Fama, 1991)	**Examples of tests**
I. Tests of return predictability (weak form)	
A. Statistical tools	
	1) Autocorrelation
	▪ *Box-Pierce*
	▪ *Ljung-Box*
	2) Variance ratio
	i) Single
	▪ *Lo-Mackinley (lomac)*
	ii) Multiple
	▪ *Chow-Denning (chode)*
	▪ *Johansen-Juselius*
	3) Runs
	4) Unit root
	▪ *Dicky-Fuller*
	▪ *Phillips-Perron*
B. Mechanical trading rules / model comparison / anomalies	
	▪ *ARIMA*
	▪ *GARCH*
	▪ *ANN*
	▪ *Weekend effect*
	▪ *January effect*
	▪ *Investor overreaction*
II. Event studies (semi strong form)	
III. Tests for private information (strong form)	

Following on from Fama's classification, Campbell, Lo and MacKinely (1997) classified tests of return predictability into three successively stronger categories: random walk 3 (RW3), random walk 2 (RW2) and random walk 1 (RW1).

Random walk 3 (RW3) is the most relaxed version of random walk and is used most often in the literature. In a market that complies with this category, price movements have uncorrelated increments although they may be dependent. Tests for RW3 are based on checking for serial correlation, which is the correlation between two observations of the same series at different dates. Under this version of random walk, increments are uncorrelated under all leads and lags. Some of the tests in this category are:

- Autocorrelation coefficients
- Box-Pierce and Ljung-Box
- Variance ratio tests (Lomac)

Random walk 2 (RW2) is a stronger test of weak form efficiency. It imposes an additional condition – price increments are uncorrelated and independent, but don't have to be identically distributed (heteroskedasticity assumption). The condition of independence implies that any function of past increments and any function of future increments are uncorrelated (INID). Campbell *et al* (1997) classify the following tests in this category:

- Filter rules
- Technical analysis

Random walk 1 (RW1) is the most restrictive. In random walk 1 price increments are independent and identically distributed (IID). A test for RW1 implies a test for homoskedasticity in historical price movements, in addition to the tests for RW2. Although tests with this assumption are elegant and simple, "the assumption of identically distributed increments is not plausible for financial asset prices over long time spans" (Campbell *et al*, 1997:32) and was proven incorrect in research by the likes of Errunza & Losq (1985) and Urrutia (1995). Campbell *et al* (1997) classify the following tests in the RW1 group:

- Sequences and reversals
- Runs

This classification is presented in Table 2 below:

Table 2

Classification of tests of return predictability (as per Campbell *et al*, 1997)
A. Random walk 3 (RW3): uncorrelated increments
1.Autocorrelation coefficients
2. Portmanteau studies (Box-Pierce, Ljung-Box)
3. Variance ratio (Lomac)
B. Random walk 2 (RW2): independent and non identically distributed increments
1. Filter rules
2. Technical analysis
C. Random walk 1 (RW1): independent and identically distributed increments
1. Sequences and reversals
2. Runs tests

This classification (RW3 – RW1) is complex and has been misinterpreted in the literature. For example, Magnusson & Wydick (2002) use one of the autocorrelation tests (partial auto correlation) to test whether a market conforms to RW3 and RW2. For RW3 they use simple log price increments, and for RW2 they use log price increments squared. To test for RW1, in addition to passing tests for RW3 and RW2, they use the White test for homoskedasticity.

For RW2 and RW1, however, increments have to be not just uncorrelated (RW3), but also independent, meaning that "*any* arbitrary transformation of future price increments is unforecastable using *any* arbitrary transformation of past price increments" (Campbell *et al*, 1997:33). This includes but is not limited to correlation of squared increments. No single test is comprehensive enough to encompass this definition, and testing RW2 as described by Campbell *et al* (1997) relies on trying to reject random walk based on complex prediction models (filter rules or technical analysis).

It is possible that an example given by Campbell *et al* (1997:33) had led Magnusson & Wydick (2002) in the wrong direction: “A simple example of a process that satisfies the assumptions of RW3 but not of RW1 or RW2 is any process for which $Cov\ (E_t, E_{t-k}) = 0$ for all $k \neq 0$, but where $Cov\ (E_{t2}, E_{t-k2}) \neq 0$ for some $k \neq 0$”.

Both Fama’s (1991) and Campbell *et al* (1997) classifications include, but do not explicitly describe tests for cointegration. Cointegration tests indicate joint inefficiency between different markets/stocks: i.e. past returns from one market / stock can be used to predict returns in another market/stock. Common tests used in the literature are:

- Cross-autocorrelation, used in Lo & MacKinlay (1998)
- Johansen-Juselius vector autoregression, used in Dockery & Vergari (2001), Gilmore & McManus (2003), Jha & Nagarajan (2000), Payne & Sahu (2004)
- Augmented Dicky-Fuller, used in Chan, Gup & Pan (1992)

These tests are generally used to test cointegration between emerging markets in the same or different regions, or cointegration between emerging and developed markets. In the second case, findings of low or negative correlation are encouraging to international investors who consider investing in emerging markets, as it provides additional diversification of their portfolios.

The following sections give a brief overview of some of the most commonly used testing methodologies: autocorrelation, variance ratio, unit root, runs and some of the model comparison / anomalies tests.

2.3.2 Runs Tests

Runs tests are as classified by Campbell *et al* (1997) in tests for RW1. These tests compare the number of sequences of consecutive positive and negative returns against a sampling distribution (usually normal distribution) as per

random walk hypothesis. If we label a positive return as 1 and a negative return as 0, we could encounter the following sequence in share price movement: 1001110100, where we can observe 6 runs; 3 runs of 1 (length 1, 3, 1) and 3 runs of 0 (length 2, 1, 2). Alternatively, we could encounter the following sequence: 0000011111, which has the same number of 0s and 1s, but only 2 runs (one of five 0 and one of five 1). The test of IID is constructed by comparing the number of runs in the data with the expected number of runs, but as explained by Campbell *et al* (1997) some researchers compare distributions of runs by length and by sign as well. Runs tests have been used in a number of studies, such as: Butler & Malaikah (1991) and Errunza & Losq (1985).

2.3.3 Autocorrelation

This group of tests is based on correlation coefficients between observations in a time series (autocorrelation), which in a random walk should be zero. Box-Pierce and Ljung-Box developed more powerful versions of autocorrelation tests, which test whether all autocorrelations are zero, and detect departures from zero in all directions and all lags (Campbell *et al*, 1997). Autocorrelation tests have been used in a number of studies, such as: Butler & Malaikah (1991), Fama (1965), Solnik (1973) and Song, Liu, Romilly (1998).

2.3.4 Unit Root

As Chan, Gup & Pan (1992) explain, three regression models are used for the unit root tests:

Model 1 (standard): $X_t = \alpha X_{t-1} + e_t$

Model 2 (with trend and drift): $X_t = \mu + \beta(t - \frac{T}{2}) + \alpha X_{t-1} + e_t$

Model 3 (with drift): $X_t = \mu + \alpha X_{t-1} + e_t$

Where

X_t = any stock price series (in log)

μ = the drift

T = total number of observations

e_t = error terms following any zero mean stationary process (Campbell *et al*, 1997).

And the hypotheses are:

H_o: $\alpha = 1$

H_a: $\alpha \neq 1$

The null hypothesis is also called the unit root, as α is one (unity). If the null hypothesis is not rejected, random walk is usually inferred, indicating market efficiency. A number of different tests have been developed and used in the literature to test for market efficiency, e.g.:

- Dickey-Fuller, described by Dickey & Fuller (1981), used in Alimov, Chakraborty, Cox & Jain (2004),
- Phillips-Perron, used by Chan, Gup & Pan (1992), Chauduri & Wu (2003), Gilmore & McManus (2003), Payne & Sahu (2004)
- Kwaitakowski, used by Laopodis (2003) and
- Augmented Dickey-Fuller, as used by Chauduri & Wu (2003) and Gilmore & McManus (2003)

Unit root tests, however, were proven not to be powerful enough by a number of studies such as: Summers (1986) Poterba & Summers (1988) and Fama & French (1988). The test fails to reject the null hypothesis of random walk when it is in fact false (Karemera, Ojah & Cole, 1999). As Dockery (2000) and Campbell *et al* (1997) explain, these tests are structurally insensitive to predictability. Error terms are allowed to be an arbitrary zero-mean stationary process under both null and alternative hypothesis and there are non-random walk alternatives in the null hypothesis (the increments of X_t may be predictable). Therefore, the focus of the unit root test is not on predictability of

X_t, but on the permanent / temporary nature of shocks to X_t (Campbell *et al*, 1997).

2.3.5 Variance Ratio

Variance ratio tests are very widely used in the literature for testing random walk properties of stock and other exchanges. These tests exploit the fact that the variance of a random walk increases with the size of sampling interval linearly. Therefore, a variance of *q* intervals should be *q* times the variance of one interval (Campbell *et al*, 1997; Coggin, 1998). The null hypothesis is that the variance ratio (*VR*) is one, which implies random walk of the underlying timeseries. A *VR* of less than one implies negative serial correlation, while a variance ratio greater than one implies positive serial correlation (Darrat & Zhong, 2000).

Lo & MacKinlay (1988) proposed a variance ratio test (known as Lomac), which can be used under both homoskedasticity and heteroskedasticity assumptions (Campbell *et al*, 1997). Lo & MacKinley (1989), using Monte-Carlo simulation, reported that under heteroskedastic random walk, the Lomac test performs better than Box-Pierce or Dickey-Fuller. A number of researchers found that the Lomac test is harder to pass than the alternatives. E.g. Alimov *et al* (2004) in an investigation of the Bombay stock exchange found no rejection using the Dickey-Fuller unit root test, but found mixed results for various lags using the Lomac test.

Coggin (1998) lists some of the attractive properties of the Lomac test:

- It uses overlapping intervals.
- It allows for heteroskedasticity and non-normality of returns assumptions.
- Both versions of the test (with homo and heteroskedasticity) result in a Z statistic which is asymptotically normally distributed.

The Lomac test is possibly the most commonly used test of random walk in the recent literature; e.g: Abraham, Seyyed & Alsakran (2002), Alimov, Chakraborty, Cox & Jain (2004), Coggin (1998), Darrat & Zhong (2000), Dockery (2000), Dockery, Vergari & Vergari (2001), Gillmore & McManus (2003), Karemera, Ojah & Cole (1999), Laopodis (2003), Liu & He (1991), Ojah & Karemera (1999).

As explained by Karemera, Ojah & Cole (1999), Chow & Denning in 1993 developed an even more sophisticated multiple variance ratio test which explores the unity of all variance ratios simultaneously. Their technique is known as Chode or the multiple variance ratio test. This test was used in a number of studies, such as: Karemera, Ojah & Cole (1999), Ojah & Karemera (1999).

Other variance ratio tests include a multiple ratio test similar to Chode, developed by Eckbo & Liu (1993) and the Cochrane variance ratio test used by Payne & Sahu (2004).

2.3.6 Model Comparison

The model comparison approach tests random walk hypothesis by comparing ex post forecasts from NAÏVE (random walk model) with forecasts from other (technical) models. If the market exhibits random walk, predictions from other models should not be better than NAÏVE (which is simply last week's price). Darrat & Zhong (2000) use the following alternative models to test the efficiency of the Shanghai and Shenzhen stock exchanges: ARIMA (autoregressive integrated moving average), GARCH (generalized auto regressive conditional heteroskedasticity) and ANN (artificial neural network). Similarly, Gilmore & McManus (2003) use ARIMA and GARCH in their model comparison study of the Czech, Hungarian and Poland stock exchanges.

2.3.7 Anomalies

There have been a number of studies proving that markets are not efficient by finding an obvious anomaly that contradicts random walk. Some of these findings are used to attack efficient market hypothesis, when in fact they merely prove that random walk (and therefore market efficiency) does not hold for the market under observation.

Muller (1999) demonstrates a simple contrarian investment strategy of buying losers in a certain formation period, after a certain holding period, which gives abnormal results. He attributes it to investor overreaction in discounting information into the share price, particularly information that impacts share price negatively.

Robins, Sandler & Durand (1999) describe the January effect on the JSE, where stock returns are significantly higher during the month of January.

Sullivan & Liano (2002) describe the Monday effect on the NYSE, where average returns are negative from the close of Friday to the close of Monday, particularly for small firms.

In addition, Malkiel (1989, 2000) lists other anomalies found in various researches:

- Seasonals in some markets
- Higher returns for value stocks
- Higher returns for smaller companies over longer periods of time

2.4 Existing Research on Market Efficiency

The first studies of market efficiency focused on the major stock exchanges, and especially on the NYSE (Fama, 1965; Fama & French, 1988; Lo & MacKinlay, 1988; Summers, 1986), but with the expanding interest of investors in emerging markets, a number of studies of market efficiency of these markets has been conducted.

The research conducted on market efficiency, specifically random walk, is vast. Table 3 summarises some of the more prominent research conducted, both on developed and emerging markets, presented in chronological order.

No market efficiency study has been conducted for any of the former Yugoslav republics' stock markets, including Serbia and Montenegro (Belgrade Stock Exchange).

The majority of research shows that market efficiency is lower in emerging than in developed markets (Table 3). Exact estimated levels vary, however, depending on the country and methodology used to determine efficiency level.

A number of researchers used a combination of tests in their studies, and got different results depending on the test used. For example, the Lomac test is shown as more difficult to pass than Chode (Karemera, Ojah & Cole, 1999; Ojah & Karemera 1999), runs (Abraham, Seyyed & Alsakran, 2002), unit root (Alimov, Chankraborty, Cox & Jain, 2004) or Box-Pierce (Liu & He, 1991).

It is particularly interesting that the runs test was proven to be easier to pass than Lomac (Abraham, Seyyed & Alsakran, 2002), although runs is classified by Campbell *et al* into RW1 and Lomac is classified in RW3 (RW1 should be more difficult to pass than RW3).

Some of the model comparison tests seem to be more difficult to pass than Lomac and, amongst the models, ANN gives the best predictions (Darrat & Zhong, 2000).

Results also depend on whether tests are done using data expressed in local currency or USD. For example Magnusson & Wydick (2002) find that tests are easier to pass when data is expressed in USD than in local currency.

Table 3

Abbreviation	Method	Markets	Findings
Fama (1965)	Descriptive stats, Autocorrelation, Runs tests, Filter techniques	NYSE (1952-1962)	Could not produce abnormal profits. Finds NYSE more efficient than Amsterdam SE
Solnik (1973)	Autocorrelation	Number of stocks from 8 European markets: France, UK, Germany, Italy, Netherlands, Belgium, Switzerland, Sweden	Finds no significant deviation from random walk particularly for individual stocks, but (with exception of UK) lower efficiency than US market
Dickey & Fuller (1981)	Unit root D-F		Describes Dicky-Fuller unit root test
Errunza & Losq (1985)	Autocorrelation and Runs tests	Individual securities on 10 LDC markets: Argentina, Brazil, Chile, Greece, India, Jordan, Korea, Mexico, Thailand, Zimbabwe (1975-1981)	30-35 % of stocks have normal returns distribution. Less efficient than developed markets
Lo & MacKinlay (1988)	LOMAC	US market indexes and portfolios (1962-1985)	Describe LOMAC test. Reject random walk hypothesis, but patterns of rejection do not indicate mean-reverting process.
Butler & Malaikah (1991) - published in 1992	Autocorrelation and runs tests	Kuwait and Saudi Arabia individual stocks (1985-1989)	Rejects random walk for both markets, although Kuwait seem to be more efficient than Saudi Arabia
Liu & He (1991)	LOMAC and autocorrelation (Box-Pierce)	Exchange rate series (Canadian $, FF, DM, Yen, Pound - all relative to USD)	LOMAC test rejects random walk under both homoskedasticity and heteroskedasticity, while Box-Pierce rejects in only under homoskedasticity assumption.
Chan, Gup & Pan (1992)	Unit root (Phillips-Perron) and Cointegration (Augmented Dickey-Fuller cointegration test)	Hong Kong, South Korea, Singapore, Taiwan, Japan and US indexes (1983-1987)	All markets pass unit root test. No evidence in support of cointegration is found either.
Eckbo & Liu (1993)	Own multiple variance ratio test similar to CHODE (using Chi-square distribution)	NYSE stocks (1926-1986)	Shows equity price as sum of random walk and stationary transitory (often predictable) component
Huber (1997)	LOMAC	Vienna (1986-1992)	Rejects random walk for examined 2 indexes and 7 stocks

Coggin (1998)	LOMAC and R/S (rescaled range test for long term dependence)	US market and equity style indexes (1963-1996, 1975-1996)	Lomac test does not reject random walk for either equity or market style indexes. In addition, R/S cannot find evidence in support of long term memory.
Lo & Mac Kinlay (1998)	Autocorrelations and cross-autocorrelations	US stock market (1962-1994)	Finds significant autocorrelation in returns. Finds lead/lag pattern between large and small stocks: this week's large stocks movement can forecast next week's small stocks movement.
Song, Liu, Romilly (1998)	Autocorrelation, Model comparison (GARCH) and descriptive stats	Shanghai and Shenzhen indexes (1992-1996)	Distributions of returns are not normal. Market independence hypothesis is rejected.
Karemera, Ojah & Cole (1999)	LOMAC & CHODE	15 emerging markets stock indexes (Argentina, Brazil, Chile, Hong-Kong, Indonesia, Israel, Jordan, Korea, Malaysia, Mexico, Philippines, Singapore, Taiwan, Thailand, Turkey (1986/7 - 1997)	LOMAC test rejects random walk for 9 out of 15 markets. CHODE test rejects random walk for 5 out of 15 (using USD). Find that exchange rate matters in the determination of emerging markets equity returns, as results in local currency differ.
Muller (1999)	Anomalies	JSE shares (1986-1998)	Demonstrates investor overreaction and reversion to the mean
Ojah & Karemera (1999)	LOMAC, CHODE, GPH, other	Mexico, Chile, Brazil and Argentina (1987-1997) in USD	While LOMAC rejects random walk for 3 out of 4 markets (only Argentina passes – same finding to Urrutia, 1995), CHODE and GPH test cannot reject random walk for any of the four markets.
Robins, Sandler & Durand (1999)	Anomalies	JSE shares (1990-1999)	Find that effect on achieveing above average market returns is significant for small caps, low P/B ratio companies and in January compared to other months of the year.
Darrat & Zhong (2000)	LOMAC and model comparison (ARIMA, GARCH, ANN)	Shanghai and Shenzhen (1991-1998)	LOMAC test rejects random walk. ANN provides better forecast than NAÏVE, thus rejecting random walk. Arima, however does not outperform NAÏVE.
Dockery (2000)	LOMAC	Warsaw share price index (1991-1995)	Rejects random walk
Jha & Nagarajan (2000)	Cointegration (Johansen-Juselius)	Bombay and Indian National Stock Exchange indexes (1996-1997)	Finds both markets to be relatively efficient

Dockery & Vergari (2001)	Cointegration (Johansen)	Czech, Hungary, Poland, Germany, UK (1991-1995)	Emerging East European capital markets are cointegrated with the equity markets of Germany and UK.
Dockery, Vergari & Vergari (2001)	LOMAC	Greece - Athens stock exchange individual stocks (1988-1994)	Tests fail to reject random walk hypothesis for about two thirds of shares
Abraham, Seyyed & Alsakran (2002)	LOMAC and Runs tests	Kuwait, Saudi Arabia and Bahrain stock market indexes corrected for infrequent trading (1992-1998)	When using observed indices, LOMAC test strongly rejects random walk on all their markets. When corrected for infrequent trading, LOMAC cannot reject random walk for Bahraini and Saudi Arabia. Runs test with observed indices reject random walk for Saudi Arabia and Bahrain, while Kuwait is marginally efficient. When corrected for infrequent trading, runs tests cannot reject random walk for any of the three markets.
Magnusson & Wydick (2002)	Autocorrelation	African markets and LA markets(comparison)	Amongst African markets six of eight (when tests performed in USD) pass weak efficiency test, compared to five of nine comparison markets. When measured in local currency, weak form efficiency is rejected in more instances.
Sullivan & Liano (2002)	Anomalies	NYSE (1966-1999)	Describe Monday effect, which places greater emphasis on small firm securities.
Chaudhuri & Wu (2003)	Unit root (Augmented Dickey-Fuller, Phillips-Perron) and panel based.	17 emerging markets (1985-2002) in USD: Argentina, Brazil, Chile, Colombia, Greece, India, Jordan, Korea, Malaysia, Mexico, Nigeria, Pakistan, Philippines, Taiwan, Thailand, Venezuela and Zimbabwe	Unit root tests do not reject random walk, while panel based test rejects it, giving evidence to support mean reverting process.
Gilmore & McManus (2003)	Autocorrelation (Ljung-Box), Unit root (Augmented Dickey-Fuller, Phillips-Perron), LOMAC, Cointegration (Johansen-Juselius), Model comparison (ARIMA, GARCH)	Czech, Hungary, Poland indexes (1995-2000)	Number of tests show some evidence that stock prices in these markets exhibit a random walk and that markets are not correlated. ARIMA and GARCH are, however, shown significantly superior to NAÏVE, thus rejecting random walk.

Laopodis (2003)	LOMAC , autocorrelation and unit root (Kwaitakowski)	Greece - Athens Stock Exchange Index (1985-2000)	Tests whether financial market liberalization announcements have made any difference to market efficiency. All tests conducted indicate that market was weak form efficient before and after announcements.
Alimov, Chakraborty, Cox & Jain (2004)	Unit root D-F and LOMAC	Bombay, selection of stocks and indexes (2001-2003)	Dickey-Fuller finds unit roots and cannot reject random walk for either shares or indexes. LOMAC test, cannot reject random walk for selection of 14 shares, but rejects it for indexes.
Payne & Sahu (2004)	Unit root (Augmented Dickey-Fuller, Phillips-Perron), Variance ratio (Cochrane), Cointegration (Johansen-Juselius)	Domestic real estate index for US, world real estate index and world stock market index (1980-1997)	Unit root tests provide support for random walk hypothesis for all three markets. Variance ratio cannot reject random walk for any market for 1% significance level. Cointegration test provides little evidence in support of predictive power.
Samanta & Bordoloi (2005)	Model comparison (ANN)	Bombay and Indian National Stock Exchange indexes (1999-2000)	ANN performs better than random walk model, and thus rejects random walk model.

3 Hypothesis

H_0: The Belgrade Stock Exchange is weak form efficient.

H_a: The Belgrade Stock Exchange is not weak form efficient.

4 Research Methodology

4.1 Data

4.1.1 Population

The population referred to in this research consists of stock traded on The Belgrade Stock Exchange (BSE). Currently, there are 767 stocks that trade on the BSE, with a total market cap of 339 463 million Dinars.

Share prices and trading history data is published on The Belgrade Stock Exchange official web site (www.belex.yu) and is publicly available. In order to verify the correctness of data, another source was used – the Senzal Brokerage official web site (www.senzal.co.yu). No discrepancies could be found between the two sources.

4.1.2 Sample Size and Selection

In carrying out tests for market efficiency, price history data for the composite index of The Belgrade Stock Exchange (belexfm) and the selection of 11 shares will be used. Selected shares are the largest on the BSE by market cap and are therefore included in the Belex15 index and have sufficient trading history (more than 60 weekly observations).

The Belex15 index consists of the 14 largest shares which account for more than 10% of the total market cap of the BSE (39 303 million Dinars). The Belex15 index itself is not used in the study as it has been recently formed and does not contain sufficient data for tests to be conducted (October 2005).

All data/tests are expressed/conducted in local currency (Dinars) only. Weekly data will be used. Weekly data is determined based on Wednesday's price. If the share did not trade on Wednesday, Tuesday's price is used.

The observation period will vary, as not all stocks achieved the level of liquidity required for statistical tests at the same time (at least weekly trading). Table 4 below lists stocks composing the Belex15 index and some of their properties. Table 5 lists stocks composing the Belex15 index and the number of days per month when each one traded. Finally, Table 6 specifies the selected observation period for each stock/constituent.

Table 4 – Constituents of Belex15

Issuer	**No. of Shares**	**Free Float Factor**	**FFcMCap (millions)**	**Shares traded/ FFc No. of Shares**	**Index Particip-ation**
Hemofarm koncern a.d., Vršac	3 300 000	0,5516	12 833	3,49%	20,00%
Energoprojekt holding a.d., Novi Beograd	5 626 549	0,9806	5 407	3,82%	16,34%
Alfa plam a.d., Vranje	131 083	0,8588	3 287	7,28%	9,93%
Metalac a.d., Gornji Milanovac	1 020 000	0,8132	2 986	3,40%	9,02%
Tigar a.d., Pirot	156 224	0,9729	2 930	9,96%	8,86%
Imlek a.d., Beograd	8 112 574	0,1835	2 351	7,68%	7,11%
Soja protein a.d., Bečej	460 770	0,2537	1 636	9,44%	4,95%
Bambi a.d., Požarevac	337 000	0,4318	1 527	8,39%	4,62%
Pupin Telecom a.d., Zemun	1 012 555	0,9086	1 333	7,09%	4,03%
Tehnogas a.d., Beograd	1 151 075	0,1627	1 273	12,41%	3,85%
Galenika Fitofarmacija a.d., Zemun	398 615	0,4136	1 080	18,32%	3,27%
Toza Marković a.d. Kikinda, Kikinda	891 628	0,3843	993	8,66%	3,00%
Banini a.d., Kikinda	42 412	0,5281	974	30,05%	2,94%
Srbolek a.d., Beograd	955 074	0,9600	687	3,90%	2,08%
SUM			***39.303***		***100,00%***

Table 5 – Number of days traded / month

Month	Stock													
	Hemofarm	Energoprojekt	Alfa plam	Metalac	Tigar	Imlek	Soja protein	Bambi	Pupin Telecom	Tehnogas	Galenika	Toza Marković	Banini	Srbolek
04-06	17	17	17	14	15	17	15	13	11	15	14	16	16	13
03-06	23	22	22	23	16	23	23	22	19	23	20	22	17	15
02-06	19	19	19	18	12	18	19	18	14	19	19	12	17	9
01-06	17	15	16	16	14	13	17	11	13	15	17	8	13	13
12-05	22	20	22	20	18	21	21	20	16	22	21	3	18	4
11-05	22	22	22	21	17	22	22	21	22	21	20	6	20	22
10-05	20	19	20	19	20	19	19	20	18	20	19	10	16	18
09-05	22	22	22	22	22	22	21	21	20	22	21	17	18	22
08-05	23	23	23	21	22	23	23	23	23	23	23	23	19	22
07-05	21	21	21	21	21	20	21	20	19	21	20	21	18	21
06-05	22	21	22	21	22	22	22	20	22	22	14	17	22	20
05-05	20	20	20	15	1	20	19	19	20	19	18	19	13	19
04-05	19	19	19	18		19	19	19	19	19	18	18		19
03-05	23	23	23	23		23	23	22	23	23	21	23		10
02-05	19	19	19	19		19	19	19	19	18	7	19		
01-05	16	16	16	16		15	16	16	15	9	2	16		
12-04	23	22	23	19		21	19	15	21	14	7	23		
11-04	22	22	12	20		21	21		21	20	5	21		
10-04	21	21		20			17		15	21	9	21		
09-04	22	22		20		10	12		11	17	16	22		
08-04	22	22		21		22	16			22	15	17		
07-04	20	16		19		20	13			4	18	9		
06-04	2	2				3	2							
05-04	2	2				2	2							
04-04	2	3				1	2							
03-04	3						1							
02-04	1													
01-04														

Table 6 – Observation periods

Item	Start	End
Belexfm	05-05-2004	26-04-2006
Hemofarm koncern a.d., Vršac	07-07-2004	26-04-2006
Energoprojekt holding a.d., Novi Beograd	14-07-2004	26-04-2006
Alfa plam a.d., Vranje	17-11-2004	26-04-2006
Metalac a.d., Gornji Milanovac	07-07-2004	26-04-2006
Tigar a.d., Pirot	N/A	
Imlek a.d., Beograd	03-11-2004	26-04-2006
Soja protein a.d., Bečej	07-07-2004	26-04-2006
Bambi a.d., Požarevac	15-12-2004	26-04-2006
Pupin Telecom a.d., Zemun	05-10-2004	26-04-2006
Tehnogas a.d., Beograd	02-08-2004	26-04-2006
Galenika Fitofarmacija a.d., Zemun	02-03-2005	26-04-2006
Toza Marković a.d. Kikinda, Kikinda	03-08-2004	28-10-2005
Banini a.d., Kikinda	N/A	
Srbolek a.d., Beograd	N/A	

4.2 Statistical Tests

Two tests will be conducted. Firstly the variance ratio test as presented by Lo & MacKinlay (1988) is used. This test is probably the most frequently used test in other similar research. This will ensure that results are comparable with the results from other markets. In addition to the variance ratio, the runs test will be used. Firstly, this will contribute to the reliability of the study. Secondly, it may re-confirm or disprove Abraham et al's (2002) conclusion that the runs test (which is a RW1 test) is easier to pass than Lomac (which is a RW3 test). The runs test used will follow the methodology documented in Abraham *et al* (2002).

4.2.1 Variance Ratio Test

The variance ratio test for random walk, developed by Lo and MacKinlay (1988), tests whether the variance of the returns in a particular share price time series increases linearly with the sampling interval (e.g. variance of monthly returns should be 4 times variance of weekly returns), which would indicate random walk.

In the sample of n*q +1 share prices (P_t,), the variance ratio, *VR(q)*, is defined as:

$$VR(q) = \frac{\sigma_c^{\,2}(q)}{\sigma_a^{\,2}(q)} \qquad (1)$$

Where $\sigma_c^2(q)$ is *1/q* of the variance of the *q*-differences and $\sigma_a^2(q)$ is the variance of the first differences.

Where:

$$\sigma_c^{\,2}(q) = \frac{1}{m}\sum_{t=q}^{nq}(X_t - X_{t-q} - q\hat{\mu})^2 \qquad (2)$$

$$\sigma_a^{\,2}(q) = \frac{1}{nq-1}\sum_{t=1}^{nq}(X_t - X_{t-1} - \hat{\mu})^2 \qquad (3)$$

$$\hat{\mu} = \frac{1}{nq}(X_{nq} - X_0).$$

$m = q(nq - q + 1)(1 - q/nq)$ and (4)

$X_t = \ln(P_t)$ (5)

The asymptotic variance of the variance ratio under homoscedasticity, $\phi(\theta)$ is:

$$\phi(q) = \frac{2(2q-1)(q-1)}{3q(nq)} \quad (6)$$

The standard normal test statistic under homoscedasticity, *Z(q)* is then:

$$Z(q) = \frac{VR(q) - 1}{[\phi(q)]^{1/2}} \overset{a}{\sim} N(0,1) \quad (7)$$

Here $\overset{a}{\sim}$ indicates that the data fits the distribution asymptotically.

Next, the heteroscedasticity-consistent asymptotic variance of the variance ratio, $\phi^*(\theta)$ is:

$$\phi^*(q) = \sum_{j=1}^{q-1}\left[\frac{2(q-j)}{q}\right]^2 \hat{\delta}(j) \quad (8)$$

Where

$$\hat{\delta}(j) = \frac{\sum_{t=j+1}^{nq}(X_t - X_{t-1} - \hat{\mu})^2 (X_{t-j} - X_{t-j-1} - \hat{\mu})^2}{\left[\sum_{t=1}^{nq}(X_t - X_{t-1} - \hat{\mu})^2\right]^2} \quad (9)$$

The heteroscedasticity-consistent standard normal test statistic, $Z^*(q)$, is then:

$$Z^*(q) = \frac{VR(q) - 1}{[\phi^*(q)]^{1/2}} \overset{a}{\sim} N(0,1) \quad (10)$$

4.2.2 Nonparametric runs test

The actual runs *(R)* are counted and compared to the expected number of runs *(m)*, defined below. This is done under the assumption of independence.

$$m = \frac{\left[N(N+1) - \sum_{i=1}^{3} n_i^{\,2}\right]}{N} \quad (11)$$

Where N is the total number of return observations and n_i is a count of price change in each category (increase, decrease or no change). For a large number of observations *(N>30)*, m approximately corresponds to a normal distribution with standard error (σ_m) of runs as specified below:

$$\sigma_m = \left[\frac{\sum_{i=1}^{3} n_i^2 \left\{ \sum_{i=1}^{3} n_i^2 + N(N+1) \right\} - 2N \sum_{i=1}^{3} n_i^3 - N^3}{N^2(N-1)} \right]^{\frac{1}{2}} \qquad (12)$$

The standard normal Z statistic can be used to test whether the actual number of runs is consistent with the independence hypothesis. In this case:

$$Z = \frac{R-m}{\sigma_m} \qquad (13)$$

Positive Z value indicates a negative serial correlation in the returns series and vice versa.

4.3 Data Analysis and Interpretation

4.3.1 Interpretation of Variance Ratio Test

Hypothesis

The variance ratio tests random walk by testing whether the variance of the returns in a particular share price time series increases linearly with the sampling interval. In other words a variance using *q* intervals should be *q* times the variance of one interval (Campbell *et al*, 1997; Coggin, 1998). The null hypothesis is that the variance ratio (*VR*) is unity, which implies random walk of the underlying timeseries.

Therefore our research hypotheses:

- H_0: Belgrade Stock Exchange is weak form efficient.
- H_a: Belgrade Stock Exchange is not weak form efficient.

translates into:

- H_0: Variance ratio equals one.
- H_a: Variance ratio does not equal one.

for each examined timeseries (share).

A variance ratio less than one implies negative serial correlation, while a variance ratio greater than one implies positive serial correlation (Darrat & Zhong, 2000). Therefore, variance ratio is inherently a two-tailed test.

Significance Level and Decision Rule

The variance ratio test calculates the variance ratio and standard normal Z statistic. Interpretation of the test is based on comparison of Z calculated to Z critical. The critical Z value varies based on the selected significance level and the number of observations (as represented by the degrees of freedom).

For example, for 60 degrees of freedom (Wits Business School, 2004):

- For significance level of 10%, Z critical is 1.67;
- For significance level of 5% Z critical is 2.00 ; and
- For significance level of 1% Z critical is 2.66.

Therefore, the decision rules for data analysis in a sample of 61 observations (60 degrees of freedom) can be defined as follows:

- If calculated Z value is more than 1.67 H_0 can be rejected at the 90% confidence interval.
- If calculated Z value is more than 2.00 H_0 can be rejected at the 95% confidence interval.
- If calculated Z value is more than 2.66 H_0 can be rejected at the 99% confidence interval.

As the number of observations varies between different price timeseries, different Z values will be used. Table 7 below lists the number of observations for each tested timeseries. Table 8 lists Z values for two-tailed tests for different degrees of freedom.

Table 7 – Number of observations and degrees of freedom for each timeseries

Item	Observations	DOF
Belexfm weekly	103	102
Hemofarm koncern a.d., Vršac	94	93
Energoprojekt holding a.d., Novi Beograd	93	92
Alfa plam a.d., Vranje	75	74
Metalac a.d., Gornji Milanovac	94	93
Tigar a.d., Pirot	N/A	
Imlek a.d., Beograd	77	76
Soja protein a.d., Bečej	94	93
Bambi a.d., Požarevac	71	70
Pupin Telecom a.d., Zemun	81	80
Tehnogas a.d., Beograd	64	63
Galenika Fitofarmacija a.d., Zemun	60	59
Toza Marković a.d. Kikinda, Kikinda	65	64
Banini a.d., Kikinda	N/A	
Srbolek a.d., Beograd	N/A	

Table 8 – Critical Z values for two-tailed test

DOF	10%	5%	1%
40	1.684	2.021	2.704
60	1.671	2.000	2.660
120	1.658	1.980	2.617
Large Samples	1.645	1.960	2.576

4.3.2 Interpretation of Runs Test

Hypothesis

The runs test counts and compares the actual number of runs to the expected number of runs. This is done under the assumption of independence.

Therefore our research hypotheses:

- H_0: Belgrade Stock Exchange is weak form efficient.
- H_a: Belgrade Stock Exchange is not weak form efficient.

translates into:

- H_0: Actual number of runs is the same as expected.
- H_a: Actual number of runs is not the same as expected.

for each examined timeseries (share).

Negative serial correlation is implied when the actual number of runs is greater than expected, while positive serial correlation is implied when the actual number of runs is less than expected. Therefore the runs test is inherently a two-tailed test.

Significance Level and Decision Rule

As the runs test is a two-tailed test, the interpretation of which is based on comparison between Z calculated and Z critical, the interpretation (significance level and decision rule) will be the same for the runs test as for the variance ratio test.

4.4 Validity and Reliability of Study

The validity of the study is defined as “accuracy, meaningfulness and credibility” of the study as a whole (Leedy & Ormrod, 2001:103). The reliability of the study is concerned with the consistency of results within the study (Leedy & Ormrod, 2001).

4.4.1 Internal Validity

Internal validity refers to the ability of the researcher to draw accurate conclusions from the study. In other words, how great is the possibility that the study results are caused by other reasons apart from the ones concluded? (Leedy & Ormrod, 2001).

Using a proven methodology which has been previously applied in the literature contributes to the internal validity of this study. It is acknowledged that infrequent trading and the small data set may be a reason for bias in the results.

4.4.2 External Validity

External validity refers to the extent to which results from a specific study can be generalised. One method of improving external validity is by using a representative sample. Another method is replicating previous research in another context (Leedy & Ormrod, 2001).

It is acknowledged that this research, in addition to composite index of the Belgrade Stock Exchange, uses a selection of shares that are chosen amongst largest market cap companies, and might not be fully representative of the BSE market as a whole. This might affect external validity of the study.

Furthermore, this research replicates, in a new context, research done on market efficiency in a number of developing and emerging markets. The

results of this research can be later compared to similar research done in other Eastern European emerging markets.

4.4.3 Reliability

Reliability refers to the consistency of results within a study (Leedy & Ormrod, 2001). This research uses two tests of random walk; if both tests provide the same results, then the reliability of findings is a great improvement on research using only one test.

5 Presentation of Results

5.1 Runs Test

Results of the runs test are presented in table 9, below. For each individual share and for the Belex FM index, the table lists the number of weekly observations used, the number of runs of each category (positive, negative and zero runs), the expected and actual number of runs, standard error and Z-statistic.

Asterisk (*) next to Z value indicates rejection of H_0 at 10% significance level (90% confidence), two (**) indicate rejection of H_0 at 5% significance level (95% confidence) and three (***) indicate rejection of H_0 at 1% significance level (99% confidence).

Table 9 – Results of runs tests

ITEM	Observations	Positive returns	Negative returns	Zero returns	Expected runs	Actual runs	Standard error	Z-statistic
	N =	n(+) =	n(-) =	n(0) =	m =	R =	sm =	Z =
Alfa	74	30	40	4	41	36	4.00	-1.25
Bambi	70	29	31	10	44	42	3.85	-0.48
BelexFM	102	40	62	0	50	45	4.79	-0.97
Energoprojekt	92	41	46	5	51	44	4.55	-1.64
Galenika	59	30	23	6	35	29	3.50	-1.76*
Hemofarm	93	34	46	13	57	39	4.38	-4.11***
Imlek	76	28	31	17	50	41	4.02	-2.30**
Metalac	93	44	44	5	52	41	4.59	-2.42**
Pupin	80	40	36	4	45	42	4.25	-0.61
Soja	93	43	42	8	54	42	4.51	-2.76***
Tehnogas	63	26	35	2	34	27	3.74	-1.81*
Toza	64	26	32	6	38	34	3.68	-1.05

5.2 Variance Ratio Test

Table 10, on the next page, presents results of the variance ratio test. For each individual share and Belex FM index, the table lists variance ratio (VR), Z statistic under homoscedasticity assumption (Z(q)) and Z statistic under heteroscedasticity assumption (Z*(q)), for each of selected observation intervals (q = 2, 4 and 8, with weekly observations as a base).

Asterisk (*) next to Z value indicates rejection of H_0 at 10% significance level (90% confidence), two (**) indicate rejection of H_0 at 5% significance level (95% confidence) and three (***) indicate rejection of H_0 at 1% significance level (99% confidence).

Table 10 – Results of variance ratio test

ITEM	VARIANCE RATIO TEST		
	q=2	q=4	q=8
	VR Z(q) Z*(q)	VR Z(q) Z*(q)	VR Z(q) Z*(q)
Alfa	1.33 2.76 *** 0.63	1.52 2.35 ** 0.74	1.48 1.36 0.50
Bambi	0.84 -1.37 -0.47	0.86 -0.60 -0.33	0.96 -0.11 -0.07
BelexFM	1.25 2.49 ** 1.15	1.61 3.26 *** 1.42	2.10 3.65 *** 1.89 *
Energoprojekt	1.15 1.41 0.37	1.45 2.29 ** 0.83	1.98 3.10 *** 1.48
Galenika	1.05 0.38 0.13	0.79 -0.86 -0.44	0.63 -0.93 -0.49
Hemofarm	1.25 2.36 ** 0.62	1.35 1.78 * 0.71	1.41 1.30 0.56
Imlek	0.85 -1.35 -0.54	1.02 0.11 0.04	1.38 1.09 0.44
Metalac	1.49 4.68 *** 1.45	2.36 6.97 *** 2.49 **	2.84 5.84 *** 2.75 ***
Pupin	1.08 0.75 0.31	1.23 1.08 0.51	1.43 1.29 0.66
Soja	1.28 2.64 ** 1.05	1.61 3.13 *** 1.28	2.12 3.55 *** 1.75 *
Tehnogas	1.30 2.33 ** 0.68	1.01 0.05 0.02	0.81 -0.47 -0.27
Toza	1.34 2.74 *** 1.10	1.64 2.76 *** 1.55	1.42 1.14 0.76

6 Analysis and Interpretation of Results

6.1 Interpretation

As can be observed in Table 9, at 95% confidence interval (5% significance level) the runs test rejects H_0 hypothesis (actual number of runs is equal to expected number of runs under random walk) for 4 out of 11 selected shares, while it fails to reject it for BelexFM index and 6 shares. This means that whn using the runs test, random walk cannot be rejected for a composite index of the Belgrade Stock Exchange and more than half of the selected individual shares.

The results of the variance ratio test, presented in Table 10, are somewhat mixed, depending on homo/heteroscedasticity assumption and selected observation interval, q.

At 95% confidence interval (5% significance level), under homoscedasticity assumption, the test rejects H_0 (variance ratio equals one) for:

- BelexFM index and 6 out of 11 shares at q=2;
- BelexFM index and 5 out of 11 shares at q=4; and
- BelexFM index and 3 out of 11 shares at q=8.

Variance ratios which were found statistically different from 1, are greater than one, implying positive serial correlation (Darrat & Zhong, 2000).

At the same confidence interval under heteroscedasticity assumption, the variance ratio test, however, cannot reject H_0 for all but one share for q = 4 and q = 8. This means that using the variance ratio test, under heteroscedasticity assumption, random walk cannot be rejected for composite index of the Belgrade Stock Exchange and practically all selected individual shares.

Overall, results of both tests show that random walk properties cannot be rejected for the composite index of the Belgrade Stock Exchange and more than half/majority of the selected shares. This provides support for efficient market hypothesis for the Belgrade Stock Exchange, although it cannot be taken as a proof of its efficiency as a whole. Future research could use longer observation periods, a bigger share sample and stronger tests in order to confirm the findings of this research with more confidence.

6.2 Tests: LOMAC vs Runs

Overall, in this research, it appears that the LOMAC test is easier to pass than the runs test. This finding is consistent with the classification of tests (RW1-RW3) presented in Campbell *et al* (1997), but not with the majority of empirical research where, as discussed previously, LOMAC is found more difficult to pass than runs. One probable explanation for this inconsistency is that, as noted by number of authors (Chow & Denning, 1993; Coggin, 1998; Lo & MacKinlay, 1989), the variance ratio test appears to be weaker than alternatives when the number of observations is relatively small. Lo & MacKinlay (1989) note this as the observation interval, q, approaches one half of the sample size, while Chow & Denning (1993) specify 256 observations as the generally accepted minimum.

Research using the LOMAC test on a lower number of observations had, however, been conducted. For example Alimov *et al* (2004) use the unit root and LOMAC test on the Bombay Stock Exchange using 115 weekly observations, and find the LOMAC test stronger than the unit root.

6.3 Consistency with other research

Runs and variance ratio tests performed, fail to reject random walk for the composite index of the Belgrade Stock Exchange and more than half of the selected individual shares, lending support to the efficient market hypothesis

for the Belgrade Stock Exchange. These results are consistent with other research recently conducted on emerging markets, both in Europe and worldwide, which indicate that emerging markets are, although less efficient than developed markets, not necessarily inefficient (Abraham *et al*, 2002; Alimov *et al*, 2004; Dockery E. *et al*, 2001; Errunza & Losq, 1985; Gilmore & McManus, 2003; Karemera *at al*, 1999; Laopodis, 2003; Ojah & Karemera, 1999). For example, Gilmore & McManus (2003) using serial correlation and variance ratio tests, fail to reject random walk for Hungarian, Czech and Polish stock exchanges, although ARIMA and GARCH models do reject it. Both Laopodis (2003) and Dockery E. *et al* (2001) using the variance ratio test cannot reject random walk for the Athens Stock Exchange. Abraham *et al* (2002), find that when corrected for infrequent trading, the variance ratio test cannot reject random walk for either Bahraini or Saudi Arabian market, although it is rejected for the Kuwaiti market, while the runs test cannot reject random walk for either of them. Ojah & Karemera (1999) find that South American equity markets (Argentina, Brazil, Chile and Mexico) conform to random walk using variance ratio tests. Karemera *at al* (1999), using runs tests, find 9 out of 15 world emerging equity markets weak form efficient, while using the LOMAC test they find about half of them weak form efficient.

6.4 Implications

Since the results lend support to the hypothesis that the Belgrade Stock Exchange is weak form efficient, potential investors can derive a certain amount of confidence in the Exchange. As it is an emerging market, on which stocks only started actively trading two years ago, international investors would most likely be slow to trade on the Belgrade Stock Exchange. This research is thus valuable, as it shows that the Belgrade Stock Exchange should be considered a fair trading place.

7 Conclusion

Runs and variance ratio tests performed, using local currency weekly data, in the period 2004-2006, fail to reject random walk for the composite index of the Belgrade Stock Exchange and more than half of the selected individual shares. This provides support for the efficient market hypothesis for the Belgrade Stock Exchange and for the recent research on emerging markets that finds that emerging does not necessarily mean inefficient. This will hopefully increase international investor confidence and attract capital towards the country.

8 Suggestions for Further Research

Four out of six former Yugoslav republics have their own stock exchanges, all of which started operating recently. They are the Belgrade Stock Exchange (Serbia and Montenegro), the Ljubljana Stock Exchange (Slovenia), the Zagreb Stock Exchange (Croatia) and the Macedonian Stock Exchange (Macedonia). They are considered emerging markets and present interesting research opportunities.

Similar research to this could be conducted for the other three stock exchanges, determining their level of efficiency. A comparison between efficiency levels of the four exchanges could be made as well as analysis of reasons for possible differences. It would also be interesting to investigate the correlation among four markets, or their correlation with other European markets.

Efficiency tests for the Belgrade Stock Exchange could be conducted at a later stage, using longer timeseries and/or a different set of tests.

Finally, if any research shows signs of inefficiency, it could be investigated whether that inefficiency could be exploited to achieve abnormal profits in real trading conditions (taking trading costs into account).

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