EFFICIENCY IN EMERGING MARKETS: APPLYING THE AUTOMATIC VARIANCE RATIO TEST

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Abstract

This paper analyzes the efficiency of the market in its weak form, as proposed by Fama (1970), in 24 emerging countries, after the subprime crisis of 2007/2008. To answer the research problem, initially calculated the log return of the main contents of these countries. After we used the automatic variance ratio for small samples, as Kim (2006) and Kim (2009). The results indicate monthly market inefficiency for Chile, Hungary and Malaysia as well as demonstrated inefficiency, on a daily basis, for the Chilean, Egyptian, Filipino, Israeli, Jordanian, Malaysian, Mexican, Russian and Thai market.

Keywords: Market Efficiency, Emerging Markets, Automatic Variance Ratio

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1. Introduction

The random walk hypothesis provides a way to test the predictability of stock returns and efficiency in its weak form in stock markets. According to Fama (1970), a market is considered efficient when the price system reflects a whole set of information available for players. If this set of information is only made up of past prices, such definition implies the weak form of efficiency.

On a random walk, there is no way to make a prediction based on past values of the time series. For a stock, e.g., the current price will be the best prediction of a future price. Thus, according to that hypothesis, the univariate prediction models would not be able to infer the future behaviour of that asset.

Many authors have dedicated their studies to empirically test this hypothesis in stock markets, putting together several methods in order to test it, among which we point out the variance coefficient. Despite Lo & MacKinlay (1988) and Cochrane (1988) not having been the first ones to deal with this subject – since other authors had already used the variance ratio concepts in several contexts, such as Campbell & Mankiw (1987), Fama & French (1988) and French & Roll (1986) – they were the ones who formalised the sample theory for tests statistics.

These last five decades there were numerous empirical studies regarding the market's efficiency. In this sense, Lim (2009) comments that this number is still growing – although in a slower pace – emphasising more the emerging stock markets (e.g. Squalli (2006), Chakraborty (2006) and Hassan & Chowdhury (2008), Hoque *et al*. (2007), Kim & Shamsuddin (2008), Al-Khazali et al. (2007), Ntim *et al*. (2007), Smith (2007), Smith (2008), Lagoarde-Segot & Lucey (2008), Smith (2009), Righi & Ceretta (2011)).

Several refinements were suggested in order to increase the variance ratio test robustness related to heteroscedastic procedures, besides decreasing the size distortions and improve its power. Tests that consider the whole variance ratio statistics distribution were suggested in order to solve the size super-dimensioning problem that results from using the same set of data for different inferences (Richardson & Smith (1991); Chow & Denning (1993); Chen & Deo (2006).

Choosing the investment horizons is the only parameter to be determined in the variance ratio test. Normally, random values are picked and they are limited by the sample size; meanwhile, according to the author, the test result is sensitive to these parameters choice.

In order to solve such sampling problems, Choi (1999) developed an automatic variance ratio test where the aggregation value (investment horizon) is chosen by using an optimal rule suggested by Andrews (1991). Recently, Kim (2006, 2009) suggested some improvements to Choi's test (1999), where the author presents the application of a resampling wild bootstrap method so as to improve its performance. Kim's test (2009) has not shown any distortions in size and it had a relatively greater power when compared to other competing tests, such as Chen & Deo's (2006) and Chow & Denning's (1993).

After Kim's article (2006), several authors verified the efficiency of Kim's variance ratio test for small samples (2006, 2009), e.g.: Charles & Darné, (2009c), (Montagnoli & De Vries (2010), Charles, Darné, & Fouilloux (2011), Al-Khazali, Pyun, & Kim (2012), Charles, Darné & Kim (2010).

Considering that the equity markets' efficiency studies in emerging countries has had a growing relevance in finances empirical literature, and that several studies have shown changes in emerging markets behaviour after a crisis period (e.g.: Lim, Brooks, & Kim (2008), Chen & Jarett (2011), Righi & Ceretta (2011)), the use of traditional techniques in order to verify the variance ration and eventually market's efficiency can be harmed due to the small number of observations, where we would point out a more aggregated evaluation, using monthly basis. In this context, using techniques with wild bootstrap re-sampling, such as Kim's (2006, 2009) might be an important alternative to this type of evaluation.

Recently, the 2007/2008 sub-prime global crisis significantly changed the equity market in emerging countries (Chen & Jarett, 2011, Righi & Ceretta, 2011). Considering this fact and, given the small number of daily and especially monthly observations, this research had the objective of answering the following research problem: *"Do emerging markets after the 2007/2008 sub-prime crisis show the market efficiency assumption in its weak form as suggested by Fama (1970)?"*

2. CONCEPTUAL AND THEORETICAL STRUCTURE

2.1. Market's efficiency

The efficient markets' hypothesis was effectively originated in Samuelson's (1965) and Fama (1963), Fama (1965a), Fama (1965b) and Fama (1970) research. Samuelson showed that in a market with informational efficiency price changes cannot be foreseen, since prices already incorporate all the information and expectations of market participants. His interest in the mechanics and behaviour of prices led to several research schedules that included solutions for dynamically allocating assets and optimal investment policies, culminating in the options pricing model by Black & Scholes (1972) and Merton (1973).

Eugene Fama was focused on measuring the statistical features of stock prices, focusing the debate between technical and fundamentalist analysis, that use past prices and companies fundaments, respectively, in order to foresee prices and to price stocks. Fama was the first one to use the expression "efficient markets" (Fama, 1965b), which are characterised by prices utterly reflecting the available information and structuring the several sets of available information for market participants, thus making the efficient markets hypothesis viable.

According to Fama (1991), the efficient market hypothesis argues that stock prices do not follow any type of pattern, i.e., that it has a random dynamics where it is not possible to identify any regularity such as cycles or seasonality. According to this author, considering that stock prices' behaviour is completely random, investors would not have the conditions to structure ay sort of negotiation strategy based on specific time intervals that produce extraordinary return rates.

The efficient market hypothesis is divided into three categories, in which we observe different references regarding the information type. Those are: weak form, semi-strong form and strong form. The weak form efficiency is based on a set of information that only includes the prices History or stocks return. The semi-strong form considers a set of information that only includes the public knowledge obtained by all participants in the market. The strong form efficiency includes all information obtained by any participant in the market.

There were other definitions of market efficiency suggested by Rubinstein (1975), Jensen (1978), Beaver (1981), Black (1986), Dacorogna *et al*. (2001), Malkiel (2003), Timmermann & Granger (2004) and Milionis (2007). Since there is no consensual definition for the pattern of market efficiency, we adopted the version by Fama (1970) that emphasises both speed and precision of prices adjustment to new information.

Much research has tested the market efficiency hypothesis in its weak form using variance ratio tests. This subject will be approached in the next section.

2.2. Variance ratio tests

The serial correlation and spectral analysis tests are the tools that were initially used in market efficiency literature, in its weak form, and their precursors are Fama (1965a) and Granger & Morgenstern (1963), respectively. These statistical procedures test the least restrictive hypothesis of a random walk, which is RW3 (model by Campbell, Lo & MacKinlay (1997)).

On the other hand, the first statistical tests to determine if a stochastic process is a random walk are older. Cowles & Jones (1937) focused RW1 random walk tests, where errors and independent and identically distributed (i.i.d.). Authors built a test based on the comparison between the constancy of sequences and reversions showed up on stock return. Mood (1940)developed a runs test, based on the number of sequences of positive or negative consecutive returns. This type of test was generalised for procedures with dependent errors (Aldous (2010); Aldous & Diaconis (1986)). Another test for the RW1 hypothesis, based on procedures' auto-correlations, is the Box & Pierce *Q* test (1970).

Also from this point of view, Alexander (1961) presented RW2 random walk tests. The author suggested a filter where an asset would be bought when its price would go up a determined percentual and sold when it decreased a certain amount. Thus, the total return of his strategy would be a measure of predictability of assets return. Fama (1965a) and Fama & Blume (1966) presented a more thorough analysis on filters. There are other methods used to measure returns predictability, such as the graphic analysis techniques, using geometrical patterns in graphics on stock volume and price to foresee future prices.

Several authors have used mean reversion stationary models in order to verify the existence of transitory components in stock prices and test the weak form market efficiency hypothesis via an RW3 model (Shiller & Perron (1985); Summers (1986); Poterba & Summers (1988); Fama & French, 1988). As a consequence, Lo & Mackinlay (1988) & Cochrane (1988) explored the fact that the error variance on a random walk is a linear function of time, making it possible to test several random walk hypotheses, including RW3. The authors built a variance ratio test for the random walk hypothesis and demonstrated it via an American stocks analysis in a 20-year period. Cochrane (1988) used the variance ratio as a fluctuations persistency measure for the American GDP, from 1869 to 1986.

Since Lo & MacKinlay's (1988) research, the variance ratio test has emerged as the main tool to test the random walk hypothesis and, consequently, the weak form market efficiency. As a consequence, Charles & Darne (2009b)provide an extensive bibliographical research on its recent evolution. The variance ratio test as suggested by Lo & MacKinlay (1988) was created under two null alternatives, in order to capture two sides of the random walk: (a) independent and identically distributed innovations as a normal distribution (i.i.d.); and (b) not correlated but weakly dependent innovations with the possibility of heteroscedasticity on its frequency distribution (m.d.s.). The crucial point on this test is that if the return of one stock item follows a purely random walk, the return variance of a period q is q times the variance on the first difference. Thus, the null hypothesis in this test states that the variances ratio equals 1.

After Lo & MacKinlay (1988) several improvements were performed, where the research by Chow & Denning (1993) stand out; they suggested the multiple variance ratio test. This test implies a change on the Lo and MacKinlay's test where one can simultaneously verify if all variance ratios equal 1. Another remarkable innovation in the variance ratio test was presented by Wright (2000); the author suggested the use of non-parametrical variances ratio tests based on positions and signals of time series.

Another refinement of the variance ratio test was the automatic determination of investment horizons, initially suggested by Choi (1999), using the optimal rule for estimating the spectral density on zero frequency, developed by Andrews (1991). Kim (2009) analyse this test's performance and suggested using the wild bootstrap method to improve it in small samples. The test suggested by Kim (2009) did not show any distortions in size and the power was substantially bigger than in other tests, such as the ones by Chen & Deo (2006) and Chow & Denning (1993). The importance of this test is about the fact that one does not need random investment horizons choices that can lead to contradictory results depending on the values chosen. In order to control the test's dimension, other procedures were suggested in literature (Richardson & Smith, 1991; Whang & Kim (2003), Kim (2006) and Kim & Shamsuddin, (2008)).

The past five decades, there were numerous empirical studies related to the market efficiency which make it impossible to review all of them for this one project. On the other hand, Lim & Brooks (2006) provide an extensive list of published articles between 1965 and 2005. Review is thus focused on recent stock market studies.

As quoted by Lim (2009), the quantity of empirical evidence regarding market efficiency is still growing in the past few years, though at a slower pace, creating a greater emphasis on emerging stock markets. As a consequence, Squalli (2006) examines the weak form market efficiency for two stock markets in the Arabian Emirates: the Dubai Financial Market (DFM) and the Abu Dhabi Securities Market (ADSM). Both are relatively young, since they were opened on the turn of this millennium. Results from the variance ratio test consistently show that most economical sectors at DFM and ADSM are inefficient. Other studies associated to the Bangladesh and Pakistan stock market are presented by Chakraborty (2006) and Hassan & Chowdhury (2008).

Other studies have shown the weak form market efficiency in emerging markets such as the ones in Eastern Europe (Smith & Ryoo, 2003), African markets (Lagoarde-Segot & Lucey, 2008). Other markets were also analysed, such as Egypt, Jordan, Kuwait, Morocco, Oman, Saudi-Arabia and Tunisia (Al-Khazali *et al.*, 2007); also in Israel, Jordan and Lebanon (Smith, 2007); Korea, Taiwan and Thailand (Kim & Shmsuddin, 2008) and in Egypt, Nigeria, South Africa and Tunisia (Smith, 2008); Poland and

Turkey (Smith, 2009); or even in more robust markets such as the American (Campbell & Yogo (2006) and Kim, Shamsuddin, & Lim(2011)), the American and the Japanese (Chang, Lima, & Tabak, 2004).

The recent methodological refinements for the variance ratio tests led to a series of studies performed in the Asian stock market where we point out Hoque *et al*. (2007), Kim & Shamsuddin (2008). We also verify studies developed in Europe (Smith, 2009), Middle East & Africa (Al-Khazali *et al*., 2007; Ntim *et al*., 2007; Smith, 2007; Smith, 2008; Lagoarde-Segot & Lucey, 2008).

On the other hand, several authors of international research have applied – with excellent results – the automatic variance ratio for small samples, as suggested by Kim (2006) and Kim (2009). In their research, Charles & Darné (2009c) apply the automatic variance ratio for small samples in order to test market efficiency in the brent-like oil market. Authors demonstrated that this market has shown to be inefficient in the analysed period (1994-2008).

On the other hand, Montagnoli & Vries (2010) used Kim's test (2006, 2009) to analyse a relatively young and immature market, which represents a very limited set of negotiations: the European Union Emissions Trading Scheme. In their research, authors show that this market was inefficient between June 2005 and December 2007, and that it was efficient between February 2008 and April 2009, indicating that this market is showing its first signs of maturity.

Like Montagnoli & Vries (2010), Charles, Darné & Fouilloux (2011) used the automatic variance ratio for small samples, as suggested by Kim (2009), in order to test the European Carbon Credits market efficiency (BlueNext, European Energy Exchange and Nord Pool), on a daily and monthly basis. Authors showed that this market has shown to be inefficient, except for the period between April 2006 and October 2006.

More recently, Al-khazali (2012) have applied Kim's (2006, 2009) automatic variance ratio in order to test the currency markets of seven different Asian countries plus the Australian dollar. In their research, the authors did not reject the null random walk hypothesis for the whole sample for the following currencies: the Australian dollar and the South-Korean won. On the other hand, currencies from countries like Malaysia (*Ringgit*), Indonesia (rupee), the Philippines (the Philippine peso), Singapore (Singaporean dollar), Taiwan (Taiwanese dollar) and Thailand (*baht*) have shown to be inefficient, especially after the 1997 Asian crisis. Charles, Darné & Kim (2011) proved Kim's (2006, 2009) automatic variance ratio efficiency by performing comprehensive tests using Monte Carlo experiments on their simulations, thus demonstrating the method's efficiency.

This research seeks to answer the research problem using the variance ratio test for small samples, according to Kim (2006, 2009). The methodological details are as follows.

3. METHOD

Now, one must define the markets to be studied. Despite not having a consensual definition for and emerging market, the World Bank defines this concept when that GDP is smaller than that of developed countries. The economist Jim O'Neil classifies Mexico, South Korea, Turkey, Brazil, Russia, China, and India as growing markets.

The MSCI EM (emerging markets) is a dollar calculated index that is adjusted by liquidity and capitalization of the assets market. Countries that qualify to make up the index are those that belong to the universe of emerging countries regarding the criteria used in MSCI pattern method.

Emerging markets – classified on MSCI EM – are: Argentina, Brazil, Chile, China, Colombia, Czech Republic, Egypt, Hungary, India, Indonesia, Israel, Jordan, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Poland, Russia, South Africa, South Korea, Taiwan, Thailand and Turkey. The companies listed in these countries in January 2011 piled up over 15 trillion dollars (the equivalent to the market value of the companies listed on the USA stock markets), representing 30.80% of the total market value of stock markets all over the world (CIA, 2011).

We used for this research the emerging stock markets indexes that currently belong to MSCI EM. The collected data considered the definition of the American post-crisis period as in De Freitas (2009), where the author comments that as of June 2009 the 2007/2008 subprime crisis started showing a smaller influence in equity markets. The analysed post-crisis period comprehended 28 months between June 2009 and September 2011 and, in average, it made up 582 days of daily negotiations in the analysed markets.

We calculated the indexes' logarithmic return for the analysed countries and we then tested the data stationarity. In this research we used the Augmented Dickey-Fuller test suggested by Dickey & Fuller (1979) in order to test the presence of a unitary root in the series. The Dickey-Fuller test is based on the following model in Equation (1):

$$\Delta y_t = \alpha + \beta_t + \eta y_{t-1} + \xi_t \quad (1)$$

where:

$$\eta = \sum_{j=1}^{\rho} \rho_i - 1 \quad (2)$$

And where y denotes the dependent variable and Δ denotes the difference operator ($\Delta y_t = y_t - y_{t-1}$). The parameters to be estimated are α, β and η. Statistics τ_τ and τ_μ and τ presented by Dickey & Fuller (1981) correspond to the t test to estimate the variable coefficient of the variable y_{t-1} in Equation (2). These statistics are specified for a model that includes a quadratic trend and constant (τ_τ), a model including lag and a constant (τ_μ) and a model with no constant or trend (τ). The hypotheses tested for these models correspond to a null hypothesis stating that the series is not stationary (H_0 : y_t is not I(0) or $\eta = 0$); against the alternative hypothesis stating that the series is not integrated, i.e., it is a stationary series (H_1: y_t is I(0)).

After the ADF test we calculated Kim's (2006, 2009) automatic variance coefficient. This is a refinement of the automatic variance ratio, initially suggested by Choi (1999), using the optimal rule for estimating the spectral density for zero frequency developed by Andrews (1991). Before dealing with this test, one must demonstrate the variance ratio test as it is on the following section.

3.1. Variance ratio

According to Lo & MacKinlay (1988), the variance ratio VR_k is defined as:

$$VR_k = \frac{1}{k} \times \frac{\sigma_t^2 + k}{\sigma_t^2 + 1} \quad (3)$$

where $\sigma_t^2 + k$ is the differences' variance and k is the variance of the first differences. The null hypothesis of interest states that the variances' ratio equals one. If returns are linearly independent, then we have $VR_k = 1$ for all horizons. The test suggested by Lo & MacKinlay (1988) is shown on (4).

$$VR(y;k_i) = \left\{ \frac{1}{Tk} \sum_{t=k+1}^{T} (y_t + ... + y_{t-k} - k\mu)^2 \right\} \div \left\{ \frac{1}{T} \sum_{t=1}^{T} (y_t - \mu)^2 \right\} \quad (4)$$

where y_t is the observation of a time series for instant t and

$$\mu = T^{-1} \sum_{i=1}^{T} y_t \quad (5)$$

where k is the number of lags used; T is the number of observations of the time series. If y_t is i.i.d., then $M_1(y,k_i)$ represented in (6), asymptotically follows the normal pattern distribution. Meanwhile, such supposition does not stand when y_t shows a conditional heteroscedasticity (Azad, 2009). In order to dodge that obstacle, Lo & MacKinlay (1988) suggest a robust statistics test. This test, which also follows the pattern normal distribution, and that should have a critical value based on a determined significance level as a rejection criterion, is mathematically represented on Equation (7).

$$M_1(y,k_i) = [VR(y;k) - 1] \times \left[\left(\frac{2(2k-1)(k-1)}{3kT} \right) \right]^{-1/2} \quad (6)$$

$$M_2(y,k_i) = [VR(y;k) - 1] \times \left[\sum_{j=1}^{k-1} \left(\frac{2(k-j)}{k} \right)^2 \delta_j \right]^{-1/2} \quad (7)$$

where δ_j is:

$$\delta_j \left\{ \sum_{t=j+1}^{T} (y_t - u)^2 (y_{t-j} - u)^2 \right\} \div \left\{ \left[\sum_{t=1}^{T} (y_t - u) \right]^2 \right\} \quad (8)$$

The difficulty in interpreting M_1 and M_2 tests is that results may be conflicting for several k values. In order to dodge this issue, Chow & Denning (1993) suggested the multiple variance ratio test. According to the authors, such test represents a change to the Lo & MacKinlay (1988), where it is possible to simultaneously verify if all variance ratios equal one. This test, according to Hoque *et al*. (2007), is based on the idea that the decision regarding the null hypothesis may be based on the absolute maximum value of the individual variances ratio statistics. Chow and Denning's test (1993) is shown on Equation (9).

$$MV(y;k_i) = \sqrt{T \max_{1 \le i \le m} |M(y;k_i)|} \quad (9)$$

where $MV(y;k_i)$ represents the individual variance ratio test for the period k_i; T is the total number of observations in the analysed time series. Such statistics follow an SMM (*student maximum modulus*) distribution with m and T (sample size) degrees of freedom; if the value obtained exceeds a determined critical value, one must reject the null hypothesis.

3.1.1. Automatic variance ratio test

One other refinement of the variance ratio test was the automatic determination of the investment horizons, as it was initially suggested by Choi (1999), using the optimal rule in order to estimate the spectral density for zero frequency, developed by Andrews (1991). Kim (2009) analysed this test's performance and suggested using the *wild bootstrap* method so as to improve it in small samples. The test suggested by Kim did not show distortions in size and its power was significantly greater than in other tests, such as the ones by Chen & Deo (2006) and by Chow & Denning (1993). The importance of this test lies on the fact that we do not need random choices of investment horizons, which can lead to contradicting results, depending on the chosen values, as demonstrated in Kim (2006), Kim (2009) and Charles, Darné & Kim (2011).

Considering y_t as the asset return through time t (t=1,..., T). Choi's test (1999) is based on the following Equation:

$$VR(k) = 1 + 2\sum_{i=1}^{T-1} m\left(i/k \right) \rho(i) \quad (10)$$

where $\rho(i)$ is given:

$$\rho(i) = \frac{\sum_{t=1}^{T} (Y_t - \hat{\mu})(Y_{t+i} - \hat{\mu})}{\sum_{t=1}^{T} (Y_t - \hat{\mu})^2} \quad (11)$$

and $\hat{\mu}$ is given by:

$$\hat{\mu} = T^{-1}\sum_{t=1}^{T} Y_t \quad (12)$$

while $m(x)$ is Kernel's quadratic spectral kernel:

$$m(x) = \frac{25}{12\pi^2 x^2}\left[\frac{\sin(6\pi/5)}{6\pi/5} - \cos 6\pi/5\right]. \quad (13)$$

Choi (1999) stated that $VR(k)$ on (8) is a consistent estimator for $2\pi f_y(0)$ where $f_y(0)$ is the normalised spectral density for y_t in zero frequency. The author also showed that for $H_0^A : y_t$ it is serially not-correlated or $H_0^B : 2\pi f_y(0) = 1$

$$AVR(k) = \frac{\sqrt{T/k}\,[VR(k) - 1]}{\sqrt{2}} \xrightarrow{d} N(0,1) \quad (14)$$

as $k \to \infty,\ T \to \infty,\ T/k \to \infty$, when y_t is i.i.d. as a finite moment. Choi (1999) further states that the result in (14) holds when y_t is generated from a martingale difference sequence. In order to choose the value of lag truncation point (or holding period) k optimally, Choi (1999) adopted a data-dependent method of Andrews (1991) for spectral density at the zero frequency. The AVR test statistic with the optimally chosen lag truncation point is denoted as $AVR(\hat{k})$.

Kim (2009) states that $AVR(\hat{k})$ can be deficient for small samples. So, Kim (2006) suggested using the wild bootstrap method. The wild bootstrap suggested by Kim (2006) is made up of three stages:

Form a bootstrap sample of T observations $Y_t^* = n_t Y_t (t = 1,...T)$, where n_t is a random sequence with $E(n_t) = 0$ and $E(n_t)^2 = 1$;

Calculate $AVR^*(\hat{k}^*)$, the AVR statistic obtained from $\{Y_t^*\}_{t=1}^{T}$; and

Repeat (i) and (ii) B times to form a bootstrap distribution.

The two-tailed p-value of the test is obtained as the proportion of the absolute values of $\left\{AVR^*(\hat{k}^*; j)\right\}_{J=1}^{B}$ greater than the absolute value of $AVR(\hat{k})$.

To simulate the wild bootstrap method, we used the Monte Carlo experiment, where 1,000 interactions were simulated and their critical values analysed, as well as the p-value of the test demonstrated in (12).

4. RESULTS

Initially, we used the unit root test for the logarithmic return of each analysed index.

Table 1. Results of the Augmented Dickey-Fuller unit root test for the null hypothesis stating that daily and monthly logarithmic returns of the indexes are not stationary (using a lag)

Country	Index	obs	Tτ	τμ	T	obs	Tτ	τμ	T
				Monthly basis				Daily basis	
Argentina	Merval	28	-5.7713*	-5.5076*	-4.8673*	554	-12.2894*	-12.1022*	-8.2931*
Brazil	Ibovespa	28	-5.5489*	-5.4679*	-4.6825*	581	-18.5755*	-18.5020*	-18.4258*
Chile	IGPA	28	-4.9082*	-3.7433**	-3.2886**	587	-24.9788*	-24.9860*	-24.8704*
China	HSI	28	-5.2055*	-5.0025*	-4.1895*	593	-19.9892*	-19.825*	-19.7072*
China	SSEC	28	-5.9197*	-6.0887*	-6.1915*	574	-23.6168*	-23.6375*	-23.6003*
Czech Republic	PX	28	-4.7448*	-4.8395*	-3.8289*	589	-18.4720*	-18.4773*	-18.2664*
Egypt	EGX30	28	-5.7934*	-5.9180*	-5.2729*	541	-19.4681*	-19.4618*	-19.3985*
Hungary	BUX	28	-3.7745**	-3.8605**	-2.6757**	592	-24.5307*	24.5405*	-24.2932*
India	Bse Sensex	28	-7.6167*	-7.5892*	-6.8007*	585	-23.2143*	-23.2103*	-23.1489*
Indonesia	JKSE	28	-4.7913**	-4.7136*	-4.2717*	585	-23.7903*	-23.7646*	-23.6668*
Israel	TA100	28	-5.1679*	-5.2595*	-0.0030*	585	-26.589*	-26.5930*	-26.3983*
Jordane	ASE	28	-5.1399*	-5.2107*	-5.3789*	592	-21.6095*	-21.5246*	-21.5372*
Malaysia	KLSE	28	-4.8930**	-4.8177*	0.00814**	581	-25.0792*	-25.0780*	-24.9867*
Mexico	MXX	28	-5.8868*	-6.0176*	-4.9312*	591	-22.7439*	-22.7609*	-22.6924*
Morocco	Casablanca	28	-5.9408*	-5.4712*	-5.5845*	587	-19.4575*	-19.4300**	-19.4433*
Pakistan	KSE 100	28	-5.3575*	-5.3948*	-4.9534*	584	-23.5972*	-23.6149*	-23.5579*
Peru	IGBVL	28	-6.7795*	-7.0691*	-5.6138*	586	-22.9024*	-22.8213*	-22.8345*
Philippines	PSEi	28	-5.5828*	-5.7515*	-5.5161*	568	-16.7703*	-16.7573*	-16.7082*
Poland	WIG 20	28	-5.1353**	-4.2939**	-3.8614**	584	-17.7836*	-17.6993*	-17.6148*
Russia	RTS.RS	28	-4.0967**	-3.93279**	-3.3996**	573	-21.4025*	-21.2772*	-21.2346*
South Africa	JSE-Alsi	28	-5.7934*	-3.8603**	-5.5845*	nd	nd	nd	nd
South Korea	KS11	28	-5.6053*	-5.9697*	-5.4028*	583	-17.9012*	-17.8761*	-17.8037*
Taiwan	TWII	28	-6.8478*	-6.9972*	-6.1358*	586	-19.4575*	-25.0780*	-23.1489*
Thailand	MSCI Timi	28	-4.8603*	-4.4563*	-4.0511*	593	-26.7002*	-26.5886*	-26.4716*
Turkey	XU100	28	-6.4074*	-6.5578*	-5.2065*	583	-23.1659*	-23.1821*	-23.0831*

* indicates rejection of null hypothesis at 1% significance level. ** indicates rejection of null hypothesis at 5% significance level. nd = no data available

On Table 1, it is shown that all tests rejected the null hypothesis stating that data are not stationary and that their significance is in most cases 1%. Then, we performed the variance ratio test for small samples (on a monthly basis), as in Kim (2006, 2009). Results are shown on Table 2.

Table 2. Results of the automatic variance test for small samples, as in Kim (2006, 2009) for the main indexes in emerging countries stock markets (on a monthly basis)

Country	Index	*p*-value	Market value	Country	Index	*p*-value	Market value
Argentina	Merval	0.136	48,930	Mexico	MXX	0.724	340,600
Brazil	Ibovespa	0.888	1,167,000	Morroco	Casablanca	0.662	62,910
Chile	IGPA	0.021**	209,500	Pakistan	KSE 100	0.783	33,240
China	HSI	0.736	2,702,000	Peru	IGBVL	0.487	160,900
China	SSEC	0.418	5,008,000	Philippines	PSEi	0.809	202,300
Czech Republic	PX	0.494	73,100	Poland	WIG 20	0.582	89,950
Egypt	EGX30	0.634	89,950	Rússia	RTS.RS	0.124	861,400
Hungary	BUX	0.045**	27,880	South Korea	KS11	0.943	836,500
India	Bse Sensex	0.073***	1,179,000	South Africa	JSE-Alsi	0.422	704,800
Indonesia	JKSE	0.577	361,200	Taiwan	TWII	0.838	784,100
Israel	TA100	0.253	182,100	Thailand	MSCI Timi	0.760	138,200
Jordane	ASE	0.275	31,860	Turkey	XU100	0.877	225,700
Malaysia	KLSE	0.055***	256,000				

Obs.: the market value is about the value of companies listed on the stock market on 01/01/2011, in billions US$
** indicates that the null hypothesis is rejected at a 5% significance level. *** indicates that the null hypothesis is rejected at a 10% significance level.

On Table 2 we show that for the analysed period (June 2009 – September 2011) the random walk null hypothesis was rejected at a 5% significance level in the Chilean and Hungarian stock markets and at a 10% significance level in the Indian and Malay markets. It is important to note that rejecting the null hypothesis denotes weak form inefficiency, i.e., past returns can be an indicator of future profitability of these markets.

Monthly inefficiency denotes significant arbitrage opportunities because if we add up the respective market values of the companies listed on their stock markets this year, we can see that they approximately represent 1.7 trillion dollars. There is a special note on the inefficiency of the Chilean market that showed the smallest *p*-value, reinforcing the arbitrage hypothesis in this market that showed a 209 billion dollar market value. On the other hand, other more expressive markets, such as the Chinese and the Brazilian, have shown to be efficient in the analysed period.

After calculating the automatic variance ratio for small samples (on a monthly basis), we performed the same test on a daily basis, as it is demonstrated on Table 3.

Table 3. Results of the automatic variance ratio for small samples, as in Kim (2006, 2009) for the main indexes in emerging countries stock markets (on a daily basis)

Country	Index	*p*-value	Market value	Country	Index	*p*-value	Market value
Argentina	Merval	0.507	48,930	Mexico	MXX	0.069***	340,600
Brazil	Ibovespa	0.191	1.167,000	Morroco	Casablanca	0.031	62,910
Chile	IGPA	0.096***	209,500	Pakistan	KSE 100	0.573	33,240
China	HSI	0.831	2.702,000	Peru	IGBVL	0.383	160,900
China	SSEC	0.739	5.008,000	Philippines	PSEi	0.078***	202,300
Czech Republic	PX	0.423	73,100	Poland	WIG 20	0.568	89,950
Egypt	EGX30	0.050**	89,950	Russia	RTS.RS	0.028**	861,400
Hungary	BUX	0.949	27,880	South Africa	JSE-Alsi	nd	704,800
India	Bse Sensex	0.326	1.179,000	South Korea	KS11	0.469	836,500
Indonesia	JKSE	0.963	361,200	Thailand	MSCI Timi	0.066***	138,200
Israel	TA100	0.017**	182,100	Taiwan	TWII	0.191	784,100
Jordane	ASE	0.009*	31,860	Turkey	XU100	0.358	225,700
Malaysia	KLSE	0.007*	256,000				

** indicates that the null hypothesis is rejected at a 5% significance level. *** indicates that the null hypothesis is rejected at a 10% significance level. nd = no data available.

On Table 3 we can see that the Malayan and Jordanian indexes returns have rejected the null random walk hypothesis at a 1% significance; on the other hand, the Russian, Egyptian and Israeli markets have rejected the null hypothesis at a 5% significance, and eventually, the null random walk hypothesis was rejected at a 10% significance in the Chilean, Philippine, Mexican and Thai markets. These results denote arbitrage opportunities in these countries, on a daily basis, especially in markets such as the Jordanian and the Malayan ones, where markets have shown to be even more inefficient. It is important to note that putting all these nine markets together at the beginning of 2011, they represented approximately 2.4 trillion dollars in market value, reinforcing the hypothesis of the existence of abnormal gaining opportunities in these countries' equity markets.

5. FINAL NOTE

Despite there not being a consensual definition of "emerging market", this term is commonly used to describe the industrializing market business and activity or emerging regions in the world. Granted the importance of such countries for world economy and, considering that the market value of companies listed in equity markets in these countries represent more than 30% of the world value, and considering the weak form market efficiency hypothesis, this research sought to analyse the efficiency of these markets after the 2007/2008 subprime crisis.

In this research we used secondary data coming from the scoring of the main equity market indexes of the 24 analysed countries. The automatic variance ratio test for small samples, as in Kim (2006, 2009) points at the inefficiency (on a monthly basis) for the Chilean, Hungarian, and Malayan indexes, and also demonstrated inefficiency (on a daily basis) for the Chilean, Egyptian, Philippine, Israeli, Malayan, Mexican, Russian and Thai markets.

Such inefficiency denotes arbitrage opportunities in these markets that in January 2011 summed 2.4 trillion dollars, making it possible to make abnormal gains in these countries. On the other hand, Kim's (2006, 2009) automatic variance ratio results show that even bigger markets, such as the Chinese, the Brazilian, the Taiwanese and the South African ones have shown to be efficient showing their robustness.

It is important to note that the analysis had been carried out in a period comprised between June 2009 and September 2001, after the 2007/2008 subprime crisis; it is hence suggested that this sample should be amplified so as to show the influence of this crisis on the analysed markets. The evaluation of the causes of the noted inefficiency should also be made, since this was not the objective of this research.

References

1. Al-Khazali, O. M., Pyun, C. S., & Kim, D. (2012). Are exchange rate movements predictable in Asia-Pacific markets? Evidence of random walk and martingale difference processes. *International Review of Economics & Finance, 21*(1), 221-231.
2. Al-Khazali, O. M., Ding, D. K., & Pyun, C. S. (2007). A new variance ratio test of random walk in emerging markets: a revisit. *Financial Review, 42*(2), 303-317.
3. Aldous, D. (2010). *Probability approximations via the Poisson clumping heuristic*: Springer-Verlag New York, Inc.
4. Aldous, D., & Diaconis, P. (1986). Shuffling cards and stopping times. *The American Mathematical Monthly, 93*(5), 333-348.
5. Alexander, S. S. (1961). Price movements in speculative markets: Trends or random walks. *Industrial management review, 2*, 7-26.
6. Andrews, D. W. K. (1991). Heteroskedasticity and autocorrelation consistent covariance matrix estimation. *Econometrica: Journal of the Econometric Society*, 817-858.
7. Azad, A. (2009). Random walk and efficiency tests in the Asia-Pacific foreign exchange markets: evidence from the post-Asian currency crisis data. *Research in International Business and Finance, 23*(3), 322-338.
8. Beaver, W. H. (1981). Market efficiency. *Accounting Review*, 23-37.
9. Black, F. (1986). Noise. *Journal of finance, 41*(3), 529-543.
10. Black, F., & Scholes, M. (1972). The valuation of option contracts and a test of market efficiency. *The journal of Finance, 27*(2), 399-417.
11. Box, G. E. P., & Pierce, D. A. (1970). Distribution of residual autocorrelations in autoregressive-integrated moving average time series models. *Journal of the American statistical association*, 1509-1526.
12. Campbell, J. Y., Lo, A. W., & MacKinlay, A. C. (1997). *The econometrics of financial markets* (Vol. 1): princeton University press Princeton, NJ.
13. Campbell, J. Y., & Mankiw, N. G. (1987). Are output fluctuations transitory? *The Quarterly Journal of Economics, 102*(4), 857.
14. Campbell, J. Y., & Yogo, M. (2006). Efficient tests of stock return predictability. *Journal of financial economics, 81*(1), 27-60.
15. Chakraborty, M. (2006). Market Efficiency for the Pakistan Stock Market. *South Asia Economic Journal, 7*(1), 67.
16. Chang, E. J., Lima, E. J. A., & Tabak, B. M. (2004). Testing for predictability in emerging equity markets. *Emerging Markets Review, 5*(3), 295-316.
17. Charles, A., & Darné, O. (2009b). VARIANCE-RATIO TESTS OF RANDOM WALK: AN OVERVIEW. *Journal of Economic Surveys, 23*(3), 503-527.
18. Charles, A., & Darné, O. (2009c). The efficiency of the crude oil markets: Evidence from variance ratio tests. *Energy Policy, 37*(11), 4267-4272.
19. Charles, A., Darné, O., & Fouilloux, J. (2011). Testing the martingale difference hypothesis in CO2 emission allowances. *Economic Modelling, 28*(1-2), 27-35.
20. Charles, A., Darné, O., & Kim, J. H. (2010). Small sample properties of alternative tests for martingale difference hypothesis. *Economics Letters*.
21. Chen, F., & Jarrett, J. E. (2011). Financial crisis and the market efficiency in the Chinese equity markets. *Journal of the Asia Pacific economy, 16*(3), 456-463.
22. Chen, W. W., & Deo, R. S. (2006). The variance ratio statistic at large horizons. *Econometric Theory, 22*(2), 206.
23. Choi, I. (1999). Testing the random walk hypothesis for real exchange rates. *Journal of Applied Econometrics, 14*(3), 293-308.
24. Chow, K. V., & Denning, K. C. (1993). A simple multiple variance ratio test. *Journal of Econometrics, 58*(3), 385-401.
25. CIA, E. (2011). The World Factbook 2010 *Avaliable at https://www.cia.gov/library/publications/the-world-factbook/*: Central Intelligence Agency Washington, DC.
26. Cochrane, J. H. (1988). How big is the random walk in GNP? *The Journal of Political Economy*, 893-920.
27. Cowles, A., & Jones, H. E. (1937). Some a posteriori probabilities in stock market action. *Econometrica, Journal of the Econometric Society*, 280-294.
28. Dacorogna, M., Mller, U., Olsen, R., & Pictet, O. (2001). Defining efficiency in heterogeneous markets.

29. DE FREITAS, M. C. P. (2009). The Effect of the Global Crisis in Brazil: Risk Aversion and Preference for Liquidity in the Credit Market1. *Estudos Avançados, 23*(66), 125.
30. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American statistical association*, 427-431.
31. Fama, E. F. (1963). Mandelbrot and the stable Paretian hypothesis. *The Journal of Business, 36*(4), 420-429.
32. Fama, E. F. (1965a). The behavior of stock-market prices. *The Journal of Business, 38*(1), 34-105.
33. Fama, E. F. (1965b). Random walks in stock market prices. *Financial Analysts Journal, 21*(5), 55-59.
34. Fama, E. F. (1970). Efficient capital markets: A review of theory and empirical work. *The journal of Finance, 25*(2), 383-417.
35. Fama, E. F. (1991). Efficient capital markets: II. *Journal of finance*, 1575-1617.
36. Fama, E. F., & Blume, M. E. (1966). Filter rules and stock-market trading. *The Journal of Business, 39*(1), 226-241.
37. Fama, E. F., & French, K. R. (1988). Permanent and temporary components of stock prices. *The Journal of Political Economy*, 246-273.
38. French, K. R., & Roll, R. (1986). Stock return variances* 1:: The arrival of information and the reaction of traders. *Journal of financial economics, 17*(1), 5-26.
39. Granger, C. W. J., & Morgenstern, O. (1963). SPECTRAL ANALYSIS OF NEW YORK STOCK MARKET PRICES1. *Kyklos, 16*(1), 1-27.
40. Hassan, M. K., & Chowdhury, S. (2008). Efficiency of Bangladesh stock market: evidence from monthly index and individual firm data. *Applied Financial Economics, 18*(9), 749-758.
41. Hoque, H. A. A. B., Kim, J. H., & Pyun, C. S. (2007). A comparison of variance ratio tests of random walk: A case of Asian emerging stock markets. *International Review of Economics & Finance, 16*(4), 488-502.
42. Jensen, M. (1978). Some anomalous evidence regarding market efficiency. *Journal of Financial Economics, Vol. 6, Nos. 2/3, pp. 95-101, 1978*.
43. Kim, J. H. (2006). Wild bootstrapping variance ratio tests. *Economics Letters, 92*(1), 38-43.
44. Kim, J. H. (2009). Automatic variance ratio test under conditional heteroskedasticity. *Finance Research Letters, 6*(3), 179-185.
45. Kim, J. H., & Shamsuddin, A. (2008). Are Asian stock markets efficient? Evidence from new multiple variance ratio tests. *Journal of Empirical Finance, 15*(3), 518-532.
46. Kim, J. H., Shamsuddin, A., & Lim, K. P. (2011). Stock return predictability and the adaptive markets hypothesis: Evidence from century-long US data. *Journal of Empirical Finance*.
47. Lagoarde-Segot, T., & Lucey, B. M. (2008). Efficiency in emerging markets--Evidence from the MENA region. *Journal of International Financial Markets, Institutions and Money, 18*(1), 94-105.
48. Lim, K. P. (2009). An Empirical Analysis of the Weak-form Efficiency of Stock Markets. *Monash University Department of Econometrics and Business Statistics PhD Thesis*
49. Lim, K. P., & Brooks, R. D. (2006). The evolving and relative efficiencies of stock markets: empirical evidence from rolling bicorrelation test statistics: SSRN Working Paper, available at http://ssrn. com/abstract= 931071.
50. Lim, K. P., Brooks, R. D., & Kim, J. H. (2008). Financial crisis and stock market efficiency: Empirical evidence from Asian countries. *International Review of Financial Analysis, 17*(3), 571-591.
51. Lo, A. W., & MacKinlay, A. C. (1988). Stock market prices do not follow random walks: Evidence from a simple specification test. *Review of financial studies, 1*(1), 41.
52. Malkiel, B. G. (2003). The efficient market hypothesis and its critics. *The Journal of Economic Perspectives, 17*(1), 59-82.
53. Merton, R. C. (1973). Theory of rational option pricing. *The Bell Journal of Economics and Management Science*, 141-183.
54. Milionis, A. E. (2007). Efficient capital markets: A statistical definition and comments. *Statistics & probability letters, 77*(6), 607-613.
55. Montagnoli, A., & De Vries, F. P. (2010). Carbon trading thickness and market efficiency. *Energy Economics, 32*(6), 1331-1336.
56. Mood, A. M. (1940). The distribution theory of runs. *The Annals of Mathematical Statistics, 11*(4), 367-392.
57. Ntim, C., Opong, K., & Danbolt, J. (2007). An empirical re-examination of the weak form efficient markets hypothesis of the Ghana stock market using variance-ratios tests. *African Finance Journal, Vol. 9, No. 2, pp. 1-25, 2007*.
58. Poterba, J. M., & Summers, L. H. (1988). Mean reversion in stock prices* 1:: Evidence and Implications. *Journal of financial economics, 22*(1), 27-59.
59. Richardson, M., & Smith, T. (1991). Tests of financial models in the presence of overlapping observations. *Review of financial studies, 4*(2), 227-254.
60. Righi, M. B., & Ceretta, P. S. (2011). Random Walk and Variance Ratio Tests for Efficiency in the Sub-Prime Crisis: Evidence for the U.S. and Latin Markets. *International Research Journal of Finance and Economics*(72), 25-32.
61. Rubinstein, M. (1975). Securities market efficiency in an Arrow-Debreu economy. *The American Economic Review, 65*(5), 812-824.
62. Samuelson, P. A. (1965). Proof that properly anticipated prices fluctuate randomly. *Industrial management review, 6*(2).
63. Shiller, R. J., & Perron, P. (1985). Testing the random walk hypothesis* 1:: Power versus frequency of observation. *Economics Letters, 18*(4), 381-386.
64. Smith, G. (2007). Random walks in Middle Eastern stock markets. *Applied Financial Economics, 17*(7), 587-596.
65. Smith, G. (2008). Liquidity and the informational efficiency of African stock markets. *South African Journal of Economics, 76*(2), 161-175.
66. Smith, G. (2009). Martingales in European emerging stock markets: Size, liquidity and market quality. *The European Journal of Finance, 15*(3), 249-262.
67. Smith, G., & Ryoo, H. J. (2003). Variance ratio tests of the random walk hypothesis for European emerging stock markets. *The European Journal of Finance, 9*(3), 290-300.

68. Squalli, J. (2006). A non-parametric assessment of weak-form efficiency in the UAE financial markets. *Applied Financial Economics, 16*(18), 1365-1373.
69. Summers, L. H. (1986). Does the stock market rationally reflect fundamental values? *Journal of finance*, 591-601.
70. Timmermann, A., & Granger, C. W. J. (2004). Efficient market hypothesis and forecasting. *International Journal of Forecasting, 20*(1), 15-27.
71. Whang, Y. J., & Kim, J. (2003). A multiple variance ratio test using subsampling. *Economics Letters, 79*(2), 225-230.
72. Wright, J. H. (2000). Alternative variance-ratio tests using ranks and signs. *Journal of Business & Economic Statistics*, 1-9.