NEW EMPIRICAL EVIDENCE ON E.M.H.: CASE OF DEVELOPED AND EMERGING MARKETS – A MICROECONOMIC APPROACH

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Abstract

In today's globalized world, with interconnected global markets, and implicitly a higher level of sensitivity, one of the most important issues to be addressed is represented by the way market mechanisms are functioning. The main purpose of the present study is to answer the question of whether the selected markets are consistent with the Efficient Market Hypothesis, at a microeconomic level, by creating an Efficiency Index, using L. Kristoufek si M. Vosvrda (L. Kristoufek, M. Vosvrda, 2013, 184) method.

We use estimators of long term memory, fractal dimension, and approximate entropy, in order to create the Efficiency Index. The results are commented both at a macroeconomic level and at a microeconomic level, as we apply the methodology on 150 companies, part of 12 stock market indices from developed and emerging economies. We find that the results are consistent with those obtained by L. Kristoufek si M. Vosvrda (L. Kristoufek, M. Vosvrda, 2013, 184), with most of the efficient companies being part of the developed markets, while the least efficient companies part of emerging economies. This implies the existence of a market dynamics characterized by going through areas with distinctive levels of "informational efficiency".

The present study contributes to a better understanding of financial market mechanisms at a microeconomic level, by testing the Efficient Market Hypothesis, and constructing the Efficiency Index.

Keywords: Efficient Market Hypothesis, Efficiency Index, Hurst, Fractal Dimension, Approximate Entropy

JEL Classification: G14, G15, C10

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Introduction

The notion of Efficient Markets, swiftly summarized in the epigram "asset prices fully reflect all available information" (Fama 1991, p. 1575) is postulated for the first time by Eugene Fama in 1965, within the controversial Efficient Market Hypotheses (E.M.H.).

Beyond its limitations, the hypothesis was accepted over time, mainly due to the stability of the financial markets in a time-span of more than 20 years (from the period of the Great Depression – 1930's, until the year 2000).

However, the recent financial and economic turbulence offered new arguments to the criticism of EMH. Its main postulates (informational efficiency, rationality in decision making, effective, self-corrective mechanisms of the market), can be critically examined in the light of recent empirical evidence that suggests that financial markets may present an intrinsic functional instability.

Given the need to understand the metamorphosis of financial markets, the testing of the informational efficiency hypothesis remains a fundamental problem for economics.

In this sense, the main contributions the paper aims to bring are:

- tackling the notion of efficiency at a microeconomic level, by using a measure comprised of long term memory, fractal dimension and approximate entropy;
- analysing the market dynamics through 4 periods of observation: at a global level, the time building up to the last global financial crisis, the period of the crisis and the following aftermath.

The research hypothesis we are adopting is that E.M.H., as an explicative model of the neo-classical paradigm, is not sufficiently realistic to describe the current developments of the financial markets, being necessary to substitute it with a wider conceptual framework, in which the recording of a high level of informational efficiency to emerge as just a "private case".

The testing of informational efficiency was accomplished by building an efficiency Index using the methodology put forward by Kristoufek and Vosvrda (Kristofek, Vosvrda 2014, p. 162), on the basis of 3 impact variables:

- long term memory – estimated using the Hurst coefficient
- short term memory – estimated using the fractal dimension with the Genton, Hall-Wood and Box-Count methods
- system complexity – estimated using the approximate entropy.

Starting from the hypothesis that an efficient market implies the lack of a correlating structure, the expected values of the 3 variables taken into consideration for the building of the Efficiency Index are easily determined: for an efficient market the value of the Hurst exponent is 0.5, the fractal dimension is 1.5 and the approximate entropy is 1. The table is arranged pertaining to the value of the index, with the smallest value implying the highest efficiency.

Following the Bayesian analysis it can be observed that the biggest impact on the dependent variable is generated by the Hall-Wood Estimator of fractal dimension (50.12%), followed by the Genton Estimator (36.90%). Approximate entropy has a weight of 7.45%, long term memory accounts for 0.711%, while the Box-Count Estimator has an insignificant influence of just 0.003%. The positive values obtained in all the cases indicate that a change in these coefficients will determine a change in the dynamics of financial markets efficiency.

The methodology is further applied to 150 companies from 12 countries, from which we form mean values for the indexes from which they come and show that indeed, both at macro- and micro-economy levels, the existence of a financial markets dynamic (embedded within the international financial flows) can be observed, a dynamic characterized by going through areas with distinctive levels of "informational efficiency", this level being dependent upon the economic development of the country.

The paper is structured as follows: Section I contains a brief description of the scientific literature, Section II follows the research methodology used, focusing on the long-term memory, short term memory, entropy and the index – as a measure of efficiency. Section III includes the results, while the last section concludes.

1. Theoretical Frame

The notion of efficiency associated with financial markets appears for the first time in The Stock Exchange of London, Paris, and New York: a Comparison, written by Gibson George Rutledge (1889).

In 1900, French mathematician Louis Bachelier published in his thesis the mathematics and statistics behind the Brownian movement, and stated that "the mathematical expectation of the speculator is zero" (Bachelier 1900, pp. 21-86). In the years to come, scientists around the world have conducted various data series testing, trying to establish a schematic framework of the mechanisms for defining financial asset pricing by addressing issues which are related to the typology of data series movements, autocorrelation, cyclicality, stationarity or non-stationarity etc.

In 1961, for the first time, John Muth puts forward the hypothesis of investor rationality: "A rational anticipation is one that efficiently incorporates all available information" (Muth, 1961). Possibly the most important application of Muth's work is represented by the Efficient Market Hypothesis, the cornerstone of modern finance, and the subject of this paper.

The theory takes shape from the research of both Eugene F. Fama, as well as economist Paul A. Samuelson, in the early 60's. Although both Fama and Samuelson explain the random character of prices as a consequence of market rationality, the difference between the two is generated by the probabilistic model (framework) used to describe the variations: while Fama chooses the already known Random Walk model, Samuelson introduces the Martingal model, for the first time.

One of the controversies vowed around EMH is represented by the Rationality → Random Movement → Information Efficiency trinom. First, the informational efficiency implies the existence of a constant equilibrium between the price of the financial assets and the informational ensemble, their variations being explained by the arrival of new information on the market, arbitrary by definition. Going on, the random movement is conditioned by the existence of investment rationality, a slippery concept that in the end determined an economic scene divided between the advocates of investors' rationality and those who do not adhere to the idea.

For example, if in 1966 Mandelbrot demonstrates that in a competitive market with rational investors, risk-neutral, profit is impossible to predict, i.e. the prices follow a martingale (Mandelbrot 1966, p. 242), in 1973 LeRoy showed that under aversion to risk there was no theoretical justification for the martingale property (Leroy 1973, p. 436).

After 1976, when Fama publishes the Foundations of Finance, in 1980 Sanford J. Grossman and Joseph E. Stiglitz show that it is impossible for a market to be perfectly efficient from an informative point of view: because information is "expensive", prices cannot perfectly reflect the available information, because if they would, investors who consume resources to obtain and analyze this information would not receive any reward (Grossman și Stiglitz 1980, p.393–408). A year later, LeRoy and Porter demonstrate excess volatility in profit, and reject the idea of efficient markets.

Also, on the side of non-advocates of information efficiency, we find LeRoy and Porter, who find excess volatility in profits (Leroy, Porter 1981, p.555); Lo and MacKinlay reject the random walk hypothesis for weekly profits (Lo, MacKinlay, 1988, p.41–66) in 1989, in his book *Market Volatility*, Shiller analyzes the volatility sources that raise issues for EMH, Laffont and Maskin show that EMH is not sustainable, in case the competition on the market is imperfect (Laffont and Maskin, 1990 p. 70-93) , Lehman finds reversals in weekly profits and rejects EMH (Lehmann, 1990 p. 1-28), and Jegadeesh presents in documents evidence of predictability of profit behaviour and rejects the random walk hypothesis (Jagadeesh 1990, p. 881–898).

If in the original version the efficient market is defined in terms of the ability to quickly adapt prices under the impact of new available information (Fama 1969, p. 1), in 1991, considering a set of variables wider than the initial one, Fama offers a compact summary of the concept of Efficient Markets in the epigram "stock prices reflect all available information" (Fama 1991, p. 1575).

Depending on the variables that constitute the theory of information efficiency (the typology of information and its time to integrate in prices), Professor Eugene Fama has postulated three main forms of efficiency: weak, semi-strong and strong form.

For a better understanding of the limits of the traditional trading paradigm, the main principles underlying it must be taken into account: (1) The positive relationship between risk and profit; (2) The existence of a trade-off linearity, implying that the risk is measured by "beta", and the revenue by "alpha", the average deviation on CAPM's profitability portfolio from the reference value; (3) Attractive investments are obtained through passive acquisition-oriented strategies of highly diversified stock portfolios; (4) The most important investment decision is represented by the strategic allocation of the various shares in a portfolio, in direct connection with the risk tolerance and long-term investment policy objectives; (5) All investors should hold long-term shares.

The Efficient Market Hypothesis limits are found within the limits of these abstractions (rationality, constant distribution of income and the relationship between risk and profitability, etc.) which have sparked controversy among scientists since the postulation of the theory.

With the emergence of empirical studies by psychologists Daniel Kahneman and Amos Nathan Tversky, the proximity of 1990 marks an amplification of disputes, and the rising of a new field in economics, namely behavioural finance. The significant impact of it lies in its focus, which is to understand the dynamics of financial markets through the impact of investors’ group behaviour.

Some of the most common cognitive heuristics, as result of irrationality in investors’ behaviours are: heuristics of representativeness, anchoring, flocking, excess confidence. Besides these heuristics, another impact factors in the decision making process is represented by a series of forgeries, such as: aversion to loss, mental accounting, aversion to regret, etc.

Deviations from efficiency are also market anomalies, categorized within three main forms: fundamental anomalies, technical anomalies and temporal anomalies. One of them is excess volatility: asset price oscillations tend to be higher than they should, according to efficient market theory (Dima, Milos 2009, p. 1-41).

Of course, both classical economists and heterodox economists have had, have and will continue to have divergences in the efficiency of financial markets and investors' rationality, generating the emergence of alternative theories of explaining the financial asset price mechanisms.

Among these theories we find the Fractal Markets Hypothesis, first approached by Edgar Peters in 1994, which uses fractals, rescaling and nonlinear dynamic models to understand and explain the behaviour of price movements (Peters, 1994).

Campbell, Lo and Mackinlay, (1997) propose the Relative Market Hypothesis, the hypothesis suggesting the relativity of the market, but which fails to address the behaviour of investors.

In 2004, Professor M.I.T. Andrew Lo proposes Adaptive Market Hypothesis (AMH), a paradigm that attempts to integrate the hypothesis of efficient financial markets with the principles of behavioural finance. The theory is based on the meta-hypothesis that the functioning of the financial markets is carried out under conditions of non-uniform informational efficiency, which changes along their evolutionary trajectory. These changes occur both under the impact of structural, functional and institutional factors, as well as due to factors of a psychological and socio-behavioural nature.

Beyond its limits, E.M.H. has been accepted over time, mainly due to the stability of financial markets over a time horizon of more than 20 years. However, the 2007 global financial crisis represents a key moment in the history of modern finances, not only because of the negative impact it has generated, but also because it forces us to rethink the way the financial markets work and focus our attention to the impact factors specific to the post-modern period we are transiting.

Until recently, most of the studies were based on the fair play game theory, a theory that comes from the hypothesis that the establishment of market equilibrium conditions can be made on the basis of the anticipated level of profit generated by traded assets (Dima, Pirtea, Murgea 2006, p. 43 -47). Based on the need to understand the metamorphosis of financial markets, testing the information efficiency hypothesis remains a fundamental problem for the economic field, given the relative character of the postulate that the theory relies on, and which makes its empirical testing difficult and oscillating in interpretation.

2. Research methodology

In order to test the informational efficiency hypothesis, we took into consideration the methodology proposed by Ladislav Kristoufek and Miloslav Vosvrda in their study entitled Measuring capital market efficiency: long-term memory, Fractal size and approximate entropy, published in The European Physical Journal B, 87 (7), p. 162. The dates used are daily and include blue chips companies, part of the indexes of the following countries: Argentina, Brazil, France, Germany, Italy, Japan, Malaysia, Poland, Singapore, Spain, the United Kingdom and the United States of America. The period taken into account is January 1, 2005 - January 1, 2017.

The methodology used aims at the formation of an Efficiency Index, which takes into account three main variables: the Hurst exponent - in order to estimate the long-term memory, the fractal dimension - for estimating the short-term memory and the roughness of the series of data, and the approximate entropy - estimating system complexity. The most efficient companies/countries will be those with the lowest value of the efficiency index.

In order to observe the evolutionary dynamics of profits, this test will be carried out over four analysis periods: global (2005-2017), the period preceding the financial crisis (2005-2007), the financial crisis (2007-2008), and the period following the recent crisis (2009-2016).

2.1. Efficiency Index

The Efficiency Index is a procedure for classifying the financial data series to compare their levels of efficiency, depending on the distance between the current market position and an ideal market in terms of efficiency.

The index computation formula is as follows:

$$EI=\sqrt{\sum((Mt - M^*i)/Ri)^2} \quad (1)$$

where:

M*i – Efficiency measure

Mt – Estimate of that efficiency measure

Ri – A scale of that measure

The efficiency index for a particular market/company, etc., aims to measure the deviation from the efficiency value of the analyzed companies and then that of the markets from which they originate.

For our case, the formula for calculating the efficiency index is as follows:

$$IE=\sqrt{\sum(Mhurst.-0,5)^2+(Mhall-1.5)^2+(Mbox-1.5)^2+(Mvario-1.5)^2+((Ment.-1)/2)^2} \quad (2)$$

where:

Mhurst – Expected Value of Hurst variable

Mhall – Expected Value of Fractal Dimension, using Hall-Wood estimator

Mbox – Expected Value of Fractal Dimension, using Box-Count estimator

Mvario – Expected Value of Fractal Dimension, using Genton estimator

Ment. – Expected Value of Approximate Entropy

The variables taken into account to measure the efficiency of capital markets are: The Hurst Exponent (H) - an indicator of long-term memory, with a 0.5 benchmark for efficient markets; The Fractal Dimension (D) with a value of 1.5 representing the point of efficiency; and The Approximate Entropy (AE), with a value of 1 for efficient markets.

2.1.1. Long Term Memory (Hurst Exponent)

Long-term memory or long-term dependence/persistence is an important phenomenon in the analysis of time series, starting from the premise of a non-negligible dependence between the present and all the points of the past. This is usually characterized by a decay of the power law of the autocorrelation function (in the time domain), and a near-origin spectrum divergence in the frequency domain.

The characteristic feature of long-term memory is the Hurst coefficient, which varies between $0 \leq H < 1$ for stationary processes. The reference value of 0.5 is considered to belong to efficient informational time series, being an indicator of random processes and lack of long-term memory.

For a Hurst coefficient > 0.5, the time series is persistent, with strong positive correlations determined by deterministic processes and stationary at the same time. For a Hurst < 0.5, the time series is anti-persistent and characterized by shifts in the growth direction, more frequent than a random process.

There are various estimates of the Hurst coefficient, both in the domains of time and of frequency. For the construction of this report I chose the liftHurst function in the program R, function which exploits the linear relationship in wavelets per scale. Wavelet lifting is done for a time series in order to convert it into a set of wavelet coefficients and corresponding "lift" integrals, specific to the moment when the data is raised during decomposition. Coefficients are then grouped on artificial levels using the integrals to imitate wavelet support in the classical setting, and so a scale concept is made. Subsequently, the coefficients in each artificial level are used to calculate the wavelets energy values for a specific level. The linear relationship (inclination) between scales and their energies is used to estimate the Hurst exponent of the data series.

2.1.2. Fractal Dimension

The fractal dimension can be defined as a report that provides a statistical index of complexity by comparing how the details of a model change with the scale it is being measured on. Of the different types of estimates of fractal dimension, in this paper we will focus on the main three: the Genton Estimator, the Box-Count Estimator, and the Hall-Wood Estimator.

2.1.2.1. Box-Count Estimator

The well known Box-Count estimator takes account of the scaling law $N(\varepsilon) \propto \varepsilon^{-D}$, where $N(\varepsilon)$ is the notation of the number of boxes required for a width or scale ε, the estimator equalising slope in a regression of the smallest squares (OLS) log N (ε) per log ε.

$$D_{BC} = -\left\{\sum (s_k - \bar{s}) \log N(\varepsilon_k)\right\}\left\{\sum (s_k - \bar{s})^2\right\}^{-1} \quad (3)$$

where:

D_{BC} – Expected value of Fractal Dimension, using Box-Count estimator

s_k – $\log s_k$

$\bar{s}$ - Arithmetic mean of $s_0, s_1, ..., s_k$

Various problems have been identified in this estimator, in terms of fitting regressions, and therefore, other methods of estimating the fractal dimension have occurred in the attempt to minimize the biases.

2.1.2.2. Hall-Wood Estimator

In 1993 Hall and Wood introduced an improved version of the box-count estimator, a version that is applied to the smallest observed scale and characterized by simplified implementation rules. With the m=1 parameter, the Hall-Wood method is based on the regression of the smallest squares of $\log \hat{A}(l/n)$, si $\log(l/n)$:

$$D_{HW} = 2 - \left\{\sum (s_l - \bar{s}) \log \hat{A}(l/n)\right\} * \left\{\sum (s_l - \bar{s})^2\right\}^{-1} \quad (4)$$

where:

$L \geq 2$, $s_l = \log(l/n)$

$\bar{s} = 1/L \sum s_l$

D_{HW} - Expected value of Fractal Dimension, using Hall-Wood estimator

Hall and Wood recommend using L=2 to minimize errors. In our case, and in harmony with the other two methods of estimating the fractal dimension, the number of considered lags is 3.

2.1.2.3. Genton Estimator

The Genton Estimator, or Variogram estimator, is proposed by Genton in 1998, and is one of the most robust estimators of short-term memory.

$$D_G = 2 - 1/2 \left(\sum (s_l - \bar{s}) \log(\hat{V}_2(l/n))\right) * \left(\sum (s_l - \bar{s})^2\right)^{-1} \quad (5)$$

where: $L \geq 2$, $s_l = \log(l/n)$, and $\bar{s} = 1/L \sum s_l$

2.1.3. Approximate Entropy

Approximate entropy (A.E.) can be defined as a measure of the complexity of a system. The higher it is, the more random the system in question, and in vice versa, more deterministic. Efficient markets are those markets that are characterized by a maximum entropy.

In order to determine the entropy of the used data series, we use the Pincus method with an embedding dimension of 4, where for every i in $1 \leq i \leq T - m + 1$, we define:

$$C_t^m(r)=\frac{\sum 1_{d[i,j]\leq r}}{T-m+1} \quad (6)$$

where:

$C_t^m(r)$ – measure of autocorrelation

$1_{(d[i,j]\leq r)}$ – Binary function with an expected value of 1 if $d[i,j]\leq r$ condition is fulfilled, and 0 on the contrary case.

$$d[i,j]=\max_{k=1,2\ldots,m}\left(|x_{i+k-1}-u_{j+k-1}|\right) \quad (7)$$

Therefore, $C_t^m(r)$ can be seen as a measure of autocorrelation, based on the maximum distance between the series offsets. The correlation dimension (βm) is viewed as a measure of entropy and system complexity and is calculated as follows:

$$\beta_m=\lim_{r\to 0}\lim_{T\to +\infty}\frac{\log C_t^m(r)}{\log r} \quad (8)$$

in which: β_m – measure of entropy, comprised between 0 – for deterministic series, and 1 – for random series.

3. Results and discussion.

In the present paper we analyse 150 companies ("blue chips"), part of 12 country indexes, as it follows: Argentine, Brazil, France, Germany, Italy, Japan, Malaysia, Poland, Singapore, Spain, the United Kingdom and the United States.

The data used are daily, with the range considered to cover different phases in the behaviour of financial markets, and which is divided into four sub-periods of observation: at a global level (January 2005- January 2017), the preceding period of the financial crisis (2005-2006), the financial crisis timeframe (2007-2008), and the period following it (2009-January 2017). Testing the authenticity of the theory in the current context (the pre-crisis period of the crisis in 2007 - crisis - post-crisis) was achieved by building an Efficiency Index, according to the method proposed by Kristoufek and Vosvrda (Kristoufek & Vosvrda 2014, p. 162) including the long-term memory, fractal dimension and approximate entropy as explanatory variables of information efficiency.

Table no. 1, part I and part II, summarizes the results obtained at macroeconomic level in terms of: descriptive statistics (Skewness, Kurtosis, KPSS), long-term memory, fractal dimension, approximate entropy, and efficiency index.

3.1. Results - Macroeconomic level

At the macroeconomic level, the results of the descriptive statistics indicate that the returns are leptocurical, asymmetrically distributed, with a predominant inclination towards the left (negative majority skewness), and asymptotic stationary, according to the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS).

From long-term memory point of view, it can be noticed that both the developed and emerging markets considered are characterized by periods of inefficiency, either in a deterministic sense (persistence) or in a random-chaotic sense(anti- persistence, with more intense movements than random ones), suggesting a non-negligible dependence between the past and the present, and periods in which markets fail to fully enclose the information in the trading prices.

Table no. 1. Results at macroeconomic level – part I

RESULTS – MACROECONOMIC LEVEL

COUNTRY	KURTOSIS	SKEWNESS	HURST	F.D. - VARIOGRAM	F.D. - HALLWOOD	F.D. - BOXCOUNT	APPROX. ENTROPY	KPSS tau	KPSS mu	EFFICIENCY INDEX
GLOBAL (January 2005- January 2017)										
ARGENTINE	117.087	1.901	0.557	1.968	1.988	1.446	0.559	0.101	0.253	**0.72**
BRAZIL	138.764	-4.507	0.455	1.969	1.984	1.448	0.423	0.046	0.219	**0.748**
FRANCE	60.387	-2.858	0.561	1.93	2.016	1.468	0.392	0.072	0.12	**0.745**
GERMANY	158.409	-4.47	0.562	1.93	1.996	1.472	0.505	0.056	0.145	**0.716**
ITALY	100.017	-4.208	0.557	1.945	1.986	1.469	0.516	0.08	0.163	**0.718**
JAPAN	56.505	-1.546	0.521	1.957	2.023	1.481	0.415	0.085	0.119	**0.758**
MALAYSIA	95.642	-2.09	0.497	2.009	2.024	1.451	0.507	0.074	0.222	**0.782**
POLAND	118.842	-4.498	0.574	1.925	2.005	1.446	0.559	0.13	0.188	**0.714**
SINGAPORE	65.387	-2.513	0.516	1.946	2.033	1.467	0.486	0.046	0.097	**0.747**
SPAIN	88.381	-0.945	0.546	1.959	2.014	1.473	0.442	0.087	0.147	**0.751**
U.K.	72.614	-2.083	0.543	1.946	2.003	1.467	0.446	0.063	0.103	**0.736**
USA	70.447	-2.724	0.543	1.928	2.006	1.474	0.44	0.046	0.102	**0.729**
PRECEDING PERIOD OF FINANCIAL CRISIS (2005-2006)										
ARGENTINE	13.135	0.524	0.469	2.038	2.138	1.42	0.1	0.078	0.267	**0.963**
BRAZIL	7.588	0.386	0.466	2.023	1.97	1.448	0.07	0.09	0.155	**0.862**
FRANCE	8.304	-0.287	0.527	2.019	2.034	1.466	0.038	0.071	0.173	**0.894**
GERMANY	6.285	0.417	0.511	2.011	2.014	1.476	0.042	0.073	0.104	**0.874**

ITALY	17.411	-0.503	0.458	2.021	2.026	1.445	0.085	0.062	0.173	**0.88**
JAPAN	5.781	0.535	0.567	2.03	2.083	1.476	0.033	0.076	0.114	**0.938**
MALAYSIA	7.284	0.655	0.428	2.054	2.044	1.457	0.133	0.066	0.285	**0.904**
POLAND	10.434	0.654	0.58	1.983	1.968	1.441	0.1	0.065	0.152	**0.824**
SINGAPORE	9.394	0.253	0.446	2.046	2.056	1.454	0.091	0.088	0.241	**0.928**
SPAIN	8.373	0.091	0.563	2.004	2.071	1.461	0.046	0.066	0.204	**0.91**
U.K.	9.321	0.712	0.482	1.971	2.064	1.459	0.054	0.079	0.138	**0.9**
USA	7.375	0.099	0.55	1.984	2.066	1.461	0.041	0.064	0.152	**0.895**

Table no.2. Results at macroeconomic level – part II

RESULTS – MACROECONOMIC LEVEL

COUNTRY	KURTOSIS	SKEWNESS	HURST	F.D. - VARIOGRAM	F.D. - HALLWOOD	F.D. - BOXCOUNT	APPROX. ENTROPY	KPSS tau	KPSS mu	EFFICIENCY INDEX
FINANCIAL CRISIS PERIOD (2007-2008)										
ARGENTINE	72.133	-6.493	0.558	1.941	2.071	1.429	0.359	0.121	0.388	**0.847**
BRAZIL	53.338	-4.270	0.491	2.007	2.084	1.431	0.168	0.091	0.273	**0.912**
FRANCE	43.383	-4.466	0.462	1.921	1.864	1.431	0.215	0.115	0.434	**0.697**
GERMANY	72.669	-6.429	0.592	1.960	1.971	1.426	0.302	0.116	0.372	**0.797**
ITALY	69.234	-6.479	0.591	1.946	2.025	1.449	0.353	0.114	0.427	**0.802**
JAPAN	48.468	-4.845	0.542	1.961	1.979	1.471	0.177	0.116	0.284	**0.804**
MALAYSIA	23.430	-1.955	0.384	2.056	2.067	1.394	0.105	0.054	0.326	**0.933**
POLAND	69.524	-6.191	0.589	1.946	1.916	1.396	0.326	0.098	0.531	**0.745**
SINGAPORE	40.533	-4.273	0.537	1.977	2.012	1.427	0.170	0.092	0.393	**0.833**
SPAIN	66.078	-3.691	0.595	1.969	1.977	1.412	0.256	0.107	0.367	**0.813**
U.K.	48.517	-4.697	0.547	1.939	1.885	1.419	0.240	0.102	0.329	**0.752**
USA	55.332	-5.728	0.591	1.932	1.928	1.457	0.265	0.111	0.351	**0.770**
SUBSEQUENT PERIOD OF FINANCIAL CRISIS (2009-January 2017)										
ARGENTINE	108.884	5.273	0.482	2.002	1.926	1.435	0.411	0.189	0.269	**0.729**
BRAZIL	47.071	-0.767	0.461	1.984	1.919	1.455	0.263	0.084	0.322	**0.744**
FRANCE	34.388	-0.434	0.477	1.981	1.899	1.455	0.228	0.087	0.118	**0.740**
GERMANY	86.835	0.440	0.465	1.996	1.899	1.464	0.320	0.085	0.186	**0.728**
ITALY	72.835	-1.899	0.480	1.995	1.915	1.457	0.348	0.103	0.201	**0.740**
JAPAN	37.040	1.454	0.448	2.023	1.975	1.474	0.284	0.125	0.193	**0.796**

MALAYSIA	101.792	-1.136	0.426	2.024	1.915	1.433	0.437	0.096	0.460	**0.741**
POLAND	74.309	-0.020	0.458	1.985	1.908	1.445	0.390	0.172	0.286	**0.712**
SINGAPORE	43.905	0.505	0.463	1.987	1.939	1.470	0.328	0.092	0.356	**0.742**
SPAIN	27.472	0.050	0.483	1.989	1.942	1.465	0.260	0.076	0.188	**0.760**
U.K.	44.806	1.146	0.462	2.002	1.918	1.463	0.290	0.077	0.163	**0.749**
USA	32.156	1.907	0.456	2.004	1.920	1.472	0.265	0.069	0.193	**0.755**

The periods of inefficiency are also confirmed by the results obtained for the short-term memory variabile, estimated by the fractal dimension, when massive deviations from the 1.5 reference value occur, especially during the financial crisis and at the level of emerging economies, where we also find multifractality. This can be explained by the fact that this market typology presents a series of natural features in terms of trading mechanisms, liquidity, risk aversion of the participants, the institutional framework and the degree of integration with the mature financial markets.

We can observe massive deviations from efficiency also in the case of entropy, suggesting a high data complexity, thus a certain inconsistency in the process of integrating existing information into the market.

At he Efficiency Index level, we find that in the periods of financial stability, both developed and emerging markets in the top of the ranking. However, during bubbles and financial crisis, the most efficient markets are part of mature economies (France, UK, USA, Germany, Italy), except for Poland, which, although emerging country, occupies leading positions in all periods of analysis. This can be explained by the fact that this type of economy is not fully integrated into international capital flows, and thus less it is exposed to shocks of exogenous nature and contagion.

As an overview, we observe different levels of efficiency, depending on the stage of the development of the considered markets, the geographical positioning, and the analysed period.

The critical issue that the research confirms is the existence of certain shocks (of endogenous and / or exogenous nature) that are likely to move, on a short and a long term, the market from a "close to balance" functional area, i.e. the existence of a financial market dynamics (integrated into international financial flows) characterized by areas with distinctive levels of "information efficiency".

The results, which contradict the main postulates of the Efficient Market Theory, suggest the correctness of the adopted research hypothesis, in the sense that EMH, as an explanatory model of the neo-classical paradigm, is not realistic enough to describe the current evolutions of the financial markets. Thus, it is necessary to replace it with a wider conceptual framework, within which the recording of a high level of informational efficiency to appear to be only a "particular case".

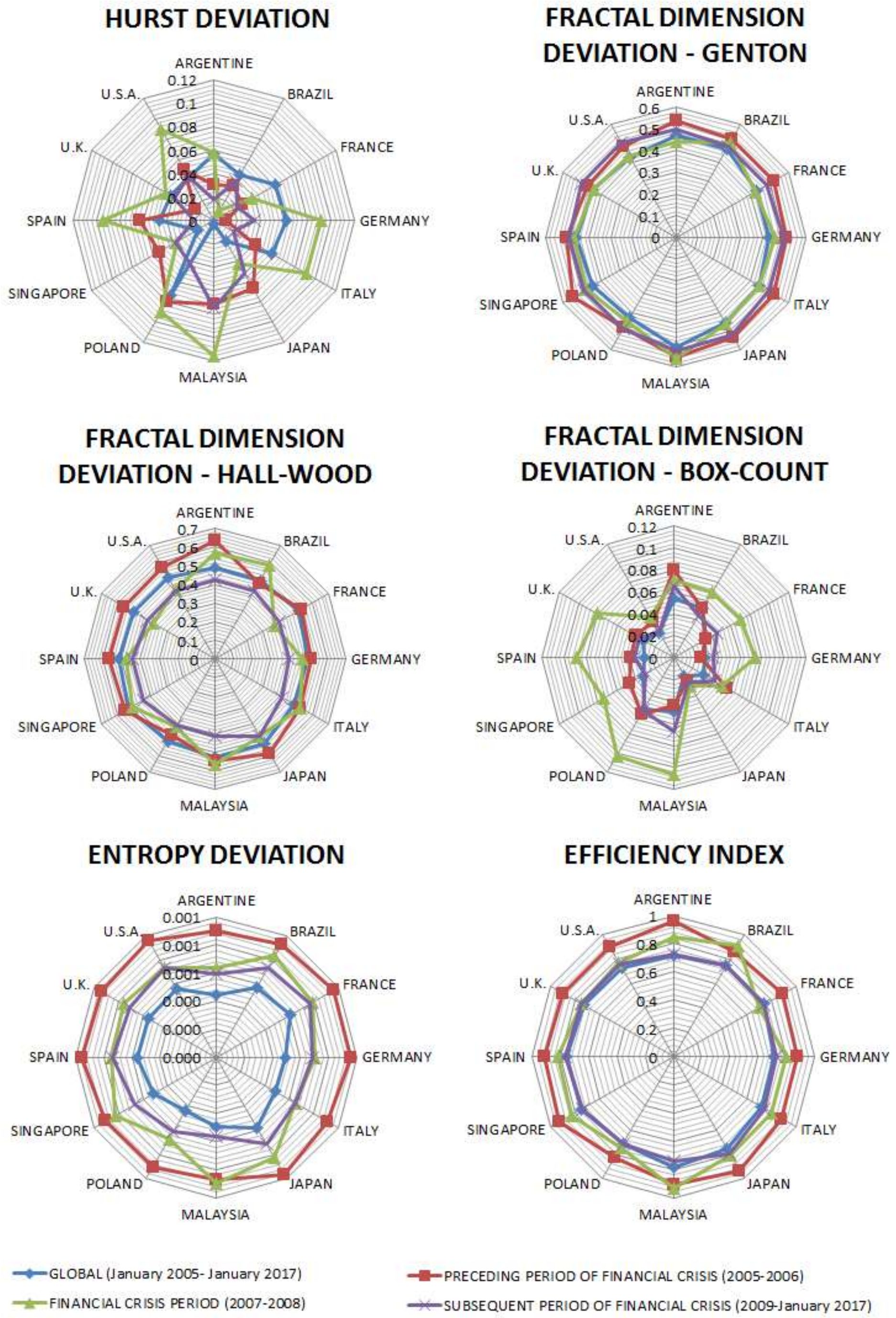

Figure Nr. 1 - Deviations in absolute terms of the variables considered

3.2. Results - Microeconomic level

At the global microeconomic level, it is noted that Renault SA (France) with a value of 0.618 for the Hurst exponent, a fractal dimension of 1,730 (Genton), 1,910 (Hall-Wood) and 1,450 -Count), an approximate entropy of 0.598, and an efficiency index value of 0.527, is the first in ranking. The biggest deviation in this period, and the 150th place in the classification, is for TIM Participações S.A. (Brazil), where the value of 0.975 of the index is based on a Hurst of 0.234, a fractal dimension of 2.00 (Genton), 2.2 (Hall-Wood), 1.28 (Box-Count), and an entropy of 0.392.

In the precursor period of the crisis we see a domination of emerging-market companies in the top positions. Thus, occupying the 1 st position with an efficiency index of 0.715, a Hurst exponent of 0.416, a fractal dimension of 2.020 (Genton), 1.830 (Hall-Wood) and 1.400 (Box-Count), and an entropy of 0.324 is Snam SpA (Italy). In the last positions of the ranking, we also find companies from emerging economies, headed by Mirgor SACIFIA (Argentina), with the variable Hurst of 0.554, fractal dimension of 2,030 (Genton), 2,470 (Hall-Wood) and 1,460(Box-Count), and approximate entropy of 0.114 and respectively an efficiency index of 1.193.

Amica S.A. (Poland) ranks first in the ranking during the financial crisis with an index value of 0.469, based on the Hurst coefficient of 0.812, the fractal dimension of 1,640 (Genton), 1,660 (Hall-Wood) and 1,370 (Box- Count), and an approximate entropy of 0.507.

If in the top of the ranking we find lower values of the efficiency index, respectively a higher level of efficiency, in the other side the results show the lowest level of efficiency, with TIM Participações S.A. (Brazil), occupying the 150th position. The company is characterized by a value of 1,731 of the efficiency index, a Hurst exponent of 0,569, a fractal dimension of 2,00 (Genton), 3,080 (Hall-Wood) and 1,330 (Box-Count), and an entropy of 0.071. It is followed in the rankings by Mirgor S.A.C.I.F.I.A. (Argentine, IE = 1,172), Burberry Group plc (UK, IE = 1,117), Volkswagen Aktiengesellschaft (Germany, IE = 1,106) and StarHub Ltd. (Singapore, IE = 1,102).

The subsequent period of financial crisis from 2007 marks a return of efficiency indicators closer to the benchmark. Thus, the top 5 positions of the ranking are occupied by Mirgor S.A.C.I.F.I.A. (Argentine, IE = 0.570), AMMB Holdings Berhad (Malaysia, I.E. = 0.575), DBS Group Holdings Ltd (Sinagapore, I.E. = 0.601), UMW Holdings Bhd (Malaysia, I.E. = 0.611), Boryszew S.A. (Poland, I.E. = 0.619).

The last position is occupied by Telekom Malaysia Berhad (Malaysia), with a Hurst coefficient of 0.131, a fractal dimension of 2.140 (Genton), 2.060 (Hall-Wood) and 1.320 (Box-Count), an entropy of 0.657 an efficiency index of 0.960.

The overall picture at microeconomic level is consistent with the results obtained at the macroeconomic level, namely that both the developed and emerging markets considered are characterized by periods of inefficiency, either in a deterministic sense (persistence) or in a random-chaotic sense(anti- persistence, with more intense movements than random ones), suggesting a non-negligible dependence between the past and the present, and periods in which markets fail to fully enclose the information in the trading prices. The different levels of efficiency, depend on the stage of the development of the considered markets, the geographical positioning, and the analysed period.

Table no. 3. Results at microeconomic level

COMPANY (COUNTRY)	SYMBOL	KURTOSIS	SKEWNESS	HURST	F.D. - GENTON	F.D. - HALL-W.	F.D. - BOX COUNT	ENTROPY	KPSS - tau	KPSS - mu	EFF. INDEX	RANKING
GLOBAL (January 2005- January 2017)												
Renault SA (France)	**RNO.PA**	235.981	-10.227	0.618	1.730	1.910	1.450	0.598	0.044	0.098	**0.527**	**1**
Infineon Technologies AG (Germany)	**IFX.DE**	590.050	-18.364	0.382	1.880	1.870	1.460	0.786	0.033	0.097	**0.555**	**2**
Beiersdorf Aktiengesellschaft (Germany)	**BEI.DE**	37.634	-2.384	0.512	2.050	2.110	1.520	0.323	0.079	0.087	**0.889**	**149**
TIM Participações S.A. (Brazil)	**TIMP3.SA**	1210.640	-34.317	0.234	2.000	2.200	1.280	0.392	0.056	0.152	**0.975**	**150**
PRECEDING PERIOD OF FINANCIAL CRISIS (2005-2006)												
Snam S.p.A. (Italy)	**SRG.MI**	114.080	-9.176	0.416	2.020	1.830	1.400	0.324	0.045	0.496	**0.715**	**1**
Boryszew S.A. (Poland)	**BRS**	10.648	1.067	0.615	1.910	1.850	1.410	0.080	0.090	0.271	**0.723**	**2**
Itaúsa - Investimentos Itaú S.A. (Brazil)	**ITSA4.SA**	4.275	0.037	0.156	2.230	2.130	1.490	0.108	0.086	0.089	**1.117**	**149**
Mirgor S.A.C.I.F.I.A. (Argentine)	**MIRG.BA**	7.867	1.198	0.554	2.030	2.470	1.460	0.114	0.056	0.063	**1.193**	**150**
FINANCIAL CRISIS PERIOD (2007-2008)												
Amica S.A. (Poland)	**AMC**	75.434	-7.273	0.812	1.640	1.660	1.370	0.507	0.143	0.393	**0.469**	**1**
Société Générale (France)	**GLE.PA**	48.920	-5.689	0.462	1.720	1.840	1.450	0.355	0.092	0.442	**0.522**	**2**
Mirgor S.A.C.I.F.I.A. (Argentine)	**MIRG.BA**	197.433	-13.520	0.315	2.290	2.320	1.430	0.604	0.144	0.393	**1.172**	**149**
TIM Participações S.A. (Brazil)	**TIMP3.SA**	222.781	-14.825	0.569	2.000	3.080	1.330	0.071	0.070	0.085	**1.731**	**150**

SUBSEQUENT PERIOD OF FINANCIAL CRISIS (2009-January 2017)												
Mirgor S.A.C.I.F.I.A. (Argentine)	**MIRG.BA**	457.170	18.324	0.465	1.990	1.740	1.430	0.706	0.186	0.256	**0.570**	**1**
AMMB Holdings Berhad (Malaysia)	**1015.KL**	291.497	-12.314	0.501	1.970	1.740	1.440	0.560	0.091	0.856	**0.575**	**2**
Davide Campari-Milano S.p.A.(Italy)	**CPR.MI**	231.767	0.318	0.226	2.160	2.020	1.450	0.747	0.095	0.109	**0.894**	**149**
Telekom Malaysia Berhad (Malaysia)	**4863.KL**	381.343	14.412	0.131	2.140	2.060	1.320	0.657	0.088	0.255	**0.960**	**150**

We note that the highest deviations occur namely in the case of companies part of emerging economies, mainly located in South America and Asia, and during the 2007-2008 financial crisis.

Thus, we contend that the results obtained also at the microeconomic level are in contradiction with the postulates of the efficient market theory, in which the price movement follows a random trajectory, with no persistence or deterministic behavior.

3.3. Impact Analysis

In order to determine the correctness of the explanatory variables considered for the Efficiency Index, we used two methods to analyse their individual impact on the dependent variable: Generalized Linear Model (GLM) and Bayesian Analysis Model (BMS).

For the case of GLM, with a probability of 99%, the obtained results indicate a large impact of the fractal dimension estimated by the Hall-Wood method (50.16%) and Genton (36.96%), on the dependent variable, respectively on the Efficiency Index. Approximate entropy accounts for 7.56%, Hurst exponent for 0.733%, and the fractal dimension estimated by Box-Count method only 0.149%. However, this last explanatory variable is not statistically significant, having $P > 0.05$.

Based on the Bayesian analysis, the largest impact on the dependent variable is generated by the Hall-Wood Estimator of the Fractal Dimension (50.12%), followed by the Genton Estimator (36.90%). Approximate entropy accounts for 7.45%, long term memory for 0.711%, and Box-Count Estimator has an insignificant influence of only 0.003%. The positive values obtained for all cases indicate that a change in these coefficients will cause a change in the dynamics of financial market efficiency.

Conclusions

In the post-modern times we are living in, with interconnected financial markets, and an implicit high level of sensibility to existing motions, one of the most important problems that require our attention pertains to the way our capital market mechanisms function.

Even though an efficient market is an ideal environment for those participating in the market, a series of arguments can be made against the Efficient Market Hypothesis, and through the progress in researching financial markets it has been proven that these tenants are not infallible, and models of transaction based on this theory do often times generate faulty results. Also, as it can be observed in the last decade, capital markets are characterized by ever-growing instability and volatility, suggesting the idea of different financial mechanisms, with faster, bigger and more diverse markets, than at any other point in modern history.

Since testing informational efficiency remains a fundamental problem to modern economy, the current paper wishes to further the understanding of financial assets price mechanisms, by offering a broader picture on market behavior, especially at a microeconomic level. We use the methodology proposed by Ladislav Kristoufek and Miloslav Vosvrda in their study entitled "*Measuring capital market efficiency: long-term memory, Fractal size and approximate entropy"*(Kristofek, Vosvrda 2014, p. 162), spanning 12 years divided in 4 periods of observation (2005/2016, 2005/2006, 2007/2008, 2009/2016).

The *main findings* of the paper suggests that:

- Both the developed and emerging markets considered have inefficient intervals, either in a deterministic sense (persistence) or in a random-chaotic (anti-persistent, with more intense movements than random ones), multifractality and a high degree of data complexity, suggesting a non-negligible addiction to present and past, and periods in which markets fail to fully incorporate existing information into trading prices;
- These inefficiencies depend also on the geographical location of the companies, with the most efficient ones being part of Europe or the United States, and the least efficient one part of countries from Latin America and Asia;
- The levels of inefficiency depend also on the period considered: we find that prior to the crisis the level of deviation from efficiency is more reduced, during the financial crisis it expands before eventually returning closer to the reference value following the crisis.

The "temporal efficiency" hypothesis is also sustained by the descriptive statistic results, which indicates stationarity, asymmetry and pronounced fat-tails effects.

The findings raise a critical issue: that of the existence of shocks (of an endogenous and / or exogenous nature) susceptible to move the market on a long and short term, from a "near balance" functional area. This suggests the existence of a dynamic of financial markets (embedded within the international financial flows), characterized by going through areas with distinctive levels of "informational efficiency".

The results, which contravene the basic tenants of the Efficient Market Theory, suggest that the theory, as an explanatory model of the neo-classical paradigm is not sufficiently realistic to describe the current developments of the financial markets. This implies the necessity to substitute it with a wider conceptual framework, in which the recording of a high level of informational efficiency to emerge as just a "particular case".

In this regard, an alternative is offered by the Adaptive Markets Hypothesis (A.M.H.). We do, however, consider that the A.M.H. is not in this state of development a sufficiently “mature” explicative framework. One of its main problems is the need of a clearer definition of its core hypotheses and of the implications that can be deduced thereof, as well as phrasing these implications in a manner in which they can be empirically tested. Thus, in our further researches we intend focusing on A.M.H., especially from a methodological point of view, and take upon ourselves the sketching of some of the theoretical implications.

References

1. Bachelier, L., 1900. Theorie de La Speculation. Annales scientifiques de l’É.N.S. 3e série, 17, pp.21–86.
2. Barberis, N. & Thaler, R., 2003. Barberis, N., & Thaler, R. (2003). A survey of behavioral finance. Handbook of the Economic of Finance, 1052–1121. http://doi.org/10.2139/ssrn.327880A survey of behavioral finance. Handbook of the Economic of Finance, pp.1052–1121.
3. Dima, Bogdan & Milos, Laura Raisa (2009). "Testing The Efficiency Market Hypothesis For The Romanian Stock Market," Annales Universitatis Apulensis Series Oeconomica, Faculty of Sciences, "1 Decembrie 1918" University, Alba Iulia, vol. 1(11), pp. 1-41.
4. Dima, Bogdan & Pirtea, Marilen & Murgea, Aurora. (2006). Testing the Informational Efficiency on the Romanian Financial Market. Theoretical and Applied Economics. 1(496), pp. 43-47.
5. Fama, E.F. et al., 1969. The Adjustment of Stock Prices to New Information. International Economic Review, 10(1), p.1. Available at: http://www.jstor.org/stable/2525569?origin=crossref.
6. Fama, E.F., 1991. Efficient Capital Markets: 2. Journal of Finance, 46(5), pp.1575–1617.
7. Grossman, S.J. & Stiglitz, J.E., 1980. On the Impossibility of Informationally Efficient Markets. American Economic Review, 70(3), pp.393–408.
8. JEGADEESH, N., 1990. Evidence of Predictable Behavior of Security Returns. The Journal of Finance, 45(3), pp.881–898.
9. Kristoufek, L. & Vosvrda, M., 2014. Measuring capital market efficiency: long-term memory, fractal dimension and approximate entropy. The European Physical Journal B, 87(7), p.162. Available at: http://link.springer.com/10.1140/epjb/e2014-50113-6.
10. Laffont, J.-J. & Maskin, E.S., 1990. The Efficient Market Hypothesis and Insider Trading on the Stock Market. Journal of Political Economy, 98(1), pp.70–93.
11. Lehmann, B.N., 1990. Fads, Martingales, and Market Efficiency. The Quarterly Journal of Economics, 105(1), pp.1–28.
12. LeRoy, S.F. & Porter, R.D., 1981. The Present - Value Relation: Tests Based on Implied Variance Bounds. Econometrica (pre-1986), 49(3), p.555. Available at: http://ezproxy.lib.vt.edu:8080/login?url=http://proquest.umi.com/pqdweb?did=677755021&Fmt=7&clientId=8956&RQT=309&VName=PQD.

13. LeRoy, S. (1973). Risk Aversion and the Martingale Property of Stock Prices. International Economic Review, 14(2), p.436.
14. 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), pp.41–66.
15. Lo, A.W., 2004. The Adaptive Markets Hypothesis. The Journal of Portfolio Management, 30(5), pp.15–29.
16. Lo, A.W., 2007. Efficient market hypothesis. The new Palgrave: A dictionary of Economics, 46(5), pp.1–28.
17. Mandelbrot, B. (1966). Forecasts of Future Prices, Unbiased Markets, and "Martingale" Models. The Journal of Business, 39(S1), p.242.
18. Muth, J.F., 1961. Rational Expectations and the Theory of Price Movements. Econometrica, 29(3), p.315. Available at: http://www.jstor.org/stable/1909635?origin=crossref.
19. Peters, E. (1994). Fractal market analysis. New York: John Wiley & Sons.
20. Samuelson, P.A., 1965. Proof that properly anticipated prices fluctuate randomly. Industrial Management Review, 6, pp.41–49