Nonlinear analysis of financial indexes: comparing behaviors of developed and developing markets

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Abstract

The efficient market model has been questioned. In econometric, efficient markets are those that have no linear correlation. A lack of linear correlation is not sufficient, since the return series can also produce non-linear dependence. Thus, this study presents the method of the coefficients of correlation and bi-correlation of Portmanteau in analyses of financial markets series. The market efficiency was evaluated through the windows percentage that has significant coefficients, correlations or bi-correlations. The results reinforce the criticism of the efficient market model and demonstrated the existence of significant nonlinearities in all indices studied and the presence of evolutionary trajectories.

Key Words: Financial Markets, Market Efficiency, Linear Dependence, Nonlinear Dependence, Bi-correlation of Portmanteau.

Classificação JEL: C1, C4, C5, G1, M2

1. Introduction

It has seen increased the interest among researchers in exploring nonlinear behavior in time series of financial data. This line of research has produced results, in which the empirical evidences suggested that the nonlinearity is a universal phenomenon (Lim and Hinich 2005). The evidences of nonlinearity founded out by researches enhanced that the behavior of structures with nonlinear dependences is episodic in nature.

Among the studies exploring nonlinear behavior can be cited to Brooks and Hinich (1998) who analyze the ten largest markets of exchange and Ammermann and Patterson (2003) who analyze the six major financial stock markets and two hundred forty-seven stocks more traded in the Taiwan Stock Exchange. Lim et al. (2003) analyze four currency markets of Southeast Asia and Romero-Meza et al. (2005) find the performance of seven indices of stock markets in Latin America.

In all these studies mentioned above, the behavior of the market proved to be determined by random disturbances in long periods and fewer episodic inter-dispersed in such random noise, with nonlinear effects of high significance. In this context the question to be answered

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in the article is: financial markets are efficient or there are short bursts of nonlinear behavior in the markets?

Therefore, this research aims to determine the presence of larger events that activate endogenous nonlinear effects on the behavior of financial markets. Therefore, we will seek: (i) identify dependency relationships linear and non-linear indices of financial market, including: the indexes BOVESPA (Brazil), MERVAL (Argentina), IPSA (Chile), IPC-Mex (Mexico) Dow-Jones (USA), S-KOSPI (South Korea) and the NIKKEI (Japan), and, comparatively analyzing the efficiency of their markets, in order to raise the degrees of effectiveness.

This paper is organized as follows. Beyond this brief introduction, section 2 presents a theoretical discussion of the Markets Efficiency and the presence of non-linearity in financial series. Section 3 details the mathematical aspects of the analysis tool used in addition to statistical tests. Section 4 describes the methodology and data used, and sections 5 and 6 presents the results and conclusions of this paper respectively.

2. Literature Review

The aim of this session is to review the main points about the EMH (Hypothesis of Efficiency Markets) and the particularities of financial series, especially, with regard to the presence of nonlinearity in the series of stock returns. This strong belief in the existence of non-linearity in the behavior of asset prices in certain periods of time placed in doubt the hypothesis of market weak efficiency, EMH, and put the following question: how the stock markets evolve over time? So we discuss the EMH and the stock markets evolution in the next two subsections.

2.1 Efficiency Markets

In the context of time series, the presence of randomness for long periods of time in the series of asset prices is consistent with the hypothesis of market weak efficiency, in the way of Fama (1970). In this case, the market response to the new information is instantly entered into the environment. But when surprises or unexpected shocks (economic and/or political) hit the market, the price adjustment process generally generates movement patterns with correlations linear and nonlinear, often related to the acts of caution and uncertainty for investors about how to react facing to such events, resulting in slow responses to the adjustments by the market (Antoniou et al., 1997, Brooks et al., 2000). In resuming if the market is efficient it will present a random behavior over time in the price series, and if it is

inefficient will produce autocorrelation between the current and past prices, i.e., relations of dependencies linear or/and non-linear.

The aspect of the presence of nonlinear events in the financial market structure provides a potential prediction that has generated considerable interesting and has established an explosion in the development of nonlinear models (Lim et al. 2006). As proposed by Ramsey and Zhang (1997, p. 370), the dominant reactions in financial markets related to shocks non-linear are characterized as a succession of brief periods of intense activity and represented by narrow bands of data with high frequency oscillations.

Therefore, in the definition of an efficient market, prices are a reflection of all available information, and are so general that deserve more detailed attention. Because of these characteristics, the theoretical models, and more specifically, the empirical tests of efficiency of capital markets attributed the assumption that the market equilibrium is a function of expected returns. However, as Fame (1970) states, the expected return value is just one of many possible distributions of returns and of market efficiency. Therefore, the results of testing this condition, by itself, do not ascribe to them the condition of market efficiency.

2.2 Financial series and the presence of nonlinearity

Antoniou et al. (1997) listed some factors that may induce the existence of nonlinearity in a series of stock returns, which are: (i) the specific characteristics of the microstructures of markets, which may cause difficulties for arbitrage transactions and inducing non-linearity (examples are the restrictions on sales and/or short-term transactions, imposed in many countries and behavioral aspects of agents); (ii) nonlinear due feedback in price movements. For example, when the price deviates from its fundamental value, then market will drive it to its level equilibrium, but almost always, the back-price will not be equal the price original (these differences arise due to the new balance of investor cognitive biases, and also due to interactions between investors informed and residual, these who enter and exit the market every day); (iii) the existence of market imperfections such as transaction costs can cause nonlinearities; (iv) finally, the nonlinearities can appear from the uninformed investor behavior, who take an excessive time to submit their replies to the market and waiting to see how informed investors behave, because they lack the resources to completely analyze information or because the information is not secure.

There are some common models used in the analysis of asset returns (and therefore the finding of the hypothesis EMH). Some of these models try to test the presence of autocorrelation of return series among distinct periods of the series, for example, of one

current period with other previous. Others establish regression models of time series, like Auto-regressive, or the Unit Toot test to determine if the series has a behavior of random walk, or even tests of variance equalities, estimated with time series data, in different times. The validity the EMH by conventional tests is questioned by Saadi et al. (2006), who emphasizes that the lack of linear correlation does not necessarily imply in efficiency, because a series of returns can be not correlated linearly, but can be nonlinearly dependent. Granger (1983) already had conjectured this argument.

The strong belief in the existence of nonlinearity in the behavior of asset prices in certain periods of time restricts the importance of the efficient market hypothesis, EMH. Thus, the issue being discussed is how the stock markets evolve over time? In seeking answers to this question, new econometric models have been introduced to analyze the behavior of financial time series. Among them we can cite the studies of Cajueiro and Tabak (2004) using the technique of computed Hurst Exponents, Hinich and Patterson (1995) and Lim et al. (2006), who suggested the use of statistical tests to analyze fragmented periods of time, with a approach denominated windowing and Zahnd (2002) which uses a multivariate GARCH structure. These econometric models would solve the common critical characteristic to conventional models that usually reach the simple conclusion that markets are efficient or not. With these new approaches of econometric tests, the hypothesis that has been formulated in the studies on the issue of efficiency of financial markets is: the degree of efficiency of markets follows a path which ultimately leads to better over time?

Another assumption made in the behavioral analysis of financial markets is the Adaptive Markets Hypothesis, AMH. Lo (2004) noted that an evolutionary theory to the efficient markets would solve the controversies debated among researchers, regarding the EMH hypothesis. For the author, the AMH can co-exist with the EMH. The basic argument to the adaptive approach and, consequently, to the loss of rational economic behavior are due to the individual's adaptation to environmental changes, by complacency, as overconfidence, extreme reactions and even superstition. Already the market efficiency is nothing more than the impact of evolutionary forces in financial institutions that reduce profits and make them tend to zero, such as: competition, mutation, reproduction and natural selection.

There is not a condition that allows all markets could be efficient, but rather a characteristic that varies continuously over time and with the markets. Lo (2005) argues that convergence to equilibrium is not guaranteed and that is incorrect the conception that to the improve their governance, the market is marching inexorably toward an ideal state, stationary. Consequently, the AMH implies the existence of an extremely complex market

dynamics, with cycles and trends, panics, manias, bubbles, booms and other effects.

Therefore, this study intends to apply the technique of windowing, which estimates the correlation coefficient of Portmanteau (the correlation C) and the test of bi-correlation of Portmanteau (bi-correlation H), applied in sequential windows, proposed by Hinich and Patterson (1995), which will be explained in the next section.

3. Mathematical Representation of Portmanteau Correlation and statistics tests

The sequence y(t) is the series data to be tested, where t is the unit of time, an integer. In the procedure there is no windows overlapping, so if n is the the number of data in each window, then the kth window consists of the following data set: $\{y(t_{(k-1\times n+1}), y(t_{(k-1)\times n+2}), \dots, y(t_{(k-1)\times n+n})\}$, where $k=1,2, \dots, N_w$, with N_w being the number of windows. For the first window $k=1$, and so subsequently.

The null hypothesis for each time window is that y(t) is a process of pure white noise. Thus, under the Null Hypothesis, the correlations $C_{yy}(r) = E[y(t) \times y(t+r)]$ and the bi-correlations $H_{yyy}(r,s) = E[y(t) \times y(t+r) \times y(t+s)]$ are all equal to zero for all r and s except if $r=s=0$. The alternative hypothesis is that the process has some correlation non-zero for C or H, for $0<r<s<L$, where L is the number of lags for the window. Thus, if there is a linear second-order dependence or a nonlinear third-order dependence in the process, then $C_{yy}(r) \neq 0$ or $H_{yyy}(r,s) \neq 0$, at least one value of r or a pair of r and s, respectively.

The procedure starts by defining Z(t) as the standardized observations, obtained from:

$$Z(t) = [y(t) - m_y]/s_y \tag{1}$$

for each $t = 1, 2, .., n,$ being m_y and s_y, respectively, the mean and standard deviation of the window sample. Following are determined $C_{zz}(r)$ correlations, taking r lags, starting with $r=1$ and increased steadily. Thus, we have that:

$$C_{ZZZ}(r,s) = (n-r)^{-1}\sum_{t=1}^{n-s} Z(t)Z(t+r)Z(t+s) \text{ for } 0 \le r \le s \tag{2}$$

The C statistic designed to test the existence of linear correlations (i.e. linear dependence) within a window, is estimated as follows:

$$C(r) = \sum_{r=1}^{L}[C_{zz}(r)]^2 \approx \chi^2(L) \tag{3}$$

where L is the maximum number of lags used in estimating the correlation and being the degrees of freedom of chi-square distribution in Formula (3) above. The coefficient of bi-correlation (r, s) is estimated as follows:

$$C_{ZZZ}(r,s) = (n-r)^{-1}\sum_{t=1}^{n-s} Z(t)\times Z(t+r)\times Z(t+s), \text{ for } 0 \le r \le s \tag{4}$$

As indicated above, the statistic H was developed to test the existence of nonlinear dependence (i.e., the existence of bi-correlation different from zero) within a window. Their corresponding distributions are:

$$H(r,s) = \sum_{s=2}^{L}\sum_{r=1}^{s-1}[G(r,s)]^2 \approx \chi^2([(L-1)L]/2) \tag{5}$$

where $G(r,s) = (n-s)^{\frac{1}{2}} C_{ZZZ}(r,s)$ and $[(L-1)L]/2$ are the degrees of freedom of chi-square distribution shown in Equation (5) above.

4. Data and Methodology

The C statistic and the H statistic were estimated using a computer program developed for this purpose, in STATA 10. To develop the software to be used in estimates of tests C and H, it must decide the size of the window to be applied in the study. The rule is to find through trial and analysis, the ideal window size for the survey. In this study, data were divided into equal mobile windows and non-overlapping of 30 observations each. This window size proved to be long enough to validate the estimates of tests C and H.

In the estimates of C and H tests should establish the appropriate maximum number of lags (lags) for the analysis of the problem. Hinich and Patterson (1995) suggested the formula $L = n^b$ (where L is the maximum number of lags to be applied to each window, n the sample size of each window and b is a parameter of choice by user, however, remained in the range $0<b<0.5$). As also suggested by Hinich and Patterson (1995), it was used the value of $b\approx 0.4$, regarded as the optimal value that enables to estimate the minimum number of lags, which is sufficient to maximize the power of the tests and provide a valid approach to the theory, even for a n small. According to the formula $L = n^b$, it can be obtained $L = 30^{0.4} \rightarrow L \approx 4$. This implies that we use all the numbers of lags less than or equal to L, possible to be applied in each window.

The statistics C and H are measured by a p-value obtained by test of significance with chi-square distributions, respectively, with L and $(L-1)L/2$ degree of freedom**.** If the p-value of the statistic C and/or H of each window is sufficiently low (maximum 0.1), it is reject the null

hypothesis (H_0) of pure white noise, and accept the hypothesis H_1 of the existence of linear correlation (linear dependence in the case of C statistic) and non-linear correlation (non-linear dependence in the case of statistical H).

In this study, we used data sets of financial performance indices of stock exchange in developing countries in South America and North America (IBOVESPA, MERVAL, IPSA, IPC of Mexico), in developing country in Asia (KOSPI-S) and in developed countries (DOW JONES and NIKKEI), obtained from the Bloomberg database (2008). The observations were computed by the closing price on the days between 04/01/1999 and 15/10/2008.

The data were processed in sets of returns, i.e., $r_t = (p_{t+1} - p_t)/p_t$, where p_t is the closing price of the index on day t, and p_{t+1} the price of the day later. The data series of returns from different countries have different numbers of observations because the number of sessions conducted by each financial market of each country were different, resulting in different numbers of windows for each series.

Table 1- Descriptive statistics.

	DJI	NIKK	MERVA	KOS	IBOVESP	IPC_ME	IPS
Mean	5,43E-05	-3,52E-05	0,000676	0,000518	0,000912	0,000798	0,001287
Median	0,000322	0,000173	0,000776	0,001132	0,001268	0,001061	0,000550
Maximum	0,110803	0,141503	0,204090	0,080056	0,333992	0,110052	2,122166
Minimum	-0,07333	-0,096212	-0,106767	-0,120188	-0,099697	-0,079348	-0,692000
Std. Dev.	0,011614	0,014544	0,021963	0,018828	0,020938	0,015033	0,049339
Coefficient of Skewness	0.095616	0.030676	0.2094407	-0.324500	-0.2048832	0.196311	1.752165
Kurtosis	9.838066	9.206592	7.325931	6.315539	4.877888	6.529827	33.45616
Jarque-Bera Probability	0.000000	0.000000	0.000000	0.00000	0.000000	0.000000	0.000000
Sum Sq. Dev.	0.331696	0.510210	1.163018	0.858898	1.062229	0.557296	5.129211

This table shows a summary of the descriptive statistics for index return series of stock markets of Brazil (BOVESPA), Japan (NIKKEI), Argentina (MERVAL), Korea (KOSPI), Mexico (IPC_MEX) and Chile (IPSA).

5. Results

Table (1) provides descriptive statistics for the series of returns of all seven markets surveyed, estimated by STATA 10. Note that the NIKKEI index and DJI are those with relatively higher volatility on average, as can be seen through their respective coefficient of variation (CV), defined by the relation standard-deviation/average. This coefficient is a measure of relative variability (how higher it is, higher is the level of volatility). So we can see through the respective coefficients of variation, without exception, all the indexes analyzed showed high relative levels of fluctuation. Likewise we can also see through standard deviation and the sum of squared residual (Sum Sq. Dev) that the levels of absolute

dispersion of the frequency distributions of index returns of IPSA, IBOVESPA and MERVAL predominate with respect to others, however, with less dispersion on average, due to present higher average returns. It was also observed by the average returns for the period under review, that in the long term (Jan/1999-Oct/2008), the average residual returns are, for all indices examined, approaching zero, what characterizes that the average returns of markets over the long term do not show a significant arbitrages. Also, we noted in Table (1) that, except for indices IPSA (Chile), the others have a low degree of asymmetry, can be considered as symmetrically distributed as a normal distribution (Gaussian). The IPSA index (Chile) appears strongly asymmetric, with right asymmetry. As for the kurtosis coefficients, we can observe that the seven indices present coefficients with strong excess kurtosis in the case, excessively higher than three, which means that all have a strong concentration of its returns around the mean, i.e., they are leptokurtic distributions. Again, the IPSA (Chile) calls attention to the large number of its coefficient of skewness and kurtosis, becoming the most peculiar series of seven, in terms of descriptive statistics. The test of normality Jarque-Bera test indicates, for all indices, probability of 0% for the null hypothesis of normality. Thus, the distributions of the seven indices do not follow normal distributions, which is a peculiar feature of a series that does not behave like white noise, although they all present averages close to zero. These characteristics of index series returns manifest themselves as strong evidence of the presence of serial correlation, linear and nonlinear, which induces the presence of conditional variance that changes due to intermittence in the levels of fluctuations between groups of high variability with small durations, and smaller groups of variability, however, with great durability. The datasets with these characteristics can be modeled using nonlinear models capable of identifying these movements and establish predictability in the midst of apparent unpredictability and uncertainty.

In terms of efficiency, what is expected of a financial market is that it presents to its returning series distribution NID (Normally and Independent Distributed), a necessary condition for this market be governed by their own forces. In this case, the fluctuations of asset prices are, effectively, the actions of investors, due to the rapid absorption of new information by all market players, featuring a fully efficient market. In this case, one cannot expect anything else, unless these effects act on the prices at random, which attaches to a price series character of a random walk (Gujarati, 2006, ch. 22) and the return series presents itself as a distribution NID. Clearly, according to the statistical properties shown in Table (1), none of the return series of the indices under consideration is characterized as NID.

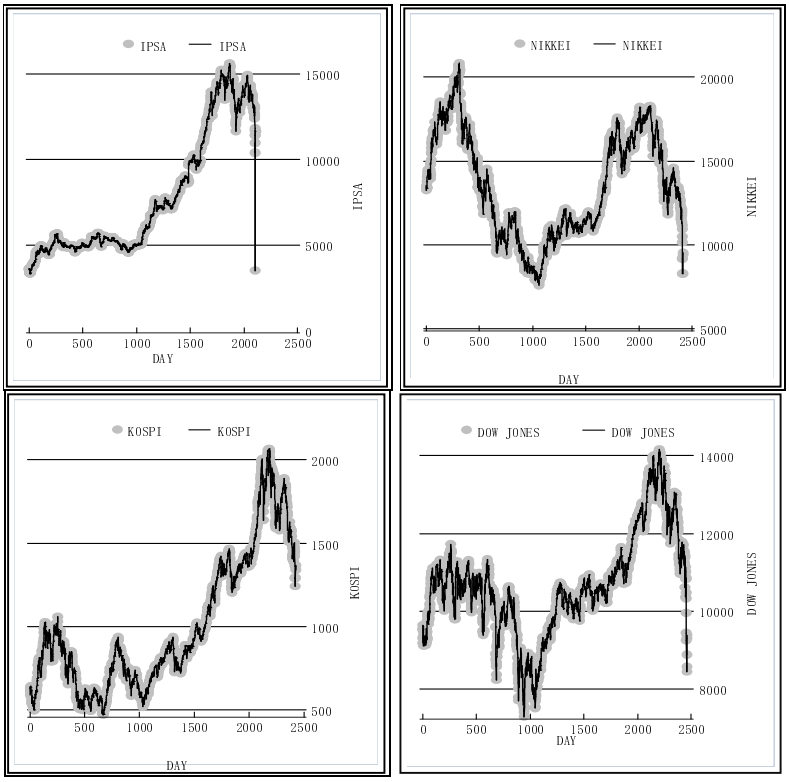

Figure 1: Evolution of price series of stock indices of IPSA, NIKKEI, KOSPI and DJI (Dow Jones), from 04/01/1999 to 15/10/2008.

There is a marked difference in price evolution between the indices of stock exchanges in developing countries and developed countries. It was noticed in the figures (1) and (2) that the evolutions of the index prices for the financial markets of developing countries (IBOVESPA, MERVAL, IPC_MEX, IPSA and KOSPI-S) present stochastic trends. Already, the index prices for the financial markets in developed countries (DJI and NIKKEI) fluctuate around the mean, i.e., prices move with characteristics of a random walk. Among the explanations for this finding may be cited the tradeoff between risk premium and return. Developing countries have a positive trend in the return rates because they have a higher risk premium than the developed countries, possibly due their macroeconomic performances that are worse, essentially, the evolutions of inflation and short interest rate. The risk premium must be larger so that there are investment incentives in these countries, as a calculated risk in the market. Already in developed countries, the interests and inflations of the economies, in general, are much lower and more stable than those of developing countries. The risk is small and therefore the risk premium is very low. The risk premium is reflected in returns, which, in turn, are reflected in asset prices in an economy.

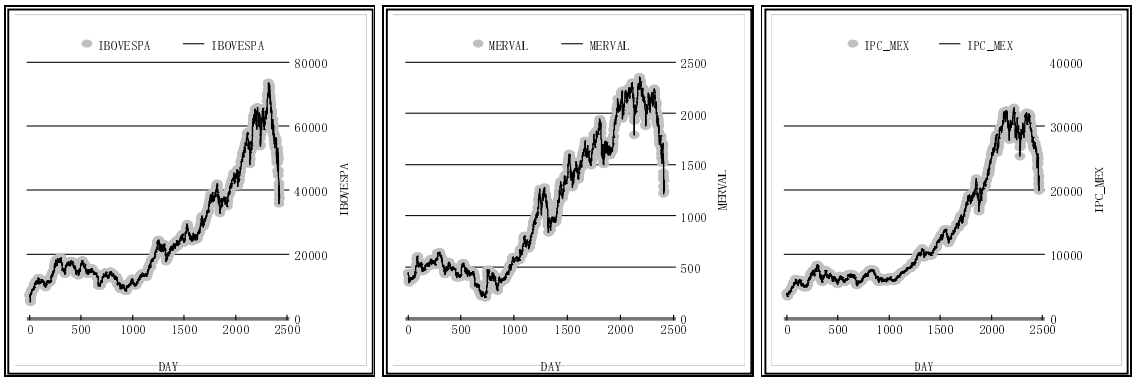

Figure 2: Evolution of the price series of stock indices IBOVESPA, MERVAL and IPC_MEX, from 04/01/1999 to 15/10/2008.

Table 2: Results of Portmanteau correlation test.

Index	Windows Number	5% of significance			10% of significance		
		Number of significant	%	P*	Number of significant	%	P*
DJI	82	5	6.09	4	10	12.19	2
IBOVESPA	81	4	4.90	6	9	11.11	4
IPC_MEX	82	4	4.87	7	10	12.19	3
IPSA	70	5	7.14	2	9	12.85	1
KOSPI	81	5	6.17	3	6	7.40	7
MERVAL	80	4	5.00	5	7	8.75	5
NIKKEI	81	6	7.40	1	7	8.64	6

This table presents the results of Portmanteau correlation test (C statistic) for the markets: NIKKEI, MERVAL, KOSPI-S, DJI, IBOVESPA, IPC_MEX and IPSA, taking with basic significance levels of 5% and 10%.
Note: P* represents the position. in decreasing order, in terms of volatility of the Index.

The overall results of the H statistic are shown in Tables (3), and the results of individual estimates are illustrated in Figures (5) and (6). Through the results shown in Table (3), in percentage terms, the index which gives more significant H statistic is the Santiago IPSA, with 28.57% of the windows containing nonlinearities, at a significance level of 5% and 35.71% at 10% level, and the IBOVESPA is the index that less displays windows containing nonlinearities, with 13.58% at a significance level of 5% and 17.28% at 10% level.

Regarding the presence of non-linear events along the data series, some general observations can be made by inspection of Tables (3) and in the graphs of the Figures (5) and (6). Firstly, it should be noted that p-values curves evolve as a function of time, in which it is

possible to evince that the degree of market efficiency follows an evolutionary[†] path. In particular, all the returns series follow a process of pure white noise for long periods of time and brief periods are disturbed by non-linear predictability. Therefore, the results shown in this study add empirical support to the argument that markets are not in a steady-state, in terms of efficiency.

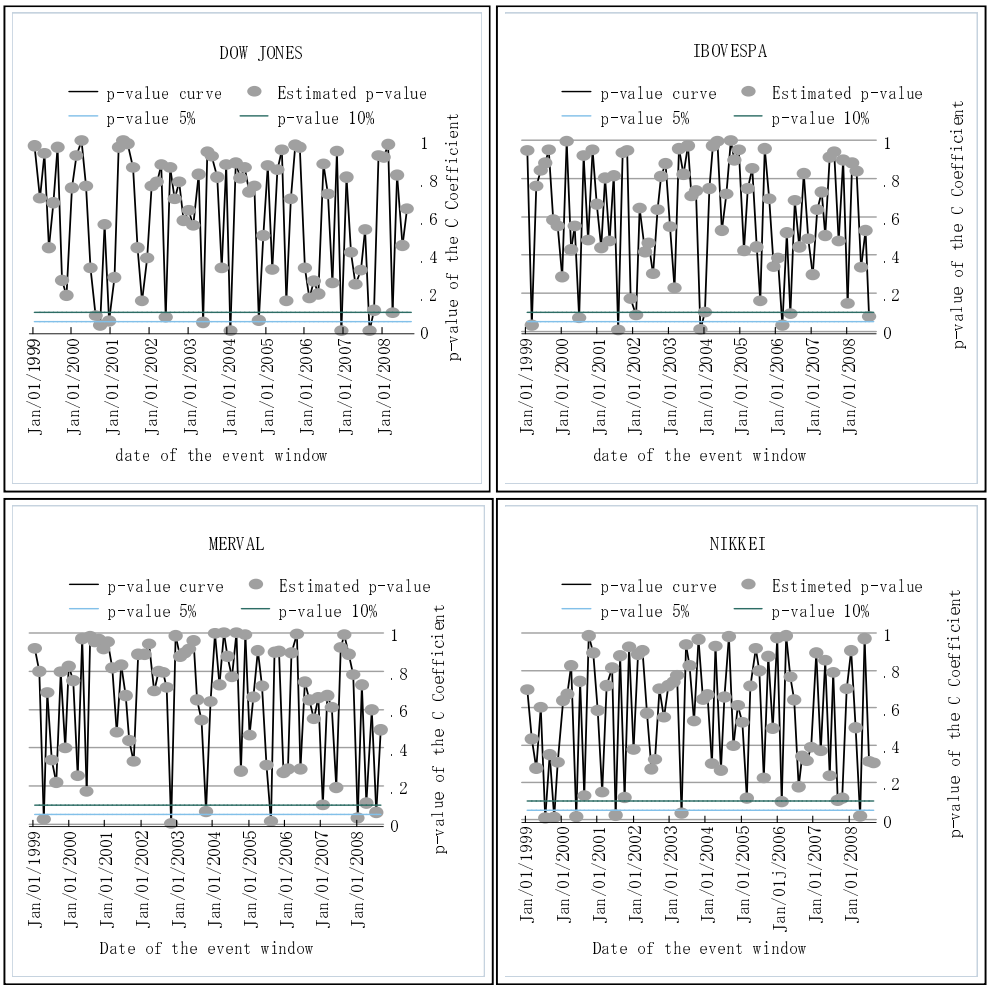

Figure 3: p-values evolution graphs of the C Coefficient of Portmanteau, estimated for the indices DOW JONES, IBOVESPA, MERVAL and NIKKEI, from 01/04/1999 to 10/15/2008.

[†] The term evolutionary refers to the fact that efficiency does not improve with time but evolves in cycles through the evolutionary forces of the market (adaptation, selection, mutation) in accordance with the Adaptive Markets Hypothesis (AMH) of Lo (2004).

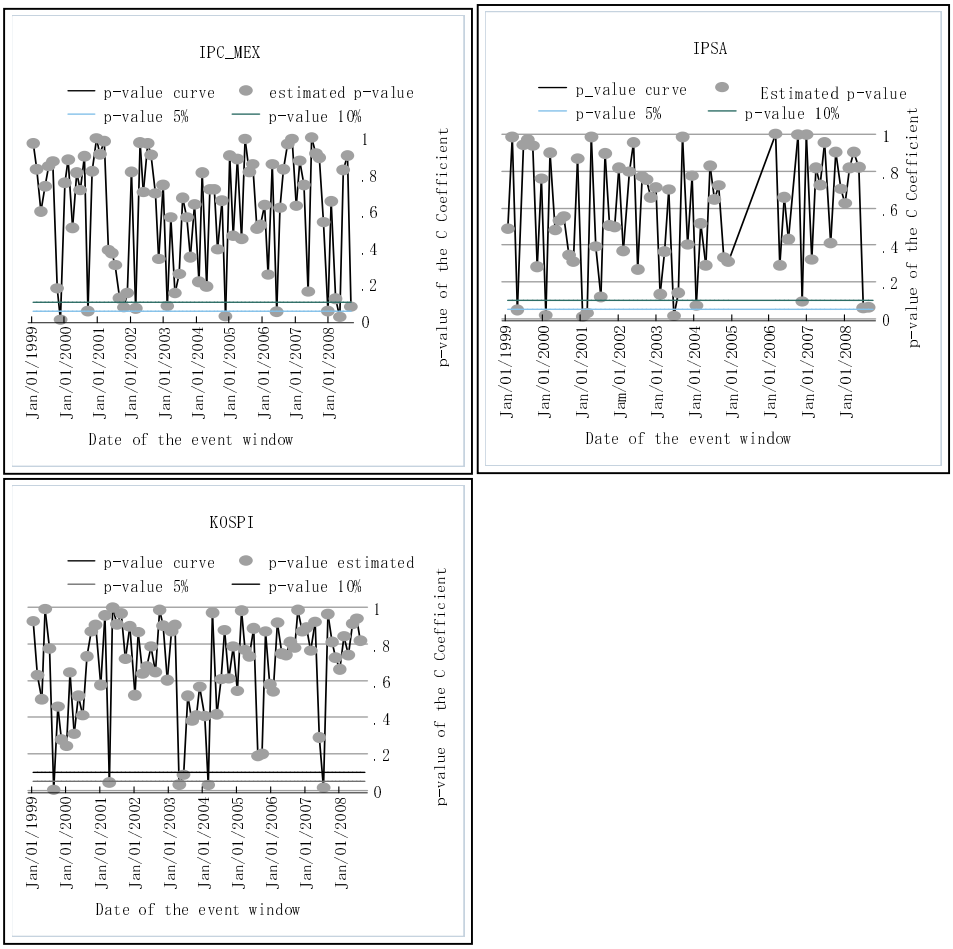

Figure 4: p-values evolution graphs of the C Coefficient of Portmanteau, estimated for the indices IPC_MEX, IPSA and KOSPI, from 04/01/1999 to 15/10/2008.

Table 3 - Results of Portmanteau bi- correlation test.

Index	Windows Number	5% of significance			10% of significance		
		Number of	%	P*	Number of	%	P*
DJI	82	15	18.29	3	17	20.73	6
IBOVESPA	81	11	13.58	7	14	17.28	7
IPC_MEX	82	15	18.29	4	20	24.39	4
IPSA	70	20	28.57	1	25	35.71	1
KOSPI	81	13	16.04	5	19	23.45	5
MERVAL	80	20	25.00	2	25	31.25	2
NIKKEI	81	13	16.04	6	20	24.69	3

This table presents the results of bi-correlation of Portmanteau (H statistic) test to the markets: NIKKEI, MERVAL, KOSPI-S, DJI, IBOVESPA, IPC_MEX and IPSA.
Note: * P represents the position, in decreasing order, in terms of volatility of the Index.

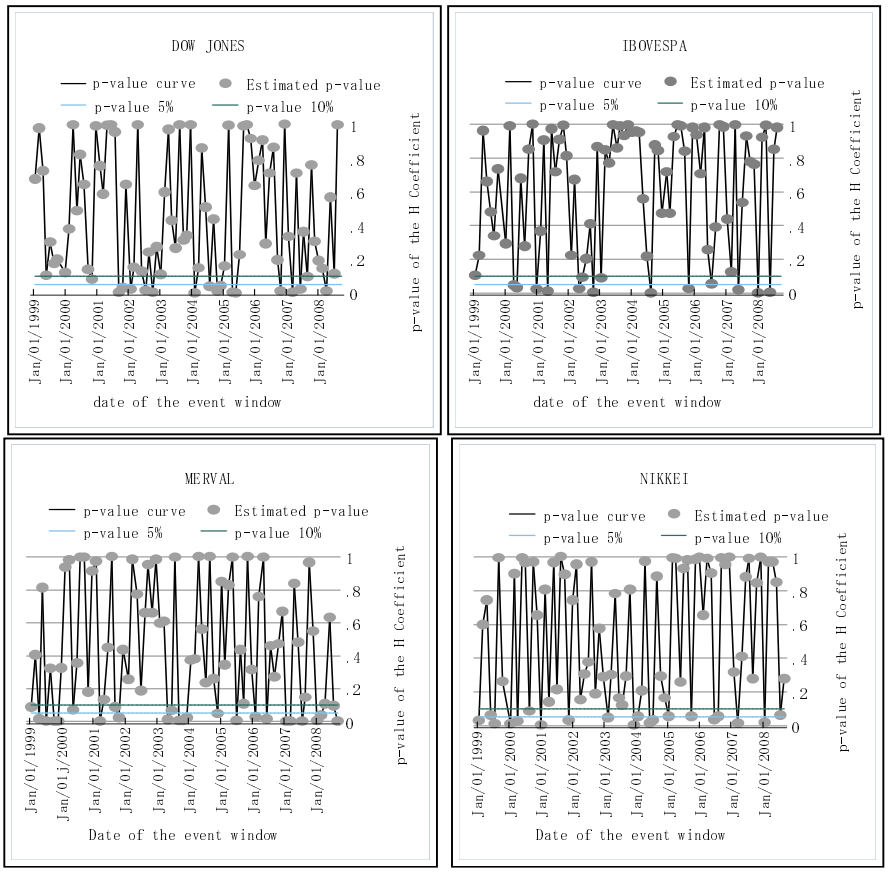

Figure 5: p-values evolution graphs of the H Coefficient of Portmanteau, estimated for the indices DOW JONES, IBOVESPA, MERVAL and NIKKEI, from 04/01/1999 to 15/10/2008.

In research conducted here, all indices, including the DJI and the NIKKEI belonging to developed countries showed significant H statistics in recent times, confirming that the efficiency does not improve with time but evolves in cycles, conducted by market forces (adapting, selection, mutation), in accordance with the Adaptive Markets Hypothesis (AMH) of Lo (2004).

In terms of relative efficiency in line with that proposed by Campbell et al. (1997), this study provides interesting results. The presence of the H statistic in a given window means that the market reached it took much time to respond to the impacts of external of political events, as a result of care and caution on the part of market (Antoniou et al., 1997). Table (3) presents the results of relative efficiency for the indices under study. It is revealed, therefore, that in descending order (with a significance level of 10%), the markets more efficient are:

IBOVESPA (Brazil), DJI (USA), KOSPI (Korea), CPI-MEX (Mexico), NIKKEI (Japan), MERVAL (Argentina) and IPSA (Chile).

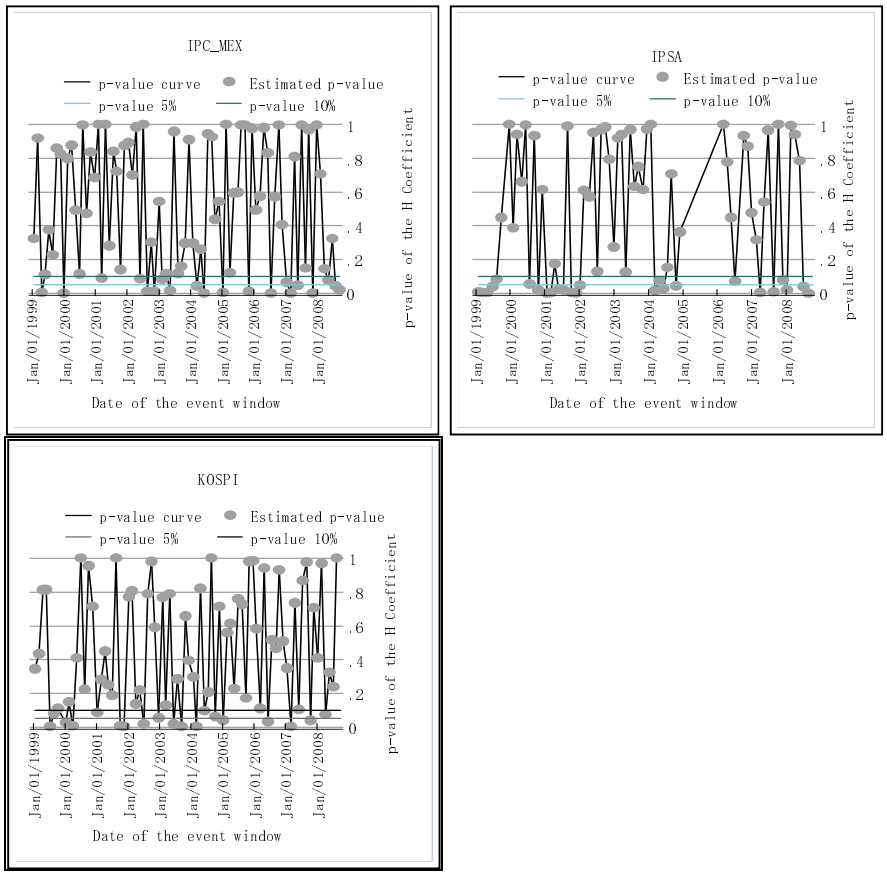

Figure 6: p-values evolution graphs of the H Coefficient of Portmanteau, estimated for the indices IPC_MEX, IPSA and KOSPI, from 01/04/1999 to 10/15/2008.

The study of relative efficiency raises the following question: is there a relationship between the stage of market development and efficiency of this? With the U.S. stock market, in second place and Japan in fifth in terms of efficiency, one may suggest that these markets in more developed stages do not exhibit higher levels of efficiency. In general, this result is surprising because it is expected that the markets of developed countries have higher levels of liquidity, sophisticated investors with greater access to information and greater reliability and, in contrast, developing countries have greater institutional impediments and restrictions on information. However, Brazil (with higher levels of efficiency that the U.S. market, as Table (3)) does not seem to be an exception from emerging countries, therefore, KOSPI (Korea), CPI-MEX (Mexico) appear, respectively, in third and fourth place in terms of

efficiency, in front of the Japanese market (NIKKEI), raising doubts about a positive response to the previous question. Several investigations lead to the fact that emerging markets are less efficient than markets in developed countries, and simply conclude that this does not happen by chance. However, this is not what one can conclude in this study. The fact the Brazilian market has shown to be the most efficient is not characterized as an exception because it is the third largest market in the world. In general way, we can affirm that financial markets are inherently inefficient due to several factors, for example: asymmetric information, the inefficiency of corporate governance and the irrationality of investors. A typical example of these situations has appeared in the news over the past two years, especially in the subprime crisis in 2008.

6. Conclusions

This work has exposed and discussed three issues of the econometric literature that have been largely ignored by conventional studies, in which the efficiency tests should be able to (i) detect both types of serial dependence: linear and nonlinear; (ii) capture the dynamics surrounding the patterns over time, and; (iii) evaluate the relative efficiency among the stock markets. Guided by these criteria, this study adopted the approach "Windowing" and computed the correlation tests and bi-linear correlation Portmanteau. The first test identified the relations of linear dependence and the second detected movements of non-linear dependence. The percentage of windows with significant H statistic was used as an indicator for comparing the relative efficiency of the markets. Another contribution of this work was to use the sample of developing countries and developed, allowing us to make inferences about the degree of development of a market does not necessarily imply efficiency.

The major results of this work can be seen as follows. Firstly, the test of bi-correlation shows that the degree of efficiency in markets varies in a cyclical way over time. This fact contradicts the assumption of the inexorable trend to the efficiency of the efficient market hypothesis EMH formulated by Fama (1970). In fact, the results are in agreement with the Adaptive Markets Hypothesis (AMH) of Lo (2004), who argued that market efficiency is determined by the impact of evolutionary forces in financial institutions and market participants. Moreover, the evidence for predictability in returns provides us with a justification for endless studies and analysis on the apparent efficiency of a market. However, if there is predictability, the markets are not efficient and there are opportunities for profit. Secondly, based on the percentage of windows with significant H statistic, we can say that in general, developed markets are not more efficient than emerging markets. Thirdly, the

application of the nonlinear correlation test of Portmanteau put further doubt whether the degree of development of a market implies efficiency. In this test, IBOVESPA of Brazil appears as a more efficient market that Japan's NIKKEI DJI and the U.S.

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