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Efficiency in Brazilian Market: Applying the Automatic Variance Ratio and Box-Jenkins Method after Greek Crisis

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ABSTRACT

This paper analyzes the efficiency of the market in its weak form in the Brazilian market, after the Greek crisis. To answer the research problem, initially we estimate the structural breaks in the data series. After we calculated the log return on a monthly basis. The efficiency of the market in its weak form was then analyzed using automatic variance ratio for small samples. The Box-Jenkins Method were tested for their ability to predict the return on a monthly basis. The analysis suggested an efficiency in weak form and Box-Jenkins model has shown to be not able to demonstrate the returns non-randomness, denoting efficiency for this market, with no arbitrage opportunities to investors.

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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.

The efficient market hypothesis divides efficiency into three categories: weak form, semi-strong form and strong form. Weak form efficiency is based on a dataset of information that only includes the price or stocks return history. The semi-strong form considers a set of information that only includes the public knowledge available to all participants in the market. Strong form efficiency includes all information obtained by any participant in the market.

Other definitions of market efficiency have been 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 definitions provided by Fama (1970), which emphasize both speed and precision of price adjustment to new information.

Since the pioneering research of Lo and MacKinlay (1988), the variance ratio test has emerged as the main tool to test the random walk hypothesis and, consequently, weak form market efficiency. As a consequence, Charles & Darne (2009b) provide an extensive review of its recent evolution. In order to capture both sides of the random walk, the variance ratio test as developed by Lo and MacKinlay (1988) has two null alternatives: (a) independent and identically distributed innovations as a normal distribution (*i.i.d.*); and (b) non-correlated but weakly dependent innovations with the possibility of heteroscedasticity on their frequency distribution. 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 of the first difference. Thus, the null hypothesis (H_0) in this test states that the variance ratio equals 1.

After Lo and MacKinlay (1988) several improvements have been made to the test, including the work of Chow and Denning (1993) who suggested a multiple variance ratio test, differing

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from the previous in that one can simultaneously verify if all variance ratios equal 1. Another remarkable innovation in the variance ratio test was developed by Wright (2000) who suggested the use of non-parametrical variance 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) assessing this test's performance suggested using the wild bootstrap method to improve its use with small samples. The test suggested by Kim (2009) did not show any distortions in size and the power was substantially greater than that of other tests (e.g., Chen and Deo, 2006; Chow and Denning, 1993). The importance of this test is that it does not require random investment horizon choices, which could lead to contradictory results depending on the values chosen. In order to control the test's dimension, other procedures have been suggested in the literature (Richardson and Smith, 1991; Whang & Kim, 2003; Kim, 2006; Kim & Shamsuddin, 2008).

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), Cavalheiro *et al* (2015a), Cavalheiro *et al* (2015b), Cavalheiro *et al* (2015c)), 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 Greek political crisis influenced the equity market in emerging countries. 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: "Does Brazilian market, after the Greek political crisis, shows the market efficiency assumption in its weak form as suggested by Fama (1970)?"

MATERIALS AND METHODS

In this research, we use the monthly log return stock indexes of the stock market of Brazil (Bovespa Index), for the period 2000 January to 2015 September. Before analyzing the market efficiency, it is necessary to choose the period to analyze, so, we tried to identify the structural breaks in that period.

To adequately treat the time series, some authors have presented several tests that make it possible to identify and estimate the moments for structural breaks. Among the first works to be published, we can find the tests by Chow (1960) and CUSUM, by Brown, Durbin and Evans (1975), where the first test had the inconvenient of implying the a priori knowledge of where the structural break was. The second test is part of another class, which allows us to detect breaks of several types for interesting parameters and for which we do not have the need to specify the number of breaks in the series (Covas, 1997).

Dias and Castro Jr. (2005) comment that the CUSUM test is based in recursive residuals. The technique is adequate for time series data and can be used, even when there is uncertainty on when the structural break occurred. The null hypothesis is that there is no structural break in the series, i.e., that the coefficient of a vector β, is the same for the whole period.

After, 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). In order to evaluate the predictions' accuracy the δ^2 statistic (Ivaknenko *et al*., 1993) was employed:

$$\delta_i^2 = \frac{\sum_{i=1}^{i=N}(y_i - \hat{y}_i)^2}{\sum_{i=1}^{i=N}(y_i - \bar{y})^2} \rightarrow min. \qquad (1)$$

where,

N is number of observations

y_i is return during *i period*

$\hat{y}_i$ is computed values according to the model

$\bar{y}$ is the mean value

A value of $\delta^2 \leq 0.5$ represents excellent accuracy, $0.5 < \delta^2 < 0.8$ represents satisfactory accuracy, and $1.0 < \delta^2$ represents misinformation and a poor models. To compare the efficiency of predictability at ANN, ARIMA and GA models, we used the sample coefficient of determination R^2, the MSE and MAE.

$$R^2 = 1 - \frac{\sum_{i=1}^{i=N}(\hat{y}_i)^2}{\sum_{i=1}^{i=N}(y_i - \bar{y})^2}$$

$$MSE = \sqrt{\frac{1}{N}\sum_{i=1}^{i=N}(y_i \quad \hat{y}_i)^2}$$

$$MAE = \frac{1}{N}\sum_{i=1}^{i=N}\left|\sqrt{y_i^2} - \sqrt{\hat{y}_i^2}\right|$$

Additionally, we analyzed the Theil's inequality coefficient (U) whose numerator is the MSE, but whose denominator is such that $0 \leq U \leq 1$, where $U = 0$ would represent a perfect match between predicted and observed values, while $U = 1$, would represent the worse possible match between predicted and observed values:

$$U = \frac{\sqrt{\frac{1}{N}\sum_{i=1}^{i=N}(y_i-\hat{y}_i)^2}}{\sqrt{\frac{1}{N}\sum_{i=1}^{i=N} y_i^2}+\sqrt{\frac{1}{N}\sum_{i=1}^{i=N} \hat{y}_i^2}}$$

We analyzed the trend and variance proportions (U^M and U^S, respectively) of U proportion), which allow one to decompose the error into its characteristic sources (Pindyck and Rubinfeld, 1991). The value of U^M addresses the possible systematic error, measuring how the series' average values deviate from each other. Whatever value U takes, one expects U^M to be close to 0, whereas if $U^M > 0.1$ this would indicate the presence of a systematic trend, requiring a revision of the models.

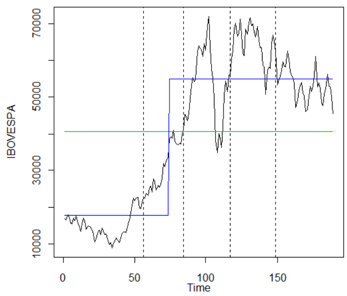
$$U^M = \frac{(\bar{y}^S-\bar{y}^A)^2}{\frac{1}{T}\sum_{t=1}^{t=T}(y_t^S-y_t^A)^2} \quad (6)$$

$$U^S = \frac{(\sigma^S-\sigma^A)^2}{\frac{1}{T}\sum_{t=1}^{t=T}(y_t^S-y_t^A)^2} \quad (7)$$

where, $\bar{y}^S, \bar{y}^A, \sigma^S$ and σ^A are, respectively, the mean and the standard deviations of the estimated and observed values. The variance proportion U^S, indicates the ability to replicate the variable of interest's degree of variability (Pindick and Rubinfeld, 1991) . If U^S is high, it indicates that the effective series floated substantially, whereas a low value would indicate very little floatation. That high U^S would also be concerning and could lead to reviewing models.

Results:

Initially, we tested the hypothesis of the existence of structural breaks in the Ibovespa series, and rejected the null hypothesis stating that the vector b variance were constant throughout the whole series (stats = 6.1329, sig. 0,000), indicating the existence of structural breaks in the time series. We used the Bai & Perron (1998) method so as to estimate the structural breaks in the data series. Results are shown in Picture 1.



Picture 1: Structural Breaks in Ibovespa. Source: own data organization

Picture 1 shows four rupture points in the Ibovespa series, in the period comprised between January 2010 and September 2015. The last rupture in this series occurred in May 2012 when the Greek crisis was increased when the European Committee admits to the emergency plan for Greek euro exit for the first time. Then, we used this period (May 2012 to September 2015) to calculate logarithmic returns and performed the variance ratio test for small samples (on a monthly basis), as in Kim (2006, 2009).

For the analyzed period, the random walk null hypothesis was not rejected (sig. 0.724). It is important to note that no rejecting the null hypothesis denotes weak form efficiency, i.e., past returns can not be an indicator of the future profitability of these markets.

Table 1: Results of the unit root from the Augmented Dickey-Fuller test for the null hypothesis stating that the monthly logarithmic returns of the Ibovespa are not stationary.

Total Lags	Tτ	τμ	T
1	13.80*	20.83*	21.13*
2	7.72*	10.43*	10.57*
3	6.00*	7.69*	7.74*
* indicates the null hypothesis is rejected for a significance level of 1%			

Initially, we applied to the unit root test for the logarithmic return of the Ibovespa. We can see in Table 1 that the null hypothesis that the indexes are not stationary must not be rejected for all simulations, then we have a stationary time series. After determining the period of analysis and his stationary, we determined the periods of training (75% of the period) and testing (25% of the period). We then applied the Box-Jenkins Model (ARIMA).

The models' analysis was carried out using the autocorrelation function (ACF) coefficient, accompanied by the residues Ljung-Box test. Autocorrelation is verified when at least one of the autocorrelation coefficients is different from zero and when the p-value, as well as the Ljung-Box Q-statistic are small enough to reject the null hypothesis that states that the errors in the models have no correlation. It was considered a 95% interval for the autocorrelation coefficients different from zero and for the Ljung-Box test. Figure 2 shows the ACF test results for the residues and the p-value for the Ljung-Box statistic.

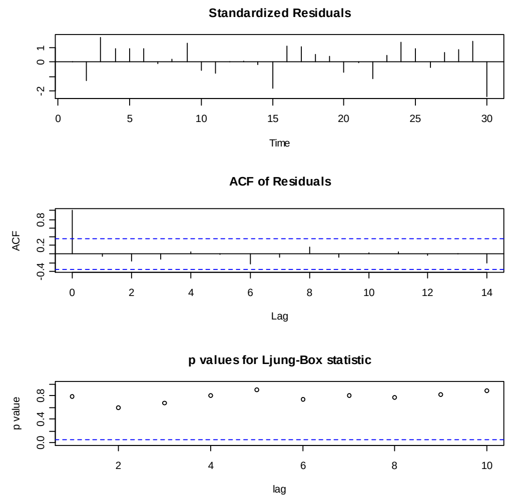


Fig. 2: results for the ARIMA model (1,1,1) residue test.

Figure 2 shows the ARIMA model diagnosis graphics (1,1,1). We can see that the ACF statistic for residues shows that no correlation can be not null and that the p-values for the residue independence test, measured by the Ljung-Box statistic, they are always above 60%. Having p-values always above 60%, it is impossible not to reject the null hypothesis, thus being possible to conclude that the model is properly adjusted, and the residue seems to be white noise.

After estimating and validating the model, we then move on to the forecast process. We carried out 11 forecasts, only for t+1, i.e., only for one step (month) ahead, between October 2014 and September 2015. The forecast results are shown in Table 2.

Table 2: Forecasts' results in the logarithmic returns of the Ibovespa.

R^2	Correlation	Signals	MSE	MAE	U	U^M	U^S	Ivakhnenko
0.0167	0.1294	0.6364	0.0028	0.0454	0.0390	0.1045	0.0006	0.9938

In Table 2, we note that the Theil U, the variance proportion (UM) and the error bias proportion (US) have shown to be adequate, thus indicating the absence of a systematic error in the forecast, which would denote that significant information– contained in the original series – had teen modelled. But, In the same table, we can see that, according to the Ivakhnenko criterion, shown in Equation (1), the logarithmic return forecast for Ibovespa have completely degenerated and the Ivakhnenko criterion, Ivakhnenko and Müller (1993), showed the performed forecasts to be unsatisfactory and the results to be misinformation. These results corroborate with the variance ratio test for small samples denoting efficiency in the weak form of the Brazilian market (Ibovespa) in this analyzed period.

Final Considerations:

In this research we tried to assess the predictability of the monthly return of Brazilian market using a Bovespa Index (Ibovespa). Initially, we defined a period for analysis, using the Bai & Perron (1998) method so as to estimate the structural breaks in the data series. After, the logarithmic return of this series was calculated.

Then, we tested the hypothesis that stated that returns would follow a random walk which would prevent predictability. The forecast results have shown to be unsatisfactory for all samples and the Box-Jenkins model has shown to be not able to demonstrate the returns non-randomness, denoting efficiency for this market, with no arbitrage opportunities to investors.

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