RANDOM WALKS AND MARKET EFFICIENCY TESTS: EVIDENCE FOR US AND AFRICAN CAPITAL MARKETS

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Abstract: *The 2020 Russia-Saudi Oil Price War was an economic war triggered in March 2020 by Saudi Arabia in response to Russia's refusal to reduce oil production to keep oil prices at a moderate level. This economic conflict resulted in a sharp drop in the price of oil in 2020, as well as crashes in international markets. In the light of these events, our aim was to test the efficient market hypothesis, in its weak form, in the stock markets of Botswana (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the MARKET of the USA (DOWJONES INDUSTRIALS), in the period of September 2, 2019 to January 11, 2021. The results therefore support the evidence that the random walk hypothesis is not supported by the financial markets analyzed in this period of global pandemic. The values of variance ratios are lower than the unit, which implies that the yields are autocorrelated in time and, there is reversal to the mean. In order to validate the results, we estimate the model αDFA that shows that the stock markets NSE 20 (0.75), TUNINDEX (0.69), MASI (0.63), EGX 100 (0.64), BSE (0.61), DOW JONES (0.58) show autocorrelation in their profitability, that is, these markets show signs of (in) efficiency, in its weak form, persistence in profitability, validating the results of the variance test by Rankings and Wright Signs. In conclusion we can show that the U.S. stock market has more market efficiency when compared to the African stock markets analyzed. The authors consider that the results achieved are of interest to investors looking for opportunities for portfolio diversification in these regional stock markets.*

Keywords: *Market efficiency, African capital markets, Arbitration.*

1. INTRODUCTION

Since the mid-2000s, international financial markets have been subject to a number of significant financial crises, notably the subprime crisis in the US in 2008, and the sovereign debt crisis in Europe in 2010, which originated in developed economies. These events significantly infected developed economies, however, this significance was not dense in emerging economies. Understanding the synchronism between stock markets, as well as the study on the occurrence of movements in periods of turbulence is important for investors, investment fund managers, academics, in various aspects, particularly when it is to implement strategies for diversifying efficient portfolios (Alexandre, Dias, and Heliodoro, 2020; Alexandre, Heliodoro, and Dias, 2019; Dias, and Pereira, 2020; Dias and Carvalho, 2020; Dias, Alexandre, and Heliodoro, 2020; Dias, da Silva, and Dionysus, 2019; Dias, Heliodoro, and Alexandre, 2019, 2020; Dias, Heliodoro, Alexan-

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dre, Santos, and Farinha, 2021; Dias, Heliodoro, Alexandre, and Vasco, 2020a, 2020b; Dias, Heliodoro, Alexandre, et al., 2020a, 2020a; Dias, Heliodoro, Teixeira, and Godinho, 2020a, 2020b; Dias, Pardal, Teixeira, & Machová, 2020c; Heliodoro and Alexandre, 2019; Heliodoro, Dias, and Alexandre, 2020; Heliodoro, Dias, Alexandre, and Vasco, 2020; Heliodoro, Dias, Alexandre, et al., 2020; Sparrow, P., Dias, R., Šuleř, P., Teixeira, N., and Krulický, 2020; Santos and Dias, 2020).

The 2020 Russia-Saudi Oil Price War was an economic war triggered in March 2020 by Saudi Arabia in response to Russia's refusal to reduce oil production to keep oil prices at a moderate level. This economic conflict resulted in a sharp drop in the price of oil in the spring of 2020. On March 8, 2020, Saudi Arabia started a price war with Russia, facilitating a quarterly drop in the price of oil. In the first weeks of March, oil prices in the United States fell 34%, crude oil fell 26% and Brent oil fell 24% (Cardona-Arenas and Serna-Gómez, 2020; Dias, Heliodoro, Alexandre, et al., 2020b; L. Liu, Wang, and Lee, 2020).

On the African continent there are 29 stock markets with very significant differences, either in volume, liquidity, and access to information, and these restrictions have relevant implications in the efficient market hypothesis (EMH). In view of the events in 2020, namely the global pandemic and the oil war, it is important to analyze its efficiency, in its weak form, in African markets, as well as in the US stock markets to assess whether there are significant differences. The results show that the random walk hypothesis is not supported by the financial markets analyzed in this period of global pandemic. In order to validate results, we estimate the model *αDFA* that shows that the stock markets NSE 20 (0.75), TUNINDEX (0.69), MASI (0.63), EGX 100 (0.64), BSE (0.61), DOW JONES (0.58) show autocorrelation in their profitability, that is, these markets show signs of (in) efficiency, in their weak form. However, when comparing the results, we find that the U.S. stock market exhibits less persistence, that is, more efficient when compared to the African markets analyzed.

In terms of structure, this paper is organized into 5 sections. In addition to the current introduction, section 2 presents a Literature Review with regard to articles on the random walk hypothesis in the African financial markets, in section 3 the methodology is described, and section 4 contains the data and results. Section 5 presents the general conclusions of the work.

2. LITERATURE REVIEW

The first concept of market efficiency was presented by Gibson (1889), who considered that the stock prices had the complete information. Later the French mathematician Bachelier (1900), found that the behaviors of asset prices fluctuated randomly, that is, they are independent of previous fluctuations, thus formulating the hypothesis of random *walk* (Fama, 1965b, 1965a, 1970).

According to Fama (1965a) the efficient market is constituted by a group of rational agents that competes for the prediction of the behavior of asset prices. Assuming that all relevant information is already available to all market players, i.e. the arrival of new information is quickly reflected in the stock prices, thus preventing agents from being able to predict the fluctuation of prices and thus obtain abnormal profitability without incurring additional risk. To sum up, an efficient market is one in which its prices fully reflect all available information (Fama, 1970).

The Efficient Market Hypothesis (EMH) is one of the most important assumptions in financial economy, arguing that profitability rates have no memory, which implies that agents cannot obtain abnormal profitability in financial markets through arbitrage-adjusted trading strategies. A market is designated as efficient, when all relevant information about the stock price is reflected in the market price. The lack of consensus among economists and financial analysts regarding market efficiency requires the study of the efficient market hypothesis (EMH). Another significant reason to study market efficiency is the role of stock markets to act as financial intermediaries between the saver and the borrower in the distribution of scarce resources via the price mechanism (Dias, da Silva, and Dionísio, 2019; Dias, Heliodoro, and Alexandre, 2020; Dias et al., 2021; Dias, Heliodoro, Teixeira, et al., 2020; Dias, Teixeira, Machova, et al., 2020; Jain, 2020; Karasiński, 2020)

The authors Obayagbona and Igbinosa (2015), Kelikume (2016), Abakah, Alagidede, Mensah, and Ohene-Asare (2018), Hawaldar, Rohith, and Pinto (2020) analyzed market efficiency, in its weak form, in the African stock indexes. Obayagbona and Igbinosa (2015) tested the Nigerian market in the context of market efficiency, the authors show that the price series do not show randomness, that is, they present long memories. Kelikume (2016) shows that Nigeria's stock market follows a random walk behavior, i.e. stock prices fully reflect all the information available on the market and investors are unable to achieve abnormal *yields at* the same level of risk. Abakah, Alagidede, Mensah, and Ohene-Asare (2018) analyzed the stock markets of South Africa, Nigeria, Egypt, Ghana, Mauritius and tested the hypothesis of market efficiency in its weak form. The authors suggest that the markets analyzed, for the most part, follow the random *walk hypothesis,* that is, they do not present autocorrelation in the price series, while the markets of Ghana and Mauritius show evidence of some (in) efficiency, in its weak form. Hawaldar, Rohith, and Pinto (2020) tested the persistence of the yields of 8 African stock markets, i.e., examined whether these markets are predictable. The authors show that the price series are independent and do not present memory, that is, investors are unable to obtain abnormal profitability, based on historical prices.

In short, this work aims to contribute to the provision of information to investors and regulators in African financial markets, where individual and institutional investors seek to efficiently diversify their portfolios, in a period of uncertainty and lack of confidence in international financial markets due to the global pandemic of 2020.

3. METHODOLOGY

3.1. Data

The stock markets analyzed are from Botswana (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the US market (DOWJONES INDUSTRIALS) from September 2, 2019 to January 11, 2021. Prices index are found in local currency to mitigate exchange rate distortions. The time scales are daily and were obtained from the *DataStream* database.

To analyze the behavior of financial markets, Tsay (2005) proposes the use of profitability series to the detriment of price series, because investors are primarily interested in knowing the profitability of an asset or an asset portfolio. In addition, the profitability series show statistical characteristics that simplify analytical treatment, namely the characteristic of stationarity, which is not usually present in price series. For the above reasons, the series of price indices were modified in growth rates or in series in the differences of neperian logarithms of current and previous profitability, of logarithmic yields, instantaneous or continuously composed r_t , by the following expression:

$$r_t = \ln P_t - \ln P_{t-1} \tag{1}$$

where r_t is the rate of return, on the day t and P_t and P_{t-1} are the closing prices of the series, at the times t and t–1, respectively.

3.2. Methodology

The research will develop through several stages. Market graphs were made, at levels, and in profitability, to estimate the evolution of the markets that are studied. The characterization of the sample will be performed using descriptive statistics in order to verify whether the data follow a normal distribution. In form to assess whether the time series follow a white noise (mean = 0; constant variance), the tests of unit roots in Levin, Lin, and Chu panel (2002), Breitung (2000) will be used, which postulate the same null hypotheses. To answer the research question, we will use the non-parametric test developed by Wright (2000), because it is a more resilient test to time series that do not exhibit normality and quite consistent when they present correlation in series. In order to validate results, we will use *the Detrended Fluctuation Analysis (DFA).* DFA *is* an analysis method that examines temporal dependence on non-stationary data series. This technique, by assuming that time series are non-stationary, avoids spurious results when the analysis focuses on the relationships of data series in the long term (Bashir et al., 2019; Guedes et al., 2018).

The *Detrended Fluctuation Analysis (DFA)* presents the following interpretation:

Table 1. Detrended Fluctuation Analysis (DFA)

Exponent	**Type of Signal**
$\alpha_{DFA} < 0.5$	long-range anti-persistent
$\alpha_{DFA} \simeq 0.5$	uncorrelated, white noise
$\alpha_{DFA} > 0.5$	long-range persistent

Source: Own elaboration

Wright's methodology (2000) consists of two types of tests, the position test (Rankings) for homoscedastic series and the signal test for heteroscedastic series.

The variance position test is supported in order of the series of yields. The position of profitability $r(r_t)$, shall be considered r_t between $r_1, r_2, \ldots, r_T$

$$r'_{1t} = \frac{\left(r(r_t) - \frac{T+1}{2}\right)}{\sqrt{\frac{\frac{(T-1)(T+1)}{2}}{12}}} \tag{2}$$

$$r'_{2t} = \Phi^{-1}\left(\frac{r(r_t)}{T+1}\right) \tag{3}$$

In what Φ^{-1} translates the cumulative inverse standardized normal distribution r'_{2t}, it is a standardized linear transformation of the position of profitability r'_{2t} and is a standardized reverse normal transformation.

$$R_1(q) = \left(\frac{\frac{1}{Tq}\sum_{t=q+1}^{T}(r'_{1t}+r'_{1t-1}+\cdots+r'_{1t-q})^2}{\frac{1}{T}\sum_{t=q+1}^{T}(r'_{1t})^2}\right) \times \left(\frac{2(2q-1)(q-1)}{3qT}\right)^{-1/2} \quad (4)$$

$$R_2(q) = \left(\frac{\frac{1}{Tq}\sum_{t=q+1}^{T}(r'_{2t}+r'_{2t-1}+\cdots+r'_{2t-q})^2}{\frac{1}{T}\sum_{t=q+1}^{T}(r'_{2t})^2}\right) \times \left(\frac{2(2q-1)(q-1)}{3qT}\right)^{-1/2} \quad (5)$$

The rejection of the random walk hypothesis of profitability is generated by a simulation process, in which the values of r'_{1t} and r'_{2t} statistics and are replaced by the simulated values r'^{*}_{1t} and r'^{*}_{2t}. Using bootstrap estimates, which result in the successive and random generation of data, in order to simulate the statistical properties of the true sample distribution, the exact distribution of $R_1(q)$ and $R_1(q)$ can be approximated to a certain level of confidence.

Wright's methodology (2000) proposes a second test, called a ratio of variances by signals, which considers the signal of profitability, to calculate the ratio of r_t signals, being the same heteroscedastic; so, we can use the following test statistics:

$$S_1(q) = \left(\frac{\frac{1}{Tq}\sum_{t=q+1}^{T}(S_t+S_{t-1}+\cdots+S_{t-q})^2}{\frac{1}{T}\sum_{t=q+1}^{T}(S_t)^2}\right) \times \left(\frac{2(2q-1)(q-1)}{3qT}\right)^{-1/2} \quad (6)$$

Where

$$S_t = 2\upsilon(r_t, 0) \quad (7)$$

$$\upsilon(x_t, p) = \begin{cases} 0{,}5 & se\ x_t > p \\ -0{,}5 & se\ x_t \leq p \end{cases} \quad (8)$$

The distribution of $S_1(q)$ can be approximated through $S^*_1(q)$ using bootstrap techniques, as happened in the variance ratio by rankings. $S^*_1(q)$ is obtained from the sequence $\{S_t^*\}_{t=1}^{T}$, as each of its elements being able to register the values 1 or -1, with the same probability.

4. RESULTS

Figure 1 shows the evolution of the Botswana (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex) and the US Market (DOW JONES INDUSTRIALS) from 2 September 2019 to 11 January 2021. The prices index, in levels, show market downs in the first quarter of 2020, which coincides with the move of Covid-19 viruses from China to Europe, as well as the oil price war triggered in March 2020 by Saudi Arabia in response to Russia's refusal to reduce oil production to keep oil prices at a moderate level.

Figure 2 shows the evolution in profitability of the 6 stock markets from September 2019 to January 2021. The graphic representation allows us to visualize that the first wave of the pandemic (first trimester of 2020) caused sharp breaks in the stock markets under analysis

Table 2 shows the main descriptive statistics of the Botswana stock markets (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the US market (DOW JONES INDUSTRIALS) from September 2, 2019 to January 11, 2021. The stock markets analyzed show negative average yields, with the exception of the Dow Jones market (0.000460). The U.S. market (US) has the sharpest standard deviation (0.019900), the smallest deviation seen in the BSE stock index (0.001349); in terms of analysis, the Dow Jones market shows higher risk because it has a global scale dimension and has liquidity levels that cannot

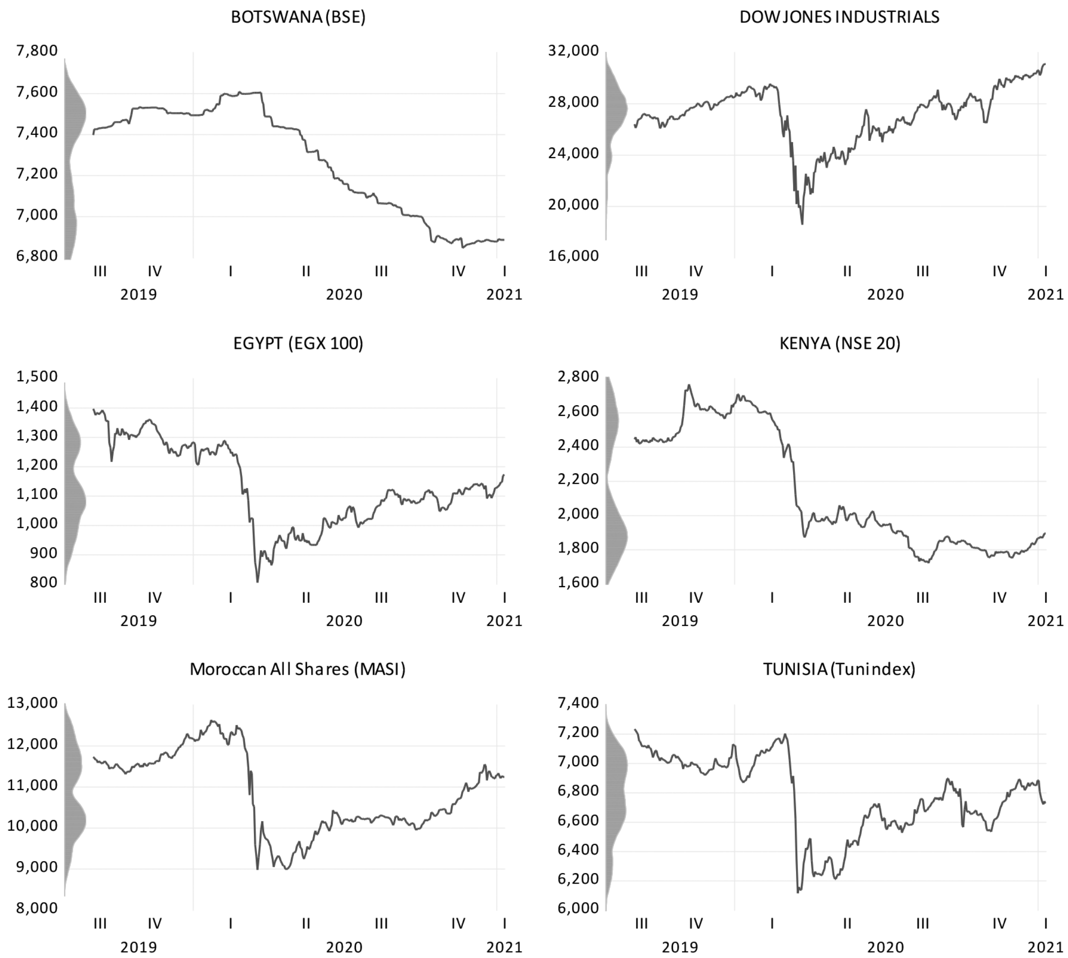


Figure 1. Evolution, in levels, of the 6 stock markets,
in the period from September 2, 2019 to January, 11 2021.

Source: Own elaboration

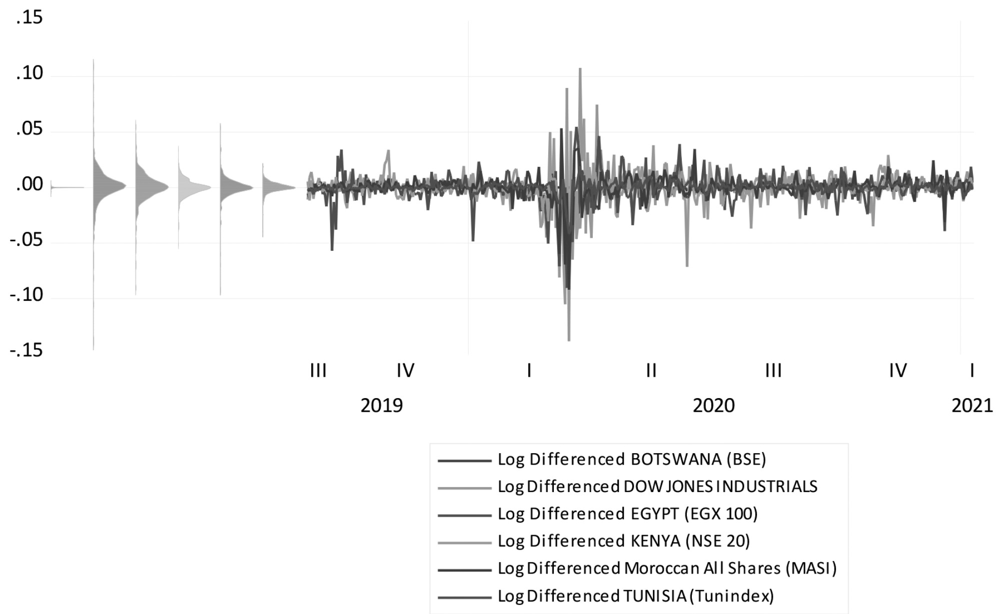


Figure 2. Evolution, return, of the 6 stock markets,
in the period from September 2, 2019 to January 11, 2021.

Source: Own elaboration

be compared with the Botswana stock market. Additionally, we found that all markets have negative asymmetries, while in the kurtosis there are values above 3, which is contrary to the hypothesis that the data follow a normal distribution (asymmetry = 0, kurtosis = 3). In corroboration, the Jarque-Bera adherence test shows that the data series do not follow normal distributions, due to their null chance being rejected with a mean of 1%.

Table 2. Descriptive statistics return, 6 stock markets, in the period from September 2, 2019 to January 11, 2021.

	BSE	DOW JONES	EGYPT	KENYA	MOROCCAN	TUNISIA
Mean	-0.000201	0.000460	-0.000488	-0.000714	-0.000117	-0.000204
Std. Dev.	0.001349	0.019900	0.014647	0.008712	0.010990	0.005731
Skewness	-2.191377	-0.974641	-1.444163	-1.225348	-2.419688	-2.516450
Kurtosis	15.73302	16.24111	11.01526	9.438406	24.95555	18.33445
Jarque-Bera	2689.853***	2657.048***	1076.705***	703.9749***	7497.738***	3863.718***
Sum	-0.071385	0.163654	-0.173781	-0.254109	-0.041745	-0.072450
Sum Sq. Dev.	0.000646	0.140585	0.076159	0.026941	0.042873	0.011660
Observations	356	356	356	356	356	356

Notes: ***, **, * represent significance at 1%. 5% and 10%, respectively.

Source: Own elaboration

Table 3. Levin, Lin , and Chu parking test (2002), applied to the 6 stock markets, in the period from September 2, 2019 to January 11, 2021.

Method				Statistic		Prob.**	
Levin, Lin & Chu t*				-37.5913		0.0000	
Series	2nd stage Coefficient	Variance Of Reg	HAC of Dep.	Lag	Max Lag	Band-Width	Note
Botswana	-0.88629	2.E-06	3.E-08	0	16	109.0	355
DOW JONES	-0.84239	0.0003	4.E-05	8	16	15.0	347
EGYPT	-0.74971	0.0002	3.E-06	0	16	138.0	355
KENYA	-0.65624	7.E-05	2.E-06	0	16	62.0	355
MOROCCAN	-0.81971	0.0001	4.E-06	0	16	67.0	355
TUNISIA	-0.57514	3.E-05	3.E-06	0	16	18.0	355
	Coefficient	T-Stat	Reg SE	mu*	sig*		Note
Pooled	-0.73217	-32.393	1.006	-0.503	0.719		2122

Notes: ***, **, * represent significance at 1%. 5% and 10%, respectively.

Source: Own elaboration

Table 4. Hadri parking test (2000), applied to the 6 stock markets, in the period from September 2, 2019 to January 11, 2021.

Method			Statistic	Prob.**
Hadri Z-stat			0.10907	0.4566
Heteroscedastic Consistent Z-stat			1.48933	0.0682
Series	Lm	Variance Hac	Bandwidth	Note
Botswana	0.7445	2.72E-06	7.0	356
DOW JONES	0.1008	0.000317	7.0	356
EGYPT	0.2710	0.000295	3.0	356
KENYA	0.1553	0.000176	10.0	356
MOROCCAN	0.1805	0.000169	4.0	356
TUNISIA	0.0917	6.62E-05	8.0	356

Notes: ***, **, * represent significance at 1%. 5% and 10%, respectively.

Source: Own elaboration

As we are estimating time series, we should examine the stationary nature of the data series of the 6 stock markets under analysis. The Levin, Lin, and Chu (2002) test postulates that the null hypothesis has unitary roots, while the Hadri test (2000) shows the parking in the null hypothesis, that is, the tests have opposing hypothesis. The intersections of the unit root tests in panel show the stationary of the time series (return), that is, we are facing a white noise (mean = 0; constant variance) (see tables 3 and 4).

In figure 3 we can verify the results of the non-parametric version of the Wright variance test (2000), conducted on the Botswana stock markets (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the US market (DOW JONES INDUSTRIALS), which includes the Rankings and Signals Variance Ratios tests. In both cases, statistics were calculated for 2 to 16 days, with 1-day scales. Taking into account the results of the Variance test by Wright's Rankings and Signs (2000) the random walk hypothesis is rejected in all stock indexes. The results therefore support the conclusion that the random walk hypothesis is not supported by the financial markets analyzed in this period of global pandemic. The values of variance ratios are lower than the unit, which implies that the yields are autocorrelated in time and, there is reversal to the mean. In these conditions, markets tend to overreact to information, eventually correcting in the following days, whether it is good news or bad news. But when we compared the U.S. stock markets to African markets, we find that the U.S. stock index is less persistent, which shows that institutional investors will have a harder time achieving abnormal yields without incurring additional risk.

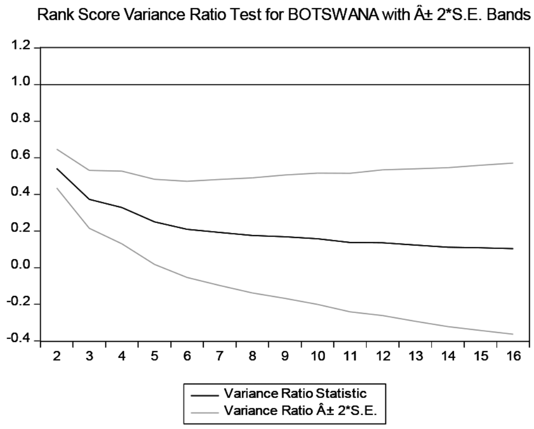
Table 5 shows the results of *the detrended fluctuation analysis (DFA)* exponents, carried out on the Botswana (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the US (DOW JONES INDUSTRIALS) stock markets. The results of αDFA the show sharp long memories, particularly in the stock markets NSE 20 (0.75), TUNINDEX (0.69), MASI (0.63), EGX 100 (0.64), BSE (0.61), DOW JONES (0.58), i.e. these markets show signs of (in) efficiency, in its weak form, showing persistence in profitability, validating the results of the variance test by Rankings and Wright Signs (2000), which show the rejection of the *random walk hypothesis*. These findings show that prices are not independent and that they have memory, i.e., investors using adjusted trading strategies will be able to achieve anoint yields without incurring additional risk. This evidence is contrary to the results of the authors Hawaldar, Rohith, and Pinto (2020) who examined the predictability of 8 African stock markets, showing that investors cannot obtain abnormal profitability, based on historical prices.

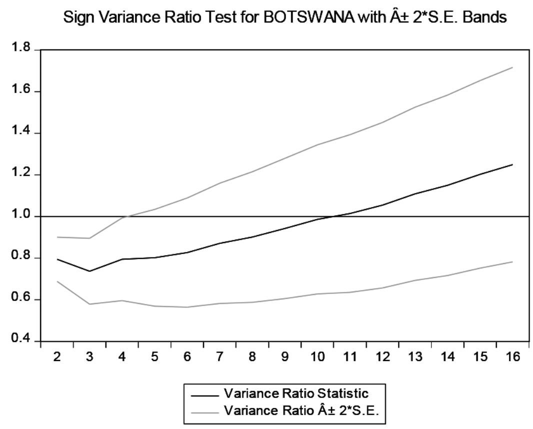
Table 5. DFA exponent for return. The values of the linear adjustments for always had > 0.99 αDFA^2

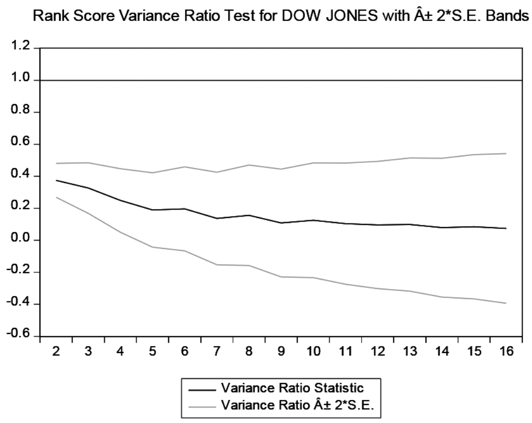
Index	EXPOnent DFA
BSE	0.61 ≅ 0.0033
EGX 100	0.64 ≅ 0.0037
NSE 20	0.75 ≅ 0.0008
MASI	0.63 ≅ 0.0011
TUNINDEX	0.69 ≅ 0.0084
DOW JONES	0.58 ≅ 0.0032

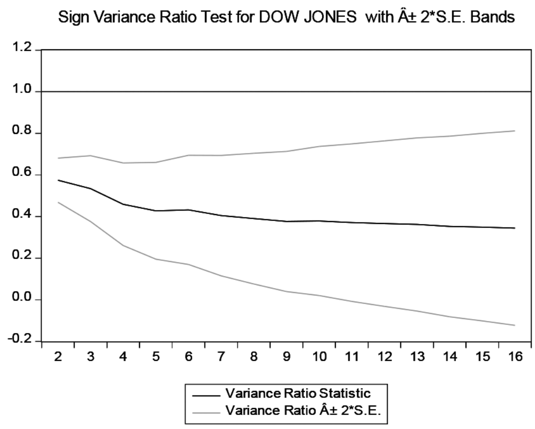
Note: The hypotheses are: H_0 $\alpha = 0.5$ and: H_1 $\alpha \neq 0.5$

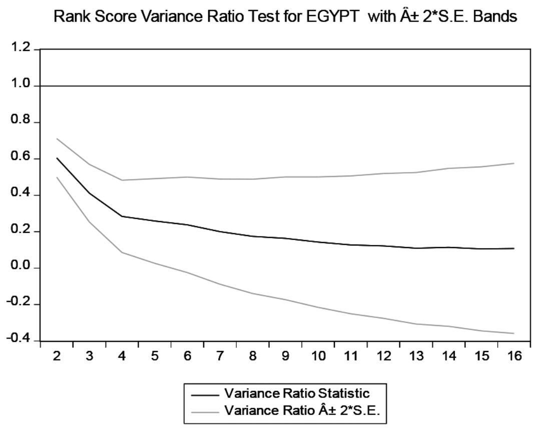
Source: Own elaboration

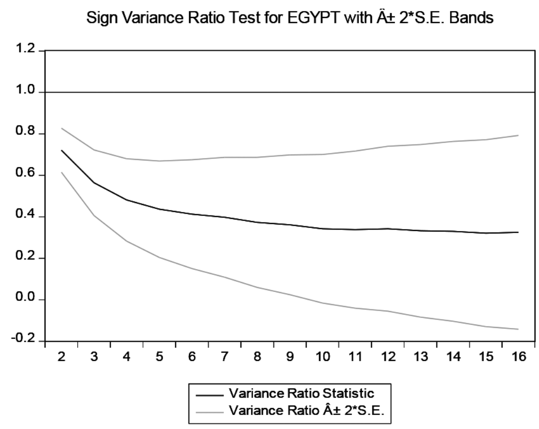

Rank Score Variance Ratio Test for BOTSWANA with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.

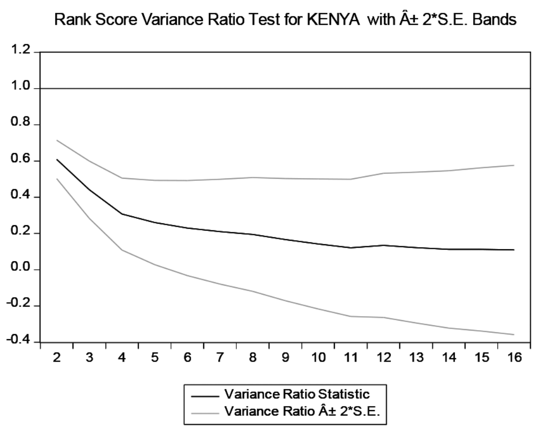

Sign Variance Ratio Test for BOTSWANA with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.

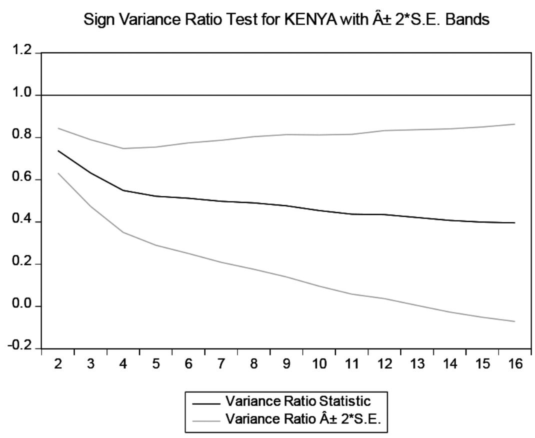

Rank Score Variance Ratio Test for DOW JONES with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.


Sign Variance Ratio Test for DOW JONES with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.


Rank Score Variance Ratio Test for EGYPT with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.


Sign Variance Ratio Test for EGYPT with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.


Rank Score Variance Ratio Test for KENYA with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.


Sign Variance Ratio Test for KENYA with Â± 2*S.E. Bands
Variance Ratio Statistic
Variance Ratio Â± 2*S.E.

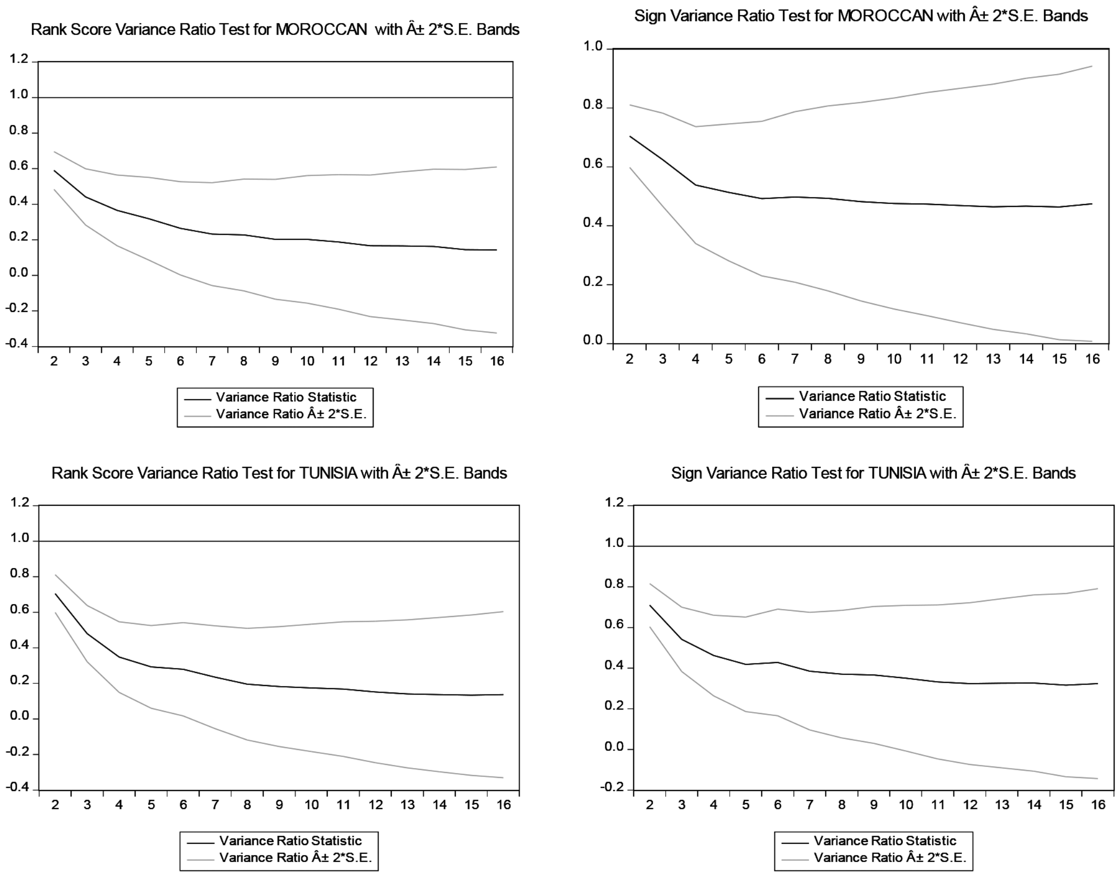


Figure 3. Wright's Ranking and Signal Variance Ratios Tests (2000) in yields, with 16-day lags, applied to the 6 stock markets, from September 2, 2019 to January 11, 2021.

Source: Own elaboration

5. CONCLUSION

This paper aims to test the efficient market hypothesis, in its weak form, in the stock markets of Botswana (BSE), Egypt (EGX 100), Kenya (NSE 20), Moroccan All Shares (MASI), Tunisia (Tunindex), and the US market (DOW JONES INDUSTRIALS) in the period from September 2, 2019 to January 11, 2021. For this purpose, we carried out two tests, an econometric and an econophysics one for this purpose. The first tests market efficiency, in its weak form, through a non-parametric test, the position test (Rankings) for homoscedastic series and the Signals test for heteroscedastic series. The second test analyzes temporal dependence on non-stationary data series using the *Detrended Fluctuation Analysis (DFA) methodology.*

In the first test, we estimated the Test of Variance Ratios of Rankings and Signs. In both cases, statistics were calculated for 2- 16-day lags. Considering the results of the variance test by Rankings and Signs, the *random walk hypothesis* is rejected in all stock indexes. The values of variance ratios are lower than the unit, which implies that the yields are autocorrelated in time and, there is reversal to the mean. In these conditions, markets tend to overreact to information, eventually correcting in the following days, whether it is good news or bad news.

The second test the *exponents Detrended Fluctuation Analysis* (*DFA*), show signs of (in) efficiency, in its weak form, showing persistence in profitability, that is, the existence of long memories, validating the results of the variance test by Rankings and Signs. These findings show that prices do not fully reflect the information available and that price changes are not i.i.d., in all markets.

The general conclusion to be withheld and sustained in the results obtained, through the tests carried out with econometric and mathematical models demonstrate that the global pandemic sees a significant impact on the memory properties of the markets analyzed. The results indicate that markets have persistence and long memories in their profitability, which implies that investors will be able to obtain abnormal profitability without incurring additional risk. In conclusion we can show that the U.S. stock market has more market efficiency compared to the African stock markets analyzed. The authors consider that the results achieved are of interest to investors looking for opportunities for portfolio diversification in these regional stock markets.

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