Revisiting efficiency in MENA stock markets during political shocks: evidence from a multi-step approach

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1. Introduction

By and large overwhelmingly, the efficient market hypothesis has received much attention from the academic financial literature. Perhaps not surprisingly, such hypothesis helps to apprehend the behavior of financial markets and the price dynamics. That is why many researchers have continually investigated the concept of efficiency in the emerging stock markets. Although such markets are distinctively characterized by low quality of information disclosure, lack of market transparency, low degree of competition, weak trading volume and an inadequate accounting regulation (Lagoarde-Segot and Lucey, 2008), they increasingly attract foreign investors for diversification purposes.

From empirical standpoint, the findings on emerging market efficiency still remain mixed. While some researchers show that emerging market returns are not autocorrelated, supporting thus the weak efficiency hypothesis (Füss, 2005), some studies’ findings give conflicting results. For instance, Abeysekera (2001) rejects the hypothesis of weak-form efficiency for stock markets in Bahrain, Kuwait, Saudi Arabia and Sri Lanka. Wheeler et al. (2002) also fail to support the weak-form efficiency hypothesis for the Warsaw Stock Exchange (Poland). Dockery and Vergari (1997) display that the Budapest and Turkish stock markets are efficient in the weak-form. Dahel and Laabas (1999) document that the stock market in Kuwait (resp. Bahrain, Saudi Arabia and Oman) is (resp. inefficient) efficient in the weak-form. These mixed empirical conclusions can be attributed to differences in market development and institutions (Lagoarde-Segot and Lucey, 2008).

Other researchers rather prefer to analyze the effect of particular events (e.g. the financial liberalization and financial crisis) on the informational efficiency in the emerging stock markets. For instance, Kawakatsu and Morey (1999) test the weak-form efficiency hypothesis in nine emerging markets before and after the financial liberalization. They display that the financial liberalization does not contribute to enhance the stock market efficiency, implying that many emerging markets are efficient before the effective liberalization. Hoque et al. (2007) investigate the weak-form efficiency for the pre-crisis period (1990–1997) and post-crisis period (1998–2004) in eight Asian stock markets. They show that crisis has no significant influence on the efficiency's degree in Hong Kong, Indonesia, Malaysia, Philippines, Singapore and Thailand. The inefficiency persists even after the crisis whereas the opposite occurs for Korea. Nonetheless, a higher efficiency from the pre-crisis to post-crisis period is recorded for Taiwan.

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In this context, a variety of data (stock prices indices and/or individual stock price series) and methods are used for testing weak-form efficiency hypothesis in emerging stock markets. Most notably, the approaches include the unit root analysis (Annuar and Shamser, 1993), probability distribution functions (Gabaix et al., 2003), correlation functions (Podobnik et al., 2002), and network analysis (Jeong et al., 2000). Another method proposed by Peng et al. (1994) and widely used to test the weak-form efficiency is the Detrended Multifractal Fluctuation Analysis (henceforth, MF-DFA). Using this approach, Zunino et al. (2008) investigate the weak-form efficiency in fourteen emerging markets and eighteen developed stock markets. They display that the relationship between the stage of market development and multifractality degree is negative, i.e. greater multifractality is related to a less developed (low efficiency) market.

This paper brings out the extent of literature on the informational efficiency by investigating the impact of political events on markets efficiency ranking and the dynamic behavior of efficiency on the MENA markets over the period 18/03/2005-18/03/2016. According to the efficient market hypothesis, the stock market reacts immediately and fairly to any type of information. Needless to say, information about political events such political assassinations, terrorist attacks, dissolution of government, can affect the economic situation and market performance (El-Charraoni, 2015). That is why the MENA stock markets can be good candidates for analyzing the behavior of efficiency over time given that they have increasingly been disrupted by political events. As well, we select these countries based on their pecuniary development stage and market size.

At methodological level, a multi-step approach is used to examine the nature of market efficiency in the MENA markets. First, we apply the Wavelet Transform Modulus Maxima approach (henceforth, WTMM) on the emerging markets indexes’ returns. Such method can remove trends and focuses on the fluctuations’ analysis. It can also inspect the multi-scale features of time series and detect their potential multifractal character. The MF-DFA can be a useful complement to the WTMM-based analysis by providing a ranking of the MENA stock markets’ efficiency. As such, it allows us to closely investigate the complex behavior of financial markets. Together, the WTMM and MF-DFA can determine whether the market is efficient over the whole period. Nonetheless, such methods ignore the existence of a perpetual ever-changing economic environment where the market over(under)reacts to macroeconomic events (stocks become overpriced or underpriced). Cognizant this fact, we then use the automatic variance ratio rank-based test and the overlapping moving window approach to analyze the dynamic behavior of the MENA market efficiency over time. Collectively, our multi-step approach allows us to apprehend the nature of the MENA markets efficiency and gets some insights on the potential driving forces of short-term and long-term dynamics.

This paper contributes to the literature in different important aspects. First, we search for investigating the nature of returns dynamics and examine if there is a difference between markets during the outbreak of political events. Such issue still remains underexplored academically. Second, we attempt to identify distinguishable time-varying behavior of efficiency among different markets during the pre- and post-political event. That is why we use different methods to detect different aspect of dynamic efficiency. Third, we propose to rank the market efficiency based on the outbreak of political events. This can provide insightful information about the emergency measures undertaken by policymakers and the investors’ behavior.

The remainder of this paper is organized as follows. Section 2 reports methodology design. Section 3 presents data and empirical results. Section 5 provides further discussions and concluding remarks are drawn in Section 5.

2. Related literature

Overall, a capital market is described as an efficient market where stock prices at any time fully reflect all available and relevant information. Since its introduction by Fama (1970), the Efficient Markets Hypothesis (EMH) was largely examined in developed and emerging markets. Although many researchers show that the developed markets are generally weak form efficient (e.g. Kendall, 1953; Fama, 1965), the empirical studies on emerging market efficiency are very challenging with rather inconclusive results (Phiri, 2015). By applying variance ratio and unit root tests on stock returns in Bahrain, Kuwait, Oman and Saudi Arabia, Dahel and Laabas (1999) reveal that all markets are weak-form inefficient, except for Kuwait market. Butler and Malakih (1992) show the non-random (resp. random) stock price behavior and reject (resp. fail to reject) the weak-form efficiency in the Saudi (resp. Kuwaiti) stock market. By analyzing the behavior of stock returns, Khababa (1998) finds that the Saudi market is not efficient due to high transaction costs, thinness of trading and market illiquidity. Al-Khazali et al. (2007) find that eight MENA markets (Bahrain, Egypt, Jordan, Kuwait, Morocco, Oman, Saudi Arabia and Tunisia) are not weak-form efficient. Lucey and Segov (2005) employ KPSS unit root test to investigate the efficiency in MENA markets. The empirical results exhibit that efficient market hypothesis was only valid for Turkey and Israel. By performing a range of statistical techniques on stock returns of Egypt, Israel, Jordan, Morocco and Turkey, Omran and Fararr (2004) find the evidence of the non-random stock price behavior and inefficiency for all markets, except for Israel. Dickinson and Muragi (1994) employ the serial correlation analysis and the run test to prove that the stock returns in the Nairobi Securities Exchange violate the weak-form EMH. Magnusson and Wydick (2002) display that stock markets in Ghana and Zimbabwe (resp. Ivory, Coast, Kenya, Mauritius, Nigeria, South Africa and Botswana) are not (resp. are) weak-form efficient. Appiah-Kusi and Menyah (2003) examine the weak-form market efficiency on eleven African stock markets. The findings reveal that Egypt, Kenya, Mauritius, Morocco, and Zimbabwe exhibit weak-form efficiency. Based on parametric and non-parametric tests, Simons and Layea (2005) reveal that Egypt, Ghana and Mauritius are not efficient in the weak-form whereas South Africa is efficient. Mollah (2007) did not support for the weak-form efficiency in Botswana Stock Exchange.

By using various approaches and tools1, some researchers have rather focused on the behavior of weak efficiency during the outbreak of dramatic events. Nonetheless, the findings seem to be mixed. For instance, Lye and Hooey (2012) use the MF-DFA approach to investigate the weak-form efficiency of Malaysian sectoral indices. The empirical results display that the Malaysian sectoral efficiency is negatively impacted by both Asian and global financial crises and adversely affected by the capital control implemented by the Malaysian government over the Asian financial crisis. Based on MF-DFA tools, Rizvi and Arshad (2016) compared the efficiency of Asian markets during pre-and post-crisis episodes and find a deteriorating and negative effect of the Asian financial crisis on the market efficiency. However, the effects of global financial crisis differ with respect to the country’s economic structure. For the most of the countries, the findings show that the efficiency appears to be greater during the pre-crisis periods than post crisis periods. As well, Lim et al. (2008) found that the 8 Asian markets influenced by the 1997 Asian financial crisis have declined efficiency over the post-crisis period. Using two variance ratio tests, Hoque et al. (2007) found no improvement in the efficiency’s degree over the pre-crisis and post-crisis period for the Asian countries. Sensy (2013) investigated the time-varying efficiency of fifteen MENA stock markets over the period 01/2007-12/2012. The empirical results displayed that all MENA markets show different levels of long-range dependence which

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1 For instance, they use the Detrended Fluctuation Analysis to detect long-range dependence in time series (e.g. Podobnik et al., 2006; Jiang et al., 2007) and the Multifractal Detrended Fluctuation Analysis (MF-DFA) to capture the multifractal behavior in stock returns (e.g. Kantelhardt et al., 2002). Also, they refer to methods of rolling window and Hurst exponent method (e.g. Caissier and Tabak, 2007), Wavelet methods (e.g. Manimaran et al., 2008), nonlinear models (e.g. Cheong et al., 2007), and ADF unit root test (e.g. Kim and Shamsuddin, 2008).
change over time. They also showed that Tunisia and Iran seem to be the most inefficient markets whereas Turkey stock market was the least inefficient one. The Arab spring event has a negative impact on the MENA market efficiency. Charfeddine and Khediri (2016) test for the weak-form efficiency of the GCC stock markets over the period 05/2005-09/2013 by using different techniques. They reported that not only the GCC stock markets have various degrees of time-varying efficiency but also such markets are characterized by periods of efficiency improvements. They also displayed that the Arab spring event and subprime crisis have affected the time path evolution of market efficiency. Al-Shboul and Alsharari (2018) examined the dynamic behavior of market efficiency in the UAE markets by taking into account the advent of the 2008 global financial crisis, the Arab spring event and the 2014 oil prices crisis. They reported that the UAE stock markets are characterized by evolving efficiency. Al-Shboul and Alsharari (2018) also revealed that shocks resulting from crises do not affect the dynamic behavior of market efficiency.

3. Methodology design

We use a multi-step approach to better analyze the behavior of the MENA markets' efficiency during the outbreak of dramatic political events in the MENA area. First, the WTMM approach serves to investigate the behavior of the emerging markets indexes' returns and detect the potential features in such time series (in particular the multifractality). The behavior of the emerging markets indexes' returns and detect the events in the MENA area. For this study, we use the fractal feature and compare the efficiency of the MENA stock markets by ranking the efficiency of such markets. Finally, the automatic variance ratio rank-based test and the overlapping moving window approach are used to detect the potential changing behavior of MENA market efficiency before and after the advent of the country-specific events.

3.1. Wavelet transform modulus maxima (WTMM)

The wavelet transform modulus maxima of a function allows to detect the fractal dimension of a signal. More especially, it can inspect the multifractality. Second, the MF-DFA approach can both identify the potential fractal feature and compare the efficiency of the MENA stock markets by ranking the efficiency of such markets. Finally, the automatic variance ratio rank-based test and the overlapping moving window approach are used to detect the potential changing behavior of MENA market efficiency before and after the advent of the country-specific events.

On the other hand, continuous wavelet transforms permits to detect singularities areas in the signal. According to Muzy et al. (1994), the coefficients at maxima are sufficient to inform about the corresponding signal. As the holder exponents, $h_i$ are calculated by a power fit to the coefficients of the wavelet transform along the maxima line.

3.2. Multifractal detrended fluctuation analysis

To assess and rank the efficiency in the MENA stock markets, we use the multifractal detrended fluctuation analysis (MF-DFA). Following Kantelhardt et al. (2002) and Rizvi et al. (2014), the MF-DFA can be given as follows:

For a correlated signal noted by $\{x_i, i = 1, \ldots, N\}$, where $N$ is the length of the signal, its related profile is determined by integration:

$$X(i) = \sum_{i=1}^{N} x_i - \langle x \rangle, \quad i = 1, \ldots, N$$

The constructed profile $Y(k)$ is partitioned into non-overlapping windows of equivalent lengths. In this paper, the window is equal to 4 days. It is worth mentioning that the does not need to be the integer multiple of $s$. On the other hand, it is primeval to use the least squares fit of data to assess the local trend of each window $Y_{s,i}$, where $s$ is the length of the time series and the fits:

$$Y_s(i) = Y([v - N_s + 1], i) - p_s(i)$$

For $v = 1, \ldots, N_s$ and

$$Y_s(i) = Y(N_s - (v - N_s) + 1, i) - p_s(i)$$

For $v = N_s + 1, \ldots, 2N_s$ with $p_s(i)$ is the fitting polynomial in the $s$th window. Given that the de-trending of the time series is accomplished by subtraction of the fits from the profile, these processes differ in their ability to eradicate trends from data. In the $m$th order of MF-DFA, trends of order $m$ in the original record are removed. To do so, one might assess the different orders of MF-DFA which provide an estimation of the polynomial trend in the time series. Based on the crux, the variance for both of the $2N_s$ of the de-trended time series $Y_s(i)$ is approximated by averaging over all data point $i$ in the $s$th window:

$$F_s^2(v) = \frac{1}{s} \sum_{i=1}^{s} \left( Y_s(i) \right)^2$$

The $q$th order fluctuation function is acquired by averaging over all segments:

$$F_q(s) = \left( \frac{1}{N_s} \sum_{v=1}^{N_s} \left( F_s^2(v) \right)^{\frac{q}{2}} \right)^{\frac{1}{q}}$$

Starting from the beginning and starting from the end.

$$F_q(s) = \left( \frac{1}{N_s} \sum_{v=N_s-1}^{1} \left( F_s^2(v) \right)^{\frac{q}{2}} \right)^{\frac{1}{q}}$$

The order $q$ can take any real value. When $q = 0$, the value of $h(0)$ cannot be determined due to the diverging exponent. That is why we use a logarithm average procedure. When $q = 2$, the standard DFA procedure is retrieved.

At the final step, for each value of $q$, we analyze the log-log plots of $F_q(s)$ versus $s$ in order to determine the scaling behavior of the fluctuation. If the series $\nu$ are long-range correlated $F_q(s)$ raises, for large value of $s$, as a power-law.

$$F_q(s) \sim s^{\nu(q)}$$

Depending on the nature of the time series, the profile (Eq. (10)) can
take two values. Thus, for a stationary time series, the profile is a Brownian
motion (fBm). Instead, \( 0 < h(q = 2) < 1 \) for these process, and \( h(q = 2) \)
is similar to Hurst parameter \( H \). If the original time series is a fBm, the profile
is the sum of fBm and \( h(q = 2) > 1 \). In such case, the relationship between
the exponent \( h(q = 2) \) and \( H \) is \( H = h(q = 2) - 1 \). As a result, the exponent
\( h(q) \) frequently considered as the generated Hurst exponent.

3.3. Automatic variance ratio test

According to Lo and Mackinlay (1988), the random walk hypothesis plays a key role to explain the weak-form market efficiency. Indeed, it implies that the variance of log price increases is linear in the observation interval. Lo and Mackinlay (1988) implemented the variance ratio test for examining the randomness of stock prices. They reported that the variance ratio has more interesting features than other methods. However, we need to unerringly precise the holding period \( k \) when the variance ratio tests are performed. To overcome this issue and use an optimal data dependent approach, Choi (1999) proposed a new variance ratio test based on the frequency domain estimated by Quadratic spectral kernel and utilized a data-dependent process to identify automatically the optimal value of \( k \).

Following Kumar (2018), we assume that \( P_t \) is an asset price at time \( t \) where \( t = 1, \ldots, T \), and \( 
\ln(P_t) \) (the natural log of the price series). The first order autoregressive model is thus given as \( y_t = \mu + y_{t-1} + \varepsilon_t \). \( \mu \) denotes an arbitrary drift parameter and \( \varepsilon_t \) is the random disturbance term. The Choi (1999)’s variance ratio estimator is given as follows:

\[
VR(k) = 1 + 2 \sum_{i=1}^{T-k} \frac{m(i/k) \widehat{\rho}(i)}{T-k}
\]

(11)

where \( \rho(i) \) is the return’s autocorrelation of lag \( i \) and \( \widehat{\rho}(i) \) is the following estimator of \( \rho(i) \) :

\[
\widehat{\rho}(i) = \frac{\sum_{t=i+1}^{T} (y_t - \bar{y})(y_{t-i} - \bar{y})}{\sum_{t=1}^{T} (y_t - \bar{y})^2}
\]

(11a)

and

\[
\bar{y} = \frac{1}{T} \sum_{t=1}^{T-1} y_t, \quad y_t = x_t - x_{t-1}
\]

(11b)

Note that the null hypothesis of the variance ratio test is \( VR(k) = 1 \) which is equivalent to \( \rho(i) = 0 \) for all \( i \). In this regard, when the asset return is identically and independently distributed, Choi (1999) shows that the \( AVR(k) \) statistics is given by the following equation:

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

(12)

4. Data and empirical findings

4.1. Data

The dataset used in this paper is provided from DataStream covering 11 MENA region markets (Abu-Dhabi, Bahrain, Dubai, Egypt, Israel, Jordan, Lebanon, Morocco, Oman, Saudi Arabia, and Tunisia). Interestingly, it bears to mention that we preclude Yemen, Iraq, Libya, Algeria, Palestine, Kuwait, Qatar and Syria because of the lack of market index data. This study covers the period from March 18, 2005 to March 18, 2016, for a total of 2871 daily stock prices.

Even though MENA markets seem to be small compared to other developing markets, there is a considerable intra-regional discrepancy in terms of the markets’ organizational structures, their history of evolution and even their establishment. From Table A1 in Appendix 1, the selected MENA stock markets extend back in history as far as the 19th century. It is clearly noticeable that the most stock markets are established and continue to operate as state-owned organization or public institution. Very few exchanges in our sample are mutually-owned (only 4 markets) and self-listed (only 2 markets). Here, it worth mentioning that some MENA markets are contemplating restricting by making some meaningful changes in ownership/governance of exchanges such as the demutualization of the Moroccan Stock Exchange. On the other side, the ongoing development of stock markets has sparked a requirement for greater transparency by introducing corporate governance codes. Nonetheless, most corporate governance codes in the MENA region are

\footnote{We refer to Kumar (2018) to describe the Choi (1999)’s variance ratio test procedure.}

\footnote{The demutualization is the process of converting a non-profit, mutually owned organization to a for-profit, investor-owned corporation.}
applicable on a voluntary basis. Accordingly, the stock market authorities monitor companies’ compliance with the governance code. Table A2 in Appendix 1 reports further information on the salient features of selected MENA stock exchanges, including the number of listed companies, market capitalization, turnover ratio and market capitalization as a percentage of the GDP. By taking a close look at the number of listed companies and their capitalization, in each stock market and over time, we note that while some MENA markets are exceedingly small markets, others such as the Saudi Stock Exchange seems to be rather large. Overall, both the number of listed companies and their market capitalization tend to evolve over time. This can reflect the substantial development of MENA stocks. As well, some markets have experienced significant increases in terms of capitalization as a proportion of GDP.

Figures 1 and 2 illustrate the evolution of the stock price indices and daily returns over time, respectively. As we can see in Figure 1, time series plots evolve differently, although all plots exhibit cyclical swings.

4.2. Empirical findings

4.2.1. Wavelet transform modulus maxima method

We carry out the WTTM to examine the weak-form efficiency of the MENA stock markets over the advent of dramatic political events. Allowing for the multifractal analysis of processes, the WTTM method helps to find out the whole singularity spectrum directly from an experimental signal. In other words, the WTTM can detect the mono/multifractal behavior of time series. As well, the scaling behavior of partition functions $Z(q, a)$ is doable by dint of the WTTM. Obviously, the slope of partition functions reveals the scaling $\tau(q)$ of the distribution’s moments. Whether the scaling function is linear, the time series exhibit monofractal behavior (e.g. Muzy et al., 1991; Yalamova, 2006).

Figures 3 and 4 illustrate the continuous wavelet transform (CWT) and the wavelet skeleton for the MENA stock markets, respectively. More precisely, Figure 3 displays the continuous wavelet transform which highlights the fractal structure of the investigated signals. The wavelet coefficients are shown in their absolute values and colored according to color bar. While dark colors refer to lower absolute wavelet coefficient values, light colors correspond to high absolute wavelet coefficient values which indicate large price fluctuations. Therefore, Figure clearly shows the inefficiency of the MENA stock markets. Afterwards, Figure 4 displays the skeleton functions (SF) for the MENA stock markets. Time shifting coefficients and scales are drawn in X axis and Y axis.

Table 1. Descriptive statistics of the selected MENA markets.

| Country     | N  | Mean   | S.D   | Skewness | Kurtosis | J-B test |
|-------------|----|--------|-------|----------|----------|----------|
| Abu Dhabi   | 2870| -0.0034| 1.6200| 1.063    | 218.4    | 5670.8***|
| Bahrain     | 2870| -0.0206| 0.5710| -0.665   | 6.719    | 5551.3***|
| Dubai       | 2870| -0.0009| 1.8830| -1.030   | 5.500    | 3606.7***|
| Egypt       | 2870| 0.0276 | 0.8268| -0.324   | 5.512    | 7703.2***|
| Israel      | 2870| 0.0223 | 1.1600| -0.390   | 15.57    | 4574.6***|
| Jordan      | 2870| -0.0099| 1.1851| -0.324   | 61.99    | 4575.4***|
| Lebanon     | 2870| 0.1772 | 1.2836| -1.138   | 259.3    | 8010.9***|
| Morocco     | 2870| 0.0199 | 1.7120| -0.977   | 7.805    | 3678.2***|
| Oman        | 2870| 0.0095 | 1.0679| -0.903   | 15.57    | 2927.1***|
| Saudi Arabia| 2870| -0.0151| 1.6855| -0.605   | 6.719    | 1462.2***|
| Tunisia     | 2870| 0.0488 | 0.5590| -0.569   | 12.08    | 1752.1***|

Note: This Table reports the descriptive statistics of returns series of MENA stock markets over the sample period from March 18, 2005 until March 18, 2016. S.D and J-B stand for standard deviations and Jarque-Bera test of normality. The asterisks (****) refers to the significance level at the 1% and when significant reject the null hypothesis of normality.

Figure 2 shows not only cyclical movements of all returns time series but also volatility clustering behavior of the indices returns. Table 1 summarizes a host of descriptive statistics of daily returns for the selected MENA region indices for the period 18/03/2005-18/03/2016. As reported in Table 1, the mean return varies from 0.0206% (Bahrain) to 0.1772% (Lebanon). Interestingly enough, the Dubai market seem to be the riskiest market given the highest standard deviation (1.883) whereas the Tunisian market can be qualified as the least risky market (0.559). As well, the daily returns for all stock markets (except for the Abu Dhabi market) are negatively skewed during the sample period, implying that the left tail is particularly extreme (i.e. negative values or losses are much more likely). The leptokurtic feature of return distribution is very salient in our sample.
respectively. Local maxima lines are constructed based on the wavelet coefficient matrix by singling out local maxima points on each scale parameter. The scope of all local maxima lines corresponds to the so-called skeleton function which enlightens the periodicity of the signal on descent scales. Light colors (resp. dark colors) refer to higher (resp. lower) absolute wavelet coefficient values. As well, continuous maxima lines ranged from small to large scales figure out the time of the singularity at different scales.

Once the skeleton function is established, one might estimate the thermodynamic partition function for all the MENA markets. The thermodynamic partition function represents a three-dimensional graph with scales parameter $a$ and power argument $q$ which refers to the set of zero-
Figure 4. Skeleton function (SF) for MENA markets.
Figure 5. Thermodynamic partition function (TPF).
Figure 6. MENA indices local scaling exponential functions.
mean numbers (in interval $q \in [-5, 5]$). It helps to highlight the existence of wavelet modulus maxima coefficients of different values. As pointed out by Puckovs and Matvejevs (2012), the existence of relatively large (resp. relatively small) wavelet modulus maxima coefficients are detectable with large $Z$ values when the $q$ values are positive (resp. negative). Figure 5 illustrates the thermodynamic partition functions for all the MENA markets. Overall, the different behavior of the thermodynamic partition functions seems to be well-pronounced among different markets.

Based on the aforementioned Figures, one might construct the scaling exponential function as evidenced in Figure 6. It is interesting to note that the scaling exponential function is a non-decreasing function which indicates the scalability of a signal (Puckovs and Matvejevs, 2012) detected by the interdependence between the thermodynamic partition function value and scaling parameter $a$. In this respect, there are two different signals: mono-and multifractal signals. If the scaling exponential function is linear, the monofractal case is well-documented. In the multifractal case, the scaling exponential function is rather convex. From Figure 6, there are different behaviors of MENA selected indexes. Except for Bahrain and Israel, all plots clearly show that scaling exponential functions are convex, indicating the multifractal behavior of these market indexes. This multifractal behavior indicates that these indexes are characterized by a scope of fractal measures (Puckovs and Matvejevs, 2012). Most notably, the significant multifractality clearly highlights that the stock markets are not efficient in weak-sense.

Afterwards, we compute the Holder exponents based on the WTMM method. According to Puckovs and Matvejevs (2012), the typical fractal measure of a signal is revealed by $h_0$. If $h_0$ is high, the anti-persistent time series are well-documented and a lowest value indicates the persistence (or sustained trend) properties of the signal (Puckovs and Matvejevs, 2012), i.e. the presence of fractal properties of time series. The estimation results related to multifractal spectra maxima for all the MENA indices are reported in Table 2.

From Table 2, high values level of $h_0$ (or the Spectrum maxima) clearly indicate the anti-persistence properties of time series. As well, the fuzziness of multifractal (given by $\Delta h$ indicator) which show how fractal feature is fairly regular is well-documented for the MENA indices in average, low levels. This empirical result overwhelmingly indicates that fractal behavior is quite regular as $\Delta h < 1$. In this regard, The Egyptian index records higher $\Delta h$ indicator, indicating that the time series encloses a wide scope of fractal measures. Nevertheless, lower $\Delta h$ indicators are shown for the Tunisian and Morocco indices, implying more regular fractal properties.

### 4.2.2. The MF-DFA approach

We first calculate the fluctuation functions from which one might estimate the generalized Hurst exponents. Using the Matlab codes of

| Country   | $h_0$   | $h_{min}$ | $h_{max}$ | $\Delta h$ |
|-----------|--------|----------|----------|-----------|
| Abu-Dhabi | 1.6064 | 1.3447   | 1.9147   | 0.5767    |
| Bahrain  | 1.7349 | 1.447    | 2.0932   | 0.6462    |
| Dubai    | 1.6055 | 1.2575   | 1.8722   | 0.6147    |
| Egypt    | 1.6040 | 1.3190   | 6.4016   | 5.0826    |
| Israel   | 1.6115 | 1.3077   | 1.8842   | 0.5765    |
| Jordan   | 1.5874 | 1.2854   | 1.9119   | 0.6265    |
| Lebanon  | 1.6769 | 1.1886   | 1.9961   | 0.8075    |
| Morocco  | 0.6226 | 0.3625   | 0.8489   | 0.4864    |
| Oman     | 1.6223 | 1.4107   | 1.9357   | 0.5250    |
| Saudi-Arabia | 1.5822 | 1.3249 | 1.9324   | 0.6075    |
| Tunisia  | 1.7235 | 1.4776   | 1.9119   | 0.4343    |

Note: $h_0$ designates the spectrum maxima indicating the typical fractal measure of signal, $\Delta h$ reports the fuzziness of the multifractal spectrum, $h_{min}$ and $h_{max}$ are respectively the maximum and minimum level of spectrum maxima.

**Table 2. Multifractal spectrum fuzziness and maxima.**

![Figure 7. Multifractal Character for all MENA stock markets.](image-url)
We apply the MF-DFA method on each index. Figure 7 illustrates the MF-DFA method. Here, it is worth mentioning that the plots of fluctuations functions $F_q(s)$ and the evolution of $r(q)$ which depend on the moments $q$ are reported in the left-hand panel. On the other hand, the evolution of the multifractal spectrum and the Hurst exponent $H(q)$ according to moments $q$ are shown in the right-hand panel.

As clearly shown, all the graphs of fluctuation functions for a scale $16 < s < 1024$ and different values of $q = \{-5, 0, +5\}$ (except for the Egyptian market index) indicate that adjustment lines are neither supposed nor parallel. This clearly implies that many Hurst exponents can exist in the corresponding indices series. Such results can be explained by the existence of cyclical fluctuations and in particular the bullish and bearish phases. Not surprisingly, the emerging markets seem to be the more evident candidates for detecting and identifying changes in cyclical bearish phases. Not surprisingly, the emerging markets seem to be the more evident candidates for detecting and identifying changes in cyclical bearish phases. As we can see in Figure 7, the multifractal behavior for all the MENA indices is well-pronounced, except for the Egyptian index. The multifractal feature of the series can be shown by the function $H(q)$ which is linear and decreasing, the series has a multifractal behavior of the time series' fluctuations. When $H(q) > 0$ there clearly exists a behavior of persistence in time series. The multifractal feature of the MENA markets becomes weaker. These empirical results also reflect that the stock markets become relatively more efficient (Rizvi and Arshad, 2016). Interestingly enough, the Hurst exponent is considered as a prominent measure of long-term memory of a signal. As well, the value of Hurst exponent provides interesting information about the behavior of the time series’ fluctuations. When $H(q) > 0.5$, there clearly exists a behavior of persistence in time series. The fluctuations’ persistence reflects that an increase (resp. a decrease) in the preceding period is followed by another increase (resp. decline) in the succeeding period (Niere, 2013). Analogically, when $H(q)$ exceeds 0.5, the fluctuations of time series seem to be anti-persistent, indicating that an increase (resp.

**Table 3a. Generalized Hurst exponents through MF-DFA approach– Short-run.**

| q-order | -4 | -3 | -2 | -1 | 0  | 1  | 2  | 3  | 4  |
|---------|----|----|----|----|----|----|----|----|----|
| **Panel A. Generalized Hurst exponents for full sample period** |
| Abu Dhabi | 0.813 | 0.776 | 0.734 | 0.686 | 0.629 | 0.554 | 0.453 | 0.337 | 0.234 |
| Bahrain | 0.655 | 0.647 | 0.642 | 0.637 | 0.626 | 0.601 | 0.562 | 0.515 | 0.468 |
| Dubai | 0.662 | 0.669 | 0.675 | 0.671 | 0.648 | 0.602 | 0.541 | 0.477 | 0.422 |
| Egypt | 16.600 | 16.430 | 16.070 | 14.870 | 0.703 | 0.545 | 0.521 | 0.496 | 0.471 |
| Israel | 0.610 | 0.597 | 0.580 | 0.560 | 0.538 | 0.512 | 0.481 | 0.447 | 0.415 |
| Jordan | 0.616 | 0.604 | 0.519 | 0.588 | 0.581 | 0.559 | 0.594 | 0.472 | 0.428 |
| Lebanon | 0.678 | 0.666 | 0.655 | 0.648 | 0.646 | 0.625 | 0.548 | 0.452 | 0.374 |
| Morocco | 0.733 | 0.714 | 0.689 | 0.655 | 0.614 | 0.567 | 0.519 | 0.478 | 0.448 |
| Oman | 0.731 | 0.721 | 0.710 | 0.692 | 0.652 | 0.571 | 0.451 | 0.337 | 0.256 |
| Saudi Arabia | 0.609 | 0.616 | 0.629 | 0.638 | 0.627 | 0.588 | 0.534 | 0.483 | 0.445 |
| Tunisia | 0.698 | 0.697 | 0.696 | 0.692 | 0.673 | 0.629 | 0.551 | 0.455 | 0.367 |
| **Panel B. Generalized Hurst exponents for the pre-revolution period** |
| Abu Dhabi | 1.962 | 1.898 | 1.813 | 1.720 | 1.644 | 1.595 | 1.572 | 1.565 | 1.562 |
| Bahrain | 1.751 | 1.729 | 1.705 | 1.680 | 1.667 | 1.688 | 1.737 | 1.779 | 1.801 |
| Dubai | 1.828 | 1.799 | 1.769 | 1.735 | 1.697 | 1.674 | 1.669 | 1.665 | 1.652 |
| Egypt | 1.799 | 1.763 | 1.728 | 1.699 | 1.637 | 1.647 | 1.622 | 1.598 | 1.577 |
| Israel | 1.730 | 1.717 | 1.704 | 1.689 | 1.666 | 1.932 | 1.591 | 1.550 | 1.513 |
| Jordan | 2.086 | 2.018 | 1.917 | 1.791 | 1.685 | 1.614 | 1.563 | 1.525 | 1.497 |
| Lebanon | 1.947 | 1.910 | 1.872 | 1.848 | 1.831 | 1.778 | 1.696 | 1.628 | 1.579 |
| Morocco | 2.039 | 1.967 | 1.876 | 1.783 | 1.707 | 1.650 | 1.607 | 1.571 | 1.539 |
| Oman | 1.946 | 1.905 | 1.857 | 1.807 | 1.763 | 1.726 | 1.692 | 1.663 | 1.640 |
| Saudi Arabia | 1.718 | 1.702 | 1.690 | 1.680 | 1.655 | 1.610 | 1.562 | 1.521 | 1.490 |
| Tunisia | 1.941 | 1.913 | 1.885 | 1.857 | 1.810 | 1.738 | 1.664 | 1.600 | 1.547 |
| **Panel C. Post-revolution period** |
| Abu Dhabi | 1.721 | 1.690 | 1.658 | 1.635 | 1.612 | 1.588 | 1.573 | 1.567 | 1.564 |
| Bahrain | 1.711 | 1.690 | 1.665 | 1.640 | 1.635 | 1.674 | 1.738 | 1.785 | 1.807 |
| Dubai | 1.712 | 1.693 | 1.681 | 1.676 | 1.670 | 1.669 | 1.672 | 1.668 | 1.655 |
| Egypt | 1.754 | 1.716 | 1.684 | 1.665 | 1.654 | 1.641 | 1.622 | 1.600 | 1.579 |
| Israel | 1.714 | 1.697 | 1.682 | 1.668 | 1.648 | 1.618 | 1.583 | 1.546 | 1.512 |
| Jordan | 1.936 | 1.886 | 1.815 | 1.736 | 1.669 | 1.613 | 1.565 | 1.527 | 1.499 |
| Lebanon | 1.921 | 1.882 | 1.851 | 1.845 | 1.840 | 1.784 | 1.700 | 1.630 | 1.581 |
| Morocco | 1.917 | 1.879 | 1.829 | 1.764 | 1.694 | 1.641 | 1.602 | 1.568 | 1.539 |
| Oman | 1.841 | 1.817 | 1.793 | 1.771 | 1.751 | 1.725 | 1.695 | 1.666 | 1.643 |
| Saudi Arabia | 1.868 | 1.833 | 1.792 | 1.744 | 1.684 | 1.621 | 1.567 | 1.524 | 1.492 |
| Tunisia | 1.933 | 1.904 | 1.877 | 1.854 | 1.818 | 1.751 | 1.674 | 1.605 | 1.549 |

Note: Panel A, Panel B and Panel C respectively report the Generalized Hurst exponents through MF-DFA approach for the short term horizon for the full, pre-revolution and post-revolution periods.
the multifractality behavior of the MENA indices becomes weaker. This sized Hurst exponent (except for the Egyptian market index) indicates that fractality in time series. When

MENA indices. Accordingly, we show the presence of noticeable multi-

measure of efficiency. Following Rizvi and Arshad (2017), we analyze the long-

fluctuations of the generalized Hurst exponents over different sample periods. The estimation results are reported in Tables 3a and 3b. Second, we attempt to rank the efficiency of MENA markets for the same horizons and same periods. For this end, we the following measure of efficiency:

\[ D = \frac{1}{2} \left( |h(-4) - 0.5| + |h(4) - 0.5| \right) \] (13)

From Tables 3a and 3b, a modest change in generalized Hurst exponents \( H(q) \) with changing of \( q \) from -4 to 4 is well-pronounced for all the MENA indices. Accordingly, we show the presence of noticeable multifractality in time series. When \( q \) varies, the moderate change in general-

ized Hurst exponent (except for the Egyptian market index) indicates that the multifractality behavior of the MENA indices becomes weaker. This clearly reflects that the selected MENA markets become moderately more efficient.

"Table 4 reports the efficiency ranking for different sample periods. Based on Eq. (13), if a market is efficient, the value of \( D \) must be close to zero. However, a large value of the deficiency indicator shows a less efficiency. In short term, the Israeli market show high level of efficiency followed by the Jordanian market. The results also prove that Omani, Abu-Dhabi and Egyptian markets are not efficient in weak-form. In long term, however, a remarkable change in the efficiency ranking is well-proved. Indeed, the Israeli market records the highest level of efficiency. The Abu-Dhabi market has crept to the top five MENA markets efficiency. These results corroborate those of Rizvi et al. (2014). As pointed out by Arshad et al. (2015), it is possible to obtain a biased efficiency ranking due to the high period length which is characterized by the onset of dramatic country-specific events. This leads to a more volatile nature for one market compared to another one. The most important political is the Arab spring which corresponds to anti-government protests and social uprisings that spread across several Arab countries such as Tunisia, Egypt and Bahrain. Cognizant this fact, we divide the study period into two sub-periods (pre- and post-Arab spring periods) to better
analyze the behavior of the market efficiency. Looking afterwards deeper into the pre-Arab spring period efficiency ranking, Jordan seems to be the most efficient in the short-term. Nonetheless, Bahrain appears to be the least efficient market. Unlike the whole period, Israel does not show high level of market efficiency during the pre-Arab spring period. Surprisingly, Bahrain becomes the most efficient market followed by Egypt in the long-term level. Once again, the empirical results display the existence of apparent multifractality in the time series over the post-Arab spring period (see Table 4).

From Table 4, a difference between the pre- and post-Arab spring efficiency ranking in short term seems to be increasingly obvious. Jordan displays variegated levels of efficiency for short run between the pre- and post-Arab spring periods. During the post-Arab spring period, Jordan ranks at the lower end of the range while it ranked the first place over the pre-Arab spring period. This change in efficiency ranking can be attributed to the decrease in development stage which is reflected by a decline in number of listed companies, in market capitalization and even in market capitalization as a percentage of GDP (c.f. Table A2 in Appendix 1). Jordan and Saudi Arabia have stripped down the efficiency ranking after the Arab-spring period. This can be attributed to cross-border sentiment contagion, implying a loss in investor confidence and even fear of the international stock market investment climate. On the other hand, Israel has kept its position in efficiency ranking (the third place) during the post-Arab-spring period. This is in line with the development stage of the market, i.e. market capitalization and market capitalization as percentage of GDP (c.f. Table A2 in Appendix 1). So, the Israel market efficiency seems to be not affected by the Arab political event. For Tunisian and Egyptian Stock markets, the impact of Arab-spring on the level of efficiency appears to be controversy. Indeed, the Arab-spring has adverse implications on the Tunisian stock market, leading to higher levels of inefficiency. Nevertheless, the Egyptian market displays an enhancement in the efficiency ranking during the post-Arab spring period. This can be attributed to the effectiveness of emergency measures which are taken to preclude severe liquidity shortages in the stock market. For the Tunisian case, the thinness of stock market coupled with pervasive climate of insecurity and the fragile socio-political situation of the country have increasingly contributed towards worsening efficiency in this market.

Looking again at Table 4, we note some stability in efficiency ranking for long-term horizon during the post-Arab spring compared with pre-Arab spring period, except for Tunisia. During both sub-sample periods, Bahrain is the most efficient market followed by Egypt (second place) and Dubai (third place) in long-term horizon. However, Tunisia becomes the least efficient market due to its increasing political and economic instability.

To sum up, the estimation results provide evidence of inefficiency for most MENA markets. We also show that the market efficiency varies over both horizons and sub-periods. Nevertheless, the WTMM and MF-DFA consider the stable level of market over time. Many factors can result in the degree of market efficiency to change over time (Urquhart and McGroarty, 2016). In this regard, we further examine the time-varying behavior of MENA markets efficiency using the overlapping moving window approach (Choi, 1999; Kim et al., 2011; Kumar, 2018).

4.2.3. Overlapping moving window analysis

The overlapping moving window analysis is used to examine the evolution of market efficiency features. In particular, we analyze the behavior of market efficiency before and after the outbreak of Arab spring event. For all sub-sample periods, Figure 8 (Panel A, Panel B and Panel C) illustrates the results of overlapping moving window analysis based on the Automatic Variance Ratio (AVR) test.

Based on the AVR plots, when the p-values are less than 10%, the martingale hypothesis is rejected at 10% level of significance. For the whole sample period, we show that all the MENA markets (except for the Israeli stock market) display a disappearance from the martingale hypothesis for some periods. More precisely, dismissing the martingale hypothesis is well-documented during the sub-prime turmoil (2008–2009) for most stock markets and over the recent crude oil crisis (2014) especially for the GCC markets (Abu-Dhabi, Dubai, Bahrain, Jordan). We also deny the martingale hypothesis for the Tunisian and Omani markets during the whole sample period, indicating that these markets are vulnerable and exhibit a high inefficiency degree. For the Tunisian market, the martingale hypothesis is rejected over the period 2010–2011 which corresponds to the beginning of Arab-spring event. However, the martingale hypothesis is rejected for the other MENA markets over the period 2008–2009 (before the pre-Arab spring event). For the post-Arab spring period, the rejection of this hypothesis occurs in different periods, for example: Lebanon (2011), Morocco (2012), Oman (2011–2012), Saudi Arabia (2012) and Tunisia for the whole sub-sample.

To sum up, our empirical findings indicate that MENA markets exhibit time-varying efficiency characteristics and show inefficient behavior during the periods of political event. The rejection of the efficiency market hypothesis in MENA markets during all sub-periods can be attributed to the turbulence in such markets, reflecting by the onset of different country-specific events (e.g. the Arab-spring turmoil, financial crisis, crude oil decline, Saudi market crash 2006, Arab-spring event). Therefore, the dynamic behavior of market efficiency seems to be closely dependent on the nature of country-specific event and the specific features of stock market. The indexes returns can be predictable and the markets are inefficient in the weak-form sense.
5. Weak-form efficiency in the MENA stock markets: lessons from a multi-step approach

Investigating and apprehending the behavior of emerging markets is of paramount importance to the financial arena. In this respect, apprehending the nature of market efficiency of such markets can help policymakers and investors to make better appropriate decisions. Such understanding can be improved if it is linked with the specific features of emerging markets, their macroeconomic environment and the onset of country-specific events. Briefly, as supported by researchers (e.g. Bley, 2011; Mobarak and Mollah, 2016; Rizvi et al., 2014), the facts are as follows. The emerging stock markets are characterized by the absence of relevant and reliable infrastructure such as specialized portfolio management institutions, few financial specialized portfolio management institutions and financial instruments, as well as the lack of appropriate laws to protect minority shareholders. The issue of poor quality of information disclosures and the absence of the international accounting including the International Financial Reporting Standards are also relevant in emerging capital markets. An additional challenge for investment in emerging markets hinges increasingly on the market microstructure. Obviously, the market microstructure distortions entail the lack of experience and resources in issuing stocks. As a result, the market participants appear to speculate on financial markets and sometimes behave in irrational way. Collectively, the emerging markets seem to be less
liquid, more volatile and prone to greater risk premium. Needless to say, the onset of country-specific events (e.g. political events) increasingly makes the emerging economies more vulnerable. The nature of such information gain makes the analysis of the behavior of the emerging markets and the price dynamics very interesting.

In this context, we attempt to re-examine the weak-form efficiency in the MENA markets by taking into account the last development in terms of the occurrence of dramatic country-specific events (e.g. Arab-spring event) based on a multi-step approach which bundles the WTMM, the MF-DFA and the overlapping moving window analysis based on AVR test.

Based on the WTMM and MF-DFA methods, we clearly display the multifractality and anti-persistent movements of MENA indices returns, implying a departure from the weak-form efficiency hypothesis. More explicitly, the anti-persistent behavior of returns indicates that a decrease (resp. an increase) is generally followed by another increase (resp. decrease) in stock returns. Such feature could not only be linked to the apparent lack of fundamental traders that makes the stock prices quite volatile but also reflecting the high degree of market nervousness and uncertainty due to the dramatic country-specific events such as the Arab spring event.

Using afterwards the overlapping moving window based on AVR test completes our analysis of the emerging market dynamics by estimating the time-varying efficiency of MENA markets during turbulence periods. Based on AVR p-values plots, that major dramatic events (e.g. Arab-spring event) closely change the degree of return predictability. In other words, broader and national country-specific events have an adverse impact on the weak-form efficiency.

Collectively, the aforementioned evidences clearly indicate that the nature of price behavior seems to be unstable which is in line with the dynamic market efficiency. As well, the dynamic behavior of market efficiency appears to be related to the nature of country-specific event and the specific features of stock market.

As far as the emerging markets literature is concerned, our empirical results confirm those of many researchers analyzing the behavior of emerging markets. Among them, Zunino et al. (2008) display that the multifractality is more pronounced in the emerging markets than mature markets given that emerging markets mainly pose salient challenges with respect to the lack of institutional development and market microstructure distortions (Belalaah et al., 2005). According to Alam et al. (2007), the slow flow of information and the lack of adjustment of stock prices to information lead to inefficient market. Interestingly, Arouri et al. (2010) invoke several factors which hinder emerging markets from the efficient state: 1) discontinuous and infrequent trading; 2) the poor quality of both information and processing; 3) low market liquidity; 4) few number of institutional investors; 5) significant transaction costs; 6) low quality and quantity of information disclosure. In this respect, many researchers indicate that standard models often fail to deal with the specific features of the emerging stock markets.

At practical level, a sound apprehending of the nature of market efficiency and the driving forces of short-term and long-term dynamics allows to develop more realistic expectations of investment returns and in particular successful investment management.

6. Conclusion

Much research has been investigated the weak-form efficiency in emerging markets over the past several years. With the burgeoning financial crises in emerging markets, the interest in these stock markets has revived again recently. In general, insufficient data, inadequate regulations, lack of inspection and administrative loose in the involvement of rules make difficult to study the informational efficiency in emerging markets. The emerging countries are usually characterized by low quality of information disclosure, lack of market transparency, low degree of competition, weak trading volume and an inadequate accounting regulation. Based on this crux, we investigate whether the dramatic country-specific events (i.e. Arab-spring event) have adversely affected the efficiency of MENA markets. More precisely, this paper attempts to gauge the efficiency of eleven MENA stock markets during the period 2005–2016 and propose an efficiency ranking by incorporating the pre-and post-Arab spring periods. From methodological standpoint, we use three approaches. First, we utilize the WTMM analysis which allows us to detect the fractal dimension in the signal. Second, we use the MF-DFA method which has proven particularly useful for measuring the market efficiency and also is credited for being proficient in determining the level of market inefficiency. Third, the overlapping moving window is used to examine the time-varying change in market efficiency depending on market conditions. Overall, some MENA markets display a trend of enhancing efficiency whereas others show a worsening in their degree of efficiency throughout the sub-sample periods. Thus, the weak-form efficiency evolves over time and among countries due to the stage of development, investor’s confidence and the willingness of market’s authorities and governments to promote reforms. In addition, the return predictability for MENA markets is changing over time depending on market conditions and macroeconomics events. Such findings call for testing the Adaptive Markets Hypothesis as an evolutionary perspective on market efficiency.

From a practical view, improving the general apprehending of multifractal behavior and time-varying efficiency in emerging stock markets permits investors to optimize their decision-making process. As well, it may be of great interest for policymakers to enhance the financial market infrastructure and curtail speculative tendencies in stock market which in turn spurs investment and economic growth.

Declarations

Author contribution statement

Azza Béjaoui: Analyzed and interpreted the data; Wrote the paper. Besma Hkiri: Conceived and designed the experiments; Performed the experiments.
Chaïma Gharbi: Contributed reagents, materials, analysis tools or data.
Hashem A. AlNemer: Contributed reagents, materials, analysis tools or data.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.
Appendix

Table A1. General description of selected MENA stock markets

| Country       | Stock Exchange                          | Date of establishment | Ownerships structure | Key national corporate governance codes and principals                      |
|---------------|-----------------------------------------|-----------------------|----------------------|--------------------------------------------------------------------------------|
| Saudi Arabia  | Saudi Stock Exchange (Tadawul)          | 1984                  | State-owned          | Corporate governance regulations                                               |
| Lebanon       | Beirut Stock Exchange                   | 1920                  | Public institution   | The Lebanese code of corporate governance                                       |
| Oman          | Muscat Stock Exchange                   | 1988                  | State-owned          | Code of corporate governance of public listed companies                         |
| Israel        | Tel Aviv Stock Exchange                 | 1953                  | Mutualised           | The Company’s Corporate Governance Code                                         |
| Tunisia       | Bourse de Tunis                         | 1969                  | Mutualised           | Code of best practices of corporate governance                                   |
| Morocco       | Bourse de Casablanca                   | 1929                  | Mutualised           | Moroccan code of practices, good corporate governance                           |
| Egypt         | Egyptian Stock Exchange                 | 1883                  | Public institution   | Corporate governance code for Egyptian companies                                |
| Bahrain       | Bahrain Stock Exchange                  | 1987                  | State-owned          | Corporate governance code                                                      |
| United Arab Emirates | Dubai Financial Market, Abu Dhabi Securities Exchange | 2000 | State-owned | UAE corporate governance code                                                   |
| Jordan        | Amman Stock Exchange                    | 1999                  | Public institution   | Corporate governance code for shareholding companies listed on the Amman Stock Exchange |

Sources: OECD Corporate Affairs Division 2013, Report for the World Economic Forum’s MENA Regional Business Council, 2016.
Notes: State-owned exchange refer to market which share capital is detained by the state while the term ‘public institution is used to denote market with no share capital.

Table A2. Some features of the selected stock markets

| Country       | Number of listed companies | Market capitalization ($millions) | Market capitalization (% of GDP) | Stock traded, total value ($millions) | Stock traded, Turnover ratio of domestic shares |
|---------------|---------------------------|-----------------------------------|---------------------------------|---------------------------------------|-----------------------------------------------|
| Saudi Arabia  |                           |                                   |                                 |                                       |                                               |
| Lebanon       |                           |                                   |                                 |                                       |                                               |
| Oman          |                           |                                   |                                 |                                       |                                               |
| Israel        |                           |                                   |                                 |                                       |                                               |
| Tunisia       |                           |                                   |                                 |                                       |                                               |
| Morocco       |                           |                                   |                                 |                                       |                                               |
| Egypt         |                           |                                   |                                 |                                       |                                               |
| Bahrain       |                           |                                   |                                 |                                       |                                               |
| United Arab Emirates |                  |                                   |                                 |                                       |                                               |
| Jordan        |                           |                                   |                                 |                                       |                                               |

Source: World Bank Group.
References

Abeysekera, S.P., 2001. Efficient markets hypothesis and the emerging capital market in Sri Lanka: evidence from the Colombo stock exchange—A note. J. Bus. Finance Account. 28, 249–261.

Alam, M.M., Alam, K., Uddin, M.G.S., 2007. Market depth and risk return analysis of Dhaka Stock Exchange: an empirical test of market efficiency. Publ. ASA Univ. Rev. 1, 93–101.

Al-Khazali, O.M., Ding, D.K., Pyun, C.S., 2007. A new variance ratio test of random walk in emerging markets: a revisit. Financ. Rev. 42, 303–317.

Al-Shboul, M., Alsharari, N., 2018. The behavior of stock prices in the GCC markets. J. Dev. Econ.

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Choi, I., 1999. Testing the random walk hypothesis for real exchange rates. J. Appl.

Kawakatsu, H., Morey, M.R., 1999. Financial liberalization and stock market ef

Cheong, C.W., Mohd Nor, A.H.S., Isa, Z., 2007. Asymmetry and long-memory volatility: an empirical examination of nine emerging market countries. J. Multinatl. Financ. Manag. 9, 353

Jiang, J., Ma, K., Cai, X., 2007. Non-linear characteristics and long-range correlations in Asian stock markets. Phys. A. 379, 249–307.

Kanstelhardt, J.W., Zechinger, S.A., Koscielny-Bunde, E., Havlin, S., 2002. Multifractal detrended fluctuation analysis of nonstationary time series. Phys. A. 316, 87–114.

Kawakatsu, H., Morey, M.R., 1999. Financial liberalization and stock market efficiency: an empirical examination of nine emerging market countries. J. Multinatl. Financ. Manag. 9, 353–371.

Kendall, M., 1953. The analysis of economic time series. J. R. Statist. Soc. Ser. A. 96, 11–25.

Khababa, N., 1998. Behavior of stock prices in the Saudi Arabian financial market: empirical research findings. J. Financ. Manag. Anal. 11, 48–55.

Kim, J.H., Shammuddin, A., 2008. Are Asian stock markets efficient? Evidence from new multiple variance ratio tests. J. Empir. Finan. 15, 518–532.

Kim, J.H., Shammuddin, A., Lim, K.P., 2011. Stock return predictability and the adaptive markets hypothesis: evidence from century-long U.S. data. J. Empir. Financ. 18, 868–879.

Kumar, D., 2018. Market efficiency in Indian exchange rates: adaptive market hypothesis. Theor. Econ. Lett. 8, 1582–1598.

Lagoarde-Segot, T., Lucy, B.M., 2008. Efficiency in emerging markets: evidence from the MENA region. Inter. Financ. Inst. Mark. Money 18, 94–105.

Lim, K.P., Brooks, R.D., Hinrich, M.J., 2008. Nonlinear serial dependence and the weak-form efficiency of Asian emerging stock markets. Int. Financ. Mark. Inst. Money 18, 527–544.

Lo, A.W., MacKinlay, A.C., 1988. Stock market prices do not follow random walks: evidence from a simple specification test. Financ. Rev. Stud. 1, 41–66.

Lucy, B.M., Lagoarde-Segot, T.L., 2005. Stock Market Predictability in the MENA: Evidence from New Variance Ratio Tests and Technical Trade Analysis. School of Business Studies and Institute for International Integration University of Dublin. Discussion Paper No. 92.

Lye, C.T., Hooy, C.W., 2012. Multifractality and efficiency: evidence from Malaysian sectoral indices. Inter. J. Econ. Manag. 6, 278–294.

Magnusson, M.A., Wylick, B. 2002. How efficient are Africa’s emerging stock markets. J. Dev. Stud. 38, 141–156.

Manimaran, P., Panigrahi, P.K., Parikh, J.C. 2008. Difference in nature of correlation between NASDAQ and BSE indices. Phys. A. 387, 5810–5817.

Moharek, A., Mollah, S., 2016. Global Stock Market Integration: Convergence, Crises, and Efficiency in Developed and Emerging Markets. Palgrave Macmillan.

Mollah, A., 2007. Testing weak-form market efficiency in emerging market: evidence from Botswana stock exchange. Int. J. Theor. Appl. Finance 10, 1077–1094.

Muzy, J.F., Bacry, E., Arneodo, A., 1991. Wavelets and multifractal formalism for singular signals: Application to turbulence data. Phys. Rev. Lett. 67, 3515–3518.

Muzy, J.F., Bacry, E., Arneodo, A., 1994. The multifractal formalism revisited with wavelets. Int. J. Bifurc. Chaos. 4, 245–302.

Nierre, H.M., 2013. Multifractality in the Philippine foreign exchange market. Magnan. Sci. Eng. 7, 67–70.

Omran, M., Farrar, S.V., 2006. Tests of weak form efficiency in the Middle East emerging markets. Stud. Econ. Finance 23, 13–26.

Peng, C.K., Buldyrev, S.V., Havlin, S., Simons, M., Stanley, H.E., Goldberger, A.L., 1994. Mosaic organization of DNA nucleotides. Rev. E. Stat. Phys. Plasmas Fluids Relat. Interdiscip. Top. 94, 1685–1689.

Phiri, A., 2015. Efficient market hypothesis in South Africa evidence from linear and nonlinear unit root tests. Manag. Global Transit. 15, 369–387.

Podobnik, B., Fu, D., Jagric, T., Grosse, I., Stanley, H.E., 2006. Fractionally integrated process for transition economics. Phys. A. 362, 465–470.

Podobnik, B., Grosse, I., Stanley, E., 2002. Stochastic processes with power-law stability and a crossover in power-law correlations. Phys. A. 316, 153–159.

Puckovs, A., Matvejevs, A., 2012. Wavelet transform modulus maxima approach for world stock index multifractal analysis. Univers., Inf. Technol. Manag. Sci. 76

Rizvi, S.A., Ashraf, S., 2017. Analysis of the efficiency-inegration nexus of Japanese stock market. Phys. A. 407, 296–300.

Rizvi, S.A., Dwenduru, G., Bacha, O.I., Masih, M., 2014. An analysis of stock market efficiency: developed vs. Islamic stock markets using MF-DEA. Phys. A. 407, 86–99.

Rizvi, S.A., Ashraf, S., 2016. How does crisis affect efficiency? An empirical study of East Asian markets. Bona Istanbul Rev. 1–8.

Sensoy, A., 2013. Generalized Hurst exponent approach to efficiency in MENA markets. Phys. A. 5019–5026.

Simons, D., Laryea, S.A., 2005. Testing the Efficiency of African Markets. Available at SSRN. http://ssrn.com/abstract=874808.

Urghart, A., McGoarty, F., 2016. Are stock markets really efficient? Evidence of the adaptive market hypothesis. Int. Rev. Finan. Anal. 39–49.

Wheeler, F.P., Bill, N., Tetsuzai, K., Stive, R.L., 2002. The efficiency of the Warsaw Stock Exchange: the first few years 1991-1996. Poznan Univers. Econ. Rev. 2, 37–56.

Yalamova, R., 2006. Wavelet test of multifractality of Asia-Pacific index price series. Asian Acad. Manag. J. Account. Finance 2, 63–83.

Zumino, L., Taba, B.M., Figliola, A., Perez, D.G., Garavaglia, M., Roso, O.A., 2008. A multifractal approach for stock market inefficiency. Phys. A. 387, 6558–6566.