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Hurst's exponent behaviour, weak-form stock market efficiency and financial liberalization: the Tunisian case

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Abstract

In this paper, we test the weak-form stock market efficiency for the Tunisian stock market (TSE). Our empirical approach is founded on the analysis of the behaviour over time of the Hurst's exponent. Thus, we computed the Hurst's exponent using a “rolling sample” with a time window of 4 years. The sample data covers in daily frequency the period (January, 1997- October 2007). Since the classical R/S analysis is strongly affected by short-range dependencies both in the mean and the conditional variance of TSE daily volatility, daily stock returns were filtered using the traditional AR-GARCH(1,1) model. Our results for Hurst's and filtered Hurst's exponents behaviour analysis show a strong evidence of long-range dependence with persistent behaviour of the TSE. However, during the last two years, the filtered Hurst's exponent seems to exhibit a switching regime behaviour with alternating persistent and antipersistent behaviour but where it was somewhat close to 0.5.The nonparametric statistic approach results reveal that some TSE reforms including the launching of the Electronic quotation system on April, 1998, the fiscal regime for holdings, the security reinforcement laws, the legal protection of minority shareholder may play a role in understanding the Hurst's exponent behaviour over time

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1. Introduction

Informational efficiency is a key concept joining stock markets, financial liberalization and economic growth in emerging countries. More specifically, the weak form efficiency market hypothesis (WFEMH) stipulates that all the information afferent to a given financial asset is already reflected on its current price. Consequently, the historical asset price data does not in any way help to predict future stock prices. On the practical side, the WFEMH is closely related to the geometric Brownian motion assumption (Mandelbrot, 1977). According to the WFEMH, the time series return for a given stock follow an uncorrelated Gaussian process (i.e. white noise process). Explicitly, if the stock returns exhibit a long range dependence, the white noise hypothesis is not valid and then the WFEMH is violated (Fama, 1991). There is a large body of the empirical literature focused on the relationship between the WFEMH and long range-dependence. Empirical investigations have been conducted on both developed and emerging stock markets and provided mixed evidence. Briefly speaking, we can range studies within two empirical approaches. The earlier studies including Crato (1994), Ding and Granger (1993, 1996), Barkoulas and Baum (1996), Barkoulas *et al.* (2000), Cheung and Lai (1995) and Henry (2002) are based on a static estimation of the Hurst exponent for all the sample time series. The second approach investigated the Hurst exponent behaviour over time. In fact, the concept of time-varying Hurst (Hurst, 1951) exponent was introduced by Costa and Vasconcelos (2003). The absence of long-range dependence in developed stock markets behaviour may be reasonable if we know that they are informationnaly efficient. So, publicly information's are instantaneously incorporated in stock prices and any new one is fully arbitraged away. Inversely, thin stock markets are characterized by several institutional rigidities that propagate informational inefficiency and asymmetry. According to Levine (1999), legal environment including minority investor's protection, is found to be strongly associated with low levels of financial sector and, in particular stock market development. Levine's (1999) conclusions are supported by Limam (2003). The author revealed that fractional integration in stock market behaviour is strongly linked to their level of development. For the MENA stock markets, long-range memory property is associated with the peculiar characteristics and legal environment of each stock market (Limam, 2003, p. 263). In their paper, Cajueiro and Tabak (2004a) investigated long-range dependence and market efficiency for eleven emerging countries and other developed markets including U.S. and Japan (January, 1992-December, 2002). The authors suggested a rolling sample approach (with a window of four years) in order to analyze the dynamics of the Hurst exponent over time. Their results suggest that Asian equity markets show greater inefficiency than those of Latin America and that developed markets rank first of efficiency (Cajueiro and Tabak, 2004, 349). In another paper, Cajueiro and Tabak (2005) have implemented the same time-varying Hurst exponent approach to squared and absolute stock returns in order to rank efficiency of 11 emerging countries from Asia and Latin America for the period (1991-2004). Their findings suggested that three markets exhibit strong long-range dependence in volatility. According to these authors Asian stock markets seem to be more efficient than those of Latin America (Cajueiro and Tabak, 2005, p. 671). More recently, Cajueiro and Tabak (2006) analyzed the predictability of stock returns for some European transition markets. Employing the Hurst exponent, they provided strong evidence of time varying long-range dependence in stock returns (Cujueiro and Tabak, 2006, p. 56). Also, Da Silva *et al*. (2007) implemented the time-varying Hurst exponent approach to investigate the WFEMH in the Brazilian foreign exchange market. They found evidence of weak-form efficiency. Lim (2007) used a rolling sample approach in order to detect nonlinear dependence in stock returns (11 emerging and 2 developed stock markets for the period 1992-2005). More precisely, the author implemented the Hinich (1996) portmanteau bi-correlation test to seek for nonzero bi-correlations in stock market returns. It was found that the US market is the most efficient while Argentine is at the end of the ranking. In his study, Limam (2003) examined the long-range dependence of stock markets returns for 14 countries with diverse degree of development and including eight Arab countries. His empirical investigation was based on both parametric and semi-parametric estimation procedures of long-range dependence. He showed that the "long-range dependence property of Arab stock markets seem to be associated with peculiar characteristics and the legal environment of each country" (Limam, 2003, p. 251). Using a battery of long range dependence tests, Aloui *et al.* (2005) detected long memory on the Tunisian stock market volatility. Also, Saadi *et al.* (2006) re-examined the WFEMH for the Tunisian context. They employed a Fractionally Integrated Exponential GARCH (FIEGARCH) model in order to specify the nonlinear dependence between the returns and their past values. Extending Aloui *et al.'s* (2005) paper for other MENA stock markets (Tunisia, Egypt, Jordan, Morocco and Turkey), Assaf (2006) provided evidence of long memory behaviour. His empirical investigation was based on the Modified Rescaled Range statistic R/S suggested by Lo (1991). In a more recent paper, Lim *et al.* (2008) analyzed the WFEHM for several Asian emerging stock markets. They showed the presence of some predictable non-linearities in stock index time series. Furthermore, Lim *et al.* (2008) revealed that the cross-country differences in the non linear departure from WFEMH can be explained by market size and trading activity (Lim *et al.*, 2008, p. 527). In their study, Lagoarde-Segot and Lucey (2008) investigated the WFEMH of seven MENA stock markets for the period (1998-2004). They proposed an efficiency index founded on random walk tests and technical trade analysis. The authors showed evidence of heterogeneous efficiency levels in the MENA stock markets. With reference to Lagoarde-Segot and Lucey (2008), "MENA stock market efficiency seems to be influenced by market depth and other corporate governance factors"(Lagoarde-Segot and Lucey, 2008, p. 94). The purpose of this paper is to contribute to the empirical literature on stock market development and WFEMH. More specifically, we are concerned with linkage between the Hurst's exponent behaviour, long-range dependence of volatility, the WFEMH and different stages of stock market liberalization in the Tunisian context. Although the research focused on long-range dependency for the developed and emerging stock markets has been largely extended, there is a scant empirical study concerned with MENA stock markets. In fact, only few studies were focused on the MENA stock markets. To our knowledge, this paper is the first empirical study on Hurst's exponent behaviour and the WFEMH in the Tunisian context. Our research is motivated by at least three raisons: Firstly, the traditional informational efficiency studies commonly consider the WFEMH as a static characteristic that remains unchanged during different stages of the stock market development. In contrast, the rejection of the efficiency hypothesis for a full sample period may veiled some eventual sub-periods where the market is effectively efficient and vice-versa. So, it will be very important to analyse the degree of efficiency behaviour over time instead of testing absolute stock market efficiency. Secondly, according to Rockinger and Urga (2000), *"[...] this approach appears to be the only way of measuring whether market efficiency has increased since there is no observable variable for emerging markets that might be used to quantify improvement in stock market efficiency"* (Rockinger and Urga, 2000, p. 458). Thirdly, in spite of a common economic reform trajectory due to its integration in the European's Union neighbourhood policy, the Tunisian stock market have achieved during the last two decades different stage of financial liberalization. For instance, the stock market capitalisation goes from 2,632 to 6,527 million dinars during the period (1997-

2007). Thus, it would be worthy to analyse the linkage between WFEMH to stock market liberalization for the particular case of Tunisia. The present paper is structured as follows. Section 2 provides an overview of the Tunisian stock market. Some methodological considerations related to long-range memory concept and time varying Hurst's exponent are given in section 3. Data and empirical results are provided in section 4. Section 5 contains summary and some concluding remarks.

2. The Tunisian stock market main reforms

2.1. The Tunisian stock market (TSE) main reforms (1997-2007)

- *Fiscal regime for holdings*

Any listed firm on TSE and holding, directly or indirectly, at least 95% of capital in other companies can, as the parent company, opt for tax assessment on the basis of the combined earnings which (see, Article 2, paper 2, TSE, General rules). Firms should be first subject to corporate tax law, have the same accounting year opening and closing dates and be both established in Tunisia. Tax incentives to firms which open their capital to the public were initially granted for a period of three years starting from January 1999, in the form of a reduced tax rate from 35% to 20%. This measure was extended for an additional period of three years starting from February 2002. The underlying idea of this reform is to encourage listed firms to be more transparent and also mobilising public savings by increasing the range of offerings by including new stocks on the TSE.

- *Amendment of Financial Market Council (FMC)*

The main objective of this reform is to provide more transparency in public calls for savings by requiring that firms, seeking this kind of financing, to publish a more complete and consistent information. Subsequently, firms will have to provide to the FMC and to the shareholders the required information[1].

- *Trading commissions*

In order to encourage new issues and trading on the TSE, commissions to the FMC and the TSE have been reduced. Previously estimated on the basis of the amount of the issue, commissions to the FMC are henceforth set at 0.2% of the nominal value of the issue[2].

- *Legal protection of minority shareholders*

With the intention of providing better protection to minority shareholders and to support greater transparency in the TSE, the FMC have decided that any individual or a legal entity, acting alone or jointly, who detains, directly or indirectly, more than 5%, 10%, 20%, 33.33%, 50% or 66,66% in the capital of a public shareholding company, is contiguous to declare the crossing of a threshold or thresholds to that company, to the FMC and to the TSE within five working days from the date of the crossing and to declare the total number of shares and voting

[1] "Any company or organism which issues transferable securities or financial products by calling for public shareholding must first and for each issue, publish a prospectus intended to inform the public about the organization of the company or the organism, its financial situation and the development of its activity, as well as the characteristics and the object of the security or the product issued. The prospectus is prepared according to models elaborated by the Financial Market Council", (Article 2, paper 2, TSE, General rules).

[2] For more detailed information, see the General rules of the Tunisian Stock Exchange, available at the TSE website. www.TSE.gov.tn

rights which he detains therein according to conditions fixed by regulation issued by the FMC[3] (Article 8, chapter 4).

2.2. The TSE trends (1997-2007)

In Table 1, we provide some market performance indicators such as market capitalisation, trading volume, market liquidity and market turnover ratios for the period (1997-2007).

3. Long range dependence, Hurst's and adjusted Hurst's exponents' behaviour

As mentioned above, we employ the Hurst's exponent in order to measure the long-range dependence in the TSE volatility. As in Cajueiro and Tabak's (2004a,b,c) papers, the Hurst's exponent is computed using the traditional R/S analysis. In fact, due to this simplicity, the *R/S* analysis is very used in empirical investigations detecting long-range dependence in financial time series. Formally, the *R/S* statistic is the range of partial sums of deviations of time series from the mean, rescaled by its standard deviation. Considering a sample of continuously compounded asset returns $\{r(1), r(2), r(3), \ldots r(\tau)\}$, the *R/S* statistic test is given by (Cajueiro and Tabak, 2004a, p. 524):

$$(R/S)_\tau = \frac{1}{\hat{\sigma}_\tau(q)}\left[\max_{1\le t\le\tau}\sum_{t=1}^{\tau}\left(r(t)-\overline{r_\tau}\right)-\min_{1\le t\le\tau}\sum_{t=1}^{\tau}\left(r(t)-\overline{r_\tau}\right)\right] \quad (1)$$

Where, $\overline{r}_\tau$ is the sample mean of the return time series, $\overline{r}_\tau = \frac{1}{\tau}\sum_{t=1}^{\tau} r_t$ and s_τ is the standard deviation estimation, $s_\tau = \left[\frac{1}{\tau}\sum_t \left(r(t)-\overline{r_t}\right)^2\right]^{1/2}$

$$\hat{\sigma}_\tau(q) = \frac{1}{\tau}\sum\nolimits_\tau (r(t)-\overline{r}_t)^2 + \frac{2}{\tau}\sum_{i=1}^{q} w_i(q)\left\{\sum_{t=i+1}^{\tau}\left(r(t)-\overline{r_\tau}\right)\left(r(t-i)-\overline{r_\tau}\right)\right\}$$

$$= \hat{\sigma}_x^2 + 2\sum_{i=1}^{q} w_i(q)\hat{\gamma}_i \quad (2)$$

$$w_i(q) \equiv 1 - \frac{1}{q+1}, q \prec \tau \quad (3)$$

Where $\hat{\sigma}_x^2$ and $\hat{\gamma}_i$ are respectively the usual variance and autocovariance estimators of the returns and the weights $w_i(q)$ are those suggested by Newey and West (1987). We can easily find the classical R/S statistic. The Hurst exponent estimated by the R/S analysis is computed using a rolling approach (Cajueiro and Tabak, 2004a, p. 524). This approach can be explained as follows. Consider we have 5,511 daily stock returns for the TSE. We use the first 1,000 daily returns (four years) and we estimate the Hurst exponent for this time series, then we drop the first observation and we use the next day observation also using the 1,000 observations and compute the Hurst's exponent. We proceed with this sampling approach until the last observation. Finally,

[3] This declaration shall also be made within the same deadline and to the same organisms when the participation in the capital or the number of the voting rights becomes inferior to the thresholds provided in this article.

we plot the Hurst's exponent time series in order to analyse his behaviour over time. The main idea of the rolling sample approach is to check whether long-range dependence is varying over time. This approach is practical to test whether stock market efficiency is changing over time.

3.1. Short-range dependence, filtered returns and Hurst's exponent behaviour

Lo (1991) have shown that the *R/S* statistic is sensitive to short-range dependence in financial time series. In order to avoid any short-range dependence in both mean and variance of the stock returns, we implement the classical *R/S* statistic on the adjusted time series. More precisely, the daily returns are filtered in order to avoid any short-range dependence. In line with some previous studies including Cajueiro and Tabak (2004a,b,c, and 2005) and others, we employ the GARCH(1,1) model in order to filter the stock return time series. The mean and the variance equation of the GARCH(1,1) are given by Eqs. 4 and 5.

$$r_t = c + \delta r_{t-1} + \varepsilon_t \qquad (4)$$

$$h_t = \overline{w} + \alpha\varepsilon_{t-1}^2 + \beta h_{t-1} \qquad (5)$$

Where r_t is the daily stock return at time (t), while h_t is the conditional variance of the residuals from the mean return equation. $c, \overline{w},$ and α are the estimated parameters. Consequently, we implemented the *R/S* statistic on the standardized residuals $\zeta(t) = \frac{\varepsilon(t)}{\sqrt{h(t)}}$.

Table 1
The main Tunisian stock market performance indicators (1997-2007)

	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
BVMT index [(a)]	455.64	464.56	810.24	1,424.91	996.09	782.93	939.78	974.82	1,142.46	1,599.07	1,936.78
TUNINDEX [(b)]	1,000	917.08	1,192.57	1,442.61	1,266.89	1,119.15	1,250.18	1,331.82	1,615.12	2,331.05	2,614.07
Stock market capitalisation [(c)]	2,632	2,452	3,326	3,889	3,275	2,842	2,976	3,085	3,840	5,491	6,527
Stock market capitalisation/GDP (in%)	12.6	10.9	13.5	14.6	11.4	9.5	9.2	8.8	10.2	13.3	14.5
Number of listed companies	34	38	44	42	45	46	45	44	45	48	51
Trading volume	590	927	881	1 814	1 204	1 006	948	689	1,660	4607[(e)]	1744
of witch: official quotation [(d)]	287	237	554	919	508	343	238	317	701	746	915
Turnover (in %) [(c/d)]	10.9	9.7	16.7	23.6	15.5	12.1	8.0	10.3	18.3	13.6	14.0
Liquidity rate (in %)	36	37	46	51	49	42	33	38	55	55	49

(a) base 100 on 30 September, 1990, adjusted on 31 march 1998 to 465.77. (b) base 1000 on 31 December 1997.(e) exclusive of TUNISIE TELECOM this volume amounts to 1,555. The stock market capitalisation and the trading turnovers are expressed in local currency (million Dinars).
Sources: Tunis Stock Market and Capital Market council (CMF).

3.2. Data

The data used in this study consists of closing stock market indexes for five the TSE (IBVMT[4]). The data has a daily frequency and covers the period (January, 3, 1997 - October, 30, 2007), resulting in 5,511 observations. Data was extracted from the TSE Website[5]. We should note that the stock indexes are expressed in local currency (Tunisian Dinar). We focus our attention on the series of returns defined as:

$$r_t = 100 \times Log\left(\frac{P_t}{P_{t-1}}\right) \tag{6}$$

where r_t and P_t are the return in percent and the index on day *t*, respectively.

4. Empirical results

4.1. Hurst's exponent and filtered Hurst's exponent behaviour analysis

Table 2 provides descriptive statistics for the Hurst's exponent and the filtered Hurst's exponent for the TSE absolute returns over the period (January 2002- October 2007).

Table 2
Descriptive statistics for the Hurst exponent and filtered Hurst exponent for absolute returns

	Mean	Median	Max.	Min.	S.D.	Skewness	Kurtosis
Hurst	0.670089	0.663264	0.781246	0.584183	0.004868	0.44419	2.342791
Filtered Hurst[(a)]	0.584567	0.577878	0.703996	0.490781	0.045745	0.557879	2.659052

(a) The filtered Hurst's exponent is the traditional R/S analysis used for the standardized residuals of the mean equation of the AR-GARCH(1,1) model.

As we can see, the Hurst's exponent has 0.670089 as a mean value and it is above 0.5. The maximum value is equal to 0.781246 while the standard deviation is equal to 0.004868. The mean value of the filtered Hurst's exponent is less than the one for the Hurst's exponent while the median values are respectively equal to 0.663264 and 0.577878. The two Hurst's exponents are above 0.5 indicating the presence of long-range dependence on the TSE stock market volatility. In addition, the TSE daily volatility exhibits a persistent behaviour. This preliminary result is consistent with previous empirical studies including Aloui *et al.* (2005) and Saadi *et al.* (2006). Moreover, the skewness and the kurtosis statistics reveal that both the Hurst's and filtered Hurst's exponent are not normally distributed. This result is confirmed by the normal probability plots against normal distribution and the Kernel density function plots (Figs. 1b, 1c, 2b and 2c). This preliminary finding is supported by several normality test results. More precisely, we have employed diverse normality tests, namely Lillefors (D), Cramer-von Mises

[4] The BVMT index represents a synthetic security that corresponds to a basket made up of shares from each security listed in the index. Thus, all securities have the same weight whatever their market capitalization is. The security sizes are not considered against the size of the whole. The IBVMT index was launched in September, 30th 1990 with a base value of 100. It's a yield based index (the dividends are reinvested). Its composing sample is open to securities admitted for their ordinary shares in the Stock Market and whose quotation frequency is greater than or equal to 60%.

[5] Tunis Stock Exchange: www.TSE.com.tn

(W2), Watson (U2) and Anderson-Darling (A2) tests. The test results displayed in Table 3 are consistent and strongly reject the Gaussian distribution for both Hurst's and filtered Hurst's exponent's time series. Therefore, we are able to employ usual tests in order to compare the median values for different sub-samples of the Hurst's and filtered Hurst's exponent's time series.

Table 3
Normality test for the Hurst's and the filtered Hurst's exponents

	Hurst's exponent			Filtered Hurst's exponent		
	Value	Adj. value	Probability	Value	Adj. value	Probability
Lilliefors (D)	0.067832	NA	0.0000	0.076277	NA	0.0000
Cramer-von Mises (W2)	2.153176	2.153896	0.0000	2.319983	2.320759	0.0000
Watson (U2)	1.825853	1.826464	0.0000	1.903506	1.904143	0.0000
Anderson-Darling (A2)	15.48410	15.49188	0.0000	15.06004	15.06761	0.0000

In Figs. 1a-1c, we present respectively the Hurst's exponent over the sample period, the Normal probability plot and the Kernel density plot against normal distribution. The same Figs. (Figs. 2a-2c) are reported for the filtered Hurst's exponent.

The most striking feature seen in Figs. 1(a) and 2(a), is perhaps the fact that the TSE shows persistence $H > 0.5$ during the first two years (2002-2003) after which it switches to a regime it altering persistent and antipersistent behaviour. But, during the last two years (2006-2007) the Hurst's and the filtered Hurst's exponents remain close to 0.5 and they momentarily dip towards 0.5. Overall, the TSE daily volatility display over the sample period strong evidence of long-range dependence indicating large deviations from WFEMH. Also, TSE inefficiency degree seems to change over time. TSE financial reforms including legal protection of minority shareholders, fiscal amendments, the reorganization of the financial market which separates the functions of control and management of the TSE, the lunching of the alternative market may have an eventual impact on the Hurst's behaviour over time.

4.2. TSE reforms and Hurst's exponent behaviour

We employed a nonparametric statistic approach to analyse the impact of financial TSE reforms on the Hurst's exponent behaviour. More specifically, we subdivide the filtered Hurst's exponent time series in to subsamples (pre and post reform) with respect to the reform date. Then, we compare the medians for each subsample. From these tests we can see if the filtered medians values are statistically different. Our main purpose is to check whether the TSE financial liberalization has an impact on the filtered Hurst's over time. In other words, we research if the financial liberalization has an eventual effect on the deviations from the WFEMH.

We should mention that we selected the major reforms namely, the security reinforcement law, the amendments of the FMC, the launching of the alternative market, fiscal regime for holdings, trading costs and laws relative to legal protection of minority shareholders. Fig. 3 reports jointly the filtered Hurst's exponent behaviour and financial reforms during the period (January, 2002 – October, 2007). The nonparametric test results are displayed in Table 4.

As mentioned above, the filtered Hurst's exponent behavior exhibit large deviation from the Gaussian distribution, we can therefore employ the nonparametric test for equality of medians for the period's pre and post TSE reform. Results reported in Table 4, reveal that all the selected nonparametric tests are statistically significant at the 1% and 5% significant levels indicating significant difference between the two periods pre and post TSE reform.

More importantly, for all the selected TSE reform measures, the filtered Hurst's median values for the pre reform periods are significantly different. Even though they are above the benchmark 0.5, the filtered Hurst's exponents for the pre reform periods are higher than those for the post periods. Thus, it seems that the TSE major reforms may play a significant role in explaining the filtered Hurst's exponent behavior over time. More specifically, the TSE reforms are determinant features understanding the dynamic behavior of the deviations from the WFEMH.

5. Summary and concluding remarks

In this paper, we employed a "rolling sample" approach proposed by Cajueiro and Tabak (2004) in order to analyze the behaviour of the Hurst's exponent over time. In contrast with some previous empirical studies based on a single static measure of long memory dependence, we employed a rolling-sample approach to test whether the Tunisian stock market is being more efficient. The Hurst's exponent behaviour over time is analysed using a "rolling sample" method with a window of four years observations. The stock market volatility has been approximated by absolute returns. Our empirical investigations were conducted on for the period (December, 1997, October 2007). The obtained results reveal that the Hurst's exponent changes over time and the TSE volatility exhibit a strong evidence of long-range dependence indicating large deviations from the WFEMH. Since the classical R/S analysis is strongly affected by short-range dependencies both in the mean and the conditional variance of TSE daily volatility, daily stock returns were filtered using the traditional AR-GARCH(1,1) model. Then the classical R/S analysis was implemented for the standardized residuals. Our filtered Hurst's exponent behaviour analysis pointed out a strong evidence of long-range dependence with persistent behaviour. However, during the last two years, the filtered Hurst's exponent seems to exhibit switching regime behaviour with alternating persistent and antipersistent behaviour but where it was somewhat close to 0.5. The nonparametric statistic approach results reveal that some TSE reforms including the launching of the electronic quotation system on April, 1998, the fiscal regime for holdings, the security reinforcement laws, the legal protection of minority shareholder and the amendments of the FMC may play a role in understanding the Hurst's exponent behaviour over time and therefore the long-range dependence on the TSE volatility. More specifically, TSE liberalization measures can be assimilated to determinant factors reducing the deviations from the WFEMH. Our results have at least two academic and policy making implications. For the academicians, more research is needed to detect and understand the long-range dependence in other emerging stock markets. For, governments and financial authorities, stock market liquidity, shareholder protection, information disclosure, and fiscal regimes are the main stock market development factors. We suggest two directions for further research. First, the econometric tests should be extended in order to detect long-range dependence and to model the Hurst's exponent behaviour over time. We would also extend our study to some other emerging countries from the MENA region, allowing for a wider comparative analysis.

Fig. 1 (a)
Hurst's exponent over time

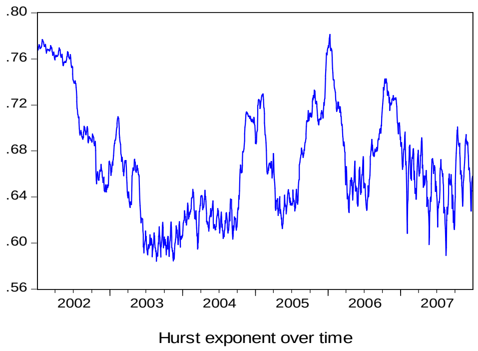

Fig. 1 (b)
Normal probability plot of the Hurst's exponent

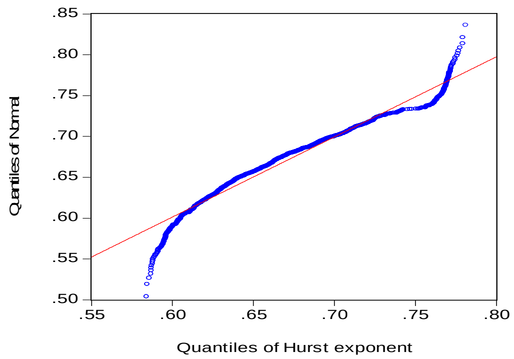

Fig. 1 (c)
Kernel density function plot

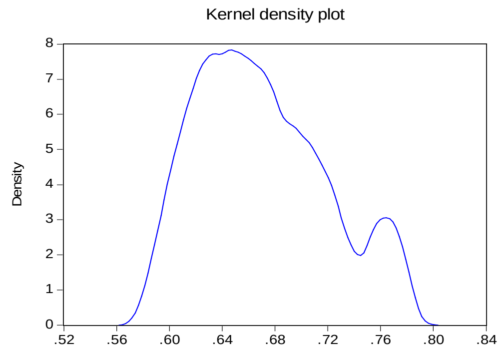

Fig. 2 (a)
Hurst's exponent over time

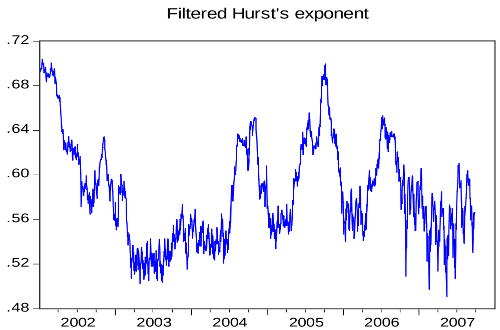

Fig. 2 (b)
Normal probability plot of the Hurst's exponent

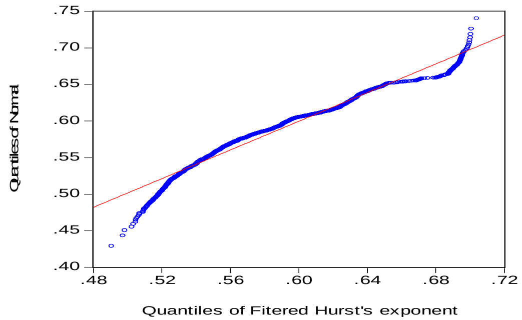

Fig. 2 (c)
Kernel density function plot

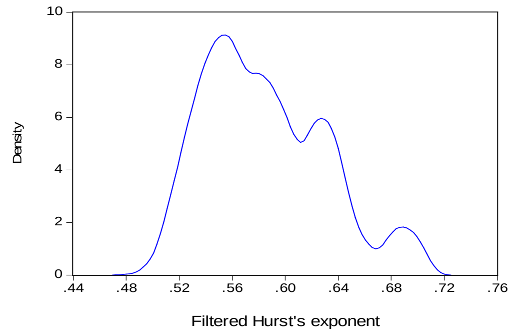

Table 4

Nonparametric tests for equality of medians for the periods pre and post TSE reforms

Method	Security reinforcement		Lunching of the alternative market		Transaction costs		Legal protection of minority shareholders		Fiscal regime for holdings	
Median value	pre	post	pre	post	pre	post	pre	post	pre	post
	0.5794	0.5771	0.5852	0.5626	0.6123	0.5789	0.6211	0.5543	0.6754	0.6143
Wilcoxon/Mann-Whitney	2.2065* (0.0273)		7.1347 (0.000)		25.456 (0.000)		44.452 (0.000)		88.245 (0.000)	
Wilcoxon/Mann-Whitney (tie-adj.)	2.2065* (0.0273)		7.1347 (0.000)		25.456 (0.000)		44.452 (0.000)		88.245 (0.000)	
Med. Chi-square	0.1595 (0.6896)		69.5360 (0.000)		74.324 (0.000)		77.986 (0.000)		83.568 (0.000)	
Adj. Med. Chi-square	0.1190 (0.7300)		68.2527 (0.000)		73.112 (0.000)		77.664 (0.000)		83.568 (0.000)	
Kruskal-Wallis	4.8689* (0.0273)		50.9065 (0.000)		65.768 (0.000)		78.342 (0.000)		81.657 (0.000)	
Kruskal-Wallis (tie-adj.)	4.8689* (0.0273)		50.9065 (0.000)		65.768 (0.000)		78.342 (0.000)		81.657 (0.000)	
van der Waerden	3.5654* (0.0509)		46.7637 (0.000)		58.554 (0.000)		73.431 (0.000)		79.447 (0.000)	

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