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NOVA SCHOOL OF BUSINESS & ECONOMICS

**Weak Form Market Efficiency: A Comparative Study**

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**Abstract**

This paper is a comparative study analyzing the efficiency of three different stock markets. Using data from the Casablanca Stock Exchange, Euronext Lisbon and the New York Stock Exchange, I look at the predictability of asset prices from 2002 to 2018. In the case of Morocco, I adapt the methodology to account for the institutional features of an emerging market by correcting daily returns for thin-trading and including a non-linearity term. The results show that all three markets are characterized by inefficient pricing during the whole period. I also divide the sample period into three sub-periods to track potential improvement in informational efficiency as a result of structural and institutional reforms of stock markets.

**Keywords**: Emerging Market, Inefficiency, Infrequent Trading, Non-Linearity

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## 1. Introduction

The past few decades have witnessed a relatively large growth in attention given to emerging economies. Equity markets in those economies have particularly garnered consideration from Western portfolio managers who are attracted to the possibility of earning higher yields and achieving international diversification. Naturally, empirical research on the efficiency and performance of these markets is compelling to many academics around the world.

The Efficient Market Hypothesis (EMH) is a foundational theory of modern financial literature since it asserts that an efficient market is one where asset prices reflect all available information and adjust to integrate new corporate and macroeconomic information in real time (Fama, 1970). EMH distinguishes between three types of efficiency. First, in the weak-form efficiency, asset prices reflect all available information in trading data, trading volumes and past prices. This means that abnormal yields cannot be achieved by looking at past prices or performing any kind of technical analysis. Second, in semi-strong efficient markets, public information disclosed by the company is incorporated in prices and this means that both fundamental and technical analysis cannot aid in capturing abnormal returns. Finally, in the strong form of market efficiency, asset prices incorporate both public and private information, meaning that excess returns cannot be realized by using any type of information.

Furthermore, the EMH implicitly presumes that investors follow a certain rationality in their decisions. This rationality is mainly characterized by risk aversion, timely response to new and relevant information and unbiased market predictions. However, in the context of the Middle East and North Africa (MENA) region, especially for exchanges that are relatively new and undeveloped, unexperienced investors do not typically demonstrate this rationality. Thaler (1993) found that investors act in a manner more sensitive to losses than to gains. In this case an investor may behave in an inconsistent and irrational way. Additionally, unsophisticated investors do not respond to news in a timely manner eventually leading to a non-linear behaviour of prices (Schatzberg and Reiber, 1992).

Informational efficiency is key to both MENA equity investors and corporations. However, if the empirical evidence is to be rightly interpreted and assessed, it is essential for the statistical methodology to be adapted based on the trading conditions and other institutional peculiarities in that particular market. Emerging stock markets such as the Casablanca Stock Exchange are typically considered to have low liquidity, thin trading, as well as fewer well-informed investors. It is also plausible that infrequent trading and non-linearity of returns can alter the results by introducing bias into the empirical study. Since the indices of undeveloped markets may not represent the true value of the composite securities, there could be a predisposition towards the rejection of the EMH.

In this paper, using data from the Casablanca Stock Exchange, Euronext Lisbon and the New York Stock Exchange, I evaluate the efficiency of an emerging market in contrast with the exchanges of two mature economies, taking into account institutional idiosyncrasies of the former, namely infrequent trading and non-linearity. The implemented econometric tools allow the identification of potential non-linearity and correction for any thin trading. Moreover, I investigate the efficiency of the market over time in order to observe any possible maturing and the effects of regulatory changes in the market. The second part of the paper is a comparative study where I apply the same methodology to test the efficiency of more established and mature indices, namely Euronext Lisbon's PSI-20 and NYSE's S&P 500, to note any difference in findings between three relatively different markets.

## 2. Review of the Literature

### 2.1. <u>Efficiency of Developed Capital Markets</u>

Empirical work on the efficiency of developed markets has been divided since its start in the early 20th century. Early studies on efficiency and the Martingale model done by Osborne, Fama, Countner and many others laid the groundwork for statistical evidence that equity price changes are random in their nature and fundamentally unpredictable. However, the discovery of many seasonal, fundamental and technical anomalies, and the rise of behavioural finance has sparked a debate among finance scholars. In their paper "Stock Market Prices do not Follow Random Walks", Lo and MacKinley (1998) reject the EMH and put forth the Adaptive Market Hypothesis (AMH). Singal (2004) aggregates trading anomalies in the US stock markets and constructs trading strategies that generate abnormal returns. Markets can be inefficient for many reasons including trading costs, limits of arbitrage and the cost and reliability of information. These inefficiencies lead to patterns and return predictability in developed markets as well as emerging markets (Risso, 2008).

Studies on Portugal's PSI-20 have also yielded ambiguous evidence for the efficient market hypothesis. Dias et al. (2002) find evidence confirming the random walk hypothesis using an Augmented Dickey–Fuller test (ADF) but find no such evidence using the variance ratio test. Worthington and Higgs (2004) test the efficiency of many European indices and find conflicting results for Portugal. Using daily data from 1995 to 2003, they do not find strong evidence to reject the random walk hypothesis.

### 2.2. Efficiency of Emerging Capital Markets

Efficiency of stock exchanges in emerging economies has been widely researched in the last decades. However, the weak-form efficiency is still a topic of debate since many empirical studies reach conflicting and inconclusive results. Ojah and Karemera (1999) find the Latin American exchanges to be weak-form efficient. However, Urrutia (1995) finds the same markets, in the same period, to be inefficient using the variance ratio test and thus rejects the random walk hypothesis (RWH). Antoniou and Ergul (1997) reject the RWH in the first years of the Istanbul Stock Exchange but find that the market gains more efficiency over time, as the effects of structural improvements take place. In Arab markets, Omran and Farrar (2001) reject the RWH for countries of the Arab world and find seasonal trading anomalies in the returns.

Recent literature on emerging markets efficiency takes into consideration institutional structures of each equity market to find the true underlying value of its index. One of the idiosyncrasies tackled is infrequent trading. Typically, emerging markets are characterized by thin trading which introduces artificial autocorrelations into the results (Oprean, 2012). Abraham, Seyyed and Alsakran (2002) analyze the efficiency of three emerging markets (Kuwait, Jordan and Saudi Arabia) characterized by thin trading and find them to be inefficient. However, the markets move towards efficiency when index returns are corrected for infrequent trading.

For a market to be efficient, it should be characterized by an independence of successive price changes. Moreover, for this linear relation to exist, it is assumed that investors follow a certain rationality in their decisions. This rationality is characterized by risk aversion, timely response to new and relevant information and unbiased market predictions (Antoniou, 1997). However, emerging markets typically have a non-linear information behaviour that introduces serial dependence in time series returns (Oprean, 2012). Hassan, Al-Sultan, Al-Saleem (2003) find the stock exchange of Kuwait to be efficient after correcting for infrequent trading and considering the non-linearity of returns.

### 2.3. Testing for Efficiency in Emerging Markets

#### *2.3.1. Tests for Independence*

The weak form of efficiency states that rates of return of securities are independent and that a rational investor cannot realize abnormal returns given that. Market efficiency also implies the absence of autocorrelation since information is impounded immediately and has no influence on current prices. One statistical measure to test independence is serial correlation. This method describes the correlation between returns of a random process. However, research has shown that this method shows no autocorrelation, expect in portfolios of relatively small stocks (Oprean, 2012). Alternatively, the Runs test is used, and it is a non-parametric test to detect serial dependence in random movements. A run is a sequence of symbols such as + or – or 0. The null hypothesis is that consecutive return variations of an index are independent and uncorrelated during the sample period.

One popular approach was proposed by Lo and MacKinley (1988) called the overlapping variance ratio test. It examines the randomness of a time series by comparing variances of return differences calculated over different periods of time. Assuming the series follows a random walk, the variance of a $q$-period difference variance should be $q$-times the variance of the one-period difference (Abuzarour, 2006).

### 2.3.2. *Correcting for Thin-Trading*

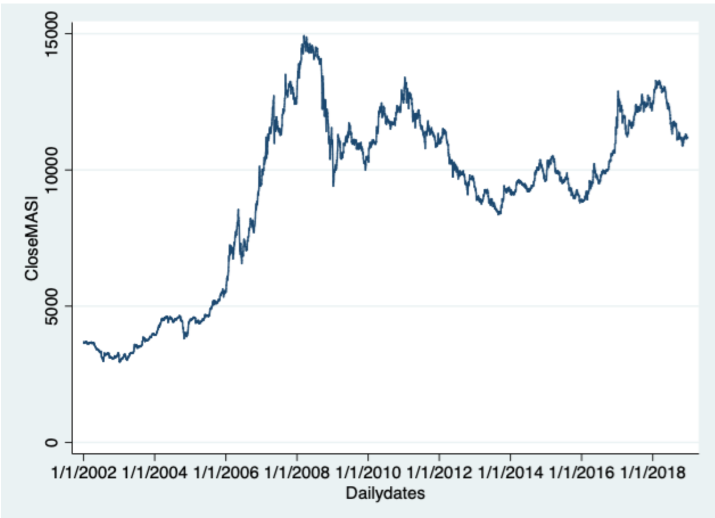
Thin trading occurs when securities are not traded every successive interval. The issue of thin trading, or non-trading, is that the value of asset cannot be accurately observed during a period if it is not traded during the whole period. Since the value of indices is computed based on the last observed transaction prices of its component stocks, the index price does not reflect the underlying value of the portfolio. Thin trading creates serial correlation that suggests dependence and predictability. However, literature suggests that dependence created by non-trading is a statistical illusion that leads in some cases to the false rejection of the random walk hypothesis.

To correct for infrequent trading, Miller, Muthuswamy, and Whaley (1994) suggest that a moving average model of non-trading days can be estimated, and returns can be adjusted accordingly. However, given the difficulty of estimating the number of non-trading days, Miller suggests that similar results can be achieved by using a autoregressive model AR(1). They also find that correcting for thin trading reduces the negative correlation of returns.

## 3. Methodology and Data

### 3.1. Overview of the Moroccan All Shares Index (MASI)

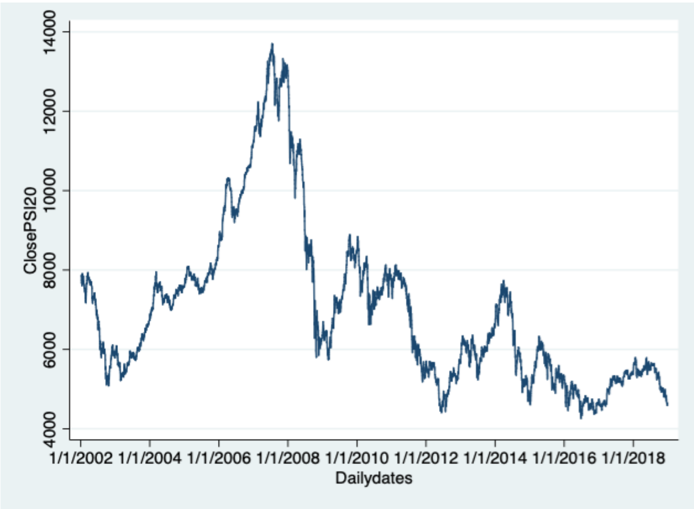
The Casablanca Stock Exchange (CSE) was established in 1929 as a clearing house. Since its inception, the stock exchange has witnessed substantial growth both in size and liquidity. In 1967, major structural changes and reforms provided Morocco's stock exchange with solid legal and technical framework. In 1993 more reforms followed, as all listed companies were forced to comply with the newly implemented transparency measures by publishing their yearly accounting and financial statements. Even though the CSE has been slow to develop in the last few years, with relatively few Initial Public Offerings (IPOs), reforms and legislation have sparked the interest of investors, which in turn enabled the CSE to quadruple in size in the recent years. However, Belkahia (2005) finds that despite a high level of investor interest and involvement, listed companies do not release their accounting information properly and executives fail to disclose their participation in any trades or transactions related to the company. These failures in corporate governance lead to market inefficiencies and non-linearity of returns. The Moroccan All Shares Index (MASI) was established in 2002 and encompasses all the shares traded in the exchange.




*Closing Prices for the CSE (2002-2018)*

### 3.2. Overview of PSI-20

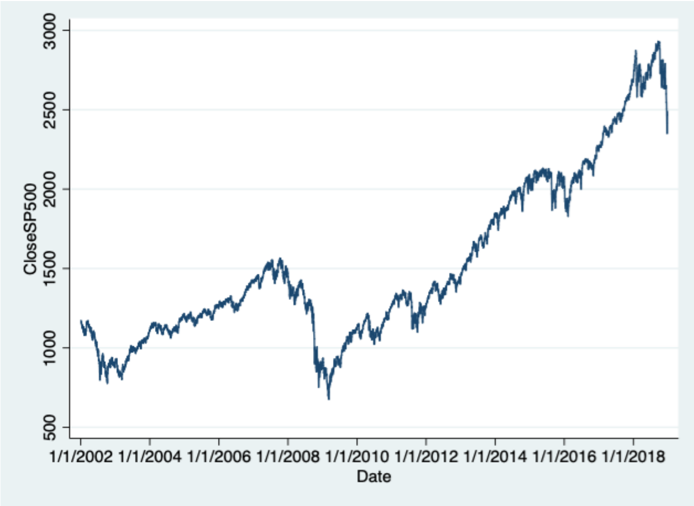
The Portuguese Stock Exchange Index 20 (PSI-20) was established in 1992 at 3000 points and reached a peak of 14,000 points in the late 1990s. The index tracks prices of the twenty largest market capitalizations and highest share turnover companies in Portugal. It is one of the main indices of the pan-European group Euronext, along with France’s CAC 40, Belgium’s BEL20 and the Netherland’s AEX. The exchange is regulated by the Portuguese Securities Market Commission (CMVM), which monitors compliance with rules and regulations in capital market activities and corporate governance.




*Closing Prices for the PSI-20 (2002-2018)*

### 3.3. Overview of the S&P 500

Standard & Poor's 500 Index (S&P 500) is a market capitalization-weighted index and is regarded as the most important indicator of the overall US equity market performance. The index was established in 1957 and has a market capitalization of over $26 billions as of June 2019. The index tracks the performance of 500 companies that are chosen based on their market capitalization, liquidity and representation of their respective industry. The index is part of the New York Stock Exchange and is regulated by the Securities Exchange Commission (SEC).




*Closing Prices for the S&P500 (2002-2018)*

### 3.4. Methodology and Data

Linearity and non-linearity in returns refers to the feedback mechanism after a price movement. The occurrence of non-linearity could be explained by the psychological biases of investors. DeBondt and Thaler (1985) find that investors overact to bad news and underreact to good news. Non-linearity can also be attributed to market imperfections. For instance, investors may choose not to trade on newly available information because of transaction costs. In other words, investors might trade only when it is lucrative, which results in a lagged response to information and a clustering of price returns. Naturally, these complexities do not always result in a linear feedback mechanism.

Accounting for these peculiarities, it would be unreasonable to use conventional tests based on linear models such as autocorrelation and the variance ratio test to study efficiency in emerging markets. I consider a logistic map for a series based on the following equation, which captures feedback mechanisms:

$$X_t = aX_{t-1}(1-X_{t-1}) = aX_{t-1} - aX_{t-1}^2 \tag{1}$$

The second term in the equation is a negative non-linear feedback that competes with the first term to stabilize the series. In self-regulatory markets, after a price deviates in high proportion from its true value, market mechanisms are expected to bring the asset price back to its true value. If the feedback is flawed and non-linear, the self-regulatory forces of a given market might not correct the asset price back to its true fundamental value.

To account for any non-linearity in the MASI, PSI-20 and S&P 500 the following equation is estimated:

$$R_t = \alpha_0 + \alpha_1 + R_{t-1} + \alpha_n R_{t-1}^n + \varepsilon_t \tag{2}$$

Where R is the daily return of the index at time *t,* and n = 2,3. For the market to be informationally efficient, the three coefficients need to equal zero, $\alpha_0 = \alpha_1 = \alpha_n = 0$, and the error term needs to be a white noise process.

As mentioned above, thin trading can be corrected using a method proposed by Miller, Muthuswamy, and Whaley (1994) where an autoregressive model AR(1) is used. To do so, the following equation is estimated:

$$R_t = a_1 + a_2 R_{t-1} + e_t \tag{3}$$

Using the residuals from the previous equation, I estimate the following:

$$R_t^{\mathrm{adj}} = \frac{e_t}{(1-a_2)} \tag{4}$$

Where $R^{adj}_t$ is the daily return at time *t* adjusted for infrequent trading. A common assumption of time-series analysis is that estimated parameters are constant over-time. While this assumption might hold for markets with high liquidity, in the case of the CSE, the equation will be estimated recursively. One method to examine the consistency of the model parameters is to compute the estimates recursively over a moving window with a fixed sample size through the whole sample. If the parameters are time-invariant, the rolling estimates will not vary significantly. For the S&P 500 and the PSI-20, there will be no correction for infrequent trading since the two indices include only the most traded shares of the market.

The data for this study consists of daily returns of the MASI Index (Moroccan All Shares Index), the PSI-20 and the S&P 500 from 2002 to 2018, retrieved from the Bloomberg Terminal Database. The choice of the MASI index over the MADEX index (Moroccan Most Active Shares Index) is relevant for two reasons: first, it incorporates all the publicly traded companies; second, the composition of the index helps to identify the effect of institutional reforms and the maturing of the stock exchange as a whole over the years. Below is a summary statistics table of the three indices:

| Statistics | MASI | PSI20 | S&P500 |
|---|---|---|---|
| Number of Stocks | 75 | 20 | 505 |
| Mean | 0.02633 | -0.00815 | 0.02020 |
| Median | 0.03343 | 0.02738 | 0.05885 |
| Range | 11.2807 | 20.5751 | 20.4267 |
| Standard Deviation | 0.74864 | 1.17887 | 1.18074 |
| Skewness | -0.41336 | -0.26866 | -0.25923 |
| Kurtosis | 9.85682 | 9.80891 | 13.1189 |
| Minimum Value | -6.81719 | -10.3791 | -9.46951 |
| Maximum Value | 4.46354 | 10.1959 | 10.9572 |

*Table 0: Summary Statistics of the MASI, PSI-20 and the S&P500*

## 4. Empirical Results

*Table 1a* shows the estimated coefficients for the linear equation (3) during the whole sample period for unadjusted index returns of the MASI. The coefficients are significant for any conventional significance level and I reject the null hypothesis that the Casablanca Stock Exchange is informationally efficient. *Table 1b* shows the same results for all coefficients of equation (2) even after accounting for non-linearity. Based on the Portmanteau White Noise

Test, the error terms of both estimated equations follow a white noise process, meaning that they are uncorrelated, have a finite variance and have a mean of zero.

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t}$$

*Random-walk model for unadjusted returns without non-linearity terms (MASI)*

| $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|
| 0.01900<br>(1.70) | 0.27963<br>(10.12) | 37.1940 | 0.5973 |

*Table 1a*

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R^2{}_{t-1} + \alpha_3 R^3{}_{t-1} + \varepsilon_t}$$

*Random-walk model for unadjusted returns with non-linearity terms (MASI)*

| $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|
| 0.01804<br>(1.57) | 0.28665<br>(10.55) | 0.00109<br>(0.07) | -0.00122<br>(-0.30) | 37.2558 | 0.5945 |

*Table 2b*

After adjusting for infrequent trading using the method proposed by Miller, Muthuswamy, and Whaley (1994), I re-estimate equation (3) and the results are shown in Table 2a. Even after adjusting the returns, the efficiency of the MASI does not improve and the error term no longer has white noise properties. This confirms that adjustments are necessary in emerging markets in order to draw to appropriate conclusions. *Table 2b* confirms that the Casablanca Stock Exchange is not informationally efficient even after introducing non-linearity terms. Results from *Tables 1* and *2* show that there is a predictability in the returns of the MASI and suggest that the random walk hypothesis is rejected for the whole sample period.

$$\mathbf{R^{adj}_t = \alpha_0 + \alpha_1 R^{adj}_{t-1} + \varepsilon_t}$$

*Random-walk model for adjusted returns without non-linearity terms (MASI)*

| $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|
| 0.01728<br>(27.14) | 0.50954<br>(41.30) | 1161.6056 | 0.0000 |

*Table 2a*

$$\mathbf{R^{adj}_t = \alpha_0 + \alpha_1 R^{adj}_{t-1} + \alpha_2 R^{2(adj)}_{t-1} + \alpha_3 R^{3(adj)}_{t-1} + \varepsilon_t}$$

*Random-walk model for adjusted returns with non-linearity terms (MASI)*

| $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|
| 0.04875 (12.06) | -1.4490 (-6.29) | 33.0746 (8.55) | -158.592 (-8.22) | 972.0384 | 0.0000 |

*Table 2b*

I divide the sample period into three sub-periods to note if there is any improvement or change in market efficiency. Based on *Tables 3a* and *3b,* I conclude that the regulatory and institutional changes implemented during the late 1990s were not sufficient to improve efficiency and eliminate predictability. All coefficients are significant during all three sub-periods for any conventional significance level. I find similar results after including non-linearity terms.

$$\mathbf{R^{adj}_t = \alpha_0 + \alpha_1 R^{adj}_{t-1} + \varepsilon_t}$$

*Random-walk model for adjusted returns without non-linearity terms (MASI)*

| Year | $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|
| 2002 - 2007 | 0.01746 (16.21) | 0.50331 (23.83) | 1190.4799 | 0.0000 |
| 2008 - 2013 | 0.01745 (16.19) | 0.50608 (24.30) | 1177.5368 | 0.0000 |
| 2014 - 2018 | 0.01684 (14.55) | 0.52156 (23.58) | 1108.3207 | 0.0000 |

*Table 3a*

$$\mathbf{R^{adj}_t = \alpha_0 + \alpha_1 R^{adj}_{t-1} + \alpha_2 R^{2(adj)}_{t-1} + \alpha_3 R^{3(adj)}_{t-1} + \varepsilon_t}$$

*Random-walk model for adjusted returns with non-linearity terms (MASI)*

| Year | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|---|
| 2002 - 2007 | 0.04913 (7.15) | -1.48080 (-3.78) | 33.8488 (5.12) | -163.831 (-4.96) | 989.6044 | 0.0000 |
| 2008 - 2013 | 0.05004 (7.32) | -1.5299 (-3.93) | 34.5616 (5.29) | -166.63 (-5.12) | 986.3487 | 0.0000 |
| 2014 - 2018 | 0.04667 (6.34) | -1.30768 (-3.13) | 30.2185 (4.32) | -141.709 (-4.08) | 929.8509 | 0.0000 |

*Table 3b*

Table 4a shows the estimated coefficients for the unadjusted returns of the PSI-20, which yields the same results as *Table 1a.* Even though the error term follows a white noise process, I cannot accept the null hypothesis that the market is informationally efficient. As is the case with the Casablanca Stock Exchange, the PSI-20 does not improve in efficiency even after including non-linearity terms.

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t}$$

*Random-walk model for returns without non-linearity terms (PSI-20)*

| $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|
| -0.01134 (-0.64) | 0.08307 (3.31) | 42.8559 | 0.3497 |

*Table 4a*

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R^2{}_{t-1} + \alpha_3 R^3{}_{t-1} + \varepsilon_t}$$

*Random-walk model for returns with non-linearity terms (PSI-20)*

| $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|
| -0.02709 (-1.35) | 0.10576 (4.24) | 0.01123 (1.07) | -0.00140 (-0.86) | 41.8530 | 0.3904 |

*Table 4b*

*Tables 5a* and *5b* show the estimated coefficients for equation (3) and (2) during the three sub-periods. The market is only efficient for the sub-period 2008 to 2013 before and after accounting for non-linearity. In July 2007, the index composition process changed to only include companies with a trading velocity of at least 10%. Trading velocity refers to the fraction of a company's shares that exchanged hands over the previous year. This process aimed to enhance the market liquidity of the index and is still implemented today. This was a major change in the structure of the index, and it could explain the improved efficiency from 2008 to 2013. Another reason pertaining to this improvement would be the country's recovery from financial crisis and exit from the austerity policies adopted in 2010 (Dias et al., 2002). The error terms follow a white noise process in both the linear and non-linear equations.

$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t}$

*Random-walk model for returns without non-linearity terms (PSI-20)*

| Year | $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|
| 2002 - 2007 | 0.02974<br>(1.48) | 0.07706<br>(2.18) | 42.7094 | 0.3555 |
| 2008 - 2013 | -0.04203<br>(-1.15) | 0.05681<br>(1.46) | 43.8151 | 0.3129 |
| 2014 - 2018 | -0.02327<br>(-0.72) | 0.13282<br>(3.37) | 52.2682 | 0.0926 |

*Table 5a*

$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R^2{}_{t-1} + \alpha_3 R^3{}_{t-1} + \varepsilon_t}$

*Random-walk model for adjusted returns with non-linearity terms (PSI-20)*

| Year | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|---|
| 2002 - 2007 | 0.03647<br>(1.72) | 0.13464<br>(3.26) | -0.01847<br>(-0.77) | -0.01707<br>(-2.09) | 196.5840 | 0.0000 |
| 2008 - 2013 | -0.07359<br>(-1.80) | 0.08252<br>(2.03) | 0.01516<br>(1.13) | -0.00123<br>(0.65) | 42.1154 | 0.3795 |
| 2014 - 2018 | -0.03150<br>(-0.89) | 0.15053<br>(3.13) | 0.00511<br>(0.27) | -0.00178<br>(-0.29) | 49.7446 | 0.1390 |

*Table 5b*

As for the NYSE's S&P500, *tables 6a* and *6b* show an inefficiency over the whole period with the error terms not having white noise properties. This shows that even highly liquid and mature markets may not be fully efficient. Moreover, the Q-statistics of the Portmanteau White Noise test show that error terms are correlated and do not have a mean of zero.

$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t}$

*Random-walk model for returns without non-linearity terms (S&P500)*

| $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|
| 0.01929<br>(1.06) | -0.08707<br>(-3.13) | 83.5147 | 0.0001 |

*Table 6a*

$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R^2{}_{t-1} + \alpha_3 R^3{}_{t-1} + \varepsilon_t}$

*Random-walk model for returns with non-linearity terms (S&P500)*

| $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|
| 0.00132<br>(0.07) | -0.04719<br>(-1.83) | 0.01178<br>(1.59) | -.00203<br>(-2.61) | 76.6583 | 0.0004 |

*Table 6b*

To track changes in efficiency, I repeat the same process over the three sub-periods. The tables below show that the market is highly efficient only from 2014 to 2018, even though the error terms do not display white noise properties. This makes sense given that the S&P500 has reached a record-high level of returns and liquidity in that period.

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \varepsilon_t}$$

*Random-walk model for returns without non-linearity terms (S&P500)*

| Year | $\alpha_0$ | $\alpha_1$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|
| 2002 - 2007 | 0.01646<br>(0.63) | -0.06886<br>(-1.91) | 87.6823 | 0.0000 |
| 2008 - 2013 | 0.01688<br>(0.43) | -0.11415<br>(-2.72) | 80.8944 | 0.0001 |
| 2014 - 2018 | - 0.02388<br>(1.00) | -0.00825<br>(-0.18) | 115.3764 | 0.0000 |

*Table 7a*

$$\mathbf{R_t = \alpha_0 + \alpha_1 R_{t-1} + \alpha_2 R^2{}_{t-1} + \alpha_3 R^3{}_{t-1} + \varepsilon_t}$$

*Random-walk model for adjusted returns with non-linearity terms (S&P500)*

| Year | $\alpha_0$ | $\alpha_1$ | $\alpha_2$ | $\alpha_3$ | Portmanteau (Q) statistic | Probability |
|---|---|---|---|---|---|---|
| 2002 - 2007 | 0.00988<br>(0.34) | -0.08201<br>(-2.05) | 0.00627<br>(0.28) | 0.00203<br>(0.33) | 97.6029 | 0.0000 |
| 2008 - 2013 | -0.01603<br>(-0.41) | -0.05535<br>(-1.28) | 0.01270<br>(1.57) | -0.00201<br>(-2.50) | 75.4878 | 0.0006 |
| 2014 - 2018 | 0.02303<br>(0.93) | -0.05181<br>(-1.09) | 0.00599<br>(0.24) | 0.00976<br>(1.23) | 276.9091 | 0.0000 |

*Table 7b*

## 5. Conclusion

This paper is a comparative study that investigates weak-form market efficiency for three different stock exchanges. I evaluate the random walk hypothesis for Morocco's Casablanca Stock Exchange, which operates in an emerging economy. This paper differs from others in that it accounts for institutional idiosyncrasies. In particular, I adjust for infrequent trading that characterizes emerging economies, and take into account non-linearity of returns. Conventional tests such as autocorrelation, runs tests and the variance ratio test, which are linear in nature, fail to incorporate these features and often lead to a false acceptance or rejection of the random walk hypothesis. However, even after correcting the returns and including non-linearity terms, I reach the conclusion that the MASI is informationally inefficient. This study also divides the sample into three sub-samples to track changes or improvements in efficiency following structural changes. I conclude that the market's regulating bodies need to implement more reforms in order to incentivize trading and initial public offerings in Morocco.

To contrast the results of the study on an emerging market, I repeat the same methodology for a relatively more advanced stock exchange: Euronext Lisbon. For the same period, the PSI-20 is not efficient but displays white noise properties. After accounting for non-linearity, the market does not improve in efficiency. However, when estimating coefficients in the sub-periods, I find that the market is efficient from 2008 to 2013. I hypothesize that this is due to a change in the stock exchange's trading structure and the country's emergence from financial crisis.

To contrast the previous results with a more mature and advanced economy, I repeat the calculations for the NYSE's S&P500 and surprisingly find a lack of efficiency during the whole sample period. However, the market becomes more efficient from 2014 to 2018 which is expected given the high levels of liquidity and performance of the stock market in that period.

In conclusion, this study adds to the mixed results of previous studies in that I cannot reach a conclusive answer on weak-form informational efficiency. Further investigation should be conducted to detect the potential presence of market anomalies and see if they persist in the sub-periods that show efficiency in the PSI-20 and the S&P500.

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