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ARTÍCULO

Evaluation of the adaptive market hypothesis as an evolutionary perspective on market efficiency: Evidence from the Moroccan Stock Market

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Abstract: Firstly, this paper is distinctive in that it employs a lengthy sample period that provides a comprehensive view of how market efficiency has evolved throughout the annals of the Moroccan stock market. This paper aims to evaluate both the efficient market hypothesis (EMH) and the adaptive market hypothesis (AMH) and the time-varying return predictability of the MASI. It predominantly uses the daily closing price of the MASI (Moroccan all-share index) from January 2007 to December 2021. In addition, eight distinct assessments representing primarily two distinct categories (linear and non-linear) have been utilized to determine the level of market efficacy in this study. Consequently, following the adaptive market theory, the findings of this study indicate periods of efficiency followed by periods of inefficiency. In addition, we discover evidence that the stock market's economic foundations and volatility are related to return predictability.

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1. Introduction

Fama, as he is known, was the first person to be credited with coining the term "market efficiency," emphasizing the significance of multiple concurrent price shifts in a successful securities market, where the essential data regarding the stock price has been reflected in the market price and all new data is immediately incorporated into pricing.

Following this, Market efficiency is typically classified into three potent forms, namely the weak form, the semi-strong form, and the strong form. Following this, the effectiveness of the feeble state has become the focus of most studies and discussions in the relevant field of study. In addition, a market's efficacy is shown to be inefficient if actual prices fully reflect all information included in previous prices. Fama (1965, 1970). Similarly, stock returns should follow a random walk, resulting in serially uncorrelated prices. Therefore, historical stock prices can't predict future stock price fluctuations. A trader cannot accomplish anomalous returns by relying solely on historical pricing.

In the meantime, the empirical findings yielded contradictory results regarding the viability of this hypothesis, leaving the debate between behavioral finance and the EMH completely open. In addition, Fama (1998) argued that the abnormalities reported in numerous studies, which are not permanent and disappear if the paradigm, the specimen, or the data set is altered, were consistent with the EMH.In addition, with the Adaptive Market Hypothesis (AMH), Lo (2004, 2005) proposed an alternative market theory to the EMH, stating that "it can be regarded as a new variant of the EMH based on evolutionary principles. "In addition, this strategy employs Simon's (1955) notions of limited rationality and satisficing to integrate the EMH with behavioral substitutes. Accordingly, Lo (2004) asserted that numerous behavioral fallacies in finance are compatible with an evolutionary model in which individuals learn to adapt to changing conditions. Consequently, the degree of market efficiency is determined by the impact of these selection pressures on banking firms and market participants. The following year, he added the AMH's fundamental concepts, asserting that people act in their self-interest, make mistakes, and learn from them, compete to adapt, and innovate, natural selection forms the market ecosystem, and evolution controls market dynamics.

Similarly, subsequent scientific research on the AMH focuses on determining whether this conceptual model explains market behavior better than the EMH. Lo (2005) examined the SP index for sixteen years (1987–2003) and found that AMH provides a more precise explanation for the behavior of stock gains and that there is a periodic pattern over time. Lekhal and El Oubani (2020) have examined the evolution of the Moroccan stock market from 2006 to 2019 to investigate the AMH on the Casablanca stock exchange. They have discovered that the AMH's efficacy level fluctuates over time. In addition, from January 1992 to September 2019, they analyzed the evolution of efficiency grade using rolling windows for both linear and non-linear evaluations. These tests demonstrate that the efficacy level fluctuates over time. In addition, their findings are consistent with the AMH paradigm, which has been established to explain the behavior of emerging markets more effectively than the Efficiency Market Hypothesis (EMH).

Moreover, the validity of the random walk hypothesis has significant implications for academics, businesspeople, and government officials. Intellectuals are frequently concerned with the behavior of stock prices and common return-risk systems, such as the capital asset pricing model, whose foundation relies on random or normal walk assumptions. Investors must develop trading strategies that account for certain characteristics of prices implied by random walks or short-term persistence with long-term reversion to the mean. Similarly, emergent markets are typically characterized by low trading frequency and volume and the ease with which some market participants manipulate prices. In addition, stock markets are considered inefficient if accurate information is not immediately and entirely reflected in asset prices. When the inefficiency of a market is demonstrated, the pricing mechanism does not guarantee the efficient allocation of capital within an economy. Additionally, it may have adverse effects on the economy. Demonstrating inefficiency could prompt financial authorities to take serious action and implement the necessary reforms to address the issue.

A second important application of the AMH in finance is the scheduling of adopting effective investment methods as profit opportunities change over time. According to an evolutionary perspective of the market, opportunities to accomplish anomalous yields occasionally occur but disappear as soon as they are exploited. In addition, the market environment influences the success of these approaches. Thus, the AMH validates the active management of the portfolio, where numerous studies have focused on analyzing the profitability of investment strategies, in contrast to the EMH, which asserts that active management is ineffective and cannot outperform the "buy-and-hold investment approach."

Thus, by examining the primary index of the Moroccan stock market and determining whether its evolution is consistent with the AMH from January 2007 to December 2021, during which we conducted the research detailed here, we can determine whether this research was completed successfully. Consequently, this paper aims to highlight the market efficiency dynamics. In addition, our work was the first to evaluate the EMH and AMH using linear and non-linear assessments to obtain a deeper understanding of the evolution of the efficiency level.

These findings lend credence to the theory that financial markets undergo cycles of efficiency and inefficiency. In addition, they highlight significant macroeconomic events, making it simpler to identify periods of inefficiency. In general, the findings are consistent with the AMH, and it appears that the level of efficacy corresponds with external events that significantly impact the financial market.

Consequently, this document is organized into four major sections: The paper's first section discusses the AMH literature evaluation. The second section contains a data description. The third chapter also describes the methodologies used in the empirical investigation. The results and general conclusions are presented in the fourth and final sections.

2. Review of the Literature

Throughout this investigation, the EMH's weak form efficiency was evaluated as coherence using various methods, including the variance ratio and the run test. On the question of whether financial markets are efficient, there appears to be no consensus. Various analyses suggest that the stock returns of many industrialized and developing economies follow a random walk (Chow et al., 1993; Cheung and Coutts, 2001; Fama, 1970; Poon, 1996; Tabak, 2003). This research has shown, however, that financial markets are somewhat predictable and inefficient (Hoque et al., 2007; Huang, 1995; Mills, 1993). Accordingly, Moroccan research on the efficacy of the Casablanca stock exchange did not begin until the late 1990s, with Derrabi (1998, 1999), El M'Kaddem, and El Bouhadi (2003) serving as examples. Most of these studies have provided evidence that the stock market is efficient in its current state. In addition, the Casablanca Stock Exchange (hereafter referred to as the CSE) does not contain many notable articles.

In addition, Smith et al. (2002) investigated the applicability of the random walk assumption in several countries, including Morocco, Kenya, Botswana, Zimbabwe, Egypt, Mauritius, and South Africa. Consequently, the multiple variance ratio findings indicate that the markets of all the nations mentioned above, except for South Africa, are inefficient in their current state. Using the GARCH-M model, Appiah-Kusi and Menayah analyzed the Weak-Form efficacy in the weekly price series of eleven African stock market indices in 2002. Compared to the stock markets in Ghana, Botswana, Nigeria, the Ivory States, South Africa, and Swaziland, the stock markets in Morocco, Mauritius, Kenya, Egypt, and Zimbabwe have a poor Form performance. Jeffers and Smith used the GARCH technique with time-varying variables to investigate the performance of the stock markets in Mauritius, South Africa, Nigeria, Kenya, Egypt, and Morocco in 2005. Therefore, the Data for the entire research period only demonstrate the efficiency of the South African stock market. This indicates that by the conclusion of the research, the stock markets in Morocco, Nigeria, and Egypt were undeniably effective. The RWH's applicability in the five recognized Middle Eastern markets of Morocco, Jordan, Turkey, and Egypt has also been investigated.

Consequently, the observations of Omran and Farrar (2006) contradict the RWH for all markets. In addition, according to Worthington and Higgs (2006), these studies have examined the weak-form market efficiency of 27 emerging markets, including three African nations (Egypt, South Africa, and Morocco), ten Asian countries (India, Taiwan, Indonesia, China, Korea, Malaysia, Pakistan, Thailand, Sri Lanka, and the Philippines), and four European nations (Russia, Poland, the Czech Republic, and finally Hungary). Specifically, there are three more countries in the Middle East, namely Turkey, Israel, and Jordan, and seven more in Latin America, namely Brazil, Venezuela, Chile, Peru, Mexico, Colombia, and Argentina. In addition to employing the serial correlation coefficient, runs tests, Augmented Dickey-Fuller, Phillips-Perron, the Kwiatkowski, Phillips, Schmidt, and Shin unit root analyses are utilized to analyze daily market returns for random variables. Most developing markets are characterized by weak-form inefficiency, as indicated by the serial correlation and run testing methods.

In contrast, the results of the strictest multiple variance ratio test frequently resemble those of these two methods. Similarly, Francesco Guidi et al. (2009) used parametric and non-parametric analysis to discover proof of the prevalence of weak-form efficiency in several developing African equity markets. In light of this, the statistics indicate that none of the sectors, except the South African stock market, exhibit random walks. Gyamfi et al. (2016) supported the EMH in Tunisia, Kenya, Mauritius, South Africa, Morocco, Botswana, and Egypt.

Accordingly, Hiremath and Narayan (2016) analyzed the Indian stock exchange and determined that the inefficiency is attributable to significant macroeconomic events. Khuntia et al. (2018) support that macroeconomic fluctuations affect market efficiency. Similarly, Khuntia and Pattanayak (2018) evaluated the AMH in the context of digital currencies such as Bitcoin using a time-varying technique. Their conclusions concur with Lo (2004), who emphasized that the bitcoin market passes through various phases. Regarding the outcomes of other markets, the authors demonstrate that periods of inefficiency coincide with significant political and economic events. In a similar vein, Tuyon and Ahmad (2016) analyze the efficiency of the Malaysian market alongside the various market regimes and stages of economic growth during the period of study between 1977 and 2014. After conducting AR and VR tests, they conclude that their results are consistent with the AMH. In addition, the Four assessments conducted by Trung and Pham Quang (2019) using the weekly returns from January 2005 to February 2019 demonstrate that primarily two Vietnamese financial markets exhibit an evolving temporal trajectory about return predictability. The results are in line with the AMH.In addition, Klc (2020) examined the Istanbul market's return predictability in the context of the AMH over six years (2013–2019). He concluded that regardless of the market's state, the stock market index's efficiency level remains constant over time and that the AMH is invalid for the Istanbul market.

3. Data

This investigation utilized the daily market index (MASI) price series obtained from the Bank Al Maghreb website. In addition, the data encompasses a decade (January 2007 to December 2017). The underlying data undergo a natural logarithmic transformation. Therefore, the daily return formula is as follows:

$$r_t = \ln(p_t) - \ln(p_{t-1}) = ln\left(\frac{p_t}{p_{t-1}}\right)$$

Where r_t represents the stock return at the time t, whereas p_t in addition to p_{t-1} refer to the stock prices at periods t and t-1.

4. Methodology

4.1 Serial Correlation of Returns

The relationship between a time series' past and future outcomes is known as auto-correlation. This method is also used to determine whether a series of random variables are independent or dependent, as Box and Pierce (1970) described. When a random process is applied to the MASI index results, the returns are similarly uncorrelated regarding the general delays. We conduct least-squares regressions on latencies 1 through 36 of the return series. The joint hypothesis that all serial coefficients (t) are simultaneously equal to zero can be tested using the Box Pierce Q-statistic, as shown below:

$$Q_{BP} = n\sum_{t=1}^{m}\hat{\rho}(t)$$

Where Q_{BP} refers to an asymptotical distribution as an X^2 with levels of freedom m. Then, n represents the number of observations. Besides, m is considered as the m maximum lag taken into consideration. It has been stated that the series is projected to follow a stochastic process, where we believe that the market is effective at the weak level concerning the statistical significance, with autocorrelations tests being infrequent.

4.2 Runs Test

The Wald-Wolfowitz runs test was developed for the first time by Abraham Wald and Jacob Wolfowitz, after whom it is commonly named. Bradley (1968) applies a non-parametric statistical test to the sample values to determine whether successive price changes are unrelated, as the null hypothesis suggests (the given sequence is arbitrary). In addition, note the runs, a series of consecutive price fluctuations with a nearly identical mark. For instance, the number of runs is determined by arranging the observations in ascending order of return above or below the mean return.

Moreover, if the return exceeds the average, each observation is denoted with a (1). Similarly, if the return is less than the average return, a zero (0) is indicated. Following the independence assumption, the actual and expected number of runs (R) runs (R) are added and evaluated. In contrast to its parametric counterpart, the serial correlation test of independence, the runs test does not require returns to be normally distributed.

Let n_0and n_1 be the number of returns with sign (0) and sign (1), respectively, in a sample of n observations, where n=n_0+n_1 The test statistic is approximately normally distributed for vast data sets.

$$Z = \frac{R - \mu_R}{\sigma_R} \approx N(0,1)$$

Where:

$$\mu_R = \frac{2n_0n_1}{n} + 1 \text{ and } \sigma_R = \sqrt{\frac{2n_0n_1 - (2n_0n_1 - n)}{n^2(n-1)}}$$

In addition, the null hypothesis is refuted because the return series exhibits random walk behavior when the expected number of runs significantly deviates from the observed number of runs R. A Z score is positive (negative) when the actual number of runs exceeds (falls short of) the expected number of runs. Moreover, this positive (negative) Z value indicates that the returns have a positive, i.e., negative, serial correlation (Abraham et al., 2002). Therefore, a positive autocorrelation indicates the predictability of short-term returns, whereas a negative autocorrelation indicates the predictability of long-term returns (Fama, 1988, and 1991). Its randomization approaches are 95%, so the null hypothesis is accepted if Z is 1.96.

4.3 Unit Root Tests

Because market price fluctuations are not arbitrary, the stock market demonstrates slight inefficiency. A unit root in the time series is required for a random process. The Phillips-Perron, Augmented Dickey-Fuller (ADF), and Kwiatkowski, Phillips, Schmidt, and Shin (KPSS) analyses, which were all utilized in the original study, can also be used to locate a unit root test in a series of price fluctuations in a succession of stock indexes.

4.4 The Augmented Dickey-Fuller (ADF)

This measure, referred to as the ADFT Test, is a standard statistical measure for determining whether a time series is stationary. It is considered stationary if neither the mean of a series nor its autocovariance is dependent on time. The assumption is that the (y) series follows an AR(p) process with the addition of a lagged difference (p) in (y) terms that is dependent on the test right-side regression. Additionally, the ADF generates a parametric adjustment for a correlation with a higher order. In addition, the ADF test employs the three models listed below.

$$\Delta y_t = c + bt + \delta y_{t-1} - \sum_{j=2}^{p} \beta_j \Delta y_{t-j+1} + u_t \qquad (1)$$

$$\Delta y_t = c + \delta y_{t-1} - \sum_{j=2}^{p} \beta_j \Delta y_{t-j+1} + u_t \qquad (2)$$

$$\Delta y_t = \delta y_{t-1} - \sum_{j=2}^{p} \beta_j \Delta y_{t-j+1} + u_t \qquad (3)$$

In the first model, Equation 1 with a consistent term c and also a trend term bt. Concerning equation number 2, the second model only has a constant component. In the third model, there are no intercepted terms of trend. About all three models, the lagged terms' number is represented in p, where u_t denotes white noise, and $H_0: \delta = 0$ denotes that the null hypothesis following the random process $H_1: \delta \neq 0$ is another hypothesis that is substitutive. Moreover, failing to dismiss H_0 suggests that the possibility that the series of time possesses the random walk features is not to be ruled out. In addition, we employ MacKinnon's (1994) critical values to establish the t-statistic's significance related to δ.

4.5 Phillips-Perron Test

Phillips and Perron (1987, 1988) and Phillips (1987) offered a different method for identifying the stationary of a series. Dickey and Fuller have modified the non-parametric test for this test. Moreover, there is a substantial difference between evaluating the unit root, the PP (Phillips-Perron), and the ADF test. Specifically, the two analyses' heteroskedasticity and error sequence correlation approaches diverge the most. In addition, the calculation below illustrates the tests involved in determining whether the PP test has progressed.

$$\Delta y_t = c + bt + \delta y_{t-1} + \emptyset y_{t-1} + u_t \qquad (1)$$

where u_t is I (0), which also can be characterized as heteroskedasticity. Therefore, the test of PP directly modifies the test statistics to account for any sequence correlation and heteroscedastic in the errors u_t of the test regression. The adjusted statistics $Z(\hat{\emptyset})$and $Z(t_{\hat{\emptyset}})$ are computed using the following equations.

$$Z(\hat{\emptyset}) = T.\hat{\emptyset} - \frac{T^6(\hat{\sigma}_\pi^2 - \hat{s}^2)}{24D_{xx}}$$

Where D_{xx} refers to a value defined by Bresson and Pirotte (1995).

$$\Delta y_t = c + \emptyset y_{t-1} + u_t \qquad (2)$$

Thus, the modified statistics $Z(\hat{\emptyset})$and $Z(t_{\hat{\emptyset}})$are given by:

$$Z(\hat{\emptyset}) = T.\hat{\emptyset} - \frac{T^2(\hat{\sigma}_\pi^2 - \hat{s}^2)}{\sum_{t-2}^{T}(y_{t-1} - \bar{y}_{-1})^2}$$

$$Z(t_{\hat{\emptyset}}) = \left(\frac{\hat{s}}{\hat{\sigma}_\pi}\right) t_{\hat{\emptyset}} - \frac{0.5.T(\hat{\sigma}_\pi^2 - \hat{s}^2)}{\left(\hat{\sigma}_\pi^2 \sum_{t-2}^{T}(y_{t-1} - \bar{y}_{-1})^2\right)^{1/2}}$$

Besides: $\bar{y}_{-1} = \frac{1}{T-1}\sum_{t-2}^{T} y_{t-1}\, e$

$$\Delta y_t = \emptyset y_{t-1} + u_t \qquad (3)$$

The statistics that are modified $Z(\hat{\emptyset})$and $Z(t_{\hat{\emptyset}})$are provided as:

$$Z(\hat{\emptyset}) = T.\hat{\emptyset} - \frac{0.5.T^2(\hat{\sigma}_\pi^2 - \hat{s}^2)}{\sum_{t-2}^{T} y_{t-1}^2}$$

$$Z(t_{\hat{\emptyset}}) = \left(\frac{\hat{s}}{\hat{\sigma}_\pi}\right) t_{\hat{\emptyset}} - \frac{0.5.T(\hat{\sigma}_\pi^2 - \hat{s}^2)}{\left(\hat{\sigma}_\pi^2 \sum_{t-2}^{T} y_{t-1}^2\right)^{1/2}}$$

Where:

$\hat{s}^2 = \frac{1}{T}\sum_{t-2}^{T} \hat{u}_t^2$,$\hat{\sigma}_\pi^2 = \hat{\sigma}^2 + \frac{2}{T}\sum_{T-1}^{1} w_{sl}$ and $w_{sl} = 1 - \frac{s}{l+1}$ the weight of the auto-covariance and $l = E\left(T^{1/4}\right)$

Therefore, the first model, Equation 1, has a constant term c and a term of trend bt. Equation 2, in the second model, has just a constant term. The third model has neither a trend component nor an intercept. Therefore, the statistics concerning PP $Z(\hat{\emptyset})$and $Z(t_{\hat{\emptyset}})$ happen to own similar distributions, which are asymptotic just as the t- statistic of ADF, and they also have a biased statistic that is normalized under the null hypothesis where $\emptyset = 0$. Furthermore, the tests PP are much more resistant to global heteroskedastic forms in the error term u_t than the ADF tests. Besides, it is unnecessary for the one who uses this test to identify the test regression's lag length, which is another benefit.

4.6 Kwiatkowski, Phillips, Schmidt, and Shin (KPSS)

Their assessment aims at deciding if the series of time is constant or nonconstant over a trend that is either linear or mean. A constant time series is one in which statistical features such as the variance and mean are invariable across time. In the test, the null hypothesis is represented by constant findings. The alternate test hypothesis can be changed with non-stationary data. Furthermore, unlike the other unit root tests, the KPSS test (1992) assumes the stationary of the series y_t under the null hypothesis. Moreover, the assessment of the KPSS uses residuals taken from the regression of OLS of y_t on the variables x_t which is exogenous.

$$y_t = x_t'\delta + u_t$$

The statistics concerning LM are provided as follows:

$$LM = \sum_{t=1}^{T} S^2 t \Big/ \sigma_t^2$$

Where σ_t^2 is an error variance estimator; As a result, the latter estimator σ_t^2 may include autocorrelation correction using the formula of Newey-West. Hence, the failure of rejecting the stationary nullity in the KPSS test suggests that the series could have a co-integrating relationship. The test regarding KPSS is taken and proven to comprise a unit root. This happens exactly when the test's statistics are fewer vis-à-vis critical values at the assumed significant level.

4.7 Variance Ratio Tests (VR)

This test was developed by MacKinlay and Lo (1988) to validate the EMH, which is thought to be far more reliable than the conventional unit root test. The VR test is a popular method for examining autocorrelation problems and randomness in stock market gain.

Moreover, it is necessary for the variance ratio about the q-differences scaled by q-difference to the variance ratio of the initial discrepancy to plead for unity when the X_t corresponds to a pure random walk. Thus, the variance ratio VR (q) is computed as follows:

$$VR(q) = \frac{\sigma^2(q)}{\sigma^2(1)}$$

In the context of the null Premise, VR(q) must be near unity where $\sigma^2(q)$ is $\frac{1}{q}$, the variance of the q-differences, and $\sigma^2(1)$ the variance of the first differences. For observations of $(P_0, P_1, \ldots, P_{nq})$ with a sample size of $nq + 1$: Additionally, the formulae are detailed as follows in the paper by MacKinlay and Lo (1988):

$$\sigma^2(q) = \frac{1}{m}\sum_{t=q}^{nq}(P_t - P_{t-q} - q\hat{\mu})^2$$

Where: $m = q(nq - q + 1)(1 - q/nq)$

And

$\hat{\mu}$ refers to the specimen mean of $(P_T - P_{t-1})$: $\hat{\mu} = 1/nq\,(P_{nq} - P_0)$

And

$\sigma^2(1) = \frac{1}{(nq-1)}\sum_{t=q}^{nq}(P_t - P_{t-1} - \hat{\mu})^2.$

The variance ratio assessment is computed for the categories where k = 2, 4, 8, and 16. Where, if X(t) behaves randomly across all perspectives of length k, the result should be very close to 1. Also, the negative serial correlation (mean reversal) would be inferred if the statistic is below one, also, the positive serial correlation (mean aversion) will be indicated if the value is greater than one. Further, either a negative or positive serial correlation shows that data from previous yields that do not track a random walk and include a stationary temporary element can be utilized to predict future gains. Likewise, Lo and MacKinlay (1988) investigate both the homoscedastic and the heteroscedastic increments as a result. The appropriate test statistic has an asymptotic standard normal distribution if the null hypothesis is true. In the case of homoscedastic augmentations, we get:

$$Z(q) = \frac{VR(q) - 1}{\emptyset_0(q)} \approx N(0,1)$$

Where: $\varphi_0(q) = [2(2q-1)(q-1)/3q(nq)]^{1/2}$

Assuming heteroskedastic increments, the test statistics are

$$Z^*(q) = \frac{VR(q) - 1}{\emptyset_e(q)} \approx N(0,1)$$

Where: $\emptyset_e(q) = \left[4\sum_{t=1}^{q-1}\left(1 - \frac{t}{q}\right)\hat{\delta}_t\right]^{1/2}$

And

$$\hat{\delta}_t = \frac{\sum_{j=t+1}^{nq}(P_j - P_{j-1} - \hat{\mu})^2(P_{j-t} - P_{j-t-1} - \hat{\mu})^2}{\left[\sum_{j=1}^{nq}(P_j - P_{j-1} - \hat{\mu})^2\right]^2}$$

4.8 Multiple Variance Ratio Test

In this test, Chow et al. (1993) extended Lo MacKinlay's (1988) conventional variance ratio test approach to producing straightforward multiple variance ratio tests using the Lo-MacKinlay assessment statistics as the studentized maximal modulus (SMM) statistics to manage the test size and avoid type I errors. Therefore, the random-walk null hypothesis has been hastily discarded (Chow et al., 1993).

Additionally, the researchers utilize the maximum absolute value in MacKinlay's and Lo's (1988) analyses for set ratios of estimated multiple variances to address this problem. The random walk hypothesis is refuted for a set of test statistics $\{Z(q_i)|i = 1,2,\ldots,m.\}$. If any VR (qi) significantly deviates from one, only the test statistics with the maximum absolute value are considered.

$$PR\{max(|Z(q_1)|,\ldots,|Z(q_m)|)$$
$$\leq SMM(\alpha; m; T)\} \geq 1 - \alpha$$

With the parameters m and T (sample size) levels of freedom, the supreme α point of the Studentized Maximum Modulus distribution is written as $SMM(\alpha; m; T)$, hence, asymptotically:

$$\lim_{T\to\infty} SMM(\alpha; m; \infty) = Z_{\alpha^*/2}$$

Where $Z_{\alpha^*/2}$ is standard normal with $\alpha^* = 1 - (1 - \alpha)^{1/m}$.

Additionally, comparing the approximate values of the standardized test statistics, whether Z(q) or Z*(q), with the SMM critical values. Similarly, Chow et al. (1993) controls the multiple variance ratio assessment size. Further, the random walk theory is disproved if the maximum absolute value of Z(q) surpasses the critical value at a preset significance level. The maximum total value of each variance ratio test statistic can be used to determine if the null hypothesis should be rejected. Moreover, Stoline and Ury provide the critical values for the test statistic's SMM distribution with L and T (the sample size) levels of freedom (1979). when T is large, The SMM critical values for L = 4 and α equivalent to 10%, 5%, and 1% degrees of relevance correspondingly 2.23, 2.49, and 3.03.

4.9 Wild Bootstrapping Approach of Automatic Variance Ratio Test (AVR)

Under the null premise that where: ρ_j = 0 and that the stock return is equally and independently distributed, then: Choi (1999) presented an automatic variance ratio test (AVRT). Thus:

$$AVR(k) = \sqrt{T/_k}\,[\widehat{VR}(k) - 1]/\sqrt{2} \underset{d}{\rightarrow} N(0,1)$$

Where:

$$\widehat{VR}(k) = 1 + 2\sum_{i=1}^{T-1} k\left(\frac{j}{k}\right)\hat{\rho}(j)$$

Additionally, the sample autocorrelation of order j is given by $\hat{\rho}(j) = \hat{\gamma}(j)/\hat{\gamma}(0)$ and the sample autocovariance of order j r is given by $\hat{\gamma}(j)$.

Kim (2009) proposes a wild bootstrap method to improve the small sample characteristics of variance ratio analyses under heteroskedasticity. Individual and combined variance ratio tests (Lo and MacKinlay, Chow and Denning, and Wald) are performed. In addition, the Bootstrap distribution of the test statistics is produced by weighting the original data by random variables with a mean of 0 and a variance of 1 on samples of T observations. The bootstrap P-values are directly calculated based on the fraction of repetitions that fell outside the outer limits specified by the parameter.

4.10 Automatic Portmanteau Test

In the automatic Portmanteau evaluation proposed by Escanciano and Lobato (2009), the optimal quantity of p is selected using a data-dependent method. This is one possible way to express the verification.

$$AQ = Q_p^* = T\sum_{i=1}^{p} \hat{p}_i^2 \quad AQ \sim X^2$$

where $\hat{p}$ is a balance between Akaike's information criteria and the Bayesian threshold that will decide the optimal lag order. With one level of freedom, the AQ statistic asymptotically follows the chi-squared distribution. If the quantity of AQ is larger than 3.84, the null premise of no return autocorrelation is denied at the 5% degree of significance.

4.11 Non-linear Model: McLeod-Li Test

McLeod-Li analysis is utilized to determine if the variance is non-linear. Using the squared residual of the pre-whitened time series, the test demonstrates that the autocorrelation function should be zero at all time delays under the null hypothesis of linearity (specifically variance linearity). For a good lag following this theory, the statistical point is:

$$Q(m) = \frac{n(n+2)}{n-k}\sum_{k=1}^{m} r_\alpha^2(k)$$

Where $r_\alpha^2(k) = \frac{\sum_{t=k-1}^{n} e_t^2 e_{t-k}^2}{\sum_{t=1}^{n} e_t^2}\,(k = 0,1,\ldots,n-1)$, r_α^2 denotes autocorrelation of e_t^2. If the $e_t$series is IID, then the $Q(m)$ is asymptotically distributed as x_m^2.Therefore, the null hypothesis of the assessment epitomizes no return of autocorrelation against the presence of the non-linear approaches ARCH/GARCH, which affect in data.

5. Results

5.1 Summary Statistics

Table 1. Descriptive statistics for the returns of the MASI stock index: January 2007 to December 2021

Mean	9.32E-05
Median	2.42E-05
Maximum	0.057316
Minimum	-0.091649
Std. Dev.	0.007043
Skewness	-0.826224
Kurtosis	20.13548
Jarque-Bera	46021.48
Probability	0.000000
Sum	0.347187
Sum Sq. Dev.	0.184820
Observations	3727

Note: The Jarque-Bera tests, dispersed as a x2 with two levels of freedom, examine the null premise of a normal distribution.

Where 9.32E-05 is the MASI mean. In addition, table.1 displays the MASI summary statistics, which indicate that all returns are calculated as the first difference of the daily closing share price log. Similarly, the index's volatility of 0.007043 necessitates a cautious, high-risk strategy for the Moroccan stock exchange. The distribution of returns is negatively skewed (-0.826224), indicating that larger negative returns outweigh larger positive gains. The kurtosis value is greater than 3: (20.13548). The return distribution is approximately symmetrical and leptokurtic. The leptokurtic tendency also explains why Bera's Jarque-statistic is notably greater than zero. Therefore, Jarque-Bera's statistics are non-normal. Moreover, they exhibit heteroscedasticity.

5.2 Serial Correlation

The feeble form of the effective market hypothesis is evaluated utilizing autocorrelation or serial correlation analyses. Following the random walk paradigm, current stock prices should reflect the information contained in prior share prices. In a nutshell, it is impossible to predict the future value of equities when significant historical values are used. Table 2 displays the outcomes of analyses for autocorrelation and partial correlation functions (ACF and PACFs) for the daily returns of the MASI index.

Table 2. shows the returns of the MASI market index from January 2007 to December 2017: The serial correlation coefficients and the Q-statistics

Lag	AC	AC	Q-Stat	Prob
1	0,295	0,295	323,59	0,000
2	0,067	-0,022	340,23	0,000
3	-0,045	-0,064	347,69	0,000
4	-0,035	-0,003	352,34	0,000
5	-0,036	-0,022	357,07	0,000
6	-0,01	0,004	357,48	0,000
7	-0,001	0,000	357,49	0,000
8	-0,005	-0,01	357,6	0,000
9	0,012	0,017	358,16	0,000
10	0,026	0,019	360,62	0,000

Actual results of an autocorrelation test with delays ranging from 1 to 10 are presented in Table 2. At or below 0.05, the alternative hypothesis of autocorrelation for the MASI index was approved. Due to the significance of the autocorrelation coefficient, the null premise of the weak-form hypothesis regarding market efficiency has been rejected. Therefore, the correlation between the present stock returns and those of the previous period is significant. This demonstrates that autocorrelation exists in the returns of the Moroccan stock market and that it does not exhibit weak form efficiency. Following this, the positive sign of the autocorrelation coefficients suggests that the sign of daily returns is frequently the same over time. This indicates that a return of a positive (negative) sign in the present will be accompanied by an increase (decrease) in return.

6. Runs Test

Abraham et al. (2002) state that, due to the non-normal distributions of the observed returns, the non-parametric runs assessment is significantly better suited for this test than the parametric autocorrelation test. The results of the MASI stock index from January 2007 to December 2021 are therefore utilized for the evaluations, as shown in Table 3.

Table 3. runs tests for the MASI stock index returns from January 2007 to December 2021

	R	n_0	n_1	μR	σR	Z	P-value
MASI	1571	1890	1837	1864,123155	30,51431019	-9,60608821	1,00000

Note: The null hypothesis is the subsequent price changes being independent and random. For any return above or below, the mean return is defined as a 1 signal or 0 signal refund

On the Moroccan market, the actual number of runs (R) is less than predicted by the null hypothesis of stock return independence. The run test results indicate that the consecutive return is independent at a level of 5%, corresponding to a critical value of -1.96, which is consistent with a random walk. Moreover, negative z values indicate a positive serial correlation. With 1571 actual runs compared to 1864,123155 anticipated runs, the Moroccan market is only moderately efficient in its current weak state.

6.1 Unit Root Tests

The RWH, which entails market efficiency, is supported by evidence of a unit root in the time series. In addition to the ADF, PP, and KPSS tests, these hypotheses were evaluated using additional test statistics. Table 4 demonstrates the daily return of MASI findings.

Table 4. shows unit root testing for the MASI market index results from January 2007 to December 2021

	t Statistic	1% level	5 % level	10% level
Augmented Dickey-Fuller test				
Model [1]	-45.07250	-3.960503	-3.411012	-3.127320
Model [2]	-45.07795	-3.431919	-2.862119	2.567121
Model [3]	-45.07862	-2.565583	-1.940909	-1.616642
Phillips-Perron test				
Model [1]	-44.43971	-3.960503	-3.411012	-3.127320
Model [2]	-44.44687	-3.431919	-2.862119	-2.567121
Model [3]	-44.45467	-2.565583	-1.940909	-1.616642
Kwiatkowski-Phillips-Schmidt-Shin test				
	LM Statistic	1% level	5 % level	10% level
Model [1]	0.096784	0.216000	0.146000	0.119000
Model [2]	0.103159	0.739000	0.463000	0.347000

The PP and ADF test hypotheses are Ho: unit root (non-stationary) and H1: no unit root (stationary). For the KPSS test, the hypotheses are Ho: no unit root (standing) and H1: unit root (non-stationary).

Table 4 demonstrates that the ADF and PP test statistics fall below the critical values at the 1%, 5%, and 10% confidence levels. The results of each test are also reliable and statistically significant. The null hypothesis has thus been refuted, and it has been determined that the data are somewhat stationary. Moreover, at the 1%, 5%, and 10% confidence levels, the asymptotic critical values for the KPSS analyses are more favorable than those for the LM statistics. The null hypothesis has, therefore, not been disproven. However, it is shown that the data is stationary. Consequently, the Moroccan market's stock price does not behave irrationally, and the market is not performing poorly.

6.2 Variance Ratio Tests

Table 5 displays the findings of Lo and Mackinlay (1993) regarding the variance ratio method for assessing the autocorrelation between profitability series. Similarly, the statistics were computed for 2-4-8-16-day delays in each circumstance. Thus, the results of the daily return are shown in Table 5 below.

Table 5. It contains the variance ratio analyses for lag 2, 4, 8, and 16 for MASI stock index price increases from January 2007 to December 2021

	Lag 2	Lag 4	Lag 6	Lag 8
VR(q)	0,661429	0,366955	0,178464	0,086935
Z*(q)	-7,528967	-8,133026	-7,520522	-6,387269
Probability	0.0000	0.0000	0.0000	0.0000
Z(q)	-20,6884	-20,67413	-16,96673	-12,67168
Probability	0.0000	0.0000	0.0000	0.0000

Note: In the initial rows, they are the variance ratios, VR(q), and in the parenthesis are the variance-ratio assessment statistics Z(q) for homoskedastic increments and Z*(q) for the heteroskedastic increments. Moreover, the market index values are said to follow a random walk if the variance ratios are identical to one, which is the null hypothesis.

Following the homoscedasticity hypothesis, the variance ratio is not identical to 2 at lag 16 based on the results of variance decomposition analyses for the daily returns MASI index. The random walk hypothesis is thus disproven. Consequently, the finding disproves that the financial markets examined at the time exhibited unexpected behavior. Profitability is confirmed to be a time-dependent variable with a mean reversion because variance ratio values are less than one.

6.3 Multiple Variance Ratio Test

The findings of Chow et al.'s (1993) research are presented in Table 6. The maximal value exceeds the critical importance of 2.49, so the homoscedastic and heteroscedastic nulls from Chow et al. (1993) invalidate the random walk theory for Moroccan capital markets at a 5% significance level.

Table 6. depicts the outcomes of multiple variance ratio test conducted on the MASI stock index results from January 2007 to December 2021

MV1	20.68840	Probability	0.0000
MV2	8.133026	Probability	0.0000

Note: The Chow-Denning testing is available in two different versions: MV1 is homoskedastic, while MV2 is heteroskedastic-robust

6.4 Wild Bootstrapping of AVR test

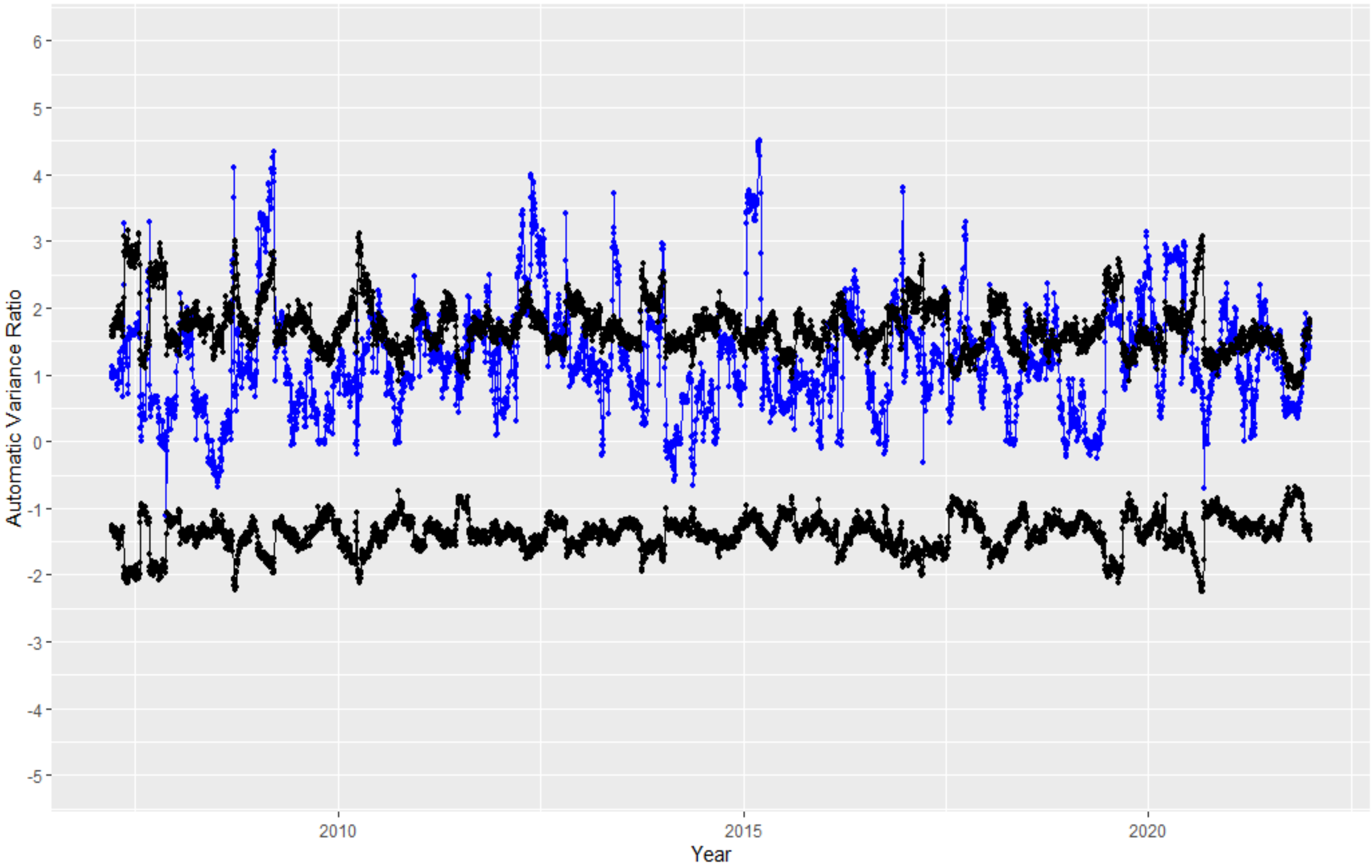

Figure1. Wild bootstrapping of AVR test

This test demonstrates that Figure 1 depicts the AVR statistics and 95% confidence scales. Moreover, these statistics alter over time—the subprime mortgage crisis between 2008 and 2009. In addition, the Arab Spring in 2011, the "February 20" movement from February 20, 2011, to the fall of 2012, the Rif Movement in 2016, and Morocco's announcement of the first case of the new Coronavirus in 2021 all contributed to the AVR statistic frequently falling outside the confidence interval. Numerous financial and political disasters marked this period. However, this test's intra-interval reliability has diminished for most of the period since 2009, indicating an increased performance level. This improvement can be attributed to the 2008 financial crisis, which resulted in a market correction, the elimination of superfluous funds, and a decline in overconfidence and exuberance. Epstein and Schneider (2008) have demonstrated that negative news has a greater impact on asset values than positive news.

As demonstrated by Shan and Gong (2012) and Huerta and Perez-Lister (2011), negative events disproportionately impact the stock market. Future research on the AMH should investigate whether certain circumstances, specifically the types of events that alter market conditions, are exclusively influenced by significant negative events or whether significant positive events may also result in inefficient intervals.

There is a tendency for markets to become more efficient, but the level of efficacy is unpredictable because it fluctuates between efficiency and inefficiency. In summary, the test results are favorable for the AMH.

6.5 Automatic Portmanteau Test

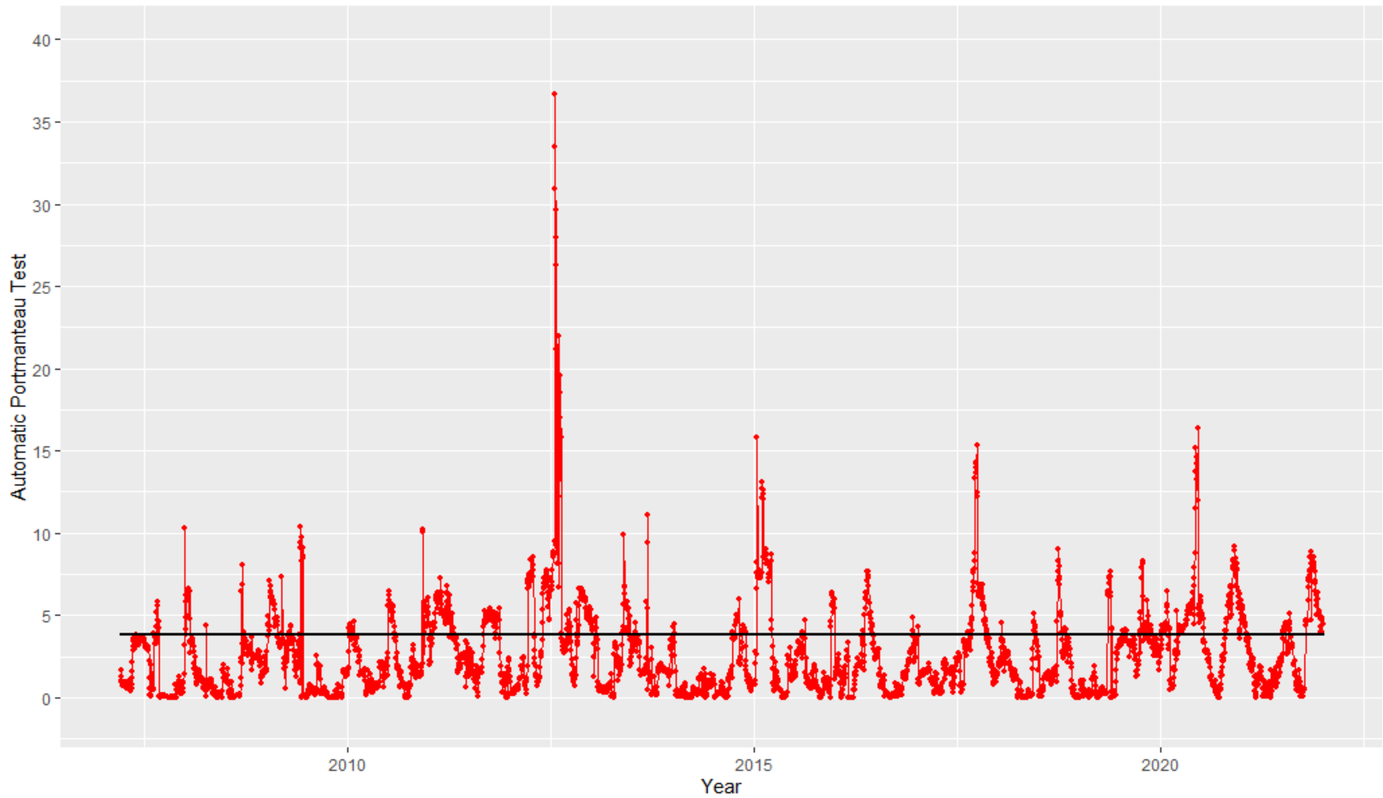

Figure 2. Automatic Portmanteau Test

Figure 2 depicts the AQ statistics and a horizontal line representing the AQ's 5% critical value. This test is a robustness check for the AVR test to ensure no positive or negative correlation offsets have occurred. The result is comparable to that of AVR.

6.6 Non-linear test of MacLeod-Li

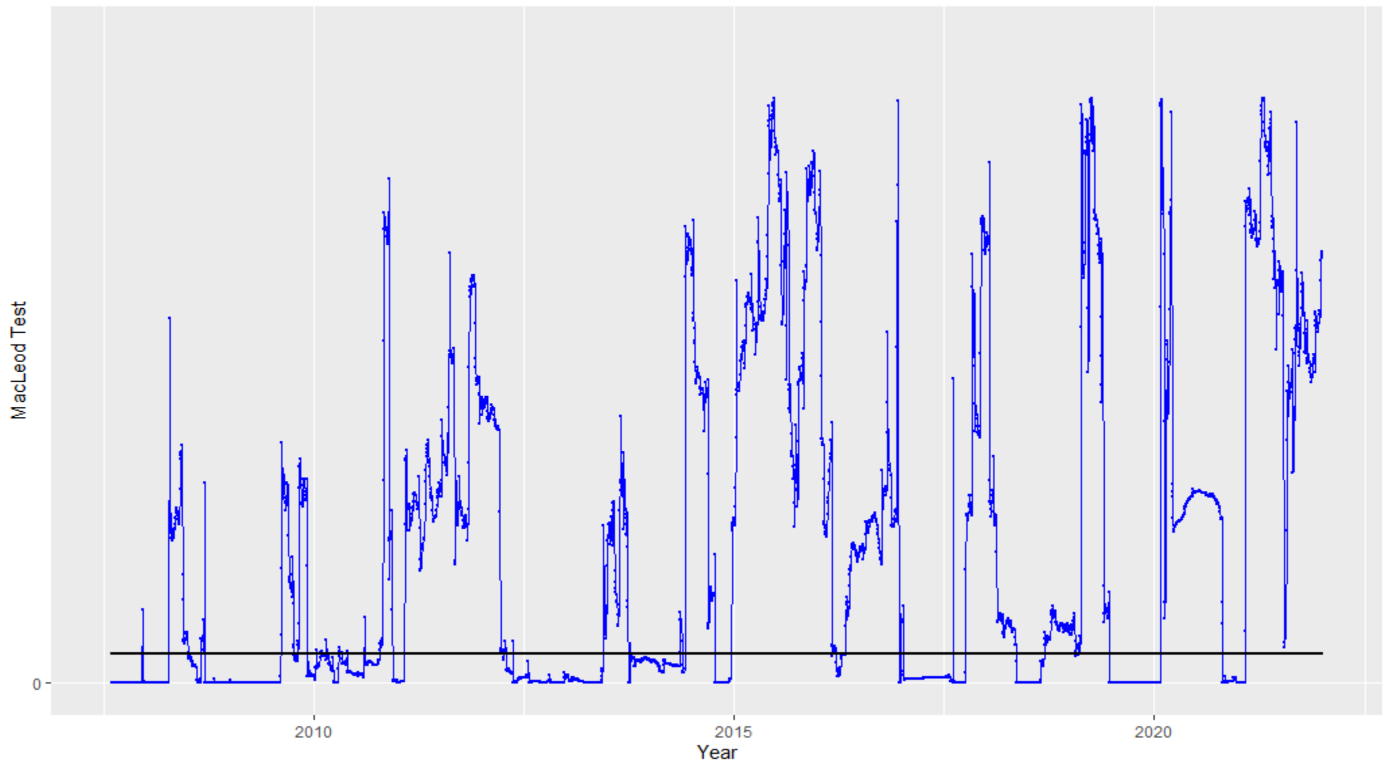

Figure 3. McLeod-Li test

The MacLeod-Li test determines the non-linear dependence of time series outputs. The findings of this evaluation, as depicted in Figure 3, indicate that the level of market efficiency has undergone multiple phases of efficiency and inefficiency. In addition, they identify several inefficient intervals overlooked by linear testing. Similarly, market efficiency is indicated by a

P-value above the 5% significance line, while a P-value below that line indicates market inefficiency. Consequentially, the testing results concur with those of the earlier evaluations, and the testing results favor the AMH.

7. Test Statistics as Measures of The Degree of Return Predictability

A standardized version of the VR, the AVR statistic is a weighted sum of autocorrelations with increasing and decreasing values. Consequently, it serves as a standard indicator of the direction and magnitude of return predictability. In addition, a positive (negative) AVR statistic score indicates an extremely positive (negative) autocorrelation in stock return. Nevertheless, since a more effective price exhibits fewer autocorrelations in both orientations, its absolute value is frequently employed.

It is possible to evaluate the statistical significance of return predictability using the 95% confidence interval derived from bootstrap samples with random seeding. If the AVR statistic is statistically different from zero at the 5% significance level, then the AVR statistic is outside of its 95% confidence interval, indicating that return predictability is statistically significant.

The confidence interval can also ascertain the uncertainty associated with the return predictability. In other terms, a wider (narrower) gap indicates that the associated level of uncertainty is greater (lower). Similarly, when the autocorrelations of other signs are considered, the AVR statistic can become problematic. This can be avoided by using the AQ statistic, which assesses the degree of return predictability naturally and is based on the sum of squared return autocorrelations.

According to Hiremath and Kumari (2014), the stock market goes through efficiency and inefficiency phases. The findings support the AMH model and are consistent with earlier findings. This study can make a substantial contribution to the literature because it supports the notion that large global macroeconomic events are associated with a high degree of predictability in yield (Charles et al., 2012; Hiremath and Narayan, 2016).

8. Conclusion

In conclusion, using daily data from 2007 to 2021, this study evaluated the efficacy of the Moroccan stock exchange. A linear and non-linear test was used throughout the investigation to assess this hypothesis. This method has the additional advantage of evaluating the predictability of time-varying returns. In addition, the results demonstrate that the Moroccan stock exchange is typically inefficient but occasionally efficient. This conclusion suggests that the AMH provides a more accurate explanation of the behavior of stock returns on the Casablanca stock exchange than the EMH.

Moreover, numerous instances of inefficiency are associated with significant cases of trustworthiness. Nonetheless, these disruptions are related to monetary, industrial, or political events, categorized as national and international variables. They disrupt the efficiency pattern of the stock market and cause an instance of inefficiency. Therefore, traders can use this conclusion to capitalize on unexpected profitable opportunities.

Furthermore, in an inefficient market, it is possible to accurately predict future prices by utilizing the information contained in past prices. Similarly, technical analysts, also known as chartists, can profit from this and use technical, economic indicators.

Due to this tendency, long-term investors may lose faith in the market. For shareholders to make prudent investment decisions, stock prices must also accurately reflect corporate performance. In this regard, effective information transmission is essential for a thriving capital market, especially in the short term. Other legislative changes are required, such as the reporting of non-financial and financial data, the simplification of trade transaction procedures, and the reduction of transaction fees. To increase market capitalization, which would have positive short- and long-term effects, regulations should be implemented to encourage more firms to register on the exchange in a market as small as the Moroccan market.

One of the limitations of our study is that it does not account for other market factors that can affect both the evolving efficiency and momentum profits. Different trading strategies can also cast light on the AMH in other ways, although they are not examined in this paper. Thus, we must conduct additional research on the subject.

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