Does the Adaptive Market Hypothesis explain the evolution of emerging markets efficiency? Evidence from the Moroccan financial market

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ABSTRACT
This paper scrutinizes different aspects of the Adaptive Market Hypothesis (AMH) in the Moroccan financial market over the period from January 1992 to September 2019 through different approaches. On the basis of daily returns on MASI index, we measure the evolution of efficiency degree based on the linear and nonlinear tests with rolling window. One of the practical implications of the AMH is that the profit opportunities arise from time to time depending on the degree of market efficiency and according to market conditions. To investigate this implication, we track the evolving performance of momentum-based trading strategies and the extent to which this performance is related to the market efficiency degree and certain market conditions. The linear and nonlinear tests reveal that the efficiency degree is time-varying. Moreover, we find via momentum test that profit opportunities appear from time to time and disappear once they are exploited. Interestingly, the momentum profits depend on both the degree of market efficiency and some market conditions. Thus, the investors can capitalize on the inefficiency and certain market conditions using trading strategies such momentum. Overall, our findings are consistent with the AMH framework, which is proved to be a better explanation of the behavior of emerging markets than the Efficiency Market Hypothesis (EMH).

1. Introduction

According to the Efficiency Market Hypothesis (EMH) (Fama, 1965, 1970), the asset price always fully reflects all available information in a timely manner. Hence, no one can exploit any information to make abnormal returns. There are three forms of market efficiency depending on the particular subsets of available information reflected in prices, namely the weak-form efficiency, the semi-strong form efficiency and the strong-form efficiency. The weak-form version of market efficiency is the most examined form of the EMH in the empirical studies. According to this form, stock returns are independent and no one is able to predict future return based on past information. Therefore, profitable trading strategies using historical information do not exist.

However, empirical findings yield mixed conclusion about the validity of this theory, which keep the conflict between the EMH and behavioral finance ongoing. In fact, on the one hand, some studies report results that confirm the EMH (Ayadi and Pyun, 1994; Cheung and Andrew Coutts, 2001; Fama, 1970; Granger and Morgenstern, 1963; Hawawini, 1984; Lock, 2007; Poon, 1996; Stachowiak, 2004). On the other hand, other studies highlight the departure from random walk (Al-Ajmi and Kim, 2012; Bley, 2011; Butler and Malaiakah, 1992; Claessens et al., 1995; Jarrett, 2010; Lovatt et al., 2007; McPherson et al., 2005; Smith, 2012; Squalli, 2006) as well as the existence of profitable investment strategies (Asem and Tian, 2010; Cheema and Nartea, 2017; Chopra et al., 1992; Cooper et al., 2004; De Bondt and Thaler, 1985; Jegadeesh and Titman, 2001; Lakonishok et al., 1994; Shi and Zhou, 2017). Furthermore, the contradiction has been seen even in the same market such as the Latin American markets (Claessens et al., 1995; Ojah and Karemera, 1999). One could assign these conflicting results to the methodological problems. In this vein, Fama (1998) argues that the EMH still held as the anomalies documented in several studies are not persistent and disappear once the model, the sample or the data frequencies change.

Nevertheless, beyond the methodological problems highlighted by Fama (1998), the controversial conclusions could be attributed to the fact that the arguments of both the EMH and behavioral finance are partially valid. Indeed, we can shift from one paradigm to another at any time depending on changing market conditions. Therefore, the two paradigms could be reconciled to provide a convincing explanation of market behavior. In this perspective, Lo (2004, 2005) proposes a theory, termed

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Adaptive Market Hypothesis (AMH), based on an evolutionary approach to economic anomalies. Such approach implies that efficiency and inefficiency co-exist in an intellectually consistent manner and allow for an evolving degree of market efficiency. Competition, mutation, adaptation, innovation and natural selection cause the waxing and waning of the market efficiency degree and the profits of trading strategies due to changing market conditions. Lo (2005) argues that convergence to equilibrium is neither guaranteed nor likely to occur and that it is incorrect to assume that the market must move toward some ideal state of efficiency.

Recently, empirical researches on the AMH focus on testing the extent to which this theoretical framework may be a better explanation of market behavior than the EMH. These studies relate to both developed (Alvarez-Ramirez et al., 2012; Boya, 2019; Ito et al., 2016; Ito and Sugiyama, 2009; Kim et al., 2011; Lim et al., 2013) and emerging equity markets (Abdmoulah, 2010; Charfeddine and Khediri, 2016; Kalc, 2020; Phan Tran Trung and Pham Quang, 2019; Shahid et al., 2019; Smith, 2012; Todea et al., 2009; Tuyon and Ahmad, 2016). Also, the AMH has been tested in other markets besides stock markets such as bond market (Charfeddine et al., 2018), foreign exchange market (Neely et al., 2009), cryptocurrency market (Chu et al., 2019), crude oil market (Ghazani and Ebrahimi, 2019) and lodging/resort real estate investment trusts (REITs) (Almudhaf et al., 2020). Strong evidences of the AMH framework have been found in these scrutinized markets.

The main practical implication of the AMH within finance is the timing of implementing profitable investment strategies as the profits opportunities evolve over time. Consistent with an evolutionary perspective in the market, the opportunities of earning abnormal returns arise from time to time, but disappear as they are exploited. The appearance of profitable strategies is conditioned by the specific market environment. Therefore, unlike the EMH which argues that the active management is worthless and it couldn’t do better than the “buy and hold strategy”, the AMH justifies the active management of the portfolio. Several studies focus on testing the profitability of investment strategies, however few of them have inspected such profitability within the AMH framework (Al-Khazali and Mirzaei, 2017; Shahid and Sattar, 2017; Shi and Zhou, 2017; Todea et al., 2009; Urquhart and McGorty, 2014; Xiong et al., 2019). For instance, Urquhart and McGorty (2014) examine the implied investment strategies based on calendar anomalies to investigate the AMH in the US using daily and monthly indexes from 1900 to 2013 with subsamples and moving window analysis. Their findings show that calendar anomalies and their performance vary over time and are influenced by certain market conditions. This evidence supports the AMH.

Among these trading strategies, momentum strategy, which involves having long positions in past best winners and having short positions in past worst losers, is proved to make abnormal returns over the holding periods from 3 to 12 months (Jegadeesh and Titman, 1993). This strategy has been widely tested within the framework of all-or-nothing condition of efficiency. They test whether the momentum profits are steady over the full sample period under study or not. Very few of them examined the evolution of momentum returns over time according to the implications of the AMH (Akhter and Yong, 2019). However, they didn’t study how the magnitude of the profits evolves in the periods of high efficiency degree and in the periods of inefficiency. Furthermore, no such study has been conducted in the Moroccan stock market where it may provide different results.

We contribute to the literature in several ways. First of all, to the best of our knowledge, this is the first study to test the evolution of the efficiency of the Moroccan financial market using different perspectives. An insight into this market could be additional relevant evidence for the AMH because of the importance of the market and its specificities. Indeed, the Moroccan stock exchange is among the largest markets in Africa, so it can provide a better understanding of the progress of the financial industry in this continent. Moreover, in respect with the firms listed in the market, some industries prevail and influence the market, namely the financial, telecommunications and real estate sectors. As for investors, the market is dominated by institutional investors who must comply with certain rules for their portfolios formation. These two characteristics may provide different results compared with other markets as they could influence the price adjustment. In addition, the Moroccan market has undergone many reforms, so it is worth noting to see whether such reforms could lead the market to be more efficient. Furthermore, each community is characterized by its own cultural specificities which distinguish it from others. Such cultural specificities have an impact on the psychological biases that prevail in a specific market, and then influence the market efficiency. Thus, examining the AMH in the Moroccan financial market is relevant as assessing the AMH across different contexts and different cultures permit to generalize the theory.

Secondly, we combine, for this study, multiple linear and nonlinear tests so as to mitigate the risk that spurious results from one test or just from linear tests affect the robustness of our conclusion. On the one hand, we combine different linear tests in order to improve the robustness of the results. For instance, we use the “Automatic Portmanteau test” as a robustness check for the results of the “Wild Bootstrapping Approach of Automatic variance ratio test” to ascertain that no positive and negative correlations are concealed out. We also employ tests that use different techniques so as to overcome the drawbacks of each technique. For example, the first two tests are conducted with rolling window approach. However, the rolling window tests face with an empirical problem about selecting the optimal window length. To address this issue, we use in addition the “non-Bayesian time-varying model approach (TV-AR) of Ito et al. (2014, 2016)” as this test could provide a more accurate measurement of market efficiency than statistical tests using the moving window method (Noda, 2016). On the other hand, it is shown that stock returns exhibit nonlinear dependency which may be neglected by linear tests (Cont, 2001). The market psychology and the transactions costs, that are ubiquitous, are among the main causes of the non-linearity. These nonlinear dependencies have been found in several studies (Almudhaf et al., 2016; Ghazani and Ebrahimi, 2019; Lim et Brooks, 2011; Ghazani et Araghi, 2014; Shahid et al., 2019). Therefore, adding nonlinear test may provide more accurate results as the Moroccan stock exchange exhibits nonlinear effects (El Alaoui, 2017).

Thirdly, our study is the first that examines the AMH using both the tests of random walk and the tests of the profitability of investment strategies in order to test the evolution of the efficiency degree and its implication on the profitability of investment strategies. In fact, the AMH implies that the arbitrage opportunities appear from time to time and disappear once they are exploited by investors. These opportunities emerge when the market deviates from random walk and disappear otherwise. Thus, we verify whether the abnormal returns arise when the market departs from random walk and vanish in the case of random walk. Specifically, we examine the evolving cross-sectional momentum returns through rolling window and compare them with the level of the market efficiency degree resulted from random walk tests.

Finally, we link the evolving efficiency and momentum profits with some market conditions. Albeit previous studies have examined this relationship, the impact of some conditions differs from one context to another. Thus, knowing in which conditions the market deviates from
efficiency and the arbitrage opportunities emerge have practical implications for both investors and regulatory authority. As for investors, these results enable them to make accurate forecasting and identify timely arbitrage opportunities from the momentum in the Moroccan stock exchange. Concerning regulatory authority, they will better understand the market behavior in order to implement appropriate regulations to improve the market efficiency.

The remainder is organized as follows: the second section reviews the existing literature, the third section exhibits the methods and the data used in this paper, the fourth section presents and discusses the empirical results, and the last section concludes.

2. Literature review

The growing studies on the AMH have shifted their focus from developed markets to emerging ones as the latter are experiencing various reforms and regulations. The objective is to assess whether these markets evolve toward efficiency, to what extent the reforms established are effective and under which conditions abnormal returns are obtained. In this vein, Jefferis and Smith (2005) inspect the changing of the weak-form efficiency degree in seven African financial markets over their different stages of development. They argue that the time-varying of efficiency degree is associated with market turnover, market capitalization and institutional characteristics. The African markets have also been examined by Smith and Dyakova (2014). Through the variance ratio tests, they investigate the evolving return predictability in eight African stock markets using three finite-sample variance ratio tests with rolling window. Their results exhibit alternating periods of return predictability and return unpredictability, which are supportive to the AMH.

Based on the Hurst exponent with a rolling sample from 1997 to 2007, Rejichi and Aloui (2012) find that MENA markets have experienced a long-range memory, but the efficiency of some of them has been improved. According to the authors, the differences in inefficiency degrees are related to trading costs, market capitalization and anti-self-dealing index. Continuing in the same direction, Sensoy (2013) scrutinizes the evolution of the market efficiency in fifteen MENA markets over the period from 2007 to 2012. He employs the Generalized Hurst Exponent Analysis on daily data through rolling window approach. He concludes that these markets have experienced a time-varying degree of long-term dependency that differs from market to market. In addition, he observes that Arab spring did not significantly influence the efficiency in the region. The same conclusion is reached by Charfeddine and Khediri (2016) in the GCC financial markets. In fact, they examine the extent to which the weak-efficiency of these markets is time-varying for the period that covers from Mai 2005 to September 2013. They use two empirical approaches: the GARCH-M model with state space time-varying parameter and the rolling technique sample test of the fractional long memory parameter d. They find that the GCC markets have different degrees of time-varying efficiency with periods of efficiency enhancement. Moreover, they conclude that the 2008 financial crisis and the Arab spring did have a significant impact on evolving efficiency. Niemczak and Smith (2013) track the evolution of the efficiency degree of eleven Middle-East financial markets and find that the majority of these markets have experienced successive periods of efficiency and inefficiency.

Tuyon and Ahmad (2016) examine the Malaysian financial market efficiency over the sample period from 1977 to 2014 along the different phases of economic development (pre-industrialization, post-industrialization, and millennium) and market states (non-crisis and crisis). Through the AR and VR tests, they conclude that their findings are congruent with the AMH. In Vietnamese financial market, Phan Tran Trung and Pham Quang (2019) conduct four tests (the Automatic Variance Ratio test, the Automatic Portmanteau test, the Generalized Spectral test and the TV-AR model) on the basis of the weekly returns from January 2005 to February 2019. They find that predictability of returns for two main Vietnamese stock markets (HSX and HNX) follows an evolutionary time path. These results are in line with the AMH. Shahid et al. (2019) inspect the AMH in the Pakistan stock market over the period 1992–2015 using subsamples and different linear and nonlinear tests. In addition, the link between market conditions and levels of return predictability has been investigated. Their empirical results support the AMH as the predictability of returns varies over time and certain market conditions are in favor of return predictability. Hull and McGoarty (2014) investigate the relations between the efficiency of twenty-two emerging markets from different continents and their development stages. They apply the ‘Hurst-Andelbroat-Wallis rescaled range test’ to returns and volatility as a measure of market efficiency. Their findings are consistent with the AMH.

As far as the European emerging markets are concerned, Dyakova and Smith (2013) investigate two prices indices and eight equity prices of Bulgarian financial market. They use the rolling window variance ratio test with the data from October 2000 to August 2009. They find a fluctuation of predictability level, which corroborates the AMH. However, the evidence of the AMH has not been found in the Turkey financial market. On the basis of the Automatic Portmanteau Box-Pierce Test, the Generalized Spectral Test and the Wild bootstrapped Automatic Variance Ratio Test with the rolling window approach, Kilic (2020) tests the predictability of return of Borsa Istanbul within the framework of the AMH over the period 2013-219. He concludes that the degree of efficiency of the stock market index does not change over time depending on market conditions. Thus, the AMH is not valid for Borsa Istanbul.

Researchers have also utilized the AMH framework to compare the evolutionary path of efficiency in emerging markets with developed markets. Lim (2007) investigates the evolving efficiency of eleven emerging financial markets and two developed markets through the Portmanteau Bicorrelation test with rolling window. He reports that the market efficiency degree varies over countries and over time in a cyclical fashion. He also finds that generally the developed markets are more efficient than emerging ones. Along the same line, Smith (2012) tracks the changing efficiency over the period 2000 to 2009 in fifteen emerging along with three developed European financial markets through the rolling window variance ratio tests. He observes that the predictability of returns experiences a large fluctuation and that the 2008 financial crisis coincided with a high return predictability in Croatia, Hungary, Poland, Portugal, Slovakia and UK.

With regard to Moroccan financial market, most studies were conducted from a static perspective within the conventional EMH framework. All these studies found no evidence of the EMH (Bakir, 2002; Hassainate and Bachesis, 2016; El Khattab and Moudine, 2014). As for testing the AMH in Moroccan stock market, Lekhal and El Oubani (2020) employ the wild Bootstrapping of Automatic variance Ratio test and the Automatic portmanteau test to track the evolution of the Moroccan financial market over the period from 2006 to 2019. They find that the degree of efficiency varies over time supporting the AMH. However, they used only linear tests, which could omit to detect nonlinear dependency.

To overcome this limit, we combine, in the current study, both linear and nonlinear tests as well as momentum profitability test.

The aforementioned studies use the tests of random walk of stock price. Nonetheless, these tests are associated to the hypothesis of weak-form efficiency and not direct tests. So, the acceptance of a random walk hypothesis implies information efficiency, while the rejection does not mean market inefficiency. Thus, the random walk tests should be accompanied by direct tests of information efficiency, such as tests of the profitability of trading strategies. In reference with trading strategy profitability, Todea et al. (2009) examine the profitability of the moving average strategy over windows in six Asian financial markets along the period from 1997 to 2008. Their findings display that returns are not constant over time; rather, they are periodic in line with the AMH. To inspect the time-varying performance of five different calendar effect in
Pakistan stock market and the market conditions in which these anomalies perform well over the period from January 1992 to December 2015, Shahid and Sattar (2017) use subsample analysis and find out that the behavior of these anomalies evolve over time and in different conditions, supporting the AMH. In the same line, through four calendar effects, Xiong et al. (2019) examine the AMH in China stock market by employing subsample analysis and rolling window as well as constructing trading strategies based on this four calendar effect. The objective is to check whether the calendar effect and the trading strategies arise from time to time according to the implications of the AMH. The empirical results exhibit that both the four calendar effect’s performance and excess returns of the investment strategies appear from time to time, which suggest that the AMH provides a better explanation for the market dynamics in China stock market. In the same market, Shi and Zhou (2017) quantify the evolving performance of trading strategies based on cross-sectional contrarian effects in the Chinese stock markets. They find that trading strategies based on contrarian portfolios wax and wane over time and are dependent on market conditions. In fact, the periods with upward trend of market state, higher market volatility and liquidity, and lower macroeconomics uncertainty are related to higher contrarian profitability. These empirical results support the AMH. In African markets, Obaadle and Muzindutu (2019) investigate the AMH by examining the behavior of the day-of-the-week (DOW) under different bull and bear market conditions. By using the Markov Switching Model, they find that the DOW effect appears in bearish state and disappears in bullish one, supporting the AMH. These findings imply that active investment management could make profits for investors during bearish conditions.

As far as Momentum profits are concerned, the seminal work of Jegadeesh and Titman (1993) shows that the momentum strategy is profitable over the holding period from 3 to 12 months. Subsequent works relate Momentum profits to market conditions and cognitive biases. Daniel et al. (1998) suggest that investor's overconfidence is higher when the markets continue in the same state (UP or DOWN) than when they reverse, which lead to higher momentum profits when the market continue in the same direction. In accordance with the model of Daniel et al. (1998), Asem and Tian (2010) study the link between momentum profits and market conditions. They find that the profits of momentum are higher when the markets continue in the same state than when they transition to a different state. By a similar approach, Cooper et al. (2004), find that momentum profits depend on the state of the market. From 1929 to 1995, the mean monthly momentum profit following positive market returns is 0.93%, whereas the mean profit following negative market returns is −0.37%. These momentum profits are not explained by macroeconomic factors. Griffin et al. (2003) reached the same conclusion arguing that momentum profits around the world are economically large and statistically significant in both good and bad circumstances and that momentum could not be explained by macroeconomic risk. However, Cheema and Narte (2017) find that momentum return in China exclusively follow down market. One can explain the momentum profits by the market's underreaction to information. Indeed, on the basis of the over-confidence and self-attribution biases, the Daniel et al.’s (1998) model implies that the underreaction to public information yields short-run momentum profits, while the overreaction to private signal leads to long-run reversal.

Recently, some studies linked momentum profits with the AMH and discover that the behavior of momentum profits varies over time in a cyclic manner. Akhtar and Yong (2019) investigate the time-varying behavior of momentum and contrarian profits within the AMH framework in Dhaka Stock Exchange (DSE) of Bangladesh over the period from January 1995 to December 2018. The empirical findings show the existence of medium-term momentum profits and long-term reversal effect that vary over time depending on market conditions. Nevertheless, these studies did not combine these direct tests of momentum anomaly with tests of random walk to assess the extent to which momentum profits are linked with periods of departure from random walk. In this current study, we will fill in this gap.

### 3. Methods and data

#### 3.1. Methods

This paper examines the evolving market efficiency through linear, nonlinear and momentum profitability tests. If these tests show return autocorrelation, then it will be possible to predict the future stock price based on historical price; thus, the investors could obtain abnormal returns using trading strategies. The paper employs the more popular and powerful linear and nonlinear tests, namely the Wild Bootstrapping Approach of Automatic variance ratio test, the Automatic portmanteau test, the Time-Varying Autoregressive model approach of Ito et al. (2014, 2016) and the Mcleod-Li test. These tests are robust against the conditional heteroscedasticity which is a common property of stock market returns. All our tests are calculated on the basis of the rolling window approach.

#### 3.1.1. Linear models

##### 3.1.1.1. Wild Bootstrapping Approach of Automatic variance ratio test (AVR)

The variance ratio test, introduced by Lo and MacKinlay (1988), has become the most commonly used test for examining the random walk hypothesis (Haque et al., 2007). The test is based on the statistical property that if a stock price follows a random walk, then the variance of the k-period return equals k time the variance of one period stock return. In other words, if the ratio of the variance of the k-period return \((\text{Var}(r_t, \ldots, r_{t+k-1}) / \text{Var}(r_t))\) on k time the variance of one period return \(r_t\) is significantly different from the unit, then the random walk hypothesis is rejected. Thus, the null hypothesis of the test is the variance ratio equals 1 for all k's. The variance ratio test VR(k) for \(r_t\) with holding period k is:

\[
VR(k) = \frac{\text{Var}(r_t, \ldots, r_{t+k-1})}{\text{Var}(r_t)} = 1 + 2 \sum_{j=1}^{k-1} \frac{(k-j)\rho_j}{k}
\]

where \(r_t\) is the asset return at time \(t\) (\(t = 1, 2, 3\ldots T\)), \(\rho_j\) is the autocorrelation of \(r_t\) of order \(j\), \(\text{Var}(r_t)\) is the variance of k-period stock return, and \(\text{Var}(r_t)\) is the variance of one period stock return.

Lo and MacKinlay (1988) show that under the assumption of homoscedasticity and under the null hypothesis that VR(k) = 1, the test statistic \(M_1(k)\) is as follows:

\[
M_1(k) = \frac{\text{VR}(r, k) - 1}{\psi(k)}
\]

which follows the standard normal distribution asymptotically. The asymptotic variance \(\psi(k)\) is:

\[
\psi(k) = 2(2k-1)(k-1) / 3kT
\]

As for the returns with conditional heteroscedasticity, the authors provide the heteroscedasticity robust test statistic \(M_2(k)\):

\[
M_2(k) = \frac{\text{VR}(r, k) - 1}{\psi'(k)}
\]

which follows the standard normal distribution asymptotically under the null hypothesis that VR(k) = 1, where:

\[
\psi'(k) = \sum_{j=1}^{k-1} \left( \frac{2(k-j)}{k} \right)^2 \delta(j);
\]

\[
\delta(j) = \left( \sum_{j > j} (r_i - \bar{u})^2 (r_{i-j} - \bar{u})^2 \right) / \left( \sum (r_i - \bar{u})^2 \right)^2;
\]
Because of some drawbacks, this test was subject to several enhancements for its robustness (see Charles and Darné (2009) for a comprehensive survey on recent improvements of the VR test). In fact, one major limit of the Lo and Mackinlay’s (1988) test is the choices of holding period k which are completely arbitrarily based on personal perceptions. To overcome this issue, Choi (1999) proposes the Automatic Variance Ratio test (AVR(ê)) that utilizes a fully data dependent method to estimate the optimal ê for k. Under the assumption that returns are independent and identically distributed (IID), the test is given by:

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

However, when the returns are subject to conditional heteroskedasticity, the test shows some distortions, especially under small sample sizes. Thus, Kim (2009) proposes the “Wild Bootstrapping version of AVR test” as an alternative to the normal distribution approach.

### 3.1.1.2. Automatic Portmanteau Test

The Automatic Portmanteau test represents an advanced version of Portmanteau test. In this test, introduced by Escanciano and Lobato (2009), a fully data dependent procedure is used to determine the optimal value of p. The test is given by:

\[ \text{AQ} = Q_p = T \sum_{i=1}^{p} \hat{p}_i^2 \sim \chi^2 \]

where \( \hat{p} \) is the optimal lag order determined through the Akaike’s information criterion (AIC) and Bayesian information criterion (BIC). The test statistic follows Chi-squared distribution with one degree of freedom.

### 3.1.1.3. Non-Bayesian Time-Varying Model Approach (TV-AR)

The above rolling window tests face with an empirical problem about selecting the optimal window length. Ito et al. (2014a,b) develop a non-Bayesian time-varying model approach (TV-AR) that can solve these empirical problems. Hence, it could provide a more accurate measurement of market efficiency than conventional statistical inferences (i.e., statistical tests using the moving window method) (Noda, 2016).

Under the hypothesis that all \( \alpha \) coefficients are time-invariant, the standard AR model is presented as follows:

\[ x_t = x_0 + \alpha_1 x_{t-1} + \ldots + \alpha_q x_{t-q} + u_t, \quad t = 1, 2, T \]

where \( u_t \) is an error term that satisfies \( E[u_t] = 0 \), \( E[u_t^2] = \sigma^2 \) and \( E[u_t u_{t-n}] = 0 \) for all \( m \neq 0 \). Nevertheless, this model is not suitable for the series with structural breaks, such as stock returns. Thus, the TV-AR model, which allows for these coefficients to vary over time, could be appropriate in such case. This model is presented in the following system of simultaneous equation with the assumption that parameter dynamics restrict the parameters:

\[ \begin{align*}
    x_t &= \alpha_0 + \alpha_1 x_{t-1} + \ldots + \alpha_q x_{t-q} + u_t \\
    \alpha_i &= \alpha_{i-1} + v_i (i = 1, 2, \ldots, q) \quad (1) \\
    \alpha_i &= \alpha_{i-1} + v_i (i = 1, 2, \ldots, q) \quad (2)
\end{align*} \]

where \( \{ u_t \} \) satisfies \( E[u_t] = 0 \), \( E[u_t^2] = \sigma^2 \) and \( E[u_t u_{t-n}] = 0 \) for all \( m \neq 0 \), \( \{ v_t \} \) satisfies \( E[v_t] = 0 \), \( E[v_t^2] = \sigma^2 \) and \( E[v_t v_{t-l}] = 0 \) for all \( m \neq 0 \). \( x_t \) represents the stock return at time t, \( \alpha_t \) denotes the time-varying coefficients, \( u_t \) and \( v_t \) are the residuals of the model.

The TV-AR model can be regarded as a state space model where the equation (1) corresponds to an observation equation and the equation (2) corresponds to a state equation. We can write the equation (1) in the matrix form:

\[ X_t = \alpha_0 + X_{t-1}^T \cdot A_t \cdot U_t, \]

where the superscript T denotes the transpose of the matrix and, \( X_{t-1} = \begin{pmatrix} x_{t-1} \\ x_{t-2} \\ \vdots \\ x_{t-q} \end{pmatrix} \).

Let assign a range of values from 1 to T to the parameter t. Accordingly, we get the equation below:

\[ 
\begin{pmatrix}
    x_1 \\
    x_2 \\
    \vdots \\
    x_T
\end{pmatrix} = 
\begin{pmatrix}
    1 & X_1^T & O \\
    1 & X_2^T & O \\
    \vdots & X_T^T & O
\end{pmatrix} \\
\begin{pmatrix}
    \alpha_0 \\
    \alpha_1 \\
    \vdots
\end{pmatrix} + 
\begin{pmatrix}
    u_1 \\
    u_2 \\
    \vdots
\end{pmatrix}
\]

\[ x = (X; Z) \]

\[ Z = \begin{pmatrix}
    1 & X_0^T & O \\
    1 & X_1^T & O \\
    \vdots & X_T^T & O
\end{pmatrix}; \beta = \begin{pmatrix}
    \alpha_0 \\
    \alpha_1 \\
    \vdots
\end{pmatrix} \]

\[ U = \begin{pmatrix}
    u_1 \\
    u_2 \\
    \vdots
\end{pmatrix} \]

We obtain the following equation:

\[ x = Z \times \beta + U \]

Similarly, we present the equation (2) as follows:

\[ 
\begin{pmatrix}
    -A_1^T \\
    0
\end{pmatrix} = \begin{pmatrix}
    0 & -I & O \\
    0 & I & -I
\end{pmatrix} \begin{pmatrix}
    \alpha_0 \\
    \alpha_1 \\
    \vdots
\end{pmatrix} + 
\begin{pmatrix}
    v_1 \\
    v_2 \\
    \vdots
\end{pmatrix}
\]

where \( A_t \) is a \( q \times q \) identity matrix.

Let,

\[ y = \begin{pmatrix}
    -A_t^T \\
    0
\end{pmatrix} \]

\[ W = \begin{pmatrix}
    0 & -I & O \\
    0 & I & -I
\end{pmatrix} \]

\[ V = \begin{pmatrix}
    v_1 \\
    v_2 \\
    \vdots
\end{pmatrix} \]

Consequently, we get the following equation:

\[ y = W \times \beta + V \]

The Eqs. (3) and (4) form the following equation system of the TV-AR model in the matrix form:

\[ \begin{pmatrix}
    x \\
    y
\end{pmatrix} = \begin{pmatrix}
    Z \\
    W
\end{pmatrix} \times \beta + \varepsilon, \text{ where } \varepsilon = \begin{pmatrix}
    U \\
    V
\end{pmatrix}. \]

Ordinary Least Squares (OLS) regression can be used to estimate the TV-AR coefficients. The OLS estimate \( \hat{\beta} \) is:

\[ \hat{\beta} = \left( \begin{pmatrix}
    Z \\
    W
\end{pmatrix}^T \begin{pmatrix}
    Z \\
    W
\end{pmatrix} \right)^{-1} \begin{pmatrix}
    Z \\
    W
\end{pmatrix}^T \begin{pmatrix}
    x \\
    y
\end{pmatrix} \]

---

1. The advantages and drawbacks of the model are highlighted in the paper of Ito et al. (2016).
Next, we measure the time-varying degree of market efficiency using the formula below:

\[
\zeta_t = \frac{\sum_{j=0}^{n} \hat{a}_{ij}}{1 - \sum_{j=0}^{n} \hat{a}_{ij}}
\]

The market is regarded as inefficient whenever \( \zeta_t \) deviates widely from zero. As \( \zeta_t \) depends on sampling errors, we construct the confidence band for possible \( \zeta_t \)'s under the hypothesis that the market is efficient, i.e. all the coefficients are zeros. The Bootstrap procedure can be used in this regard. Such technique is used as a method of statistical inferences on TV-AR estimates and their derived statistics, the degree of market efficiency. In practice, the procedure is described in the online appendix A.5 of Ito et al. (2014a,b) and in Noda’s (2016) paper.

3.1.2. Nonlinear model: McLeod-Li test

Usually the stock returns show nonlinear dependency that is neglected by linear tests. To capture this nonlinear dependency, we adopt the McLeod-Li test (McLeod and Li, 1983). The statistic of the test is given by:

\[
Q(m) = \frac{n(n + 2)}{n - k} \sum_{j=0}^{n} \hat{r}_{j}^2(k)
\]

where \( \hat{r}_{j}^2(k) = \sum_{i=1}^{n} \hat{e}_{i}^2(k) / \left( n - m - k \right)^2 \) (\( k = 0, 1, \ldots, n - 1 \)). \( \hat{r}_{j}^2 \) denotes autocorrelation of \( e_t^2 \). If the \( e_t \) series is IID, then the \( Q(m) \) is asymptotically distributed as \( \chi^2_\alpha \). The null hypothesis of the test represents no return autocorrelation against the presence of the nonlinear ARCH/GARCH effects in data.

3.1.3. Momentum profits test

To test the cross-sectional momentum profits we follow Jegadeesh and Titman (1993). For each month \( t \), all firms are ranked into quintile groups on the basis of their prior six-months returns from t-6 to t-1 (formation period), skipping month \( t \). The best performing stocks (e.g. top 20%) are assigned to the winner portfolio (the portfolio P5) and the worst performing stocks (e.g. bottom 20%) are assigned to the loser portfolio (the portfolio P1). The momentum strategy buys the winner quintile and sells short the loser quintile. These positions are held for the next 3 and 6 next months, from t+1 to t+3 and from t+1 to t+6, respectively (test period). We skip one month between the formation period and the test period to avoid microstructure distortions. The relative strength portfolio is rebalanced every month; so, the number of rebalanced portfolios in any month is equal to 1/k of the holding period months. One sample t-tests is performed on the returns of the momentum portfolio to check if the momentum profits are significantly different from zero.

The sample consists of all stocks listed on the Casablanca stock exchange from June 1997 to September 2019. Unlike previous studies that often employed subsample analysis, we conduct our study on moving time windows with the size being two years that rolls one month forward to accurately capture the behavior of momentum profits over time.

The monthly returns are calculated using the following formula:

\[
\frac{P_{t+1}}{P_{t-1}} - 1
\]

where \( P_t \) is the monthly closing price of stock \( i \) at time \( t \), and \( P_{t-1} \) is the monthly closing price of stock \( i \) at time \( t-1 \).

3.2. Data

To test the random walk, this paper uses the daily MASI index data from Moroccan stock market that covers the period from January 2, 1992 to September 10, 2019, obtained from Casablanca stock exchange website. Based on the daily closing prices, we calculate the log first difference of the time series to obtain the returns as follows:

\[
x_t = \ln(p_t / p_{t-1})
\]

Some descriptive statistics are presented in Table 1. They indicate that the MASI index returns oscillate between -0.0501 and 0.0455 with a mean of 0.0003 and a standard deviation of 0.0065. The skewness is negative indicating that the density function has a fatter left tail than right tail. The Kurtosis is excessively high suggesting that the tail of the data distribution is fatter than the normal distribution. Thus, the data is not normally distributed, which is confirmed by the Jarque-Bera test. Rather, the data distribution is leptokurtic, which is a common feature of sock returns.

To perform our tests, the data should be stationary. In order to check this condition, we employ the ADF-GLS test of Elliott et al. (1992), provided in the Table 1. The test rejects the null hypothesis that the variables contain a unit root at 1% significance level. Therefore, the time series is stationary.

4. Empirical results

In this section, we perform three linear tests (the wild Bootstrapping of AVR test, the Automatic Portmanteau test and the TV-AR model), the nonlinear test of MacLeod-Li and the momentum returns test.

4.1. Linear models

4.1.1. Wild Bootstrapping of AVR test

The Figure 1 depicts the evolution over time of the wild Bootstrapping of AVR test statistics. The results show that the efficiency degree is unstable fluctuating between efficiency and inefficiency with a trend toward the improvement of market efficiency. In fact, before 2007 the AVR test statistics were remarkably out of the upper bound most of the time, which witnesses the market inefficiency during this period. Interestingly, the period from 2002 to 2006, the MASI index variation reached its peak with a cumulative performance of 326%. Such performance could not be attributed to fundamental variation, but to psychological biases and market excess liquidity as we can see in Figure 8.

Nevertheless, the AVR test dropped within the interval confidence most of the time since 2008 suggesting an improvement in the efficiency degree. This enhancement might be explained by the 2008 crisis which induced a market correction, the evaporating of the excess liquidity and the decline in optimism and overconfidence. However, some short periods of inefficiency were marked in the first months of 2009, 2011 and 2016. Consequently, the test results are supportive for the AMH.

4.1.2. Automatic Portmanteau test

The results of the Automatic Portmanteau test are presented in Figure 2. This test is conducted as a robustness check of the AVR test to make sure that no positive and negative correlation offset is occurred. The test results are coherent with the AVR test.
4.1.3. TV-AR model approach of Ito et al. (2014, 2016)

First of all, we assume an AR model with stable coefficients using the BIC of Schwarz (1978) and the AIC of Akaike (1973) to select the optimal lag order in the AR(q) estimation. The first order autoregressive is selected in our estimation and the AR(1) estimates are presented in Table 2. These estimates are statistically significant at 1% level. But, are the model parameters constant over time?

To check whether the parameters are stable in our model, we utilize the Hansen’s (1992) test under the random parameters hypothesis. The test results, provided in Table 2, reject the null hypothesis of parameters stability at 1%. Accordingly, we estimate the TV-AR model and, then, the time-varying degree of market efficiency \( \zeta_t \) following the method described above. The estimates of \( \zeta_t \) and their 5% confidence bands are shown in Figure 3.

Based on the TV-AR model, the empirical findings exhibit that the degree of the market efficiency is time-varying. Specifically, the market was entirely inefficient before 2013 with a substantial decrease of the inefficiency degree. The tendency toward efficiency could be explained.

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| Min. | Mean | Max. | SD  | skew | Kurt | JB  | ADF-GLS Test statistics | critical values at 1% | N  |
|------|------|------|-----|------|------|-----|------------------------|------------------------|----|
| -0.0501 | 0.0003 | 0.0455 | 0.0065 | -0.077 | 10.4079 | 0.000 | -33.0174 | -2.57 | 6887 |

Notes:
ADF-GLS designates the ADF-GLS test statistics of Elliott et al. (1992);
N denotes the number of observations;
R version 3.6.1 was used to compute the statistics.

Figure 1. The wild Bootstrapping of the AVR test statistics. Notes: The blue line indicates the AVR test statistic and the black line represents the upper bound and lower bound of the confidence interval. R version 3.6.1 was used to compute the statistics.

Figure 2. The Automatic Portmanteau test results. Notes: The blue line indicates the Automatic portmanteau test statistic and the black line represents the F-statistic at 5% significance level. R version 3.6.1 was used to compute the statistics.
by the financial and microstructure reforms as well as by market capitalization, which has increased significantly as illustrated by Figure 4. However, the year of 2006 corresponds to a high degree of inefficiency, which could be assigned to the noise trading that stems largely from a high level of liquidity and cognitive biases. In fact, Figure 8 illustrates that the transaction volume was extremely high during 2006. A moderate trading volume positively influences the market efficiency, but when it is excessive, it can be a sign of market inefficiency induced by psychological biases (Akerlof and Shiller, 2009; Daniel et al., 1998; Gervais and Odean, 2001). Since 2007, the market has been corrected under the effect of the international crisis, the investor’s learning-process, and, in some extent, the negative sentiments caused by this crisis. As a consequence, stock prices were reverting to their true value until the market became significantly efficient in 2013. From 2015 to 2018, the market deviates from the significant level of efficiency before retrieving it at the beginning of 2019.

In conclusion, the empirical results provided by the TV-AR model are consistent with the AMH as the efficiency degree varies over time and is affected by financial reforms and certain market conditions such as market capitalization, market liquidity and period of crisis.

4.2. Nonlinear test of MacLeod-Li

The MacLeod-Li test is performed to detect the nonlinear dependency in time series returns. The test results (Figure 5), suggest that the degree of market efficiency has experienced several alternating periods of efficiency and periods of inefficiency. They also indicate some periods of inefficiency omitted in the linear tests. The p-value upper the 5% significance line indicates the market efficiency while the market inefficiency occurs when the p-value is under that line. Accordingly, the market was mostly inefficient before 2013, but after that, the efficiency degree has been substantially enhanced despite of some short periods of inefficiency such as the year of 2017. Thus, the test results are consistent with the previous tests.

4.3. Profitability of momentum strategies

Now, we test the implication derived from the AMH that trading opportunities evolve over time as they appear from time to time and disappear once they are exploited. For this purpose, we track the performance of momentum portfolios over time using moving window approach. The results are illustrated by Figures 6 and 7. Figure 6 displays the evolution of Momentum profits (winner minus loser) of J = 6/K = 6 strategy from June 1997 to September 2019. The results show that the Momentum profits are time-varying as they are significant in some periods and non-significant or negative (contrarian effect) in other periods. This suggests that the market anomalies and the performance of the strategies based on them evolve over time rather than remain a static state. Specifically, the momentum profits were significant at 5% from
August 1999 to July 2001 (the t-test of average monthly returns is 2,287, which is superior to the critical value 2,069), from September 1999 to August 2001 (the t-test is 2,287), from August 2015 to July 2017, from September 2015 to August 2017 and during the period from June 2016 to June 2019. The returns were negatively significant (contrarian effect) from January 2012 to December 2013 (the t-test is -2,077). During this period, the momentum strategy was a poor strategy; instead, the contrarian strategy, based on buying the previous losers and selling the previous winners, became a profitable strategy. At 10% significance, the momentum profits were also significant over the period from November 2006 to January 2009. They were insignificant in other periods, both at 5% and 10%.

Figure 7 shows that the J = 6/K = 3 strategy is less profitable than the previous one as there are fewer periods where the profits are significant at 5%, suggesting that momentum works better beyond the holding period of 3 months.

Next, we investigate the link between the profitability of trading strategies and the market efficiency evaluated via random walk tests. The comparison between the evolution of the momentum profits and the market efficiency suggests that the periods with high efficiency match
with the periods of insignificant momentum profits. For instance, in the year of 2014, all linear and nonlinear tests show high efficiency while the momentum test indicates insignificant profits. In contrast, periods of low efficiency coincide mostly with periods of high profit opportunities such as 1999–2000, 2006–2008 and 2016–2018. This evolving of the efficiency degree and thus the waxing and waning of the momentum profits are caused by changing of market conditions.

We thereby intend to investigate the relation between the profitability of momentum strategies and some market conditions, namely market liquidity and period of crisis. These two factors are deemed to have a large effect on the market price in the Moroccan context. We note that the market liquidity (Figure 8) goes through periods of high liquidity and periods of low liquidity and that significant momentum profits correspond to periods of high liquidity. In addition, the momentum profits were not statistically significant during the 2008 financial crisis. Overall, the empirical results corroborate the AMH in the Moroccan financial market.

5. Conclusions

In this paper, we investigated the AMH and its practical implications in the Moroccan financial market over the period from 1992 to 2019. First, we performed linear and nonlinear tests with moving window to examine the evolving of the degree of the market efficiency. Secondly, we tested the profitability of trading strategies based on momentum effect in moving window to check whether the performance of these strategies are time-varying and if they are related to market inefficiency as the AMH implies. Thirdly, we inspected the relation between the market efficiency, the momentum profits and some market conditions. The empirical findings exhibit that the efficiency degree is time-varying. Furthermore, we found that periods of high efficiency coincide with non-significance of the momentum profits. On the opposite, the periods with inefficiency might yield abnormal returns. In addition, it is observed that the evolution of the market efficiency and the momentum profits is affected by some market conditions such as liquidity and crisis. Specifically, the periods with higher liquidity are related to higher inefficiency degree and significant momentum profits. Also, during the crisis period, we observed a lower inefficiency degree and a disappearance of momentum profits because of the market correction. Thus, our results are in line with the AMH and its practical implications according to which the profit opportunities do exist from time to time and depend on some market conditions.

In a nutshell, based on our findings and the results of the previous studies pertaining to emerging markets, we can say that the AMH

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Data are available on the website of the Casablanca stock exchange: http://www.casablanca-bourse.com/bourseweb/Negociation-Historique.aspx?Cat=24&dLink=302.
framework provides a better explanation of the behavior of the emerging markets than the EMH.

However, one of the limitations of our study is that there can be other market conditions that could also influence the evolving efficiency as well as momentum profits which are not examined in this research. Furthermore, other trading strategies can provide more insights into the AMH, but they were not investigated in this current work. We leave that for future research.

Declarations

Author contribution statement

A. El Oubani and M. Lekhal: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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