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Adaptive Market Hypothesis: Evidence from the Turkey Stock Market

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Abstract
Adaptive Market Hypothesis argues that Effective Market Hypothesis and calendar anomalies may coexist. The focus of Adaptive Market Hypothesis is not any single behavior, but how the behavior responds to changing market conditions. Adaptive Market Hypothesis has been proposed as a hypothesis to resolve conflicts between Efficient Market Hypothesis and Behavioral Finance. With this hypothesis put forward in 2004, the studies defending the Efficient Market Hypothesis and Behavioral Finance started to be evaluated in a different framework. Accordingly, this study examines the predictability of return of Borsa Istanbul 100 index (XU100) within the framework of Adaptive Market Hypothesis. Return series were analyzed between January 02, 2013 - April 26, 2019 using Automatic Portmanteau Box-Pierce Test, Generalized Spectral Test and Wild-bootstrapped Automatic Variance Ratio Test. The rolling window approach was used to examine whether the time varying returns were predictable. It is concluded that Adaptive Market Hypothesis is not valid for Borsa Istanbul both for the full sample period and for the sub-periods. In other words, it has been determined that the degree of efficiency of the stock market index does not change over time depending on market conditions.

Keywords: Adaptive Market Hypothesis, Efficient Market Hypothesis, Behavioral Finance, Rolling Window, Turkey Stock Market, Borsa Istanbul.

JEL Codes: D53, G10, G14, G15

1. Introduction

The EMH is the basis of many recent financial theories. According to EMH (Fama, 1965, 1970), asset prices fully reflect all available information, which means that none of the market participants can systematically obtain a return above the market. When new information comes to an efficient market, security prices respond to this information immediately and prices reach a new balance (Hiremath and Kumari, 2014, p. 1).

The EMH paradigm is summarized by Lo (1999) as the 3P of Total Investment Management: prices, probabilities and preferences. 3P basically includes the principle of supply and demand, which is one of the central ideas of modern economics (Lo, 2004, p. 3). The demand curve is the sum of the demands of individual consumers under a budget constraint, each of which depends on prices and other factors such as revenue, savings needs and borrowing costs to optimize an individual's preferences. Similarly, the supply curve is the sum of the outputs of individual producers under a resource constraint, each of which depends on prices and other factors (such as raw material costs, wages and commercial loans) in order to optimize the production function of an entrepreneur. The possibilities affect both consumers and producers because they formulate their consumption and production plans over time and in case of uncertainty (uncertain income, uncertain cost and uncertain business conditions) (Lo, 1999,

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p. 14). Interactions between preferences and probabilities stem from prices that give depth and wealth to the modern financial economy. 3P has been theoretically and empirically tested for years. Initial studies examined whether prices reflect various information, and later studies considered indirect probability characteristics of asset prices. However, the strongest criticisms of EMH evolve around the preferences and behaviors of market participants (Lo, 2004, p. 4).

EMH has been valid in the finance literature for many years. However, according to behavioral economists, EMH is unable to account for time-varying market efficiency. They also think that market efficiency can be affected by changes in market conditions, the number of market actors, the composition of investors, profit opportunities and risk-reward relationships (Khuntia and Pattanayak, 2018, p. 26). Psychologists and economists have stated that decisions taken by the individual under uncertainty and behavioral prejudices that cause unexpected consequences for their economic well-being lead to deviations from EPH (Loo, 2004). Some of these behavioral prejudices against EPH are over-confidence (Fischo and Slovic, 1978; Barber and Odean, 2001), overreaction (DeBondt and Thaler, 1985), loss avoidance (Kahneman and Tversky, 1979), herd behavior (Huberman and Regev, 2001) and mental accounting (Tversky and Kahneman, 1981). Table 1 produced by Sharma (2014) shows the conflict between EMH and BF under various principles (Sharma, 2014, p. 4.)

Table 1: Summary of Contradictions between Efficient Market Hypothesis and Behavioral Finance

Principle	Efficient Market Hypothesis	Behavioral Finance
Investor Rationality	EMH assumes that investors in financial markets are always rational in terms of information analysis and decision-making.	BF says investors are not always rational. Investor behavior is usually irrational.
The Role of Emotions	EMH never includes emotions in the decision-making process.	BF takes into account emotions and psychology in investor behavior.
Information Accuracy	The strong form of EMH says that all investors are equal in accessing information and that stock prices accurately reflect all information.	BF rejects equality in accessing information, which is the assumption of EMH, and says that stock prices do not always reflect all the information.
Demographic Factors	EMH states that there is no difference between a novice investor and an experienced one.	BF indicates that investors vary by age, gender, income level, education level and experience.
Interdisciplinary principles	EMH is mainly based on economic principles.	BF includes theories of psychology, sociology and other similar disciplines.
Market Crises	If EMH was really valid, there would be no market crisis or balloons, because EMH believes that investors always behave rationally.	Market crises or bubbles are better defined by BF, because in the decision-making process, besides the rationality of the investors, various other issues need to be analyzed.

Market behavior is an important focus for academics, regulators and market participants. Regulators aim to increase the efficiency of markets while academics examine theories that are for or against the EMH. On the other hand, market participants aim to obtain abnormal returns by taking advantage of the inefficiencies of the markets (Almail and Almudhaf, 2017, p.48). In general, there has been no consensus in the studies examining EPH. Empirical investigations conducted in different countries' markets have proven that EMH is valid (Choudhry, 1994; Qian, Song and Zhou, 2008; Munir and Mansur, 2009; Alexeev and Tapon, 2011; Zhang, Wu, Chang and Lee, 2012) as well as studies that cannot prove the validity of EPH (Barkoulas, Baum and Travlos, 2000; Resende and Teixeira, 2002; Chaudhuri and Wu, 2003; Narayan, 2008; Hasanov, 2009). In this respect, it is more appropriate to examine the efficiency of markets in a time-varying manner by taking into account the changing market factors such as institutions, regulations, technology and the behavior of market participants (Al-Khazali and Mirzaei, 2017, p. 190).

In recent years, despite the fact that stock returns do not follow the Random Walking Hypothesis and there is remarkable evidence of the predictability of prices, it is seen that no theory could be proposed as an alternative to EMH (Hiremath and Kumari, 2014, p. 1; Hiremath and Narayan, 2016, p. 173). Lo (2004) has proposed a new theory to overcome differences in opinion on EMH. This theory is called Adaptive Market Hypothesis and argues that EMH and calendar anomalies may co-exist. AMH's focus is not on any single behavior, but on how behaviors respond to changing market conditions. In the context of AMH, individuals are neither completely rational nor irrational; they are forward-thinking, intelligent and competitive investors who adapt to new economic realities (Lo, 2012, p. 9). This theory, proposed by Lo (2004) as an alternative to EMH, provides a behavioral perspective and states that markets may change in terms of in/efficiency at different points of time and adapt to new conditions.

Lo (2005), as a new hypothesis, examines AMH, EMH, and the opposite situations of EMH and explains that modern financial economics models can co-exist in a consistent manner with behavioral models (Lo, 2005, p. 21). Lo (2004) bases AMH on certain known principles of evolutionary biology (competition, mutation, reproduction and natural selection). These factors over financial markets and market participants determine market efficiency, investment products, businesses, sectors and ultimately the increase and decrease of corporate and individual wealth (Lo, 2005, p. 22). According to AMH, behavior is not necessarily internal or external, it develops by natural selection and depends on the environment in which selection is made. In other words, natural selection not only works on genetic materials, but also on biology and social behavior and cultural norms (Lo, 2005, p. 30). AMH has been proposed as a hypothesis to resolve conflicts between EMH and BF. With this hypothesis put forward in 2004, studies advocating the EPH and BF hypotheses began to be evaluated within a different framework. AMH has a theoretical background to bring both EPH and BF advocates together at a common point.

In the literature, it is seen that in most of the studies examining market efficiency in its weak form, market efficiency is tested for the full sample period. However, it is also important to capture time-varying returns for sub-periods. The predictability of time-varying returns can be tested with the rolling windows approach. In this direction, this study aims to test AMH in Turkey Stock Exchange, Borsa Istanbul for the period of 2013-2019. To the best of our knowledge, there are very few studies in Borsa Istanbul that test the Adaptive Market Hypothesis. This gap in the literature increases the importance of the research and the degree of contribution to the literature.

The paper is organized as follows. Literature reviews is discussed in the section two. In the third section, the data and empirical methodology are explained. The empirical results are presented in the fourth section. The last section concludes the paper.

2. Literature Review

Since the AMH was proposed, a new perspective has emerged for the EMH and BF paradigms that have been discussed for many years. Lo (2004) argued that the efficiency of markets can be examined in a time-varying manner with AMH and this view has started to take place in the finance literature. Thus, researchers have started to empirically examine the validity of AMH in various financial markets.

Todea, Ulici and Silaghi (2009) examined the validity of AMH in the Asia-Pacific markets (Australia (All Ordinaries Index), Hong Kong (Hang-Seng Index), India (BSE national Index), Malaysia (Kuala Lumpur Composite Index), Singapore (Strait Times Index) and Japan (Nikkei 225 Index)) for the period 1997-2008 and found that market efficiency is time-varying and AMH is valid. Kim, Shamsuddin and Lim (2011) tested the validity of AMH in the Dow

Jones Industrial Average (DJIA) index between 1900 and 2009 using Automatic Variance Ratio, Automatic Portmanteau and Generalized Spectral Tests and found that predicted returns fluctuated over time, given the changing market conditions. They also found that returns were unpredictable at times of market crash; returns were highly predicted during economic and political crises; and return predictability at bubble times was lower than normal times. Urquhart and Hudson (2013) examined the validity of AMH in the US (DJIA), UK (FT30) and Japan (TOPIX) markets for the period of 1897-2009 using daily prices. Findings obtained from linear and nonlinear tests showed that AMH better describes stock return behavior than EMH. Urquhart and McGroarty (2014) concluded that calendar anomalies in the DJIA index support AMH for the period 1900-2013, and that AMH explains the behavior of calendar anomalies better than EMH. Ghazani and Araghi (2014) tested the validity of AMH using the daily returns in the Tehran Stock Exchange for the period of 1999-2013 using Automatic Portmanteau Test, nonlinear tests, Generalized Spectral Test and McLeod-Li Tests and concluded that AMH is valid. Hiremath and Kumari (2014) examined the behavior of the developing Indian Stock Exchange for Sensex and Nifty indices in terms of AMH for the period of 1991-2013 using linear and non-linear methods and found that the Indian Stock Exchange does not fully support AMH and EMH. Noda (2016) examined the validity of AMH in the Japanese markets (TOPIX and TSE2) for the period of 1961-2015 using time-varying model and found that the efficiency in both markets was time-varying; the efficiency in the TSE2 market was lower than the TOPIX market; the efficiency of the TOPIX market increased; the efficiency of the TSE2 market did not increase; and finally the AMH was valid in the Japanese markets.

The AMH has also been examined for Islamic financial markets. Al-Khazali and Mirzaei (2017) tested the validity of AMH in Dow Jones Islamic indices using stochastic dominance and mean - variance analyses. The researchers used calendar anomalies when testing AMH for the period 1996-2015. The findings supported the validity of AMH in Islamic indices. It also showed that AMH explains the behavior of calendar anomalies better than EMH. Almail and Almudhaf (2017) analyzed the validity of AMH for both the UK stock market and the British Pound. They used Automatic Variance Ratio and Automatic Portmanteau Tests for 1709-2016 period for stock exchange and 1779-2016 monthly data for currency. They found evidence of the time-varying degree of efficiency that supports AMH. Ertas and Ozcan (2018), examined the validity of AMH in the US (S&P 500 Composite) and Turkey (XU100) for the period of 1988-2018 using monthly data and found that EMH performs better than EMH in explaining the market behavior. Gyamfi (2018) examined the predictability of the two indices in the Ghana Stock Exchange (GSEALSH and GSEFSII) for the period of 2011-2015 using the daily return series. Similar to the analysis methods used by Ghazani and Araghi (2014), the author examined whether returns can be predicted by using the Generalized Spectral Test, The Automatic Portmanteau Test and the Wild-bootstrap Automatic Variance Ratio Tests. Research findings support the validity of AMH and show that the GSEALSH index is more predictable than the GSEFSII index.

AMH has been tested in different markets besides stock markets. Neely, Ulrich and Weller (2006) tested the validity of AMH in foreign exchange markets including many currencies between 1973 and 2005 using daily data and found that foreign exchange markets were not compatible with AMH and EMH. Ramirez, Arellano and Rojas (2015) examined the presence of AMH in the agricultural commodity futures market including 4,267 future contracts between 1994 and 2010 using the Hinich Portmanteau Bicorrelation Test and showed that AMH is valid in the sample market. Khuntia and Pattanayak (2018) examined the predictability of Bitcoin returns using rolling-window approach to capture time-varying linear and nonlinear dependence for the period from 2010 to 2017 and concluded that AMH is valid in the Bitcoin market.

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AMH is being examined in different stock markets throughout the world and is gaining stance as a proposal for solution to the conflict between EMH and BF in finance literature. The analysis of validity of this hypothesis for developing markets like Turkey will contribute to the growing literature on the issue and either validate or invalidate the hypothesis.

3. Data and Methods

The data set of the current study consists of 1,591 observations of the daily closing values of Borsa Istanbul Stock Exchange (XU100) for the period of January 02, 2013 - April 26, 2019. The logarithmic return series of the closing prices are obtained using $R_t = ln\,(\frac{P_t}{P_{t-1}})$ transformation.

As shown in Table 2, Borsa Istanbul 100 index returns is negatively skewed and has excessive kurtosis. It is seen that the return series shows conditional heteroskedasticity and is not normally distributed. The ADF and PP unit root test results indicate that return series is stationary. Ljung-Box-Q statistics and ARCH-LM test results show that there is autocorrelation and conditional heteroskedasticity at the 10th lag in return series, respectively. Finally, the linearity of the series has been tested employing BDS test and it was found that the series exhibited a nonlinear structure.

Table 2: Descriptive Statistics

Statistics	XU100 Returns
Observations	1591
Mean	0.0001
Std. Dev.	0.0141
Skewness	-0.5792
Kurtosis	7.2802
Jarque-Bera	1303.453
ADF	-13.1612***
PP	-40.7922***
Ljung-Box-Q (10)	107.506***
ARCH-LM (10)	8.1287***
BDS test ($\varepsilon/\sigma = 1$)	
m=2	0.004528 **
m=3	0.01265 ***
m=4	0.020079 ***
m=5	0.024834 ***

Note: **, *** indicate significance at 5% and 1% significance levels, respectively.

3.1. Automatic Portmanteau (AQ) Test

The Portmanteau test proposed by Box and Pierce (1970) is a tool used to test whether a group of autocorrelation coefficients equals zero.

Given $\{Y_t\}_{t=1}^{T}$ be a time series of index returns at time t (t = 1, . . . ,T).

$\underline{Y}$, to be the sample mean

$\hat{\gamma}_j = \frac{1}{T-j}\sum_{t=1+j}^{T}(Y_t - \underline{Y})(Y_{t-j} - \underline{Y})\,, j = 0, \dots . T-1$ to be the sample autocovariance, and the computation of the (Q_k) test is as follows:

$$Q_k = T\sum_{j=1}^{k}\hat{\rho}_j^2 \tag{1}$$

where T denotes the sample size and k denotes the optimal lag order. And then the null and alternative hypotheses can be formulated as:

$$H_0 = \rho_1 = \rho_2 = \rho_3 = \cdots = \rho_k = 0$$

$$H_1 = \rho_1 \neq \rho_2 \neq \rho_3 \ldots \neq \rho_k = 0$$

The AQ statistic asymptotically follows the chi-squared distribution with k degree of freedom under the null hypothesis of no return predictability.

Lobato et al. (2001) modified the test statistic in Equation 1 for the conditional heteroskedasticity, which is common in financial time series, as follows:

$$Q_k^* = T \sum_{j=1}^{k} \tilde{\rho}_j^2 \quad (2)$$

where $\tilde{\rho}_j^2 = \hat{\gamma}_j^2 / \hat{\tau}_j$ is the estimator for the autocovariance of index return of order j; and

$$\hat{\tau}_j = \frac{1}{T-j} \sum_{t=1+j}^{T} (Y_t - \underline{Y})^2 (Y_{t-j} - \underline{Y})^2 \quad (3)$$

Escanciano and Lobato (2009) proposed that the value of optimal k can be determined automatically based on the Akaike (AIC) and the Bayesian information criteria.

Test statistics showing asymptotic chi-square distribution can be written as follows:

$$AQ = Q_{\tilde{k}}^* = T \sum_{j=1}^{\tilde{k}} \tilde{\rho}_j^2 \quad (4)$$

When the AQ value is greater than 3.84, the null hypothesis suggesting no return autocorrelation is rejected at p<.05.

3.2. Wild-bootstrap Variance Ratio Test

Choi (1999) showed the automatic variance ratio test (AVR) as follows:

$$AVR(\tilde{k}) = \sqrt{T/\tilde{k}}\left[VR(\tilde{k}) - 1\right]/\sqrt{2} \quad (5)$$

where T is the sample size, $\tilde{k}$ is the optimum choice of k

The statistical form of the VR test is as follows:

$$V\hat{R}(\tilde{k}) = 1 + 2 \sum_{i=1}^{T-1} m(i/\tilde{k}\,)\hat{\rho}_i \quad (6)$$

where $\hat{\rho}_i = \sum_{t=1}^{T-i} \Delta r_t \Delta r_{t+i} \,/\, \sum_{t=1}^{T} \Delta r_t^2$ is the sample autocorrelation coefficient and $k(x) = \frac{25}{12\pi^2 x^2}\left[\frac{sin\,(6\pi x/5)}{6\pi x/5} - cos\,(6\pi x/5)\right]$ is the quadratic spectral kernel for the weighting function k (.)

Kim (2009) stated that AVR (k), which is an asymptotic test, may exhibit insufficient small sample characteristics and Mammen's (1993) wild bootstrap test can be applied to improve small sample property in case of conditional heteroskedasticity.

This test is carried out in three stages:

(1) Create a bootstrap sample of T observation from the original return series
(2) Calculate AVR statistics
(3) Repeat steps 1 and 2 N times to generate the bootstrap distribution of the AVR statistic

3.3. Generalized Spectral Tests

Generalized spectral test is a non-parametric test developed by Escansciano and Valesco (2006) to detect the presence of linear and nonlinear dependencies in a stationary time series. They stated that the finite sample performance of the test had a better power than other tests as a result of Monte-Carlo simulation experiments.

Escansciano and Valesco (2006) suggested that, in terms of the least mean error squares, the future values of a time series that included the available information were only unconditional expectations and that the past information did not improve in predicting the future values of the Martingale Difference Sequence. Thus, they proposed the hypothesis that returns are unpredictable (Martingale difference series).

$$H_0: E(Y_{t-1}, Y_{t-2}, \dots) = \mu \tag{7}$$

Stationary return series (Martingale Difference Series) suggesting that returns are unpredictable where μ is a real number.

The form in Equation 7 is formed as a pairwise regression functions as follows:

$$H_0: m_j(y) = 0$$

$$H_1: P[m_j(y) \neq 0] > 0 \quad for\ some\ j$$

$m_j(y) = E[Y_t - u|Y_{t-j} = y]$ are the pairwise regression functions.

The conditional mean dependency measure in nonlinear time series framework showing pairwise regression functions is given below:

$$\gamma_j(x) = E[Y_t - u)e^{ixY_{t-j}}] = 0 \tag{8}$$

$\gamma_j(x)$: measure of non-linear auto-covariance,

x: indicates any real number.

The spectral distribution function proposed by Escanciano and Velasco (2006) to test the hypothesis contained in equation (1) is expressed as follows:

$$\widehat{H}(\lambda, x) = \hat{\gamma}_0(x)\lambda + 2\sum_{j=1}^{n-1}\left(1 - \frac{j}{n}\right)^{1/2} \hat{\gamma}_j(x)\frac{sin\ j\pi\lambda}{j\pi} \tag{9}$$

$(1 - j/n)^{1/2}$ represents the finite sample correction factor. Escansciano and Valesco (2006) stated that this factor showed a better finite sample performance, especially in terms of the power of the test.

where,

$\hat{\gamma}_j(x) = \frac{1}{n-j}\sum_{1+j}^{n}(Y_t - \underline{Y}_{n-j})e^{ixY_{t-j}}$ and $\underline{Y}_{n-j} = \frac{1}{n-j}\sum_{1+j}^{n} Y_t$

$H(\lambda, x) = \gamma_0(x)\lambda$ to test the hypothesis H_0:

$$S_n(\lambda, x) = \left(\frac{n}{2}\right)^{1/2} \{\widehat{H}(\lambda, x) - \widehat{H}_0(\lambda, x)\}$$

The distance of $S_n(\lambda, x)$ to zero is obtained by Cramer - Von Mises rule:

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$$D_n^2 = \sum_{j=1}^{n-1}(n-j)\frac{1}{(j\pi)^2}\sum_{t=j+1}^{n}\sum_{s=j+1}^{n}(Y_t - \underline{Y}_{n-j})(Y_s - \underline{Y}_{n-j})exp\,(-0.5(Y_{t-j} - Y_{s-j})^2) \quad (10)$$

When the value of D_n^2 is large, the null hypothesis is rejected.

4. Results

Table 3 shows the results of the three tests explained in the methodology. Table 3 shows the test statistics for the Borsa Istanbul 100 index return series for the full sample period from January 02, 2013 to April 26, 2019. When the results of these auto-correlation-based tests were examined, the null hypothesis could not be rejected for all three tests. Based on these results, it is seen that index returns cannot be predicted for the full sample period.

Table 3: Full Sample Statistics

Test	XU100
GS test	(0.5766)
	0.4895
AQ test	(0.4841)
	-0.6820
WBAVR test	(0.3590)

Note: The expressions in parentheses indicate the probability value of the test statistics.

These results, which are predicted for the full sample period, do not show the predictability of short-term time varying return. Therefore, rolling window approach has been used to assess time-varying return predictability.

There is no theory in common practice about how to select the length of the time window (Lim et al., 2013). In this study, the window length has been chosen as 300, 400 and 500 days, respectively, in order to determine the predictability of the index return series with time-varying dynamic properties.

In below, Figure 1-3 show the time-varying returns respectively 300, 400, 500 daily rolling windows using the AQ test and Figure 4-6 show the time-varying returns respectively 300, 400, 500 daily rolling windows using the WBAVR test.

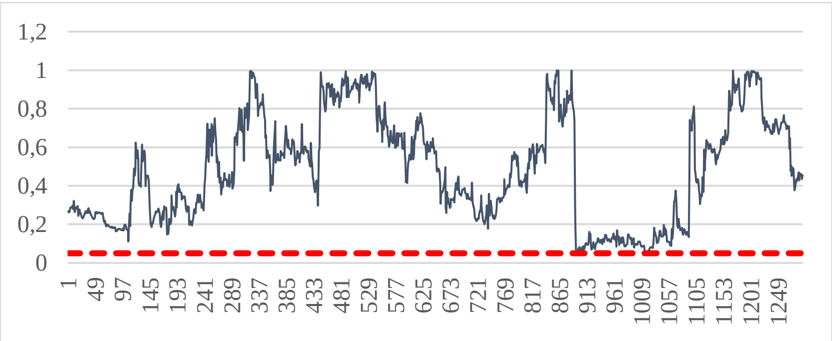

Figure 1: AQ Test Rolling Window *p* values (T=300)

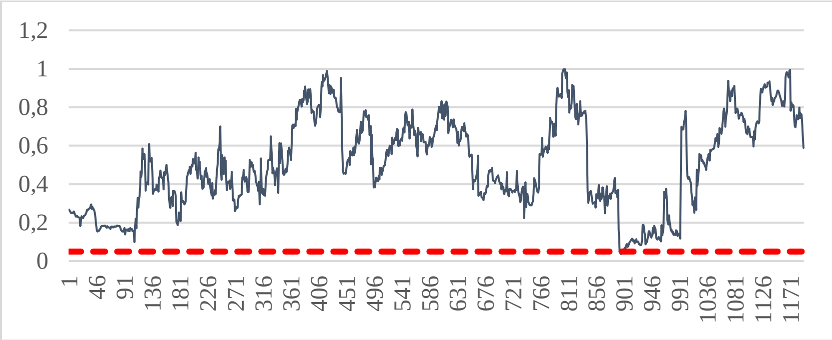

Figure 2: AQ Test Rolling Window *p* values (T=400)

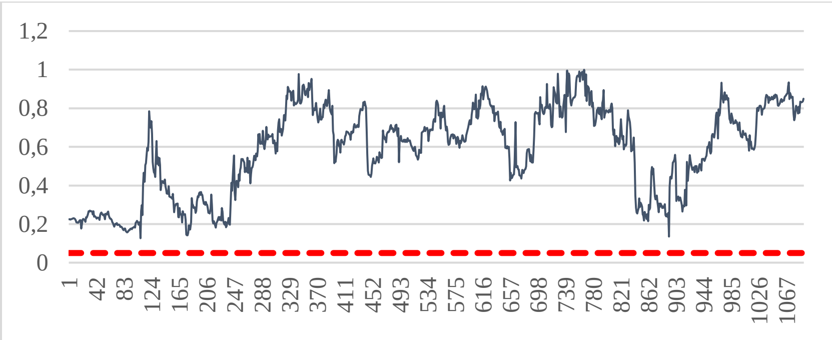

Figure 3: AQ Test Rolling Window *p* values (T=500)

Note: The horizontal line in the graphs shows the threshold level of 5% for statistical tests.

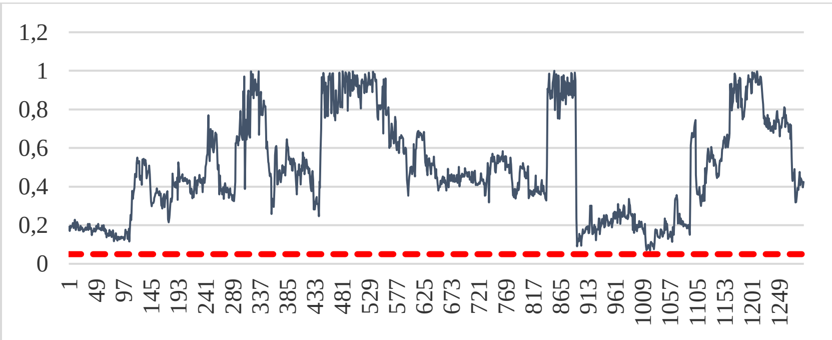

Figure 4: WBAVR Test Rolling Window *p* values (*T*=300)

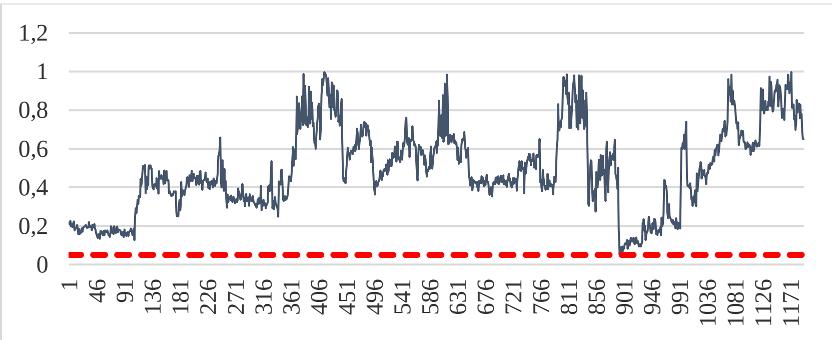

Figure 5: WBAVR Test Rolling Window *p* values (*T*=400)

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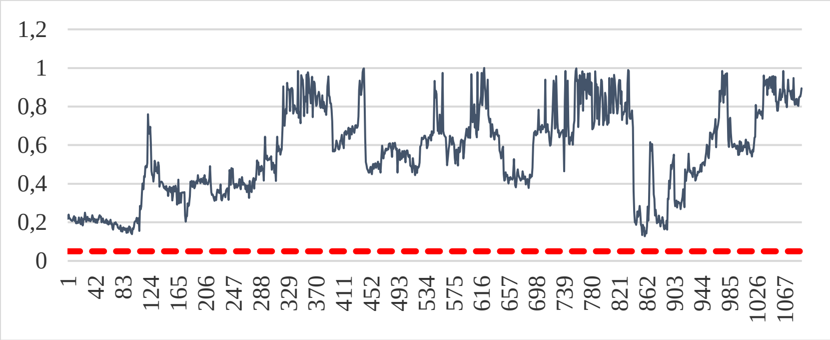

Figure 6: WBAVR Test Rolling Window *p* values (*T*=500)
Note: The horizontal line in the graphs shows the threshold level of 5% for statistical tests.

When the graphs of both Automatic Correlation Test (AQ) and Wild Bootstrap Automatic Variance Ratio test are examined using rolling window approach, it is seen that p value does not lie below 5% threshold value in any period. This shows that returns are unpredictable and the predictable structure of the data is not time-varying. This finding contradicts the AMH, which asserts that market efficiency is time-varying.

5. Conclusion

In this study, the predictability of stock returns traded on Borsa Istanbul was examined by using automatic portmanteau test (AQ) and wild-bootstrap automatic variance ratio test (WBAVR). In addition, generalized spectral test (GS) was used to determine the possible nonlinearity in return series. The validity of Adaptive Market Hypothesis was tested to take into account time-varying both for the full sample period and for the sub-periods. It was concluded that Adaptive Market Hypothesis is not valid for Borsa Istanbul for the full sample period. On the other hand, the predictability of stock returns was examined using the 300, 400 and 500 days rolling window approach and it was found that Adaptive Market Hypothesis was not supported according to all the three test results. In other words, it has been determined that the degree of efficiency of the stock market index does not change over time depending on market conditions. The findings of the research have similar results with Neely et al. (2006) and Hiremath and Kumari (2014). As a result, the analysis findings for the sample period showed that stock returns cannot be estimated in Borsa Istanbul and that investors cannot obtain abnormal returns in this market. The findings may be useful in terms of portfolio diversification for international portfolio investors. An important limitation of this study is that the findings are valid for only the specified period examined in Borsa Istanbul and cannot be generalized for different markets and periods. Therefore, future studies for different markets may contain significant contribution for the validity of the hypothesis.

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