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ANALYSIS OF EFFICENT MARKETS HYPOTHESIS IN SHARE MARKET WITH LONG MEMORY MODELS*

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Abstract

The COVID-19 pandemic has precipitated significant alterations not only in global lifestyles and daily routines but also in investment behaviors. This study aims to test the validity of the efficient markets hypothesis in the indices in Borsa Istanbul during the COVID-19 pandemic and the period when the pandemic effects on the country's economies and individuals continued. The study involves analyzing the stationarity of the return series for these equity indexes using both traditional unit root tests (ADF and PP) and those considering structural breaks (Zivot Andrews). Furthermore, the presence of the EMH was examined through the application of long memory models, employing methods such as Geweke and Porter-Hudak, Modified Log-Periodogram, and Robinson Gaussian Semi-Parametric. The findings reveal that the returns of BIST100, BIST50, BIST30, and BISTTUM indexes are non-stationary, do not exhibit mean reversion following shocks, and lack long memory characteristics. These results suggest that investors' attempts to predict price movements of these indexes may be misleading, indicating that only weak-form efficiency could be argued for these indexes.

Keywords: Efficient Markets Hypothesis, Borsa Istanbul, Covid-19, Long Memory Model
JEL Classification: G14, G17, C24

PAY PİYASASINDA ETKİN PİYASALAR HİPOTEZİNİN UZUN HAFIZA MODELLERİ İLE ANALİZİ

Öz

Covid-19 pandemisi, dünya çapında insanların yaşam tarzları ve günlük rutinler üzerinde olduğu kadar yatırım davranışları üzerinde de önemli değişikliklere neden olmuştur. Bu çalışmanın amacı Covid-19 pandemi dönemi ve sonrasında ülke ekonomileri ve bireyleri üzerinde pandemi etkilerinin devam ettiği dönemde Borsa İstanbul'da yer alan endekslerde etkin piyasalar hipotezinin geçerliliğinin test edilmesidir. Araştırma kapsamında, söz konusu pay senedi endekslerinin getiri serilerinin durağanlık durumu, hem geleneksel (ADF ve PP) hem de yapısal kırılmaları göz önünde bulunduran birim kök testleri (Zivot Andrews) aracılığıyla analiz edilmiştir. Ayrıca, Etkin Piyasa Hipotezinin varlığı, uzun hafıza modeli kullanılarak Geweke ve Porter-Hudak, Modifiye Edilmiş Log-Periodogram ve Robinson Gaussian Yarı Parametrik Yöntemlerle incelenmiştir. Araştırmanın sonuçları, BIST100, BIST50, BIST30 ve BISTTUM endekslerinin getirilerinin durağan olmadığını, şoklardan sonraki ortalamalarına dönüş eğilimi göstermediğini ve uzun hafıza özelliği taşımadığını ortaya koymaktadır. Bu bulgular, yatırımcıların bu endekslerin fiyat hareketlerini tahmin etme çabalarının yanıltıcı olabileceğine ve bu endekslerde zayıf formda etkinlikten bahsedilebileceğine işaret etmektedir.

Anahtar Kelimeler: Etkin Piyasalar Hipotezi, Borsa İstanbul, Covid-19, Uzun Hafıza Modeli
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1. INTRODUCTION

The concept of market efficiency was first introduced by the French mathematician Louis Bachelier in his doctoral dissertation in 1900, and the theoretical framework of price movements in capital markets gained momentum with the work of Samuelson (1965). The efficiency hypothesis in financial markets, on the other hand, entered the literature for the first time with Eugene Fama's (1970) study titled "Capital Market Efficiency". According to Fama (1970), the concept of efficient market has a comprehensive structure and is defined as market conditions in which rational investors aiming at profit maximization compete with each other and information is easily accessible to all investors (Bal et al., 2021: 328).

The Efficient Market Hypothesis (EMH) stands as a cornerstone topic within traditional finance theory. The pursuit of higher returns against lower risks by investors operating in capital markets has perpetually heightened interest in studies related to market efficiency. Traditionally, finance theory posits that the expectation of returns against assumed risk is a fundamental factor in investment decisions, suggesting that investors design their portfolio diversification based on the most suitable risk-return profile relative to their characteristics in the capital market. This implies that investment decisions made by investors are based on rational grounds.

The EMH measures the efficiency of financial markets through the reflection of all relevant information in the price movements of financial instruments. According to this hypothesis, a market is considered efficient when any piece of information becomes simultaneously accessible to all market participants and when access to all information concerning all firms is possible for every investor in the market. Under these conditions, where all information is simultaneously distributed and priced in, it becomes impossible for any investor to consistently achieve above-average returns.

The validity of the EMH is predicated on a series of assumptions regarding market operations and investor behaviors. The assumption that financial asset prices fully reflect all information posits a challenging scenario. In this context, three primary concepts have been proposed concerning financial market efficiency: allocational efficiency, operational efficiency, and informational efficiency (Atan et al., 2009: 35). These concepts are rooted in the three levels of efficiency discussed in Fama's (1970) work: weak-form, semi-strong form, and strong-form efficiency.

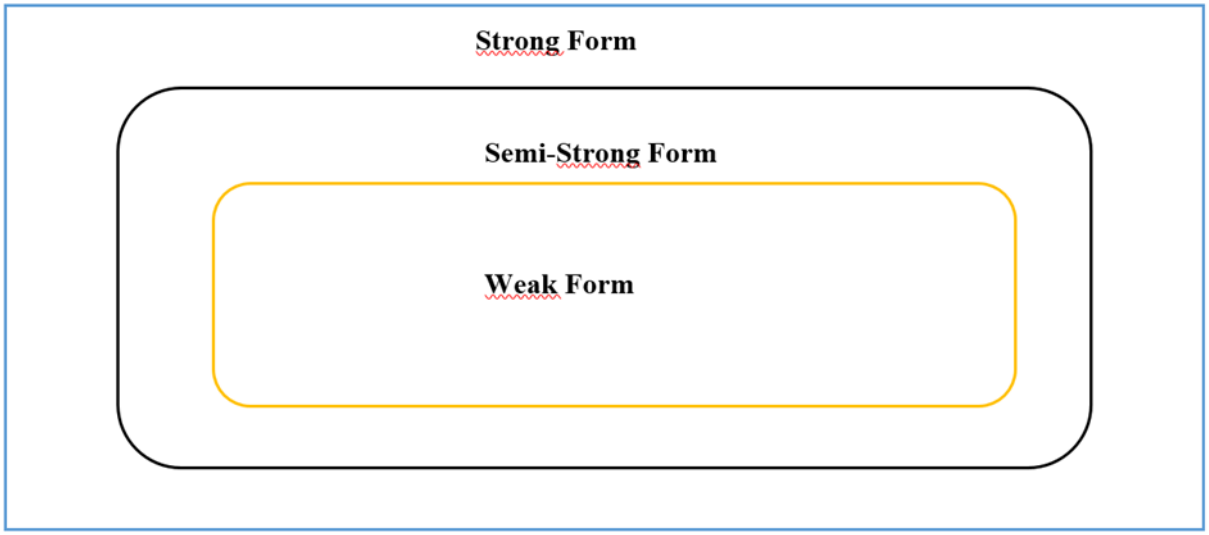

Figure 1. Types of Efficient Market

In a weakly efficient market, stock prices include all historical market information, such as past price movements, trading volume, and interest rates. In this case, trend analysis cannot be expected to

provide any advantage to investors. All this historical data is publicly available and usually does not require any cost to access. Therefore, this information is considered to be fully reflected in prices. Consequently, investors can't achieve an above-normal return using only this historical market data (Evrim Mandacı, 2018: 88).

The semi-strong form, the second stage of the EMH, is a market structure where security prices fully reflect all publicly available information. However, in such markets, the role of inside information is crucial. Some investors can gain an advantage about the future direction of the market by gaining access to unpublicized inside information. Investors who act on the basis of this inside information may earn above the average market return by taking advantage of information that has not yet been made public (Fama, 1970: 383-384).

In a strong-form, efficient market, stock prices incorporate all relevant information, including insider information. That is, all public and private information is fully captured in prices. However, this hypothesis expresses a broad assumption that corporate managers have access to private information about the firm before it is publicly disclosed and can use it to their advantage to trade in the market (Evrim Mandacı, 2018: 93).

In an efficient market, it is assumed that all information that could affect the value of a stock is priced in. The only information that can cause a change in stock prices is new information that has not been priced in before. The direction and magnitude of price changes based on emerging new information cannot be determined. This indicates that stock prices in the market follow a random walk.

The EMH articulates that since all information affecting stock prices is already incorporated into the price, investors cannot use past data of stocks to forecast future prices, thereby eliminating the possibility of achieving abnormal returns. Consequently, in capital markets, the search by investors for undervalued or overvalued stocks is considered unreasonable, and forecasts made using technical analysis tools are unlikely to yield meaningful outcomes. If studies indicate the absence of market efficiency, investors still using technical analysis tools to predict future stock prices might have the opportunity to achieve non-random, abnormal returns by identifying undervalued or overvalued stocks.

For the efficient markets hypothesis to be valid, the prices of the security should exhibit a random walk feature, and it is expected that the prices should show a short memory feature that does not include past price movements. On the other hand, if a security's price series exhibits a long memory feature, past prices impact the current period price. Accordingly, the security prices do not show a random walk feature. For this reason, investigating the existence of long memory in security prices has attracted considerable theoretical and empirical attention in the finance literature in recent years to determine whether the asset pricing model and the efficient markets hypothesis are valid (Çevik, 2012: 4438).

Türkiye has implemented comprehensive and multifaceted economic policies to support its economy and mitigate the adverse effects of the COVID-19 pandemic. The government ensured the financial sustainability of small and medium-sized enterprises (SMEs) by providing KOSGEB support and low-interest loans. In addition, short-time working allowance programs were introduced to protect employment, and social benefits to reduce unemployment were expanded. Tax postponements and reductions aimed to maintain uninterrupted cash flows, and special incentives were provided to sectors struck by the pandemic, such as tourism and exports. To ensure economic stability, the Central Bank adopted flexible interest rate policies to provide liquidity support and minimize financial market volatility. Technology investments were prioritized to accelerate digital transformation, and e-commerce and telecommuting infrastructures were strengthened. Additional resources were allocated to health expenditures to ensure the smooth functioning of the health sector, and comprehensive fiscal

stimulus packages were implemented to support the overall economic recovery. The combination of these policies contributed to the resilience of the Turkish economy during the pandemic and steady growth during the recovery.

Türkiye implemented various policies to support economic recovery after Covid-19. In the fight against inflation, the Central Bank revised interest rates and took steps to stabilize exchange rates to ensure stability in monetary policies. New trade agreements and incentives were introduced to boost exports, and exceptional support packages continued for areas that suffered during the pandemic, such as the tourism sector. These policies have contributed to Turkey's post-pandemic economic stabilization and achievement of sustainable growth targets.

Investigating the EMH during and after the COVID-19 period is of great importance for a deep understanding of the behavior and efficiency of financial markets. The high volatility and economic uncertainties experienced during this period provide ideal opportunities to analyze market behavior and assess the speed of information flow and how efficiently markets react to this information. Moreover, the price volatility observed during the pandemic provides a basis for testing the extent to which the EMH reflects the actual value of market prices, and anomalies in the markets offer the opportunity to question the validity of the EMH. In terms of understanding investor behavior, the functioning of markets can be better understood by comparing irrational and emotional responses during crisis periods with the contributions of behavioral finance theories to EMH, while the effects of algorithmic and high-frequency trading on market efficiency can also be examined during this period. In terms of policy and regulation, analyzing the impact of the central bank and government interventions taken during the pandemic on market efficiency can contribute to developing more effective policies for future crises, while assessing the effects of existing regulations on the market can help improve the regulatory framework. As for the development of long-term economic and financial strategies, the study of EMH allows investors and financial institutions to strengthen their risk management strategies and optimize portfolio diversification and investment strategies, thereby increasing financial markets' resilience and information processing capacity. In conclusion, researching the EMH during and after COVID-19 makes significant contributions to the academic literature and provides practical information for practitioners, allowing financial markets to function more healthily and efficiently.

There are many methods in the literature to examine weak-form market efficiency. In this study, the validity of the EMH will be evaluated based on whether security prices exhibit random walk characteristics. The random walk feature of prices is associated with the absence of past price movements and short memory. If the security price series exhibits long memory, this implies that current prices are affected by past prices and, therefore, security prices do not show a random walk.

When the pandemic period and its immediate aftermath are examined, there have been significant changes and disruptions in the number of active investors in Borsa Istanbul, the volume of transactions carried out, and investors' interest in financial literacy compared to the pre-pandemic period. The need to re-examine and analyze these developments experienced in Borsa Istanbul in the specified period on Borsa Istanbul Indices within the framework of EMH constitutes the motivation of the study. This study aims to test the validity of the efficient markets hypothesis in the indices in Borsa Istanbul during the COVID-19 pandemic and the period when the pandemic effects on the country's economies and individuals continued. The uniqueness of the study is that its analysis period covers the pandemic and its immediate aftermath, and the investor behavior in this period is analyzed within the framework of the EMH in Borsa Istanbul. In this respect, it is expected to contribute to the literature. Towards this objective, the study is structured with an introduction in the first section, literature review, methods, and findings in the second section, and conclusions and recommendations in the final section. In the empirical part of the study, the stationarity of series was first analyzed using traditional and structural

break unit root tests, followed by an investigation into the presence of long memory in relation to the validity of the EMH in Stock Indexes through Geweke and Porter-Hudak, Modified Log-Periodogram, and Robinson Gaussian Semi-Parametric methods. The analysis's findings suggest that the BIST100, BIST50, BIST30, and BISTTUM indices are non-stationary and weakly efficient.

2. LITERATURE

This section includes some national and international studies from the literature on the investigation of the validity of the EMH. Researchers in various markets have extensively studied the EMH and the existence of long-memory properties in financial time series to understand their impact on market efficiency and predictability. This literature review synthesizes empirical findings from many studies focusing on emerging markets, particularly the Turkish equity market, while including analysis from developed markets and cryptocurrency assets.

The originality of this study lies in its comprehensive analysis of Borsa Istanbul during and immediately after the COVID-19 pandemic, which was characterized by unprecedented market volatility and uncertainty. Unlike previous research in the literature, which predominantly examines market efficiency and long memory properties during stable or pre-crisis periods, this study specifically focuses on investor behavior and market dynamics during and immediately after a global health crisis. By aggregating data during and after the pandemic, the study captures the effects of significant external shocks on market efficiency and thus provides an assessment of EMH. In addition, this research fills a critical gap by investigating how extreme events in Borsa Istanbul affect the validity of the EMH and provides relevant insights for understanding market resilience and investor behavior, especially in times of crisis. Its focus on a turbulent period distinguishes the study from similar research that often fails to account for such extreme events, thus adding new perspectives to the discourse on market efficiency and behavioral finance in emerging financial markets.

Resende and Teixeira (2002) were among the first to apply the ARFIMA model to the Brazilian stock market data from 1986 to 1999, finding no evidence of long memory in return series. Similarly, Kılıç (2004) investigated the İMKB-100's daily index returns and their absolute and squared returns using both parametric FI-GARCH models and non-parametric methods, concluding that the İMKB-100 did not exhibit long memory properties, contrasting with emerging capital markets. In contrast, Kasman and Torun (2007) identified bi-directional long memory in both returns and volatility of the İMKB-100 Index through ARFIMA-FIGARCH modeling, suggesting predictability in stock prices and challenging the EMH. Further exploring market efficiency, Atan et al. (2009) employed ADF and KPSS unit root tests alongside the ELW fractional integration estimator on high-frequency data, ultimately asserting the İMKB's weak-form efficiency.

Subsequent research by Karanasos and Kartsaklas (2009) in the South Korean securities market and Korkmaz et al. (2009) within the İMKB-100 index corroborated the presence of long memory in volatility but not in returns, reinforcing the notion that while price series may adhere to EMH, volatility dynamics exhibit persistent behavior. Çevik and Erdoğan (2009) extended this analysis to the Turkish banking sector, revealing that considering structural breaks altered the memory characteristics, indicating mean-reversion tendencies and questioning market efficiency. Çevik (2012) further validated the failure of EMH in the İMKB by demonstrating long memory in sector index volatilities through parametric and semi-parametric models.

Additional studies have provided mixed evidence regarding market efficiency. Çevik and Topaloğlu (2014) utilized the A-FIGARCH model on BIST-100 and BIST-30 indexes, finding long memory in conditional variances and rejecting weak-form efficiency. Conversely, Gözbaşı (2014) employed linear and non-linear unit root tests on daily and hourly data, concluding that the BIST stock market maintained weak-form efficiency. Similarly, Altunöz (2016) used ADF and PP unit root tests on

banking stocks, supporting the market's weak efficiency by validating the random walk model. Çelik and Kaya (2019) and Çevik and Sezen (2020) reinforced the distinction between returns and volatility, consistently finding no long memory in returns but confirming its presence in volatility, thereby challenging weak-form efficiency in the banking sector.

Bal et al. (2021) applied various unit root tests, including the Fourier ADF test, to weekly closing prices of the BIST Banking Index from 2005 to 2018, ultimately supporting weak-form efficiency. Expanding the scope beyond traditional markets, Bezgin (2022) employed the Hurst Exponent-Rescaled Range analysis to assess the Fractal Market Hypothesis across emerging, developed, and crypto markets, finding pronounced long memory in emerging markets and Bitcoin. Konak and Türkoğlu (2023) explored the impact of DAX40 index inclusion on stock returns, identifying predictability and inefficiency in the semi-strong form of the market. Finally, Küçükkaplan et al. (2023) tested EMH validity in G-8 countries using Fourier unit root tests, affirming EMH in Germany, France, and Japan while rejecting it for the Russian stock index.

The literature presents a heterogeneous landscape regarding market efficiency and long-memory characteristics. Emerging markets, particularly the Turkish stock market, often display conflicting evidence dependent on the methodologies employed and specific market segments analyzed. While some studies uphold EMH, especially in return series, others reveal long memory in volatility, suggesting complexity in market dynamics that traditional EMH frameworks may not fully capture. Additionally, comparative analyses across different market types, including developed markets and cryptocurrencies, underscore the variability in persistence and efficiency, pointing towards a more nuanced understanding of financial market behavior. A summary of empirical studies testing the EMH is provided in Table 1.

Table 1. Summary of Empirical Studies Testing the EMH

Author(s)	Method	Sample	Finding
Resende & Teixeira (2002)	ARFIMA model	Brazilian stock market, 1986-1999	Return series did not exhibit long memory properties.
Kılıç (2004)	Parametric FI-GARCH models and non-parametric methods	İMKB-100 daily index returns	İMKB-100 index returns did not possess long memory properties, contrasting with emerging capital markets.
Kasman & Torun (2007)	ARFIMA-FIGARCH model	İMKB-100 Index, daily returns	Detected long memory in both returns and volatility, suggesting predictable stock prices and challenging the EMH.
Atan et al. (2009)	ADF and KPSS unit root tests; ELW fractional integration estimator	İMKB data from 3 Jan 2003 to 30 Dec 2005, 15-minute and session frequency data	İMKB was an efficient market in its weak form.
Karanasos & Kartsaklas (2009)	FIGARCH model	South Korean securities market, 1995-2005	Volatility possessed long memory characteristics.
Korkmaz et al. (2009)	Structural break tests and ARFIMA-FIGARCH method	İMKB-100 index, 1988-2008	No long memory in returns; long memory detected in volatility.
Çevik & Erdoğan (2009)	Structural break tests and strong memory models	Turkish banking sector, 2003-2007	Without structural breaks: weak form efficiency. With structural breaks: strong memory indicating mean reversion.

Çevik (2012)	Parametric and semi-parametric methods	İMKB 10 sub-sector indexes	Volatility of sector index returns exhibited long memory, indicating failure of the EMH.
Tufan & Sarıçiçek (2013)	Review of behavioral finance models, EMH, and its anomalies	Review Study	Momentum and contrarian strategies were more preferred by investors.
Zeren et al. (2013)	Structural break unit root tests	İMKB-100 index	İMKB-100 index was non-stationary, hence the stock market was efficient.
Çevik & Topaloğlu (2014)	A-FIGARCH model	BIST-100 and BIST-30 indexes, 1988-2014, daily closing data	Conditional variance exhibited long memory, indicating Borsa İstanbul was not efficient in its weak form.
Gözbaşı (2014)	Harvey et al. (2008) test; non-linear unit root tests by Kapetanios et al. (2003) and Kruse (2011)	BIST stock market, daily and hourly data	BIST stock market was efficient in its weak form.
Altunöz (2016)	ADF and PP unit root tests	Borsa İstanbul banking stocks, 2006-2014	Series had a unit root at level, supporting market efficiency and the validity of the random walk model.
Çelik & Kaya (2019)	ARFIMA-FIGARCH and ARFIMA-FIEGARCH models	Turkish banking sector index	No evidence of long memory in returns; presence of long memory in volatility; no long memory in returns based on ARFIMA-FIEGARCH model estimates.
Çevik & Sezen (2020)	ARFIMA and FIGARCH models	Borsa İstanbul banking sector index, 1997-2018	Long memory in volatility; Borsa İstanbul banking sector was not efficient in its weak form.
Bal et al. (2021)	ADF, Christopoulos & Leon-Ledesma (non-linear unit root tests), Fourier ADF test	BIST Banking Index, 2005-2018, weekly closing price data	BIST Banking Index is weakly efficient.
Bezgin (2022)	Hurst Exponent-Rescaled Range (R/S) analysis method	Two emerging markets, two developed markets, two crypto assets	Fractal Market Hypothesis holds in all; long memory more pronounced in emerging markets and Bitcoin.
Konak & Türkoğlu (2023)	Case study	Impact of DAX40 index formation process on stock prices	Inclusion in DAX 40 had significant effects on returns, indicating market predictability and inefficiency in its semi-strong form, offering opportunities for above-average returns.
Küçükkaplan et al. (2023)	Fourier unit root tests	G-8 countries stock indexes	EMH valid in Germany, France, and Japan; invalid in the Russian stock index.

Note: Compiled by the author based on the relevant literature.

3. DATA, METHODOLOGY AND FINDINGS

This section of the study will address the data set, methodology, and findings related to the research.

3.1. Data Set

The scope of the study, which tests the validity of the efficient markets hypothesis in Borsa Istanbul equity market indices, consists of the returns of 213 weekly closing data of Borsa Istanbul - 100 (BIST100), Borsa Istanbul - 50 (BIST50), Borsa Istanbul - 30 (BIST30) and Borsa Istanbul All (BISTTUM) equity indices in the Borsa Istanbul equity market between January 1, 2020 and January 31, 2024, when the first pandemic-related cases started to be seen. Variables are included in the analysis by taking their logarithms. Stock prices of Borsa İstanbul - 100 (BIST100), Borsa İstanbul - 50 (BIST50), Borsa İstanbul - 30 (BIST30), and Borsa İstanbul All (BISTTUM) were obtained from the investing.com website, and the analysis was carried out using Eviews and Stata programs.

3.2. Methodology

3.2.1. Unit Root Tests

Time series analysis encompasses a significant interest within various disciplines such as statistics, econometrics, and similar fields. Time series are utilized to illustrate how variables distribute from one period to another. This denotes the sequential changes of variables' numerical values over time, such as in day-time units, months, or years, expressing how these alterations are observed through time. In other words, the time series method displays the changes occurring within variables over a specified time frame, either graphically or numerically (Güriş et al., 2013: 6). In analyses based on time series, a critical aspect is whether the series exhibit stationarity. A time series being stationary implies it has a constant mean and variance over time. Moreover, if the covariance does not change between two periods and this change depends only on the distance between two data periods, it is possible to declare the series as stationary (Sandalcılar, 2012: 6).

The traditional methods most commonly applied in the literature for testing the stationarity of variables include the Dickey Fuller (1979) unit root test, the Augmented Dickey Fuller (1981) unit root test, and the Phillips Perron (1988) tests. It is stated that if there is a structural break in time series and this break is not considered in the stationarity test, the likelihood of the series being non-stationary is high. Conversely, under the condition of a break, a series that appears to be non-stationary may actually be stationary. Therefore, tests that take into account structural breaks within the series have been developed. When the period of the structural break is known, tests that externally determine the break can be utilized. However, if the break period is unknown, it is necessary to test for the presence of a break and, if present, identify the break point (Sarılar, 2020: 58). One of the unit root tests used under structural breaks in the literature is the Zivot – Andrews test.

3.2.2. Long Memory Models

Long-term dependence, or alternatively referred to as long memory, is a critical concept in time series analysis characterized by the presence of significant lagged correlations over extended periods (Mandelbrot and Van Ness, 1968: 422). This indicates that even values of a time series at distant time points can have a meaningful relationship with each other, suggesting the series possesses a strong memory property. On the other hand, weak memory or short-term dependence describes the characteristics of time series over shorter time intervals, where long-term lagged correlations become insignificant (Box and Jenkins, 1970: 307). This distinction is crucial for understanding the dynamics in time series analysis.

3.2.2.1. Geweke and Porter-Hudak Semi-Parametric Method

In the process of estimating the fractional integration parameter, a frequently referenced method in academic literature is the log-periodogram regression proposed by Geweke and Porter-Hudak (1983). This methodology is particularly favored in the context of examining the long memory properties of

time series and is effectively utilized in empirical studies across various fields (Geweke and Porter-Hudak, 1983: 237).

$(1-L)^d Y_t = u_t$

The equation used for estimating the GPH d parameter is presented below;

$Y_j = \propto -dZ_j + \in_j, \qquad j = 1, 2, 3, \ldots,$

$Y_j = \log I(\lambda_j), Z_j = \log(4sin^2(\lambda_j/2)), \qquad m = T^{\lambda}\varepsilon_t \approx ii.i.d.(0, \frac{n^2}{6})$

Robinson's (1990) method has proven that the parameter d, within the range 0<d<0.5, is asymptotically normal and consistent, thus extending the findings previously only validated for d<0 by GPH. Subsequent work by Velasco (1999) has provided a proof of asymptotic theory under additional constraints for the range 0.5<d<1, representing non-stationary cases. However, Agiakoglu et al. (1993, p. 1011) have noted that the GPH estimation encounters bias issues in finite samples and is particularly inefficient for u_t as defined in equation 4 for AR(1) or MA(1) processes. Furthermore, they discussed that GPH estimation is not robust for first differences, hence the test could lead to misleading results.

3.2.2.2. Modified Log Periodogram Method

Phillips' 1999 study has made a significant contribution in the evaluation of parameters used in cointegration analysis. In this study, an improved version of the GPH (Geweke and Porter-Hudak) method, known as the Modified Log-Periodogram (MLP) method, is introduced. This method, developed by Phillips, is capable of producing consistent results even when the cointegration parameter d≥0.5, including in AR(1) and MA(1) processes. Particularly, this method yields consistent results for the d parameter even in the case of a unit root, providing effective estimations even when the null hypothesis is d=1. Thus, the work done by Phillips (1999) establishes an important reference point for the accuracy and reliability of methods used in time series analysis (Phillips, 1999: 45).

According to the Modified Log Periodogram method, the MLP estimate is measured through the following equation;

$(1-L)^d Y_t = u_t, \quad t \geq 0, X_0 = u_0 = 0$

In the equation above, u_t represents the zero-mean stationary term, and its continuous spectral density is denoted as $f_u(\lambda) > 0$.

3.2.2.3. Robinson Gaussian Semi-Parametric Method

Robinson's (1995b) work introduced an asymptotically efficient "Gaussian Semi-Parametric" (RGSP) estimation method for cases where the spectral density function of series cannot be expressed in closed form. This method differs from the suggestions by GPH (1983) and Robinson's own earlier proposal (1995a). The primary advantage of the RGSP method over other semi-parametric approaches is its ability to provide consistent results when testing for long memory properties in time series, applicable both to series with conditional constant variance and those with conditional heteroskedastic variance (Robinson, 1995b: 104).

The RGSP estimate is dependent on the m parameter, and it is stated here that m is equal to or less than $\left[\frac{T-1}{2}\right]$ when it denotes $T \to \infty$ $\left(\frac{1}{m} + \frac{m}{T}\right) \to 0$. The GSP estimate is obtained by minimizing the formula presented below:

$$r(d) = q(\hat{g}, d) - 1 = lnm^{-1}\sum_{j=1}^{m}\frac{I(\lambda_j)}{\lambda_j^{-2d}} - 2dm^{-1}\sum_{j=1}^{m} ln\lambda_j$$

3.3. Findings

In the analysis, traditional unit root tests, namely the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, were employed to investigate the stationarity of the series used. Additionally, the Zivot-Andrews unit root test for structural breaks was utilized to examine whether the variables were stationary under structural breaks. The results of the unit root tests are presented below in Table 2 and Table 3, respectively.

Table 2. ADF and PP Unit Root Test Results

Variables	ADF		PP		Decision
	Constant	Constant and Trend	Constant	Constant and Trend	
BIST100	1.074 (0.997)	-1.448 (0.843)	1.488 (0.999)	-1.230 (0.901)	Non-stationary
ΔBIST100	-4.671 (0.00)	-5.060 (0.00)	-13.001 (0.00)	-13.214 (0.00)	Stationary
BIST50	1.161 (0.997)	-1.425 (0.850)	1.563 (0.999)	-1.221 (0.903)	Non-stationary
ΔBIST500	-4.944 (0.00)	-5.356 (0.00)	-13.463 (0.00)	-13.703 (0.00)	Stationary
BIST30	1.197 (0.998)	-1.442 (0.845)	1.588 (0.999)	-1.264 (0.893)	Non-stationary
ΔBIST30	-5.092 (0.00)	-5.517 (0.00)	-13.931 (0.00)	-14.213 (0.00)	Stationary
BISTTUM	1.137 (0.997)	-1.293 (0.886)	1.597 (0.999)	-1.035 (0.935)	Non-stationary
ΔBISTTUM	-4.512 (0.00)	-4.918 (0.00)	-11.869 (0.00)	-12.043 (0.00)	Stationary

Note: The symbol 'Δ' represents the difference. The values in parentheses indicate the probability values.

The results of the ADF and PP unit root tests for the BIST100, BIST50, BIST30, and BISTTUM variables are presented in Table 2 above. According to the outcomes of both tests, all variables possess a unit root at level values (non-stationary) but become stationary at the 1% significance level when first differences are taken. These findings are consistent with the results of studies conducted in the literature (Atan et al., 2009; Altunöz, 2016). Both ADF and PP test results indicate that the presence of a unit root at level values for BIST100, BIST50, BIST30, and BISTTUM indexes, in other words, their non-stationarity, demonstrates that the series do not exhibit a tendency to revert to their mean following shocks, thereby lacking long memory characteristics. Contrary to mean reversion, the series tends towards a new equilibrium point. This situation suggests that investors' predictions regarding index prices may be misleading. This outcome implies the possibility of discussing weak-form efficiency in these indexes since it conveys a notion of a random walk.

Table 3. Zivot-Andrews Unit Root Test Results with Structural Breaks

Variables	Model A (Constant)	Break Time	Model B (Trend)	Break Time	Model C (Constant and Trend)	Break Time
BIST100	-3.962	5/22/2023	-4.530	5/02/2022	-4.519	4/18/2022
BIST50	-3.837	5/22/2023	-4.453	4/25/2022	-4.442	4/18/2022
BIST30	-3.746	5/22/2023	-4.360	3/14/2022	-4.354	7/18/2022
BISTTUM	-3.967	5/22/2023	-4.496	5/16/2022	-4.487	4/18/2022
*Critical Values	%1	-5.34	%1	-4.93	%1	-5.57
	%5	-4.80	%5	-4.42	%5	-5.08

* Critical values are taken from Zivot and Andrews (1992).

As seen in Table 3 above, in both Model A (with intercept) and Model C (with intercept and trend), the test statistics for all variables are greater than the critical values, which means that the null hypothesis of a unit root with structural breaks (H_0) cannot be rejected at the 5% significance level. Hence, these series are non-stationary under structural breaks. For Model B (with trend), since the calculated values for the BIST100, BIST50, BIST30, and BISTTUM series are greater than the critical values, the null hypothesis (H_0) is rejected, indicating that the series are stationary under structural breaks. Overall, examining the Zivot-Andrews unit root test results with structural breaks reveals that all series are non-stationary under structural breaks, they possess a unit root. This finding is consistent with the results of studies conducted in the literature using structural break unit root tests (Zeren et al., 2013; Gözbaşı, 2014). These results demonstrate that the series do not exhibit a tendency to revert to their mean following shocks, indicating a lack of long memory characteristics. Contrary to mean reversion, the series tend towards a new equilibrium point. In other words, it is possible to discuss the presence of weak-form efficiency in the Borsa Istanbul Indexes.

In the research, three commonly used methods in the literature were employed to obtain long memory test results. These methods are the semi-parametric Geweke and Porter-Hudak (GPH) (1983), the Modified Log Periodogram (MODLPR) developed by Phillips (1999), and the Robinson Gaussian Semi-Parametric (RGSP) (1995) method.

Determining the integration orders of the series is used to reveal the presence of long memory, and it is concluded that the series exhibits long memory and reverts to its mean when $0<d<1$. When $0.5 \leq d <1$, the series is non-stationary; although it reverts to its mean, shocks do not have a long-lasting impact on the series. Reversion to the mean is desirable for investors as it indicates the series exhibits long memory characteristics. The impact of shocks increases as the estimated parameter approaches 1, becoming more persistent and long-lasting. When $d \geq 1$, the series is both non-stationary and does not revert to its mean. In this case, any attempt to predict stock prices could be misleading, implying that if the integration degree of stock prices is equal to or greater than 1, indicating a random walk, it is possible to discuss weak-form efficiency.

Table 4. Long Memory Model Test Results

	Model	GPH		MODLPR		RGSP	
BIST100	λ	d	t	d	t	d	t
	0,5	1.130	11.693	0.947	4.597	1.100	12.007
	0,6	1.066	17.749	1.119	7.833	1.044	17.773
	0,7	0.975	23.267	1.207	10.047	0.970	22.630
	0,8	0.974	28.358	1.058	12.099	0.918	27.438
BIST50	0,5	1.122	12.043	0.962	4.520	1.093	12.394
	0,6	1.069	18.034	1.096	7.556	1.045	17.966
	0,7	0.976	23.117	1.170	10.110	0.973	22.245
	0,8	0.976	27.251	1.045	12.220	0.919	26.294
BIST30	0,5	1.115	12.279	0.997	4.567	1.089	12.742
	0,6	1.074	18.493	1.087	7.612	1.051	18.437
	0,7	0.978	23.366	1.157	10.449	0.976	22.337
	0,8	0.979	26.832	1.044	12.439	0.922	25.845
BISTTUM	0,5	1.134	11.613	0.954	5.121	1.102	11.875
	0,6	1.060	17.376	1.174	5.186	1.034	17.174
	0,7	0.969	23.060	1.256	8.358	0.962	22.740
	0,8	0.966	30.141	1.069	10.365	0.912	29.250

Table 4 presents the results of the long memory model tests. Upon examination of these results, it is observed that the estimated values of the d parameter, indicating the degrees of fractional integration, are quite close to each other. The determination of the series' integration degrees is used to identify the presence of long memory, concluding that the series exhibits long memory characteristics and reverts to its mean when $0<d<1$.

When analyzing the long memory test results for the BIST100, BIST50, BIST30, and BISTTUM indexes using the GPH, MODLPR, and RGSP methods, it is noted that the fractional integration (d) values are very close to or greater than 1. This indicates that the BIST100, BIST50, BIST30, and BISTTUM indexes are non-stationary and do not exhibit a tendency to revert to their mean after shocks, hence lacking long memory characteristics. Contrary to mean reversion, the series tends towards a new equilibrium. This suggests that investors' predictions about these index prices may be misleading. Consequently, the fact that the integration degree (d) of index prices is equal to or greater than 1 implies the possibility of discussing weak-form efficiency due to its implication of a random walk.

In the GPH, MODLPR, and RGSP methods, examining the long memory test results for the BIST100, BIST50, BIST30, and BISTTUM indexes reveals that some values exhibit fractional integration degrees (d) with $0.5 \leq d < 1$, taking values very close to 1. This suggests that while the series are non-stationary, they revert to their mean without the shocks having a long-term effect on the series. Mean reversion is desirable for investors as it indicates the series exhibits long memory characteristics. The analysis findings of this study are consistent with the findings of previous studies in the literature (Kılıç, 2004; Bezgin, 2022; Küçükkaplan, 2023). Some of the reasons for the results of the study may be as follows:

- The emergence of the pandemic, which had a significant impact on stock market indices at the beginning of the study's analysis period,

- Economies that are already dealing with the consequences of the extraordinary inflationary effects on asset prices caused by the pandemic, the impact of the inflationary process will spread over a more extended period with the war between Ukraine and Russia in 2022,
- The sudden impact of the February 6 Kahramanmaraş earthquake on the stock market,
- In this period, the ratio of foreign investors in Borsa Istanbul fell to 26-27%.

4. CONCLUSION

The EMH posits that investors cannot possess knowledge about future stock prices by using past data. According to this hypothesis, since all information affecting stock prices is already reflected in the price, it is not possible to achieve abnormal returns. Therefore, it is argued that the pursuit of undervalued or overvalued stocks by investors is not rational. Moreover, making future directional predictions of stock prices through technical analysis is also deemed to be meaningless.

This study aims to test the validity of the efficient markets hypothesis in the indices in Borsa Istanbul during the COVID-19 pandemic and the period when the pandemic effects on the country's economies and individuals continued. For this purpose, the stationarity of the series related to the BIST100, BIST50, BIST30, and BISTTUM stock indexes located in Borsa Istanbul has been examined using traditional (ADF and PP) and Zivot-Andrews unit root tests allowing for a single structural break, testing the existence of the EMH in this time range through the long memory model. The presence of long memory has been investigated using Geweke and Porter-Hudak, Modified Log-Periodogram, and Robinson Gaussian Semi-Parametric Methods. The uniqueness of this study is derived from examining the validity of the EMH under pandemic conditions in Borsa Istanbul Indexes.

The findings of the study indicate that according to both traditional (ADF and PP) and Zivot-Andrews unit root tests, which allow for testing stationarity under structural breaks, the series are non-stationary. This suggests that the BIST100, BIST50, BIST30, and BISTTUM indexes are non-stationary at level values and do not exhibit a tendency to revert to their mean after shocks, thus lacking long memory characteristics. Instead of reverting to the mean, the series is moving towards a new equilibrium. This situation indicates that investors' forecasts about these index prices may be misleading. Consequently, the degree of integration (d) of index prices being equal to or greater than 1 implies the possibility of discussing weak-form efficiency due to its implication of a random walk.

When examining the long memory test results of BIST100, BIST50, BIST30, and BISTTUM index prices using GPH, MODLPR, and RGSP methods, it is observed that the fractional integration (d) values are very close to or greater than 1. This indicates that the index prices are non-stationary and do not tend to revert to their mean after shocks, thus lacking long memory. Instead of mean reversion, the series is trending towards a new balance. This suggests that investors' predictions regarding these index prices may be misleading. Therefore, the degree of integration (d) of index prices being equal to or greater than 1 suggests the possibility of discussing weak-form efficiency due to its implication of a random walk.

In the GPH, MODLPR, and RGSP methods, some values of the BIST100, BIST50, BIST30, and BISTTUM indexes in the long memory test results exhibit fractional integration degrees (d) with $0.5 \leq d < 1$, taking values very close to 1. This suggests that although the series are non-stationary, they revert to their mean without the shocks having a long-term effect on the series. Mean reversion is desirable for investors as it indicates the series exhibits long memory characteristics. Examining the findings of this study's analysis, it is observed that it shares similar findings with some studies in the literature (Kılıç, 2004; Atan et al., 2009; Gözbaşı, 2014; Altunöz, 2016; Bezgin, 2022; Bezgin, 2022; Küçükkaplan, 2023).

More technical analysis methods in weakly efficient markets suggest that more than historical price and volume data is needed to predict future price movements. This requires investors to use alternative methods rather than technical analysis to develop profitable strategies. In this context, passive investment strategies, such as low-cost index funds or exchange-traded funds (ETFs), are becoming more attractive as they enable risk allocation and cost minimization by tracking the market average. There is also a growing trend towards fundamental analysis, which offers the potential to create value beyond market efficiency by evaluating factors such as the financial condition of companies, quality of management, and industry dynamics to make long-term investment decisions. In addition, the importance of risk management in efficient markets is increasing, and portfolio diversification and increasing resilience to market volatility play a critical role in investors' generating sustainable returns. When all these factors come together, it is possible to develop a more robust and profitable investment approach to succeed in a weak-form efficient market by moving away from technical analysis, adopting passive investment strategies, focusing on fundamental analysis, and practicing effective risk management.

While weakly efficient markets have positive consequences for investors, there are several measures that policymakers can take to improve market efficiency and strengthen investor confidence. First, market transparency needs to be enhanced; to ensure transparency in financial markets, regulators should raise financial reporting standards for firms to ensure that information is clear, understandable, and accessible. Moreover, to improve information dissemination, information dissemination mechanisms should be strengthened to ensure that market participants have equal access to information, and strict inspections and criminal sanctions should be applied to prevent harmful practices such as insider trading and manipulation. Reducing transaction costs is also an important step; optimizing tax policies, commission rates, and other transaction fees to reduce high transaction costs will support efficiency by increasing the liquidity of markets. Training and awareness-raising programs should be organized to increase investors' financial literacy level so they can make more informed and rational decisions. To improve the market structure, it is essential to strengthen the technological infrastructure, regulate high-frequency trading practices, and establish mechanisms to prevent market manipulation; in addition, speeding up and automating trading processes will support market efficiency. Finally, to strengthen regulation and supervision mechanisms, the supervisory capacities of market regulators should be enhanced, market participants' compliance with the rules should be ensured, and investor confidence should be increased by maintaining market stability through adequate supervision. All these measures will improve both market efficiency and investor confidence in weak-form efficient markets.

The findings of this study are limited to the selected sample and data period. Future studies may be conducted using different sub-sector indexes located in Borsa Istanbul.

Ethical Statement

During the writing and publication of this study, the rules of Research and Publication Ethics were complied with, and no falsification was made in the data obtained for the study. Ethics committee approval is not required for the study.

Contribution Rate Statement

All the authors in the study contributed to all processes of writing and drafting the study and the final version of the study has been read and approved by them.

Conflict Statement

This study did not lead to any individual or institutional/organizational conflict of interest.

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Extended Abstract

Analysis of Efficient Markets Hypothesis in Share Market with Long Memory Models

Aim: The aim of this study is to test the validity of the Efficient Market Hypothesis (EMH) in the indices listed on the Borsa Istanbul during the pandemic period. Within this scope, the stationarity of the series related to the Borsa Istanbul 100 (BIST100), Borsa Istanbul 50 (BIST50), Borsa Istanbul 30 (BIST30), and Borsa Istanbul All (BISTTUM) stock indices has been examined using both traditional and structural break unit root tests. Additionally, the presence of the EMH during this period has been tested using a long memory model. The existence of long memory has been investigated using Geweke and Porter-Hudak, Modified Log-Periodogram, and Robinson Gaussian Semi-Parametric Methods. The novelty of the study lies in the fact that the validity of the efficient markets hypothesis has not been examined in Borsa Istanbul indices considering pandemic conditions.

Method: In the methodology section of the study, unit root tests and long memory models were utilized. The stationarity of the return series related to the stock indices was examined using both traditional (ADF and PP) and structural break unit root (Zivot Andrews) tests. Furthermore, the validity of the EMH in the stock indices was investigated, and the presence of long memory was explored using Geweke and Porter-Hudak, Modified Log-Periodogram, and Robinson Gaussian Semi-Parametric Methods.

Findings: When the findings of the study were examined, it was concluded that the series were not stationary according to the Zivot-Andrews unit root test result, which allows testing stationarity under both traditional (ADF and PP) and structural breaks. The fact that BIST100, BIST50, BIST30 and BISTTUM indices have unit roots at their level values, in other words, are not stationary, shows that the series do not tend to return to their mean after shocks, that is, they do not have long memory properties. When the long memory test results of BIST100, BIST50, BIST30 and BISTTUM index prices are examined with GPH, MODLPR and RGSP methods, it is seen that the fractional integration (d) value of these methods is very close to or greater than 1. This result indicates that BIST100, BIST50, BIST30 and BISTTUM index prices are not stationary and do not tend to return to their average after shocks, that is, they do not have a long memory feature.

Conclusion: The EPH claims that investors cannot have information about future stock prices by using past data. According to this hypothesis, an excessive return cannot be obtained because all the information that has an impact on the stock price is reflected in the price in advance. For this reason, it is claimed that it would not be rational for investors to seek discounted or premium stocks. Additionally, it is argued that it would not be meaningful to predict the future direction of stock prices by using technical analysis.

When the findings of the study were examined, it was concluded that the series were not stationary according to the Zivot-Andrews unit root test result, which allows testing stationarity under both traditional (ADF and PP) and structural breaks. The fact that BIST100, BIST50, BIST30 and BISTTUM indices have unit roots at their level values, in other words, are not stationary, shows that the series do not tend to return to their mean after shocks, that is, they do not have long memory properties. When the long memory test results of BIST100, BIST50, BIST30 and BISTTUM index prices are examined with GPH, MODLPR and RGSP methods, it is seen that the fractional integration (d) value of these methods is very close to or greater than 1. This result indicates that BIST100, BIST50, BIST30 and BISTTUM index prices are not stationary and do not tend to return to their average after shocks, that is, they do not have a long memory feature.

The results of this study are limited to the selected sample and data period (Covid19 pandemic period). In future studies, research can be conducted using different sub-sector indices in Borsa Istanbul.