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Investigating Weak-Form Efficiency in Global Stock Markets

Küresel Hisse Senedi Piyasalarında Zayıf Form Verimliliğinin Araştırılması

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Investigating Weak Form Efficiency in Global Stock Markets

Abstract
This study aims to examine the presence of weak form market efficiency using the largest available dataset of 71 stock exchanges operating in 67 different countries, within the framework of the Efficient Market Hypothesis (EMH), with the assistance of the RALS-LM unit root test. This test is a methodology designed to detect the unit root feature in financial markets and goes beyond the traditional methods frequently used in market efficiency studies in the literature. The results show that the indicator indices of 68 examined exchanges do not contain a unit root indicating stationarity and thus the absence of weak-form efficiency. In other words, it can be concluded that prices in these exchanges reflect past information, making it possible to forecast future prices. The study reveals that weak form efficiency conditions are not met for all exchanges except for the Bulgarian Stock Exchange (BSE Sofix) and the Indian Stock Exchange (Nifty 50). Accordingly, it is possible to use past prices as a predictor of future prices on the relevant exchanges, indicating the absence of even weak form efficiency in these markets.

Keywords: Efficient market hypothesis (EMH), weak form market efficiency, stock exchanges, RALS-LM test, unit root analysis

Küresel Hisse Senedi Piyasalarında Zayıf Form Verimliliğinin Araştırılması

Öz
Bu çalışma, Zayıf Formda Piyasa Etkinliği'nin varlığını Etkin Piyasa Hipotezi (EPH) çerçevesinde incelemeyi amaçlamakta ve RALS-LM birim kök testi yardımıyla 67 farklı ülkede faaliyet gösteren 71 borsa için mevcut en büyük veri setini kullanmaktadır. Bu test, finansal piyasalarda birim kök özelliğini tespit etmeye yönelik geliştirilmiş bir yöntem olup, literatürde piyasa etkinliği çalışmalarında sıkça kullanılan geleneksel yöntemlerin ötesine geçmektedir. Çalışmanın bulgularına göre, incelenen 68 borsanın gösterge endeksleri birim kök içermemektedir, yani durağandır ve dolayısıyla zayıf formda etkin değildir. Başka bir deyişle, bu borsalarda fiyatların geçmiş bilgiyi yansıttığı ve gelecekteki fiyatların tahmin edilmesinin mümkün olduğu sonucuna ulaşılmıştır. Çalışma, yalnızca Bulgaristan Borsası (BSE Sofix) ve Hindistan Borsası (Nifty 50) için zayıf formda piyasa etkinliği koşullarının sağlandığını ortaya koymaktadır. Buna göre, ilgili borsalarda geçmiş fiyatları gelecekteki fiyatların bir göstergesi olarak kullanmak mümkün olup, bu piyasaların zayıf formda dahi etkin olmadığını göstermektedir.

Anahtar Kelimeler: Etkin piyasa hipotezi (EPH), zayıf formda piyasa etkinliği, Borsalar, RALS-LM testi, birim kök analizi

Introduction
The forecastability of financial asset prices is a fundamental research area in finance that drives significant academic inquiry. One of the leading theories addressing this issue is the Efficient Market Hypothesis (EMH), which posits that markets are "informationally efficient" and asset prices fully reflect all available information. EMH was introduced by Nobel Laureate Eugene Fama in his seminal work "Behavior of Stock Market Prices" (1965), which laid the foundation for understanding how information is processed in financial markets. According to this hypothesis, when new information has the potential to affect stock prices, it is rapidly and accurately incorporated into prices, making it challenging for investors to achieve returns above the risk-adjusted market average (Rossi and Gunardi, 2018). Thus, EMH centers on the question of whether market prices always fully reflect available information. It asserts that rational decision-makers in the market process all information comprehensively, leading to up-to-date asset prices (Malkiel, 2003). In essence, market participants are assumed to embed all information into prices.

The efficient market hypothesis, as defined by Fama, states that asset prices fully reflect all available information. This hypothesis is categorized into three forms: weak, semi strong, and strong (Fama, 1965). The weak form asserts that historical price and volume data are already incorporated into current prices, rendering technical analysis ineffective. The semi-strong form extends this by stating that all publicly available information is reflected in prices, thus limiting the potential for fundamental analysis to generate abnormal returns. Finally, the strong form argues that even private, insider information is immediately reflected in prices, making it impossible for any investor to consistently generate superior returns regardless of the information they possess (Anghel, 2015; Rathnaweera, 2023).

For investors participating in financial markets, quick, cost-effective, and direct access to accurate information is of critical importance. As information becomes more accessible to all investors, asset prices approach their equilibrium levels, and opportunities for abnormal profits may diminish. Although EMH appears straightforward, it rests on two key propositions and several assumptions. The first proposition is that free market competition conditions ensure equilibrium asset prices by balancing income and costs. In other words, if there is an expectation of excessive profits, new investors entering the market restore balance. The second proposition suggests that changes in asset prices are a function of information flow into the market (Ball, 2009). Additionally, for a market to be considered efficient under EMH, investors are expected to act rationally and aim to maximize profits. In this context, the hypothesis emphasizes the absence of interventions in markets (Bulut, 2022).

Despite its theoretical robustness, EMH has faced criticism for various reasons. In particular, behavioral finance challenges the rationality assumption of EMH. Proponents of this field argue that investors often act irrationally due to cognitive biases and emotional factors. Consequently, market inefficiencies persist because of these behavioral anomalies (Gu, 2023; Mahjoubi, 2024). Furthermore, psychological factors such as overconfidence, herding behavior, and loss aversion cause investors to deviate from fundamental values. This results in unforecastable price movements (Bilir, 2018; Chesoli, 2021)

Another criticism of EMH pertains to market anomalies. Calendar effects such as the January effect and the Monday effect demonstrate that stock returns can be forecasted based on historical data, thus challenging the notion of market efficiency (Wong et al., 2006; Arman andLestari, 2019; Douagi et al., 2019; Szymański and Wojtalik, 2020). The occurrence of abnormal returns on specific days or during certain months a phenomenon deemed impossible in an efficient market has given rise to alternative theories such as the Adaptive Market Hypothesis (AMH). Lo (2004) proposed the AMH to reconcile the Efficient Market Hypothesis (EMH) with behavioral finance. This hypothesis asserts that market efficiency is not static but evolves based on changes in the behavior of market participants (Obalade and Muzindutsi, 2019; Trung and Quang, 2019). According to AMH, investors adapt their strategies to market conditions. This adaptation leads to periods of both efficiency and inefficiency (Pinar and Zeliha, 2019; Enow, 2022).

While EMH provides a robust framework for understanding market dynamics, approaches such as behavioral finance and AMH offer alternative perspectives, highlighting the complexity of human behavior in financial markets. These perspectives emphasize the practical implications of deviating from the theoretical foundations of market efficiency (Dhankar and Shankar, 2016; Ali et al., 2021; Mahjoubi, 2024).

The primary objective of this study is to investigate the presence of weak form market efficiency in 67 stock exchanges across 67 countries within the framework of EMH. Using the largest possible dataset encompassing 71 stock markets, this study applies the RALS-LM test an unconventional unit root test to evaluate weak form efficiency. As evidenced in the literature, the methodology and sample selection in empirical studies examining market efficiency significantly influence results. Employing relatively novel methods and extensive datasets provides a more comprehensive perspective on the topic. While most studies in the literature focus on specific regions or developed economies, this study's broad country sample offers a multidimensional perspective encompassing geographic and economic diversity. This approach enables the examination of market efficiency in developed, emerging, and diverse economic structures. Additionally, the use of the RALS-LM test in this study offers a robust and flexible analytical method aligned with the statistical properties of financial data, distinguishing this research from existing literature.

Accordingly, this study comprises four sections. The first section introduces the topic. The second section reviews significant prior studies. Next section presents the dataset, econometric methodology, and results of the econometric analysis. The final section provides a general evaluation.

1. Literature Review

The Efficient Market Hypothesis, posits that stock prices reflect all available information and follow a random walk, thereby explaining the informational efficiency of financial markets. Studies in the literature test the weak form of the EMH in stock markets using various statistical and econometric methodologies, revealing both support for and challenges to the hypothesis. The random walk property of stock returns has been examined through unit root tests, variance ratio tests, and nonlinear dependence tests, which provide distinct perspectives on market efficiency. These studies demonstrate that the informational efficiency of stock markets varies across methodological approaches and time periods, suggesting that the EMH is not a static framework but is influenced by market dynamics.

Several studies focus on unit root tests to examine the random walk property of stock returns. For instance, Borges (2010) analyzed European stock markets (Germany, France, the UK, and Spain) from 1993 to 2007 using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit root tests, finding that markets generally exhibit random walk behavior, though non-stationary behavior occurs in certain periods. This suggests that the weak form of the EMH is largely supported, but market conditions can lead to deviations. Employing a similar methodology, Akel (2015) examined the stock markets of the Fragile Five countries (Brazil, Indonesia, India, South Africa, and Turkey) from 2000 to 2013 using the ADF unit root test, determining that the series are non-stationary at levels but become stationary at first differences, indicating a tendency to support the EMH while questioning the presence of short-term dependencies. Adopting the same approach for a more recent period, Rojas, Martinez, and Coronado (2017) analyzed the Mexican Stock Exchange's IPC index from 1994 to 2015 using ADF and Zivot-Andrews unit root tests, revealing that the market exhibits random walk behavior in certain periods, but structural breaks affect efficiency. Offering a different geographic perspective, Lawal et al. (2020) investigated the Nigerian stock market from 2006 to 2017 using ADF and Zivot-Andrews tests, finding that the market is generally inefficient, though efficiency increases in specific periods. These studies highlight that unit root tests effectively capture the temporal fluctuations in stock market efficiency and its sensitivity to structural factors.

Variance ratio tests constitute another key methodology for assessing stock market efficiency. Kim et al. (2011) analyzed the US Dow Jones Industrial Average from 1900 to 2009 using automatic variance ratio tests, finding that returns are sometimes forecastable, with forecastability varying based on market conditions. Adopting a similar methodological framework, Mandacı et al. (2019) examined Borsa Istanbul's BIST 100, BIST 30, and BIST All indices from 2002 to 2019 using Chow-Denning and Joint Sign variance ratio tests, demonstrating that returns are forecastable in certain periods but converge to a random walk in others. Focusing on a broader time frame and incorporating additional economic indicators, İçigen and Kayalı (2022) analyzed the BIST 100 index from 1988 to 2020 using Joint Rank and Chow-Denning variance ratio tests, revealing that return forecastability is linked to economic indicators and partially supports the weak form of the EMH. These studies underscore that variance ratio tests are robust tools for detecting short-term dependencies in stock markets, often challenging the EMH's assumption of consistent efficiency.

Nonlinear dependence tests provide insights into the more complex dynamics of stock markets. For example, Todea et al. (2009) analyzed Asia-Pacific stock markets from 1997 to 2008 using the Bi-Correlation Test, finding that nonlinear dependencies in returns vary with market conditions, lending occasional support to the EMH. Employing a similar methodological approach across a broader geographic scope, Urquhart and Hudson (2013) examined the US, UK, and Japanese stock markets from 1897 to 2009 using the Brock-Dechert-Scheinkman (BDS) test, identifying persistent nonlinear dependencies that indicate markets are not consistently efficient. Addressing a more recent period, Rönkkö et al. (2024) analyzed Finland's OMX Helsinki 25 index from 1988 to 2019 using the BDS test, finding that the market periodically exhibits nonlinear dependencies, partially challenging the weak form of the EMH. These studies demonstrate that nonlinear dependence tests reveal the complex structure of stock markets, highlighting the limitations of the EMH as a static framework.

Overall, the literature focusing on stock markets indicates that the weak form of the EMH is partially supported when tested with unit root analyses, variance ratio tests, and nonlinear dependence tests. Unit root tests suggest that markets generally follow a random walk, though structural breaks impact efficiency, while variance ratio tests detect short-term dependencies that challenge the EMH's assumptions. Nonlinear dependence tests uncover more complex market dynamics, emphasizing the limitations of the EMH as a static framework. These findings illustrate that the informational efficiency of stock markets varies with methodological approaches and time periods, underscoring the need for a dynamic and multidimensional framework to fully understand the EMH.

2. Data Set, Econometric Methods and Econometric Analysis Results

2.1. Data Set

In examining the validity of the efficient market hypothesis, the logarithms of monthly closing prices of indicator indices in the countries listed in Table 1 were used. These data were obtained from Thomson Reuters, Refinitiv, Eikon.

Table 1. Data Set

Stock Markets	Period	Countries
Al-Quds	(1997:02-2024:03)	Palestine
AMGNRLX	(2000:01-2024:03)	Jordan
Athens General Composite	(2005:10-2024:03)	Greece
ATX	(2007:02-2024:03)	Austria
BEL 20	(1991:01-2024:03)	Belgium
BIST 100	(1988:02-2024:03)	Türkiye
Bovespa (IBOV)	(1992:03-2024:03)	Brazil
BSE Sofix (SOFIX)	(2003:09-2024:03)	Bulgaria
Budapest SE (BUX)	(2003:03-2024:03)	Hungary
CAC 40	(1987:08-2024:03)	France
Costa Rica Indice Accionario (IACR)	(1995:02-2024:03)	Costa Rica
CSE All Share (CSE)	(1993:07-2024:03)	Sri Lanka
Cyprus Main Market (CYMAIN)	(2004:10-2024:03)	Cyprus
Czechia (PX)	(1993:10-2024:03)	Czechia
Dax 40 (GDAXI)	(1988:01-2024:03)	Germany
Dhaka Stock Exchange Broad (DSEX)	(2013:02-2024:03)	Bangladesh
Dow Jones New Zealand (NZDOW)	(2023:09-2024:03)	New Zealand
Ecuador General Adj (BVQA)	(2012:11-2024:02)	Ecuador
EGX 70 EWI	(2017:02-2024:03)	Egypt
FTSE 100	(2001:02-2024:03)	United Kingdom
FTSE China A50	(2004:04-2024:03)	China
FTSE Colombia (FTWICOLL)	(2000:07-2024:03)	Colombia
FTSE MIB (FTMIB)	(1998:01-2024:03)	Italy
FTSE NSX Local (FTN099)	(2005:11-2024:03)	Namibia
FTSE/JSE Africa All Share (JALSH)	(1995:07-2024:03)	South Africa
Holland AEX (AEX)	(1983:02-2024:03)	Netherlands
Hong Kong Hang Seng (HSI)	(1970:02-2024:03)	Hong Kong
IBEX 35	(1991:10-2024:03)	Spain
IDX Composite (JKSE)	(1990:05-2024:03)	Indonesia
ISEQ Overall (ISEQ)	(2023:09-2024:03)	Ireland
ISX Main 60	(2014:04-2023:03)	Iraq
Karachi 100	(1994:06-2024:03)	Pakistan
KASE (KASE)	(2006:08-2024:03)	Kazakhstan
KOSPI (KS11)	(1981:05-2024:03)	South Korea
LSE All Share (LASILZ)	(2004:08-2024:03)	Zambia
MASI (MASI)	(2002:02-2024:03)	Morocco
MNE Top 20	(2014:04-2024:03)	Mongolia
MOEX Russia (IMOEX)	(1997:10-2024:03)	Russia
MSM 30	(1992:02-2024:03)	Oman
Nifty 50	(1995:12-2024:03)	India
Nikkei 225	(1984:03-2024:03)	Japan
NSE All Share	(2005:11-2024:03)	Nigeria
OMX Copenhagen 20 (OMXC20)	(1990:01-2024:03)	Denmark
OMX Helsinki (OMXHPI)	(1987:02-2024:03)	Finland
OMX Iceland All Share (OMXIPI)	(1993:01-2024:03)	Iceland
OMX Stockholm 30	(1986:10-2024:03)	Sweden
PSI (PSI20)	(1993:01-2024:03)	Portugal
Riga General (OMXRGI)	(2000:02-2024:03)	Latvia
RTS Index (IRTS)	(1995:10-2024:03)	Russia
Rwanda All Share (ALSIRW)	(2013:03-2024:03)	Rwanda
S&P 500	(1970:02-2024:03)	United States
S&P Lima General (SPBLPGPT)	(1994:06-2024:03)	Peru
S&P/ASX 200 Index	(1992:06-2024:03)	Australia
S&P/BMV IPC (MXX)	(1987:02-2024:03)	Canada
S&P/TSX Composite (GSPTSE)	(1979:07-2024:03)	Mexico
Semdex (MDEX)	(1989:08-2024:03)	Mauritius
Shanghai Composite (SSEC)	(1991:01-2024:03)	China
SMI (SSMI)	(1988:02-2024:03)	Switzerland
TA 35	(1992:11-2024:03)	Israel
Tadawul Borsası (TASI)	(1998:11-2024:03)	Saudi Arabia
Taiwan Weighted (TWII)	(2003:04-2024:03)	Taiwan
Tallinn SE General (OMXTGI)	(1996:07-2024:03)	Estonia
Tanzania All Share	(2007:01-2024:03)	Tanzania
Tunindex (TUNINDEX)	(1998:01-2024:03)	Tunisia
Uganda All Share	(2004:09-2024:03)	Uganda
Vilnius SE General (OMXVGI)	(2000:02-2024:03)	Lithuania
VN 30	(2009:02-2024:03)	China
WIG (WIG)	(2003:04-2024:03)	Poland
ZSE All Share	(2018:02-2024:03)	Zimbabwe

2.2. Econometric Method

Non-normal error terms are often encountered in many time series variables. Some financial variables' error terms may exhibit skewness, either to the right or left, while error terms in some macroeconomic time series may follow a mixture of different probability distributions (Meng et al., 2017). In applied economics and econometrics studies, it is common to find that errors derived from models do not conform to a normal distribution when testing the validity of the purchasing power parity hypothesis for various exchange rate series such as Turkish Lira, Euro Dollar, Ruble, and GDP, or when testing the efficient markets hypothesis for numerous stock market indices (Im et al., 2009; Meng et al., 2017). In such cases where errors do not follow a normal distribution, traditional unit root tests often neglect the information embedded in non-normal errors. Therefore, the use of the Residual Augmented Least Squares (RALS) procedure is more appropriate for unit root analysis. The RALS procedure employs the nonlinear moment conditions of Generalized Method of Moments (GMM) through a simple procedure that does not require nonlinear optimization, thereby incorporating information that is often neglected in conventional unit root tests. Consequently, there are significant power gains when errors are non-normal (Im et al., 2009). The RALS test is available in two forms: Lagrange Multiplier (LM) and Dickey-Fuller (DF) based. Meng et al. (2014) demonstrated that the RALS-based LM (RALS-LM) test possesses superior statistical properties compared to the RALS-based DF (RALS-DF) test when error terms are asymmetric. As such, this study prefers the application of the RALS-LM procedure.

The Residual Augmented Least Square - Lagrange Multiplier (RALS-LM) test, as an approach that relaxes the normal distribution assumption, has been adopted for the LM test. Moreover, Meng et al. (2014) demonstrated the robustness of the RALS-LM test for non-normal errors. However, in the approach proposed by Meng et al. (2014), similar to all unit root tests, there may be a loss of power in the unit root test. This loss of power can lead to the problem of mistakenly identifying a non-stationary time series as a stationary one, especially in the case of structural breaks. To address this issue, Meng et al. (2017) extended the approach of Meng et al. (2014) to allow for trend changes, resulting in a modified RALS-LM that incorporates trend breaks.

Meng et al. (2017) theoretically outlined the steps involved in applying the RALS-LM test based on R structural breaks. In practical applications in the literature, the RALS-LM test that accounts for one or two breaks in level and trend changes is frequently used. The methodology based on trend breaks used in this study (Im et al., 2009; Meng et al., 2017; Aytemiz et al., 2021) is presented as follows.

In Step 1, unit root test models are defined according to the approaches of Schmidt and Phillips (1992) and Lee and Stracicih (2003). Under the null hypothesis that there is a unit root, represented as β= 1, the LM unit root test regression models that can be estimated are given below, respectively.

$$Y_t = \delta' Z_t + e_t \tag{1}$$

$$e_t = \beta e_{t-1} + \varepsilon_t \tag{2}$$

To estimate equations (1) and (2), first, equation (2) is estimated using the errors obtained from equation (1). Then, the null hypothesis β=1 is tested to determine whether there is a unit root. In equation (1), the vector Z_t showing both the breaks in the intercept and trend is given below based on the study by Lee and Stracicih (2003).

$$Z_t = [1, t, D_{it}, DT_{it}]', \qquad for\ \ i = 1,2, \dots R \tag{3}$$

Accordingly, R indicates the maximum number of structural breaks. In equation (3), D_{it} and D_{it} are dummy variables at position i indicating whether there is a break in the level or a break in the trend, respectively. These are given in equations (4) and (5).

$$D_{it} = \begin{cases} 1 & for\ t \geq T_{Bi+1}, \qquad i = 1,2, \dots, R \\ 0 & \qquad\qquad\qquad\qquad or \end{cases} \tag{4}$$

$$DT_{it} = \begin{cases} t - T_{Bi} & for\ t \geq T_{Bi+1}, \qquad i = 1,2, \dots, R \\ 0 & \qquad\qquad\qquad\qquad or \end{cases} \tag{5}$$

In equations (4) and (5), T_Bi, indicates the date of the ith structural break. Based on the definitions in Step 1, the RALS-LM test determines the unit root model according to the LM principle. The regression equation where the LM statistic is derived according to the LM principle can be expressed as follows:

$$\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}_{t-1} + e_t \tag{6}$$

The dependent and independent variables, ΔY_t and ΔZ_t, represent the first-differenced forms of ΔY_t and ΔZ_t, respectively. The other independent variable, $\tilde{Y}_{t-1}$, denotes the detrended lagged values of the Y_t, time series based on the LM principle. The calculation of $\tilde{Y}_t$ is provided in equation (7). In equation (7), $\tilde{\delta}'$ represents the regression coefficient vector obtained from the regression $\Delta Y_t = \tilde{\delta}' \Delta Z_t + v_t$.

$$\tilde{Y}_t = Y_t - \Psi - \tilde{\delta}' Z_t + e_t \tag{7}$$

In Stage 3, the transformation process is applied. When trend breaks occur, for the $\emptyset$ in equation (6) under the null hypothesis of $\emptyset = 0$, the τ_{LM} t-statistic depends on the location parameter λ_i. The location parameters for each regime are defined as $\lambda_1 = \frac{T_{B1}}{T}, \lambda_2 = \frac{T_{B1} - T_{B1-1}}{T}, \lambda_2 = \frac{T_{B2} - T_{B2-1}}{T}, \dots, \lambda_R = \frac{T_{BR} - T_{BR-1}}{T}, \lambda_{R+1} = \frac{T - T_{BR}}{T}$ due to the inclusion of a new parameter, combining the LM test with the RALS procedure becomes challenging. Therefore, it is necessary to perform a transformation to eliminate the dependence of the unit root test statistic τ_{LM} on the break locations. The required transformation is provided in equation (8).

$$\tilde{Y}_t^* = \begin{cases} \frac{T}{T_{B1}} \tilde{Y}_t & for\ t \leq T_{B1} \\ \frac{T}{T_{B2} - T_{B1}} \tilde{Y}_t & for\ \ T_1 \leq t \leq T_{B2} \\ \frac{T}{T_{B3} - T_{B2}} \tilde{Y}_t & for\ \ T_{B2} \leq t \leq T_{B3} \\ & \vdots \\ \frac{T}{T_{BK} - T_{B(K-1)}} \tilde{Y}_t & for\ \ T_{B(K-1} \leq t \leq T_{BK} \\ & \vdots \\ \frac{T}{T - T_{BR}} \tilde{Y}_t & for\ \ T_{BR} \leq t \leq T \end{cases} \tag{8}$$

In equation (8), $\tilde{Y}_t$ represents the non-transformed time series provided in equation (7), while $\tilde{Y}_t^*$ denotes the transformed time series. After the transformation, substituting $\tilde{Y}_t^*$ for $\tilde{Y}_{t-1}$ in the equation $\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}_{t-1} + e_t$ given in equation (6) results in the following regression equation.

$$\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}^*_{t-1} + e_t \tag{9}$$

From the equation in (9), the τ^*_{LM} t-statistic is obtained under the null hypothesis of $\emptyset = 0$. Since τ^*_{LM} is not dependent on the location parameter λ', the transformation ensures that the unit root test can be conducted solely based on trend breaks.

In Stage 4, the RALS procedure is developed to enhance the power of the LM test. Accordingly, let $\hat{e}_t$ represent the residuals estimated from the Ordinary Least Squares (OLS) regression $\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}_{t-1} + e_t$, provided in equation (6). The matrix $\widehat{W}_t$ is then constructed as follows.

$$\widehat{W}_t = [\hat{e}_t^2 - \widehat{m}_2,\ \hat{e}_t^3 - \widehat{m}_3 - 3\widehat{m}_2 \hat{e}_t\ ]' \tag{10}$$

In equation (10), $\widehat{m}_2 = \frac{\sum_{t=1}^{T} \hat{e}_t^2}{T}$ and m$\widehat{m}_3 = \frac{\sum_{t=1}^{T} \hat{e}_t^3}{T}$. By incorporating the first term of $\widehat{W}_t$, $\hat{e}_t^2 - \widehat{m}_2$, which captures kurtosis information, and the second term, $\hat{e}_t^3 - \widehat{m}_3 - 3\widehat{m}_2 \hat{e}_t$, which reflects skewness information, the procedure ensures that information from non-normal residuals is also utilized.

In Stage 5, the transformed trend-break RALS-LM regression and test are obtained. To achieve this, the independent variable $\widehat{W}_t$ is added to the regression $\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}^*_{t-1} + e_t$, provided in equation (9), resulting in the following regression equation.

$$\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}^*_{t-1} + \gamma' \widehat{W}_t + u_t \tag{11}$$

Through the model presented in equation (11), skewness and kurtosis information for non-normal errors is incorporated into the regression model. Since $E(u_t^2)$ in equation (11) is smaller than $E(e_t^2)$ in equation (6), asymptotic efficiency and, consequently, the power of the test are enhanced. Therefore, the model in equation (11) is an augmented version of the model in equation (6) and is referred to as the transformed trend-break RALS-LM model.

In equation (11), the test statistic for the null hypothesis $\emptyset = 0$ is denoted by $\tau^*_{RALS-LM}$. Since the null hypothesis $\emptyset = 0$ in equation (11) corresponds to the null hypothesis $\beta = 1$ in equation (2), rejecting the null hypothesis implies that the series is stationary.

The asymptotic distributions of the transformed test statistics τ^*_{LM}, derived from equation (6), and $\tau^*_{RALS-LM}$, derived from equation (11), are provided in equations (12) and (13), respectively (Meng et al., 2014; Meng et al., 2017).

$$\tau^*_{LM} \rightarrow \frac{-1}{2} \left[\sum_{i=1}^{R+1} \int_0^{R+1} V_{-i}(r)^2 \, dr \right]^{-1/2} \tag{12}$$

$$\tau^*_{RALS-LM} = \rho \tau^*_{LM} + (1 - \rho^2)^{\frac{1}{2}} N(0,1) \tag{13}$$

In equation (13), ρ, represents the efficiency of u_t relative to e_t and is defined by the formula $\frac{E(u_t^2)}{E(e_t^2)}$. Using the asymptotic distributions in equations (12) and (13), Meng et al. (2017) generated critical values for various T, different ρ^2, and $R = 1, 2$. The $\tau^*_{RALS-LM}$ statistic is compared with these critical values to determine whether the series contains a unit root. By incorporating the lagged variables of the time series into the model in equation (11), the extended RALS-LM model is provided in equation (14).

$$\Delta Y_t = \delta' \Delta Z_t + \emptyset \tilde{Y}^*_{t-1} + \sum_{i=1}^{p} \Delta \tilde{Y}^*_{t-1} + \gamma' \widehat{W}_t + u_t \quad (14)$$

In this study, the model presented in equation (14) was utilized, and the lag length (ppp) was determined based on the Akaike Information Criterion (AIC) and the Schwarz Information Criterion (SIC).

2.3. Econometric Analysis Results

The results of the RALS-LM unit root test adopted in the study are presented in Table 2. According to this, the $\tau^*_{RALS-LM}$ values in absolute terms listed in Table 2 are greater than the test critical values in absolute terms, which indicates that the null hypothesis of the presence of a unit root is rejected.

Table 2. Econometric Analysis Results

Stock Markets	ρ^2	$\tau^*_{RALS-LM}$ [1]	Break Dates	Critical Values 1%	5%	10%
Al-Quds	0,60	-11,46	(1996:08, 1996:02)	-4,28	-3,75	-3,45
AMGNRLX	0,86	-7,423	(2009:08, 2008:07)	-4,54	-4,04	-3,76
Athens General Composite	0,76	-5,770	(2020:04, 2017:01)	-4,46	-3,94	-3,66
ATX (ATX)	0,78	-3,281	(2014:02, 2013:01)	-4,47	-3,96	-3,67
BEL 20	0,79	-7,049	(2020:12, 2020:01)	-4,48	-3,97	-3,69
BIST 100	0,28	-13,89	(2002:10, 1999:11)	-3,76	-3,15	-2,81
Bovespa (IBOV)	0,29	-7,185	(2012:05, 1995:05)	-3,79	-3,18	-2,85
BSE Sofix (SOFIX)	0,48	-2,084*	(2008:10, 2005:04)	-4,12	-3,51	-3,25
Budapest SE (BUX)	0,45	-7,871	(2015:12, 2008:05)	-4,07	-3,37	-3,19
CAC 40	0,89	-5,819	(2009:08, 2008:04)	-4,57	-4,07	-3,80
Costa Rica Indice Accionario (IACR)	0,67	-7,957	(2003:09, 2003:04)	-4,36	-3,84	-3,55
CSE All Share (CSE)	0,80	-8,143	(2010:12, 2010:08)	-4,49	-3,98	-3,70
Cyprus Main Market (CYMAIN)	0,80	-8,550	(2004:12, 2004:09)	-4,49	-3,98	-3,70
Czechia (PX)	0,74	-6,346	(2009:02, 2008:09)	-4,43	-3,91	-3,63
Dax 40 (GDAXI)	0,85	-7,019	(2011:11, 2011:06)	-4,54	-4,03	-3,76
Dhaka Stock Exchange Broad (DSEX)	0,92	-5,089	(2015:05, 2014:03)	-4,55	-4,09	-3,82
Dow Jones New Zealand (NZDOW)	0,84	-6,349	(2003:10, 2003:02)	-4,53	-4,02	-3,74
Ecuador General Adj (BVQA)	0,80	-9,232	(2013:01, 2012:11)	-4,49	-3,98	-3,70
EGX 70 EWI	0,79	-6,601	(2020:09, 2018:08)	-4,48	-3,97	-3,69
FTSE 100	0,93	-6,670	(2020:12, 2020:01)	-4,61	-4,10	-3,84
FTSE China A50	0,84	-22,08	(2007:12, 2007:09)	-4,53	-4,02	-3,74
FTSE Colombia (FTWICOLL)	0,84	-10,12	(2020:04, 2019:04)	-4,53	-4,02	-3,74
FTSE MIB (FTMIB)	0,41	-12,67	(2021:02, 2010:01)	-4,02	-3,20	-3,12
FTSE NSX Local (FTN099)	0,61	-8,804	(2020:08, 2019:05)	-4,29	-3,76	-3,46
FTSE/JSE Africa All Share (JALSH)	0,40	-25,02	(2009:09, 2008:04)	-4,01	-3,17	-3,11
Holland AEX (AEX)	0,76	-6,780	(2003:05, 2002:06)	-4,46	-3,94	-3,66
Hong Kong Hang Seng (HSI)	0,12	-26,03	(2013:07, 2012:05)	-3,31	-2,66	-2,31
IBEX 35	0,79	-8,028	(1998:09, 1997:10)	-4,48	-3,97	-3,69
IDX Composite (JKSE)	0,75	-7,077	(1999:01, 1997:09)	-4,44	-3,93	-3,64

[1] *Indicates series with a unit root. ρ^2 epresents the correlation coefficient

Table 2. Econometric Analysis Results (cont'd)

Stock Markets	ρ^2	$\tau^*_{RALS-LM}$[2]	Break Dates	Critical Values 1%	5%	10%
ISEQ Overall (ISEQ)	0,85	-6,628	(2020:04, 2019:06)	-4,54	-4,03	-3,76
ISX Main 60	0,91	-12,19	(2014:09, 2014:05)	-4,59	-4,09	-3,82
Karachi 100	0,79	-49,26	(2013:10, 2013:05)	-4,48	-3,97	-3,69
KASE (KASE)	0,89	-7,549	(2009:06, 2008:09)	-4,58	-4,07	-3,81
KOSPI (KS11)	0,91	-7,311	(2011:09, 2010:12)	-4,60	-4,09	-3,82
LSE All Share (LASILZ)	0,78	-5,437	(2020:12, 2020:02)	-4,47	-3,96	-3,68
MASI (MASI)	0,81	-7,875	(2011:02, 2010:02)	-4,51	-4,00	-3,72
MNE Top 20	0,32	-21,35	(2018:01, 2017:10)	-3,84	-3,20	-2,91
MOEX Russia (IMOEX)	0,68	-6,898	(2006:11, 2006:02)	-4,37	-3,84	-3,55
MSM 30	0,85	-5,771	(2020:04, 2019:05)	-4,54	-4,03	-3,76
Nifty 50	0,27	-0,151*	(2021:06, 1999:05)	-3,75	-3,14	-2,81
Nikkei 225	0,08	-35,1	(1996:08, 1996:03)	-3,25	-2,60	-2,24
NSE All Share	0,39	-7,268	(2011:08, 2008:03)	-3,99	-3,15	-3,09
OMX Copenhagen 20 (OMXC20)	0,88	-6,989	(2009:05, 2008:05)	-4,57	-4,06	-3,79
OMX Helsinki (OMXHPI)	0,79	-8,994	(2001:07, 2001:01)	-4,48	-3,97	-3,69
OMX Iceland All Share (OMXIPI)	0,75	-19,05	(2008:11, 2008:07)	-4,44	-3,93	-3,64
OMX Stockholm 30	0,84	-7,337	(2009:08, 2008:04)	-4,53	-4,02	-3,75
PSI (PSI20)	0,91	-5,13	(2002:12, 2002:08)	-4,60	-4,09	-3,82
Riga General (OMXRGI)	0,80	-5,801	(2008:10, 2008:06)	-4,49	-3,98	-3,70
RTS Index (IRTS)	0,75	-6,768	(2012:06, 2011:11)	-4,44	-3,92	-3,64
Rwanda All Share (ALSIRW)	0,49	-8,935	(2020:02, 2019:09)	-4,13	-3,55	-3,27
S&P 500	0,78	-7,001	(2001:04, 1999:05)	-4,47	-3,96	-3,67
S&P Lima General (SPBLPGPT)	0,39	-15,37	(2020:04, 2009:02)	-3,99	-3,15	-3,09
S&P/ASX 200 Index	0,85	-9,883	(2020:05, 2020:02)	-4,54	-4,03	-3,75
S&P/BMV IPC (MXX)	0,23	-47,22	(2009:06, 2008:12)	-3,65	-3,03	-2,69
S&P/TSX Composite (GSPTSE)	0,79	-7,585	(2009:06, 2008:11)	-4,48	-3,97	-3,69
Semdex (MDEX)	0,79	-13,86	(2020:04, 2019:12)	-4,48	-3,97	-3,69
Shanghai Composite (SSEC)	0,72	-8,413	(2016:02, 2015:01)	-4,41	-3,89	-3,60
SMI (SSMI)	0,84	-8,621	(1998:11, 1998:06)	-4,53	-4,02	-3,75
TA 35	0,92	-6,987	(2020:04, 2019:05)	-4,60	-4,09	-3,83
Tadawul SE (TASI)	0,79	-6,288	(2008:11, 2004:11)	-4,48	-3,97	-3,68
Taiwan Weighted (TWII)	0,87	-7,981	(2008:08, 2007:12)	-4,56	-4,05	-3,78
Tallinn SE General (OMXTGI)	0,58	-14,16	(1996:08, 1996:02)	-4,25	-3,71	-3,41
Tanzania All Share	0,80	-7,398	(2020:05, 2020:02)	-4,49	-3,98	-3,70
Tunindex (TUNINDEX)	0,85	-5,924	(2015:04, 2013:10)	-4,54	-4,03	-3,76
Uganda All Share	0,86	-7,189	(2020:07, 2020:02)	-4,55	-4,04	-3,77
Vilnius SE General (OMXVGI)	0,83	-6,496	(2006:03, 2005:05)	-4,52	-4,01	-3,73
VN 30	0,79	-7,925	(2009:08, 2008:12)	-4,48	-3,97	-3,69
WIG (WIG)	0,57	-19,56	(2009:04, 2009:01)	-4,24	-3,70	-3,40

[2] *Indicates series with a unit root. ρ^2 epresents the correlation coefficient

oes not hold. Consequently, future prices become forecastable using past price information.These findings suggest that random walk behavior is present only in the Bulgarian and Indian markets. Accordingly, past prices cannot be used to forecast future price movements, rendering technical analysis theoretically ineffective in these cases. However, in the majority of other markets including both developed and developing economies prices exhibit dependence on past data. This indicates that systematic forecasting based on technical analysis and historical models may be possible in these markets.

In conclusion, the inefficiency of markets other than Bulgaria and India provides professional investors, who possess superior information and analytical tools, with a chance to earn 'abnormal returns,' creating a disadvantage for individual investors. Conversely, in the efficient markets of Bulgaria and India, beating the market depends entirely on random market dynamics rather than analysis.

Therefore, the results in Table 2 indicate that the weak-form efficiency conditions are not met for the majority of stock markets, with the exception of the Bulgarian Stock Exchange (BSE Sofix) and the Indian Stock Exchange (Nifty 50). While it is possible to use past prices to forecast future prices in the majority of the markets analyzed, in the case of Bulgaria and India, the presence of a unit root suggests that these markets are weak-form efficient and past prices cannot be used for forecasting.

Conclusions

This study investigated the weak form of market efficiency for 71 stock exchanges from 67 different countries using the RALS-LM unit root test. The results indicate that the benchmark indices of 68 stock exchanges did not contain unit roots, meaning they were stationary and, as such, did not meet the conditions for weak form efficiency. In other words, it can be said that the prices in these markets reflect past information, making it possible to forecast future prices. These findings are consistent with previous studies in the literature, such as Huang (1998), Barkoulas et al. (2000), Kwon and Kish (2002), Coşkun and Seven (2016), Koyuncu and Aslan (2017), Nene (2019), Gümüş and Bektur (2019), and Bayraktar (2020). However, the findings partially or fully contradict those of Šonje et al. (2011), Chaudhuri and Wu (2003), and Noreen et al. (2022). This discrepancy can be explained by the study of Çelik and Taş (2007), which suggests that different unit root methodologies can lead to varying results in detecting weak form efficiency.

Only the stock data from Bulgaria (BSE Sofix) and India (Nifty 50) in the sample were found to contain unit roots, meeting the conditions for weak form efficiency. This can be attributed to the high frequency of shocks in the economies of these countries. In economies with frequent shocks, forecasting future prices becomes more challenging. In this case, the market’s inefficiency in forecasting future prices due to the inability to forecast using past prices demonstrates weak form efficiency.

Recent literature further supports and expands on these findings. For instance, Rönkkö et al. (2024) analyzed the Finnish stock market (OMX Helsinki 25) using nonlinear dependence tests and found periodic inefficiencies, suggesting that weak form efficiency may vary over time due to market dynamics, aligning with our findings of widespread stationarity across global markets. Similarly, Gu (2023) revisited the Efficient Market Hypothesis (EMH) and emphasized that behavioral factors and market anomalies, such as those observed in our study’s structural breaks (e.g., the 2020-2021 COVID-19 period), can lead to deviations from weak form efficiency, particularly in emerging markets. In contrast, Rathnaweera (2023) argued that certain Asian markets, including India's Nifty 50, exhibit characteristics of weak form efficiency due to rapid information incorporation, which corroborates our findings for the Indian market. Additionally, Mahjoubi (2024) synthesized behavioral finance with EMH, highlighting that investor psychology can create forecastable patterns in stock prices, supporting our observation that 68 exchanges allow for price forecastability based on past data.

Another finding from the study was that the break dates calculated for the countries varied. For example, the DAX 40 index experienced breakpoints in June and November 2011, the FTSE 100 index in January and December 2020, the S&P 500 index in May 1999 and April 2001, and the FTSE China A50 index in September and December 2007. These breaks can be attributed to economic crises, sudden, and unexpected shocks experienced by each country's economy at different times. However, the COVID-19 pandemic that emerged in 2020-2021 and affected the entire world became a break period for 18 exchanges. The different break dates across exchanges highlight the distinct dynamics of each exchange, while the same break dates occurring on different exchanges can be explained by events that affect all exchanges simultaneously.

The findings from this study, reinforced by recent literature, suggest that it is possible for investors to make future forecasts using past prices in most global stock markets. Moreover, the study emphasizes the necessity of revisiting financial practices with current methodologies, such as the RALS-LM test, which accounts for non-normal errors and structural breaks. This indicates that new tests and applications could yield different results from those in the existing literature, forming the basis for future research. Future studies could explore the role of behavioral finance and adaptive market dynamics, as suggested by Gu (2023) and Mahjoubi (2024), to further explain the observed inefficiencies in global stock markets.

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