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Testing the Adaptive Market Hypothesis for Fragile Five Countries: Time-Varying KSS Unit Root Test Application

Adaptif Piyasa Hipotezinin Kırılgan Beşli Ülkeleri için Test Edilmesi: Zamanla Değişen KSS Birim Kök Testi Uygulaması

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ABSTRACT

In this study, the validity of the Adaptive Market Hypothesis (AMH) for the Fragile Five countries (India, Brazil, Indonesia, Turkey, and South Africa) was investigated through daily data for the period 01.09.2013-30.06.2024. As a result of the time-varying KSS unit root test developed by Kapetanios, Shin and Snell (2003), it was found that the periodic weak form of market efficiency is valid for the Fragile Five countries and the AMH was confirmed for these markets. Therefore, it is understood that the random walk hypothesis is periodically valid and investors who use technical analysis methods have the potential to earn higher-than-normal returns when the random walk is not valid.

Anahtar Kelimeler:
Adaptif Piyasa Hipotezi, Kırılgan Beşli Ülkeleri, Zamanla Değişen KSS Birim Kök Testi
Jel Kodları:
C22, G14, G15

ÖZET

Bu çalışmada, Kırılgan Beşli ülkeleri (Hindistan, Brezilya, Endonezya, Türkiye ve Güney Afrika) için Adaptif Piyasa Hipotezi'nin (APH) geçerliliği 01.09.2013-30.06.2024 dönemine ait günlük veriler kullanılarak araştırılmıştır. Kapetanios, Shin ve Snell (2003) tarafından geliştirilen zamanla değişen KSS birim kök testi sonucunda piyasa etkinliğinin dönemsel zayıf formunun Kırılgan Beşli ülkeleri için geçerli olduğu tespit edilmiş ve bu piyasalar için APH doğrulanmıştır. Dolayısıyla, rassal yürüyüş hipotezinin dönemsel olarak geçerli olduğu ve teknik analiz yöntemlerini kullanan yatırımcıların rassal yürüyüşün geçerli olmadığı durumlarda normalden daha yüksek getiri elde etme potansiyeline sahip olduğu anlaşılmaktadır.

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1. INTRODUCTION

The Adaptive Markets Hypothesis (AMH), introduced by Lo (2004, 2005, 2012), is a theory that integrates principles of evolutionary biology and psychology into finance theory to explain market dynamics. Lo (2005) claims that market efficiency is affected by several environmental factors - e.g. the number of market participants, profit opportunities, and the adaptability of investors. This hypothesis defines traditional market efficiency and behavioral finance concepts by suggesting that market participants adapt to changing market conditions (Enow, 2022).

The AMH suggests that market efficiency is typically not a constant concept but evolves over time as a response to time-varying economic conditions. Kumar (2018) argues that market efficiency characteristics change depending on changing market and macroeconomic conditions (recessions, market failures and crises, bubbles) and institutional factors. AMH views markets as ecological systems in which different agents compete for resources, leading to different degrees of efficiency (Neely et al., 2007), and combines the efficient market hypothesis with behavioral finance to provide a framework that considers the evolutionary nature of human behavior in financial decision-making. The AMH acknowledges the existence of finite rationality among investors and the influence of institutional factors on market dynamics (Dhankar & Shankar, 2016, Shadid 2022). AMH is also significant for understanding how market participants make decisions under conditions of uncertainties and indecision (Shi, 2021).

According to AMH, the fact that market efficiency can change over time has important consequences for the related parties. While it is not possible to generate abnormal returns when the market is efficient, abnormal returns can be generated in inefficient markets by methods such as technical analysis. It will also be possible to achieve abnormal returns in the market if there is a shift away from efficiency due to various environmental factors such as competition and the adaptability of investors. Therefore, for the related parties, the validity of the AMH in any market means that there may be anomalies in the market in question and therefore an abnormal return can be generated. As a result, analysing the validity of AMH in a market can reveal very important results for market participants. Another important aspect of the study is to investigate whether the AMH is valid in the Fragile Five countries. In the literature review, there is no study that investigates the AMH for the Fragile Five sample. Finally, another unique aspect of the paper is the examination of the unit root with the time-varying version of the KSS unit root test developed by Kapetanios, Shin & Snell (2003). Since the nature of financial time series and have an extreme volatility structure such as daily continuously priced stock markets, it is important to examine the KSS with non-linear unit root tests in order to reach more appropriate results.

In sum, AMH represents a breakthrough within financial theory by integrating aspects of behavioral finance and evolutionary principles to provide a more comprehensive understanding of market dynamics. By allowing for the adaptive character of market participants and the time-varying nature of market efficiency, AMH presents a more plausible description of how financial markets do function. Empirical studies conducted for different asset categories and market conditions have revealed both the applicability and plausibility of AMH in explaining the complexity of modern financial markets.

The objective of this study is to explore the validity of the AMH in the Fragile Five countries for the period 2013-2024. In this regard, the main motivation of this study is that, as far as we know, AMH has never been analyzed for the Fragile Five countries. Also, the study is novel in that it is the first study to investigate the AMH with a time-varying unit root test.

The following sections briefly present and discuss the methods and findings of previous studies in literature. Then, the econometric methodology, data, empirical findings and discussion are presented respectively.

2. LITERATURE REVIEW

The Efficient Markets Hypothesis (EMH), introduced by Samuelson (1965) and Fama (1965, 1970), which assumes that markets are efficient or inefficient and that market efficiency is constant over a while, has been criticized heavily since the early 1980s. For instance, Grossman and Stiglitz (1980) stated that market efficiency is impossible, and that information will never have a symmetric spillover. Similarly, Campbell et al. (1998) pointed out that the efficiency of markets is relative and there is no absolute efficiency when comparisons between various markets are considered. Indeed, many empirical studies over the years have provided findings that contribute to the objections to the EMH. Hence, the findings that reject the basic assumptions of the EMH, i.e. that investors do not always behave rationally and that access to information in markets is asymmetric, have undermined the EMH (Kahneman & Tversky, 1979; Ball, 1978). Accordingly, Lo (2004) introduced a version of

the EMH, the AMH, which revises the basic assumptions of the EMH based on the principles of evolutionary biology. The core assumptions of AMH are listed as follows:

- Individuals act in their self-interest,
- Individuals learn and adapt,
- Individuals make mistakes,
- Competition in markets forces adaptation and innovation,
- Market ecology is structured by natural selection,
- Evolutionary principles are the determinants of market dynamics

Accordingly, the AMH hypothesis, as characterized by Lo (2004, 2005), points out that market efficiency is not always valid due to the characteristics of markets and the dynamic behavior of market agents, and that market efficiency is hampered in a cyclical fashion (Urquhart & McGroarty, 2016). As such, the AMH, which can be characterized as a challenge to settled arguments, has attracted great attention from scholars and has been the subject of many studies in the last two decades.

The earliest studies which tested the AMH were performed by Lim & Brooks (2006). Their study investigated the time-varying efficiency of developed and developing stock markets with Portmanteau bicorrelation and found that market efficiency is cyclical over time. Lim (2007) employs the portmanteau bicorrelation test on a rolling sample of eleven developing and two developed markets and found that the efficiency of each market exhibits an evolution over time consistent with the AMH. Todea et al. (2009) showed that returns are cyclical rather than constant by employing linear and nonlinear tests. Ito and Sugiyama (2009) investigate the time-varying autocorrelation of monthly S&P500 returns and show that the market efficiency is not constant, with the market efficiency at its lowest level in the late 1980s and at its most efficient around 2000.

Kim et al. (2011) investigated the predictability of daily DJIA stock returns from 1900 to 2009 using an automatic variance ratio test and an automatic portmanteau test. Using a rolling windows approach, they found clear evidence of time-varying predictability driven by market conditions. Charles et al. (2012) examined the return predictability of major exchange rates between 1975 and 2009 utilizing daily and weekly nominal exchange rates. Applying the automatic variance ratio test, the generalized spectral test and the Dominguez-Lobato consistency test showed that return predictability varies over time depending on changing market conditions, which is consistent with the AMH. Smith (2012) investigated the changing efficiency of 15 European developing stock markets and three developed markets. They used rolling window variance ratio tests and found that return predictability varies significantly, with the 2007-2008 global financial market crisis coinciding with high return predictability in Croatia, Hungary, Poland, Portugal, Slovakia and the United Kingdom. Lim et al. (2013) investigate return predictability for three major US stock indices with a rolling forecast approach using the automatic portmanteau Box-Pierce test and the wild bootstrapped automatic variance ratio test. They found evidence that periods with time-varying return predictability and significant return autocorrelations are broadly correlated with significant external events, hence consistent with the AMH.

Urquhart & Hudson (2013) tested whether the U.S, the U.K, and Japanese stock markets conform to the AMH using linear and nonlinear tests for the independence of stock returns. They demonstrated robust evidence supporting the AMH and claimed that the AMH explains stock return behavior better than the EMH. Zhou &Lee (2013) analyze GYO data using the automatic variance ratio test and automatic portmanteau test and show that market efficiency changes over time depending on market conditions. Dyakova & Smith (2013) analyzed two Bulgarian stock price indices and eight stock prices in a rolling window from October 2000 to August 2012 applying variance ratio tests. They reported the changing level of predictability supporting the AMH. Niemczak & Smith (2013) analyzed 11 Middle Eastern stock markets and found that most markets experienced successive periods of efficiency and inefficiency consistent with the AMH. Hiremath & Kumari (2014) performed linear and non-linear tests for Sensex and Nifty indices and found that the results obtained from linear tests support the AMH, while non-linear tests do not.

Recent studies have mostly confirmed the validity of the AMH hypothesis, similar to the previous ones. Obalade & Muzindutsi (2019) employed a 20-year return series to investigate the validity of the AMH hypothesis for Nigeria, South Africa, Mauritania, Morocco and Tunisia. Their results indicate that AMH is valid in all of these countries. In another study of the variance ratio test, Mandacı et al. (2019) examined Borsa Istanbul and determined that AMH is valid for the XU100. Lekhal & Oubani (2020) measured market efficiency through linear and nonlinear tests using a rolling window approach and daily return series of the MASI index for the period

1992-2019. Their results reveal that the efficiency rate changes over time. Kumar & Anandarao (2021) tested the validity of AMH for the Indonesian Forex market. Their findings conclusively prove that the Indonesian FX market is adaptive and periodically fluctuates between efficiency and inefficiency. Adaramola & Obisesan (2021) examined the validity of AMH for the Nigerian stock market using linear and nonlinear tests and a rolling window approach. The results indicate that the Nigerian stock market aligns with the AMH. Yousuf & Makina (2022), through quantile regression model, found that return estimation in South African markets varies by market conditions and thus AMH is valid. Cruz-Hernandez & Mora-Valencia (2024) tested the validity of AMH in 5 Latin American stock markets. Their findings confirmed the validity of AMH for each country.

Considering the extant literature, Kılıç (2020) is the only study available to the authors that shows that the AMH is not valid. In his study, Kılıç (2020) investigated the validity of the AMH for the XU100 index with an automatic Portmanteau generalized spectral test and automatic variance ratio test. His empirical evidence showed that inconsistent with the previous literature, the AMH is not valid, i.e., the efficiency of the XU100 index does not change over time depending on market conditions.

3. METHODOLOGY

In this research, nonlinear unit root tests are applied due to the financial nature of the time series and their extremely volatile nature as stock markets are priced continuously day-to-day. In this regard, the time-varying specification of the KSS unit root test proposed by Kapetanios, Shin & Snell (2003) was used.

The Star (1) model for nonlinear series is as in Eq. 1.
Exponential function;

$$\Theta(\theta;\ yt-d)\ =\ 1-exp(-\theta y2t-d) \tag{1}$$

$$Yt\ =\ \beta y-1\ +\ \Upsilon yt-1\Theta(\theta;\ yt-d)\ +\ \xi\varepsilon t \tag{2}$$

If the exponential function is replaced in the model;

$$\Delta yt=\ ^{\Phi}yt-1+\Upsilon yt-1[1-exp(-\theta y2t-d)\ +\ \varepsilon t \tag{3}$$

This model with constraints Φ = 0 and d = 1;

$$\Delta yt=\ ^{\Phi}yt-1\,\{1-exp((-\theta y2t-1)\ +\ \varepsilon t \tag{4}$$

where the null hypothesis states that the series is unit rooted and the alternative hypothesis states that the series is stationary. This is an exponential autoregressive process. It is consistent with a stationary ESTAR process.

$$H0:\theta\ =\ 0$$

$$H1:\theta\ <\ 0$$

The Kapetanios, Shin & Snell (2003) (KSS) unit root test tests a nonlinear process alternative to the null hypothesis of a unit root. The test is performed for the entire observation span. However, sometimes some periods of the series may be stationary, and some periods may exhibit unit root behavior. In these cases, the existing KSS test may not give reliable results, and it is necessary to use time-varying techniques to analyze these cases.

To perform the time-varying KSS unit root test, a sample size of N is first selected. The KSS unit root test is applied from the 1st unit to the Nth unit. In the second stage, the KSS test is applied to the sample from the 2nd unit to the N+ 1 unit and this procedure is repeated up to the latest unit. After the implementation to the entire sample, the test statistic obtained is divided by the 10% critical value (-2.66) in line with the normal distribution and the values obtained are graphed. The values above the "1" line indicate the periods when the series is stationary, while the values below it indicate the periods when the series is non-stationary (Kamışlı and Temizel, 2019).

4. DATA

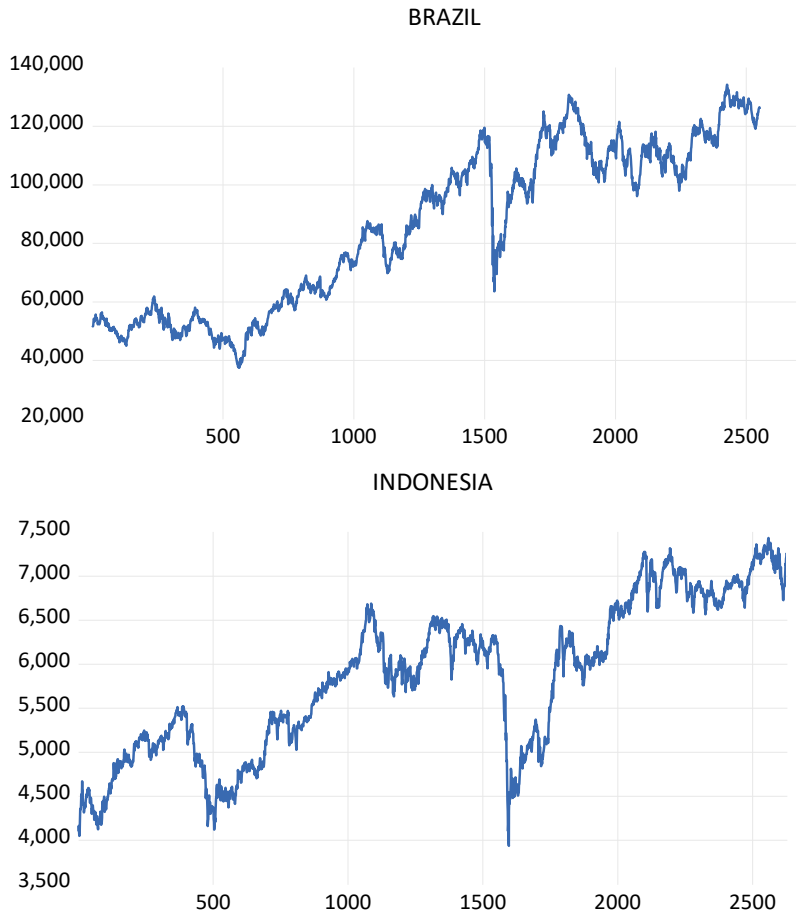
Morgan Stanley identified five countries - India, Brazil, Indonesia, Turkey, and South Africa, as the Fragile Five because of their high inflation, current account deficits, and need for foreign investment. This identification was first proposed by James Lord, one of the bank's analysts, in his August 2013 economic report. Therefore, daily

data as of September 2013 are used in this study. Daily data varies by country due to public holidays and the end date is June 2024. These data were collected from www.ukfinance.yahoo.com and www.investing.com. The summary table of the dataset is presented below.

Table 1. Data

Country	Stock Market	Obs.
India	BSE Sensex 30	2720
Brazil	IBOVESPA	2695
Indonesia	Jakarta Stock Exchange	2680
Türkiye	BIST-100	2653
South Africa	FTSE Johannesburg Top 40	2733

Time series graphs of the data are shown as follows. Time series graphs of the data are shown as follows. In these graphs, the values are shown in non-logarithmic form. In these graphs, the decline in the Covid-19 pandemic period stands out as a common property. In addition, they reflect the results of changes in their own internal economic patterns. For instance, the process of dropping two zeros from the Borsa Istanbul in Turkey can be seen in these graphs.



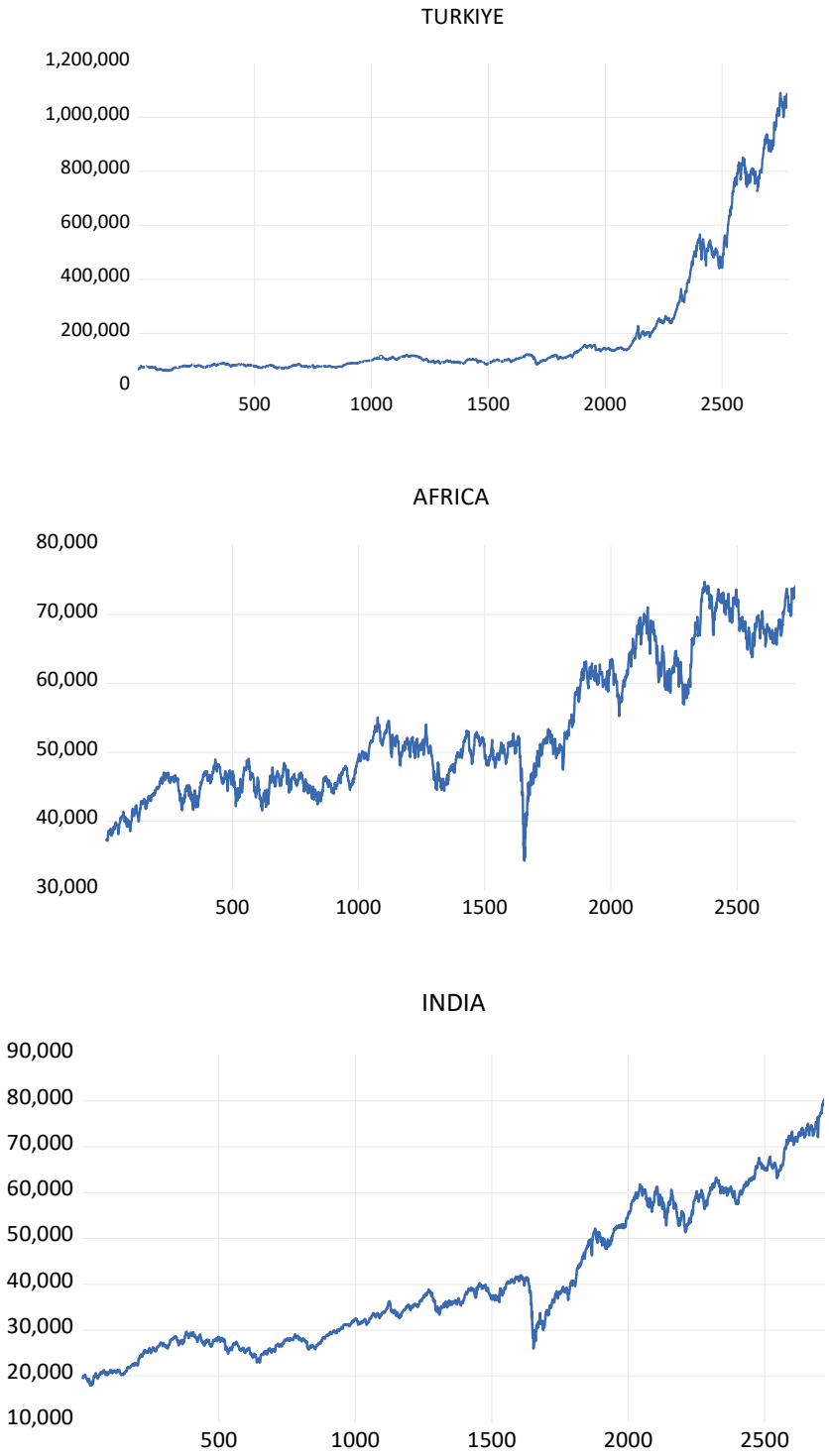
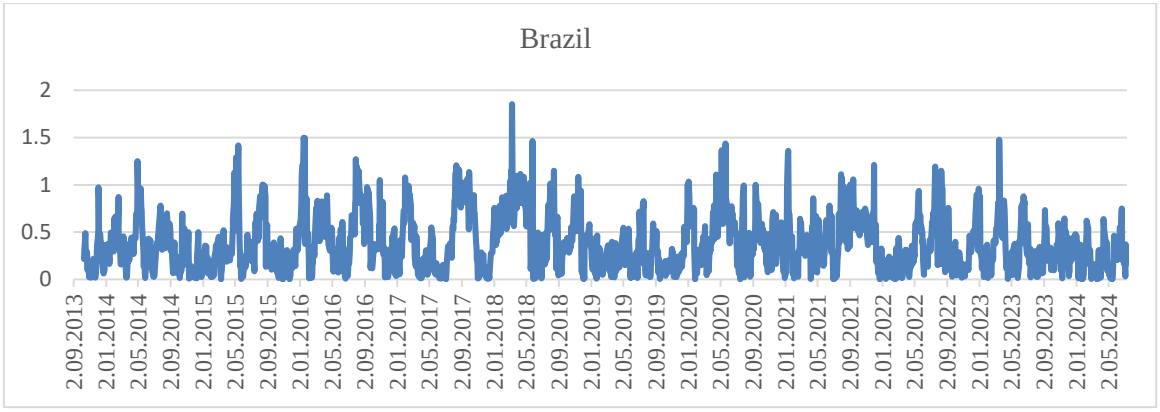


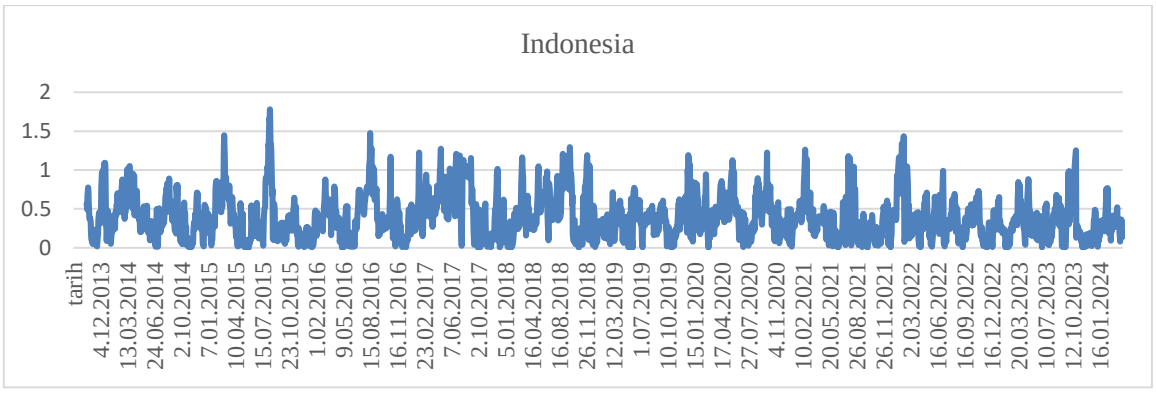
Figure 1-5. Time Series Charts of Variables

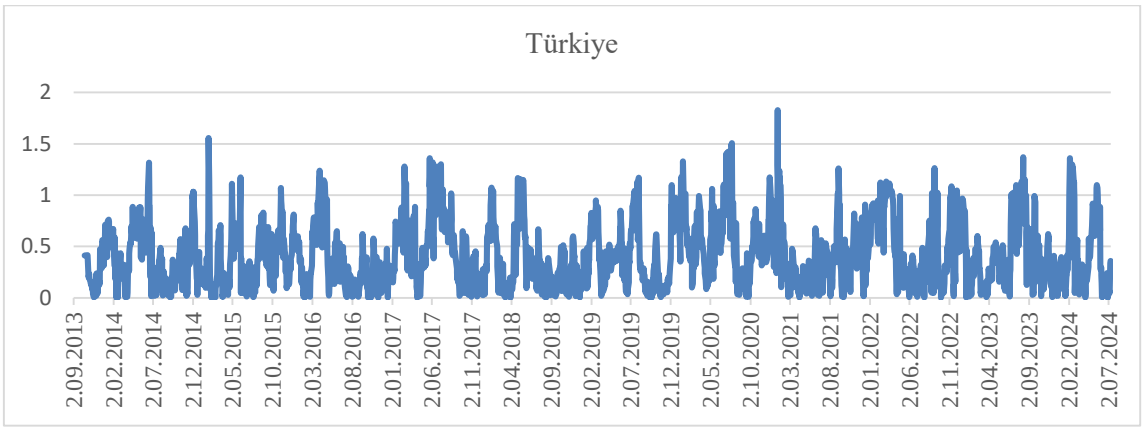
5. EMPIRICAL FINDINGS

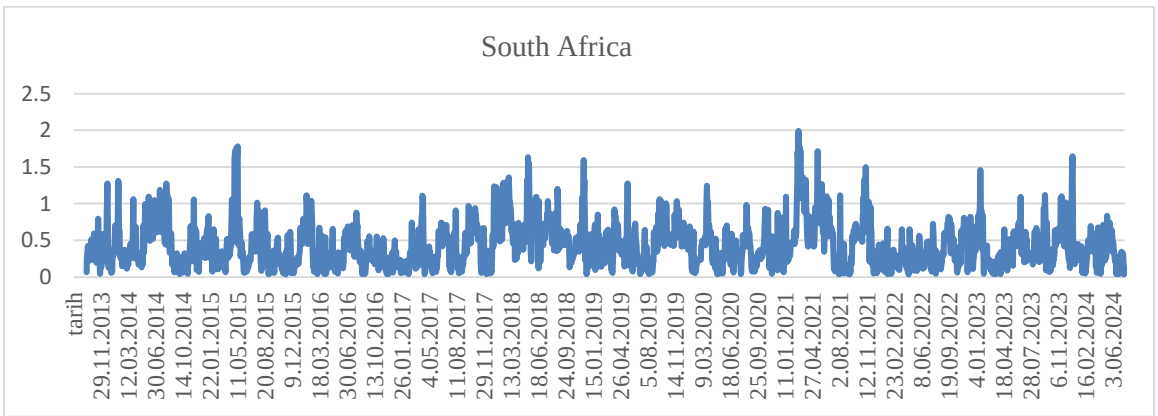
A review of various studies in the literature shows that the weak form of market efficiency can be measured by running tests, variance ratio tests, unit root tests, and many other methods. While some studies point to market efficiency, other studies have shown that market efficiency is not valid and behavioral finance anomalies are valid. In this study, the validity of the AMH, which suggests that both cases may be valid over time, was investigated. Accordingly, the time-varying KSS unit root test was used, which examines the stationarity of time series not for the entire data interval but periodically. In this regard, when the findings obtained with the figures numbered 6, 7, 8, 9 and 10 are analyzed, it is understood that the test statistics are above the 1 line periodically in all country stock markets, i.e. these time series are stationary in the periods above and have a unit root in the following periods. While the weak form of market efficiency is valid for the stock markets of these countries during periods

with unit roots, behavioral finance anomalies may be valid for the rest of the time. The graphs indicate that weak form of market efficiency especially matches the Covid-19 era. As a result, according to the findings obtained, the existence of AMH was found in 5 countries' stock markets as market efficiency is cyclically valid.









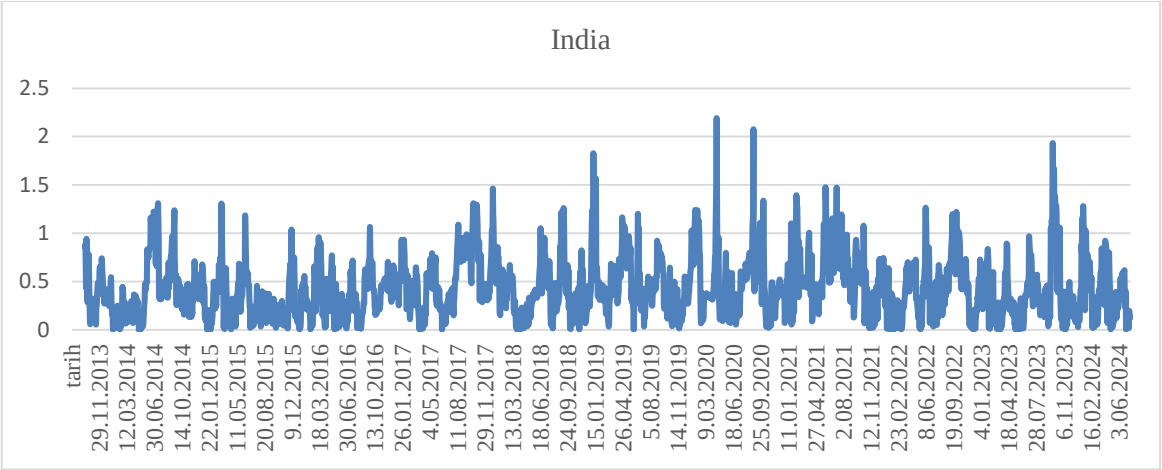


Figure 6-10. Time-varying KSS Unit Root Test Results

6. CONCLUSION AND DISCUSSION

Since its introduction, the efficient markets hypothesis has been one of the widely discussed topics in finance. There have been many empirical studies supporting the hypothesis and many criticisms. Especially the claims that market participants are always rational and that abnormal returns are impossible because prices in the market always include all the information that has been strongly criticized. The theory of Behavioral Finance, which is opposed to the efficient markets hypothesis, argues that there are anomalies in the market and that abnormal returns are possible as various assumptions of the efficient market hypothesis are not valid in financial markets. The AMH, proposed by Lo (2004, 2005, 2012), integrates the Efficient Markets Hypothesis with Behavioral Finance and suggests that markets act like ecosystems that are affected by numerous determinants. Market participants are individuals with limited rationality, competing for resources, and capable of adaptation. Therefore, market efficiency is not constant and financial markets may be efficient in some time intervals and inefficient in other times. The AMH, which integrates two controversial theories of financial markets, has attracted the attention of many researchers and several empirical studies have been conducted on this topic.

In this study, the validity of the AMH for the Fragile Five countries is examined with the time-varying KSS unit root test. With this test developed by Kapetanios, Shin & Snell (2003), it is possible to determine the time-varying periods in which the weak form of market efficiency is valid. Thus, whether the AMH is valid for the sample country stock markets was analyzed. The results of the analysis indicated that the AMH is valid for all Fragile Five countries. Because all the stock market indices analyzed by the study showed cyclical market efficiency. In other words, the time series analyzed cyclically has a unit root structure. These results indicate that the random walk hypothesis is cyclically valid in the investigated stock market indices. Since the weak form of market efficiency cannot be mentioned in periods when the random walk is not valid, investors will have the opportunity to earn above-normal returns by using various technical analysis methods during these periods.

The empirical findings obtained from the study are mostly in line with the other studies in the literature. In this sense, the findings of our study are similar to those of Cruz-Hernandez & Mora-Valencia (2024) for Brazil, Kumar & Anandarao (2021) for Indonesia, and Obalade & Muzindutsi (2019) for South Africa. However, it is partially consistent with Hiremath & Kumari (2014) who find that AMH is valid for India in linear tests but not in non-linear ones. Lastly, the findings of this study are not in line with the findings of Kılıç (2020), who finds that the AMH is not valid for BIST100. Hence, the findings suggest that the empirical evidence in the Fragile Five countries is insufficient to reach a general conclusion and that further research is still required.

Future studies may utilize another method, quantile-based unit root tests, which can provide different results across periods. On the other hand, further studies that will provide new findings for a larger data set and a larger sample will also contribute to literature.

AUTHORS' DECLARATION:

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AUTHORS' CONTRIBUTIONS:

Conceptualization, writing-original draft, editing – **ES**, data collection, methodology, formal analysis – **FZ**, Final Approval and Accountability – **TY**.

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