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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

Testing the Weak-Form Market Efficiency for the Islamic Market Indices: Evidence from Fourier Wavelet ADF Unit Root Test

İslami Endekslerde Zayıf Formda Piyasa Etkinliğinin Fourier Wavelet ADF Birim Kök Testi ile Test Edilmesi

Salih ÜLEV[1], **Mervan SELÇUK**[1]

ABSTRACT

Islamic stock markets and indices are a newly developing field and an essential phenomenon in the global financial system. Islamic stocks are different from conventional counterparts because they filter firms that do not comply with Shari'ah principles. The efficiency of stock markets is essential for all countries in regard to resource allocation and sustainable economic development. Therefore, many hypotheses have been developed to investigate market efficiency. The first and one of the most important of these hypotheses is the efficient market hypothesis. This paper aims to investigate the weak-form market efficiency of Islamic stock markets. For this purpose, we used 13 indices data in Dow Jones and S&P between 2011 and 2021, employing the Fourier Wavelet ADF (FWADF) Unit Root Test. The FWADF test enabled us to consider structural breaks with an unknown number, time, and form. The studies examining EMH and Islamic indices did not consider smooth changes and frequency information in wavelet-based unit root tests. Therefore, it is possible that the information for indices may have been incomplete. Adopting FWADF, our study contributes to the literature in that it uses all information about the stock market indices data in the analysis. The findings show that six Islamic market indices have unit roots, but seven indices are stationary. This means that all emerging market indices analyzed have market efficiency, but developed country indices do not. The results provide further understanding for investors and financial analysists enabling them to assess their decisions efficiently in constructing investment portfolios.

Keywords: Islamic market indices, emerging markets, market efficiency, fourier wavelet unit root test, Dow Jones, S&P
Jel Code: G11, C50, Z12

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[1] Asst. Prof, Sakarya University, Faculty of Political Sciences, Sakarya, Turkiye

ORCID: S.Ü. 0000-0002-0653-6821;
M.S. 0000-0001-8384-373X

Corresponding author/Sorumlu yazar:
Salih ÜLEV,
Sakarya University, Faculty of Political Sciences, Sakarya, Turkiye
E-mail/E-posta:
salihulev@sakarya.edu.tr

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ÖZ

İslami hisse senedi piyasa endeksleri, küresel finansal sistem içerisinde yeni gelişen ve önemli bir alandır. İslami hisse senedi piyasaları, Şer'i prensiplere uymayan firmaları filtrelediği için konvansiyonel muadillerinden ayrılmaktadır. Hisse senedi piyasalarının etkinliği, kaynak dağılımı ve sürdürülebilir ekonomik kalkınma için önemli bir unsurdur. Bu nedenle, piyasa etkinliğini araştıran pek çok hipotez geliştirilmiştir. Bunlardan ilki ve en önemlilerinden biri etkin piyasa hipotezidir (EMH). Bu çalışma İslami hisse senedi endeksleri için zayıf formda piyasa etkinliğini test etmeyi amaçlamaktadır. Bu amaçla, 2011-2021 yılları arasında Dow Jones ve Standard and Poors İslami endekslerinde yer alan 13 endekse ait veriler, Fourier Wavelet ADF (FWADF) birim kök testi kullanılarak test edilmiştir. FWADF testi, bilinmeyen bir sayı, zaman ve formda yapısal kırılmaları dikkate almaktadır. EMH'yi ve İslami endeksleri inceleyen çalışmalar, Wavelet temelli birim kök testlerinde yer alan yumuşak değişiklikleri ve frekans bilgisini dikkate almamaktadır. Bu nedenle, endeks verileriyle ilgili bilgilerin tamamlanmamış olma ihtimali bulunmaktadır. Çalışmamız, hisse senedi endeks verileriyle ilgili tüm bilgileri dikkate alan FWADF testini kullanarak liteatüre katkı sağlamaktadır. Çalışmada, 6 endeksin birim köklü, 7 endeksin ise durağan olduğu tespit edilmiştir. Bu bulgular, analiz edilen bütün gelişmekte olan İslami piyasa endekslerinde piyasa etkinliğinin olduğu, fakat gelişmiş ülke İslami piyasa endekslerinde piyasa etkinliğinin olmadığını göstermektedir. Çalışmanın sonuçları, yatırımcıların ve finansal analistlerin yatırım portföyleri oluştururken kararlarını etkin bir şekilde değerlendirmelerini sağlamak için bir anlayış sağlamaktadır.

Anahtar Kelimeler: İslami endeksler, gelişen piyasalar, piyasa etkinliği, fourier wavelet birim kök testi, Dow Jones, S&P
Jel Code: G11, C50, Z12

1. Introduction

Stock markets are designated as a regulated and secure platform for trading stocks of companies by investors to allocate ownership of the companies' shares and these platforms have a crucial role in the functioning of the economy. While companies use stock markets to raise capital and to determine the companies' market values, investors can have an opportunity to invest their savings in companies and become a shareholder. Many factors affect the decisions of investors who trade in stocks, and one of these factors is the price of stocks in the foregoing period. Price changes only affect the investors' decisions, and if they move randomly, they become an indicator of market efficiency. Moreover , market efficiency is essential for all countries in regard to resource allocation and sustainable economic development (Bugan, Çevik, Kırcı Çevik, & Yıldırım, 2021). Since it improves pricing and availability of capital, attracts foreign investment, and increases domestic savings, many hypotheses have been developed to investigate market efficiency (Al-Khazali, Leduc, & Alsayed, 2016). The first and one of the most important of these hypotheses is the efficient market hypothesis (EMH).

The EMH was first developed by Fama (1970), and this hypothesis is based on the notion that available information is fully reflected in prices. An efficient market represents that security prices reflect all available information in the market. This efficiency is classified into three different forms according to the availability of the data. These EMH forms are weak-form, semi-strong shape, and strong-form. The weak-form efficiency suggests that the

current price of securities only reflects the historical prices. If a stock market is weak-form efficient, then security prices rapidly react to historical prices such that investors cannot earn an above-normal risk-adjusted return on this level of information. The second form is semi-strong and demonstrates that all publicly known information is used to calculate securities' current prices. Finally, the strong-form suggests that investors have access to any information, either publicly or not (Fama, 1970).

Islamic stock markets and indices are a newly developing field and an important phenomenon in the global financial system. The Islamic finance system is a new focal point, and its assets exceeded the US $2.2 trillion in 2020 (Barbuscia, 2021). Islamic banks are still the main driver among the Islamic finance institutions with 71.7% of the share, followed by Sukuk (24.2%), Islamic funds (2.8%) and takaful (%1.3) (IFSB, 2019). Islamic stocks are different from conventional products because of the interest-free and ethical investing criteria implemented by Islamic finance. In addition, any trade in alcohol and in gambling is screened out. Islamic stock indices filter firms that do not comply with Shari'ah principles. These filters include two main criteria. First, the main activities of the firm must comply with Islamic principles. For example, the Islamic indices do not include firms that are involved in interest-based financial services, gambling, betting, alcohol production, sales of pork, and other haram foods. In the second criteria, the firm's financial indicators are examined. According to thiscriteria, the firm's ratio of total interest-bearing loans over market values and total interest-bearing financial assets over total market value must be less than 33 percent. These filters lead Islamic stock indices to differentiate from conventional counterparts in terms of low leverage, more negligible diversification, and small-capitalization (Al-Khazali et al., 2016). Hence, these differences may affect the stock return predictability and stock market efficiency and change the Islamic stock indices' response to the shocks.

One of the most common methods to investigate EMH is that of unit root tests. Thus, the robustness and convenience of the method used affect the test results. Investigating the stationary in stock prices enables us to determine whether EMH is valid or not. If stock prices have unit roots, this demonstrates that weak-form market efficiency is valid, and the current stock prices entirely reflect all the past information included in stock price movements. The validity of weak-form efficiency also implies that shocks to stock prices have a permanent effect. If stock prices have unit roots, this demonstrates that shocks to stock prices will have a permanent effect, in that prices will not return to their trend in time. This permanent effect confirms that forecasting future prices cannot be calculated based on historical movements in stock prices. On the other hand, if the results show that stock prices do not have unit-roots, then shocks will have a transitory effect, indicating that stock prices will not make a new equilibrium and future prices can be predicted concerning the historical

trend in stock prices. EMH emerged based on these propositions (Narayan, 2008).

This paper aims to investigate the weak-form of market efficiency for Islamic stock markets. For this purpose, using 13 indices data in Dow Jones and S&P between 2011 and 2021, we employed the Fourier Wavelet Unit Root Test (FWADF), which is one of the frequency domain unit root tests, to obtain stationary results between indices. The reason for adopting FWADF was to give more robust results for testing EMH for financial time series and including all information about the series with a large number of observations. In this respect, it is appropriate for our stock market data. While many studies are investigating EMH for traditional stock markets, a limited number of studies such as those of Al-Khazali et al., (2016), Ali, Shahzad, Raza, & Al-Yahyaee, (2018), Arshad, (2014), Bouoiyour, Selmi, & Wohar, (2018), Bugan et al., (2021) and Mensi, Tiwari, & Yoon (2017) examined EMH for Islamic stock markets. According to the authors' best knowledge, several studies have analyzed the weak-form efficiency for different indices in the context of the EMH. However, there is no study examining the EMH for Dow Jones and S&P Islamic market indices using FWADF, and we fill this gap in the existing literature. Thus, the main contribution to the previous literature is investigating EMH on Islamic Indices employing one of the newest techniques, which is the Fourier Wavelet Unit Root Test.

In the second part of the study, we examined the literature and previous studies. The relevant literature shows that our research is unique regarding the selected technique and sample. The econometric methods are stated in the third section. Data and empirical results are presented in the fourth section. The final part of this paper consists of a discussion and conclusion.

2. Literature Review

Several studies have investigated market efficiency using various methods. Of these, the pioneer ones are those conducted by Samuelson (1965), Fama (1965) and Mandelbrot (1966) through testing the random-walk hypothesis (RWH). After Fama (1970)'s classification, the literature progressed toward the EMH. Chaudhuri & Wu (2003) examined the validity of RWH for 18 emerging equity markets between January 1985 and April 2002 using the seemingly unrelated regression (SUR) and unit root tests. The results show that the validity of the RWH is rejected only for Chile, Korea, the Philippines, Taiwan, and Venezuela. Narayan (2008) studied the effect of shocks on G7 stock price indices, whether permanent or temporary, by employing monthly data in the period between 1975Q1 and 2003Q4 using the Lagrangian Multiplier panel unit root test. The findings demonstrate that stock price indices have no unit root. This temporary effect does not confirm the EMH.

The weak-form market efficiency argues that future security prices cannot be reflected by employing historical price information, as past price information is already incorporated

into the current security prices. Using weekly data between 1992 and 1999, Buguk & Wade Brorsen (2003) tested the weak-form market efficiency in the Borsa Istanbul composite, industrial, and financial index prices to see whether these series were a random walk or not. The findings from the ADF unit root, LOMAC variance ratio, and GPH fractional integration test showed that RWH is not rejected, and the weak-form market efficiency is validated. Islam & Khaled (2005) tested the weak-form hypothesis for the Dhaka Stock Exchange from 1990 to 2001, employing the ADF-PP unit root test and variance ratio test. The findings showed that the Dhaka stock market's short-term predictability of security prices is valid for the 1996 boom but not for the post-crash term.

Mobarek and Fiorante (2014) studied whether weak-form market efficiency was valid for BRIC countries between 1995 and 2010 using a bias-free statistical technique. The empirical results showed that variance-ratio and run test ensured more preferable results than the serial correlation as BRIC markets have fairly weak-form market efficient. Cheung & Andrew Coutts (2001) investigated the RWH for Hang Seng Index on the Hong Kong Stock Exchange through homoscedastic and heteroscedastic error variances between 1985 and 1987. The results demonstrated that the Hang Seng Index confirms weak-form market efficiency. Savaşan, Yardımcıoğlu, & Beşel (2015) examined the impacts of exogenous shocks on the Borsa Istanbul Participation 30 Index between 6 January 2011 and 31 August 2015, employing daily data through the Zivot-Andrews and Fourier unit root tests. The findings showed that the series has a non-stationary structure. Exogenous shocks permanently affect the Participation 30 Index.

Asiri (2008) tested the validity of weak-form market efficiency for the Bahrain stock market (BSE) using cross-sectional time series for 40 companies between 1 June 1990 and 31 December 2000, employing the Dickey-Fuller unit root test and autoregressive integrated moving average (ARIMA). The findings showed that RWH is valid for each sector. In addition, the ARIMA test also endorses the weak-form market efficiency in the BSE. Alexakis, Patra, & Poshakwale (2010) studied the validity of semi-strong market efficiency form in the Athens Stock Exchange (ASE) from 1993 to 2006, employing accounting information through panel data analysis. The results indicated that the selected 47 firms' financial ratios have essential information to predict the cross-section of stock returns in the ASE. This evidence showed that the ASE does not fully reflect publicly available accounting information into security prices, contrary to the semi-strong EMH.

In addition to these studies, other studies investigated the validity of EMH on Islamic stock markets. Mensi et al. (2017) tested the weak-form market efficiency for 10 Dow Jones Islamic sectoral stock indices employing the multifractal detrended fluctuation analysis (MF-DFA) approach between 9 November 1998 and 5 March 2015. The findings

demonstrated that these indices are more efficient in the long period than in the short period. Rizvi, Dewandaru, Bacha, & Masih (2014) examined the validity of EMH for 11 Islamic and 11 developed countries' markets using MF-DFA between 1 January 2001 and 31 December 2013. The results showed that the markets of developed countries are more efficient than those of Islamic countries, although the markets of Islamic countries have highly efficient performance, especially in crisis periods.

Al-Khazali et al. (2016) investigated RWH for 9 Islamic and 9 non-Islamic stock indices between 1997 and 2012 to understand whether Islamic indices are more efficient than their conventional counterpart or not. The results showed that while Europe, Japan, and the UK's conventional indices are efficient, there are no efficient Islamic indices in these markets. However, the findings also showed that the Islamic indices were slightly more efficient than their conventional counterparts in the recent financial crisis. Ali et al. (2018) also investigated the market efficiency for 12 Islamic and non-Islamic stock markets, including some developed and BRIC countries employing MF-DFA from 1 January 2003 to 31 December 2016. The findings showed that the stock markets of USA, UK and Japan are comparatively more efficient than those of BRIC Islamic stock markets indices, most notably the Turkish one, are more efficient than their conventional counterparts. It is also noteworthy that developed Islamic stock markets are comparatively more efficient than those found in emerging markets.

3. Methodology

In this study, we adopted the Fourier Wavelet ADF **(**FWADF) test, recently introduced by Aydin & Pata (2020). Time-domain methods neglect frequency information, and this leads to information not being used in an efficient way. However, employing frequency domain analysis, frequency information of the series can be provided. On the other hand, the deficiency of frequency domain analysis is that it neglects time information. The wavelet approach removes this deficiency by including both time information and frequency information in the research (Aydin & Pata, 2020).

Developed using the Wavelet approach, wavelet unit root tests have attracted significant attention recently. Fan & Gençay (2010) developed the wavelet-based variance ratio unit root test. Wavelet transformations are executed with the help of the filters in this test. There have been two types of wavelet transform in the literature: Discrete Wavelet Transform (DWT) and Continuous Wavelet Transform (CWT). Gençay, Selçuk, & Whitcher (2001) stated that DWT is more suitable for high-frequency financial and economic time series data. In addition, Eroğlu & Soybilgen (2018) emphasized that DWT obtains more robust results than any other transformations for wavelet-based ADF unit root tests. Thus, we

adopted the DWT in this study for the FWADF test. In different wavelet transform, wavelet and scaling coefficients are obtained using the following equations:

$$w_{1,t} = \sum_{l=0}^{L-1} h_l x_{2t+1-l \bmod N} \qquad t = 0,1,....,N/2-1 \tag{1}$$

$$v_{1,t} = \sum_{l=0}^{L-1} g_l x_{2t+1-l \bmod N} \qquad t = 0,1,....,N/2-1 \tag{2}$$

where $w_{1,t}$ is the wavelet coefficient, $v_{1,t}$ is the scaling coefficient, h_l represents the scaling filter, and g_l is the wavelet filter. Eroğlu & Soybilgen (2018) extended the augmented Dickey-Fuller (ADF) unit-root test via wavelet decomposition. ADF test procedure of Eroğlu & Soybilgen (2018) is as follows:

$$\Delta V_{1,t} = \sum_{j=1}^{p} \rho_j \Delta V_{1,t-j} + \delta V_{1,t-1} + \varepsilon_t \tag{3}$$

For the wavelet-based ADF (WADF) unit root test, the null hypothesis ($H_0: \delta = 0$) shows that the series has a unit root, while the alternative hypothesis ($H_1: \delta < 0$) implies that the series is stationary. Similarly, the test statistic is the same as the ADF test and is calculated as follows:

$$ADF_t^* = \frac{\hat{\delta}}{Std(\hat{\delta})} \tag{4}$$

Among the unit root tests which consider the structural breaks Wavelet-based unit root test is relatively new. Yazgan & Özkan (2015) introduced a test to determine structural breaks employing wavelet transform. Aydın (2019) also developed the first nonlinear wavelet-based unit root test that considers structural breaks. Including structural breaks to the model, Aydin & Pata (2020) proposed a data generating process for the wavelet-based unit root test as in Eq. (5):

$$y_t = \mu(t) + \varepsilon_t \tag{5}$$

Yazgan & Özkan (2015) used the form of the unknown deterministic factors as in Eq (6):

$$\mu(t) \cong \alpha \sum_{i=1}^{n} \left\{ (2i-1)^{-1} \sin\left[\frac{2\pi(2i-1)kt}{T} \right] \right\} \tag{6}$$

where n is the frequency of the deterministic component, and k represents the frequency of the Fourier term. Aydin & Pata (2020) state that smooth breaks appear in the series when n=1 and offer the model for the FWADF test as follows:

$$\Delta V_{1,t} = \sum_{j=1}^{p} \rho_j \Delta V_{1,t-j} + \delta V_{1,t-1} + \beta \sin(2\pi kt / T) + \varepsilon_t \tag{7}$$

where $V_{1,t}$ are the scaling coefficients procured by employing wavelet filtering methods. Aydin & Pata (2020) follows Enders and Lee's approach for the FWADF unit root test and uses two steps while applying the test.

In step 1, the model (7) is estimated in the range $1 \leq k \leq 5$ and chosen with the smallest residual squares as the appropriate model.

In step 2, the existence of the nonlinearity is investigated by using the t-test. Aydin & Pata (Aydin & Pata, 2020) calculated the new critical values and proposed them in the case of the unit-rooted null hypothesis. In the contrary case, they recommend using the WADF unit root test.

The frequency-domain unit root test results give more robust results since they include all information about the series with high-frequency numbers such as financial time series. As Aydin & Pata (2020) emphasized non-using frequency information in series with high-frequency numbers would lead to biased results. Our data have high-frequency numbers, which leads us to consider that FWADF test results are more robust. In addition, when compared with the ADF type unit root test that allows endogenous structural breaks, the FWADF test considers structural breaks with unknown time, number, and form. Thus, in this study, we adopted the FWADF unit root test. Previous studies examining EMH and Islamic indices using wavelet-based unit root tests did not consider smooth changes nor frequency information. Hence, it is possible that the information for indices may have been incomplete. Adopting FWADF, our study will contribute to the literature by using all information about the stock market indices data in the analysis.

4. Data and Empirical Results

This study used the 13 Islamic indices' daily data, consisting of Shari'ah-compliant stocks traded at different country stock exchanges. Since the study aims to examine the efficient market hypothesis of the last ten years, our data covers the period from 31 May 2011 to 11 June 2021. Each data set was obtained using S&P Dow Jones Global Indices (www.spglobal.com) data platform. The scope and descriptions of Islamic Market Indices are presented in Table 1.

Table 1: Scope and Descriptions of Islamic Market Indices

No.	Abbreviations	Description	Scope	Period
1	DJIAP (E)	Dow Jones Islamic Market Asia/Pacific Index	Stocks traded in Asia/Pacific region that pass rules-based Shari'ah screens.	31.05.2011 - 11.06.2021
2	DJICHM (E)	Dow Jones Islamic Market CHIME 100 Index	100 leading companies selected from China, India, and the Middle East and North Africa (MENA) region that pass rules-based Shari'ah screens.	31.05.2011 - 11.06.2021
3	DJIDEV (D)	Dow Jones Islamic Market Developed Markets Index	Stocks traded in developed-market countries that pass rules-based Shari'ah screens.	31.05.2011 - 11.06.2021
4	DJIEU (D)	Dow Jones Islamic Market Europe Index	Stocks traded in Europe that pass rules-based screens for adherence to Shari'ah investment guidelines.	31.05.2011 - 11.06.2021
5	DJIGCC (E)	Dow Jones Islamic Market GCC Index (USD)	Stocks traded in the GCC region that pass rules-based screens for adherence to Shari'ah investment guidelines. The index covers Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.	31.05.2011 - 11.06.2021
6	DJIEMG (E)	Dow Jones Islamic Market World Emerging Markets Index	This index consists of emerging-market companies that pass rules-based screens for adherence to Shari'ah investment guidelines.	31.05.2011 - 11.06.2021
7	DJIM	Dow Jones Islamic Market World Index	This index consists of stocks traded globally that pass rules-based screens for adherence to Shari'ah investment guidelines.	31.05.2011 - 11.06.2021
8	SHX	S&P 500 Shari'ah Index	The S&P 500 Shari'ah includes all Shari'ah-compliant constituents of the S&P 500, the leading benchmark for the U.S. equity market.	31.05.2011 - 11.06.2021
9	SPSHBRX (E)	S&P BRIC Shari'ah Index	The S&P BRIC Shari'ah includes leading Shari'ah-compliant companies from the emerging markets of Brazil, Russia, India, and China.	31.05.2011 - 11.06.2021
10	SPSHWDDP (D)	S&P Developed BMI Shari'ah (USD)	This index includes all Shari'ah-compliant constituents of the S&P Developed BMI. It offers investors a comprehensive developed markets benchmark including large-, mid- and small-cap stocks across 25 markets.	31.05.2011 - 11.06.2021
11	SPSHEKUP (E)	S&P Emerging BMI Shari'ah (USD)	This index includes all Shari'ah-compliant constituents of the S&P Emerging BMI. It offers investors a comprehensive emerging markets benchmark including large-, mid- and small-cap stocks the markets.	31.05.2011 - 11.06.2021
12	SHE (D)	S&P Europe 350 Shari'ah Index	This index consists of the largest and most liquid companies in developed Europe.	31.05.2011 - 11.06.2021

13	SPSHGLUP	S&P Global BMI Shari'ah	This index consists of stocks included in S&P Global BMI and screened for Shari'ah-compliance resulting in a Shari'ah-compliant benchmark covering large-, mid- and small-cap stocks across 48 developed and emerging markets.	31.05.2011 - 11.06.2021

Note: (D) indicates the indices consist of stocks traded in developed market countries. (E) indicates the indices consist of stocks traded in emerging market countries.

DJIAP, DJICHM, DJIGCC, DJIEMG, SPSHBRX, SPSHEKUP consist of stocks that are traded in emerging market countries and DJIDEV, DJIEU, SPSHWDDP, SHE of stocks traded in developed countries. Moreover, DJIM, SHX, SPSHGLUP of stocks are traded in both emerging and developed countries. Table 2 demonstrates the descriptive statistics of the Islamic Market Indices.

Table 2: Descriptive statistics of the Islamic Market Indices

Variables	Mean	Median	Max	Min	Std. Dev.	Jarque-Bera	Observations
DJIAP	1726	1570.1	3173.3	1217.9	409.4	1194.2***	2813
DJICHM	1822.6	1751	3147.9	1346.4	343.6	2613.6***	3239
DJIDEV	1872.4	1729.6	3553.8	1069.4	555.2	531.7***	2810
DJIEU	3304.6	3225.7	5332.3	2153.4	612.3	374.8***	2804
DJIGCC	1816.6	1757.2	2653.8	1312.3	254.2	601.2***	3210
DJIEMG	2314	2161.5	4140.8	1613.4	461.6	2609.4***	3241
DJIM	3196.6	2924	5917.2	1866.9	901.2	693.5***	3241
SHX	2053.1	1859.3	4005.4	997.4	693.7	251.3***	2526
SPSHBRX	1584.6	1470.5	3195.6	1043.6	392.9	1211.8***	2588
SPSHWDDP	134.1	122.2	246.7	76.2	37.8	467.8***	2619
SPSHEKUP	89.8	83.7	162.2	63.2	18.7	1802.6***	2619
SHE	1299.1	1297	2020.8	756.8	273.4	48.9***	2575
SPSHGLUP	134.1	122.2	246.7	76.2	37.8	467.8***	2619

Note: *, **, *** Indicates 10%, 5% and 1% level of significance, respectively.

The WADF unit root test results are presented in Table 4. The findings show that the Fourier term is significant for 11 indices (DJIDEV, DJIEU, DJIGCC, DJIEMG, DJIM, SHX, SPSHBRX, SPSHWDDP, SPSHEKUP, SHE, SPSHGLUP) but not significant for 2 indices (DJIAP, DJICHM). Thus, the FWADF unit root test results are interpreted for 11 indices. According to this result, while the 4 indices (namely DJIGCC, DJIEMG, SPSHBRX, SPSHEKUP) have a unit root, 7 indices (namely DJIDEV, DJIEU, DJIM, SHX, SPSHWDDP, SHE, SPSHGLUP) are stationary. On the other hand, the WADF unit root test was used for two indices (DJIAP and DJICHM) since the Fourier term is not significant for those indices. Table 3 shows WADF unit root test results which illustrate that DJIAP and DJICHM indices have a unit root. Unit root test results show that 6 indices have unit roots, but 7 are stationary. This implies that while for 6 indices EMH is valid, but for 7 indices it is not. Remarkably, whole indices having unit roots include emerging market country indices. Table 3 shows WADF unit root test results.

Table 3: WADF Unit Root Tests Results

	Tests	Fourier WADF Results				WADF Results	
No.	**Variables**	**Test Statistics**	**T Statistics**	**K**	**P**	**Test Statistics**	**P**
1	DJIAP(E)	-2.459	-1.564	3	0	-2.636	2
2	DJICHM(E)	-2.447	1.976	1	1	-1.832	1
3	DJIDEV(D)	-3.815**	2.596**	1	2	--	--
4	DJIEU(D)	-4.227*	3.261*	1	2	--	--
5	DJIGCC(E)	-2.862	2.599**	1	1	--	--
6	DJIEMG(E)	-2.151	-2.243*	3	2	--	--
7	DJIM	-3.637**	2.495**	1	2	--	--
8	SHX	-4.600*	3.346*	1	2	--	--
9	SPSHBRX(E)	-2.814	-2.907*	3	2	--	--
10	SPSHWDDP(D)	-3.710**	2.592**	1	2	--	--
11	SPSHEKUP(E)	-2.523	-2.608**	3	2	--	--
12	SHE(D)	-5.410*	3.826*	1	1	--	--
13	SPSHGLUP	-3.710**	2.592**	1	2	--	--

Notes: * and ** show the significant levels at 1% and 5%, respectively. Optimal lag lengths (p) were chosen automatically using the SIC. 1%, 5%, and 10% critical values of t-statistics are -2.85, -2.01, and -1.60, respectively.

To test the robustness of this result, we used two-time domain unit root tests. While the first of these tests is the ADF test, which does not consider the structural break, the other is the Ziwot-Andrews Unit Root Test, which considers the structural breaks. Table 4 shows the test statistics of ADF and Ziwot-Andrews unit root test. While the ADF test found three indices (DJIEU, SHX, SHE) to be stationary, the Ziwot-Andrews Unit Root Test found that only the SHE index is stationary.

Table 4: Time-domain unit root tests results

		ADF		Ziwot-Andrews Unit Root Test		
No.	**Variables**	**Test Statistics**	**P**	**Test Statistics**	**P**	**Break Dates**
1	DJIAP(E)	-2.718	2	-4.094	4	27.09.2018
2	DJICHM(E)	-1.575	0	-3.771	3	22.07.2015
3	DJIDEV(D)	-3.094	9	-4.639	8	3.10.2018
4	DJIEU(D)	-3.144***	0	-4.353	8	11.08.2015
5	DJIGCC(E)	-1.485	1	-3.815	8	26.07.2015
6	DJIEMG(E)	-2.113	2	-3.669	4	25.05.2015
7	DJIM	-2.684	8	-4.553	8	2.10.2018
8	SHX	-3.365***	9	-4.625	8	21.07.2015
9	SPSHBRX(E)	-2.552	3	-3.971	7	26.05.2015
10	SPSHWDDP(D)	-2.811	9	-4.243	8	4.10.2018
11	SPSHEKUP(E)	-2.327	1	-3.714	7	6.05.2019
12	SHE(D)	-3.654**	0	-5.707*	8	6.08.2015
13	SPSHGLUP	-2.811	9	-4.243	8	4.10.2018

Notes: *, **, and *** show the significant levels at 1%, 5% and 10%, respectively. Optimal lag lengths (p) were chosen automatically using the SIC.

When we compare frequency domain and time domain results in Table 5, it can be seen that frequency domain tests determined more series stationary than time-domain tests.

Table 5: The comparison of the unit root tests results

No.	Variables	Frequency Domain Results	Time Domain Results
1	DJIAP(E)	Unit Root	Unit Root
2	DJICHM(E)	Unit Root	Unit Root
3	DJIDEV(D)	Stationary	Unit Root
4	DJIEU(D)	Stationary	Stationary
5	DJIGCC(E)	Unit Root	Unit Root
6	DJIEMG(E)	Unit Root	Unit Root
7	DJIM	Stationary	Unit Root
8	SHX	Stationary	Stationary
9	SPSHBRX(E)	Unit Root	Unit Root
10	SPSHWDDP(D)	Stationary	Unit Root
11	SPSHEKUP(E)	Unit Root	Unit Root
12	SHE(D)	Stationary	Stationary
13	SPSHGLUP	Stationary	Unit Root

5. Conclusions

This study examined the weak-form market efficiency for Dow Jones and S&P Islamic Indices between 2011 and 2021. For this purpose, we employed the Fourier Wavelet Unit Root Test to obtain stationary results on the indices. According to the authors' best knowledge, several previous studies had analyzed the weak-form efficiency of different Islamic stock market indices in the context of the EMH. However, prior to our study there had been no study examining the EMH for Dow Jones and S&P Islamic market indices using FWADF, and we have filled this gap in the existing literature. Thus, the main contribution of this study to the existing literature is investigating EMH on Islamic Indices employing one of the newest techniques which is the Fourier Wavelet Unit Root Test.

We investigated the validity of EMH for 13 different Islamic Market Indices and interpreted the FWADF unit root test results for 11 indices. According to this result, while the 4 indices (DJIGCC, DJIEMG, SPSHBRX, SPSHEKUP) have a unit root, 7 indices (DJIDEV, DJIEU, DJIM, SHX, SPSHWDDP, SHE, SPSHGLUP) are stationary. However, the results of the WADF unit root test demonstrate that DJIAP and DJICHM have a unit root. Overall, frequency domain unit root test results show that 6 indices have unit roots but 7 indices are stationary. To examine the robustness of the frequency domain unit root test, we used two-time domain unit root tests. The time-domain unit root test results indicate that 3 indices (DJIEU, SHX, SHE) in ADF and only one index (SHE) in the Ziwot-Andrews Unit Root Test are stationary. The comparison of unit root tests shows that the validity of the efficient market hypothesis can be differentiated according to the type of unit root tests.

While the frequency domain unit root test found that 6 stock market indices have weak-form market efficiency, time-domain unit root tests found that fewer indices have it. Since frequency domain unit root tests consider the frequency information and smooth changes, we assert that the results of FWADF and WADF are more robust.

Surprisingly, our results indicate that all analyzed emerging market indices have market efficiency, but developed country indices do not. In this respect, our results contradict the study of Ali et al. (2018). They found that developed Islamic stock markets are comparatively more efficient than those found in emerging markets. However , our results partially confirm the study of Al-Khazali et al. (2016). Four of the Islamic indices (DJIDEV, DJIEU, DJIEMG, DJIM) included in Al-Khazali et al. (2016)'s study sample are also included in our study. While Al-Khazali et al. (2016) found that all four Islamic indices do not have market efficiency, we found that three of these four indices (DJIDEV, DJIEU, DJIM) have no market efficiency.

The efficiency of the stock markets has a vital role in deciding for investment that stock prices reflect all relevant information because artificial factors cannot affect the stock prices when a market is efficient. The results of the paper have practical consequences for investors and policymakers. Islamic stock market indices have become more favored than ever in the last decade. This paper also provides investors and financial analysists with an understanding to ensure that they efficiently assess their investment decisions in constructing investment portfolios. For further studies, country and sector-specific Islamic stock market indices could be investigated and analysed to explain the EMH with different econometric techniques.

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