“Testing the linkages of Arab stock markets: a multivariate GARCH approach”

AUTHORS	Mohammed Shahateet Najib Shrydeh Suleiman Mohammad https://orcid.org/0000-0002-7430-3691

ARTICLE INFO	Mohammed Shahateet, Najib Shrydeh and Suleiman Mohammad (2019). Testing the linkages of Arab stock markets: a multivariate GARCH approach. *Investment Management and Financial Innovations*, *16*(4), 192-204. doi:10.21511/imfi.16(4).2019.17
DOI	http://dx.doi.org/10.21511/imfi.16(4).2019.17
RELEASED ON	Friday, 06 December 2019
RECEIVED ON	Tuesday, 29 October 2019
ACCEPTED ON	Wednesday, 27 November 2019

LICENSE	This work is licensed under a Creative Commons Attribution 4.0 International License

JOURNAL	"Investment Management and Financial Innovations"
ISSN PRINT	1810-4967
ISSN ONLINE	1812-9358
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
42	1	9

© The author(s) 2026. This publication is an open access article.

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine

www.businessperspectives.org

Mohammad Shahateet (Jordan), **Najib Shrydeh** (Jordan), **Suleiman Mohammad** (Jordan)

TESTING THE LINKAGES OF ARAB STOCK MARKETS: A MULTIVARIATE GARCH APPROACH

Abstract

The authors undertook to examine 720 monthly observations of activity in 15 Arab stock markets over four years (from 2014 to 2017) to identify the dynamic linkages among those markets. To achieve this, several forms of the Generalized Auto-Regressive Conditional Heteroskedasticity (GARCH) model were utilized. Both panel and individual stationarity, in addition to cointegration tests, were employed to highlight the interaction between these markets. The results suggest that Arab stock markets have weak linkages with the exception of those of the Gulf Cooperation Council (GCC). The authors also find out that the TARCH, EGARCH, PARCH, and Component GARCH (1,1) models are suitable in terms of passing the econometric analysis tests. Nevertheless, they conclude that the EGARCH model is the most appropriate for capturing the cross-market dynamic linkages, thereby outperforming the other GARCH specifications under study. The empirical findings bear special implications for economic literature regarding linkages of stock markets in the Arab world.

Keywords Arab finance, stock markets, cointegration, GARCH

JEL Classification F36, G15, G32

Received on: 29th of October, 2019
Accepted on: 27th of November, 2019

© Mohammed Shahateet, Najib Shrydeh, Suleiman Mohammad, 2019

Mohammed Shahateet, Ph.D., Associate Professor, Department of Business Information Technology, King Talal School of Business Technology, Princess Sumaya University for Technology, Jordan.

Najib Shrydeh, Ph.D., Assistant Professor, Department of Accounting, King Talal School of Business Technology, Princess Sumaya University for Technology, Jordan.

Suleiman Mohammad, Ph.D. in Accounting, Assistant Professor, Head of the Accounting department, King Talal Business Technology College, Princess Sumaya University for Technology, Jordan.

This is an Open Access article, distributed under the terms of the Creative Commons Attribution 4.0 International license, which permits unrestricted re-use, distribution, and reproduction in any medium, provided the original work is properly cited.

INTRODUCTION

The growing importance of Arab stock markets has given impact to a new avenue of research in analyzing the relationship among market indices; not only because emerging stock markets play a crucial role in global monetary intermediation, but also for their role in facilitating a growing number of economic transactions and providing an essential channel for the flow of capital. More broadly, the analysis of historical price index movements enables the investors to support their decision-making process. In addition, the market index provides the investors with a historical overview of stock market performance and is widely used to measure how well individual portfolios perform. Monthly data series were gathered for 15 emerging Arab economies to explore the relationship between their stock market prices. The results suggest that, unlike the stock markets of the remaining Arab countries under study, the GCC markets are closely interrelated, which makes them potentially more open to investor risk diversification. Furthermore, this study demonstrates that most Arab stock markets are particularly influenced by those in Dubai and Saudi Arabia, which are found to be the most sensitive to events that occur within the GCC. This research makes three additions to the present body of literature; the first one is the exploration of the relationship between stock markets in the developing part of the world, which retains various investment characteristics that are distinct from those in the developed countries. Secondly, this paper examines the time-varying linkages among these markets. Thirdly, this study employs a multitude of GARCH-type models to identify the most appropriate method for pinpointing the dynamics of how the targeted stock markets interact.

http://dx.doi.org/10.21511/imfi.16(4).2019.17

1. LITERATURE REVIEW

Previous works have focused their attention on stock market indices and their bearing on different macroeconomic variables, rather than the relative relationship between the markets. However, studies that are more recent have shifted towards addressing several methods of testing the relationship among stock markets themselves, particularly in emerging countries. For instance, Al-Najjar (2016) uses symmetric and asymmetric GARCH modeling in his study of the fluctuation of prices in the Amman stock market, covering the lengthy period between 2005 and 2014. Having applied ARCH, GARCH, and EGARCH, it was found that the dynamic traits of the Jordanian stock market were effectively captured by the symmetric ARCH/GARCH models, whereas the EGARCH model failed to yield any evidence of existing leverage effects in stock returns. Rehman and Hazazi (2014) point to certain stock markets building a rapport over the years, including those of the US, Japan, the UK, and the GCC. They also indicated that the Saudi index had gradually seen a decrease in volatility. Surprisingly, no evidence of a significant causal relationship was found to exist between the stock markets under investigation. Although Hatemi (2012) stated that the US and UAE stock markets show little integration, this study, upon carrying out asymmetric causality tests, finds these markets to be integrated. Abdmoulah (2010) applied the GARCH-M (1,1) approach in order to scrutinize the markets of 11 Arab countries, using the data gathered over ten years. The study finds that all markets were significantly responsive to prior shocks in addition to being inefficient. Al-Fayoumi et al. (2009) investigate the dynamic interactions among the daily returns of the Amman Stock Exchange indices using the multivariate cointegration and the causal linkages among general, financial, industrial, and services indices. The authors find that the indices are related via one cointegrating vector in the long run, while the services index is the least integrated with the other sectors. Click and Plummer (2005) test for the integration of five ASEAN stock markets using the cointegration technique to detect the long run interactions. Their results infer that national borders do not serve to segment markets, and there is indeed a level of cointegration. Assaf (2003) employed an autoregressive vector analysis in order to examine how GCC markets interact with regard to stock market returns. His findings suggested that interdependence does exist and that all of the markets reacted to any common feedback. Bahrain's market was shown to carry a major influence over the remaining Gulf markets, while the market in the Kingdom of Saudi Arabia was revealed to respond slowly to any unexpected activity in neighboring markets.

Previous studies have fallen short in testing the interrelationship among Arab stock market indices. Moreover, there is very little empirical evidence concerning the overall linkages between Arab stock markets. In contrast, the integration and linkages between the markets of developed countries are the subject of a large body of literature, including some important and more relevant studies, where the examination of returns across these markets has been investigated. For instance, Samadder and Bhunia (2018) examine the linkages among the selected Asian stock markets by means of cointegration and causality analysis, using time series data. The primary findings reveal that Asian stock markets are interconnected in the long run, exhibiting both bidirectional and unidirectional causality among them. Moreover, Khalil (2014) reached a similar conclusion regarding the Karachi market and other Asian stock markets. Valera, Holmes, and Hassan (2017) used a panel GARCH approach to pinpoint the correlation between the fluctuation of interest rates and stock market uncertainty. Their research revealed that high level of uncertainty in the stock market causes interest rates to fall, as well as offering econometric evidence of positive relationships between uncertainty in the stock market and volatile interest rates. Al Nasser and Hajilee (2016) applied bounds testing approach when examining five stock markets in three developed markets, looking for cointegration and error-correction modeling to identify the time-varying relationship between the two sets of markets. Evidence points to both developed and emerging countries experiencing the short-run integration between stock markets. A multitude of GARCH-type models is commonly applied to examine the global and regional stock market volatility spillovers. For example, Hansen and Huang (2016) applied a Realized Exponential GARCH framework to Dow Jones Industrial Average stocks, in addition to a fund that is run

over the stock exchange and used to follow the activity of the S&P500 index. The model was designed to account for multiple volatility measures in a return series. It can be seen that single measure specifications are overwhelmed by those with multiple realized measures. Bentes (2015) highlighted that Portuguese, Spanish, Japanese, UK, and US stocks are interrelated. Beirne et al. (2010) employed a Tri-variate VAR-GARCH(1,1)-in-mean model for 41 emerging market economies (EMEs) in Asia, Europe, Latin America, and the Middle East to uncover the existence of regional as well as global return spillovers in most emerging markets, albeit to varying degrees. The Egyptian and Israeli stock markets came under the scrutiny of Floros (2008) who measured volatility by employing a wide range of GARCH specifications. The study finds the Egyptian index to be the most volatile, namely due to the price uncertainty in the Egyptian market over the specified period. The results of the abovementioned studies strongly indicate that cross-market linkages differ in nature depending upon the countries and region under examination.

In terms of causality and cointegration, Dasgupta (2014) reports the presence of an ongoing bidirectional effect between the Indian and Brazilian stock markets. Moreover, there is a domino effect whereby stock prices in Moscow's market rise and fall in response to changes in Brazil, which, in turn, are influenced by movements in China. According to Iqbal and Rafiq (2011), there is no significant cointegration between the stock markets in India, Pakistan, and the United States. The authors applied Granger-causality testing and reported findings of unidirectional causality affecting the stocks on the Indian market, with the influence coming from the US. Another study, authored by Joshi (2011), reveals that stocks in the Indian market adjust faster than those of any other stock market, including those in the US, Brazil, Mexico, and China. Kenourgios and Samitas (2011) applied Monte Carlo simulations, cointegration tests, and regime-switching models, in order to examine the dynamics between the emerging stock markets in the Balkan countries of Bulgaria, Croatia, Romania, Serbia, and Turkey and the developed markets in the UK, Germany, Greece, and the US over the period from 2000 to 2006. The main findings demonstrate the evidence of a long-run cointegrating relationship between the named Balkan stock markets, and between them and the developed stock markets. Chinzara and Aziakponoy (2009) show that returns linkages exist between the equity market of South Africa and the Chinese, Australian, and US stock markets. The researchers analyze daily stock returns for the period from 1995 to 1997, using a univariate GARCH and a multivariate VAR framework. Moreover, the study finds that the volatility is inherently asymmetric and relatively stable over the selected period, and no evidence is found in favor of the risk-premium hypothesis. A. Masih and R. Masih (1999) examine the short- and long-term dynamic linkages between four member states of the Organisation for Economic Co-operation and Development and emerging stock markets in Asia. Specifically, the study examines the dynamic causal linkages between the aforementioned markets and utilizes both a VAR model and a vector error-correction model to measure the extent of their dynamic interdependencies. By studying the daily stock prices for the period 1992 through 1997, evidence was found to support the concept that the targeted markets experienced a significant short- and long-term relationship. Regarding the Southeast Asia region, the Hong Kong market was found to occupy the dominant role, in that it is a driving force behind the volatility that may occur in the region. This finding also suggests that the Asian markets in question tend to be regionally integrated and globally segmented.

Almost all of the above studies have applied simple correlation, cointegration, Granger causality, VAR etc. to inspect the degree of inter-linkages among international stock markets. The literature review above indicates contradictory evidence regarding international stock market linkages. The results of which depend upon data, methodology, time period, and framework used. In addition to the aforementioned research papers, there is a large abundance of recent studies such as Chen, Tian, and Zhao (2017), Guo (2017), Al-Najjar (2016), Basher and Sadorsky (2016), Gabriel (2012), Teresiene (2009), Guo and Neely (2008), and many others that also employ a wide variety of GARCH-family models to investigate the linkages, integration, and cointegration among stock returns. However, the literature remains short of studies, which document the interrelationship among stock indices in Arab markets.

http://dx.doi.org/10.21511/imfi.16(4).2019.17

2. DATA AND METHODOLOGY

2.1. Data

We employ monthly observations for 15 Arab stock indices covering the period from January 2014 to December 2017. Unfortunately, for other Arab countries such as Iraq, Libya, and others, there was a short time series that, if included, would lead to serious optimization problems for estimating the models and this would significantly weaken the analysis and interpretation of the results. Therefore, the data for these countries are completely excluded from this study. Table 1 describes the statistical characteristics of monthly stock indices for each market in question, which are based on data retrieved from the Arab Monetary Fund. The indices consist of monthly closing prices, are stated in US dollars, and are market capitalization weighted, using a chained Paasche Method. The results in Table 1 suggest, in terms of the mean volume, that among the Arab countries, Qatar, Dubai, and Morocco possess the biggest stock markets, while the smallest are those of Syria, Tunisia, and Egypt.

Figure 1 also shows the dissimilarities in changes in the indices of Arab stock market indices, as a prima face of weak relations. Only some similarity patterns can be observed among Abu Dhabi, Dubai, Kuwait, Muscat, Qatar, and, to some extent, Saudi Arabia.

2.2. Methodology

The methodology used follows a generalized autoregressive conditional heteroscedastic (GARCH) framework. Specifically, under discussion are TARCH, EGARCH, PARCH and Component GARCH (1,1) models with generalized error distribution. These models are applied extensively for modelling the linkages of stock indices, particularly in the literature on developed countries. Prior to applying the GARCH-based models, some tests are required for exploring the relationship across the selected indices. Considering the weight carried by the order of integration of a time series for the analysis, the study applies a number of statistical tests. In the first set of tests, the null hypothesis is defined as the presence of a unit root against the alternative of stationarity of a given stock index. This test is carried out for both panel and individual data. For the panel analysis, we compute four types of panel unit root tests. The first is the Levin, Lin, and Chu (2002) test, for which the null hypothesis is that panel data has a unit root, assuming a common autoregressive parameter for all panels. The remaining three tests assume an individual unit root process, which includes the unit root test proposed by Im, Pesaran,

Table 1. Summary statistics of monthly prices of stock market indices, 2014M01–2017M12

Market	Rank	Mean	Median	Maximum	Minimum	Std. dev.	Obs.
QAT	1	1016.943	1078.470	1214.970	694.4200	153.6010	48
DUB	2	605.9173	572.9300	890.3800	497.7400	86.52635	48
CAS	3	445.7715	427.5700	564.7200	372.4200	53.53661	48
ABU	4	413.7517	400.6250	499.4600	366.1500	31.87623	48
MUS	5	374.4015	349.0450	485.8000	300.9700	58.70571	48
SAU	6	353.8912	337.4950	483.7600	33.86000	74.61913	48
KUW	7	352.8783	353.5300	425.8500	289.3300	39.95877	48
AMM	8	352.5954	353.6250	409.0600	303.0600	35.77964	48
PAL	9	177.6017	174.3950	209.6000	150.2100	13.96603	48
BEI	10	172.4192	172.1250	185.8700	160.8200	6.164065	48
BAH	11	140.6290	144.7400	178.2300	102.4500	23.15424	48
KHA	12	136.7535	119.2350	209.7300	112.4700	33.28214	48
EGY	13	136.7027	133.8500	171.0100	105.9600	15.44066	48
TUN	14	81.07396	80.69500	91.74000	72.89000	5.111705	48
DAM	15	21.57500	22.36500	32.44000	9.770000	5.025229	48
All	–	315.9411	299.0200	1214.970	9.770000	242.6560	720

Note: ABU, AMM, BAH, BEI, CAS, DAM, DUB, EGY, KHA, KUW, MUS, PAL, QAT, SAU and TUN, respectively, represent the stock returns of Abu Dhabi, Amman, Bahrain, Beirut, Morocco, Syria, Dubai, Egypt, Sudan, Kuwait, Muscat, Palestine, Qatar, Saudi Arabia, and Tunisia, respectively.

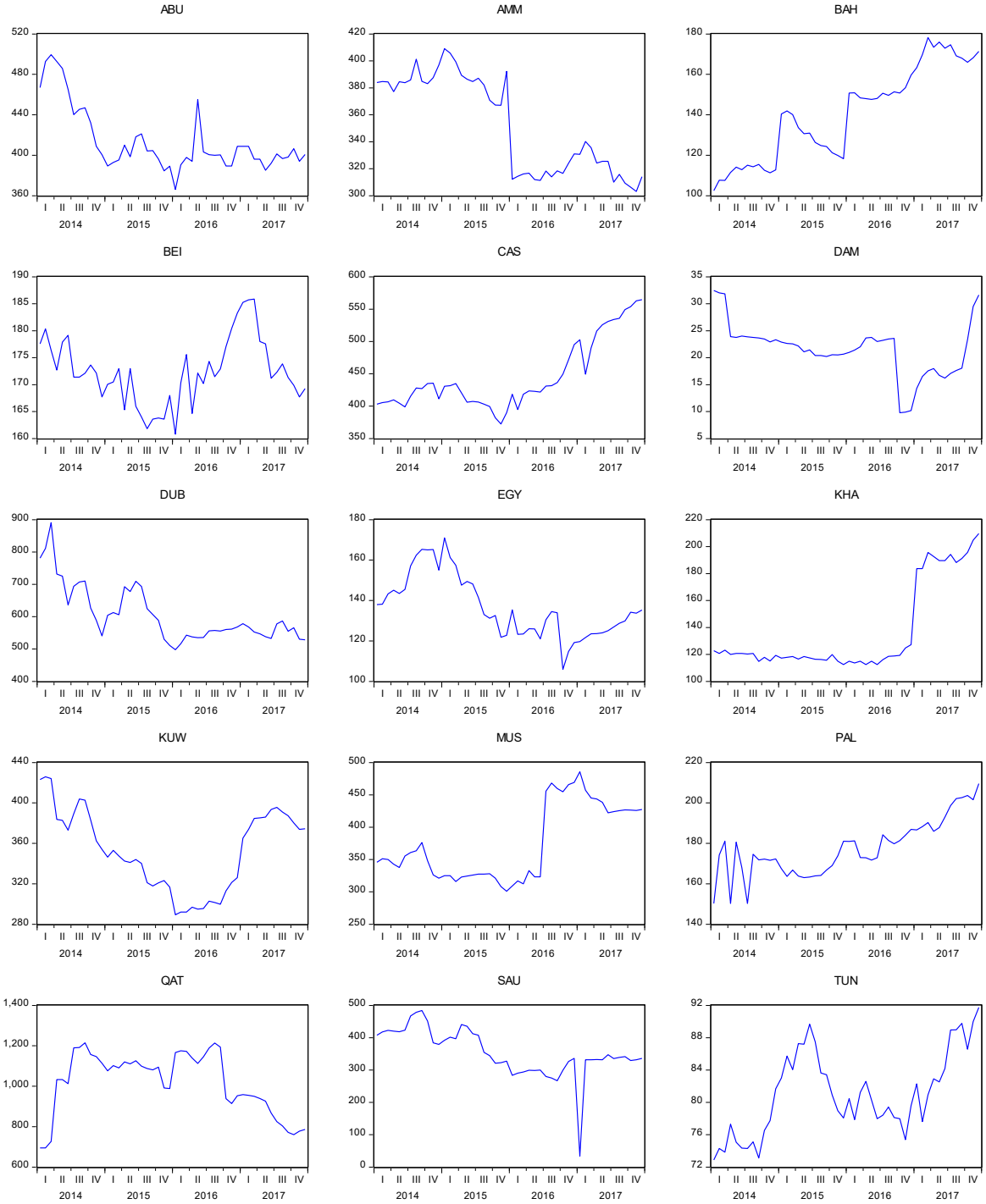

Figure 1. Changes in monthly indices of Arab stock markets, 2014–2017

and Shin (2003), the Fisher-Type ADF test proposed by Dickey and Fuller (1979), and the Fisher-Type Phillips-Perron test (1988). Generally, unit root tests are carried out on original data (i.e., level). If the test results in non-stationarity, the differenced series is subjected to a unit root test (i.e., first difference). This process may be repeated as many times as deemed appropriate for establishing the stationarity. The second set of tests includes the cointegration among time series variables. The study implements Johansen's test to quantify the level of cointegration among the markets under investigation. Although this methodology has been applied by numerous studies in the developed countries, few studies have addressed the developing markets, and none have targeted the emerging Arab stock markets.

http://dx.doi.org/10.21511/imfi.16(4).2019.17

3. THE MODEL AND TESTS

3.1. The model

Following the recent studies proposed by Hendrych and Cipra (2018), Drachal (2017), Guo (2017), Basher and Sadorsky (2016), Gabriel (2012), Joy (2011), Teresiene (2009), Guo and Neely (2008), and many others, we propose four GARCH-type models which can be written in the following forms:

Model 1. The Threshold GARCH (TARCH) Model

The generalized TARCH(p, q) model for the conditional variance can be expressed by:

$$\sigma_t^2 = \mu + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^2 + \\ + \sum_{k=1}^{r} \gamma_k \varepsilon_{t-k}^2 D_{t-k}, \quad (1)$$

where σ_t^2 is the conditional variance, μ is the constant term, ε is the error term, α, β, and γ are coefficients to be estimated, and $D_t = 1$ if $\varepsilon_t < 0$ and 0 otherwise.

Model 2. The Exponential GARCH (EGARCH) Model

$$\log\left(\sigma_t^2\right) = \mu + \sum_{i=1}^{p} \alpha_i \left(\left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| \right) - \\ - E\left(\left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| \right) + \sum_{j=1}^{q} \beta_j \log\left(\sigma_{t-j}^2\right) + \\ + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\sigma_{t-k}}. \quad (2)$$

Model 3. The Power ARCH (PARCH) Model

$$\sigma_t^{\delta} = \mu + \sum_{i=1}^{p} \alpha_i \left(\left| \varepsilon_{t-i} \right| - \gamma_i \varepsilon_{t-i} \right)^{\delta} + \sum_{j=1}^{q} \beta_j \sigma_{t-j}^{\delta}, \quad (3)$$

where $\delta > 0$, $|\gamma_i| \le 1$ for $i = 1, 2, ..., r$, $\gamma_i = 0$ for all $i > r$ and $r \le p$.

Model 4. The Component GARCH(1,1) Model

The conditional variance in the GARCH (1,1) model can be expressed in the following form:

$$\sigma_t^2 = \overline{\mu} + \alpha\left(\varepsilon_{t-1}^2 - \overline{\mu}\right) + \beta\left(\sigma_{t-1}^2 - \overline{\mu}\right), \quad (4)$$

where $\overline{\mu}$ is constant for all time.

These simple, yet powerful, GARCH-type models have been tried and tested over a long period and have shown themselves to be a valuable tool in integration and volatility modelling for numerous stock markets (Ardiaa & Hoogerheide, 2014). All of the four models outlined above are estimated for each stock index included in the study. For simplicity and ease of comparison, estimated coefficients, standard errors, z-statistics, and associated probabilities are not reported in the tables. However, the fundamental statistical properties generated by our model estimation, such as the log likelihood (LL), the Akaike information criterion (AIC), the Schwarz criterion (SC), the Hannan-Quinn criterion (HQC), and the adjusted R^2, are reported in Section 4.3.

3.2. Tests

It is of prime importance to test the stationarity for empirical modelling when wishing to validate outcomes of such models, as if the time series is non-stationary, there will be several effects based on incorrectly assuming stationarity (Hendry & Juselius, 2000). More formally, it is important to investigate the stationarity of each series before doing any econometric analysis. This is essential for not violating the application of econometric techniques, related to testing stock market integration. The augmented Dickey-Fuller regression was implemented to compute the resulting data:

$$\Delta y_t = \alpha + \beta y_{t-1} + \delta t + \sum_{j=1}^{k} \varsigma_j \Delta y_{t-j} + e_t, \quad (5)$$

where α is the constant term, β, δ, and ς are coefficients to be estimated, t is time trend, and k is the maximum number of lags lags. This test is carried out on two levels: panel and individual markets. For panel analysis, we compute four types of panel unit root tests. The first is the Levin, Lin, and Chu (2002) test for testing the null hypotheses that the panel data has a unit root, assuming a common unit root process. The other three tests are those proposed by Dickey and Fuller (1979), Phillips and Perron (1988), and Im, Pesaran, and Shin (2003), and which assume an individual unit root process. Broadly, unit root testing is performed at level (y) and the first difference (Δy).

For testing panel cointegration, Pedroni's cointegration test is carried out among all stock markets. This test was chosen since, compared to the traditional Johansen's cointegration test, it is a superior tool for checking the long-run relationship (Pedroni, 1999). The equation for the Pedroni (2004) is as follows:

$$y_{it} = \alpha_i + \beta_{1i} z_{1it} + \beta_{2i} z_{2it} + \cdots \\ \cdots + \beta_{mi} z_{mit} + \rho_t + \mu_{it}. \quad (6)$$

For testing bivariate markets, we perform Johansen's test for cointegration.

$$y_{it} = \alpha_i + \beta_{jt} z_{jt} + \rho_t + \mu_{it}. \quad (7)$$

For both equations (6) and (7), y and z are integrated at $I(1)$, α is the intercept and $\beta_{1i}, \beta_{2i}, ..., \beta_{mi}$, are slope terms that vary across individual markets, m is the number of markets and i is an index for markets $(i = 1, 2, ..., m)$. The statistics test for the null hypotheses shows that there is no cointegraton. For equation (7), $j = 1, 2, ..., m \ (i \neq j)$.

4. RESULTS

4.1. Unit root testing

Table 2 illustrates the ADF-Fisher χ^2 statistic and its corresponding probability (0.2619 > 0.05) which show that a unit root is present, as the ADF-Fisher test fails to reject the null hypotheses of a unit root. Consequently, the unit root test is performed for the first difference (Δy) where there is no indication of a unit root across the the whole range of results, as the four tests reject the null of a unit root, at a significance level of 1%.

Having secured the property of panel stationarity of the variables, at the first level, each individual market must be tested for unit root by application of the ADF test, using individual effects as exogenous variables and the method of automatic selection of maximum lags based on the AIC criterion, which applies the Newey-West automatic bandwidth selection and Bartlett kernel. To get more information regarding the intermediate results, the study tests for the panel unit root using the ADF test for each cross-section in the panel. As shown in Table 3, the *t*-statistics (in absolute terms) at level (y) are very small, thus, there is no evidence against the unit root null hypothesis in all markets, except the Saudi market. At first difference (Δy), we can reject the null hypothesis at 1% level of significance, as all the probability values are very small, hence, the null hypothesis of a unit root is rejected. In summary, the results of the stationarity tests suggest that all variables are integrated of order one.

4.2. Cointegration testing

In order to ascertain the existence of a panel cointegration relationship between the stock markets, the authors apply Pedroni's residual-based panel cointegration test (Pedroni, 1999, 2004), with a maximum lag limit of 9 and four-panel statistics (rho, v, PP and ADF). For testing cointegration between each market and each other market, we perform Johansen's system cointegration test

Table 2. Results: panel unit root test

Method	Statistic	Probabilty	Sections	Obs.
Level				
Levin, Lin and Chu *t*-stat*	–30.2660	0.0000	60	645
Im, Pesaran and Shin *W*-stat	–3.94276	0.0000	60	645
ADF – Fisher Chi-square	129.452	0.2619	60	645
PP – Fisher Chi-square	156.273	0.0146	60	660
First difference				
Levin, Lin and Chu *t*-stat*	–38.3015	0.0000	60	587
Im, Pesaran and Shin *W*-stat	–16.6600	0.0000	60	587
ADF – Fisher Chi-square	398.305	0.0000	60	587
PP – Fisher Chi-square	470.647	0.0000	60	600

Note: * Levin, Lin, and Chu (2002) assume the common unit root process, while all other tests assume individual unit root process.

http://dx.doi.org/10.21511/imfi.16(4).2019.17

Table 3. Results: intermediate ADF unit root

Cross section	*t*-stat	Prob.	*E*(*t*)	*E*(Var)	Lag	Max Lag	Obs.
Level							
ABU	–2.2226	0.2013	–1.526	0.763	0	9	47
AMM	–1.2669	0.6372	–1.526	0.763	0	9	47
BAH	–1.2683	0.6366	–1.526	0.763	0	9	47
BEI	–1.9370	0.3130	–1.522	0.790	1	9	46
CAS	0.1425	0.9657	–1.526	0.763	0	9	47
DAM	–2.6542	0.0899	–1.522	0.790	1	9	46
DUB	–2.2576	0.1897	–1.526	0.763	0	9	47
EGY	–1.5877	0.4809	–1.526	0.763	0	9	47
KHA	0.4179	0.9817	–1.526	0.763	0	9	47
KUW	–2.0472	0.2664	–1.522	0.790	1	9	46
MUS	–1.1584	0.6846	–1.526	0.763	0	9	47
PAL	–2.3338	0.1660	–1.526	0.763	0	9	47
QAT	–2.0898	0.2496	–1.526	0.763	0	9	47
SAU	–3.3064	0.0202	–1.526	0.763	0	9	47
TUN	–1.3655	0.5911	–1.526	0.763	0	9	47
First difference							
ABU	–8.8198	0.0000	–1.525	0.764	0	9	46
AMM	–8.6857	0.0000	–1.525	0.764	0	9	46
BAH	–6.5789	0.0000	–1.525	0.764	0	9	46
BEI	–9.8610	0.0000	–1.525	0.764	0	9	46
CAS	–7.4550	0.0000	–1.525	0.764	0	9	46
DAM	–5.5160	0.0000	–1.525	0.764	0	9	46
DUB	–7.5996	0.0000	–1.525	0.764	0	9	46
EGY	–7.9822	0.0000	–1.525	0.764	0	9	46
KHA	–6.7947	0.0000	–1.525	0.764	0	9	46
KUW	–5.0347	0.0001	–1.525	0.764	0	9	46
MUS	–6.1441	0.0000	–1.525	0.764	0	9	46
PAL	–11.016	0.0000	–1.525	0.764	0	9	46
QAT	–6.0644	0.0000	–1.525	0.764	0	9	46
SAU	–7.3636	0.0000	–1.522	0.792	1	9	45
TUN	–7.6874	0.0000	–1.525	0.764	0	9	46

(Johansen, 1991). Since the number of combinations is very large (i.e., 105 combinations), we summarize the results in one table. As shown in Table 4, all four statistics of Pedroni's test are not significant, implying the failure to reject the alternative hypothesis. This means that the null hypothesis of no cointegration cannot be rejected at the 0.05 level.

For bivariate markets, the study applies Johansen's system cointegration test (1995) for five deterministic trend cases, which rendered the number of cointegrating relations under each trend assumption, thus facilitating the assessment of how far the results are sensitive to the trend assumption. Table 5 summarizes the results for testing the number of cointegrating relations, using two sets of resultant statistics: the first reports the so-called trace statistics, while the maximum eigenvalue statistics are reported in the second (not shown in the summary). Based on the confirmation of both Trace and Maximum Eigenvalues tests, Table 5 shows that from 105 possible cointegration cases, only 37 exist, and mainly between some markets of GCC countries. Pairs marked "CO" are pairs that are cointegrated, while empty cells denote no cointegration. As can be seen from Table 5, cointegration exists between few markets such as those of Qatar, Kuwait, and Saudi Arabia. The proximity model may explain this result. A surprising result is that stock markets of the United Arab Emirates (Abu Dhabi and Dubai) and Omani stock market (Muscat) are not cointegrated with other Arab markets, excluding those of Kuwait and Qatar.

This paper concludes that there is segmentation among Arab stock markets, and it is desirable

Table 4. Summary results of panel cointegration

Alternative hypothesis: common AR coefficients (within-dimension)				
	Statistic	**Probability**	**Weighted Statistic**	**Probability**
Panel v-statistic	1.797417	0.0361	0.744193	0.2284
Panel rho-statistic	–4.145982	0.0000	–6.578390	0.0000
Panel PP-statistic	–5.029097	0.0000	–5.585780	0.0000
Panel ADF-statistic	–4.843808	0.0000	–5.368649	0.0000
Alternative hypothesis: individual AR coefficients (between-dimension)				
	Statistic	Probability		
Group rho-statistic	–2.575827	0.0050		
Group PP-statistic	–2.616354	0.0044		
Group ADF-statistic	–2.368461	0.0089		

Note: PP – Phillips-Perron; ADF – Augmented Dickey-Fuller.

Table 5. Summary results of testing the cointegration

	ABU	**AMM**	**BAH**	**BEI**	**CAS**	**DAM**	**DUB**	**EGY**	**KHA**	**KUW**	**MUS**	**PAL**	**QAT**	**SAU**	**TUN**
ABU													CO		
AMM													CO		
BAH													CO		
BEI										CO					
CAS												CO	CO		
DAM										CO			CO	CO	
DUB													CO		
EGY														CO	
KHA													CO	CO	
KUW				CO		CO					CO	CO	CO		
MUS										CO			CO		
PAL					CO					CO			CO		
QAT	CO	CO	CO		CO	CO	CO		CO	CO	CO	CO		CO	
SAU						CO		CO					CO		
TUN															
Total	1	1	1	1	2	3	1	1	1	5	2	3	11	4	0

that initiatives be implemented to achieve integration, which is a feasible aspiration. Currently, an international portfolio investor would find few benefits of holding a diverse international portfolio over a number of Arab stock markets.

4.3. Results of model estimation

Based on the concept of Chen and Zhao (2017), for capturing the effect among stock markets more accurately, we combine information theory and introduce transfer entropy to obtain cross-market effects among stock markets. For each market, 14 other markets are regressed on it using dynamic transfer entropy ML-ARCH-Normal distribution (BFGS/Marquardt steps) with unconditional pre-sample variance.

The results of all four models used in this study, as presented in Tables 6, 7, 8, and 9, demonstrate that the highest cross-market effects are those for Qatar, Dubai, and Saudi Arabia, while the lowest cross-market effects are those for Tunisia, Damascus, and Beirut stock markets. This finding underlines the relevance of market integration based on geographical proximity, particularly in the case of the Arab Gulf markets. Furthermore, the findings indicate that there is a systematic bias to investor expectations. The recommendation is that future research should strive to explain these empirical regularities.

http://dx.doi.org/10.21511/imfi.16(4).2019.17

Table 6. Summary results of model estimation, Model 1: TARCH

Dependent variable	LL	AIC	SC	HQC	$\overline{R}^2$
ABU	–181.1892	8.257883	8.920600	8.508324	0.791484
AMM	–159.9108	7.371285	8.034002	7.621727	0.857828
BAH	–138.1258	6.463575	7.126292	6.714017	0.916824
BEI	–120.5573	5.731553	6.394270	5.981994	0.621643
CAS	–183.4939	8.353914	9.016631	8.604356	0.932361
DAM	–102.4879	4.978664	5.641381	5.229106	0.358314
DUB	–219.0238	9.834326	10.49704	10.08477	0.870959
EGY	–140.9950	6.583127	7.245844	6.833568	0.851986
KHA	–154.3312	7.138798	7.801515	7.389240	0.944756
KUW	–159.7053	7.362721	8.025438	7.613163	0.943196
MUS	–201.4714	9.102974	9.765691	9.353415	0.714740
PAL	–142.7638	6.656827	7.319544	6.907269	0.484867
QAT	–253.4870	11.27029	11.93301	11.52073	0.676300
SAU	–214.6338	9.651407	10.31412	9.901849	0.502461
TUN	–100.3929	4.891372	5.554089	5.141813	0.722201

Note: LL – Log likelihood, AIC – Akaike information criterion, SC – Schwarz criterion, HQC – Hannan-Quinn criterion.

Table 7. Summary results of model estimation, Model 2: EGARCH

Dependent variable	LL	AIC	SC	HQC	$\overline{R}^2$
ABU	–177.4386	8.143273	8.844974	8.408447	0.804424
AMM	–168.5432	7.772633	8.474333	8.037806	0.862923
BAH	–124.0419	5.918412	6.620113	6.183586	0.869571
BEI	–112.9558	5.456491	6.158191	5.721665	0.605783
CAS	–180.1898	8.257909	8.959609	8.523083	0.929637
DAM	–106.2115	5.175478	5.877179	5.440652	0.299231
DUB	–214.5568	9.689868	10.39157	9.955042	0.874752
EGY	–139.3903	6.557931	7.259632	6.823105	0.849130
KHA	–146.6624	6.860935	7.562636	7.126109	0.925688
KUW	–156.5867	7.274448	7.976148	7.539621	0.935894
MUS	–200.3069	9.096121	9.797821	9.361294	0.711372
PAL	–135.6813	6.403389	7.105089	6.668562	0.450746
QAT	–251.1423	11.21426	11.91596	11.47944	0.719055
SAU	–209.2346	9.468108	10.16981	9.733282	0.576773
TUN	–93.53870	4.647446	5.349146	4.912620	0.717877

Note: LL – Log likelihood, AIC – Akaike information criterion, SC – Schwarz criterion, HQC – Hannan-Quinn criterion.

Table 8. Summary results of model estimation, Model 3: PARCH

Dependent variable	LL	AIC	SC	HQC	$\overline{R}^2$
ABU	–181.1392	8.339135	9.079819	8.619041	0.787617
AMM	–169.2997	7.845820	8.586503	8.125725	0.868405
BAH	–130.3142	6.221423	6.962107	6.501329	0.842647
BEI	–120.2986	5.804107	6.544791	6.084012	0.623892
CAS	–180.3896	8.307899	9.048583	8.587805	0.936082
DAM	–106.8837	5.245152	5.985836	5.525058	0.102142
DUB	–219.9650	9.956877	10.69756	10.23678	0.877330
EGY	–141.8911	6.703795	7.444479	6.983700	0.846316
KHA	–155.4880	7.270331	8.011015	7.550237	0.942861
KUW	–159.7524	7.448016	8.188699	7.727921	0.943144
MUS	–192.0864	8.795267	9.535950	9.075172	0.561817
PAL	–142.4055	6.725230	7.465914	7.005136	0.485388
QAT	–259.1368	11.58903	12.32972	11.86894	0.685511
SAU	–216.1983	9.799930	10.54061	10.07984	0.561720
TUN	–96.79674	4.824864	5.565548	5.104770	0.716464

Note: LL – Log likelihood, AIC – Akaike information criterion, SC – Schwarz criterion, HQC – Hannan-Quinn criterion.

Table 9. Summary results of model estimation, Model 4: Component GARCH (1,1)

Dependent variable	LL	AIC	SC	HQC	$\overline{R}^2$
ABU	–174.4959	8.062327	8.803011	8.342233	0.802792
AMM	–173.3516	8.014649	8.755333	8.294555	0.877026
BAH	–136.9405	6.497521	7.238204	6.777426	0.909692
BEI	–120.5232	5.813468	6.554152	6.093374	0.623588
CAS	–180.5029	8.312620	9.053304	8.592525	0.936973
DAM	–109.8402	5.368340	6.109024	5.648246	0.465410
DUB	–214.3848	9.724365	10.46505	10.00427	0.876717
EGY	–139.9538	6.623073	7.363757	6.902979	0.854363
KHA	–151.2194	7.092474	7.833158	7.372380	0.942710
KUW	–159.6827	7.445113	8.185797	7.725018	0.945561
MUS	–206.3363	9.389012	10.12970	9.668918	0.751913
PAL	–164.8458	7.660240	8.400924	7.940146	0.615079
QAT	–261.2074	11.67531	12.41599	11.95521	0.726851
SAU	–218.8971	9.912377	10.65306	10.19228	0.512621
TUN	–100.7359	4.988997	5.729681	5.268903	0.734625

Note: LL – Log likelihood, AIC – Akaike information criterion, SC – Schwarz criterion, HQC – Hannan-Quinn criterion.

5. DISCUSSION

The rapid growth of emerging markets has given rise to a research interest in analyzing the interrelationships among stock market indices for their role in facilitating a growing number of economic transactions and providing an essential channel for the flow of capital. The analysis of historical price volatility enables the investors to support their decision-making process. Moreover, the market index provides investors with a historical overview of stock market performance and is considered a benchmark for evaluating the performance of individual portfolios. This paper seeks to measure the extent of the dynamic interactions among 15 selected Arab stock markets. We apply four GARCH-based models – namely, TARCH, EGARCH, PARCH, and Component GARCH(1,1) – to examine 720 monthly observations starting from the beginning of 2014 to the end of 2017. Both panel and individual stationarity, in addition to cointegration tests, are employed to capture the interactions across these markets. Even though these models are employed by numerous studies in the literature on developed countries, very few studies have addressed the case for emerging Arab stock markets. All of the four models used in this study sufficiently pass the econometric analysis criteria. However, the EGARCH model, in particular, outperforms the other GARCH specifications in explaining the cross-market dynamic linkages across the selected markets.

CONCLUSION

The empirical findings conclude that the studied markets are generally described by weak linkages. However, the strong linkages are largely explained by geographical proximity (or region) particularly in the case of the GCC stock markets. It is clear from the results that the stock markets in Saudi Arabia and Dubai hold significant sway over the remaining markets of the Arab world, which are found to be the most responsive to events that occur within the Arab Gulf. The abovementioned model specifications show that the highest pairwise stock market effects are observed for Qatar, Dubai, and Saudi Arabia, while the lowest cross-market effects are observed for the stock markets in Tunisia, Damascus, and Beirut stock markets. It can be concluded that Arab stock markets are economically fragmented and remain to be integrated. Finally, initiatives to integrate these markets may result in potential diversification benefits for investors. Moreover, our findings show that investors hold systematically biased expectations and the recommendation is that researchers take further steps to explain these empirical regularities.

The contributions of this paper are threefold. Firstly, this paper evaluates the interactions among stock markets in a developing part of the world that is described by idiosyncratic investment characteristics

http://dx.doi.org/10.21511/imfi.16(4).2019.17

in comparison with the developed countries. Secondly, this research paper specifically examines the time-varying linkages across the markets in question. Finally, this study applies a variety of GARCH-based model specifications to identify the most robust method for detecting the dynamic interactions among the selected stock markets.

REFERENCES

1. Abdmoulah, W. (2010). Testing the evolving efficiency of Arab stock markets. *International Review of Financial Analysis, 19*(1), 25-34. https://doi.org/10.1016/j.irfa.2009.11.004
2. Al-Fayoumi, N. A., Khamees, B. A., & Al-Thuneibat, A. A. (2009). Information transmission among stock return indexes: Evidence from the Jordanian stock market. *International Research Journal of Finance and Economics, 24*(2), 194-208. Retrieved from https://www.researchgate.net/publication/265825132_Information_Transmission_among_Stock_Return_IndexesEvidence_from_the_Jordanian_Stock_Market
3. Al-Najjar, D. M. (2016). Modelling and estimation of volatility using ARCH/GARCH models in Jordan's stock market. *Asian Journal of Finance & Accounting, 8*(1), 152-167. https://doi.org/10.5296/ajfa.v8i1.9129
4. Al-Nasser, O. M., & Hajilee, M. (2016). Integration of emerging stock markets with global stock markets. *Research in International Business and Finance, 36,* 1-12. https://doi.org/10.1016/j.ribaf.2015.09.025
5. Arab Monetary Fund (2018). *Historical data of daily and monthly Arab stock markets index*. Retrieved from http://www.amf.org.ae/sites/default/files/history/hist_daily_index.htm
6. Ardia, D., & Hoogerheide, L. F. (2014). GARCH models for daily stock returns: Impact of estimation frequency on Value-at-Risk and Expected Shortfall forecasts. *Economics Letters, 123*(2), 187-190. https://doi.org/10.1016/j.econlet.2014.02.008
7. Assaf, A. (2003). Transmission of stock price movements: the case of GCC stock markets. *Review of Middle East Economics and Finance, 1*(2), 171-189. Retrieved from https://www.tandfonline.com/doi/abs/10.1080/1475368032000139305
8. Basher, S. A., & Sadorsky, P. (2016). Hedging emerging market stock prices with oil, gold, VIX, and bonds: A comparison between DCC, ADCC and GO-GARCH. *Energy Economics, 54,* 235-247. https://doi.org/10.1016/j.eneco.2015.11.022
9. Beirne, J., Caporale, G. M., Schulze-Ghattas, M., & Spagnolo, N. (2010). Global and regional spillovers in emerging stock markets: A multivariate GARCH-in-mean analysis. *Emerging Markets Review, 11*(3), 250-260. https://doi.org/10.1016/j.ememar.2010.05.002
10. Bentes, S. R. (2015). On the integration of financial markets: How strong is the evidence from five international stock markets? *Physica A: Statistical Mechanics and its Applications, 429,* 205-214. Retrieved from https://ideas.repec.org/a/eee/phsmap/v429y2015icp205-214.html
11. Bhunia, A., & Yaman, D. (2017). Is there a causal relationship between financial markets in Asia and the US? *The Lahore Journal of Economics, 22*(1), 71-90. Retrieved from https://ideas.repec.org/a/lje/journl/v22y2017i1p71-90.html
12. Chen, X., Tian, Y., & Zhao, R. (2017). Study of the cross-market effects of Brexit based on the improved symbolic transfer entropy GARCH model – An empirical analysis of stock-bond correlations. *PloS one, 12*(8), 183-194. https://doi.org/10.1371/journal.pone.0183194
13. Chinzara, Z., & Aziakpono, M. J. (2009). Dynamic returns linkages and volatility transmission between South African and world major stock markets. *Studies in Economics and Econometrics, 33*(3), 69-94. Retrieved from https://ideas.repec.org/p/rza/wpaper/146.html
14. Click, R. W., & Plummer, M. G. (2005). Stock market integration in ASEAN after the Asian financial crisis. *Journal of Asian Economics, 16*(1), 5-28. https://doi.org/10.1016/j.asieco.2004.11.018
15. Dasgupta, R. (2014). Integration and dynamic linkages of the Indian stock market with brick-an empirical study. *Asian Economic and Financial Review, 4*(6), 715. Retrieved from https://ideas.repec.org/a/asi/aeafrj/2014p715-731.html
16. Dickey, D. A., & Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74,* 427-431. https://doi.org/10.2307/2286348
17. Drachal, K. (2017). Volatility Clustering, Leverage Effects and Risk-Return Tradeoff in the Selected Stock Markets in the CEE Countries. *Journal for Economic Forecasting, 3,* 37-53. Retrieved from https://ideas.repec.org/a/rjr/romjef/vy2017i3p37-53.html
18. Floros, C. (2008). Modelling volatility using GARCH models: evidence from Egypt and Israel. *Middle Eastern Finance and Economics, 2,* 31-41. Retrieved from https://www.researchgate.net/publication/253041376_Modelling_Volatility_using_GARCH_Models_Evidence_from_Egypt_and_Israel
19. Gabriel, A. S. (2012). Evaluating the Forecasting Performance of GARCH Models. Evidence from Romania. *Procedia-Social and Behavioral Sciences, 62,* 1006-1010. Retrieved from https://doi.org/10.1016/j.sbspro.2012.09.171
20. Guo, H., & Neely, C. J. (2008).

Investigating the intertemporal risk-return relation in international stock markets with the component GARCH model. *Economics Letters, 99*(2), 371-374. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=878685

21. Guo, Z. Y. (2017). GARCH models with fat-tailed distributions and the Hong Kong stock market returns. *International Journal of Business and Management, 12*(9), 28. Retrieved from https://www.semanticscholar.org/paper/GARCH-Models-with-Fat-Tailed-Distributions-and-the-Guo/cd98294b60ba57b7b90f565310690009db7dd4ae

22. Hansen, P. R., & Huang, Z. (2016). Exponential GARCH modelling with realized measures of volatility. *Journal of Business & Economic Statistics, 34*(2), 269-287. https://doi.org/10.1080/07350015.2015.1038543

23. Hatemi-J, A. (2012). Is the UAE stock market integrated with the USA stock market? New evidence from asymmetric causality testing. *Research in International Business and Finance, 26*(2), 273-280. Retrieved from https://doi.org/10.1016/j.ribaf.2012.01.002

24. Hendry, D., & Juselius, K. (2000). Explaining Cointegration Analysis: Part 1. *The Energy Journal, 21*(1), 1-42. Retrieved from http://www.jstor.org/stable/41322853

25. Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*(1), 53-74. https://doi.org/10.1016/S0304-4076(03)00092-7

26. Iqbal, A., Khalid, N., & Rafiq, S. (2011). Dynamic Interrelationship among the Stock Markets of India, Pakistan and the United States. *International Journal of Human and Social Sciences, 6*(1), 31-37. Retrieved from https://publications.waset.org/1804/dynamic-interrelationship-among-the-stock-markets-of-india-pakistan-and-united-states

27. Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica, 59*(6), 1551-1580. https://doi.org/10.2307/2938278

28. Johansen, S. (1995). Identifying restrictions of linear equations with applications to simultaneous equations and cointegration. *Journal of Econometrics, 69*(1), 111-132. https://doi.org/10.1016/0304-4076(94)01664-L

29. Joshi, P. (2011). Market integration and efficiency of Indian stock markets: A study of NSE. *NSE Paper, 198,* 1-29. Retrieved from https://www.nse-india.com/content/research/ResearchPaper_198.pdf

30. Joy, M. (2011). Gold and the US dollar: Hedge or haven? *Finance Research Letters, 8*(3), 120-131. https://doi.org/10.1016/j.frl.2011.01.001

31. Kaur, P. (2018). Financial markets interdependence in India: An empirical analysis. *International Journal of Economics and Business, 16*(4), 513-533. https://doi.org/10.1504/IJEBR.2018.10016071

32. Kenourgios, D., & Samitas, A. (2011). Equity market integration in emerging Balkan markets. *Research in International Business and Finance, 25*(3), 296-307. https://doi.org/10.1016/j.ribaf.2011.02.004

33. Jebran, K. (2014). Dynamic Linkages between Asian countries stock markets: Evidence from Karachi stock exchange. *Research Journal of Management Sciences, 3*(5), 6-13. Retrieved from https://www.researchgate.net/publication/287217428_Dynamic_Linkages_between_Asian_Countries_Stock_Markets_Evidence_from_Karachi_Stock_Exchange

34. Levin, A., Lin, C. F., & Chu, C. S. J. (2002). Unit root tests in panel data: asymptotic and finite-sample properties. *Journal of Econometrics, 108*(1), 1-24. https://doi.org/10.1016/S0304-4076(01)00098-7

35. Masih, A. M., & Masih, R. (1999). Are Asian stock market fluctuations due mainly to intra-regional contagion effects? Evidence-based on Asian emerging stock markets. *Pacific-Basin Finance Journal, 7*(3-4), 251-282. Retrieved from https://www.sciencedirect.com/science/article/pii/S0927538X9900013X

36. Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and statistics, 61*(S1), 653-670. Retrieved from https://onlinelibrary.wiley.com/doi/abs/10.1111/1468-0084.0610s1653

37. Pedroni, P. (2004). Panel cointegration: asymptotic and finite sample properties of pooled time series tests with an application to the PPP hypothesis. *Econometric theory, 20*(3), 597-625. Retrieved from https://econpapers.repec.org/paper/wilwileco/2004-15.htm

38. Phillips, P. C. B., & Perron, P. (1988). Testing for Unit Roots in Time Series Regression. *Biometrika, 75*(2), 335-346. https://doi.org/10.2307/2336182

39. Rehman, M. Z., & Hazazi, M. A. (2014). Examining Linkages between Saudi Stock Market (TASI) and Selected Stock Markets Indices. *International Journal of Financial Research, 5*(4), 196. http://dx.doi.org/10.5430/ijfr.v5n4p196

40. Samadder, S., & Bhunia, A. (2018). Linkages among selected Asian stock markets. *International Journal of Computational Engineering & Management, 21*(2), 26-34. Retrieved from https://www.researchgate.net/publication/325046369_Linkages_among_Selected_Asian_Stock_Markets

41. Teresiene, D. (2009). Lithuanian stock market analysis using a set of GARCH models. *Journal of Business Economics and Management, 10*(4), 349-360. Retrieved from https://www.tandfonline.com/doi/abs/10.3846/1611-1699.2009.10.349-360

42. Valera, H. G. A., Holmes, M. J., & Hassan, G. (2017). Stock market uncertainty and interest rate behaviour: a panel GARCH approach. *Applied Economics Letters, 24*(11), 732-735. https://doi.org/10.1080/13504851.2016.1223817

http://dx.doi.org/10.21511/imfi.16(4).2019.17