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Volatility Spillover Effect in MENA Stock Markets: Evidence from Pre-and Post- Egyptian Revolution

MENA Hisse Senedi Piyasalarında Oynaklık Yayılma Etkisi: Mısır Devrimi Öncesi ve Sonrasına Dair Bulgular

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Abstract: This study investigates the volatility spillover of stock returns among the stock markets of Egypt, Turkey, Saudi Arabia, and Israel. The sampling period is over the period of 2007and 2013. BEKK-GARCH and DCC-GARCH models are used to test the volatility spillover of stock returns among the stock markets. In order to understand the impact of the Egyptian Revolution on the volatility spillover, the sample is split into two parts; the pre-revolution period (2007-2010) and post-revolution period (2011-2013). In addition to the pre-and post-revolution periods, we also tested the volatility spillover in MENA stock markets during the sub-prime mortgage financial crisis (2007-2009). The findings show that the Egyptian stock market experienced high volatility and dramatic decrease, in particular, during the post-revolution period. The results of BEKK-GARCH and DCC-GARCH reveal the fact that there is a strong shock transmission from Egypt to Turkey, Saudi Arabia and Israel during the pre-and post-revolution period. In particular, the volatility of Egyptian stock market drives the volatility of stock returns in Turkey, Saudi Arabia and Israel negatively in the post-revolution period. The findings further show that the volatility transmission in MENA stock markets is more apparent during the sub-prime mortgage crisis than during the pre-Egyptian Revolution period.

Keywords: volatility spillover, Egyptian revolution, MENA, BEKK-GARCH, DCC-GARCH

Öz: Bu çalışma, Mısır, Türkiye, Suudi Arabistan ve İsrail hisse senedi piyasalarındaki hisse senedi getirilerinin oynaklık yayılmasını incelemektedir. Çalışmanın örneklem dönemi 2007-2013 yılları arasındadır. Piyasalardaki hisse senedi getirilerinin oynaklık yayılmasını test etmek için BEKK-GARCH ve DCC-GARCH modelleri kullanılmıştır. Hisse senedi getirilerinin oynaklık yayılması üzerinde Mısır Devriminin etkisini anlamak için, örneklem ikiye ayrılmıştır; devrim öncesi dönem (2007-2010) ve devrim sonrası dönem (2011-2013). Devrim öncesi ve sonrası dönemin yanı sıra bu çalışmada 2007-2009 eşik-altı konut finansal krizi süresince MENA bölgesindeki hisse senedi piyasalarındaki oynaklık yayılımı da test edilmiştir. Çalışmanın bulguları, Mısır hisse senedi piyasasının çok oynak olduğunu ve özellikle devrim sonrası dönemde hisse senedi getirilerinin dramatik bir şekilde düştüğünü göstermektedir. BEKK-GARCH ve DCC-GARCH sonuçları devrim öncesi ve sonrası dönemde Mısır'dan Türkiye'ye, Suudi Arabistan'a ve İsrail'e kuvvetli bir şok geçişi olduğunu göstermektedir. Özellikle, Mısır hisse senedi piyasasındaki oynaklık Türkiye, Suudi Arabistan ve İsrail piyasalarındaki hisse senedi getiri oynaklıklarını devrim sonrası dönemde negatif etkilemektedir. Bulgular ayrıca MENA bölgesinde hisse senedi piyasalarındaki oynaklık yayılımının Mısır Devrimi öncesi döneme göre eşik-altı konut krizi döneminde daha belirgin olduğunu göstermektedir.

Anahtar Kelimeler: Oynaklık Yayılması, Mısır Devrimi MENA, BEKK-GARCH, DCC-GARCH

1. Introduction

Over the last four decades global stock markets suffered from several financial crises. The oil crisis of 1973-1974 was one of the earliest crises that hit the global markets and triggered turmoil in the Western and Asian economies. The oil crisis was followed by the Dow Jones crash in 1987, the Mexican crisis in1994, the Asian crisis in1997, the Russian ruble crisis in 1998, the Brazilian crisis in 1998 and the global financial crisis in 2007-2009.While most of the financial crises were caused by the changes in economic fundamentals in certain countries, others were sparked by political conflicts or terrorist attacks such as the September 11, Egyptian Revolution and Arab Spring.

In the existing literature, it is a general view that the volatility spillover among the financial markets tends to increase in particular during the periods of financial crisis (Yilmaz, 2009; Diebold and Yilmaz, 2009). In their study, Aggarawal et al. (1999) reported an increase in the volatility of emerging stock markets after the crash of Dow Jones in 1987. In another study, Nikkinen et al. (2008) analyzed the volatility in 53 stock markets following the September 11. They reported that the attack increased the volatility in stock markets and the attack had negative effects across regions. The impact of the attack depends on the degree on the stock market's integration with the global economy.

In the recent years, Egyptian revolution has emerged as one of the most influential political events in MENA region. The revolution took place on January 25, 2011. The Egyptian stock exchange has been suspended for almost 2 months due to chaos, panic selling and a disastrous loss of companies' values. In the year of the revolution, the devaluation of the Egyptian pound led foreign investors to withdraw their money from the stock market. The value traded on Egypt stock market dropped more than 50% of the value traded in comparison with the previous year (Abdelbaki, 2013).

Since the Egyptian Revolution was a political crisis, it is important to understand whether crisis is transmitted to neighbor countries through stock markets or through the means of a global panic (Bozkurt and Kaya, 2015; Abumustafa, 2016). As a result of the political turmoil, dramatic changes have taken place in the political systems and the financial markets have been seriously affected. The question therefore naturally arises whether the Egyptian revolution has actually had any effects on the daily movements of the stock prices in other MENA countries.

The objective of this paper is to investigate the volatility spillover among stock markets of Egypt, Turkey, Saudi Arabia and Israel. We used daily closing prices and applied BEKK-GARCH model to examine how the conditional volatility and shocks in one stock market is transmitted to others. The sampling period is from 2007 to 2013 which covers the 2007-2009 financial crisis and the Egyptian Revolution. In order to have more insight information about the impact of the Egyptian Revolution, we split the sampling period into two parts. The first period is the pre-Egyptian revolution from January 1st 2007 till December 31st 2010. The second period is the post- Egyptian revolution from January 1st 2011 till July 31st 2013. The first period can be described as a tranquil and relatively stable period while the second period is more volatile with widespread economic, political and social instability in the MENA region.

The current paper is a first study that examines the volatility spillover from Egyptian stock market to neighbor countries. The stock markets are selected according to their regional importance and their economic and political interdependence. Egypt is the "ground zero country" where the revolution took place and is considered as the second largest capital market in Africa after South Africa. Saudi Arabia has the largest capital market in the Gulf region with strong economic ties with Egypt and Turkey. Turkey has the largest GDP in the region with significant trading and political links with the other nations. Israel has peace and economic treaties with Egypt guaranteeing that economic cooperation is maintained.

The remainder of this paper is organized as follows: Section 2 provides a literature review. Section 3 introduces the data set and methodology. Section 4 documents the empirical findings and Section 5 presents the summary and conclusion.

2. Literature Review

There is a vast body of literature on the volatility spillover among the stock markets such as Ng (2000) for Pacific-Basin, Worthington and Higgs (2004) for Asia, Wong et al. (2005) and Li (2007) for China. In their comprehensive research, Beirne et al. (2009) examined volatility spillover from mature to emerging stock markets. They used 41 emerging economies and applied BEKK-GARCH model. Their findings suggest that conditional variances in emerging markets are higher during turbulent episodes in mature markets than during non-turbulent periods. Natarajan et al. (2014) examine the mean-volatility spillover effects across developed and emerging stock markets between 2002 and 2011. They reveal the fact that any news coming from US stock market has significant impact on other stock markets. In particular, the past volatility shocks in the US stock market affect the volatility of stock returns in Australian and German stock markets. In a more recent study, Popa et al. (2015) examined the returns and volatility dynamics between post-communist CEE stock markets and the two developed stock markets namely US and Germany from 2004 to 2014. Using BEKK-GARCH model, they find that the past news in the Czech market persist more than shocks in the other markets. Further, their findings show that Russia is the most stable market in terms of propagation. This can be attributed to its low level of integration with the other stock markets studied in the sample.

The Gulf region has always received noticeable interest due to its large contribution to the world oil supplies. The existing literature investigates the volatility spillover between the oil market and stock markets in MENA namely in Gulf countries. (Agren, 2006; Malik and Hammoudeh, 2007; Hammoudeh and Choi 2007; Malik and Ewing, 2009; Aloui et al.2013).Despite the growing attention on MENA region, the empirical research is constrained by the oil-related topics. Little attention has been paid on the volatility spillover among stock markets of MENA.

Among the existing studies, Al-Deehani and Moosa (2006) investigated volatility spillover effects among Gulf countries' stock markets. Their findings show that Kuwaiti stock market is influential on the stock markets of Bahrain and Saudi Arabia. In their study, Lagoarde-Segot, and Lucey (2009) investigated shift-contagion to the MENA during several financial crises including the 1997 Asian crisis, the 1998 Russian virus and its Brazilian sequel, the 2000 Turkish collapse, the 9/11 turmoil, the 2001 Argentinean crisis, the 2002 Enron/WorldCom scandal and the 2007–09 global financial crisis. Their findings show that Turkey, Israel and Jordan were the most vulnerable markets over the 1997–2009 periods, followed by Tunisia, Morocco, Egypt and Lebanon. They further conclude that MENA-based diversification strategies may not be effective in the times of global turmoil. In their paper, Hammoudeh et al. (2009) examined the dynamic volatility and volatility transmission by using the VAR (1)–GARCH (1,1) model for three major sectors (Service, Banking and Industrial/or Insurance) in four Gulf

Cooperation Council (GCC)'s countries (Kuwait, Qatar, Saudi Arabia and UAE). Their results suggest that the past own volatilities are more influential than past shocks in GCC countries, with the exception of Qatar. In another study, Eissa et al. (2010) examined the presence of volatility spillovers between nominal exchange rates and stock returns in Egypt, Morocco and Turkey using a multivariate GARCH model. Their findings show bidirectional shock and volatility spillovers between exchange rates and stock returns at sector level, with more pronounced effects in Egypt and Turkey. Alkulaib et al. (2009) investigated the lead/lag relationship among the MENA countries. They find no market causality or spillover from one country to another in the North Africa region. They further show that there is more interaction and linkage in the GCC region than in the North Africa. This could be a result of the higher level of political and economic integration of GCC countries. Abou-Zeid (2011) investigated the international transmission of daily stock index volatility movements from U.S. and U.K. to Egypt, Israel, and Turkey using a multivariate GARCH model. Their findings reveal that Egypt and Israel are significantly influenced by the U.S. stock market while Turkey is not.

3. Data and Methodology

3.1. Data

We use daily closing prices of EGX 30 for Egypt, BIST 100 for Turkey, TASI for Saudi Arabia, and TA25 for Israel. The data is taken from Datastream. The sampling period is from 2007 through 2013. The sample is divided into two groups. The first period covers the pre-Egyptian revolution period from January 1st 2007 through December 31st 2010 and the second period is post-Egyptian revolution from January 1st 2011 through July 31st 2013. The subprime financial crisis covers the period from June 1st 2007 to April 2nd 2009. In their paper, Sekmen and Hatipoglu (2015) discussed that the sub-prime crisis started with tremendous increase in the LIBOR-OIS spread in June 2007 and the effects started to decline slightly as of April 2009. Therefore, we used the time span from June 1st 2007 to April 2nd 2009 for the sub-prime crisis period.

Since the countries have different trading days, we synchronized the data. In order to achieve this task, we omitted non-overlapping trading days. The indices were matched in pairs of two with a total of 6 pairs: EGX 30-BIST 100, EGX 30-TASI, EGX 30-TA-25, BIST 100-TASI, BIST 100-TA-25, and TASI-TA-25. The spillover analysis was then conducted using each pair of indices separately in bi-variate form.

3.2. Methodology

The return for market *i* at time *t* is defined as follows:

$$R_{i,t} = \log(P_{i,t} / P_{i,t-1}), \tag{1}$$

Where $R_{i,t}$ is the daily stock index return for market *i* at time *t*. $P_{i,t}$ is the index price of market *i* at time *t* and $P_{i,t-1}$ is the index price of market *i* at time *t-1*.

3.2.1. BEKK-GARCH Model

The investigation of volatility interdependence between the four MENA stock markets is conducted using the BEKK-GARCH model proposed by Baba, Engle, Kraft, and Kroner (1990). BEKK-GARCH model generates the conditional covariance matrix positive and it renders significant parameter reduction in the estimation. These features make BEKK-GARCH model easy to use.

$$R_t = \alpha\Gamma R_{t-1} + u_t \tag{2}$$

$$u_t \middle| \Omega_{t-1} \sim N(0, H_t) \tag{3}$$

where the return vector for the stock series is given by $R_t = [R_{1,t}, R_{2,t}]$, the vector of the constant is defined by α which represents 4 × 1 vector. The residual vector, $u_t = [\varepsilon_{1,t}, \varepsilon_{2,t}]$, is bi-variate and conditionally normally distributed. Ω_{t-1} is the market information set available at time $t-1$.The conditional covariance matrix is represented by H_t, where $\{H_t\} = h_{ij,t}$ $for i, j = 1,2$. H_t is a function of lagged cross products of errors. The conditional covariance matrix can be stated as follows:

$$H_t = C_0'C_0 + A_{11}'\varepsilon_{t-1}\varepsilon_{t-1}'A_{11} + G_{11}'H_{t-1}G_{11} \quad (4)$$

C_0 is a triangular matrix where $n \times n$ A_1 matrix is showing ARCH effects and $n \times n$ G_1 matrix reveals the GARCH effects. The unrestricted matrices are A_{11} and G_{11}. The second moment can be represented by:

$$H_t = C_0'C_0 + \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}' \begin{bmatrix} \varepsilon_{1,t-1}^2 & \varepsilon_{1,t-1}, \varepsilon_{2,t-1} \\ \varepsilon_{1,t-1}, \varepsilon_{2,t-1} & \varepsilon_{2,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} + \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix}' H_{t-1} \begin{bmatrix} g_{11} & g_{12} \\ g_{21} & g_{22} \end{bmatrix} \quad (5)$$

H_t can be further expanded by matrix multiplication and it takes the following form:

$$h_{11,t} = c_{11}^2 + a_{11}^2\varepsilon_{1,t-1}^2 + 2a_{11}a_{21}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}^2\varepsilon_{2,t-1}^2 + g_{11}^2 h_{11,t-1} + 2g_{11}g_{21}h_{12,t-1} + g_{21}^2 h_{22,t-1} \quad (6)$$

$$h_{12,t} = c_{11}c_{21} + a_{11}a_{12}\varepsilon_{1,t-1}^2 + (a_{21}a_{12} + a_{11}a_{22})\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{21}a_{22}\varepsilon_{2,t-1}^2 + g_{11}g_{12}h_{11,t-1} + (g_{21}g_{12} + g_{11}g_{22})h_{12,t-1} + g_{21}g_{22}h_{22,t-1} \quad (7)$$

$$h_{22,t} = c_{21}^2 + c_{22}^2 + a_{12}^2\varepsilon_{1,t-1}^2 + 2a_{12}a_{22}\varepsilon_{1,t-1}\varepsilon_{2,t-1} + a_{22}^2\varepsilon_{2,t-1}^2 + g_{12}^2 h_{11,t-1} + 2g_{12}g_{22}h_{12,t-1} + g_{22}^2 h_{22,t-1} \quad (8)$$

Quasi Maximum Likelihood (QML) is used to estimate the BEKK-GARCH parameters under the assumption of normally distributed random errors. The QML function of Bollerslev and Woodridge (1992) has the following form:

$$L(\theta) = -Tn/2 + \ln(2\pi) - ½ \textstyle\sum_{t=1}^{T}(\ln|H_t| + \varepsilon' \mid 1/H_t \mid \varepsilon_t) \quad (9)$$

Where T is the number of observations, n is the number of markets, and θ is the vector of estimated parameters.

3.2.2. DCC-MGARCH Model

The DCC model is introduced by Engle (2002) to capture the dynamic time-varying behaviour of conditional covariance. DCC model has been used in some papers to examine the volatility spillover across different stock markets (Xiao and Dhesi, 2010; Awartani et al., 2013; Mohammadi and Tan, 2015). The DCC-MGARCH model is a dynamic model with time-varying mean, variance and covariance of return series $r_{i,t}$ for stock *i* at time *t*, with the following equations:

$$r_{i,t} = \mu_t + \varepsilon_t, \quad \mu_t = E(r_{i,t} \mid \psi_{t-1}) \text{ and } \varepsilon_t \mid \psi_{t-1} \sim N(0, H_t) \quad (10)$$

Where Ψt − 1 indicates the set of information available at time t − 1. The conditional variance–covariance matrix, H_t, can be constructed by the following equations:

$$H_t = D_t R_t D_t \quad (11)$$

$D_t = \mathrm{diag}\ (h_{11t}^{1/2} \ldots h_{NNt}^{1/2})$ is a diagonal matrix of square root conditional variances. $h_{i,t}$ can be defined as $h_{i,t} = \omega_i + \alpha_i\varepsilon_{i,t-i}^2 + \beta_i h_{i,t-1}$., where ω_i is a constant term and α_i is the ARCH effect and β_i is the GARCH effect. R_t is a time-varying conditional correlation matrix and it is stated as follows:

$$R_t = \text{diag}\,(q_{11,t}^{-1/2} \dots q_{NN,t}^{-1/2}) Q_t \text{diag}\,(q_{11,t}^{-1/2} \dots q_{NN,t}^{-1/2}) \quad (12)$$

$$Q_t = (1-\alpha-\beta)\bar{Q} + \alpha\,\mu_{t-1}\mu_{t-1}^{'} + \beta Q_{t-1} \quad (13)$$

Where μ_t^*= diag (Q_t)$^{1/2}\mu_t$, with $\bar{Q}$ the unconditional correlation matrix of μ_{t-1}^*. α and β are non-negative scalar parameters. If the value of α + β is close to one, this indicates high persistence in the conditional variance

The correlation estimator is $p_{ij,t} = \left(\frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}} \right)$ (14)

4. Empirical Results

Table 1 presents descriptive statistics for the full sample. In general, the stock returns are low. The findings show that while the stock markets of Egypt and Saudi Arabia have negative returns, the other stock markets such as Turkey and Israel have positive returns. Further, the lowest return occurs in the Egyptian stock market (-0.018%), and the highest return occurs in Turkey (0.0387%). The Egyptian stock market is the most volatile market with the highest standard deviation (1.862%). The kurtosis of all stock markets is greater than 3 indicating that all stock return series are leptokurtic. The Jarque-Bera test rejects the null hypothesis of normality for all stock return series. The L-B test results indicate evidence of autocorrelation in return series in all stock markets. The null hypothesis of no ARCH effect is rejected. The existence of ARCH effect indicates that GARCH type models can easily be adopted.

Table 1: Descriptive Statistics for Full Period (%)

	EGX	**BIST**	**TASI**	**TA25**
Mean	-0.018	0.0387	-0.001	0.0136
Maximum	7.311	12.127	9.087	8.0630
Minimum	-17.990	-10.095	-10.329	-9.178
Std. Dev.	1.862	1.828	1.514	1.436
Skewness	-1.156	-0.251	-0.902	-0.498
Kurtosis	11.610	6.872	12.580	7.805
J-B	5224.905***	1053.318***	6521.123***	1615.143***
ARCH	87.612***	28.119***	69.896***	134.140***

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange

Table 2 documents the descriptive statistics for pre-and post-revolution periods, respectively. The results reveal that the stock returns in Egyptian stock market turned to be negative during the post-crisis period. This implies that Egyptian Revolution had depressive impact on the stock returns. Consistent with the findings reported in Table 1, the lowest returns occur in the Egyptian stock market. The unconditional volatility, as measured by standard deviations, indicates that the volatility in EGX increased in the post-crisis period. Before the revolution, BIST has the highest standard deviation. The stock returns series are leptokurtic during both periods. The normality of stock returns is also rejected for both pre-and post-revolution periods.

Table 2: Descriptive Statistics Pre-and Post- Revolution period

	Pre-revolution				**Post-revolution**			
	EGX	**BIST**	**TASI**	**TA25**	**EGX**	**BIST**	**TASI**	**TA25**
Mean	0.001	0.053	-0.019	0.037	-0.048	0.018	0.027	-0.015
Median	0.155	0.074	0.090	0.122	0.022	0.108	0.069	0.022
Maximum	6.339	12.127	9.087	8.063	7.311	5.031	7.012	4.410
Minimum	-17.99	-10.095	-10.329	-9.178	-11.101	-8.131	-7.022	-7.988
Std. Dev.	1.895	2.029	1.780	1.576	1.809	1.471	0.975	1.186
Skewness	-1.381	-0.131	-0.765	-0.485	-0.733	-0.742	-1.220	-0.552
Kurtosis	13.017	6.415	9.758	7.115	8.791	5.993	18.813	8.423
J-B	4421.9***	490.3***	1994.5***	730.5***	883.1***	304.0***	6922.8***	801.4***
ARCH	12.6***	13.1***	31.4***	81.3***	60.5***	14.6***	10.6***	20.1***

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange.

Table 3 reports unit root tests, ADF and KPSS, for the full and sub-periods. We attempt to confirm that the return series are stationary and mean reverting in order to ensure the validity of our modeling approach. Both tests results indicate that all return series are stationary at the 1% level for the full and sub-periods. The presence of stationary in the series indicates that the shocks do not have permanent or long lasting effects.

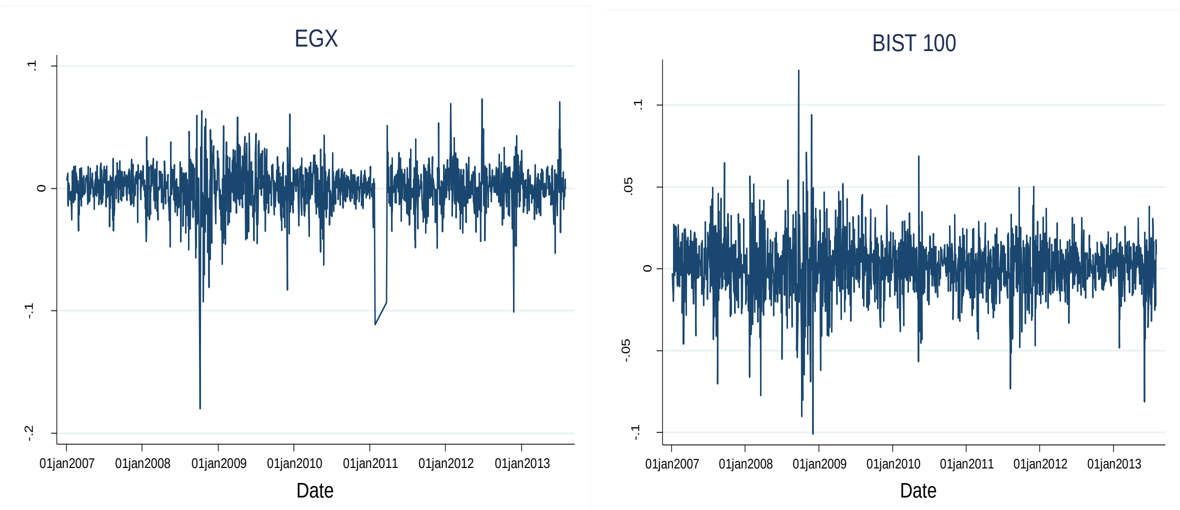
Table 3: Unit Root Tests

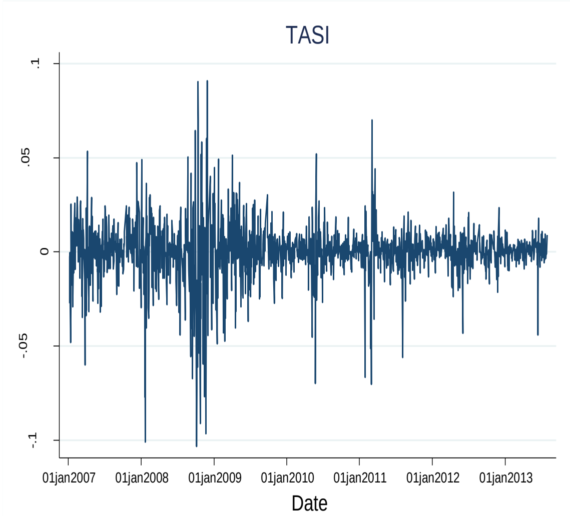
	EGX	**BIST**	**TASI**	**TA25**
Full Period				
ADF	-33.034***	-39.270***	-37.203***	-46.160***
KPSS	0.079	0.080	0.056	0.070
Pre-Revolution				
ADF	-26.427***	-30.193***	-28.883***	-36.196***
KPSS	0.157	0.131	0.098	0.154
Post-Revolution				
ADF	-19.766***	-25.466***	-23.490***	-28.445***
KPSS	0.0925	0.083	0.0454	0.0350

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. Critical values For KPSS with intercept and trend 0.216 for 1%, 0.146 for 5%, and 0.119 for 10%. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange

Figure 1 displays the daily changes in the stock returns for the stock markets of Egypt, Turkey, Saudi Arabia and Israel. The 2007-2009 financial crisis seems to have substantial impact on the all stock markets. The highest and lowest stock returns occurred during this period of time. In particular, the stock returns experienced sharp declines in the post-crisis period. Furthermore, the suspension of the Egyptian stock exchange is clearly observed in Figure 1. There is a time gap in the stock returns of EGX. The stock market closed for 8 weeks from January 2011 to March 2011. It is also important to note that there is a large swing in the stock returns of Saudi Arabia in January 2011 when the Egyptian Revolution started. For the stock markets of Turkey and Israel, relatively large swings are observed in the mid of 2011. This can be attributed to Eurozone sovereignty crisis.

Figure 1: Time variation in the stock returns of Egypt, Turkey, Saudi Arabia and Israel





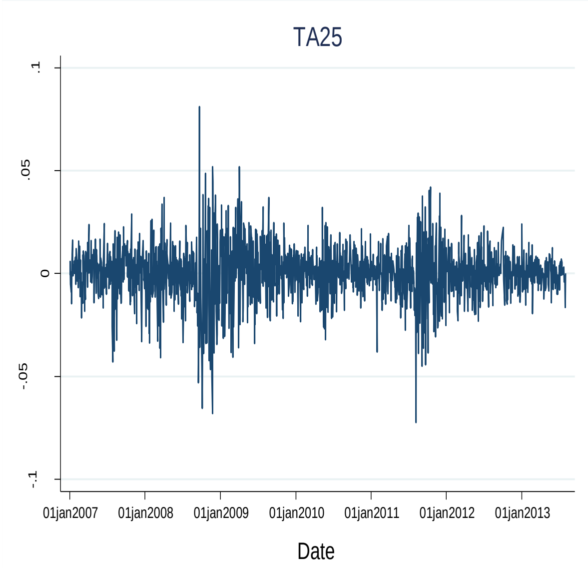


Table 4 shows Granger causality test results for pre-and post-revolution periods. Before running the BEKK-GARCH model, we use Granger Causality test in order to understand how Egyptian stock market is linked to the stock markets of Turkey, Saudi Arabia and Israel. The pre-revolution results document that while the causality is bi-directional between Egypt and Turkey, the causality is uni-directional from Israel to Egypt. While the null hypothesis of Egyptian stock market does not Granger cause Turkish stock market is rejected at 10% significance level (6.8529), the magnitude of causality from Israel to Egypt is strong, rejected at 1% significance level (22.549).

In the post-revolution period, the findings show uni-directional relationship between stock markets. The Egyptian stock market affects the Saudi stock market. An increase in EGX led to increase in the stock returns in Saudi stock market. However, there is no significant impact from Saudi stock market to Egyptian stock market. Further, like pre-revolution period, there is a significant causality from Israel to Turkey at 1% significance level (21.064).

Table 4: Granger causality tests among stock markets

Null Hypothesis	**Lags**	**F-value**	**Null Hypothesis**	**Lags**	**F-value**
		Pre-Revolution			
Null Hypothesis	**Lags**	**F-value**	**Null Hypothesis**	**Lags**	**F-value**
EGX ≠> BIST	3	6.8529*	BIST ≠> EGX	3	9.0418**
EGX ≠> TASI	3	0.8623	TASI ≠> EGX	3	2.7038
EGX ≠> TA25	3	4.6361	TA25 ≠> EGX	3	22.549***
BIST ≠> TASI	3	3.8433	TASI ≠> BIST	3	20.231***
BIST ≠> TA25	3	6.4409 *	TA25 ≠> BIST	3	28.081***
TASI ≠> TA25	3	3.5785	TA25 ≠> TASI	3	13.976 ***
		Post-Revolution			
EGX ≠> BIST	1	0.0702	BIST ≠> EGX	1	0.6584
EGX ≠> TASI	1	6.8292**	TASI ≠> EGX	1	3.5623
EGX ≠> TA25	1	0.5778	TA25 ≠> EGX	1	4.1177
BIST ≠> TASI	1	7.2972**	TASI ≠> BIST	1	1.0377
BIST ≠> TA25	1	2.9477	TA25 ≠> BIST	1	21.064***
TASI ≠> TA25	1	2.8524	TA25 ≠> TASI	1	1.1611

Note: The symbol "≠N" means "does not Granger-cause." To select the order of lags for Granger causality test, the Schwarz information criterion (SIC), also known as the Bayesian information criterion (BIC), is used. ** and *** denote statistical significance at the 5% and 1% level, respectively.

Table 5 presents the results for BEKK-GARCH model for each pair of stock markets for pre-and post-revolution periods. The pre-revolution period is from January 3, 2007 through January 25, 2011. The post-revolution covers period from January 26, 2011through July 30, 2013. While the diagonal elements in matrix A capture own past shock effect, the diagonal elements in matrix B measure own past volatility effect. During both periods, all markets are affected by their own shocks represented by the a_{11} and a_{22} parameters. The findings show that the parameter estimates of a_{12} are significant for Turkey, Saudi Arabia and Israel. The null hypothesis of no bi-directional past shock spillovers between stock markets is rejected. The past shocks of Egyptian stock market affect the present volatility of stock returns in Turkey and Israel before and after the revolution. For Saudi Arabia, the past shocks of Egyptian stock market have significant impact only during the post-revolution period. This implies that the increase in the innovation of Egyptian stock market changes the volatility of stock returns in Turkey, Israel and Saudi Arabia. The impacts of the past shocks are positive on the volatility of other stock markets. As the opposite direction, the past shocks of Turkey and Israel have significant impact on the conditional volatility of Egyptian stock market returns.

Furthermore, the findings indicate strong GARCH effects. The Egyptian stock market exhibits a sharp decrease in the coefficients of own volatility (b_{11}) during the post-revolution period from 0.980 to 0.791. This finding is in the same line with Beirne et al. (2009) and Ezzat (2012), who reported that conditional betas are usually lower during the periods of high turbulence. The past conditional volatility of Egyptian stock market has significant impact on Turkey, Saudi Arabia and Israel. The movement of 1% volatility in the Egyptian stock market pushed the stock indices of Turkey, Saudi Arabia, and Israel move in the opposite direction by -4.5%, -13.6%, and 3.6% after the revolution, respectively. As for the opposite direction, there is a volatility spillover from Turkey and Saudi Arabia to Egypt during the pre-revolution period. While the sign of spillover from Turkey to Egypt is positive, the sign of spillover from Saudi Arabia to Egypt is negative.

In Table 5, the Ljung-Box is used to test the null hypothesis of no serial correlation on the standardized residuals. The McLeod-Li statistics is employed to test the conditional heteroscedascity (ARCH) effects and the underlying null hypothesis is that there are no ARCH effects in the model. Both test results fail to reject the null hypotheses for EGX-BIST and EGX-TASI during the post-revolution period. For the remaining pairs, the null hypothesis is rejected.

Overall, the past shocks have significant impact on the volatility of stock returns for Turkey, Saudi Arabia and Israel in particular after the revolution. While the stock markets of Saudi Arabia were affected the most in terms of past shock transmission after the revolution, the stock returns of Israel were influenced the most regarding the volatility spillover both before and after the revolution.

Table 5: Estimation results of BEKK- GARCH model

	EGX – BIST		**EGX – TASI**		**EGX – TA25**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Conditional Mean						
μ_1	0.115**	-0.027	0.149**	-0.079	0.078*	-0.056
	(0.074)	(0.742)	(0.014)	(0.318)	(0.085)	(0.442)
μ^2	0.172**	0.061	0.107***	0.042	0.104***	0.026
	(0.022)	(0.382)	(0.004)	(0.260)	(0.008)	(0.499)
Conditional Variance						
c_{11}	0.119**	0.968***	0.108	1.281***	0.093	0.936***
	(0.031)	(0.000)	(0.207)	(0.000)	(0.547)	(0.000)
c_{21}	0.570***	0.114	0.109	0.153	-0.058	0.049
	(0.000)	(0.345)	(0.056)	(0.072)	(0.791)	(0.243)
c_{22}	0.001	0.171	0.054	0.001	0.218***	-0.066
	(0.999)	(0.120)	(0.537)	(0.999)	(0.002)	(0.562)
a_{11}	0.234***	0.399***	0.211***	0.642***	0.180***	0.424***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
a_{12}	0.119***	0.059*	0.016	0.142***	0.210***	0.033*
	(0.004)	(0.076)	(0.559)	(0.000)	(0.000)	(0.086)
a_{21}	0.012	-0.040	0.130***	-0.600***	0.268***	0.026
	(0.686)	(0.598)	(0.000)	(0.003)	(0.000)	(0.777)
a_{22}	0.276***	0.164***	0.314***	0.033	0.139	0.291
	(0.000)	(0.000)	(0.000)	(0.627)	(0.000)	(0.000)
b_{11}	0.980***	0.791	0.973***	0.533***	0.960***	0.755***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

b_{12}	0.055	-0.045*	-0.006	-0.136***	0.067***	-0.036**
	(0.319)	(0.055)	(0.414)	(0.000)	(0.000)	(0.046)
b_{21}	0.116***	0.024	-0.032***	0.117	0.072	0.002
	(0.002)	(0.635)	(0.000)	(0.428)	(0.000)	(0.948)
b_{22}	0.791***	0.983***	0.952***	0.965***	0.937***	0.955***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Diagnostic Tests			
Q(40)	52.837*	46.225	62.604**	51.034	74.393***	62.871**
	(0.084)	(0.231)	(0.013)	(0.113)	(0.001)	(0.012)
QS(40)	232.364*	168.863	271.612***	210.505	301.720***	229.555*
	(0.058)	(0.946)	(0.000)	(0.291)	(0.000)	(0.074)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

Table 6 presents BEKK-GARCH results for the stock returns in Turkey, Saudi Arabia and Israel. We exclude the Egyptian stock market and examine the volatility spillover among the other stock markets. Although Egypt was the origin of the political and economic turmoil in the MENA region, it is also interesting to see the linkages among the stock markets of Turkey, Saudi Arabia and Israel. Moreover, the findings show positive shock transmissions among the markets. The past shocks stock returns in Turkey and in Saudi Arabia significantly affect the volatility of stock returns in Israel. In terms of volatility spillover, there is a uni-directional negative volatility transmission of stock returns from Turkey to Saudi Arabia, from Turkey to Israel and from Saudi Arabia to Israel in the post-revolution period.

The diagnostic test results for Ljung-Box and McLeod-Li statistics are given in Table 6. While the null hypothesis for the Ljung-Box test is rejected in most cases, the null hypothesis for McLeod-Li test is accepted. This implies the presence of autocorrelation and ARCH effects in the return series.

Table 6: Estimation results of BEKK- GARCH model

	BIST– TASI		**BIST– TA25**		**TASI –TA25**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
			Conditional Mean			
μ_1	0.198**	0.126	0.120	0.063	0.086**	0.088**
	(0.048)	(0.213)	(0.129)	(0.343)	(0.043)	(0.036)
μ^2	0.155***	0.093	0.132***	0.003	0.095*	0.023
	(0.009)	(0.117)	(0.007)	(0.945)	(0.056)	(0.661)
			Conditional Variance			
c_{11}	0.697***	0.339***	1.159***	0.676***	0.130***	0.346***
	(0.000)	(0.008)	(0.000)	(0.000)	(0.001)	(0.000)
c_{21}	0.002	0.210	0.275***	0.309***	0.103	0.010
	(0.981)	(0.278)	(0.005)	(0.000)	(0.211)	(0.877)
c_{22}	0.000	0.392***	0.000	0.237***	0.129**	0.056
	(1.000)	(0.000)	(1.000)	(0.000)	(0.023)	(0.715)
a_{11}	0.176***	0.164***	-0.043	0.264***	0.347***	0.428***
	(0.000)	(0.000)	(0.533)	(0.000)	(0.000)	(0.000)
a_{12}	-0.137***	-0.012	-0.063	-0.039	0.108***	-0.068
	(0.000)	(0.708)	(0.100)	(0.249)	(0.000)	(0.124)
a_{21}	0.265***	0.012	-0.540***	0.351***	-0.031	-0.009
	(0.000)	(0.839)	(0.000)	(0.000)	(0.482)	(0.897)
a_{22}	0.355***	0.380***	0.126**	0.453***	0.210***	0.242***
	(0.000)	(0.000)	(0.030)	(0.000)	(0.000)	(0.000)
b_{11}	0.924***	0.976***	0.565***	0.848***	0.944***	0.847***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b_{12}	0.015	0.008	-0.251***	-0.040	-0.027***	0.048**
	(0.190)	(0.736)	(0.000)	(0.193)	(0.000)	(0.022)

b_{21}	-0.044***	-0.031	0.422***	-0.139***	0.000	0.021
	(0.001)	(0.467)	(0.000)	(0.006)	(0.979)	(0.285)
b_{22}	0.933***	0.846***	1.056***	0.870***	0.969***	0.956***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Diagnostic Tests			
Q(40)	54.418*	31.997	62.675**	33.818	52.703*	52.597*
	(0.0638)	(0.812)	(0.0125)	(0.744)	(0.086)	(0.088)
QS(40)	211.940	177.815	247.261**	235.021**	224.930	185.650
	(0.268)	(0.868)	(0.012)	(0.045)	(0.109)	(0.758)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

In order to take the 2007-2009 sub-prime mortgage crisis effect into account and to compare the pre-revolution period with sub-prime crisis period, we ran the BEKK-GARCH analysis for the sub-prime period. The subprime crisis period is from June 1 2007 to April 2 2009. Table 7 documents that in comparison with pre-revolution period, the volatility transmission is more apparent during the sub-prime crisis. In particular, the coefficients of b_{12} and b_{21} are statistically significant and the magnitudes of significance levels are high. A closer inspection of the findings suggests that there was a significant bi-directional volatility spillover from the Egyptian stock market to the other stock markets during the sub-prime crisis. However, the pre-revolution results reported in Table 5 indicate no significant volatility spillover from the Egyptian stock market to the stock markets of Turkey and the Saudi Arabia. For the opposite direction, there are negative and significant volatility spillover effects from Turkish and Saudi stock markets and to Egyptian stock market during the sub-prime crisis.

The diagnostic tests show robustness of our results based on the Ljung-Box and McLeod-Li statistics. The results of the Ljung-Box test indicate that in most cases, we reject the null of no serial correlation likewise the McLeod-Li statistics rejects the serial independence.

Table 7: Estimation results of BEKK- GARCH model during sub-prime crisis period

	EGX – BIST	**EGX-TASI**	**EGX-TA25**	**BIST-TASI**	**BIST-TA25**	**TASI-TA25**
			Conditional Mean			
μ_1	0.043	0.183*	0.056	-0.012	0.154	0.150*
	(0.699)	(0.069)	(0.458)	(0.941)	(0.220)	(0.083)
μ^2	-0.069	0.164*	-0.061	0.102	0.066	0.039
	(0.623)	(0.086)	(0.400)	(0.348)	(0.398)	(0.668)
			Conditional Variance			
c_{11}	-0.068	0.418***	-0.243	1.249***	1.391***	0.452
	(0.657)	(0.000)	(0.399)	(0.000)	(0.000)	(0.017)**
c_{21}	-0.798***	-0.035	-0.559***	-0.617***	0.335**	-0.542**
	(0.000)	(0.773)	(0.000)	(0.003)	(0.022)	(0.010)
c_{22}	-0.000	0.000	0.000	0.000	0.000	0.395***
	(0.999)	(0.999)	(0.999)	(0.999)	(0.999)	(0.006)
a_{11}	0.183***	0.262***	-0.074	0.011	-0.355***	0.371***
	(0.000)	(0.000)	(0.276)	(0.904)	(0.000)	(0.000)
a_{12}	-0.197***	0.134**	-0.402***	-0.109	0.079*	0.050
	(0.004)	(0.027)	(0.000)	(0.143)	(0.093)	(0.436)
a_{21}	0.079*	0.106**	0.261***	0.546***	-0.321***	0.120**
	(0.056)	(0.047)	(0.000)	(0.000)	(0.000)	(0.026)
a_{22}	0.236***	0.358***	0.251***	0.232**	-0.031	-0.011
	(0.000)	(0.000)	(0.000)	(0.025)	(0.565)	(0.844)
b_{11}	0.997***	0.931***	0.796***	0.808***	-0.739***	0.897***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b_{12}	0.119***	-0.058***	0.366***	0.118**	-0.677***	0.125**
	(0.000)	(0.002)	(0.000)	(0.044)	(0.000)	(0.029)
b_{21}	-0.058***	0.016	-0.667***	-0.005	0.142	-0.004
	(0.000)	(0.613)	(0.000)	(0.916)	(0.516)	(0.933)

b_{22}	0.889***	0.948***	0.679***	0.882***	0.973***	0.869***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Diagnostic Tests						
Q(40)	44.400	65.967***	78.667***	42.304	61.319**	44.013
	(0.292)	(0.006)	(0.000)	(0.372)	(0.017)	(0.306)
QS(40)	247.406**	246.381**	268.777***	211.101	255.969***	216.685
	(0.012)	(0.014)	(0.000)	(0.281)	(0.000)	(0.198)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

Table 8 reports the DCC-GARCH results for the pairs of stock markets with Egyptian stock market during the pre- and post- revolution periods. The sign of μ indicates the dependence of stock returns on their past returns. The findings show that the pairs of EGX-BIST, EGX-TASI, and EGX-TA25 are affected by their past own returns. The section of conditional variance reports ARCH, GARCH and conditional correlation parameter estimates for DCC-GARCH model.

The volatility persistence is measured by $(\alpha + \beta)$. The estimated α and β parameters are significant both for the pre- and post revolution periods. In all cases, the GARCH parameters are significant, indicating that the volatility transmission is bi-directional between the stock index pairs. Furthermore, the ARCH parameters are significant for all cases. The only exception is EGX-TA25 during the pre-revolution period. In general, the ARCH parameters are small and positive. It is clearly evident that $\beta > \alpha$, suggesting that the current variances are more affected by the past return innovations.

Considering the diagnostic test results, the Ljung-Box test indicate that we cannot reject the null of no serial correlation . The McLeod-Li statistics support the adequacy of the ARCH and GARCH terms in the model.

Table 8: Estimation results of DCC- GARCH model

	EGX-BIST		**EGX-TASI**		**EGX-TA25**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Conditional Mean						
μ_1	0.126*	-0.055	0.155***	-0.112	0.245***	-0.074
	(0.057)	(0.517)	(0.008)	(0.221)	(0.000)	(0.307)
μ^2	0.210***	0.069	0.099**	0.045	0.237***	0.005
	(0.007)	(0.296)	(0.042)	(0.258)	(0.000)	(0.897)
Conditional Variance						
c_1	0.058*	0.788***	0.041*	1.270***	0.559***	0.686***
	(0.071)	(0.000)	(0.089)	(0.000)	(0.000)	(0.001)
c_2	0.307***	1.474***	0.020**	0.076*	0.056***	0.021
	(0.003)	(0.000)	(0.049)	(0.076)	(0.000)	(0.355)
a_1	0.075***	0.219***	0.088***	0.309***	0.391***	0.228***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
a_2	0.112***	0.036***	0.107***	0.031	0.115***	0.095***
	(0.000)	(0.000)	(0.000)	(0.125)	(0.000)	(0.002)
b_1	0.916***	0.636***	0.908***	0.456***	0.634***	0.589***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b_2	0.836***	0.365***	0.896***	0.872***	0.859***	0.892***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α	0.001***	0.181***	0.072**	0.325***	0.001	0.006***
	(0.000)	(0.000)	(0.012)	(0.000)	(0.883)	(0.000)
β	0.733***	0.803***	0.904***	0.661***	0.815***	0.919***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.075)	(0.000)
Diagnostic Tests						
Q(50)	39.1697	51.468	51.201	32.361	41.141	33.449
	(0.814)	(0.339)	(0.349)	(0.959)	(0.747)	(0.945)
QS(50)	233.593*	171.614	245.497	200.379	270.991***	195.671
	(0.051)	(0.927)	(0.155)	(0.479)	(0.000)	(0.573)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

Table 9 presents DCC-GARCH results for the stock markets of Turkey, Saudi Arabia and Israel. It appears that the stock returns are affected by their own past returns. The only exception is BIST-TASI during the post-revolution period. It is important to note that almost in all cases, the ARCH and GARCH parameters associated with the dynamic conditional correlation are statistically significant. This implies that the conditional correlation among BIST, TASI and TA25 are highly dynamic and time-varying. The values of α and β are close to 1, indicating that conditional variances are highly persistent and only slowly mean-reverting.

Moreover, the results of the Ljung-Box statistics do not reject the null hypothesis of no serial correlation on the standardized residuals. The McLeod-Li statistics support the adequacy of the ARCH and GARCH terms in the model.

Table 9: Estimation results of DCC- GARCH model

	BIST– TASI		**BIST– TA25**		**TASI –TA25**	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**
Conditional Mean						
μ_1	0.314*** (0.000)	0.130 (0.157)	0.106* (0.073)	0.119* (0.079)	0.086* (0.054)	0.085** (0.042)
μ^2	0.040 (0.470)	0.080 (0.175)	0.075** (0.045)	0.000 (0.984)	0.124** (0.013)	0.007 (0.889)
Conditional Variance						
c_1	1.646*** (0.000)	1.589*** (0.000)	0.268*** (0.000)	0.385 (0.181)	0.023* (0.066)	0.094*** (0.009)
c_2	2.155*** (0.000)	0.344*** (0.000)	0.043*** (0.000)	0.127*** (0.007)	0.033* (0.091)	0.022 (0.295)
a_1	0.309*** (0.000)	0.099*** (0.000)	0.060*** (0.000)	0.153** (0.030)	0.116*** (0.000)	0.141*** (0.000)
a_2	0.010*** (0.000)	0.184*** (0.000)	0.058*** (0.000)	0.174*** (0.002)	0.091*** (0.000)	0.068*** (0.004)
b_1	0.559*** (0.000)	0.435*** (0.000)	0.882*** (0.000)	0.716*** (0.000)	0.888*** (0.000)	0.783*** (0.000)
b_2	0.573*** (0.000)	0.583*** (0.000)	0.923*** (0.000)	0.754*** (0.000)	0.907*** (0.000)	0.919*** (0.000)
α	0.035** (0.020)	0.009 (0.264)	0.002*** (0.000)	0.001 (0.890)	0.038** (0.031)	0.131*** (0.000)
β	0.966*** (0.000)	0.985*** (0.000)	0.047*** (0.000)	0.853*** (0.000)	0.947*** (0.000)	0.706*** (0.000)
Diagnostic Tests						
Q(50)	53.172 (0.311)	34.304 (0.931)	82.014*** (0.000)	32.396 (0.958)	46.211 (0.546)	48.125 (0.467)
QS(50)	206.648 (0.358)	183.320 (0.795)	250.838*** (0.008)	210.564 (0.290)	218.079 (0.181)	185.040 (0.768)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

Table 10: Estimation results of DCC- GARCH model during sub-prime crisis period

	EGX – BIST	**EGX-TASI**	**EGX-TA25**	**BIST-TASI**	**BIST-TA25**	**TASI-TA25**
			Conditional Mean			
μ_1	0.097	0.213**	0.294***	-0.044	-0.037	-0.046
	(0.446)	(0.027)	(0.000)	(0.777)	(0.768)	(0.898)
μ^2	0.003	0.145	-0.075	0.001	-0.049	-0.205
	(0.983)	(0.115)	(0.290)	(0.997)	(0.598)	(0.416)
			Conditional Variance			
c_1	0.199**	0.139	0.309***	0.702***	0.361***	1.367***
	(0.027)	(0.137)	(0.001)	(0.000)	(0.000)	(0.000)
c_2	0.518**	0.062*	0.723***	3.194***	0.148***	1.357***
	(0.031)	(0.073)	(0.000)	(0.000)	(0.000)	(0.000)
a_1	0.104***	0.177***	0.277***	0.125***	0.104***	0.096***
	(0.006)	(0.003)	(0.000)	(0.000)	(0.000)	(0.000)
a_2	0.113***	0.139***	0.225***	0.127***	0.057***	0.071***
	(0.004)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b_1	0.869***	0.827***	0.707***	0.826***	0.851***	0.603***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
b_2	0.827***	0.871***	0.599***	0.504***	0.905***	0.597***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
α	0.014	0.069***	0.001***	0.022**	0.001	0.022
	(0.156)	(0.000)	(0.001)	(0.035)	(0.320)	(0.122)
β	0.953***	0.902***	0.827***	0.965***	0.819***	0.977***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
			Diagnostic Tests			
Q(50)	39.948	44.849	41.796	77.824***	30.622	44.653
	(0.789)	(0.602)	(0.723)	(0.004)	(0.976)	(0.610)
QS(50)	227.285*	264.911***	280.357***	214.395	250.838***	222.404
	(0.090)	(0.000)	(0.000)	(0.230)	(0.008)	(0.112)

Note: *** Significant at 1% level. ** Significant at 5% level. * Significant at 10% level. EGX: Egyptian Stock Exchange, BIST: Borsa Istanbul, TASI: Saudi Stock Exchange, TA: Israeli Stock Exchange. Q(50) and QS (50) denote the 50th order Ljung Box test for serial correlation on the standardized residuals and Mcleod-Li test for nonlinearity (ARCH effects), respectively.

Table 10 documents the DCC-GARCH results for the sub-prime crisis period. The findings show that the current returns are not affected by their lagged returns. The exceptions are the pairs of EGX-TA25 and BIST-TASI. This finding is consistent with the findings of BEKK-GARCH reported in Table 7. It is important to note that while the stock returns are affected by their previous stock returns during the pre-and post revolution periods, the stock returns are not affected by the previous stock returns during the sub-prime financial crisis.

The estimates for conditional variance are positive and significant in most cases. This finding implies the existence of own ARCH and GARCH effects. In general, the ARCH parameters are small and positive. However, the ARCH parameters are significant only for the pairs of EGX-TA25 and BIST-TASI. A closer inspection of findings further suggests that the GARCH values are large and close to one indicating a high degree of persistence. While the pairs of TASI-TA25, EGX-BIST and BIST-TASI are characterized by strong persistence, the pairs of EGX-TASI, EGX-TA25 and BIST-TA25 seem to be less persistent. When we compare the sub-prime crisis results with pre-revolution results, the findings provide more persistency for the sub-prime crisis period.

The diagnostic test results indicate that Ljung-Box test results fail to reject the serial correlation on the standardized residuals and Mcleod-Li test results reject the serial independence in most cases.

5. Summary and Conclusion

This paper investigates the volatility spillover among the stock markets of Egypt, Turkey, Saudi Arabia and Israel. Egypt is considered as a “ground zero country” where the revolution took place in 2011. The other stock markets are chosen for their regional importance. The sampling period is from 2007 through 2013.The first period covers the pre- revolution period from January 1st 2007 to December 31st 2010. The second period is the post- revolution period from January 1st 2011 to July 31st 2013 which was characterized by widespread economic, political and social instability. In addition to the pre- and post-revolution periods, we tested the volatility spillover during the sub-prime financial crisis. For empirical analyses, we used Granger causality test to understand the causal relationship among stock markets. In order to examine the volatility spillover across stock markets, we applied BEKK-GARCH and DCC GARCH models.

The descriptive statistics show that the Egyptian stock market is the most volatile stock market amongst others. During the revolution, the Egyptian stock market has shown excessive volatility and dramatic drop in the stock returns. The unconditional volatility of Egyptian stock market increased and the stock returns turned to be negative particularly in the aftermath of the revolution.

The findings regarding the volatility spillover posit that the observed spillovers of past shocks are quite influential. The volatility of Egyptian stock market drives the volatility of stock returns in Turkey, Saudi Arabia and Israel negatively in particular during the post-revolution period. In comparison with Turkish stock market, the Saudi and Israeli stock markets are more sensitive to Egyptian stock market shocks. This can be explained by the regional integration of stock markets in MENA region.

Moreover, the findings present that in comparison with pre-revolution period, the volatility transmission is more apparent during the sub-prime crisis. The results suggest that there exists significant bi-directional volatility spillover from the Egyptian stock market to the Turkish, Saudi and Israeli stock markets during the sub-prime crisis. However, during the pre-revolution period, the only significant volatility spillover occurs from the Egyptian stock market to the Israeli stock market.

Our findings have important implications in the evaluation of investment and asset allocation decisions by practitioners such as portfolio managers and institutional investors. The market participants should evaluate cross-linkages with great care if they seek international portfolio diversification. High positive interdependencies suggest significant linkages among the markets. A high level of volatility in the stock market increases the levels of anxiety. Investors may become more risk-averse, demanding a higher risk premium before committing funds to a volatile market**.**

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