Volatility spillovers and Financial contagion during global financial crisis: Islamic versus conventional equity indices with Multivariate GARCH approch

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Volatility spillovers and Financial contagion during global financial crisis: Islamic versus conventional equity indices with Multivariate GARCH approch

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Abstract

This paper examines the volatility spillovers and the contagion effects of the 2007-2009 global financial crisis across the U.S. conventional stock market and a sample of local and global Islamic and conventional stock markets provided by the Dow Jones index, namely the United Kingdom, Canada, Europe, the Emerging-market countries and Asia-Pacific. The analysis extends from December 31, 2004 to September 30, 2016 and encompasses expansion and recession periods of the global financial crisis using the BEKK-GARCH, the DCC-GARH and the ADCC-GJR-GARCH-*t* models. As a result, we show evidence of high volatility transmission and significant dynamic correlations spread from the U.S. traditional stock market to each global and regional Islamic and conventional stock markets. In this light, the resilience and the decoupling hypotheses are not supported for the Islamic indices. This study has significant policy implications for portfolio diversification and provides more insights into systemic risk in these regions.

Keywords : Volatility spillovers ; Financial contagion ; Dynamic conditional correlations ; Islamic finance ; Global finacial crisis ; Global and regional stock markets ; Multivariate GARCH.

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1. Introduction

It is well known in the literature that international stock markets react, in terms of returns and volatility, instantly and simultaneously to major financial crises. Moreover, the timing and magnitude of changes in stock returns and volatility differ from market to market around the globe, (Roll, 1988). In this context, the 2007-2009 global financial crisis offers a unique opportunity to study the dynamic relationships among local and global stock markets, such as studies on the one hand, on the transmission of volatility and shocks from one market to another, and on the other hand, the co-movements and dynamic correlations between the stock markets which are essential in the financial field, (Jin and An, 2016).

Accordingly, one of the most tumultuous economic events in recent history was the recent global financial crisis sparked by the U.S. subprime mortgage market in August 2007. Compared to previous financial crises, the global financial crisis (GFC) was a clear case of materialization and propagation of systematic risk, which eventually led to the European sovereign debt crisis, (Kenourgios and al., 2016). The crisis inevitably spread throughout the world, especially to Europe and this event triggered a new cycle of uncertainty in the Eurozone and fears of contagion effects to global financial markets.

Interestingly, the stock markets commonly seem to evolve accordingly with one another in the course of both increase and decrease periods, providing further evidence of strong co-movements and interdependency, (Hemche et al., 2014). More precisely, according to the empirical literature, the volatilities of the global stock markets increase significantly during the crisis, which implies that the volatilities and correlations of the stock markets evolve together over time, (Jin and An, 2016). Thus, according to Kenourgios et al. (2016), Forbes and Rigobon (2002) suggests that contagion is a significant increase in cross-market linkages after a shock to one country (or group of countries). In general, contagion relates to the spread of financial shoks from one country to others. Therefore, during periods of stability, if two markets formally exhibit a high degree of co-movement and they continue to be highly correlated after a shock to one of the markets, this may not constitute contagion, (Kenourgios et al., 2016).

From a methodological point of view, Kenourgios et al. (2016) point out that several studies have been using multivariate GARCH models as appropriate for studying the transmission mechanism and volatility and correlation dynamics among financial markets. The first attempt was made by Bollerslev et al. (1988) who proposed the VECH specification. Engle and Kroner (1995) suggested the BEKK model. Bollerslev (1990) introduced the Constant Conditional Correlation (CCC) model, however, its main drawback is the assumption of constant correlations, (Kenourgios et al., 2016). Engle (2002) suggested an expansion of the CCC model, the dynamic conditional correlation (DCC) model, in which the correlation varies in time and is capable of capturing the changes over time. Cappiello et al. (2006) extend the original model of Engle (2002) and proposes an asymmetric specification (A-DCC) to investigate asymmetries in conditional variances and correlation dynamics. Finally, the latest techniques used to investigate financial contagion and market dependence are dynamic copulas (e.g., Rodriquez, 2007; Bhatti and Nguyen, 2012) and continuous wavelet transform (e.g., Dewandaru et al., 2014), (Kenourgios et al., 2016).

Following the subprime crisis, the financial infrastructure has marked the emergence of the Islamic financial industry, based in particular on Sharia principals, as an innovative alternative investment that can deal with financial crises more effectively than conventional counterparts. Thus, international investors seeking to protect their investments against crises can be offered a solution by the Islamic financial industry. According to Kenougios et al. (2016), the Islamic equity index are exposed to rigorous screenings for business activities and financial ratios and purification of dividends. Stocks are screened to filter firms involved in any non-Sharia compliant activity, in particular gambling, the production of pork and alcohol. Furthermore, financial ratios are employed to restrict the firms' interest-based income and interest-bearing securities and receivables. If an Islamic equity fund allocates part of their portfolio to cash or short-term securities, they must be non-interest bearing, (Kenougios et al., 2016).

This paper uses Dow Jones Islamic equity indices and their conventional benchmarks to examine the volatility spillovers and the financial contagion between the U.S. conventional stock market and a sample of slamic stock markets and their traditional equivalents, especially during turbulence. Generally, the purpose of this study is to answer the following questions: (1) : How the 2007-2009 global financial crisis has impacted the volatility spillover and the dynamic co-movements between the U.S. traditional stock market each Islamic and conventional stock markets ? (2) Are the resilience and decoupling hypotheses of Islamic stock market indices valid compared to their conventional counterparts in the context of the 2007-2009 global financial crisis? (3) Do the Islamic indices offer diversification benefits for the investor compared to their conventional counterparts following the multivariate GARCH models?

Moreover, several studies reported a rise in stock market linkages since the subprime crisis, providing additional evidence of volatility spillover and contagion effects across regions both during and after the subprime crisis which extended to the sovereign debt crisis. In this context, the majority of empirical studies examines cross-country traditional equity market contagion and contagion between different types of asset during periods of recession. Indeed, while the crisis effects pointed a priori to the presence of time-varying linkages, the paper offers a more comprehensive analysis of cross-market linkages and contributes to the relevant literature in different aspects. First, the empirical research on Islamic and conventional markets is still growing, primarily examining the transmission of shocks and volatilities and dynamic co-movements between the global and regional Islamic and conventional equity indices in the context of the global financial crisis. This view suggests that this crisis has triggered changes in the global appetite for risk to investors, and allows us to test the hypothesis of decoupling. The core of the decoupling hypothesis states that some markets manifest immunity during crisis periods and that the volatility links in Islamic markets differ from traditional markets since there are structural differences between Islamic stock market and their classical equivalents. Several studies have claimed, according to Ben Rejeb (2017), that Islamic stock markets are not presumed to transmit volatility to traditional stock markets because they are fundamentally different. Second, since that the GFC originated from the developed financial system, we use the U.S. Dow Jones index as a source of volatility spillover and contagion for the Islamic stock markets and their classical consorts. In this respect, it is necessary to understand the behaviour of Islamic and conventional stock markets during crises to help policymakers and international investors to be more effective in dealing with financial contagion and international portfolio diversification. Furthermore, we explore whether the Islamic equity market is more (less) exposed to the effects of financial contagion in developed countries (namely, the United-States, the United kingdom and Canada), Europe, the emerging countries and Asia-Pacific. Also, our sample (2004-2016) enables comparison of the contagion effects during the GFC periods. For this purpose, we examine volatility spillovers and cross-market co-movements between the U.S. conventional stock market and a set of Islamic and conventional stock markets using the BEKK-GARCH model proposed by Engle and Kroner (1995) that allows the conditional variances of two markets to be transmitted to each other, Engle's (2002) dynamic conditional correlation multivariate (DCC-GARCH) model allows us to reproduce dynamic market cross-correlations and then enables for symmetric time-varying contagion effects and the Asymmetric Generalized Dynamic Conditional Correlation GARCH (AGDCC–GJR-GARCH-t)[3] process developed by Cappiello et al. (2006) which enables us to assess time-varying asymmetric

[3] According to Kenourgious et al. (2016), The A-DCC model allows for series-specific news impact and smoothing parameters, permits conditional asymmetries in correlation dynamics and accounts for heteroskedasticity directly by estimating correlation coefficients using standardized residuals. Moreover, this multivariate specification overcomes the problem with omitted variables (e.g., economic fundamentals, risk perception and preferences) and is well suited to investigate the presence of asymmetric responses in conditional variances and correlations during periods of negative shocks. The GJR-GARCH-*t* model increases the flexibility and asymmetry of the conditional variance specification.

dynamic conditional correlations among the U.S. traditional stock market (source of crisis) and each Islamic and traditional stock markets in the light of the GFC.

Our empirical results provide interesting insights and take the literature forward. Clearly, these results offer the strongest evidence appearing in the literature so far on the decoupling hypothesis of the Islamic equities from the conventional financial system. The volatility spillovers and the contagion is very present in Islamic equity as much as their conventional counterparts. Also, Islamic stock markets show the same behaviour vis-à-vis the U.S. conventional stock market. In fact, the analysis on a crisis level reveals a strong and positive evidence on equity contagion and volatility transmission mostly relates to the GFC. The results have important implications for investors who seek to diversify stock portfolios in heterogeneous markets and for financial makers to establish necessary market policies prevent shock effects.

The remainder of the paper is structured as follows: The literature review is summarized in Section 2. Section 3 introduces the econometric methodology and description data by motivating the choice of countries. Section 4 provides the test framework, including the volatility and contagion test model. Section 5 presents the empirical analysis and the results. Section 6 addresses the discussion. Section 7 Finally presents the conclusions.

2. Literature review

2.1. Background on volatility spillovers in the context of Islamic finance

Due to various reasons of interest in the impact and spillover effects of financial crises on stock markets, it is not surprising that the relationship between financial crises and volatility spillover is examined in different studies, taking into account the U.S. recession in various developed countries and also in emerging regions around the globe. Although there is a consensus on the relevance of Islamic finance compared to conventional finance, the literature on the transmission of volatility and contagion between these markets is still limited.

According to Nazlioglu et al. (2015), Kim and Kang (2012) examine the mechanism of transmission of volatility between Islamic indices, Sukuk and the bond markets in Malaysia, as representatives of Islamic finance using using a VAR-bivariate GARCH model during the Subprime crisis, while taking into account essential roles they play in portfolio and risk management. Dania and Malhotra (2013) examine dynamic linkages between four main Islamic indices and their conventional counterparts of North America, European Union, Far East and Pacific nation markets. The results show positive and significant transmissions from the conventional market to the Islamic market. Nazlioglu et al. (2015) examine the transmission of volatility and risks between the Dow Jones Islamic indices and three conventional stock markets (the United States, Europe and Asia) during the pre-crisis, the crisis period and after the crisis of 2008. They also explore the dynamics of the transmission of volatility between these markets and American monetary policy, oil prices, global financial risks and factors of uncertainty. Kim and Sohn (2016) study the effect of volatility spillovers between the conventional financial market and the Islamic financial market. Their Empirical results show unidirectional transmission of volatility from the conventional US stock market to the Islamic stock indexes, but not vice versa. Akhtar et al. (2016) analyse the volatility linkages between Islamic and conventional assets. These authors show that the inclusion of at least one Islamic asset reduces the transmission of volatility by up to 7.17 %. These authors argue that the peculiarities of Islamic financial assets decrease the degree of dynamic links between Islamic markets and their conventional counterparts. Ben Rejeb (2017) analyzes the interdependencies between traditional stock markets and their Islamic counterparts in stable times and during cycles of financial fragility and crisis in terms of volatility (transmission, contagion). Using the Quantile Regression-based GARCH model, he finds that the Islamic stock markets are not completely immune to the 2007-2009 global financial crisis. In addition, he proved that interdependencies from conventional markets to Islamic markets spread across Islamic markets. Finally, he suggested that Islamic finance is not resilient does not seem to be able to provide a good cushion against economic and financial shocks affecting conventional markets.

2.2. Background on financial contagion

Financial market contagion is a widely discussed term within financial market research and in this context the empirical studies investigate equity market contagion across various assets, countries and regions in the 1987 U.S. stock market crash, the Asian, Russian, Mexican, Brazilian, global, and Eurozone crises, (Mollah et al. 2016). In regard to financial contagion, evidence can be observed from the temporarily changing co-movement across different markets during crisis periods, (Dewandaru et al., 2014). More precisely, the correlations increase during crisis events, indicating contagion effects between the markets, and remain on a high level after the crisis break, showing the investors' herding behaviour, (Karanasos et al., 2016). An evaluation of the contagion effect is important since financial systems globally have experienced periodic occurrences of crises, causing a rapid spread of financial shocks from one country into other countries. Recently, the remarkable U.S. born subprime crisis of 2007-2009 and the European sovereign debt crisis of 2010-2012 considerably affected markets all over the world, which raises critical questions about the stability of the global financial system, (Dewandaru et al.,2014).

Moreover, empirical research on Islamic market indices, mainly, examining co-movements and dynamic correlation between these latter and conventional counterparts during boom and bear markets is still growing. Hence, on the recent literature on islamic markets, Arshad and Rizvi (2013), while studying the correlation between the stock markets using the DCC-GARCH model, suggest a low correlation between the conventional and Islamic indices, confirming that the Islamic index could provide a better solution to the crisis. Dewandaru et al. (2014) explore market co-movements in Islamic and mainstream equity markets across different regions in order to discover contagion during nine major crises and to measure integration between markets. They generally find incomplete market integration, with relatively higher fundamental integration for Islamic markets which may be attributable to their real sector allocation nature. Majdoub and Mansour (2014) examine the conditional correlations across the U.S. market and a sample of five Islamic emerging markets using GARCH BEKK, CCC, and DCC and find low volatility spillovers between the U.S. stock market and Islamic emerging stock markets. Aloui et al. (2015a) examine the volatility spillovers in the GCC countries using a multivariate Fractionally Integrated Asymmetric Power ARCH model with dynamic conditional correlations (DCC) model. They find a negative dynamic correlation between the Islamic indices and Sukuk and structural breakpoints along the path of the DCC, which correspond to extreme events, in particular, the collapse of Lehman Brothers in September 2008. Kenourgios et al. (2016) investigate the contagion effects of the global financial crisis (GFC) and Eurozone sovereign debt crisis (ESDC) on Islamic equity and bond markets using a sample of Islamic stock indices from various developed and emerging markets and the global Islamic stock and bond (sukuk) indices through APARCH-A-DCC. The results fail to provide strong contagion evidence between conventional and Islamic equity and bond indices, supporting the decoupling hypothesis of the Islamic securities. Kiliç and Bugan (2016) analyse the financial contagion effect between international Islamic indices and conventional regional indices using the DCC-MV-EGARCH model. Their results show that there is a high correlation between the returns of Islamic and conventional indices. They conclude that the Islamic markets do not react differently from conventional markets against financial shocks and they are not "safe haven" for investors during a financial crisis. Umar and Suleman (2017) examine the interdependence between Islamic and conventional indices, taking into consideration the asymmetric effect of returns and the volatility spillovers. They empirically study the hypothesis of decoupling of Islamic and conventional indices and the potential effect of contagion using the multivariate VAR-EGARCH model. They analyse the intra-market and inter-market transmission of Islamic and conventional indices in three major markets: the United States, the United

Kingdom and Japan during the period from 1996 to 2015. Moreover, they separate the study period into three sub-periods covering a period prior the 2007 financial crisis, the crisis period and the post-crisis period. They find little support for the decoupling hypothesis during the post-crisis period. Finally, Hasan (2019) examines the transmission of volatility and the co-movements between traditional (DS30) and Islamic (DSES) indices in Bangladesh over the period from 20 January 2014 to 25 June 2018. Using ARDL bounds testing cointegration procedure and GARCH family models (BEKK, CCC and DCC garch), the findings demonstrate that in the short-run and long-run both markets are integrated. Besides, there is a significant transmission of volatility between Bangladesh's traditional and Islamic stock markets, strong links and a high conditional correlation between these markets. This study shows that in Bangladesh, Islamic and traditional indices do not offer diversification benefits to investors in these stock markets.

3. Methodology and data description

Our data set includes daily closing prices for six global and local conventional stock markets (USC, UKC, CAC, EUPC, EMGC and ASIAC) and five global and regional islamic stock markets (UKI, CAI, EUPI, EMGI and ASIAI) provided by the Dow Jones index. For each index, 3006 daily observations were collected. Hence, we choose data from December 31, 2004 to September 30, 2016. The choice of daily data is induced owing to the fact that the dynamic co-movements between markets are more likely to occur at high frequency levels. Data are expressed in U.S. dollars to avoid the undesirable impacts from exchange rate movements. For our empirical analysis, we consider log-returns that are computed as $r_t = \ln(P_t/P_{t-1})$ with P_t being the index or the price at time *t*. All data series are sourced from Bloomberg.

We analyse our data in four periods: the entire and the three sub-periods of the 2007-2009 global financial crisis. Regarding the three sub-periods of subprime crisis, the first phase, called the pre-subprime crisis period, is from 31/12/2004 to 29/06/2007. The second called subprime and financial crisis period covers the period from 02/07/2007 to 30/06/2009. The third, called the post subprime crisis period, covers the period from 01/07/2009 to 30/09/2016. To examine the volatility spillover and the co-movements between Islamic and their classic counterparts, we conducted a comparative econometric modelling procedure over the expasion and the recession periods of the U.S. recession.

The summary statistics for each index return, for the entire period to give a more clear insight about our sample, are reported in Table 1. The table states that the average stock returns of conventional and Islamic equity index are similar, positive and close to zero with a very slight performance of Islamic indices compared to their conventional benchmarks. Also, the means of the returns are small relative to their standard deviations, showing relatively high risks. The unconditional volatility, measured by standard deviation, is relatively similar across Islamic and conventional indices since the values are very close and also higher than the returns. Moreover, from a financial perspective, skewness and kurtosis are considered important measures of risk. A generally accepted conclusion is that investors dislike highly negative skewness and high kurtosis of their investment portfolios, (Basher et al., 2014). The estimated sample coefficients of skewness and kurtosis reveal the presence of negative skewness and excess kurtosis. The negative values for skewness are common, thus, for all series indicating that these returns are asymmetrical to the left showing more strong downward than upward movements. Whereas, the results of the sample kurtosis coefficients indicate the presence of fat-tailed behaviour, as the null hypothesis of the test is strongly rejected at the 5% level. The presence of fat-tail in financial time series led Bollerslev (1987) to propose the use of t-distribution to match the excess sample kurtosis in GARCH models, as discussed further below. Both the skewness and the excess kurtosis display that the return series are not normally distributed. The Jarque-Bera test firmly rejects the return distribution null hypothesis of normality.

Table 1
Summary statistics for returns series.

	Conventional stock markets					
	USC	UKC	EUPC	EMGC	CAC	ASIAC
Mean	0.020828	0.000867	0.004918	0.017864	0.013168	0.010766
Std. Dev.	1.250163	1.443652	1.462630	1.282334	1.473735	1.179841
Skewness	-0.384655	-0.223569	-0.211257	-0.503933	-0.628692	-0.562076
Kurtosis	13.67079	13.01342	10.26278	10.59044	11.26378	10.53222
Jarque-Bera	14335.81	12583.69	6629.040	7343.482	8751.351	7264.255
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
	Islamic stock markets					
	USI	UKI	EUPI	EMGI	CAI	ASIAI
Mean	0.025299	0.005393	0.012435	0.016030	0.009004	0.014844
Std. Dev.	1.188315	1.494844	1.404623	1.239934	1.812194	1.180268
Skewness	-0.178747	-0.174325	-0.033412	-0.567765	-0.665559	-0.643832
Kurtosis	14.13379	10.61193	11.23771	11.33790	11.73157	11.49500
Jarque-Bera	15542.17	7272.386	8500.008	8868.945	9771.024	9246.345
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Note: USC, UKC, EUPC, EMGC, CAC and ASIAC denote the aggregate index returns of conventional stock markets in the United States, the United Kingdom, Europe, Emerging Countries, Canada and Asia Pacific.respectively. USI, UKI, EUPI, EMGI, CAI and ASIAI refer to the aggregate index returns of Islamic stock markets in the United States, the United Kingdom, Europe, Emerging Countries, Canada and Asia Pacific respectively.

Table 2a and Table 2b reports the correlation matrix across Islamic and conventional stock markets returns. Figure.1 (Please see Appendix A) show 10 panels of the country pairs' daily moving correlations of returns. The USC/CAI, USC/EUPI and USC/UKI pairs and their conventional counterparts reveals the highest correlation since these indices are highly bonded over the sample period. Except for these pairs, the remaining pairs show low correlations. Although the conventional and Islamic stock markets vis-à-vis the U.S. conventional market have almost the same trend over time, and clearly they cross each others by showing the same behaviour versus this latter.

Table 2a
Correlation matrix of conventional market return.

Correlation	USC	UKC	CAC	EUPC	EMGC	ASIAC
USC	1.000000					
UKC	0.571495	1.000000				
CAC	0.730586	0.703817	1.000000			
EUPC	0.588249	0.944603	0.695185	1.000000		
EMGC	0.488255	0.690146	0.625494	0.710466	1.000000	
ASIAC	0.152774	0.434110	0.350478	0.458448	0.698909	1.000000

Source : Author's calculations.

Table 2b
Correlation matrix of islamic market return.

Correlation	USC	UKI	CAI	EUPI	EMGI	ASIAI
USC	1.000000					
UKI	0.544880	1.000000				
CAI	0.656001	0.614087	1.000000			
EUPI	0.563397	0.953714	0.620173	1.000000		
EMGI	0.458293	0.689100	0.563419	0.702767	1.000000	
ASIAI	0.195395	0.488508	0.357228	0.502841	0.821732	1.000000

Source : Author's calculations.

Indeed, when the subprime crisis erupted, the coefficients of correlations of classical and Islamic stock markets were positive and extremely high showing a similar behaviour vis-à-vis the U.S. conventional market. Also, there is a slight significant correlation between all these pairs in the course of the sovereign debt crisis in 2011 and in 2016 following the Brexit. Thereby, it can be concluded, a priori, the presence of volatility transmission and contagion effects between pairs into consideration and thus Sharia compliance can not be restrictive enough to make Islamic indexes very different from their conventional counterparts against shocks.

4. Model specification

We used a multivariate MGARCH model in order to examine the evolution of dynamic co-movements and volatility spillovers between Islamic and conventional equity indices with respect to the U.S. conventional market during the 2007-2009 global financial crisis. Firstly, we utilise the BEKK model of Engle and Kroner (1995) since it has a good property according to which the conditional covariance matrices are positive definite by construction. Secondly, we obtain a time-varying measure of correlation based on the dynamic conditional correlation (DCC) model of Engle (2002) and the Asymmetric-DCC (ADCC) model of Cappiello, Engle and Sheppard (2006) based on the Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MV-GARCH) techniques, respectively, to isolate the time-varying conditional correlations from the conditional variance component.

4.1. Conditional volatility : The BEKK-GARCH (1,1) model

The BEKK-GARCH model represents an approach, initially suggested by Baba, Engle, Kraft and Kroner (1990), which guarantees the positivity of the conditional variance-covariance « H_t » matrix and then synthesized by Engle and Kroner (1995). This model represents an improvement of the VECH model because it ensures to obtain H_t, the matrix of variances-covariances, positive definite. However, although the number of parameters to be estimated is lower than that of the VECH model, it remains very high. This model is attractive to our research as it allows the transmission of the conditional variances between the two markets. It is also capable of capturing the effects of time-varying conditional correlations. In this model, the variance-covariance matrix of equations depends on the squares and cross products of innovation ε_t, which are drived from the following mean equation :

$$R_t = \mu + \varepsilon_t \quad (1)$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, H_t) \quad (2)$$

$$\varepsilon_t = H_t^{\frac{1}{2}} \epsilon_t \quad (3)$$

where: r_t: 2×1 vector of returns at time t for each market, μ_t: 2×1 constant vector at time t, ε_t: vector n×1 of errors i.i.d represents the innovation for each market at time t with its corresponding 2×2 conditional variance-covariance matrix H_t, here we assume that ε_t fllows a Gaussian distribution with with E(ε_t) = 0 and cov (ε_t) = H_t and we suppose ε_t= ($\varepsilon_{1,t}$, $\varepsilon_{2,t}$)' to have a time-varing conditional variance. ϵ_t = ($\epsilon_{1,t}$, $\epsilon_{2,t}$)' ~ i.i.d. $\begin{bmatrix}0\\0\end{bmatrix}, \begin{bmatrix}1 & 0\\0 & 1\end{bmatrix}$.

Ω_{t-1}:the information set at *t-1*.

The bivariate BEKK-GARCH (1,1) is represented by :

$$H_t = C'C + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'H_{t-1}B \qquad (4)$$

where: H_t is a 2×2 matrix of conditional variance-covariance at time *t*, *C*= [c_{ij}], i, j = 1, 2 is a 2×2 lower triangular matrix with interception parameters. *A* = [a_{ij}] and *B* = [b_{ij}] are 2×2 parameter matrices. *A* measures the extent to which conditional variances is correlated with past squared errors and consequently the effects of shocks on volatility. *B* depicts the extent to which current levels of the conditional variance-covariance matrix are related to past conditional variance-covariance matrices. Furthermore, this model ensures that the conditional variance-covariance matrix, H_t = [$h_{ij,t}$], i, j = 1, 2, is positive definite under rather weak assumptions. Accordind to Engle and Kroner (1995), the conditional variance-covariance matrix H_t is positive definite if at least one of *C* or *B* is of full rank.

Because of its fewer parameters, the BEKK model is more appropriate for estimation compared with alternative multivariate GARCH representations. However, Engle and Kroner (1995) demonstrate that the BEKK model is stationary in second-order except if all of the eigenvalues of (A ⊗ A + G ⊗ G) modulus[4] are less than unity. In addition, the limit of this model is that it does not take into account the dependence of conditional volatilities across markets which makes this specification too restrictive, (De Santis et al., 2003).

Moreover, the estimation of BEKK model is done by maximum likelihood, assuming that the errors are normally distributed, and is optimized by using the BFGS and BHHH algorithms. Accordingly, the likelihood function where the contribution of $\boldsymbol{\varepsilon_t}$= (**$\varepsilon_{1,t}$,$\varepsilon_{2,t}$**)' to the joint Gaussian log-r with T observations is given by:

[4] ⊗ is the Kronecher Tensor product.

$$L(\theta) = -\mathrm{T}\log(2\pi) - \frac{1}{2}\sum_{t=1}^{T}[\ln(H_t) + \varepsilon_t'(H_t^{-1}) + \varepsilon_t] \quad (5)$$

where: T is the number of observations and θ is the vector of parameters to be estimated.

4.2. Dynamic conditional correlation

Bollerslev (1990) introduced a class of multivariate GARCH models, specifically the Constant Conditional Correlation (CCC-MGARCH) in which the conditional correlations are time-invariant, (Majdoub and Mansour, 2014). Engle and Sheppard (2001) revealed that testing the model for constant correlations is difficult, because testing for dynamic correlations requires using data with time-varying volatilities that can result in a misleading conclusion, and rejection of a true constant correlation because of mis-specified volatility models, (Mollah et al., 2016). Accordingly, the DCC–GARCH model that belongs to the class of conditional variance and covariance models presents the advantage of flexibility and reproduce possible changes in conditional correlations over time, which enables us to test contagion effects over time, and more precisely in period of crisis, (Hemche et al., 2016).

At first, we apply the DCC framework to identify the presence of contagion at the country level and augment this model with asymmetric influences, as shown by Cappiello et al. (2006) that allows computing the time-varying conditional correlations to assess the financial market integration. The model generalizes and improves substantially the DCC–GARCH process of Engle (2002) by accounting for the asymmetry in conditional correlations, (Jouini, 2015).

4.2.1. The DCC-GARCH model

Following Engle and Sheppard (2001), Engle (2002) and Hemche et al. (2016), the DCC–GARCH model estimation is performed in two steps. In the first step, we estimate separately the conditional variance by a univariate GARCH model for each time series. We generalize the Bollerslev constant conditional correlation in the second step to estimate DCCs based on the standard residuals obtained from the GARCH estimation in the first step.

Formally, to specify the DCC–MGARCH, let's retain the following process for stock returns:

$$r_t = \mu_t + \varepsilon_t \tag{6}$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, H_t) \tag{7}$$

$$\varepsilon_t = H_t^{\frac{1}{2}} \epsilon_t \text{ , avec } \epsilon_t \sim N(0, I_n) \tag{8}$$

where: r_t: n×1 vector of returns of n assets at time t, μ_t: vector n×1 of expected returns of n assets at time t, ε_t: vector n×1 of errors i.i.d with E(ε_t) = 0 and cov (ε_t) = H_t , ϵ_t: vector n×1 i.i.d standardized residuals $E(\epsilon_t) = 0$ and $E(\epsilon_t \epsilon_t') = I_n$, $H_t^{\frac{1}{2}}$: matrix n×n at time t such as H_t is the conditional variance matrix of ε_t, $H_t^{\frac{1}{2}}$ can be obtained by a Cholesky factorization of H_t , Ω_{t-1}:the information set at t-1, I_n: is the n×n dimensional identity matrix.

The conditional variance-covariance matrix can be written as: $H_t = D_t R_t D_t$

where: H_t is a n×n matrix of time-varying variances at time t, R_t: is the n×n time-varying correlation matrix of ε_t at time t and D_t is the diagonal matrix n×n of conditional standard deviations for return series. The matrix D_t is obtained from estimating a univariate GARCH (p,q) [eq. 4] model with $\sqrt{h_{i,t}}$ on the *ith* diagonal, ∀ i = 1,2,.., n.

so:
$$h_{i,t} = c_{0,i} + \sum_{q=1}^{q_i} \alpha_{iq} \varepsilon_{i,t-q}^2 + \sum_{p=1}^{p_i} \beta_{ip} h_{i,t-q} \tag{9}$$

where : $c_{0,i}$: is a constant, α_i and β_i ARCH and GARCH coefficients respectively.

The time-varying conditional correlation matrix, noted R_t is computed using the standardized residuals obtained from the GARCH estimation. According to Engle (2002), we define R_t as follows:

$$\mathrm{R_t} = Q_t^{*-1} Q_t Q_t^{*-1} \tag{10}$$

We can specify the conditional correlation matrix as :

$$\mathrm{R_t} = (diag\ (Q_t))^{\frac{-1}{2}} Q_t (diag\ (Q_t))^{\frac{-1}{2}} \tag{11}$$

$$diag(Q_t)^{\frac{-1}{2}} = diag\ (\frac{1}{\sqrt{q_{11,t}}}, \dots, \frac{1}{\sqrt{q_{nn,t}}}) \tag{12}$$

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

where : $\epsilon_{i,t} = \frac{\varepsilon_{i,t}}{\sqrt{h_{i,t}}}$ is the vector containing the standardized residues resulting from the estimation of the GARCH univariate model, $\overline{Q} = \text{cov}\,(\epsilon_t\epsilon_t{}') = E(\epsilon_t\epsilon_t{}')$ is the unconditional variance-covariance matrix of standardized residues obtained by univariate GARCH, $\alpha + \beta < 1$, α and β are non-negative parameters to be estimated, α measures the effect of a given shock, β captures the past dynamic correlation, $Q_t = |q_{ij,t}|$ denotes the variance-covariance matrix of ϵ_t, $Q_t^* = \sqrt{q_{ij,t}}$ is a diagonal matrix including the squared root of the main elements of Q_t.

Thus the conditional correlation at time *t* can be defined as:

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}}, \forall\, i,j = 1,\ldots.,n.\ et\ i \neq j \quad (14)$$

$$\rho_{ij,t} = \frac{(1-\alpha+\beta)\overline{q_{ij}} + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \beta q_{ij,t-1}}{\sqrt{(1-\alpha+\beta)\overline{q_{ii}} + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \beta q_{ii,t-1}}\sqrt{(1-\alpha+\beta)\overline{q_{jj}} + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \beta q_{jj,t-1}}} \quad (15)$$

where : $q_{ij,t}$is the element of the *ith* line and *jth* column of the matrix Q_t.

In our case, the conditional correlation matrix calculated using standardized residuals from the univariate GARCH (1,1) model:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (17)$$

$$Q_t = (1-\alpha_{DCC}-\beta_{DCC})\bar{Q} + \alpha_{DCC}\epsilon_{t-1}\epsilon'_{t-1} + \beta_{DCC}Q_{t-1} \quad (18)$$

Following Hemche et al. (2016), the parameters are estimated using the quasi-maximum likelihood method introduced by Bollerslev et al. (1992), which provides consistent estimators. The expression of the log-likelihood function corresponds to:

$$L(\theta) = -\frac{1}{2}\sum_{t=1}^{T}[(n\log(2\pi) + \log|D_t|^2 + \varepsilon'_t D_t^{-1}\varepsilon'_t) + (\log|R_t| + \epsilon'_t R_t^{-1}\epsilon_t - \epsilon'_t\epsilon_t)] \quad (19)$$

where : n : denotes the number of equations, T : refers to the number of observations, θ denotes the vector of parameters to be estimated.

Precisely, this log-likelihood function is separated into the log-likelihood function of variances (Eq.14) and that of correlations (Eq.15)): $L(\theta) = l_1 + l_2$. While the variance parameters in l_1 are determined by maximizing l_1, those for the time-varying correlations are determined by maximizing the log-likelihood function: l_2.

$$l_1 = -\frac{1}{2}\sum_{t=1}^{T}[(n\log(2\pi) + \log|D_t|^2 + \varepsilon_t' D_t^{-1}\varepsilon_t')] \tag{20}$$

$$l_2 = -\frac{1}{2}\sum_{t=1}^{T}[(\log|R_t| + \epsilon_t' R_t^{-1}\epsilon_t - \epsilon_t'\epsilon_t)] \tag{21}$$

4.2.2. The ADCC-GJR-GARCH-*t* model

As Jouini (2015) mentioned, the A-DCC model developed by Cappiello et al. (2006) represents a generalization Engle's (2002) DCC-GARCH model. Indeed, due to the limits of Engle's (2002) DCC model, where the dynamic conditional correlation ignores asymmetrical effects, AGDCC-GARCH model proposed by Cappiello, Engle and Sheppard (2006) extends the DCC model to account for the asymmetry "leverage effect" in dynamic conditional correlations based on a GJR-GARCH formulation that, in turn, accounts for conditional asymmetries in volatility.

The general form of the mean return equation with *t*-student distributed errors is specified as follows:

$$r_t = c_0 + \varepsilon_t,\ \ \varepsilon_t \sim \mathrm{t.d.}(0, H_\mathrm{t}^{1/2}, v) \tag{22}$$

where : where $r_t = [r_{1t}, r_{2t}]'$ is a 2×1 vector including each return series and $\varepsilon_t = [\varepsilon_{1t}, \varepsilon_{2t}]'$ is a 2×1 vector of innovations conditional on the information set at time *t-1*. The error term is assumed to be conditionally multivariate *t*-student distributed with a mean of zero while *v* represents the degrees of freedom.

The variance–covariance matrix is specified as follows:

$$H_t = D_t R_t D_t \tag{23}$$

where : R_t is the time-varying conditional correlation matrix and D_t is the diagonal matrix of the conditional standard deviation from univariate GARCH models. The elements in D_t are assumed to follow the univariate GJR-GARCH (1,1) model proposed by Glosten Jagannathan and Runkle (1993) that allow the asymmetry in volatility.

$$h_{i,t} = \omega_i + (\alpha_i + \gamma_i I_{i,t-1})\epsilon^2_{i,t-1} + \beta_i h_{i,t-1} \quad (24)$$

and
$$\epsilon_t = D_t^{-1}\varepsilon_t \quad (25)$$

where : $\omega_i, \alpha_i, \gamma_i, \beta_i > 0$ and $\alpha_i + \beta_i + \frac{\gamma_i}{2} < 1$, for $i = 1, 2,\ldots,$ k to ensure a positive and mean-reverting model, and therefore stationary. $I_{i,t-1}$ is an indicator function such as $I_{i,t-1} = 1$ if $\epsilon_{i,t-1} < 0$ et $I_{i,t-1} = 0$ otherwise.

The evolution of the correlation in the standard DCC model of Engle (2002) given by Eq.8 does not account for asset specific news and asymmetry in conditional correlations. Therefore, Cappiello et al. (2006) propose the following modified matrix :

$$Q_t = (\bar{Q} - \alpha\bar{Q} - \beta\bar{Q} - \gamma\bar{N}) + \alpha\epsilon_{t-1}\epsilon'_{t-1} + \gamma n_{t-1}n'_{t-1} + \beta Q_{t-1} \quad (26)$$

where : $n_t = I[\epsilon_t < 0] \circ \epsilon_t$, $\bar{N} = \mathrm{E}[n_t n_t^{'}]$ (or the empirical counterpart: $\bar{N} = \frac{1}{T}\sum_{t-1}^{T} n_t n_t^{'}$ to simplify), " $\circ$ " is the Hadamard product and $\bar{Q} = \mathrm{E}\left[\epsilon_{t-1}\epsilon_{t-1}^{'}\right]$ (or the empirical counterpart: $\bar{N} = \frac{1}{T}\sum_{t-1}^{T} \epsilon_{t-1}\epsilon_{t-1}^{'}$). Thus, to guatantee that Q_t positive definite, the following condition must be satisfied: $\alpha + \beta + \delta\gamma < 1$, where δ is the eigenvalue of $\left[\bar{Q}^{-1/2}\bar{N}\bar{Q}^{-1/2}\right]$.

Finally, within the setting provided by the A-DCC model, the time-varying correlation matrix is given by :

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1} \quad (27)$$

where Q_t^* is a diagonal matrix with a square root of the *ith* diagonal of Q_t on its *ith* diagonal position.

The maximum likelihood method is used to estimate the model based on the BFGS optimization algorithm[5].

Furthermore, please see Appendix B for the test assumptions of volatility spillovers and financial contagion in this study.

[5] Cappiello et al. (2006) outline that the quasi-maximum likelihood estimation method is applied when the variables do not satisfy the normality hypothesis, (Jouini, 2015).

5. Main empirical results

According to Karanasos and al. (2016), multivariate GARCH models with time-varying correlations are essential for enhancing our understanding of the relationships between the (co-) volatilities of economic and financial time series. Therefore in this Section, within the framework of the multivariate BEKK, DCC and ADCC models, we will analyse the dynamic adjustments of the variances and the correlations for the various indices.

In this regard, we investigate the financial contagion between the U.S. conventional stock market and Islamic stock markets and their counterparts conventional of global and regional economies, namely the United Kingdom, Canada, Europe, Emerging and Asia-Pacific markets index. The UK, Canada and Europe equity markets serve as global factors in United States. The selection of Asia-Pacific and the Emerging market in the sample is justified by their strong trade links with the United States. The reasons for selecting these countries also include the crucial role of the Europe, UK and U.S. equity markets in the world financial system since they are among the largest markets in the world and also to introduce, in second place, the impact of the sovereign debt crisis 2010-2012 following the post-crisis period. The emerging countries know growing economic activity and considered as promising area for international equity portfolio diversification given their relatively high expected returns.

Moreover, all selected stock markets are now largely open to global investors Islamic and classic, reflecting thus their importance in the international financial integration process. For all these reasons, it is then interesting to examine the volatility spillover and the degree of financial linkages between the U.S. conventional stock market and the selected countries especially at the time of common external shocks. Nevertheless, considering stock markets from different areas is helpful for investors who want to gather more information on the opportunities of equity portfolio diversification in international markets with heterogeneous financial systems.

5.1. Volatility spillover : the BEKK-GARCH (1,1) estimates

In this section, we investigate the estimates results of time-varying variance-covariance BEKK-GARCH (1,1) model following the entire period of study and the three sub-periods of the 2007-2009 global financial crisis. The results of estimated BEKK model are showen in Table 3. The estimation results of BEKK model show that the off-diagonal coefficients are significant at 1% in different periods of crisis, showing an increased links of volatility between the U.S. conventional stock market and all Islamic and conventional pairs. By analogy, we note that Islamic pairs values and those of their classical equivalents are very close and heterogeneous by region. Overall, we note that transmission of volatility in Islamic markets is slightly more present than in their traditional benchmarks. Nevertheless, this means that these markets, as well as their mainstream counterparts, are vulnerable to risks emerging from the U.S. conventional stock market. We note, however, that the transfer intensity of past shocks on current volatility (ARCH effect) is generally low over the entire period, the different crisis sub-periods, and the various regions. In addition, For the pre-crisis period, we conclude that the Islamic pairs are slightly resilient to transmission shocks and volatility spillovers compared to the conventional pairs, but at the same time show similar behaviour to their conventional counterparts vis-à-vis the U.S. conventional stock market. Moreover, during the crisis period, we find significant increase in the ARCH effect (short-term volatility persistence) and the effect of GARCH (long-term volatility persistence) for both markets relative to the previous period.

Table 3
Estimates results of BEKK-GARCH (1.1) model.

Variance Equation								
	Entire period		*Pre-crisis*		*Crisis*		*Post-crisis*	
Markets	a_{12}	b_{12}	a_{12}	b_{12}	a_{12}	b_{12}	a_{12}	b_{12}
USC →UKC	-0.357872765***	0.128485338***	0.314826***	0.465171**	-0.543504010***	0.596984482***	-0.188724796***	0.127928717***
	(0.00000000)	(0.00000000)	(0.00040059)	(0.01431012)	(0.00000000)	(0.00000000)	(0.00018920)	(0.00007074)
USC →CAC	-0.232335524***	0.202010668***	0.279963314***	0.152700177***	-0.496685634***	0.189156314***	-0.164646456***	0.073148565***
	(0.00000000)	(0.00000000)	(0.00028472)	(0.00000000)	(0.00000000)	(0.00082185)	(0.00000000)	(0.00001121)
USC → EUPC	-0.357952001***	0.231899016***	-0.581824570***	0.326814716***	0.507360319***	0.094878322***	-0.140592390**	0.118672379***
	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.01747777)	(0.00319335)
USC → EMGC	-0.169428343***	0.056388707***	0.468073885***	0.081275627***	-0.501634676***	0.357916137***	-0.345665616***	0.401215608***
	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000001)	(0.00000000)
USC → ASIAC	-0.511401636***	0.170602723***	-0.230933873***	0.431442472***	0.188264253***	0.554134188***	-0.689421130***	0.145973548***
	(0.00000000)	(0.00000000)	(0.00012366)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00491453)
USC →UKI	-0.382868157***	0.205985968***	-0.5322230***	0.4454216**	-0.447409027***	0.580710431***	-0.238989061***	0.139190904***
	(0.00000000)	(0.00000000)	(0.00000000)	(0.03307933)	(0.00000000)	(0.00000000)	(0.00044121)	(0.00031492)
USC →CAI	-0.206567729***	0.103040810***	0.095144218***	-0.144401840***	-0.425737749***	0.127271509***	0.134191850***	-0.066478182***
	(0.00000000)	(0.00000000)	(0.00475025)	(0.00000000)	(0.00000001)	(0.00000000)	(0.00000034)	(0.00000288)
USC → EUPI	-0.370703763***	0.222220306***	-0.577508743***	0.020777683***	-0.496960546***	0.138157494***	-0.074438919***	0.061354341***
	(0.00000000)	(0.00000000)	(0.00000000)	(0.00989738)	(0.00000000)	(0.00044188)	(0.00000000)	(0.00000000)
USC → EMGI	-0.244790650***	0.102764078***	0.528117068***	0.062642606***	-0.600736555***	0.318688894***	-0.156407903**	0.197634533***
	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.01198606)	(0.00024479)
USC → ASIAI	-0.498470996***	0.229625553***	-0.218919119***	0.419551681***	0.194986718***	0.556420083***	-0.650610958***	0.248210567***
	(0.00000000)	(0.00000000)	(0.00006097)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)	(0.00000000)

Notes : The parameters (aij) and (bij) correspond to the off-diagonal elements of the matrices A and B. (***), (**) and (*) denote the significance at 1%, 5% and 10% levels respectively.

Nonetheless, in most cases, the ARCH effect has a negative sign, which means that the transmission of past shocks has a weak impact on current volatility relative to the GARCH effect, which showed during that time a significant increase in volatility in those markets. For the post-crisis period, we notice that the amplitude and transmission of shocks on both the Islamic and traditional market pairs decreased compared to the previous crisis period. As regards the transmission of volatility, we notice that the values have decreased significantly for all pairs, except for the conventional USC / EUPC and USC / EMGC pairs, which implies a strong correlation, integration, and interdependence between these markets, due to the long-term persistence of the impact of the 2007-2009 global financial crisis. Furthermore, the findings are heterogeneous between the different regions and between pairs of Islamic markets and their traditional counterparts. Therefore, during this time, the investor may turn to the less volatile and less correlated markets, whether Islamic or traditional, to diversify his portfolio and minimize the risk. Overall, the shocks and volatilities transmitted from the U.S. traditional stock market largely affected the Islamic and conventional stock markets during the 2007-2009 global financial crisis. Consequently, all the pairs under-consideration are interrelated by volatility, which implies their integration and interdependence vis à vis the U.S. conventional stock market, which, in turn, limits the diversification benefits for investors. However, according to the findings of the BEKK-GARCH model, in the context of the subprime crisis, the Islamic markets do not act differently from traditional markets. This leads us to reject the decoupling hypothesis of the Islamic indices from the conventional universe. Finally, Islamic indices present a similar risk to investors, and this leads us to reject the resilience hypothesis of these indices as compared with their traditional benchmarks. Our research is consistent with Kim and Sohn's study (2016) and against the findings of Majdoub and Mansour (2014) with regard to Islamic index resilience in the context of the 2007/2009 global financial crisis.

5.2. Symmetry in conditional correlations : the DCC-GARCH (1.1) estimates

We examine financial market contagion based on time-varying conditional correlation based on the DCC-GARCH (1.1) for the entire and the three sub-periods of the global financial crisis. We computed dynamic conditional correlation between the U.S. conventional market and Islamic stock markets and their counterparts conventional and reported them in Table 4 and Table 5. Accordingly, Figure.2 (please see Appendix C) plots the estimated symmetric conditional correlations (DCC) between the U.S. conventional stock market and each Islamic and conventional stock index.

Table 4
DCC-GARCH (1.1) model estimation for the entire period of study.

Variance Equation			
Markets	*ARCH* (α_{DCC})	*GARCH* (β_{DCC})	*Persistence and Stationarity* $\alpha_{DCC} + \beta_{DCC}$
USC →UKC	0.009861*** (0.000)	0.987266*** (0.000)	0.9971
USC →CAC	0.025557*** (0.000)	0.967721*** (0.000)	0.9932
USC → EUPC	0.010200*** (0.000)	0.985672*** (0.000)	0.9958
USC → EMGC	0.009905*** (0.022)	0.983744*** (0.000)	0.9936
USC → ASIAC	0.004072** (0.035)	0.993351*** (0.000)	0.9974
USC →UKI	0.009594*** (0.000)	0.987248*** (0.000)	0.9968
USC →CAI	0.034774*** (0.000)	0.956091*** (0.000)	0.9908
USC → EUPI	0.009922*** (0.000)	0.986763*** (0.000)	0.9966
USC → EMGI	0.006733*** (0.007)	0.990400*** (0.000)	0.9971
USC → ASIAI	0.005020*** (0.006)	0.993013*** (0.000)	0.9980

Notes : (***), (**) and (*) denote the significance at 1%, 5% and 10% levels respectively. The values reported in the last column correspond to the sum of the ARCH and GARCH coefficients and evaluate the degree of persistence.

Accordingly, we noted several interesting results. First, the presence of positive cross-market dynamic correlation points to further evidence of significant co-movements between the U.S. conventional stock market and the Islamic and conventional stock markets' pairs under-consideration. Second, the sum of the $\alpha_{DCC} + \beta_{DCC}$ parameters is close and less than 1 for each pair of markets, which indicates a very high degree of persistence of the long-term conditional correlation at current conditional variance level for all pairs studied. In sum, there is a strong and positive conditional correlation between all pairs in the sample which implies a presence of contagion effect between the U.S. index and all the Islamic and conventional stock markets. Moreover, we see that the values between all the pairs studied are generally very close and there is no significant difference over the whole sample period which leads us to conclude that Islamic indices present a similar risk for investors as well as conventional indices while rejecting the resilience and the decoupling hypotheses of the Islamic indices compared to their conventional counterparts. Furthermore, these significant co-movements highlight poorer diversification benefits from portfolios including U.S. financial assets and other assets from Islamic and conventional stock markets and the increase in stock market linkages can be justified by the fact that several banking systems include CDO "Collateralized Debt Obligations" in their holdings, and several other instruments and assets directly associated with the U.S. real estate market, making their exposition to systemic risk very high. Lastly, it can be concluded that the two types of markets are highly correlated and integrated with the U.S. conventional stock market, which limits the diversification opportunity in these markets for the investor and, thus, Sharia compliance rules are not restrictive enough to make the Islamic stock market index very different from conventional indices.

As shown in Fig. 2, the DCCs for all pairs exhibit fluctuations and strong co-movements over the entire sample period, especially during the subprime crisis and Eurozone sovereign debt crisis 2010-2012, implying that the assumption of constant correlations is not appropriate. Besides, there is a relatively moderate correlation for the pre-crisis period from 2005 to 2007 across all regions and across all pairs, whether conventional or Islamic. On the other hand, since the year 2008 and until 2012, we note a strong increase of the dynamic correlation across all the regions following all the pairs in consideration, generally between 0.5 and 0.7. This shows the harmful impact of the U.S. recession and the Eurozone sovereign debt crisis worldwide and thus the presence of contagion effects on international stock markets. Moreover, we take into account that the effect of the crisis has been prolonged in the post-crisis period since the correlation and the volatility continue to be high, strong and positive in the long-term, which explains the high persistence and the interdependence of the different markets with the U.S. conventional stock market. Finally, following these plots, we can deduce the harmful impact of the 2007-2009 global financial crisis followed by the Eurozone sovereign debt crisis 2010-2012 on Islamic and conventional stock markets across all the regions studied. This indicates, as a result, a strong correlation (contagion effect) and a strong integration between these markets and for this reason we can reject the decoupling hypothesis of the Islamic indices from the conventional universe.

Table 5
DCC-GARCH (1.1) model estimation for the three sub-periods of study.

	Variance Equation								
	Pre- Crisis			Crisis			Post-crisis		
Markets	α_{DCC}	β_{DCC}	$\alpha_{DCC} + \beta_{DCC}$	α_{DCC}	β_{DCC}	$\alpha_{DCC} + \beta_{DCC}$	α_{DCC}	β_{DCC}	$\alpha_{DCC} + \beta_{DCC}$
USC →UKC	0.005358** (0.016)	0.987771*** (0.000)	0.9931	0.009225** (0.015)	0.989801*** (0.000)	0.9990	0.052824*** (0.000)	0.707802*** (0.000)	0.7606
USC →CAC	0.024187*** (0.008)	0.958743*** (0.000)	0.9829	0.030258*** (0.000)	0.967461*** (0.000)	0.9977	0.015033*** (0.000)	0.978803*** (0.000)	0.9938
USC → EUPC	0.003350** (0.016)	0.989494*** (0.000)	0.9928	0.012328*** (0.000)	0.985234*** (0.000)	0.9975	0.006758** (0.011)	0.983326*** (0.000)	0.9900
USC → EMGC	0.006774* (0.070)	0.9734922*** (0.000)	0.9802	0.017663 ** (0.045)	0.980637*** (0.000)	0.9983	0.007839** (0.020)	0.980470*** (0.000)	0.9883
USC → ASIAC	0.012982* (0.062)	0.985581* (0.099)	0.9985	0.011656 *** (0.000)	0.987309*** (0.000)	0.9989	0.001267*** (0.000)	0.987466*** (0.000)	0.9887
USC →UKI	0.001902*** (0.004)	0.988029*** (0.000)	0.9899	0.013898* (0.085)	0.980390*** (0.000)	0.9942	0.042926*** (0.004)	0.451537** (0.039)	0.4944
USC →CAI	0.029981** (0.036)	0.947197*** (0.000)	0.9771	0.041557*** (0.009)	0.950477*** (0.000)	0.9920	0.027919*** (0.000)	0.960672*** (0.000)	0.9885
USC → EUPI	0.022975*** (0.000)	0.877447*** (0.000)	0.9004	0.009356*** (0.009)	0.986865*** (0.000)	0.9962	0.047535*** (0.000)	0.512534*** (0.008)	0.5600
USC → EMGI	0.024687*** (0.000)	0.690082*** (0.000)	0.7147	0.013216*** (0.003)	0.984240*** (0.000)	0.9974	0.003405*** (0.002)	0.990965*** (0.000)	0.9943
USC → ASIAI	0.047614*** (0.000)	0.943611*** (0.000)	0.9912	0.008774* (0.088)	0.982898*** (0.000)	0.9916	0.009853*** (0.000)	0.990145*** (0.000)	0.9999

Notes : (***), (**) and (*) denote the significance at 1%, 5% and 10% levels respectively. The values reported in the last column correspond to the sum of the ARCH and GARCH coefficients and evaluate the degree of persistence.

According to the three sub-periods, as shown in Table 5, the ARCH and GARCH coefficients are generally statistically significant for each pair of Islamic and conventional indices, thus indicating significant time-varying co-movements. In addition, the ARCH coefficient is lower than the GARCH coefficient, significant, close to zero and less than 0.05 showing a small response to innovation. Moreover, the GARCH coefficient is significantly high indicating a large persistence of the conditional correlation in the future. The persistence of the conditional correlation measured by the sum of the ARCH and GARCH coefficients is generally high and close to 1. This, in turn, confirms the high persistence of the variance. This sum satisfies the condition of $\alpha_{DCC} + \beta_{DCC} < 1$, implying that the conditional variance is mean-reverting toward its equilibrium.

In order to check the financial contagion hypothesis, according to the two periods of low volatility and high volatility (crisis), all pairs of conventional and Islamic markets exhibit a high degree of co-movement vis-à-vis the U.S. stock index, leading to positive and significant correlation between all stock markets under-consideration. Therefore, no significant temporary shift in co-movements between these pairs was observed, as the degree of correlation intensification between these two periods is weak. Thus, these findings lead us to accept the hypothesis of the interdependence between the U.S. stock index and the conventional and Islamic stock markets, and thus the contagion, in this case, manifests itself as a fundamentals-based contagion rather than pure contagion. Thus, interdependence is explained by the substantial development of technology that allows traders to transmit information more quickly from one financial market to another, by the increase of the capital flow between countries following less restrictive controls on asset market transactions, through financial liberalization, deregulation and market integration. All of this has led to greater market interdependence and, as a result, this conclusion has major policy implications and a significant impact on current risk management practices. During the crisis period, the DCC-GARCH coefficients increased quite slightly in comparison with the pre-crisis period, suggesting close ties and strong co-movements between both Islamic and traditional pairs. According to the ARCH effect (α_{DCC}), we notice that the Islamic pairs, USC/UKI and USC/CAI respectively, are more vulnerable to shocks than their counterparts. On the other hand, the conventional pairs, USC/EUPC, USC/EMGC and USC/ASIAC respectively, are more influenced by shocks than their Islamic counterparts. And in accordance with the GARCH effect (β_{DCC}), we notice, on the one hand, that the Islamic pairs USC/EUPI and USC/EMGI are slightly higher than their traditional counterparts and, on the other hand, the conventional pairs USC/UKC, USC/CAC and USC/ASIAC are slightly higher than their Islamic equivalents. However, in the post-crisis period, we notice that the degree of long-term persistence of the conditional correlation between the respective USC/UKC, USC/UKI, and USC/EUPI pairs has significantly decreased relative to those during the pre-crisis period during the crisis. In short, according to the DCC-GARCH model (1,1), we note that the values of both market pairs are very similar, and so we can conclude that there is no significant difference between the Islamic and conventional financial systems, which implies that Islamic indices present, overall, the same risk as their conventional benchmarks during crises. Such findings, however, are far from supporting the argument that Islamic financial markets are more resilient to financial shocks and that there is no financial contagion effect on these markets. We may, therefore, reject the resilience hypothesis and the decoupling hypothesis of Islamic indices from their traditional equivalents. Therefore, our study using the DCC-GARCH model (1,1) supports the interdependence hypothesis under the different sub-periods of the 2007-2009 global financial crisis between the pairs under-consideration.

5.3. Asymmetry in conditional correlations : the ADCC-GJR-GARCH (1.1)-*t* estimates

Based on the Bayesian information criterion, the above GJR–GARCH (1.1)-*t* model is the most properly specified model compared to other univariate GARCH-type processes. Considering the advantages of this model, Table 6 reports the estimation results from the bivariate ADCC model for the Islamic and conventional equity indices vis-à-vis the U.S. conventional stock market to examine dynamic co-movements and financial contagion. Besides, Figure. 3 (please see Appendix D) indicates the evolution of ADCC behaviour over time.

Table 6
ADCC-GJR-GARCH (1.1)-*t* model estimation for the entire period.

Variance Equation					
Markets	*ARCH* (α_{ADCC})	*GARCH* (β_{ADCC})	*Asymetry* (γ)	*Persistence and Stationarity* $\alpha + \beta + \gamma < 1$	*Student-df*
USC →UKC	0.011838***	0.979142***	0.002561**	0.9935	10.14513
	(0.003)	(0.000)	(0.049)		(0.000)
USC →CAC	0.023653***	0.962767***	0.004178***	0.9905	9.953248
	(0.000)	(0.000)	(0.001)		(0.000)
USC → EUPC	0.015406***	0.973343***	0.003332**	0.9920	10.73480
	(0.000)	(0.000)	(0.023)		(0.000)
USC → EMGC	0.020644***	0.951193***	0.004783**	0.9766	9.279594
	(0.001)	(0.000)	(0.015)		(0.000)
USC → ASIAC	0.022538***	0.960206***	0.005827***	0.9885	10.47877
	(0.000)	(0.000)	(0.000)		(0.000)
USC →UKI	0.012400***	0.967526***	0.004074***	0.984	10.56887
	(0.003)	(0.000)	(0.009)		(0.000)
USC →CAI	0.037945***	0.942945***	0.001750***	0.9826	8.437361
	(0.000)	(0.000)	(0.000)		(0.000)
USC → EUPI	0.010629***	0.966567***	0.004507***	0.9817	10.73711
	(0.009)	(0.000)	(0.004)		(0.000)
USC → EMGI	0.014247***	0.963296***	0.004490**	0.9820	10.16251
	(0.003)	(0.000)	(0.011)		(0.000)
USC → ASIAI	0.063570***	0.924897***	0.000372***	0.9888	6.506942
	(0.000)	(0.000)	(0.000)		(0.000)

Notes : (***), (**) and (*) denote the significance at 1%, 5% and 10% levels respectively. The values reported in the last column correspond to the sum of the ARCH and GARCH coefficients and evaluate the degree of persistence.

The estimate results depicted in Table 6 document that most coefficients are statistically significant at 1% level. The estimates of the parameters α_{ADCC} and β_{ADCC} are positive and significantly different from zero. Furthermore, the estimate of the asymmetric term γ is significantly positive, implying the presence of asymmetric movements. This finding indicates that correlations among the stock indices are considerably greater during extreme downturns than during upturns. Overall, these results suggest that, in general, the data set fits the model specification very well, and thus, the derived dynamic conditional correlation series can offer a reasonable inference on the evolution of correlations over time. In general, the dynamic co-movements, according to this table, is strong and positive between the couples under-consideration, which take us to conclude the presence of contagion effects between the conventional and Islamic pairs vis-à-vis the U.S. equity market and that all the regions are largely affected by the 2007-2009 subprime crisis. Thus, this empirical result suggests that the 2007-2009 global financial crisis has similarly affected Islamic and conventional markets, which, in turn, presents a similar risk for the investor in diversifying his portfolio since portfolio strategies are highly sensitive to the dynamic correlation between financial assets, particularly during periods of recession and expansion. Finally, according to the ADCC model, we can confirm the rejection of resilience and decoupling hypotheses of Islamic indices from their conventional counterparts in the context of the subprime crisis.

As shown in Fig. 3, the 2007-2009 stock market crash hits all cross correlations. According to Jouini (2015), this is of great interest since the recourse to equity portfolio diversification techniques rises in high instability periods. Also, we notice a great correlation between the markets under-consideration which starts from 2008 following the beginning of the subprime crisis, and which continues until 2013 after the sovereign debt crisis 2011-2012. Moreover, it is deduced that the variations are well observable according to the ADCC model since there are very large peaks across the different regions of the two types of indices. This can be explained by the incorporation of asymmetric effects by the ADCC model in contrast to the DCC model. In sum, the Islamic and conventional stock markets prove a similar behaviour with respect to the U.S. conventional stock market which justifies the contagion effect in the context, firstly by, the financial crisis 2007-2009 and secondly by the sovereign debt crisis 2010-2012 and the harmful impact of these latter on a global level.

5.4. Best fit model

To check the best suitable model for our sample, we use the AIC criterion as set out in table 7. Hence, Table 7 shows that the ADCC- JGR-GARCH (1,1)-*t* model is best suited for estimating returns on Islamic and conventional equities. This is explained by its properties as it also takes into account asymmetry in conditional volatility and the leverage effect in dynamic conditional correlations.

Table 7
AIC criterion for the best fit model.

DCC-GARCH (1 ,1)		ADCC-GJR-GARCH(1,1)-*t*	
USC/UKC	5.567074	USC/UKC	5.399299
USC/CAC	5.279047	USC/CAC	5.101926
USC/EUPC	5.362105	USC/EUPC	5.202628
USC/EMGC	5.492059	USC/EMGC	5.420066
USC/ASIAC	5.698661	USC/ASIAC	5.661037
USC/UKI	5.529996	USC/UKI	5.328559
USC/CAI	5.159567	USC/CAI	5.084325
USC/EUPI	5.397876	USC/EUPI	5.329263
USC/EMGI	5.452173	USC/EMGI	5.383388
USC/ASIAI	5.656538	USC/ASIAI	5.611779

Source : Author's calculations.

6. Discussion

As is evident, the findings of the DCC and ADCC GARCH models are consistent with those of the BEKK-GARCH model. This indicates that the transmission of volatility (conditional variance) is positively related to the increased correlation between stock markets, suggesting that the diversification benefits decrease significantly during volatile periods. Cappiello et al. (2006) point out that if correlations and volatilities move in the same direction, long-term risks are higher than short-term risks. However, the strong integration between the U.S. conventional stock market and the traditional and Islamic stock markets indicates that there is no diversification benefit since performance and return are strongly correlated in these markets. In short, instability has not spared the Islamic stock markets as an intrinsic feature of the current financial system. These latter were unable to avoid the effects of the 2007-2009 global financial crisis. This study shows that the Islamic stock index do not respond to financial shocks differently from traditional markets and do not provide a safe haven for investors during the U.S. recession.

Therefore, this finding may be attributable to (i) the selection criteria of the islamic indices, which leads to a high concentration in certain sectors and thus results in more volatile returns and subsequently a decline in financial performance, (ii) a very restricted investment universe which limits diversification potentials and involves specific risks which can not be compensated by higher returns and better performance, (iii) the constant rise in monitoring costs and this continuous monitoring could lead to frequent adjustments of portfolio composition, as well as losses and additional transaction costs. This is especially true during the downturn, as a decrease in the value of equity immediately increases the debt ratio. Thus, shares that are ineligible will be sold at a loss. So managers, like their counterparts in conventional investment, often will find it difficult to implement a ' buy-and-hold' strategy under these circumstances. Moreover, portfolio managers and Islamic investors who seek to invest according to Shariah principles can add additional asset categories to their portfolios to mitigate risk. However, despite all the prohibitions imposed by Shari'ah principles on Islamic investments, this situation presents the most disappointing result from the perspective of religious investors and risk diversifiers. Thus, our result is in line with previous studies by Kiliç and Bugan (2016), Kim and Sohn (2016), Ben Rejeb (2017), Umar and Suleman (2017), and Abu Hasan (2019).

7. Conclusion

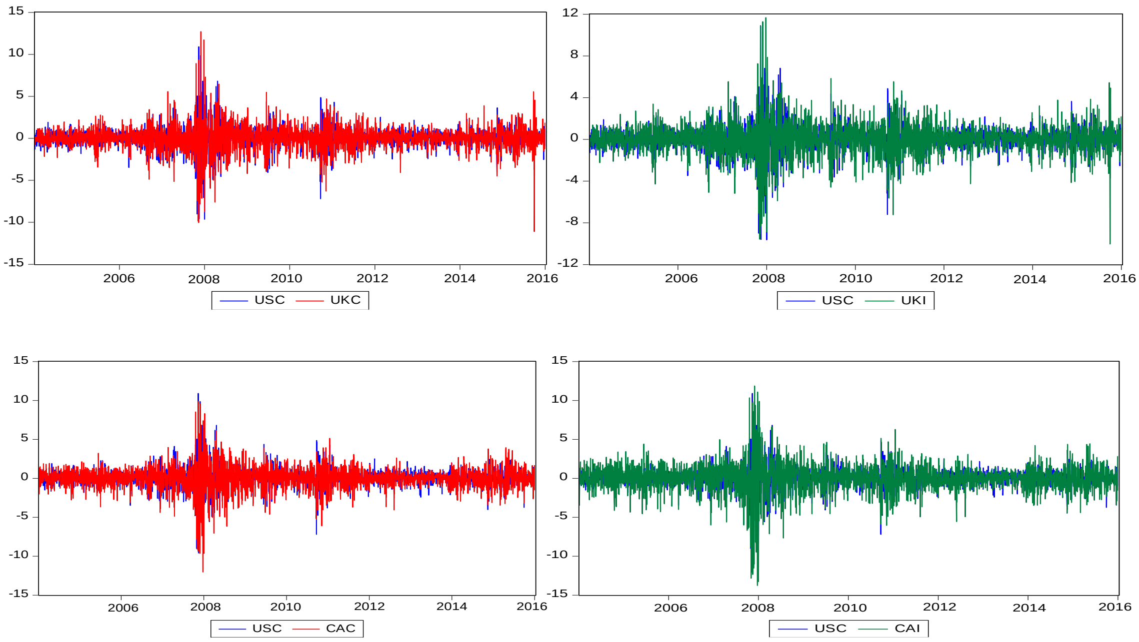
The contagion effect on financial markets during extreme market movements is one of the primary concerns of market participants, investors and policymakers. The portfolio strategies are strongly sensitive to the dynamic correlation between financial assets, particularly during crisis period. The continuous growth of Islamic equity has raised the question of whether they can offer effective diversification benefits, which may partially replace the use of conventional equity, particularly in turmoil periods.

Our study attempts to explore stock market co-movements and volatility spillover of the GFC among Islamic equity markets and their conventional counterparts vis-à-vis the U.S. conventional stock market for different regions (Asia–Pacific, U.S., Eurozone, United Kingdom, Canada and Emerging countries) between 2004 and 2016 using a mutivariate BEKK-GARCH, DCC-GARCH and ADCC-GJR-GARCH-*t* models. The main goal of this comparative study is to find whether Islamic equity markets are less integrated among the conventional system, as well as less susceptible to the most recent crises.

We find that the concerned equity markets are significantly affected by historical periods of both regional as well as global shocks from the 2007-2009 global financial crisis and these shocks have been transmitted via strong linkages, thereby representing evidence of volatility spillover and contagion effects. Also, this evidence shows that the United States is a source of volatility transmission and contagion during this crisis.

In summary, the empirical results show that the examined Islamic indices are also exposed to global shocks common to the world financial system or to contagion risks in the case of financial crises. In contrast to previous work on Islamic equity markets (e.g., Kenourgios et al., 2016) and in line with others (e.g., Dewandaru et al., 2014 and Majdoub and Mansour, 2014), this paper provides the strongest evidence to reject the decoupling of Islamic equity from the crises. Finally, this finding implies that investors who invest in Islamic stocks should distinguish between markets and regions and thus maintained better possibilities for profitable asset allocation.

Appendix A



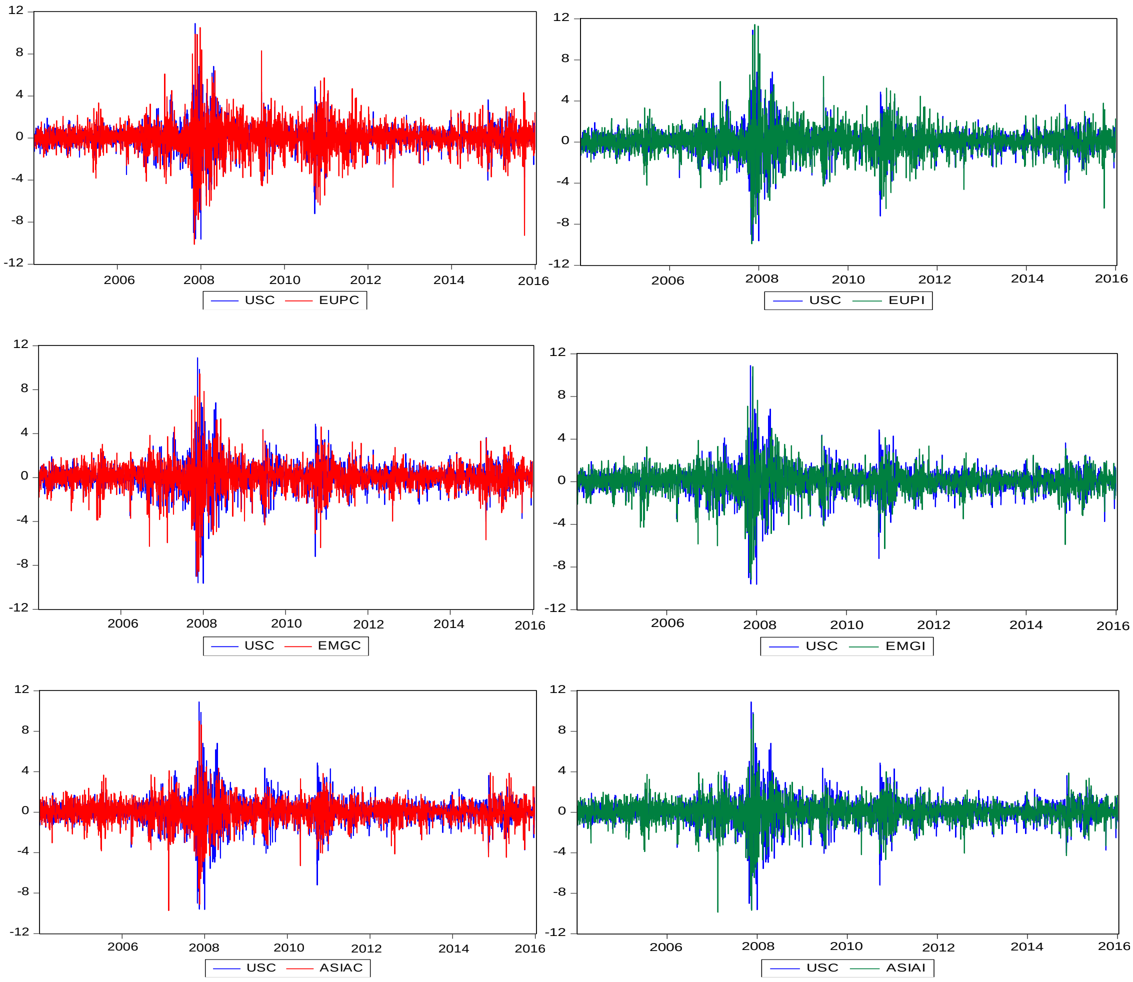


Fig. 1. Country pairs' daily moving correlation coefficients

Appendix B

Volatility spillovers and Financial contagion test assumptions

These tests consist of checking for volatility spillovers and correlation increases over time using the variance-covariance matrix and dynamic conditional correlation matrix. In this context, it's well knowen that the United States was the country at the origin of the subprime crisis. In this regards, our comparative study, consists of a unidirectional analysis of shock and volatility transmissions from the U.S. conventional stock market to all other conventional and Islamic stock markets under-consideration during the entire sample et the tree sub-sample (prior-during and after the crisis) in order to explore the causal link and the existence of financial contagion between pairs under-consideration. According to Majdoub and Mansour (2014), the impact of the crisis is measured by the increase in co-movements and volatility transmission during the crisis. In this regard, we will analyse the phenomenon of contagion in terms of the transmission of volatility from one crisis-generating country to another by examining the assumptions for the entire sample period and the three sub-sample.

Thus the hypotheses regarding this section are manifested as follows:

- **Assumptions related to shock and volatility spillovers**

The most important feature of the BEKK model is the explanation of the causal relation between variance and conditional covariance. Following Majdoub and Mansour (2014), the existence of any causal link between the variance and covariance included in H_t implies that the off-diagonal coefficients of matrices A (aij) and B (bij) are statistically significant. Moreover, the significance of the off-diagonal coefficients indicates the presence of volatility spillover from the U.S. conventional stock market to Islamic stock markets and their conventional counterparts. Kim and Sohn (2016) suggest that only the level of significance of the parameters is important, not the sign, since only the squared ARCH and GARCH terms enter the path of volatility transmission. However, in the context of the subprime crisis, the positive (negative) sign indicates a strong (weak) transmission of shocks and volatility from the American conventional stock market to both types of conventional and Islamic stock markets.

$h_{12,t}$ represents the conditional covariance between the series, therefore:

- *Assumption* 1 :

H_0 : ($\alpha_{USC/islamic}$, $\beta_{USC/islamic}$) and ($\alpha_{USC/conventional}$, $\beta_{USC/conventional}$) : are non-significant[6] → Absence of transmission of shocks and volatility among market pairs under-consideration : (no spillover effect and resistance to the subprime crisis).

- *Assumption* 2 :

H_1 : ($\alpha_{USC/islamic}$, $\beta_{USC/islamic}$) and ($\alpha_{USC/conventional}$, $\beta_{USC/conventional}$) : are significant → evidence of transmission of shocks and volatility from the US convenional stock market to the Islamic and conventional stock market under-consideration : (evidence of spillover effect).

- *Assumption* 3 :

[6] Past shocks and volatility on the U.S. conventional stock market do not affect the current conditional volatility of the conventional/Islamic markets. As a result, the current conditional volatility of the conventional and Islamic markets does not depend on the past shocks and volatility of the U.S. conventional stock market.

($\alpha_{USC/islamic}$, $\beta_{USC/islamic}$) < ($\alpha_{USC/conventional}$, $\beta_{USC/conventional}$)[7] during the entire and the crisis periods → strong support to the resilience hypothesis and the decoupling hypothesis.

- *Assumption* 4 :

($\alpha_{USC/islamic}$, $\beta_{USC/islamic}$) > ($\alpha_{USC/conventional}$, $\beta_{USC/conventional}$) during the entire and the crisis periods → the resilience hypothesis and the decoupling hypothesis are widely rejected.

- **Assumptions related to financial contagion**

As far as financial contagion is concerned, evidence of a temporary change in co-movement through various markets during crisis periods can be found. Indeed, there are two distinct theoretical camps regarding transmission channels of contagion: pure and fundamentals-based contagion (interdependence), (Dewandaru et al., 2014). Forbes and Rigobon (2002) claim that pure contagion is an excessive transmission of shocks beyond any specific disturbances and fundamental links. However, the fundamentals-based contagion, as N'Diaye et al. (2010) mentioned, is transmitted through financial market integration and interdependence or trade linkages.

In this study, the presence of the contagion is generally verified by an explicit statistical test: two periods are chosen: an expasion period and a period of crisis (or turbulence). The null hypothesis of no contagion is that the crisis affects one country or the shock propagation mechanism remains the same in both periods (interdependence). The rejection of the null hypothesis means that both countries are affected by the crisis or that the transmission mechanism has changed considerably between the stable period and the period of crisis, which suggests the presence of contagion. In this context, Forbes and Rigobon (2002) have shown that contagion and interdependence cause an increase in correlation, but that a contagion event leads to a relatively greater increase. Following Goetzmann et al. (2005), a correlation of 40% or more during a stable period would be interpreted in this study as a strong positive correlation, which will serve as a guide to interpret market relationships before and during the crisis.

[7] Islamic indices are resilient to financial crises and decoupled from the conventional universe.

❖ ***The entire period of study:***

- *Assumption 1 :*

H₀ : $(\alpha_{USC/islamic}, \beta_{USC/islamic})$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional}) \leq 0$: are weak/non-significant → negative correlation and absence of co-movements between market pairs : (no contagion).

- *Assumption* 2 :

H₁ : $(\alpha_{USC/islamic}, \beta_{USC/islamic})$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional}) > 0$: are strong/significant → positive correlation and increased co-movement between market pairs : (contagion).

❖ ***The Sub- periods of study: Contagion or interdependence ?***

- *Assumption 1 :*

$(\alpha_{USC/islamic}, \beta_{USC/islamic})_{prior\text{-}crisis}$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional})_{prior\text{-}crisis} = (\alpha_{USC/islamic}, \beta_{USC/islamic})_{crisis}$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional})_{crisis} =$ the degree of intensification of the correlation between the stable and crisis periods is weak → interdependence[8], with highly integrated markets.

- *Assumption* 2 :

$[(\alpha_{USC/islamic}\ \beta_{USC/islamic})_{prior\text{-}crisis}$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional})_{prior\text{-}crisis} \neq (\alpha_{USC/islamic}, \beta_{USC/islamic})_{crisis}$ and $(\alpha_{USC/conventional}, \beta_{USC/conventional})_{crisis}] =$ the degree of intensification of the correlation between the stable and crisis periods is strong → pure contagion[9].

- *Assumption* 3 :

$[\Delta\ (\alpha_{USC/conventional}, \beta_{USC/conventional}) > \Delta\ (\alpha_{USC/islamic}, \beta_{USC/islamic}) = (\alpha_{USC/conventional}, \beta_{USC/conventional})_{crisis} - (\alpha_{USC/conventional}, \beta_{USC/conventional})_{prior\text{-}crisis} > (\alpha_{USC/islamic}, \beta_{USC/islamic})_{crisis} - (\alpha_{USC/islamic}, \beta_{USC/islamic})_{prior\text{-}crisis}] =$ strong support to the resilience hypothesis and the decoupling hypothesis.

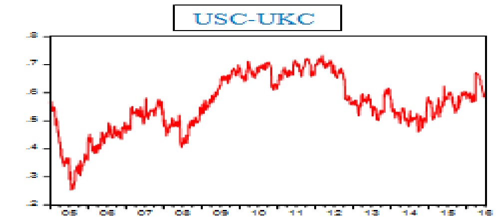
- *Assumption* 4 :

$[\Delta\ (\alpha_{USC/conventional}, \beta_{USC/conventional}) = \Delta\ (\alpha_{USC/islamic}, \beta_{USC/islamic})] = [((\alpha_{USC/conventional}, \beta_{USC/conventional})_{crisis} - (\alpha_{USC/conventional}, \beta_{USC/conventional})_{prior\text{-}crisis}) = ((\alpha_{USC/islamic}, \beta_{USC/islamic})_{crisis} - (\alpha_{USC/islamic}, \beta_{USC/islamic})_{prior\text{-}crisis})] \rightarrow$ the resilience hypothesis and the decoupling hypothesis are widely rejected.

[8] The correlation generated endogenously or fundamentals based-contagion.

[9] Thanks to a shock (crisis), the conditional correlation increased. In this context, there is a phenomenon of transmission of exogenous shocks following the volatility spillover between market pairs.

Appendix C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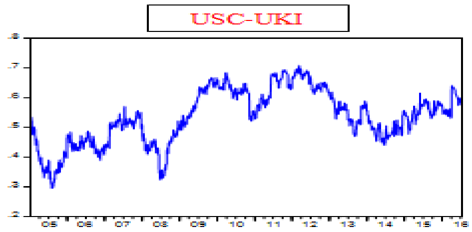
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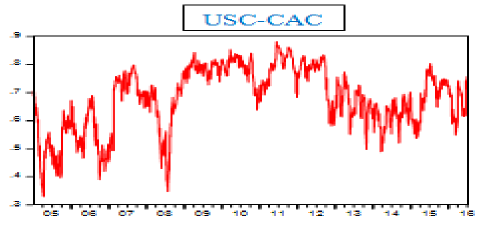
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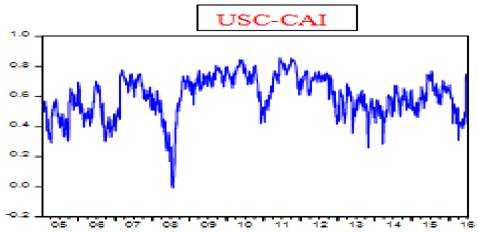
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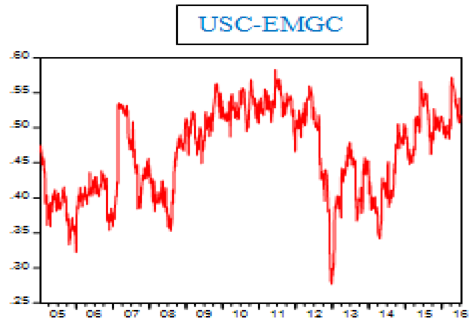
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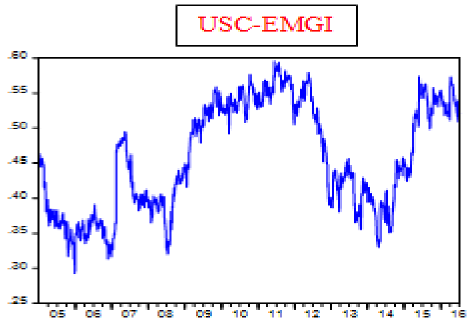
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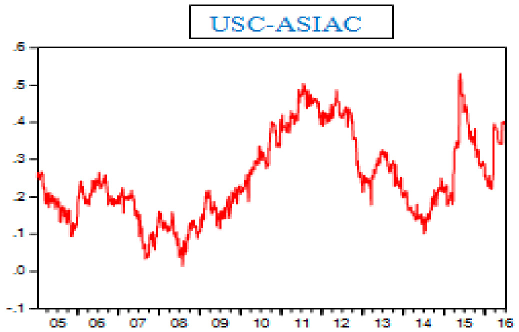
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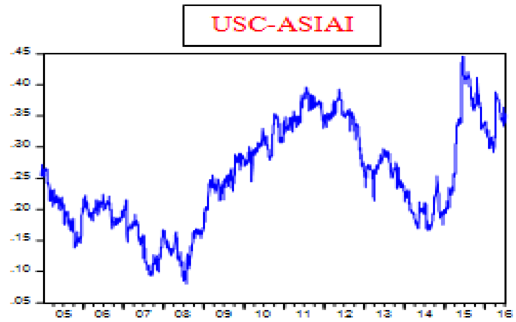
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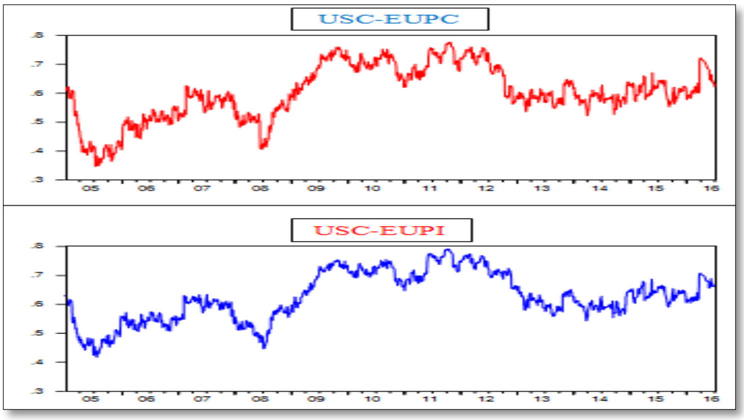
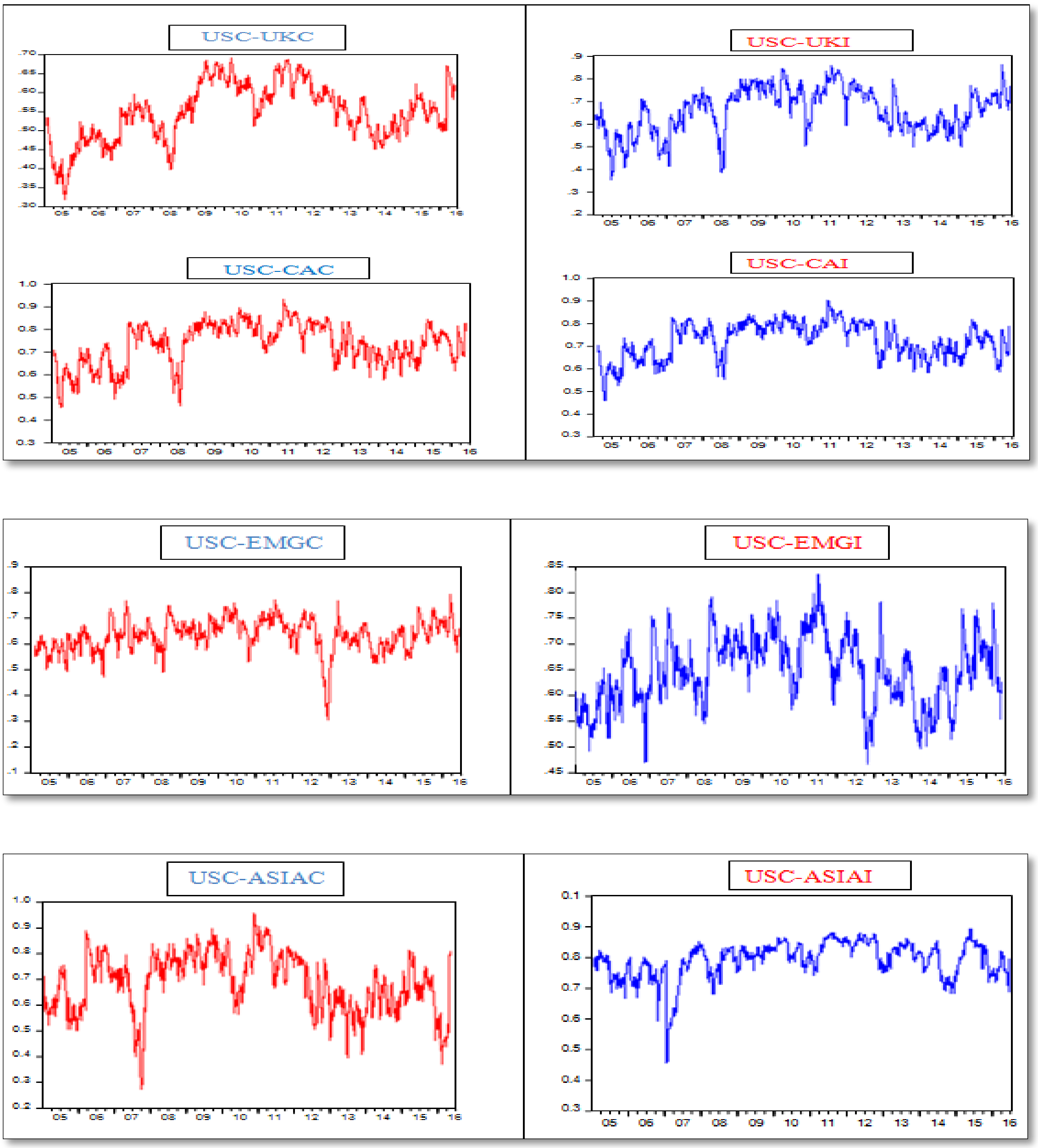


Fig. 2. Time-varying daily conditional correlations (DCC) with U.S. market

Appendix D



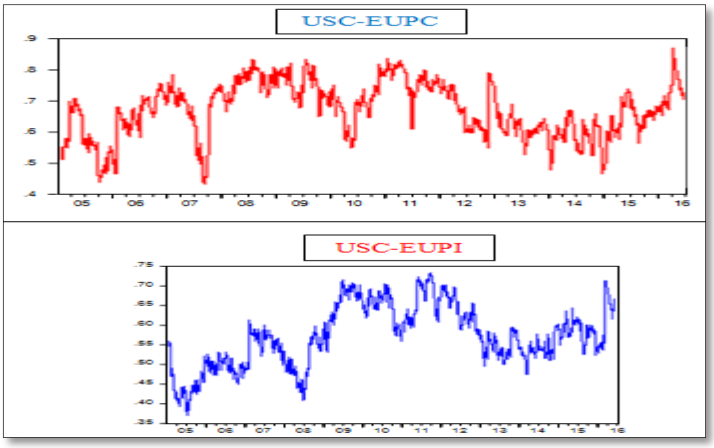


Fig. 3. Time-varying daily asymmetric conditional correlations (ADCC) with U.S. market

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