The Effect of Recent Financial Crisis over Global Portfolio Diversification Opportunities – Empirical Evidence A Comparative Multivariate GARCH-DCC, MODWT and Wavelet Correlation Analysis

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The Effect of Recent Financial Crisis over Global Portfolio Diversification Opportunities – Empirical Evidence

A Comparative Multivariate GARCH-DCC, MODWT and Wavelet Correlation Analysis

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ABSTRACT

The purpose of this paper is to analyze the possible portfolio diversification opportunities between Asian Islamic Market and other regions' Islamic Markets; namely USA, Europe and BRIC. This study makes the initial attempt to fill in the gaps of previous studies by focusing on the proxies of global Islamic markets - based on the 6 years' daily data, from 04/2008 to 03/2014 - to identify the correlations among those selected markets by employing the recent econometric methodologies such as MGARCH-DCC, MODWT and the Continuous Wavelet Transform (CWT). By utilizing the MGARCH-DCC, this paper tries to identify the strength of the correlation among the markets. On the other hand, to see the time-varying nature of these mentioned correlations, we utilized CWT. For robustness, we have applied MODWT methodology as well. The findings tend to indicate that the Asian investors have a better portfolio diversification opportunities with the US markets followed by the European markets. BRIC markets do not offer any portfolio diversification benefits, which may be explained partly by the fact that the Asian markets cover partially the same countries of BRIC markets, namely India and China. Considering the time horizon dimension, the results narrow down the portfolio diversification opportunities only to the short-term investment horizons. The very short-run investors (up to 8 days only) can benefit through portfolio diversification, especially in the USA and European markets. The above-mentioned results have policy implications for the Asian Islamic investors (e.g. Portfolio Management, Strategic Investment Management).

Keywords – MGARCH-DCC, MODWT, Continuous Wavelet Transform CWT, Contagion, Volatility Spillover, Shariah Indices.

1 Introduction: The Issue Motivating This Paper

The economic integration of international stock markets has become especially relevant over the last two decades. The substantial development of technology and the increased flow of capital between countries are the main factors for this globalization process. Thus, understanding the linkages between different financial markets is of great importance for portfolio managers and financial institutions. Volatility, as measured by the standard deviation or variance of returns, is often used as a crude measure of the total risk of financial assets (Brooks, 2002), so when referring to international equity markets integration, researchers not only investigate the return causality linkages, but they also measure volatility spillover effects. Information about volatility spillover effects is very useful for the application of value at risk and hedging strategies.

Recently, with the role of the emerging markets becoming more important, economists not only focus on developed countries, e.g. United States, the United Kingdom and Japan, but they also pay great attention to the emerging markets. For example, in the equity markets, the extent of the linkages of the emerging stock market exchanges with developed stock market exchanges has important implications for both the developing and the developed countries' investors. If the emerging market stock exchange is only weakly integrated with the developed market, it has the implication that there would be portfolio diversification possibilities for developed countries' investors through including the emerging market stocks in their portfolio as this diversification should reduce risk, and vice versa. On the contrary, if the emerging stock markets were fully integrated with the developed stock markets, there would not be any portfolio diversification benefit for either developed and/or emerging countries' investors.

Several researches (Kumar and Mukhopadhyay (2002), Wong, Agarwal and Du (2005) support the notion that there is a correlation between the various markets globally. Furthermore, Yang (2005) inspected the international stock exchange correlations between Japan and the Asian Four Tigers (Hong Kong, Singapore, South Korea and Taiwan) and found that stock exchange correlations vary widely over time and volatilities seem to be contagious across the markets. The importance of these studies was also confirmed by Levy and Sarnat (1970) in which they have shown, how the correlations between developed and developing countries provide a paramount risk-reduction benefit.

More recently the focus of the studies of these topics shifted to the contagion effect of Financial Crisis. For example, Lucia and Bernadette's (2010) analysis show the evidence that the current global financial crisis has been affecting differently the world economic regions. In the same year, Charles, Darne and Pop (2010) discovered that during the crisis, both Islamic and conventional indexes were affected to the same degree by variance changes. However, in terms of portfolio diversification, Achsani et al (2007) in general finds that the interdependence of the Islamic stock markets tend to be asymmetric across a wide geographical area. While there are strong correlations between the Islamic stock indices of Indonesia and Malaysia, the US and Canada, and Japan and Asia Pacific, this is not exactly the case across the region.

Grubel's fundamental work in 1968, the idea of international portfolio diversification resulting in lower portfolio risks is still broadly acknowledged and accepted in the literature. International stock market relations are very important to international investors and funds managers to identify a set of international stocks that forms a best diversified portfolios with the lowest possible risks (Dajcman et al, 2012). The substance of lower risks from international diversification is significantly reliant upon low correlations across cross-border markets (Grubel and Fadner, 1971). Therefore, an increase in co-movements between asset returns of international stock market can subsequently reduce the advantage of international diversified investment portfolios (Ling and Dhesi, 2010). It has been further accepted in the literature that correlations amongst markets are rising through time due to changes in interdependence across markets (Engle, 2002). Likewise, market returns are not only time varying, but may also be reliant on time scales highlighting the importance of investment horizons (Gencay et al, 2001).

Over the past decade, the global financial markets have observed the fast growing "Islamic Financial Sector". According DeLorenzo (2000) the Islamic financial system is founded around the fundamentals of Shari'ah (Islamic Law) that requires profits from investment to be earned in an ethical and socially responsible way that follow teachings of Islam. Equities traded under Shari'ah indices run through a screening procedure to guarantee they are free from the prohibited elements as commanded by Shari'ah. The common screening elements comprise of riba (interest rates), gharar (uncertain outcomes), maysir (gambling), prohibited commodities (liquor, pork, etc.) and fulfillment of contractual requirements as required in Islamic Law of Contracts (Rosly, 2005). Over the past decade, the average annual growth rates of the Islamic financial sector range between 15% to 20% per annum (IIFM, 2010), this fact invites researchers and investors to study and analyze the volatilities and co-movement of asset returns amongst Shari'ah compliant indices across regions to provide Islamic investors and fund managers an idea on riskiness and potential international portfolio diversifications benefits.

In spite of the fact that there is enormous number of studies in portfolio diversification issues focusing on different regions, the concentration of the studies were based on the conventional (Shariah non-compliant) stock indices. Thus, this paper attempts to study the portfolio diversification aspect with the focus only on the Sharia Indices of the selected regional financial markets. We concentrate in our study on four regional Islamic financial markets; those are BRIC, European, USA and Asian, with the Asian being selected as the focus market. These markets represent a global picture of the potential possibilities of portfolio diversification benefits. Hence, the specific research questions of this study are as follows:

1. Should the Asian Islamic stock market investors invest in USA, European or BRIC markets to gain international portfolio diversification benefits?

2. Given the answer from the previous research question, how would the international portfolio diversification strategy change given different investor stock holding periods (e.g. 2-4 Days, 4-8 Days, 8-16 Days, etc.)?

The results from each of the research questions are expected to have significant implications for the regional Islamic market, specifically for the Asian Islamic stock market investors and fund managers in their decisions concerning portfolio allocations and investment horizons.

The unique contributions of this study which enhance existing literature is in empirically testing for the "time-varying & scale dependent" volatilities and correlations of the selected regional financial markets. Particularly, by integrating scale dependence, this study is able to identify unique portfolio diversification opportunities for different type of investors with different investment horizons or holding periods of stocks (for e.g. weekly, monthly, quarterly, etc.). The ability to do this is achieved by applying the modern empirical research techniques: Multivariate Generalized Autoregressive Conditional Heteroscedastic – Dynamic Conditional Correlations (MGARCH-DCC) model of Engle (2002) and the Continuous Wavelet Transform (CWT) analysis of volatility and correlations, and the Maximal Overlap Discrete Wavelet Transform (MODWT) analysis.

First part of our findings suggest that Asian investors have a better portfolio diversification opportunities with the US markets followed by the European markets. BRIC markets do not offer any portfolio diversification benefits which can be explained partly by the fact that the

Asian markets cover partially the same countries of BRIC market, namely India and China. The second part of our findings considers the time horizon dimension and the results narrow down the portfolio diversification opportunities only to the short-term investment horizons, i.e. 2-8 days. Overall, excepting the very short-run, the markets are all highly correlated yielding minimal portfolio diversification benefits. As a result, the Asian investors are advised to consistently re-asses their stock exposures and holding positions within a period of one year and ideally every month or two.

The following chapters of this study are organized as follows. Chapter 2 discusses the existing literature and it is followed by the theoretical underpinnings and the very recent methodology used in chapter 3 and 4, respectively. Data, empirical results and discussions are dealt in chapter 5. Finally, this paper ends with the conclusion in chapter 6 followed by the future research suggestions in chapter 7.

2 Literature Review

2.1 Co-movement among the financial markets

Acknowledging the rapid growth of Islamic financial industries during the last three decades, researchers have started shifting their focus to the integration of both Islamic and conventional stock markets. However, in comparison with the studies on the conventional stock markets, efforts devoted to the Islamic stock markets are still trivial. Hence, it is the opinion of the author that there is not sufficient research conducted on the unity of global Islamic indices using the wavelet technique.

In Lucia and Bernadette’s (2010) analysis, in regards to the contagion effects in a worldwide framework, shows the evidence that the current global financial crisis has been affecting differently the world economic regions. In general terms, there is no evidence that supports the existence of world market or across regional market contagion effects. Further, they claim that instead of contagion, markets suffered mostly from spillover effects, originating from the US economy and that were transmitted and propagated by some key countries in to the different regions (Singapore in Asia, UK in Europe) Lucia and Bernadette’s (2010). According to Rizvi and Arshad (2013) the ripples of the financial crisis are still being felt over different parts of the world causing much distress to the real economy. The capital market, in particular, took a massive hit during the crisis declined to all-time lows. However in the pace of globalization, a financial shock to the US capital market can cause a spillover effect to other markets; including the Islamic capital market.

Charles, Darne and Pop (2010) discovered that during the crisis, both Islamic and conventional indexes were affected to the same degree by variance changes. Conversely, when they tested the indices over other periods, it was found that the variance was not the same, where Islamic indices showed a slightly higher volatility as compared to their financial counterpart. However in contrary, Al-Zoubi and Maghyereh (2007) found Islamic indices to be less risky than the benchmark, accrediting it to the profit and loss sharing principle in Islamic finance.

While studying the correlation between indices, Rizvi and Arshad (2012) suggest a low moving correlation between the conventional and Islamic indices substantiating that Islamic index may provide a better alternative for hedging against crisis.

Several researches (Kumar and Mukhopadhyay (2002), Wong, Agarwal and Du (2005) support the notion that there is a correlation between the various markets globally. They further emphasis that dramatic movements in one equity market can have a powerful impact on different market. The same applies for Islamic indices, where any volatility in major global markets is very likely to influence Islamic indices Majid, Meera and Omar (2007), Rahman and Sidek (2011), Siskawati (2010). Karim, Kassim and Arip (2010) and Yusof and Majid (2007) contradict this, as they failed to find any empirical existence of co-integration among the Islamic indices.

With the abovementioned studies, this paper attempts to contribute to the literature on the Islamic stock market by undertaking a unique study of how the regional Islamic stock markets are correlated to each other by employment of the new econometric technique like MGARCH-DCC, Wavelet etc.

2.2 International portfolio diversification

International stock index diversification studies date from the 1970s, when globalization and international investing became paramount (e.g. see Levy and Sarnat, 1970; Solnik, 1974, 1982; Black and Litterman, 1992; Jankus, 1998). The fundamental focus of such research is to examine the size of the constant correlations to determine the relative diversification benefits of constructing international stock portfolios. For example, Levy and Sarnat (1970) show how the correlations between developed and developing countries provide a paramount risk-reduction benefit, while Solnik (1974) provides evidence that combining stocks from US and European countries generates portfolios that are only half as risky as domestically well-diversified portfolios of US stocks. Nevertheless, several studies in the past concentrate on constant correlations and the profits of diversification to US investors, consequently other attributes of international stock portfolios and the diversification benefits to foreign investors are regularly disregarded. New insight about the financial market interdependence raised in later studies after the stock market crash in 1987 which partially contradicted the previous theories and empirical results. Using seven months of daily data before and after October 1987 in Dwyer and Hafer (1988) confirms that changes in the stock price indices in USA, Germany and Japan are generally related. Further studies, for example, by Eun and Shim (1989), Von Furstenberg and Jeon (1989), Bertera and Mayer (1990), likewise examined different stock price indices around stock markets crash of 1987 and discovered significant correlations among national stock markets.

Later, inconsistencies in the empirical finding appeared in the literature finding strong correlation among markets - for instance, the studies in Becker et al (1990), Hamao et al. (1990), and Kasa (1992) find strong correlation between USA and Japan stock markets with an asymmetric spill-over effects from the US to the Japanese stock market. Different other studies found contradicting results for the same market samples – for instance, Smith et al. (1993) recommending that the US equity prices don't lead Japanese equity prices. Furthermore, Li et al (2003), Rezayat and Yavas (2006), Flavin et al (2008), Middleton et al. (2008), and Mansourfar et al (2010) are the latest studies with the same objective of international portfolio diversification opportunities.

In short, studies on the stock market linkages and its resulting impact for international portfolio diversification strategies have remained inconclusive with results reporting contradicting evidence. Subsequently this subject needs further investigation.

2.3 Time-varying and scale dependent correlations

Numerous late studies have empirically tested and given proof that the correlation crosswise over national markets may not be consistent and are developing through time. For e.g. Longin and Solnik (1995) study the correlation and covariance of monthly excess returns for seven significant nations over the period 1960-1990 and find that both correlations and covariances are volatile over time. Yang (2005) inspected the international stock exchange correlations between Japan and the Asian Four Tigers (Hong Kong, Singapore, South Korea and Taiwan) and found that stock exchange correlations vary widely over time and volatilities seem to be contagious across the markets. Also, correlation increase during periods of high market volatilities when risk diversification is required most, and that is bad news for international diversification. Most recently, Dacjman et al (2012) find that co-movement dynamics between the developed European stock markets of the United Kingdom, Germany, France and Austria are not constant and returns are time varying. Subsequently, when modeling volatilities and correlations, it is more proper to utilize time varying correlations models as contrasted with constant connections model.

Additionally, studies have likewise found that investment holding periods (for e.g. 2 days, 6 days, 30 days, etc.) also have an effect on the volatilities and correlations dynamics of stock market returns. This kind of research is relatively new and there are a couple of empirical papers that incorporated time-scaling in examining volatilities and correlations. Gencay et al (2001) were one of the earliest supporters of the time scaled dependence of returns and correlations in financial markets. In and Kim (2013) have group a cluster of their papers using wavelet time-scaling in finance to produce a book simply published called “An introduction to Wavelet Theory in Finance”. Dacjman et al (2012), in their late study on co-movement dynamics between the developed European stock markets of the United Kingdom, Germany, France and Austria also find evidence in favor of scale dependence for stock market returns. Subsequently, future studies are recommended to consider the time scale properties in modeling volatilities and correlations.

2.4 Islamic stocks and portfolio diversification

Shari'ah advocates socially responsible investments incl. profit-sharing, partnership, leasing and sale-based contracts, in contrast to fixed interest earnings (Girard and Hassan, 2008). Consequently, conventional debt-based instruments such as treasury bills, corporate bonds, certificates of deposits and preferred stocks are prohibited to be used as means of incomes or source of funds (Merdad et al, 2010). In addition, conventional insurance products are prohibited as they involve uncertainties in outcomes which are contingent on insured events occurring and Islamic principles require commercial transactions to be free from ambiguity. Concequently, several derivative products such as trading of futures, warrants, options, as well as short-selling and anything speculative is prohibited (El-Gamal, 2000). Investments in non-productive and/or potentially harmful activities such as pure games of chance, prostitution, production and/or distribution of non-permissible products such as alcohol, tobacco, pork, pornography and arms are also prohibited according Shari’ah (Hassan, 2001).

Empirical studies on stock market integration among Islamic stock markets worldwide are relatively scarce compared to the extensive numbers of studies on integration and performances among conventional stock markets both in the West and Islamic countries (Moeljadi, 2012). Hakim and Rashidian (2004) endeavored to study the returns performances of the Dow Jones Islamic Market Index (DJIM), Dow Jones World Index (DJW) and Dow Jones Supportability World Index (DJS). Utilizing a capital asset pricing model (CAPM) framework, they found that DJIM has performed well compared the DJW, however has failed compared to DJS. Hussein (2005) broke down the DJIM returns for the period 1996 to 2003 and found that Islamic indices provide investors with positive unusual returns throughout the bull market period, but they fail in performance against their counterpart non-Islamic indices during the bear market period.

Abderrezak (2008) studies 46 Islamic Equity funds (IEFs) during January 1997 to August 2002. Applying Fama's 3 factor model, he finds that Islamic funds performed poorly against their respective indices. The co-movement of IEFs returns with the market, measured by the betas, is low and he found poor evidence for selectivity. Small cap firms and growth preference stocks significantly affect IEFs and finally he found that IEFs do suffer from lower diversification.

Achsani et al (2007) study finds in terms of portfolio diversification, that the interdependence of the Islamic stock markets tends to be asymmetric across a wide geographical area. More specific, there are strong correlations between the Islamic stock indices of Indonesia and Malaysia, the US and Canada, and Japan and Asia Pacific, but this is not exactly the case for across the region basis. Additionally, the study finds that while the Islamic stock market in the US has a strong influence on the other Islamic stock markets, the reverse is not true. In particular, the Indonesian, Malaysian, Canadian and Asia Pacific stock markets have smaller effects on the US' Islamic stock market. However an earlier study, Aziz and Kurniawan (2007) conclude that there are potential diversification benefits for investors considering the Islamic stock markets in Indonesia and Malaysia. In particular, detailed empirical investigation using recent econometric analysis finds that the Jakarta Islamic Index and the Kuala Lumpur Shari'ah Index have significant leverage and asymmetric effects. Other studies such as Majid (2010), Kassim (2012), Kamil et al (2012) etc. also find mixed results in their analysis.

As evident from the review above, there are inconsistencies in empirical literature analyzing the portfolio diversification properties of the Islamic indices across the globe. While some studies find evidence of strong correlations across Islamic stock indices, others have found Islamic stocks to be weakly correlated allowing investors to gain international diversification opportunities.

3 Theoretical Underpinnings

The academic underpinnings expected in this paper draw upon from the fundamental works of Markowitz (1959) ”Modern Portfolio Theory” and Grubel (1968) “Internationally Diversified Portfolios”. Markowitz formed the contemporary portfolio hypothesis where the volatility of a portfolio is less than the weighted average of the volatilities of the securities it holds given that the portfolio comprises of assets that are not completely correlated in returns. The variance of the expected return on a portfolio might be estimated as:

$$\sigma_p^2 = (\Sigma W_i^2\sigma_i^2 + \Sigma\Sigma W_i W_j Cov_{ij})$$

Where the sums are over all the securities in the portfolio, W_i is the proportion of the portfolio in security i, σ_i is the standard deviation of expected returns of security i, and Cov_{ij} is the covariance of expected returns of securities of i and j. Assuming that the covariance is less than one (which is always true), this will be less than the weighted average of the standard deviation of the expected returns of the securities. This is why diversification reduces risk.

Drawing from Markowitz’s model, Grubel (1968) applied the modern portfolio theory to explore the potential benefits of holding long-term international assets. Grubel modeled international portfolio diversification benefits between two countries A and B as follows:

$$E(r_{a,b}) = W_a R_a + W_b R_b$$

$$V(r_{a,b}) = W_a^2\sigma_a^2 + W_b^2\sigma_b^2 + 2W_a W_b Cov_{ab}$$

Where $E(r_{a,b})$ is the expected returns on portfolio invested in Country A and B with investment weights of W_a and W_b and $V(r_{a,b})$ measures the variance on the portfolio. The crucial factor here is the Cov_{ab} and the lower the covariance between countries A and B, the greater would be diversification benefits. Grubel found that if US investors allocate a part of capital to foreign stock markets, they could achieve a significant reduction in portfolio risk and better portfolio return opportunities.

Subsequent to these seminal papers, various writers have attempted to empirically test the covariance of asset returns amongst cross-border stock markets in order to identify international portfolio diversification opportunities. A higher covariance between asset returns can therefore diminish the advantage of internationally diversified investment portfolios (Ling and Dhesi, 2010). This paper drawing upon such theoretical foundations also studies the volatilities and cross-correlations amongst sample Islamic stock indices to answer the research questions albeit using recent empirical methodologies.

One of the criticisms of the earlier models of modern portfolio theory was the assumption that the portfolio variances are normally distributed. Markowitz himself thought normally distributed variances are inadequate measure of risk. However, subsequent models have been developed that use asymmetric and fat tailed distributions that are closer to real world data. The methodology to be adopted in this paper M-GARCH-DCC has the ability to adopt a student-*t* distribution of variances which is more appropriate in capturing the fat-tailed nature of the distribution of index returns (Pesaran and Pesaran, 2009). Furthermore, the use of wavelet transform methodologies makes no assumptions and is tantamount to produce more realistic results (In and Kim, 2013). The paper elaborates the methodologies to be adopted in achieving the research objectives in the following section.

4 The Methodology Used

4.1 Multivariate GARCH & Dynamic Conditional Correlations (DCC)

One of the earliest volatility models, autoregressive conditional heteroscedastic (ARCH), was proposed by Engle (1982) which captured the time-varying conditional variances of time series based on past information. This model was then enhanced by Bollerslev (1986) who proposed a generalized ARCH (GARCH) which took into account both past error terms and conditional variances into its variance equation simultaneously to avoid the problem that the number of parameters to be estimated becomes too large as the number of lagging periods to be considered increases in the ARCH model. Bollerslev (1990) further extended the GARCH model in a multivariate sense to propose a Multivariate GARCH – Constant Conditional Correlation (MGARCH-CCC) model where the conditional correlation amongst different variables were assumed to be constant. The MGARCH-CCC model only allows the variances of each variable to be time varying while keeping the correlation coefficient among them constant. However, while the CCC assumption makes estimation simple, it may be inconsistent with reality (Longin and Solnik, 1995, 2001). Therefore, Engle (2002) finally proposed an MGARCH-DCC model where the conditional correlations amongst variables were allowed to be dynamic and this paper makes use of this model in answering parts of the research questions. It can be stated as follows:

$$\mathbf{r}_t = \boldsymbol{\beta}_0 + \sum_{i=1}^{k} \boldsymbol{\beta}_i \mathbf{r}_{t-i} + \mathbf{u}_t = \boldsymbol{\mu}_t + \mathbf{u}_t$$

$$\boldsymbol{\mu}_t = E[\mathbf{r}_t | \Omega_{t-1}]$$

$$\mathbf{u}_t | \Omega_{t-1} \sim N(0, \mathbf{H}_t)$$

$$\mathbf{H}_t = \mathbf{G}_t \mathbf{R}_t \mathbf{G}_t$$

$$\mathbf{G}_t = \text{diag}\left\{\sqrt{h_{ii,t}}\right\}$$

$$\mathbf{z}_t = \mathbf{G}_t^{-1} \mathbf{u}_t$$

Source: Ku (2008)

Where $h_{ii,t}$ is the estimated conditional variance from the individual univariate GARCH models, $\mathbf{G_t}$ is the diagonal matric of conditional standard deviations, $\mathbf{R_t}$ is the time-varying conditional correlation coefficient matrix of returns, and $\mathbf{z_t}$ is the standardized residuals vector with mean zero and variance one. After the above basic construction, the dynamic correlation coefficient matrix of the DCC model can be specified further:

$$\begin{aligned} \mathbf{R}_t &= (\mathrm{diag}(\mathbf{Q}_t))^{-1/2}\mathbf{Q}_t(\mathrm{diag}(\mathbf{Q}_t))^{-1/2} \\ \mathbf{Q}_t &= (q_{ij,t}) \\ (\mathrm{diag}(\mathbf{Q}_t))^{-1/2} &= \mathrm{diag}\left(\frac{1}{\sqrt{q_{11,t}}}, \ldots, \frac{1}{\sqrt{q_{nn,t}}}\right) \\ q_{ij,t} &= \overline{\rho}_{ij} + \alpha(z_{i,t-1}z_{j,t-1} - \overline{\rho}_{ij}) \\ &\quad + \beta(q_{ij,t-1} - \overline{\rho}_{ij}) \end{aligned}$$

Source: Ku (2008)

Where $\overline{\rho}_{ij}$ is the unconditional correlation coefficient and the new time-varying conditional correlation coefficient is $\rho_{i,j,t} = q_{i,j,t}/\sqrt{q_{ii,t}\,q_{jj,t}}$. Meanwhile, the returns on financial assets have often been documented to be fat tailed or leptokurtic where a normal distribution assumption is not appropriate. One possible remedy for such is to use a Student-*t* distribution setting. That is, the conditional distribution $\mathbf{u}_t|\Omega_{t-1} \sim N(0, \mathbf{H}_t)$ is replaced by $\mathbf{u}_t|\Omega_{t-1} \sim f_{\text{Student}-t}(\mathbf{u}_t; v)$, where v is the degree of freedom parameter.

4.2 Maximum Overlap Discrete Wavelet Transformation (MODWT)

Co-movements between stock market returns may not only be time varying, but also scale dependent (Gencay et al., 2001), and can be analyzed with wavelet tools. A MODWT-based estimator has been shown to be superior to the earlier DWT-based estimators (Percival, 1995). The MODWT is a variant of the discrete wavelet transform (DWT) that, unlike the classical DWT, can handle any sample size and not just those that are multiples of 2^x. The MODWT is highly redundant, non-orthogonal transform – this enables alignment of the decomposed wavelet and scaling coefficients at each level with the original time series, thus allowing a ready comparison between the series and its decompositions. This feature is not in DWT. The MODWT variance estimator is also asymptotically more efficient than the same estimator based on the DWT. MODWT is generally known as stationary wavelet transform, shift or translation invariant DWT, time invariant DWT, and non-decimated DWT. Hence, this research makes use of the MODWT method which can be described as follows.

Let $\boldsymbol{X}$ be an N-dimensional vector whose elements represent the real-valued time series $\{X_t: t = 0, \ldots, N-1\}$. For any positive integer, J_0, the level J_0 MODWT of $\boldsymbol{X}$ is a transform consisting of the $J_0 + 1$ vectors $\widetilde{W}_1, \ldots, \widetilde{W}_{J_0}$ and $\widetilde{V}_{J_0}$, all of which have dimension $\boldsymbol{N}$. The vector $\widetilde{W}_J$ contains the MODWT wavelet coefficients associated with changes on scale $\tau_j = 2^{j-1}$ (for $j = 1, \ldots, J_0$) while $\widetilde{V}_{J_0}$ contains MODWT scaling coefficients association with averages on scale $\lambda_{J_0} = 2^{J_0}$. Based on the definition of MODWT coefficients we can write (Percival and Walden, 2000, p. 200):

$$\widetilde{W}_J = \widetilde{W}_J X \text{ and } \widetilde{V}_J^0 = \widetilde{V}_J^0 X$$

Where $\widetilde{W}_J$ and $\widetilde{V}_{J_0}$ are N x N matrices. Vectors are denoted by bold italics. By definition, elements of $\widetilde{W}_J$ and $\widetilde{V}_{J_0}$ are outputs obtained by filtering $\boldsymbol{X}$, namely:

$$\widetilde{W}_{j,t} = \sum_{l=0}^{L_{j-1}} \widetilde{h}_{j,l} \, X_{t-l \bmod N}$$

and

$$\widetilde{V}_{j,t} = \sum_{l=0}^{L_{j=1}} \widetilde{g}_{j,l} \, X_{t-l \bmod N}$$

For $t = 0, \ldots, N-1$, where $\widetilde{h}_{j,l}$ and $\widetilde{g}_{j,l}$ are jth MODWT wavelet and scaling filters.

The MODWT treats the series as if it were periodic, whereby the unobserved samples of the real-valued time series $X_{-1}, X_{-2}, \ldots, X_{-N}$ are assigned the observed values at $X_{N-1}, X_{N-2}, \ldots, X_0$. The MODWT coefficients are thus given by:

$$\widetilde{W}_{j,t} = \sum_{l=0}^{N-1} \widetilde{h}_{j,l}^{\circ} \, X_{t-l \bmod N}$$

and

$$\widetilde{V}_{j,t} = \sum_{l=0}^{N-1} \widetilde{g}_{j,l}^{\circ} X_{t-l \bmod N} \text{(for } t = 0, \ldots, N-1;$$

$\widetilde{h}_{j,l}^{\circ}$ and $\widetilde{g}_{j,l}^{\circ}$ are periodization of $\widetilde{h}_{j,l}^{\circ}$ and $\widetilde{g}_{j,l}^{\circ}$ to circular filters of length N)

Wavelet variance is defined for stationary and non-stationary processes with stationary backward differences. Considering only the non-boundary wavelet coefficient, obtained by filtering stationary series with MODWT, the wavelet variance $v_X^2(\tau_j)$ is defined as the expected value of $\widetilde{W}_{j,t}^2$. In this case $v_X^2(\tau_j)$ represents the contribution to the (possibly infinite) variance of $\{X_t\}$ at the scale $\tau_j = 2^{j-1}$ and can be estimated by the unbiased estimator (Percival and Walden, 2000, p. 306):

$$\hat{v}_X^2(\tau_j) = \frac{1}{M_j} \sum_{t=L_j-1}^{N-1} \widetilde{W}_{j,t}^2$$

where $M_j \equiv N - L_j + 1 > 0$ is the number of non-boundary coefficients at the *j*th level.

The MODWT correlation estimator for scale τ_j is obtained by making use of the wavelet cross-covariance and the square root of wavelet variances:

$$\hat{\rho}_{X,Y}(\tau_j) = \frac{\hat{v}_{X,Y}(\tau_j)}{\hat{v}_X(\tau_j)\hat{v}_Y(\tau_j)}$$

Where $|\hat{\rho}_{X,Y}(\tau_j)| \leq 1$. The wavelet correlation is analogous to its Fourier equivalent, the complex coherency (Gencay et al., 2002, p. 258).

4.3 Continuous Wavelet Transformation (CWT) and Wavelet Coherence (WTC)

There has been a general practice to utilize Fourier analysis to expose relations at different frequencies between interest variables. However, the shortcomings of the use of Fourier transform for analysis has been well established. A big argument against the use of Fourier transform is the total loss of time information and thus making it difficult to discriminate ephemeral relations or to identify structural changes which is very much important for time series macro- economic variables for policy purposes. Another strong argument against the use of Fourier transform is the reliability of the results. It is strongly recommended (i.e., it is based on assumptions such as) that this technique is appropriate only when time series is stationary, which is not so usual as in the case with macro-economic variables. The time series of macro-economic variables are mostly noisy, complex and rarely stationary. To overcome such situation and have the time dimensions within Fourier transform, Gabor (1946) introduced a specific transformation of Fourier transform. It is known as the short time Fourier transformation. Within the short time Fourier transformation, a time series is bro- ken into smaller sub-samples and then the Fourier transform is applied to each sub-sample. However, the short time Fourier transformation approach was also criticized on the basis of its efficiency as it takes equal frequency resolution across all dissimilar frequencies (see, for details, Raihan et al., 2005). Hence, as solution to the above mentioned problems wavelet transform took birth. It offers a major advantage in terms of its ability to perform "natural local analysis of a time-series in the sense that the length of wavelets varies endogenously: it stretches into a long wave- let function to measure the low-frequency movements; and it com- presses into a short wavelet function to measure the high-frequency movements" (Aguiar-Conraria and Soares, 2011, p. 646). Wavelet possesses interesting features of conduction analysis of a time series variable in spectral framework but as function of time. In other words, it shows the evolution of change in the time series over time and at different periodic components i.e., frequency bands. However, it is worthy to mention that the application of wavelet analysis in the economics and finance is mostly limited to the use of one or other variants of discrete wavelet transformation. There are various things to consider while applying discrete wavelet analysis such as up to what level we should decompose. Further, it is also difficult to under- stand the discrete wavelet transformation results appropriately. The variation in the time series data, what we may get by utilizing any method of discrete wavelet transformation at each scale, can be obtained and more easily with continuous transformation.

Even if wavelets possess very interesting features, it has not become much popular among economists because of two important reasons as pointed out by Aguiar-Conraria et al. (2008). Aguiar-Conraria et al. (2008, p. 2865) pointed out that “first, in most economic applications the (discrete) wavelet transform has mainly been used as a low and high pass filter, it being hard to convince an economist that the same could not be learned from the data using the more traditional, in economics, band pass-filtering methods. The second reason is related to the difficulty of analyzing simultaneously two (or more) time series. In economics, these techniques have either been applied to analyze individual time series or used to individually analyze several time series (one each time), whose decompositions are then studied using traditional time-domain methods, such as correlation analysis or Granger causality.”

A number of authors have recently begun to use the continuous wavelet transform (CWT) in economics and finance research (for e.g. see Vacha and Barunik (2012), Madaleno and Pinho (2012), Saiti (2012), etc.). The CWT maps the original time series, which is a function of just one variable time-separate into function of two different variables such as time and frequency. One major benefit CWT has over DWT/MODWT is that we need not define the number of wavelets (time-scales) in CWT which generates itself according to the length of data. Other than that, the CWT maps the series correlations in a two-dimensional figure that allows us to easily identify and interpret patterns or hidden information. For both MODWT and CWT, we use the Daubechies (1992) least asymmetric wavelet filter of length L=8 denoted by LA (8) based on eight non-zero coefficients. Previous studies on high-frequency data have shown that a moderate-length filter such as L=8 is adequate to deal with the characteristic features of time-series data (see Gencay et al., 2001, 2002, In and Kim 2013, etc.). In literature, it is argued that an LA (8) filter generates more smooth wavelet coefficients than other filters such as Haar wavelet filter.

The continuous wavelet transform (CWT) $W_X(u,s)$ is obtained by projecting a mother wavelet ψ onto the examined time series $x(t) \in L^2(\mathbb{R})$, that is:

$$W_X(u,s) = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{s}} \psi\left(\frac{t-u}{s}\right) dt$$

The position of the wavelet in the time domain is given by *u*, while its position in the frequency domain is given by *s*. Therefore, the wavelet transform, by mapping the original series into a function of *u* and *s*, gives us information simultaneously on time and frequency. To be able to study the interaction between two time series, how closely X and Y are related by a linear transformation, we need to apply a bivariate framework which is called wavelet coherence. The wavelet coherence of two time series is defined as:

$$R_n^2(s) = \frac{\left|S(s^{-1}W_n^{xy}(s))\right|^2}{S(s^{-1}|W_n^x(s)|^2 . S(s^{-1}\left|W_n^y(s)\right|^2}$$

Where *S* is a smoothing operator, *s* is a wavelet scale, $W_n^x(s)$ is the continuous wavelet transform of the time series X, $W_n^y(s)$is the continuous wavelet transform of the time series Y, $W_n^{xy}(s)$ is a cross wavelet transform of the two time series X and Y (Madaleno and Pinho, 2012). For brevity, we omit further detailed mathematical equations and interested readers may refer to Gencay et al (2001; 2002) and In and Kim (2013) for full methodological models.

5 Data Analysis and Empirical Results

5.1 Descriptive Statistics

In addressing our research question, we utilize four indices for the empirical investigation; firstly, the S&P ASIA PAC x JAPAN BMI Shariah Index is used as a focus variable where the stocks for this index are drawn from the Asian country indices in the S&P Global BMI index, excluding Australia, Japan and New Zealand. Additionally, three other indices are employed here, S&P 500 Shariah Index. This index is widely regarded as the best single gauge of the U.S. equities market, this world-renowned index includes 500 leading companies in leading industries of the U.S. economy. S&P EUROPE 350 Shariah Index, which combines the benefits of representation with replication for the Europe region, spanning 17 exchanges and S&P BRIC Shariah Index that is designed to provide exposure to the leading companies from the emerging markets of Brazil, Russia, India, and China, while at the same time complying with Shariah law. These mentioned Islamic indices were selected to represent a global picture the potential possibilities of portfolio diversification benefits.

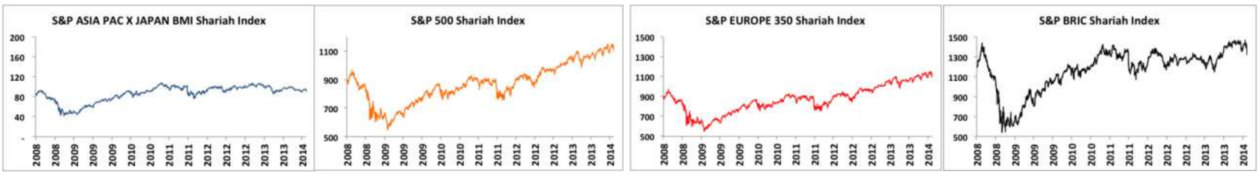
All the sample indices are from Standard & Poor's Indices family. Primarily, two reasons contribute towards sticking with Standard & Poor's Indices, firstly, for the purpose of uniformity' in the underlying universe of stocks and index pricing computation. Secondly, in order to have a harmonized Shariah screening criterion in the Islamic indices. All index providers follow roughly a similar criterion, but with slight variations in cut-offs for different ratios. Sticking with Standard & Poor's Islamic Indices family provides us this consistency.

We have taken daily values of indices, transformed to daily returns for an extended time period of 6 years starting from April 7, 2008 to March 14, 2014; covering 1549 daily observations.

Table 1: Selected Indices for Research

#	Code	Description
1	**ASIA**	S&P ASIA PAC X JAPAN BMI Shariah Index
2	**USAM**	S&P 500 Shariah Index
3	**EURO**	S&P EUROPE 350 Shariah Index
4	**BRIC**	S&P BRIC Shariah Index

Figure 1: Graphs based on the raw data



Preliminary observation of graphs from Figure 1 suggests that the variables are of random walk in nature. At the first glance it can be seen that BRIC represent high volatility (ASIA least volatile) over the last 6 years.

Table 2: Descriptive Statistics of Indices Returns Series

#	Code	Mean	Median	Minimum	Maximum	Std. Dev.	Skewness	Kurtosis	Obs
1	**ASIA**	0.00006	0.00030	-0.14770	0.14800	0.01862	0.17720	15.10362	1549
2	**USAM**	0.00012	0.00050	-0.07390	0.09910	0.01259	0.11440	9.63846	1549
3	**EURO**	0.00004	0.00050	-0.12920	0.13740	0.01620	-0.51633	9.73948	1549
4	**BRIC**	0.00032	0.00030	-0.08630	0.11540	0.01267	0.02240	11.17960	1549

From now onwards we are going to answer the questions of this study by employing MGARCH-DCC, CWT and MODWT (for robustness) respectively.

5.2 Research Question01: Should the Asian Islamic stock market investors invest in USA, European or BRIC markets to gain international portfolio diversification benefits?

We ran a MGARCH-DCC analysis on the S&P ASIA PAC X JAPAN BMI Shariah Index returns, S&P BRIC Shariah Index returns, S&P EUROPE 350 Shariah Index returns and S&P 500 Shariah Index returns. First we look at the unconditional volatilities and correlations and the results are illustrated in Table 4 below[1].

Table 3: Unconditional volatility and correlations – ASIA, BRIC, EURO and USAM

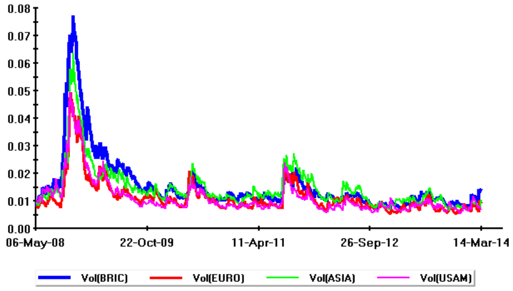
	ASIA	BRIC	EURO	USAM
ASIA	***0.01626***	0.64358	**0.43442**	**0.27356**
BRIC	0.64358	***0.01871***	0.66249	0.61934
EURO	**0.43442**	0.66249	***0.01263***	0.55622
USAM	**0.27356**	0.61934	0.55622	***0.01269***

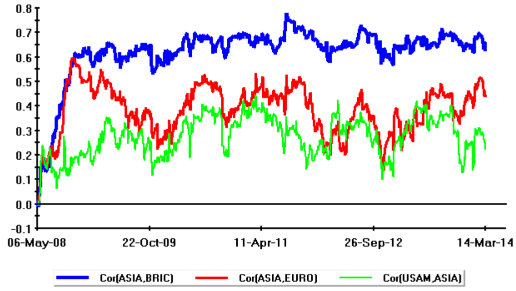
The diagonal elements in *italics* represent the volatilities of the returns while the off-diagonal elements illustrate the unconditional correlations between returns. Based on the unconditional results, we find that European Shariah index returns **are least volatile** (0.01263) followed by USA Shariah index returns (0.01269), Asian Shariah index returns (0.01626) and BRIC Shariah index returns (0.01871). Furthermore, it appears an Asian investor is **better off by investing in USA market followed by the European market to gain portfolio diversification benefits** as opposed to the BRIC market as the correlations in returns are much lower for USA market (0.27) and European market (0.43) as compared to BRIC market (0.64). We proceed to examining the dynamic conditional correlations which capture the time-varying properties in volatilities and correlations. Figures 2 and 3 illustrate the results.

Figure 2: Conditional Volatilities – ASIA, BRIC, EURO and USAM

Figure 3: Conditional Correlations – ASIA with BRIC, EURO and USAM

[1] Please refer to Appendix 1 to see the underlying data driven from the Micro-fit upon which the results are shown in this part of the study and the necessary tests applied regarding MGARCH-DCC methodology.





Figures 2 and 3 confirm the time-varying properties of volatilities and correlations. Figure 2 illustrates a stable volatility nature of all markets prior the financial crisis of 2008. However, the BRIC markets returns hits the highest volatility in a very short time during the financial crisis followed by the Asian market returns. This can be explained by that the Asian market covers partially the same countries of BRIC market, namely India and China. US and European markets' returns face similar volatility magnitude and being the least volatile among those selected markets. Post financial crisis however, the volatilities of all markets more or less move together and are similar. Figure 3 confirms that consistently, the Asian returns are less correlated with US market return as compared to the European and BRIC markets returns. However, post financial crisis the correlation between Asian and European market returns follow the same pattern as the Asian and US market return. Hence it suggests Asian investors are better off by investing in US markets followed by the European markets to gain portfolio diversification benefits.

We suspected that the BRIC returns maybe highly correlated with Asian returns since BRIC countries India and China are a component of the S&P ASIA PAC X JAPAN BMI Shariah Index.

5.3 Research Question02: Given the answer from the previous research question, how would the international portfolio diversification strategy change given different investor stock holding periods (e.g. 2-4 Days, 4-8 Days, 8-16 Days, etc.)

Earlier using MGARCH-DCC analysis, we observed how the Asian investors can gain portfolio diversification benefits by investing in US markets followed by European markets. However, the previous analysis ignored investor stock holding periods and the results were based on daily volatilities in indices. In this section, we use modern wavelet transformations to analyze the impact on portfolio diversification benefits given different investment horizons.

Figures 4 and 5 present the estimated **continuous wavelet transform** and phase difference of Asian Market returns with US Market returns, European Market returns and BRIC Markets returns from scale 1 (one day) up to scale of 9 (approximately two market years, 512 days).

Time is shown on the horizontal axis in terms of number of trading days, while the vertical axis refers to the investment horizon. The curved line below shows the 5% significance level which is estimated using Monte Carlo simulations. The figure follows a colour code as illustrated on the right with power ranges from blue (low correlations) to red (high correlations).

A first layman glance instantly confirms the lower correlations of the Asian markets returns with the USA and European markets returns as evident by the greater number of blue spots on the coherence diagram compared to the BRIC markets returns. More specifically, we find that for **very short holding periods consisting of 2-4 days and 4-8 days**, the **USA markets return and European markets returns are consistently weakly correlated to Asian returns** over the past 6 years thus **offering effective portfolio diversification opportunities.** However, temporary higher correlation between Asian and USA market returns can be seen during the Global Financial Crisis in 2008/09 and between Asian and European market returns during the Euro-Sovereign Debt crisis in 2011/12. The **same is not true for BRIC markets** where particularly during Global Financial Crisis 2008/09 and Euro-Sovereign Debt crisis 2011/12, the correlations become very high thus effectively eliminating any diversification opportunities.

For the **short investment horizon consisting of 8-16, 16-32 and 32-64 days holding periods**, once again we find **USA markets correlations to be lower correlated** as compared to European and BRIC markets which exhibit very strong levels of interdependence in returns. Thus, investors have international portfolio diversification opportunities in USA markets. However, moving towards **medium investment horizons consisting of 64-128 and 128-256 days**, interestingly we observe **post financial-crisis higher correlations for both European and BRIC markets** suggesting that investors with such holding periods are **unable to exploit international portfolio diversification opportunities**, except with the USA markets.

For **long-term investors** as well consisting of 256-512 days holding periods, there are **very strong correlations in returns for both European and BRIC markets** that **eliminate** potential international portfolio diversification **opportunities**. However, USA markets still remain less correlated and therefore offer potential opportunities for international portfolio diversification. We can clearly see the contributions of the wavelet transformations in helping us understand international portfolio diversification opportunities for investors with different investment horizons.

Figure 4: Continuous Wavelet Transform ASIA and USAM

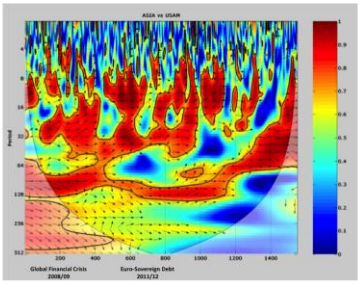


Figure 5: Continuous Wavelet Transform ASIA and EURO

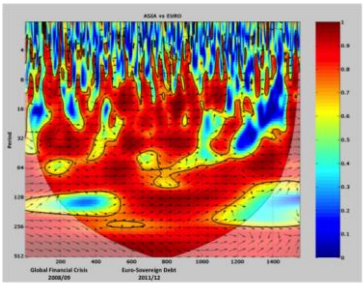
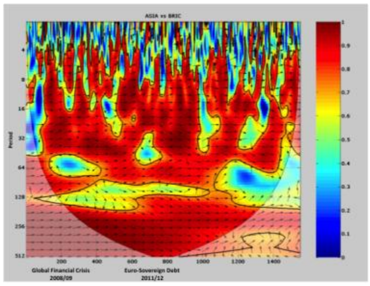


Figure 6: Continuous Wavelet Transform ASIA and BRIC



5.4 Robustness and Validation of results – application of MODWT

To further reassure ourselves regarding results from previous methodologies, we applied a Maximum Overlap Discrete Wavelet Transform (MODWT) to our original returns series for all the four indices. Unlike CWT, an MODWT requires the researcher to specify time-scales for the returns and we specified a total of seven scales (2-4 days, 4-8 days, 8-16 days, 16-32 days, 32-64 days, 64-128 days and 128-256 days). Using the newly generated MODWT returns series, we examined the correlations between the Asian Islamic stock market returns and the other index returns and the results are presented in Table 4 below[2].

Table 4: Correlations of Asian Islamic Stock Market Returns vis-à-vis other sample market returns – MODWT Transformations

MODWT Scaling	BRIC	EURO	USAM
2-4 Days	0.45	0.17	0.01
4-8 Days	0.73	0.58	0.45
8-16 Days	0.86	0.80	0.72
16-32 Days	0.88	0.80	0.71
32-64 Days	0.90	0.88	0.75
64-128 Days	0.79	0.87	0.74
128-256 Days	0.91	0.96	0.78

Note: Green shades indicate portfolio diversification opportunity due to having lower correlations with Asian returns relative to the other index and red shades are vice versa. ***Correlations exceeding the 0.6 level are arbitrarily considered to be strong*** *and hence not effective for portfolio diversification.*

[2] Please refer to Appendix 2 to see the underlying wavelet correlation tables and charts driven from the Matlab upon which the results are shown in this part of the study regarding MODWT methodology.

The results are partially consistent with the results obtained from the earlier CWT analysis. The results driven from the CWT are more transparent and accurate compared to MODWT. Therefore we rely on the CWT results. For a very short holding period of time (up to 2-4 days) all Islamic stock market returns and up to 4-8 days holding period even the European and USA market returns offer effective portfolio diversification opportunities to the Asian investors.

However, for investment horizons longer than that, the correlations are quite high thus eliminating any potential portfolio diversification opportunities for the Asian investors.

5.5 Summary of the Empirical Results

Table 5 below summarizes the empirical results from this section concerning the international portfolio diversification opportunities for Asian Islamic Stock Market investors. The table clearly highlights the answers to the objectives of this study in the form of whether any possible international portfolio diversification opportunity for Asian Islamic investors with other regions, by investing in which markets the benefits are realized. including either the dimension of different investment horizons of various investors makes any difference or not to the answer given above to the first objective. Furthermore, the differing investment horizons of various investors (e.g. 2-4 days, 4-8 days, etc.) are considered and an appropriate international portfolio diversification opportunity is identified based on such stock holding periods. This contribution is most probably the first of its kind for Asian Islamic investors.

Table 5: Summary of the overall study in a categorized form

		Objective 1: Region-based		
		BRIC	EURO	USAM
	MGARCH-DCC	N	Y	Y
	CWT			
Objective 2: Time Scaled	2-4	Y/N	Y	Y
	4-8	Y/N	Y	Y
	8-16	N	Y/N	Y/N
	16-32	N	Y/N	Y/N
	32-64	N	N	Y/N
	64-128	N	N	Y/N
	128-256	N	N	Y
	Long Term	N	N	Y/N

Note: Since the results differ based on the different year, there is no unique answer; hence we use Y/N (Yes/No) to indicate this situation

Several researches (see Kumar and Mukhopadhyay (2002), Wong, Agarwal and Du (2005) support the notion that there is a correlation between the various markets globally. They further emphasis that dramatic movements in one equity market can have a powerful impact on different market. The same applies for Islamic indices, where any volatility in major global markets is very likely to influence Islamic indices Majid, Meera and Omar (2007), Rahman and Sidek (2011), Siskawati (2010).

6 Conclusion

Understanding the linkages between different financial markets is of great importance for portfolio managers. Volatility, as measured by the standard deviation or variance of returns, is often used as a crude measure of the total risk of financial assets (Brooks, 2002), so when referring to international equity markets integration, researchers not only investigate the return causality linkages, but they also measure volatility spillover effects.

Recently, with the role of the emerging markets becoming more important, economists not only focus on developed countries, e.g. United States, the United Kingdom and Japan, but they also pay great attention to the emerging markets. For example, in the equity markets, the extent of the linkages of the emerging stock market exchanges with developed stock market exchanges has important implications for both the developing and the developed countries' investors. If the emerging market stock exchange is only weakly integrated with the developed market, it has the implication that there would be portfolio diversification possibilities for developed countries' investors through including the emerging market stocks in their portfolio as this diversification should reduce risk, and vice versa. On the contrary, if the emerging stock markets were fully integrated with the developed stock markets, there would not be any portfolio diversification benefit for either the developed and/or the emerging countries‘ investors.

More recently the focus of the studies of these topic shifted to the contagion effect of Financial Crisis. For example, Andreosso-O'Callaghan & Morales (2010) analysis show the evidence that the current global financial crisis has been affecting differently the world economic regions. In the same year, Charles, Darne and Pop (2010) discovered that during the crisis, both Islamic and conventional indexes were affected to the same degree by variance changes. However, in terms of portfolio diversification, Achsani et al (2007) in general finds that the interdependence of the Islamic stock markets tend to be asymmetric across a wide geographical area. While there are strong correlations between the Islamic stock indices of Indonesia and Malaysia, the US and Canada, and Japan and Asia Pacific, this is not exactly the case across the region.

In a nutshell, our findings suggest that Asian investors have a better portfolio diversification opportunities with the US markets followed by the European markets. BRIC markets do not offer any portfolio diversification benefits which can be explained partly by the fact that the Asian market covers partially the same countries of BRIC market, namely India and China. Furthermore, considering the time horizon dimension, the results narrow down the portfolio diversification opportunities only to the short-term investment horizons, i.e. up to 8 days. Excepting the very short-run, the markets are all highly correlated yielding minimal portfolio diversification benefits. As a result, Asian investors are advised to consistently re-asses their stock exposures and holding positions within a period of one year and ideally every month or two.

7 Suggestions for Future Research

Our analysis in this paper was performed on broad-market indices in order to recommend international portfolio diversification opportunities for the Asian Islamic investors.

As a result, future studies are recommended considering a sector-based analysis where sectors of the specific Islamic stock index (for e.g. Automobile, Manufacturing, Finance, etc.) is compared with the sectors of the other regions' Islamic stock index in order to identify portfolio diversification benefits between sectors. Such studies have great importance and value for international investors and fund managers who need to take portfolio allocation decisions that could maximize investments returns while minimizing associated risks.

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APPENDIX

1. M-GARCH/DCC Applied Tests & Results

MGARCH - Estimates (normal distribution)

3/20/2014 3:59:04 PM

Multivariate GARCH with underlying multivariate Normal distribution
Converged after 24 iterations

Based on 1529 observations from 06-May-08 to 14-Mar-14.
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.

Parameter	Estimate	Standard Error	T-Ratio[Prob]
lambda1_BRIC	.92238	.0097808	94.3049[.000]
lambda1_EURO	.88918	.015562	57.1371[.000]
lambda1_ASIA	.90584	.012985	69.7614[.000]
lambda1_USAM	.89297	.016136	55.3413[.000]
lambda2_BRIC	.073974	.0090224	8.1989[.000]
lambda2_EURO	.10066	.013399	7.5124[.000]
lambda2_ASIA	.087949	.011576	7.5974[.000]
lambda2_USAM	.099147	.014301	6.9331[.000]
delta1	.97407	.0042665	228.3044[.000]
delta2	.014532	.0020535	7.0768[.000]

Maximized Log-Likelihood = 19833.3

Estimated Unconditional Volatility Matrix
1529 observations used for estimation from 06-May-08 to 14-Mar-14
Unconditional Volatilities (Standard Errors) on the Diagonal Elements
Unconditional Correlations on the Off-Diagonal Elements

	BRIC	EURO	ASIA	USAM
BRIC	.018705	.66249	.64358	.61934
EURO	.66249	.012631	.43442	.55622
ASIA	.64358	.43442	.016261	.27356
USAM	.61934	.55622	.27356	.012690

For the time-varying conditional volatilities and correlations see the Post Estimation Menu.

Page 1

MGARCH - Estimates (t-distribution)

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Multivariate GARCH with underlying multivariate t-distribution
Converged after 26 iterations

Based on 1529 observations from 06-May-08 to 14-Mar-14.
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.

Parameter	Estimate	Standard Error	T-Ratio[Prob]
lambda1_BRIC	.92937	.011164	83.2478[.000]
lambda1_EURO	.89855	.016931	53.0727[.000]
lambda1_ASIA	.91631	.012977	70.6121[.000]
lambda1_USAM	.91093	.016022	56.8533[.000]
lambda2_BRIC	.066958	.010255	6.5295[.000]
lambda2_EURO	.091741	.014566	6.2984[.000]
lambda2_ASIA	.077395	.011463	6.7519[.000]
lambda2_USAM	.082193	.014136	5.8146[.000]
delta1	.97310	.0047699	204.0077[.000]
delta2	.016524	.0024319	6.7948[.000]
df	10.1614	1.2188	8.3373[.000]

Maximized Log-Likelihood = 19890.0

df is the degrees of freedom of the multivariate t distribution

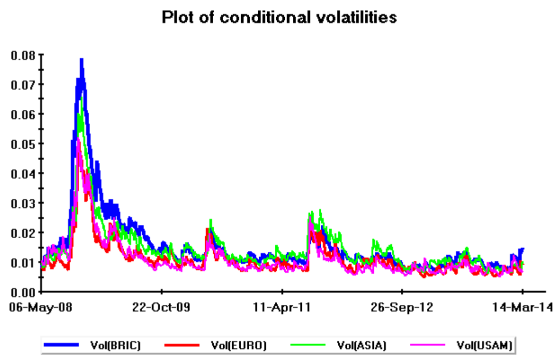
Estimated Unconditional Volatility Matrix
1529 observations used for estimation from 06-May-08 to 14-Mar-14
Unconditional Volatilities (Standard Errors) on the Diagonal Elements
Unconditional Correlations on the Off-Diagonal Elements

	BRIC	EURO	ASIA	USAM
BRIC	.018705	.66249	.64358	.61934
EURO	.66249	.012631	.43442	.55622
ASIA	.64358	.43442	.016261	.27356
USAM	.61934	.55622	.27356	.012690

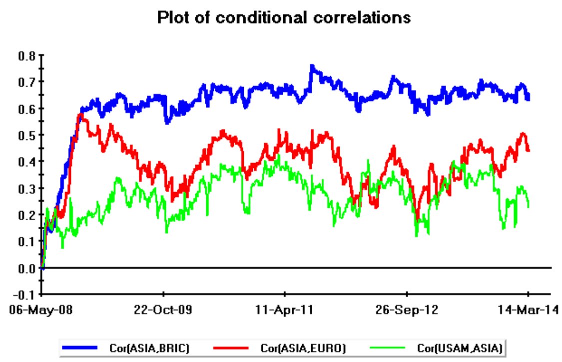
For the time-varying conditional volatilities and correlations see the Post Estimation Menu.

Page 2

MGARCH - Plot of Conditional Volatilities (normal distribution)



MGARCH - Plot of Conditional Correlations (normal-distribution)



MGARCH - Testing Linear Restrictions

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            Analysis of Function(s) of Parameter(s)
*******************************************************************
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.
1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************

List of specified functional relationship(s):
ZERO = 1 - LAMBDA1_BRIC - LAMBDA2_BRIC
*******************************************************************
Function          Estimate     Standard Error      T-Ratio[Prob]
ZERO              .0036735       .0011620          3.1613[.002]
*******************************************************************

    Estimated Variance Matrix of the Function(s) of the Parameters
   1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************
          ZERO
ZERO      .1350E-5

*******************************************************************
```

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            Analysis of Function(s) of Parameter(s)
*******************************************************************
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.
1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************

List of specified functional relationship(s):
ZERO = 1 - LAMBDA1_EURO - LAMBDA2_EURO
*******************************************************************
Function          Estimate     Standard Error      T-Ratio[Prob]
ZERO              .0097067       .0029497          3.2908[.001]
*******************************************************************

    Estimated Variance Matrix of the Function(s) of the Parameters
   1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************
          ZERO
ZERO      .8701E-5

*******************************************************************
```

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            Analysis of Function(s) of Parameter(s)
*******************************************************************
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.
1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************

List of specified functional relationship(s):
ZERO = 1 - LAMBDA1_ASIA - LAMBDA2_ASIA
*******************************************************************
Function          Estimate     Standard Error      T-Ratio[Prob]
ZERO              .0062907       .0021090          2.9828[.003]
*******************************************************************

    Estimated Variance Matrix of the Function(s) of the Parameters
   1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************
          ZERO
ZERO      .4448E-5

*******************************************************************
```

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            Analysis of Function(s) of Parameter(s)
*******************************************************************
The variables (asset returns) in the multivariate GARCH model are:
BRIC EURO ASIA USAM
Volatility decay factors unrestricted, different for each variable.
Correlation decay factors unrestricted, same for all variables.
1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************

List of specified functional relationship(s):
ZERO = 1 - LAMBDA1_USAM - LAMBDA2_USAM
*******************************************************************
Function          Estimate     Standard Error      T-Ratio[Prob]
ZERO              .0068759       .0023067          2.9808[.003]
*******************************************************************

    Estimated Variance Matrix of the Function(s) of the Parameters
   1529 observations used for estimation from 06-May-08 to 14-Mar-14
*******************************************************************
          ZERO
ZERO      .5321E-5

*******************************************************************
```

Indices	1-λ1-λ2	Std. Errors	t-ratio
BRIC	0.00367	0.00116	3.16130
EURO	0.00971	0.00295	3.29080
ASIA	0.00629	0.00211	2.98280
USAM	0.00688	0.00231	2.98080

The above result suggest very slow but statistically significant mean-reverting volatility for all indices.

MGARCH - Test of Serial Correlation of Residuals (OLS case)

3/23/2014 3:38:22 PM

Test of Serial Correlation of Residuals (OLS case)

Dependent variable is U-Hat
List of variables in OLS regression:
Intercept
265 observations used for estimation from 11-Mar-13 to 14-Mar-14

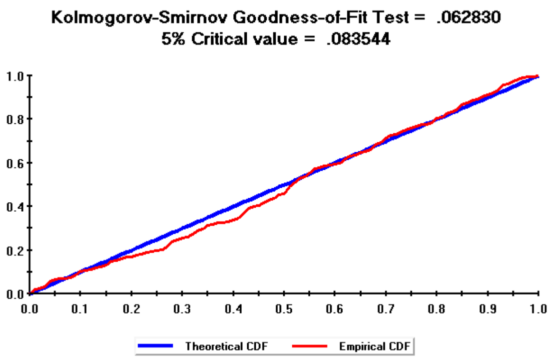
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
OLS RES(-1)	.22037	.062730	3.5130[.001]
OLS RES(-2)	-.026760	.064287	-.41625[.678]
OLS RES(-3)	.0091304	.064642	.14125[.888]
OLS RES(-4)	-.081163	.064518	-1.2580[.210]
OLS RES(-5)	.038435	.064927	.59198[.554]
OLS RES(-6)	.031605	.065046	.48588[.627]
OLS RES(-7)	.0021067	.065053	.032384[.974]
OLS RES(-8)	-.011754	.065044	-.18071[.857]
OLS RES(-9)	.073538	.065318	1.1258[.261]
OLS RES(-10)	-.017810	.065970	-.26997[.787]
OLS RES(-11)	.023591	.066074	.35703[.721]
OLS RES(-12)	-.11938	.064758	-1.8434[.066]

Lagrange Multiplier Statistic	CHSQ(12)=	18.8576[.092]
F Statistic	F(12,252)=	1.6089[.089]

U-Hat denotes the probability integral transform.
Under the null hypothesis, U-Hat should not display any serial correlation.

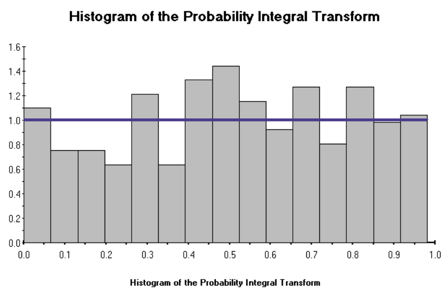
The LM test equal to 18.8576 (p-value=0.092) which is not statistically significant at 5% significant level and we cannot reject the null hypothesis and we conclude that t-DCC model is correctly specified.

MGARCH - Kolmogorov-Smirnov Goodness-of-Fit

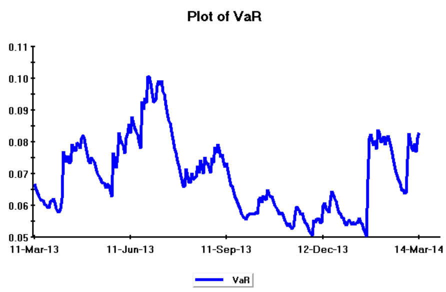


The above graph compares the empirical cumulative distribution function of the probability integral transform variable with that of a uniform. In the above figure, we can see that the Kalmogorov-Smirnov test statistic is 0.63, which is lower than the 5% critical value of 0.84. Therefore, we cannot reject the null hypothesis that the probability integral transforms are uniformly distributed.

MGARCH - Histogram of the Probability Integral Transform



MGARCH - Plot of VaR



MGARCH - Testing for VaR Exceptions

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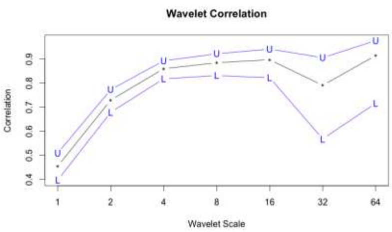
      Mean VaR Exceptions and the Associated Diagnostic Test Statistics
*******************************************************************************
 Mean Hit Rate (pihat statistic) =     .98113 with expected value of     .99000
 Standard Normal Test Statistic=  -1.4509[.147]
*******************************************************************************
```

From the above table we can see that the mean hit rate (0.98113) is very close to the expected value (0.99000), and the test statistic is not significant, both supporting the validity of the t-DCC model.

2. MODWT - Wavelet Correlation Charts & Underlying Numbers

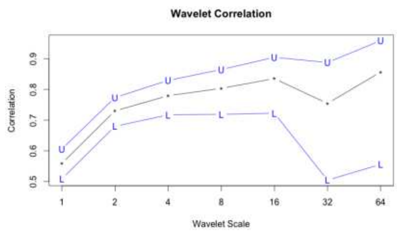
MODWT - Wavelet Correlation

ASIA-BRIC



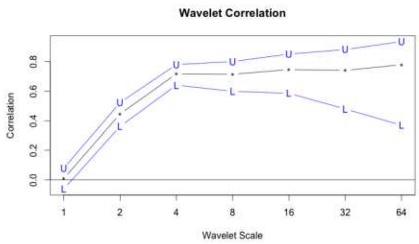
	wavecor	lower	upper
d1	0.45386	0.39605	0.50808
d2	0.72862	0.67819	0.77221
d3	0.85923	0.81716	0.89219
d4	0.88397	0.83071	0.92120
d5	0.89645	0.82159	0.94092
d6	0.79000	0.56744	0.90499
d7	0.91411	0.71565	0.97600
s7	0.95560	0.64171	0.99529

ASIA-EURO



	wavecor	lower	upper
d1	0.16903	0.09975	0.23668
d2	0.58414	0.51440	0.64620
d3	0.79809	0.74030	0.84417
d4	0.79727	0.71032	0.86025
d5	0.87519	0.78668	0.92845
d6	0.86742	0.71378	0.94140
d7	0.95528	0.84420	0.98769
s7	0.93025	0.48437	0.99251

ASIA-USAM



	wavecor	lower	upper
d1	0.00808	-0.06242	0.07851
d2	0.44516	0.36151	0.52169
d3	0.71631	0.63979	0.77876
d4	0.71320	0.59825	0.79938
d5	0.74517	0.58487	0.84945
d6	0.73944	0.47889	0.88026
d7	0.77806	0.36886	0.93462
s7	0.72846	-0.20327	0.96784