Can gold be used as a hedge against the risks of Sharia-compliant securities? Application for Islamic portfolio management

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Abstract

This paper investigates the ability of gold as a hedge for sharia-compliant securities (Sukuk and sharia-compliant stocks) based on daily data covering the period of September 2005 to October 2017. The analysis is performed using two approaches; DCC-GARCH model and wavelet coherence analysis. On the whole, the findings suggests that gold is not effective hedges against sharia-compliant securities fluctuations, though it is useful for diversification and portfolio optimization opportunities. This result has important implications for investors and portfolio managers who have interest in sharia-compliant securities.

JEL *Classification:* C32, C11, C14, C21

Keywords: Sharia compliant stocks, Sukuk, Gold, Hedge, Portfolio optimization, Wavelet coherence analysis

1. Introduction

With the increased uncertainty and integration of financial markets, asset managers became more interested in protecting their portfolios by including investments that are robust to financial markets shocks such as gold. The increasing price of gold after the global financial crisis has attracted the attention of portfolio managers to the value of inclusion this asset in a diversified portfolio. In contrast to the other commodities, gold is well-known to be durable, storable, divisible, easily recognizable and standardized, and provides a hedge against inflation, political uncertainty, slow economic growth and exchange rate risks (Capie et al., 2005; Baur, 2013). Therefore, some researchers have started to investigate the role of gold in hedging and diversifying financial asset classes portfolios (see for instance, Baur and Lucey, 2010; Baur and McDermott, 2010; Lean and Wong, 2015; Mensi et al., 2016; and Basher and Sadorsky, 2016). Generally, gold is believed to be a good asset for hedging of financial portfolios because of its weak correlation (or negative correlated) with the other assets. This is due to the difference between the determinants of gold prices and the other financial assets (Lean and Wong et al., 2015).

Despite the advantages of gold as a hedge and against stock market uncertainty, investigation on this issue is relatively scarce in the emerging countries, particularly using gold. We are also unaware of any studies that examine the issue from the Islamic product perspective. Historically, Muslim investors within Islamic financial markets however always found themselves restricted in the Sharia-compliant asset classes such as sharia-compliant stocks and Islamic bonds (sukuk).[1] There are virtually no official sharia-compliant gold products on the market. In most cases trading gold futures contracts is forbidden or proscribed by Islamic sharia law. In other words, Muslims are not allowed trading gold for profit, or for speculation. Gold investment has therefore been limited to use only as a currency or jewellery. However, on December 6, 2016, the World Gold Council

[1] During the last two decades, the Islamic finance has gained significant attention due to its size, fast-paced growth, offering alternative asset classes, and the potential impact on the international financial markets (Al Zubi and Maghyereh, 2007). The industry's total assets estimated at $2.1 trillion at year-end 2016, and the industry is expected to grow further in the future to top $3.0 trillion in assets by the end of 2018 (Islamic Finance Outlook, 2017).

(WGC), Accounting, and Auditing Organization for Islamic Financial Institutions (AAOIFI) have launched and approved a new "Sharia Gold Standard". The standard sets out for the first time the rules and guidelines for Islamic investors to participate in the gold market, explaining which specific gold based products are permissible under Islamic law (Sharia). Up until that point, little guidance had existed for Islamic investors on whether gold could be purchased and owned as an investment which meant that investors largely stayed away from the gold market altogether. In fact metal is considered an interest (riba) item according to the available Islamic literature on this issue, which means it can be traded only on the basis of its physical properties such as its weight, rather than on its future value or for any speculative purposes. Therefore, new created standard provides clear guidance from the Sharia perspective on the usage of gold in financial and investment transactions for Islamic financial institutions and investors.[2] Thus, this is the first time that Muslim investors got definitive rules for the use of gold as an investment in the Islamic finance industry.

The new standard, however, completely changes the prospects for the Islamic countries and allows its current 110 million investors to invest in: vaulted gold, gold savings plans (such as GoldCore's GoldSaver)[3], gold certificates, physically-backed gold ETFs, certain gold futures and gold mining equities. The main objectives of these rules are to open up a new investment asset class to facilitate the creation of a broader range of hedging and diversification products to Muslim investors. Furthermore, Islamic banks can use gold now as a high-quality liquid asset to comply with more stringent Basel III banking standards that are being phased in.[4]

[2] WGC and AAOIFI stated, **"***The opportunity for the use of gold in Islamic finance is clear. This Standard will enable the foundation of what could be the most significant event for shariah finance in modern times*,"(http://www.nst.com.my/news/2016/12/197925/shariah-standard-gold-great-leap-islamic-finance).

[3]Founded by Mark O'Byrne and Stephen Flood in 2003, GoldCore is an international bullion dealer experts in both delivery and storage specialized precious metals market such as gold, silver, platinum and palladium. GoldSaver is a regular savings account, but instead of saving in Dollars, the account facilitates saving in the form of gold.

[4] As soon as the "Sharia Gold Standard" was launched, Fintech and HelloGold launched the first shyaria-compliant online gold platformis. The Chief Executive Officer of HelloGold, Robin Lee said, "*With HelloGold, everyone can buy gold. We have made it simple and affordable for everyone to buy, sell, save, send gold and to use it as collateral from as low as RM1*," (https://e27.co/startup/hellogold).

In view of the above, 25 percent of the world's population now has significantly greater access to the most liquid products available on the gold market. Certainly, the most significant implication of this new development for the gold market is that the Islamic financial industry is valued at a hefty $2 trillion. Standard & Poor's projects that this figure could rise to $5 trillion by 2020, which Islamic Financial Services Board (IFSB) expects the 2020 figure to be $6.5 trillion. Although at present the overwhelming majority of Islamic investors' holdings are currently invested in sukuk (Islamic bonds), equities and real estate investment trusts, the new standard is now expected to open up a massive innovative source of demand for gold-related products. According to data from the World God Council, the most popular Islamic assets have all underperformed when compared to gold as have the major currencies that are traded in the developing countries of the world. This suggests that Islamic investors will be looking to shift a substantial proportion of the assets into gold products in the hope of more lucrative returns.

While our the main purpose of this study is to investigate the potential hedging and the diversifying role that gold may play for portfolio selection and risk management practices in Islamic finance the exposure of what is effectively a new asset class to the Islamic investment horizon is bound to have a significant impact on world gold prices going forward. Given that , this paper empirically analysis the hedge probability of gold against two traditional Sharia-compliant securities (Sharia-compliant stocks and sukuk). Also we analysis the ability of gold to provide protection for these two investment securities during extreme events. For this purpose, we first use the multivariate generalized autoregressive conditional heteroskedasticity dynamic conditional correlation (MGARCH-DCC) to estimate the dynamic co-movements and volatility spillovers between gold and the two Sharia-compliant securities. The DCCs between gold and the two securities are then used to compute dynamic hedge ratios and portfolio weights, and thus investigates the hedging opportunities arising from including gold in Sharia-compliant portfolios over time. Second, we apply the wavelet coherence analysis for the study of the dynamics of correlations between gold and the two Sharia-compliant securities. One of the huge advantages of this method is that it allows us to investigation the dynamics interdependence in both time and frequency domains, and thus controls for potential nonlinearities, structural breaks, seasonal and cyclical patterns in the relationship between variables (Crowley, 2005). In this way, we may obtain short- as well as long-term dependence structures, an issue that so far has been largely overlooked in the empirical literature. Additionally, we employ the wavelet coherence analysis of Grinsted et al., (2004), which illustrate the phase pattern explains the cause-effect relationship between the variables under study at various frequencies. Further, in construct with parametric DCC GARCH approach, wavelet coherence analysis is better in dealing with nonstationary problem of time series (Roueff and Sach, 2011).[5]

The empirical findings of this project have some important policy implications for Islamic market participants who invest in sharia-compliant securities, given the prevailing view in the literature that gold is a good hedging instrument. Specifically, our results provide useful information for risk management and for optimal portfolio allocation decisions, which is the important objective of financial market participants that is to understand the risk over time and across scales in order to make their strategic decisions. Moreover, the in-depth examination of the relationships may also appeal to the monetary authorities in Islamic countries who maintain substantial levels of gold in their reserves to hedge against the U.S. dollar downswings while providing a safe haven against political and economic crises.

Our contributions in this paper are in three-fold and can be summarized as follows. First, we evaluate the hedging potential of gold for Islamic portfolio managers who want portfolio diversification and investment protection against downside risk. To the best of our knowledge, the studies on the role of gold in Islamic risk management are very scarce. Second, our study covers a

[5] In parametric DCC GARCH methods we have to transform the data to obtain stationary by takes first-differenced logarithmic prices. By this transformation, we may be lose information about long-term dependencies behavior (Baruník et al., 2016).

period that is rich in events such as the global financial crisis, the European sovereign debt crisis, the Arab Spring, and the historic peak of gold prices in 2010 and the subsequent fall. Thus, by comparing and contrasting the different impacts from these events, we can provide useful implications for investors related to risk management across different regimes. Third, in addition to the standard time-domain approach (DCC-GARCH), we use the wavelet coherence analysis which allow us to investigation the dynamics interdependence in time-frequency domain which may be instructive for risk management and optimal portfolio allocation decisions.

Our results indicate that Sukuk and Islamic equities exhibit low correlation with gold, suggesting that, opposed to previous studies, gold are effective diversification instruments but not good hedges in equity portfolios. This is confirmed by the negligible dynamic hedge ratios, which indicate that any hedging opportunities are small and very short lived, mainly around financial crises. The implications of our study are useful for investors and portfolio managers who have interest in sharia-compliant securities, and suggest that the gold should not be used for hedging but for portfolio diversification.

The rest of this paper is structured as follows: Section 2 reviews related studies. Section 3 analyses the empirical methods followed, section 4 presents the data used in this study, section 5 discusses the empirical findings, while section 6 concludes the paper by summarising the main results and provide some policy implications.

2. Literature Review

Gold has been traditionally considered as a precious metal, which maintains its value through time, therefore serving as a hedge against inflation (see for example, Jastram, 1977; Jaffe, 1989; Ghosh et al., 2004; Worthington and Pahlavani, 2007; Hoang et al., 2016). Another very important feature of gold is its role as a hedge, bust most prominently as a safe haven against extreme stock exchange fluctuations. McCown and Zimmerman (2006) observed that gold, apart from being a hedge to stocks; it also behaves as a zero-beta asset; that is an asset with uncorrelated returns to the market portfolio. Baur and McDermott (2010) examine the role of gold as a hedge and as a safe haven over a period of 30 years (1979 to 2009) and across developed, developing and emerging markets. They find that gold is both a hedge and a safe haven for European and US stock markets. Further supporting evidence on the safe haven status of gold can be found in Chua et al., (1990), Baur and Lucey (2010), and Beckmann et al., (2015). Hood and Malik (2013), on the other hand, find evidence that gold can serve as a hedge in the US stock market, but its performance as a safe haven is weak.

Also, gold has a monetary policy role as central banks hold it in their reserves as an instrument to adjust the value of their currencies. At the same time gold is denominated in US dollars and therefore it can be used to hedge against dollar devaluations; if the US dollar falls, the nominal US dollar price of gold will rise to maintain its real value. This has been empirically confirmed by Capie et al., (2005) using weekly data on gold and GBP/USD and YEN/USD exchange rates for the period from 1970 to 2005. This is further supported by Reboredo (2013) who finds that gold can act as both a hedge and a safe haven across major currencies and, in addition, that including gold in a portfolio of currencies yields superior performance in terms of value at risk and expected shortfall.

Despite the obvious links between stocks and gold, their joint consideration for portfolio diversification has not yet attracted much attention. Choi and Hammoudeh (2010) study the volatility behaviour of four commodities among which gold, as well as of the S&P 500 index. They find that gold is associated with high duration, especially under high volatility states, which they attribute to the fact that gold is the preferable safe haven among commodities during crises. Creti et al., (2013) examine the links between equity and 25 commodities, among which gold. They find that gold exhibits a different behaviour among precious metals in that it is negatively correlated to the stock market while correlations tend to decline with falling prices. Arouri et al., (2015) examine both return and volatility spillovers between the stock market and gold prices in China. They find a significant return and volatility transmission between gold prices and China's stock market.

Furthermore, their results show that adding gold to a portfolio of stocks reduces portfolio risk and enhances the hedge against stock risk. In a more recent study, Chkili (2016) reveal similar results when he analysis the relation for BRICS countries.

In the gold related studies, some investigators have found the positive relation between Islamic stock market and the gold returns. Ajmi et al., (2014) examine the nonlinear causal relationship between Islamic stock markets and conventional and their reaction towards the global economic and financial contagion. The result displays that the Islamic stock markets are not isolated from the different types of external shocks and Islamic financial system is a weak safe guard against financial shocks upsetting conventional stock markets and has less portfolio diversification benefits. Further, Abbes et al., (2015) examine the dynamic interdependence across a wide range of developed and emerging Islamic stock markets during turmoil (2002-2007) and tranquil (after crises period) and found that the Islamic stock indices have potential diversification benefits in short-run and it is witnessed for both developed and emerging markets during crises period.

In their study, Dewandaru et al., (2015) employed wavelet analysis to examine the risk and returns pattern at different time scales and found that the both the conventional and Islamic stock markets show similar tendency towards the risk i.e. generally stronger at higher time scale. Khazali et al., (2014) compare the performance of the Dow Jones Islamic Market Index regional and country indices with their conventional counterparts in crises and after crises periods. They contends that except European market, conventional stock indices outperform their Islamic counterparts in all markets and during financial crises period Islamic stock indices perform better than their conventional peers.

Also, Rizvi et al., (2015), Alaoui et al., (2015) and Saiti et al., (2014) investigated the diversification benefits of Islamic stock markets by utilizing a wide range of empirical methodologies to explore the dynamic dependence of global equities with their mainstream Islamic stock indices across different markets i.e. developing, emerging, Asia and GCC countries. Their results suggest that in comparison to conventional stock markets their Islamic counterparts provide better avenues of diversification with strong implications for domestic as well as for international investors. Furthermore, they documented that the Sharia principles enables Islamic financial system to safeguard against unforeseen risk and against multiple economic and financial crises. Ghazali et al., (2014) and Mensi et al., (2015) examine the hedge and safe haven characteristics of sharia compliant stocks and gold in Malaysia and GCC markets respectively. They found that gold provides strong hedge during the periods of financial downturns and suggest that including gold or Islamic stock in global portfolio will reduce the downside risk of the portfolio. Also, Nagayev and Masih et al., (2013) investigate the role of gold in time and frequency domain and produced quite similar results that gold acts as hedging instrument at higher time scale and during the crises periods gold exhibits low correlation with Islamic stock indices of developed and emerging markets.

While there are relatively considerable empirical evidences on the benefit of gold as a diversifier, hedge and safe haven against stock markets, commodities, and currencies risks, to the best of our knowledge, studies on the role of gold in hedging and diversifying risks of Islamic financial securities are very scarce. Furthermore, all of these studies examined the dynamic correlations between gold and Islamic equities, while no studies consider additional Islamic securities like Sukuk. Our initial attempt to fill this gap is our major contribution to providing an insight for both the policy makers and practitioners in the Islamic financial industry. It will be also a better insight to discover at what time and where gold act as hedge and safe haven for investor's perspective, to provide aid for decision making for better asset allocation in their portfolio.

3. Methodology

3.1 DCC GARCH model

The cross-market interactions are examined via the dynamic conditional correlation (DCC) GARCH model of Engle (2002). For the returns equation, we use a VAR model that endogenously accounts for structural breaks, while we follow the multivariate GARCH approach of Ling and

McAleer (2003) in modelling the volatility equation. The DCCs between gold and the two Islamic securities are subsequently used to compute the dynamic hedge ratios and the optimal portfolio weights. This approach is applied by, among others, Sadorsky (2012, 2014) and Basher and Sadorsky (2016) to study the volatility dynamics between emerging market stock prices and commodity prices, and appears to be flexible and efficient in studying time-varying correlations and volatility spillover effects.

Let $R_{it} = \left(R_{gt}, R_{kt}, R_{st}\right)'$ be a $k \times 1$ vector containing the returns at time t on $k = 3$ assets, and in particular the gold $\left(R_{gt}\right)$, sukuk (R_{kt}) and Islamic stock (R_{st}). The conditional mean equation is specified by the following VAR model:

$$\begin{cases} R_t = c + \Psi R_{t-1} + \Xi b_t + \varepsilon_t \\ \varepsilon_t = H_t^{1/2} v_t\,, \quad v_t \sim N(0,1) \end{cases} \tag{1}$$

where $c = \left(c_g, c_k,, c_s\right)'$ is a $k \times 1$ vector of constant terms; Ψ and Ξ are time-invariant 3×3 matrices of coefficients with elements $[\Psi]_{ij} = \psi_{ij}, [\Xi]_{ij} = \xi_{ij}$, where $i, j = \{s, o, g\}$; $b_t = \left(b_{gt}, b_{kt}, b_{st}\right)'$ is a 3×1 vector of dummy variables that take the value 1 for $t \geq t_{break}$; $\varepsilon_t = \left(\varepsilon_{gt}, \varepsilon_{kt}, \varepsilon_{st}\right)'$ is a 3×1 vector of error terms; $v_t = \left(v_{gt}, v_{kt}, v_{st}\right)'$ is a 3×1 vector of independently and identically distributed errors. H_t is a symmetric $k \times k$ conditional variance-covariance matrix. From the above specification, testing for return spillovers is equivalent to testing $\psi_{ij} = 0,\ \forall\, i \neq j$.

Following Engle (2002), H_t can be written as $H_t = D_t R_t D_t$, where $D_t = diag\left\{\sqrt{h_{i,t}}\right\}$ is a 3×3 matrix of time-varying conditional volatilities along the main diagonal; R_t is a symmetric $k \times k$ matrix of time-varying conditional correlations with ones on the diagonal and $[R_t]_{ij} = \rho_{ij,t} \neq 1$ for $i \neq j$; and H_t has elements $[H_t]_{i=j} = h_{i,t}$ on the diagonal (time-varying conditional variances) and

$[H_t]_{i \neq j} = \sqrt{h_{i,t}h_{j,t}}\rho_{ij,t}$ off the diagonal (time-varying conditional covariances), where $i, j = \{g, k, s\}$.

The common practice in estimating the DCC model is to assume that the conditional volatilities are univariate. In this paper, we follow Ling and McAleer (2003) and obtained the elements of D_t from a multivariate GARCH specification instead. Their approach to modelling the conditional variances allows measuring the volatility spillovers between assets. Therefore, the conditional variance will be specified as follows:

$$h_t = \gamma + A\varepsilon_{t-1}^2 + Bh_{t-1} \quad (2)$$

where $\gamma = (\gamma^g, \gamma^k, \gamma^s)$ is a 3×1 vector of constant terms; A and B are 3×3 matrices of estimated ARCH and GARCH coefficients, respectively, with elements $[A]_{ij} = \alpha_{ij}, [B]_{ij} = \beta_{ij}$, where $i, j = \{g, k, s\}$.[6] For $i = j$, α_{ij} represent own conditional ARCH effects which measure short-term persistence, whereas β_{ij} represent own GARCH effects which measure long-term persistence. The mean reverting condition $0 < \alpha_{ij} + \beta_{ij} < 1$, for $i = j$ is required to ensure that a long run equilibrium in conditional volatility is established. For $i \neq j$, the α_{ij} and β_{ij} coefficients capture volatility spillovers between assets. In particular α_{ij} measures the shock spillovers from asset j on the conditional volatility of asset i, while β_{ij} measures past volatility spillovers from asset j on the conditional volatility of asset i.

In testing for volatility spillovers (with one period lag) from one asset to another, we need to test the joint null hypothesis: $\alpha_{ij} = \beta_{ij} = 0, \forall\, i \neq j$. For example, if the null hypothesis $\alpha_{kg} = \beta_{kg} = 0$ is rejected, there is evidence that the volatility in gold was transmitted into the sukuk during the period under consideration. The test for the reverse volatility transmission (sukuk to gold) would $\alpha_{gk} = \beta_{gk} = 0$. The usual likelihood ratio test is utilised for the hypothesis tests:

[6] Note that Eq. (2) is not extended to take into account asymmetric responses, because sign and size bias tests (as in Engle and Ng, 1993) results (not reported but are available upon request from the authors) produced no evidence of asymmetry for all variables under consideration.

$$LR = -2(L_R - L_{UR}) \overset{a}{\rightarrow} \chi^2(\kappa) \tag{3}$$

where LR is the log likelihood ratio, and L_R and L_{UR} are the values of the log-likelihood functions of the restricted and unrestricted models respectively. The LR statistic has an asymptotic $\chi^2(\kappa)$ distribution with κ degrees of freedom; equal to the number of restrictions.

Given the conditional variances in Eq (2), the time-varying conditional correlation matrix R_t in the DCC model takes the following form:

$$R_t = \big(diag\ (Q_t)\big)^{-1/2} Q_t \big(diag\ (Q_t)\big)^{-1/2} \tag{4}$$

where Q_t is a $k \times k$ symmetric positive-definite matrix, given by

$$Q_t = (1 - \theta_1 - \theta_2)\overline{Q} + \theta_1 \varepsilon_{t-1} \varepsilon_{t-1}^{\prime} + \theta_2 Q_{t-1} \tag{5}$$

where $\overline{Q}$ is the unconditional covariance matrix of the standardized residuals ε_t; $\theta_1$and θ_2 are nonnegative scalar coefficients with a sum of less than unity which deal with the effects of previous shocks and previous dynamic conditional correlations on the current dynamic conditional correlation; and the elements of $[Q_t]_{ij} = q_{ij,t}$ can be interpreted as the dynamic conditional covariances between assets i and j. By imposing the restriction $\theta_1 = \theta_2 = 0$, $\overline{Q}$ reduces to the constant conditional correlation (CCC) model. The conditional correlation coefficient $\rho_{ij,t}$ is expressed as follows:

$$\rho_{ij,t} = \frac{\mathrm{q}_t^{ij}}{\sqrt{\mathrm{q}_t^{ii} \mathrm{q}_t^{jj}}}, \forall\ i \neq j \tag{6}$$

If the estimated $\rho_{ij,t}$ is positive and statistically significant, the correlation between asset returns are rising and moving in the same direction or vice versa.

The parameters of the DCC model are estimated using the quasi-maximum likelihood (QML) method of Bollerslev and Wooldridge (1992) that takes into account the fact that a joint multivariate normal distribution is often violated for financial series.[7] We employ the Ljung-Box (LB) statistics for the squared standardized residuals to determine the adequacy of the estimated model of the conditional variances.

To identify the date of potential structural breaks in Eq. (1), we employ the Lee and Strazicich (2003, 2004) and Lee et al., (2012) procedure. This procedure is based on testing for unit roots in the presence of structural breaks.[8] It's a (minimum) Lagrange Multiplier (LM) test for unit roots that allows the "endogenous" determination of the time and size of structure breaks; both in the levels and the trend of the time series.[9]

Following Lee et al., (2012), consider the following data generating process:

$$y_t = \delta' Z_t + \varepsilon_t, \qquad \varepsilon_t = \beta \varepsilon_{t-1} + u_t \tag{7}$$

where Z_t is a vector of exogenous variables defined by the data generating process. The test for the unit root is based on the parameter β. The unit root test is then carried out under the null hypothesis that $\beta = 1$. In this procedure, a structural break in intercept and change in trend slope can be incorporated by specifying the vector of exogenous variables Z_t as $Z_t = [1, t, D_t, DT_t]'$, where $DT_t = t - T_B$ for $t > T_B + 1$, and zero otherwise, where T_B denotes the time period when a break occurs.[10] To endogenously determine the location of the break (T_B), the LM unit-root searches for all possible break points for the minimum unit-root *t*-test statistic as follows:[11]

$$Inf\ \tilde{\tau}(\tilde{\lambda}) = Inf_{\lambda} \tau \lambda, \qquad \text{where } \lambda = T_B / T \tag{8}$$

[7] We use the quasi-Newton method of Broyden, Fletcher,Goldfarb, and Shanno (BFGS) algorithm with a convergence criterion of 0.00001. We estimated the DCC model with WinRats 9.0 using a code provided by Sadorsky (2012), which we modified for our purposes.

[8] This procedure takes into account the potential zero, one or two breaks in the process of the time series.

[9] Note that Zivot Andrews (1992), Perron (1997), and Lumsdaine and Papell (1997) also propose unit root tests which allow for breaks, the location of which is endogenously determined in the series. However, unlike Lee and Strazicich (2003, 2004) and Lee et al. (2012), these tests are subject to the spurious rejection problem and exhibits size distortions in the presence of a break under the null hypothesis.

[10] For two structural breaks in the level and the trend we must add D_{jt} terms in Z_t and is described as $Z_t = [1, t, D1_t, D2_t, DT1_t, DT2_t]'$, where $D1_t$, and $D2_t$ are dummy variables that capture the first structural break and the second structural break, respectively. For more details information see Lee and Strazicich (2003; 2004) and Lee et al., (2012).

[11] Critical values for the LM unit root test statistic are tabulated in Lee and Strazicich (2003, 2012).

The estimated results derived from the DCC model could be used to construct trading strategies that minimize unwanted risk without reducing expected returns for holding a two-asset portfolio. This study analyses two trading strategies necessary for the purpose of active portfolio risk management of gold with the sukuk or Islamic stock. More specifically, we compute the time-varying optimal hedge ratios and optimal portfolio weights. Following Kroner and Sultan (1993), we first consider the hedging problem of determining the rate at which long position of one dollar in one market (say market i) could be hedged by taking a short position in the other market (say market j) that minimizes risk while keeping the same expected returns. Thus, for a holding portfolio of two market returns, the optimisation problem is given by:[12]

$$\min_{\beta_t} var\left(r_{pt}\right) = \min_{\beta_t} \left\{var(r_{it}) + \beta_t^2 \times var\left(r_{jt}\right) + 2\beta_t \times cov\left(r_{it}, r_{jt}\right)\right\} \tag{9}$$

By solving the risk-minimizing problem (by the first-order and second-order derivatives of $var(r_{pt})$), the time-varying optimal hedge ratio $\left(\beta_{ij,t}^*\right)$ can be derived as:

$$\beta_{ij,t}^* = \frac{Cov\left(r_{it}, r_{jt}\right)}{var\left(r_{jt}\right)} = \frac{h_{ij,t}}{h_{jj,t}} \tag{10}$$

We follow Sadorsky (2012, 2014) and Basher and Sadorsky (2016) to obtain dynamic hedge ratios, by employ a rolling window analysis with out-of-sample forecasts. The hedge ratios are commonly interpreted as the dollar amount of the short position that needs to be taken in the hedge to cover one dollar of the short position in the asset under consideration. In our case, gold is considered a *cheap hedge* for an Islamic asset (sukuk or islamic stock) if the associated hedge ratio is close to zero. Following the definitions in Baur and Dermott (2010), we also characterise gold as a *strong* (*weak*) *hedge*, if it is negatively correlated (uncorrelated) with Islamic securities. Similarly, the status of *strong* (*weak*) *safe haven* can be given to gold when negative (low) correlations are observed only during financial crises.

[12] This model specification is in line with most of the previous studies (Sadorsky, 2012, 2014; Lin et al. 2014; Lin and Li, 2015; Basher and Sadorsky; 2016; Bessler et al., 2016; Maghyereh et al., 2017; among many others) on MGARCH hedging.

Similarly, conditional volatilities from the DCC model can be used to construct an optimal portfolio that minimizes the portfolio risk without lowering the portfolio expected returns. Following Kroner and Ng (1998), Hammoudeh et al. (2014), among others, the optimal weight $(w_{ij,t}^{*})$ for a two asset portfolio (i, j) is obtained by:

$$w_{ij,t}^{*} = \frac{h_{jj,t} - h_{ij,t}}{h_{ii,t} - 2h_{ij,t} + h_{jj,t}}, \qquad \text{with } w_{ij,t}^{*} = \begin{cases} 0, & if \quad w_{ij,t}^{*} < 0 \\ w_{ij,t}^{*}, & if \quad 0 \leq w_{ij,t}^{*} \leq 1 \\ 1, & if \quad w_{ij,t}^{*} > 1 \end{cases} \tag{11}$$

where $w_{ij,t}^{*}$ is the weight of asset i in a one-dollar portfolio at time t, $h_{ij,t}$ is the conditional covariance between i and j at time t; $h_{ii,t}$ and $h_{jj,t}$ are the conditional variances of assets i and j respectively. The weight of asset j in the considered portfolio is computed by $(1 - w_{ij,t}^{*})$.

3.2 A brief description of Wavelet coherence analysis

While the above DCC GARCH approach allows us to analyse the correlation solely in the time domain, its very interest to analysis how the correlations vary over time at different investment horizons. Understanding of the correlations among assets at different investment horizons is significant at least for two reasons: First, investors' preference for risk is inversely related to time and thus different investment horizons have direct implications for portfolio selection (Samuelson, 1989; and Marshall, 1994). Second, there is heterogeneity in investors' behaviour because they exhibit different consumption requirements, varied trust and risk tolerance level, heterogeneous assimilation of information, and institutional constraints (Chakrabarty, et al., 2015). These heterogeneities cause transmissions of shocks through market transactions vary according to time scale (Reboredo and Rivera-Castro, 2014).

To complement our DCC GARCH results, we use wavelet coherence method which allows us to analysis the co-movement between gold and Islamic securities at time-frequency components. In this way, we can obtain short-run, medium-term and long-run dynamics of the dependencies, and thus providing important and useful information for risk management and for optimal portfolio allocation decisions, which is the important objective of financial market participants.[13]

According to Torrence and Webster (1999), the wavelet coherence is defined as the squared absolute value of the smoothed cross wavelet power spectra of each selected time series. Using the same notations as in Torrence and Compo (1998) and Grinsted et al. (2004), wavelet coherence of two time series $x(t)$ and $y(t)$ can be expressed as follows:

$$R^2(u,s) = \frac{\left|S\left(s^{-1}W_{xy}(u,s)\right)\right|^2}{S\left(s^{-1}|W_x(u,s)|^2 S\left|W_y(u,s)\right|^2\right)} \tag{12}$$

where $W_{xy}(u,s) = W_x(u,s)W_y^*(u,s)$is the cross-wavelet transform with u refers to the position index, s to the scale, "*" indicates the complex conjugate, and $W_x(u,s)$and $W_y(u,s)$are the wavelet transforms of $x(t)$ and $y(t)$ respectively. In the above specification, S is referred to the smoothing operator in both time and frequency.[14] The squared wavelet coherence coefficient should satisfy $0 \leq R^2(u,s) \leq 1$ in time-frequency space. A value of $R^2(u,s)$ close to zero indicates that the studies time series are weakly correlation, portrayed by colors (blue) while that close to one provides evidence of strong correlation and is depicted by warmer colors (red). Cold regions indicate that the significant areas represent time and frequencies with no correlation between the time series.

From the above discussion, it's obvious that the wavelet coherence is very useful tool for detecting co-movement since it is measured the local correlation in time and scale. However, the wavelet coherency is squared, thereby we will not able to distinguish the sign of correlation between two time series in the time-frequency space (i.e., whether the dependence is positive or negative) or identify the lead–lag relationships. Torrence and Compo (1998) proposed wavelet

[13] A detailed description of the Wavelet methods of using wavelet methods can be found in Torrence and Webster (1998), Grinsted(2006), Bodart and Candelon (2009), Vacha andBarunik (2012), Chakrabarty, et al., (2015), among others.

[14] Smoothing is achieved by convolution in time and scale, represented by $S(W) = S_{scale}\left(S_{time}\left(W_n(s)\right)\right)$ where S_{scale} and S_{time} are smoothing on the wavelet scale axis and in time, respectively (for more details see Gallegati and Semmler, 2014).

phase-difference to solve this problem. Following the their contribution, the wavelet coherence phase difference phase difference $(i.e., \emptyset_{xy}(u,s))$ between two time series $x(t)$ and $y(t)$ can be expressed as follows:

$$\emptyset_{xy}(u,s) = tan^{-1}\left(\frac{\Im\left(S\left(s^{-1}W_{xy}(u,s)\right)\right)}{\Re\left(S\left(s^{-1}W_{xy}(u,s)\right)\right)}\right) \tag{13}$$

where $\Im$ and $\Re$ are the imaginary and real parts of the smoothed power spectrum respectively.

Note that phase differences are graphically displayed on the same figure of the wavelet coherence by plotting arrows inside the regions characterized by high coherence. Arrows pointing to the rightward mean that $x(t)$ and $y(t)$ are in phase (or move in the same direction). Arrows pointing to the leftward mean that that $x(t)$ and $y(t)$ are anti-phase (or move in the opposite direction). In addition, arrows pointing rightward-up mean that the variable $x(t)$ is leading the two variables are positively correlated while arrows pointing rightward- down indicate that the variable $y(t)$ is leading and the two variables are positively correlated. On the other hand, if the arrows pointing leftward-up, the first variable $x(t)$ is lagging and the correlation is negative while if the arrows pointing leftward-down, the first variable $x(t)$ is leading and the correlation is negative (see Grinsted et al., 2004; Tiwari et al., 2013; Alouri, et al., 2017; Cai et al., 2017; and Yang et al., 2017).

4. Data set and descriptive statistics

The empirical analysis will cover the period from the 30th of September 2005 to the 2nd of October 2017. This study period covers over a thirteen-year of financial history, which includes the global financial crisis from September 2008 to December 2009, the European sovereign debt crisis from April 2010 to June 2012, and the Arab Spring and political revolutions in the Middle East that began on December 2010-present.[15] The data set is consisted of daily the Dow Jones Citigroup

[15] Note that the start date of date is ruled by data availability especially on Sukuk index.

Sukuk Index, the Dow Jones Islamic stock market index and finally the price of gold represented by the gold bullion USD/troy ounce rate (Gold Cash). We use short horizon data (daily) in order to retain a high number of observations to adequately capture the rapidity and intensity of the dynamic interactions between asset prices.[16] The data were retrieved from Thomson Reuters DataStream (a total of 3131 daily observations). For each data series, continuously compounded daily returns are calculated as $r_t = ln(p_t/p_{t-1})$, where p_t is the daily closing price at time t.

The Dow Jones Citigroup Sukuk Index includes U.S. dollar-denominated Sukuk issued in the global market that has been screened and considered as Shari´ıah compliant investments. The index was launched on April 2, 2006 with history available back to September 30, 2005. To be included in this index, a bond must pass screens and meets the standards issued by the Accounting and Auditing Organization for Islamic Financial Institutions (AAOIFI). The bond has also to have at least a minimum maturity of one year and a minimum issue size of US$250 million. All bonds included in the index are of investment grade rating and all are rated by leading rating agencies.[17]

The Dow Jones Islamic stock market index provides a global investable universe of stocks that comply with Islamic finance principles. The index excludes unethical or high elements of debt and intangible assets companies or companies engaged in gambling, alcohol, tobacco, weapons and defense, pork-related products, conventional financial services (banking, insurance, etc.), and other prohibited activities in Islam (Al-Zubi and Maghyereh, 2007; Hammoudeh et al., 2014; Charles et al., 2015). As of September 2017, this index has 2876 companies from 51 countries out of the global universe of 12,000 components from 77 countries in the Dow Jones Global stock market

[16] We also employ weekly data (Wednesday to Wednesday) to test whether our results are data frequency dependent. We found that our results (available upon request), are similar to those obtained daily frequency. These results are not reported and are only available from the authors.

[17] To be eligible for inclusion in the index, bonds must have minimum quality BBB-/Baa3 by S&P, Moody’s or a leading rating agency.

index. The index has been launched since May 1999 and is reviewed quarterly.[18] This index is designed to provide portfolio managers with a comprehensive set of world indices that are useful in benchmarking and asset allocation (Maghyereh and Awartani, 2016).

The extent to which the events of the period of study have affected gold, Sukuk and Islamic equities returns is examined in Table 1 below using unit root test that accounts for one or more structural breaks in the data as in Lee and Strazicich (2003, 2004) and Lee et al., (2012). In particular, the second column reports the structural break date as determined econometrically while the third column reports the t-statistics computed for the associated LM test. The structural break for gold is manifested in late September of 2011, which coincides with the reversal of the price momentum of gold and ending up in an ongoing, steady decline in the price of the precious metal. Although it is difficult to pin down the underlying causes of this reversal, as gold has no well-defined fundamental value, it could be speculated that it is related to the expectation of a gold sell-out by the Central Bank of Cyprus to deal with its financial crisis, trading patterns of gold-related ETFs, the bearish Goldman-Sachs call as well as algorithmic trading which has gained popularity in commodities. On the contrary, Sukuk and Islamic equites exhibit a structural break following the severe crisis and recession in the same week at the end of 2009. These primary observations show clearly that Islamic products are reacted to similar events whereas gold does not follow the same pattern. [19]

[INSERT TABLE 1 HERE]

Table 2 below presents some descriptive statistics for gold along with the returns on Sukuk and Islamic equities respectively. All asset returns are positive with the highest figure exhibited by gold which has offered a high daily return of 3.2% on average while it's also presented the highest daily

[18] More information about the Dow Jones Islamic stock market index are available at http://us.spindices.com/indices/equity/dow-jones-islamic-market-world-index.

[19] To further justify the use of wavelet approach, we conducted the BDS test of Brock et al., (1996) to detect nonlinearity serial dependence in our time series. We find strong evidence (not reported but are available upon request from the authors) of nonlinearity in all series under study.

standard deviation. Islamic equities also offer considerable daily returns, with the smallest one offered by Sukuk, but for the lowest risk across the assets considered. The skewness coefficients are negative for all the return series. Moreover, the kurtosis coefficients are above three for all the return series indicate that all distributions are leptokurtic. The departure from normality is also confirmed by the Jarque-Bera statistic (JB) for all the series. The Ljung–Box statistic for autocorrelation up to the 20th order for raw and squared returns indicates the presence of serial correlation in all the returns. Finally, the autoregressive conditional heteroskedasticity-Lagrange multiplier (ARCH-LM) tests unambiguously show that all return series exhibit volatility clustering.

[INSERT TABLE 2 HERE]

Table 3 reports the pairwise simple correlations coefficients between gold returns and returns of Sukuk and Islamic equities over the sample periods. It shows unambiguously that the correlation between gold and Sukuk is tiny and negligible over the sample period (0.056). This implies that gold may have the potential to diversify and improve the tradeoff of risk and returns in a Sukuk portfolio. Similarly, the table shows that gold appears to be weakly correlated with Islamic equities. The correlation is relatively small and less than 0.135. The weak correlation with Islamic equites and Sukuk makes gold a good candidate for diversifying a Islamic equites portfolio, Sukuk portfolio and a Sukuk-Islamic equities portfolio. The results also show that the correlations between Sukuk and Islamic equities returns are close to zero or negative, providing early evidence that including gold in a portfolio of Sukuk and Islamic equities could improve its performance.

[INSERT TABLE 3 HERE]

We complement our data descriptions with the price-return plots for gold, Sukuk and the Islamic stock index in Figure 1. As we can observe from the figure that the both Islamic securities, have an increasing trend during the first two-year of study, reaching a peak in 2007, after which suffered large losses and extreme swings during the global financial crisis in 2008 and after the collapse of

Lehman Brothers on the 15th of September. However, compared to the Sukuk, the losses experienced by Islamic equities investors were relatively larger in magnitude. Moreover, the volatility of the Islamic stock index was much higher than the volatility of the Sukuk index especially during the financial crisis. On the other hand, the momentum of gold prices is not interrupted during the financial crisis, although gold prices and returns were also quite volatile. This is consistent with the perception that gold can serve as a safe have during crises. The behaviour of gold changed after 2011 along with a moderate leverage effect, while the biggest volatility spike was observed in 2013 when the price of gold fee sharply in one week.

[INSERT FIGURE 1 HERE]

5. The empirical results

5.1 DCC GARCH model results

The results of the multivariate DCC-GARCH model are presented in Panel A and Panel B of Table 4. Panel A reports the return spillover parameters while Panel B reports the volatility transmission parameters between the three assets. The estimated model coefficients and parameters are reported along with their p-values where relevant. The subscript g denote the gold, k corresponds to the Sukuk and Islamic equities is represented by s; while $i, j = \{g, k, s\}$ is used to denote the direction of effects from one asset to another and the case $i = j$ corresponds to own effects. In the returns equation (Panel A), c_i are the estimated constant terms, ψ_{ij} are the estimated AR(1) coefficients showing the effect that the lagged returns (1 trading day) of asset j have on the current returns of asset i, and ξ_{ij} are the estimated coefficients of the structural-break-related dummy variables, reflecting the contemporaneous effect of a structural break in asset j on the returns of asset i. In the variance equation (Panel B), γ_i represents constant terms, a_{ij} are the estimated ARCH effect coefficients and β_{ij} are the estimated GARCH effect coefficients. Also ρ_{ij} are the expected value of the dynamic conditional correlations between asset i and j, while θ_1 and

θ_2 correspond to the respective estimated parameters of the DCC equation. The model has been estimated via quasi-maximum likelihood (QMLE).

The results for the mean equation for gold indicates that past returns influence current ones (ψ_{gg}), with significant negative effect of the financial crisis (ξ_{gg}). The empirical results show that there are no significant return spillovers from the gold to either Sukuk or Islamic equities. The both parameters (ψ_{gk}) and (ψ_{gs}) are found to be statistically insignificant at conventional levels. The model also shows that the structural breaks of gold have no significant influence on either Sukuk returns (ξ_{gk}) or Islamic equities returns(ξ_{gs}) at the 10% critical level. These results highlight the relative importance of gold as a diversifier and hedger in Sukik-Islamic equity portfolios.

Regarding Sukuk returns, we find significant autoregressive terms and the effect of the structural break on Sukuk during the financial crisis had a negative and significant effect on Sukuk returns. On the other side, the model shows that neither Sukuk returns nor its structural breaks significantly influence gold (ψ_{kg}, ξ_{kg}) or Islamic equities (ψ_{ks}, ξ_{ks}). Inspecting the results for Islamic equities returns we find also that Islamic equities returns do affect current ones (ψ_{ss}), that the structural break in 2009 had a significant negative impact on Islamic equities returns (ξ_{ss}) and Sukuk returns (ξ_{sk}), but effect positive and significant on gold returns (ξ_{sg}). Finally, we observe there are significant positive spillover effects from Islamic equities to Sukuk (ψ_{sk}), but insignificant negative effects on gold returns (ψ_{sg}).

We now turn to the volatility equation results and we will use Table 5 to complement our analysis volatility spillovers. In particular, Table 5 shows the results of a Wald test on the joint hypothesis $H_0\colon \alpha_{ij} = \beta_{ij} = 0$. We find that all own ARCH effects (α_{ii}) and own GARCH effects (β_{ii}) are significant at the 1% level of significance. The magnitude of the GARCH effects, which measure long-term persistence, appear substantially greater than the magnitude of the ARCH effects, which measure short term persistence. It also indicates that past volatilities are more useful to predict the current volatilities of assets rather than the previous periods squared error terms. All volatility series are mean reverting, as the total persistence $(\alpha_{ii} + \beta_{ii})$ is less than one.

We find significant negative short-term volatility spillovers from gold to Sukuk (α_{gk}), but significant positive long term volatility spillovers in the same direction (β_{gk}). This is an interesting finding as it suggests that a temporary increase in volatility in gold is expected to decrease the volatility of Sukuk returns in the short run, however it is expected to amplify in the long run. Combined with the results on return spillovers, we could argue that a positive gold price shock is expected to influence negatively the returns on Sukuk and reduce its volatility in the short run, though in the long run it is expected to increase its volatility. In the direction from Sukuk to gold we find insignificant negative volatility spillovers in the short run and long-run. The latter has implications for risk management and casts reconsiderations on extending the holding horizons of both commodities in the same portfolio of assets. The Wald test in Table 5 confirmed above results and indicates that the volatility spillovers from gold to Sukuk are significant. On the contrary, in the direction from Sukuk to gold the Wald test accepts the null hypothesis of no effects in volatility exist.

The volatility spillovers between gold and Islamic equities appear insignificant in both directions at the 5% or 10% level of significance. Looking at the Wald statistics we find insignificant effects between gold and Islamic equities in the both direction which confirms the inference based on the multivariate GARCH. The results in table 4 and 5 also show that there is transmission from Islamic equities volatility to the volatility of Sukuk, but not the other way around.

[INSERT TABLES 4&5 HERE]

The results on the DCCs follow suit from the previous analysis as it can be seen at the bottom of Panel B of Table 4. The correlations between gold and the both Islamic securities (ρ_{gk}, ρ_{gs}) are positive and tiny, but significant. However, the correlation between Sukuk and Islamic equities

(ρ_{ks}) is even tinier and significant at 10% level of significance. The parameters θ_1 and θ_2 appear significant, indicating that past shocks and DCCs have a significant impact on current dynamic correlations, respectively.

To examine the behaviour of dynamic conditional correlations over time we have plotted the DCC series in Figure 2 below. The the results for gold exhibit low correlations with Sukuk and Islamic equities. Moreover, we observe the DCCs between gold and the both Islamic securities peak during the financial crises and the sign of correlation has changed several times during this period. We also observe more variability during the year 2013 around the structural break date for gold returns, but the magnitude remains unaffected. Increasing and volatile correlations are observed in 2013 as the price of gold has been observed declining. These findings indicate that gold is not a hedge nor a safe haven for Muslim investors and it would therefore be meaningless to include gold in a portfolio of Islamic securities for hedging purposes but it could be used for selective portfolio diversification. Although the correlations revered to their mean after the 2013, they were still remained positive and low for the remaining period which stresses again the importance of gold as a diversifier but puts doubts on its hedging potential. Our results are not in line with previous evidence that including gold in a well-diversified equity portfolio provides good hedging opportunities (for example, McCown and Zimmerman, 2006; Baur and McDermott, 2010; Hood and Malik, 2013; Beckmann et al., 2015; Arouri et al., 2015; Chkili,2016), hence adding more evidence to the ongoing debate.

[INSERT FIGURE 2 HERE]

As mentioned previously, conditional volatility estimates are used to construct hedge ratios. The dynamic evolution of hedging ratios are presented in Figure 3.[20] The figure shows considerable variability in optimal hedge ratios across the sample period implying that hedging positions must be

[20] Following Sadorskey (2012) and Syed and Sadorsky (2016), the dynamic hedge ratios are constructed using a rolling window analysis with out-of-sample forecasts.

adjusted frequently. Notice that hedge ratios of Sukuk/gold and Islamic equities/gold experienced large rise during the period 2008-2009 due likely to the world financial crisis. The average value of optimal hedge ratios are shown in Table 6. The table reports the amount of gold that should be longed / shorted in order to hedge a $1 portfolio of Sukuk/Islamic equities. As can be seen in the table the hedge role of gold are relatively tiny for the both Islamic securities with an average hedge ratio for Sukuk-gold is greater in absolute terms compared to the Islamic equities-gold hedge ratios. On average, a $1 portfolio of Sukuk can be hedged with a long position of 17 cents of gold. It can be also a $1 portfolio of Islamic equities with a short position of 0.3 cents of gold.

[INSERT TABLE 6 HERE]
[INSERT FIGURE 3 HERE]

The figures point out that the hedging ratios of gold and the gold correlations with Sukuk/Islamic equities are negligible and therefore, we may conclude that while gold is a good diversifier its role as a hedging instrument is minor. This conclusion is inconsistent with Ghazali et al., (2014) who found that gold provides strong hedge for sharia compliant stocks during the periods of financial downturns in Malaysia.

To investigate the diversifying role of gold we construct the optimal weights of gold in Sukuk/Islamic equities portfolios. Results are reported in column 2 of Table 6. The table shows that gold seems to be diversifying Islamic securities portfolios, however, the diversification role of gold is more pronounced for Sukuk portfolio. On average the weight of Islamic equities/gold in the optimal portfolio is 32% while the weight of Sukuk/gold is double and it is around 60%. The dynamic evolution of optimal portfolios weights are presented in Figure 4. The figure again shows considerable variability in optimal weights across the sample period implying that diversification positions must be adjusted frequently. Notice that gold could provide a higher degree of diversification during crisis periods, where the during the financial crises optimal weights peak towards 1.

Overall, our results based on multivariate DCC-GARCH model indicate that gold is not good hedges against Islamic securities fluctuations, though its suitable for portfolio diversification, which contradicts previous findings of that gold is a good asset for hedging of financial portfolios. This results provide important and useful information for investors and portfolio managers who interest in sharia-compliant securities.

[INSERT FIGURE 4 HERE]

5.2 Wavelet coherence analysis

To double check our findings under another data generating process, we employ the wavelet coherence analysis.[21] The application allows for measuring the dynamic interconnection between gold and Islamic securities return series over time and across different investment horizons. Figure 5 displayed the estimated wavelet coherence and phase-difference for the pairs from a scale of 4 (four days which is appeared in the top of plot) up to a scale of 1024 (approximately four trading years which is appeared the bottom of plot). Following standard practice in the literature, the horizontal axis in the plots refers to time intervals whereas the vertical axis refers to scale (i.e. the lower the scale, the higher the frequency).

As discussed in Section 3.2, regions inside the thick black line represent regions with significant dependence at the 5% level.[22] Coherency takes values between 0 and 1 and indicates degree of dependency between two time series, where the warmer colored (red) area represents strong correlation between pairs, while colder colored (blue) area indicates weak dependence between pairs. Cold regions beyond the significant areas represent time and frequencies with no dependence between the pairs. The warmer the colour of a region, the greater the coherence is between the

[21] The wavelet coherence analysis was performed using a slightly modified version of the wavelet R package available at http://rpubs.com/ibn_abdullah/rwcoher.

[22] As in the Rua and Nunes, (2009), the 5% significance level was estimated from a Monte Carlo simulation of 10,000 pairs white noise time series with the same length as the original samples.

pairs. The direction of correlation (cause–effect) between pairs is represented by phase arrows. Arrows pointing to the right-down or left-up indicate that the gold is leading, while arrows pointing to the right-up or left-down show that the other variable is leading.

Confirming our evidence from multivariate DCC-GARCH model, the results from wavelet coherence on aggregate suggest low level of co-dependency between gold and the two Islamic securities over time and frequency domain, represented by the dominance of colder (blue) colouring and the small significant area in low frequency during the sample period. Considering the gold-Sukuk pair first, we find no correlation between the two assets during the period from September 2005 to August 2008. However, starting from September 2008 until the end of 2011, during the sub-prime crises, the global financial collapse, European debt crisis, and we observed significant correlation at low frequency scale (256-512 days scale) which continued. The direction of the arrows pointed rightward and up indicated that the gold and Sukuk are in-phase (positively correlated with gold leading. Between early 2013 and the middle of 2014, the correlation was insignificant where the “cold” zone cover the major part of short-and long periods scale. From early 2014 to the end of time period, the interdependence between gold and Sukuk become more evident at both medium and long-term frequency scale. While it’s obvious that the two variables co-move positively during this period, the determine the leading variable is difficult due to unreliability of arrows tendency.

Similarly, our results suggest low degree of interdependence between gold and Islamic stocks as very small significant zones in low frequencies across the sample period. The degree of interdependence is relatively high and significant during the period 2009-2012 at low frequency scale (256-512 days scale). The downward and up pointing arrows indicate in-phase pattern and gold was leading Islamic stocks during this period. Another significant area is observed in 2015 with rightward and up arrows pattern, again indicating that the two variables co-move positively with gold leading.

Overall, our results based on wavelet coherence analysis reconfirmed the results from multivariate DCC-GARCH model and show relatively weak interdependence between gold and Islamic securities at various investment horizons indicates that gold can provide substantial diversification opportunities, reducing the portfolio risk of Islamic securities-based investors. In addition, we find that the statistically significant interdependence occurs at low frequency scale only around the period of the sub-prime crises, the global financial collapse and European debt crisis with gold leading over Sukuk/Islamic stocks, indicating the occurrence of contagion effect during the crises periods at low frequency scales.

6. Conclusion and policy implications

This study assesses the hedge probability of gold against the Sharia-compliant stocks and Sukuk. It also investigates the ability of gold to provide protection for these two investment securities during extreme events. During the times of market turmoil (financial crisis, European debt crisis and Arab springs etc.), investors often seek to mitigate risks associated with investment assets such as equities and debt. While previous studies have characterised the hedging properties of gold at differing aggregation level, probably the role of gold in hedging and diversifying risks of Islamic financial securities have not been tested before. Relative to previous studies, we demonstrate a richer characterise of hedging of gold for the Sharia compliant securities. In order to investigate the hedging probability of gold against Sharia compliant stocks and Sukuk, firstly we employed the multivariate generalized autoregressive conditional heteroskedasticity dynamic conditional correlation model to estimate the dynamic co-movements and volatility spillovers between gold and the two sharia-compliant securities (equity and Sukuk), using daily data spanning from 30 Sept. 2005 to 2 October 2017. Then DCCs between gold and the two securities are used to compute dynamic hedge ratios and portfolio weights, and thus investigates the hedging opportunities arising from gold in Sharia-compliant portfolios over time. Secondly, in order to test the robustness of the results, we use the wavelet coherence analysis to see gold as a hedge for both Islamic equities and Sukuk markets in different time horizons.

The empirical results allow us to draw several findings. First, we find the mean equation for gold indicates that past returns influence current ones, with significant negative effect of the financial crisis. We also find that there is no significant return spillovers from the gold to either Islamic equities and sukuk. Second, the model shows that the structural breaks of gold have no significant influence on either Islamic equity returns or Sukuk returns. These results highlight the relative importance of gold as a diversifier and hedger in Islamic equity-Sukuk portfolios.

In terms of Islamic equities and sukuk, the results show that Islamic equities returns do affect current ones, that the structural break in 2009 had a significant negative impact on Islamic equities returns and Sukuk returns, but does effect positive and significant on gold returns. Further, we observe that there are significant positive spillover effects from Islamic equities to Sukuk but insignificant negative effects on gold returns. Interestingly, we also find significant autoregressive terms and the effect of the structural break on Sukuk during the financial crisis had a negative and significant effect on Sukuk returns. On the other side, the results show that neither returns of Sukuk nor its structural breaks significantly influence gold or Islamic equities.

We observed also that conditional correlation between gold and the two Islamic securities (Islamic equity and Sukuk) peak during the financial crises and sign of correlation has changed some times during this period. Also, we observe more variability during the year 2013 around the structural break date for gold returns, but the magnitude remains unaffected. The volatile correlations are observed in 2013 as the price of gold has been observed declining. These results indicate that gold is not a hedge nor a safe haven for Muslim investors and thus, albeit gold appears as an interesting asset to diversity a portfolio away from Islamic stocks.

Using wavelet coherence analysis, the study also demonstrated low dependence between gold and both Islamic equities and Sukuk, over time and frequency domain, represented by the dominance of colder (blue) colouring, small significant area in low frequency during the sample period. Overall, the results based on wavelet coherence analysis reconfirmed the results from multivariate DCC-GARCH analysis. It showed relatively weak interdependence between gold and Islamic securities at various investment horizons indicate that gold can provide substantial diversification opportunities, reducing the portfolio risk of Islamic securities-based investors. Furthermore, empirical results show that the statistically significant interdependence occurs at low frequency scale only around the period of recent crises with gold leading over Islamic stocks and Sukuk, indicating the occurrence of contagion effect during the crises periods at low frequency scales. Overall, these results confirmed that gold cannot be considered as good hedges due to the weak correlations exhibited with both Sukuk and Islamic equities, contradicting the findings in some of the previous studies.

Overall, the resulting evidence has several implications for market regulators and international investors who wish to invest in Islamic securities. It appears that gold, Islamic equities and Sukuk provide interesting opportunities portfolio optimization and diversifications. Gold and Islamic securities help in boosting portfolio risk reductions, especially in times of market turmoil. Our overall findings have important implication for both portfolio managers and investors to provide aid in decision making for better asset allocation in their Islamic portfolios.

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Table 1: Descriptive statistics of Gold, Sukuk and Islamic stock returns

	Gold	Sukuk	Islamic Stock
Mean	0.032	0.001	0.019
Median	0.029	0.001	0.059
Maximum	6.865	7.539	9.775
Minimum	-10.162	-15.658	-8.185
Std.Dev.	1.210	0.428	1.020
Skewness	-0.471	-3.359	-0.477
Kurtosis	5.083	5.069	10.612
JB	3456.1***	3595.4***	14678.7***
$Q(20)$	26.372**	88.683***	32.364**
$Q^2(20)$	518.759***	506.32***	52.086***
ARCH-LM(10)	16.189***	159.34***	5.011**

Notes: The data for returns is daily and covers the period September 30, 2005 to August 23, 2017. JB is the value of the Jarque–Bera statistic, testing for normality. $Q(20)$and $Q^2(20)$ are Box-Pierce statistics for autocorrelations on raw data and the squared data. The ARCH-LM(10) test of Engle (1982) checks the presence of ARCH effects. The p-values are in brackets.
∗∗∗ $p < 0.01$.
∗∗ $p < 0.05$.
∗ $p < 0.1$.

Table 2. unconditional correlations of returns between gold, Sukuk and Islamic stock

	Gold	Sukuk	Islamic Stock
Gold	1.000		
Sukuk	0.056*** (0.001)	1.000	
Islamic Stock	0.135*** (0.000)	-0.009 (0.592)	1.000

The p-values are in brackets.
∗∗∗ $p < 0.01$.

Table 3: Unit root with structural break

	Break dates	F-statistics
Gold	24/08/2011	10.079
Sukuk	2/10/2009	8.903
Islamic Stock	3/10/2009	9.864

Notes: Significant at the 0.05 level, Bai-Perron (Econometric Journal, 2003) critical value 8.58).

Table 4: Estimated coefficients of the Multivariate DCC-GARCH model

	Gold $R_{gt}(i = g)$		Sukuk $R_{kt}(i = k)$		Islamic stock $R_{st}(i = s)$	
	Coeff	*p*-value	Coeff	*p*-value	Coeff	*p*-value
Panel A: Estimation results of mean equations						
c_i	0.074	(0.117)	0.038	(0.119)	0.009**	(0.011)
ψ_{gi}	-0.016	(0.426)	0.105***	(0.000)	0.124**	(0.039)
ξ_{gi}	-0.112**	(0.033)	0.090	(0.295)	-0.073	(0.415)
ψ_{ki}	-0.022*	(0.087)	0.090***	(0.000)	-0.011	(0.908)
ξ_{ki}	-0.071*	(0.089)	-0.038**	(0.013)	-0.108	(0.291)
ψ_{si}	0.001	(0.403)	0.060***	(0.000)	-0.014**	(0.026)
ξ_{si}	0.109***	(0.000)	-1.026***	(0.000)	-0.911***	(0.000)
Panel B: Estimation results of conditional variance–covariance equations						
γ_i	0.015**	(0.015)	0.012***	(0.002)	0.003***	(0.000)
α_{gi}	0.047***	(0.000)	-0.014**	(0.046)	0.008	(0.789)
a_{ki}	-0.013*	(0.082)	0.097***	(0.000)	-0.035	(0.273)
a_{si}	0.062	(0.109)	-0.149***	(0.000)	0.081***	(0.000)
β_{gi}	0.943***	(0.000)	0.146***	(0.004)	-0.065	(0.181)
β_{ki}	-0.282	(0.162)	0.890***	(0.000)	0.699	(0.432)
β_{si}	-0.1987	(0.401)	0.115**	(0.031)	0.879***	(0.006)
ρ_{gk}	0.114***	(0.009)				
ρ_{gs}	0.186***	(0.006)				
ρ_{ks}	-0.043	(0.071)				
θ_1	0.014***	(0.006)				
θ_2	0.980***	(0.000)				
Panel C: Diagnostic tests on standardized residuals						
$Q(20)$	21.354	(0.376)	16.719	(0.671)	28.501*	(0.067)
$Q^2(20)$	11.607	(0.728)	16.530	(0.683)	12.918	(0.880)
LL	-8347.5608					

Notes: This table presents the results of the DCC-GARCH model. The first panel reports the return spillover parameters, Panel B reports the volatility transmission parameters between the three markets, Panel C presents diagnostic tests on standardized residuals. The notation corresponds to the expositions in the method section. $i = g$ (for gold returns), k (for Sukuk returns), s (for Islamic stock returns).The model is estimated by the quasi-maximum likelihood (QMLE) method which can be optimized by implementing the Broyden–Fletcher–Goldfarb–Shanno (BFGS) algorithm. $Q(20)$and $Q^2(20)$ are Box-Pierce statistics for autocorrelations of the standardized residuals and the squared standardized residuals LL is the log-likelihood function value.

$***$ p < 0.01.

$**$ p < 0.05.

$*$ p < 0.1.

Table 5: Wald joint test for causality-in-variance

Panel A: Gold and Sukuk	
No causality-in-variance from $\mathrm{R_{gt}}$ to $\mathrm{R_{kt}}$	10.890***
$H_0: \alpha_{gk} = \beta_{gk} = 0$	(0.000)
No causality-in-variance from R_{kt} to R_{gt}	1.062
$H_0: \alpha_{kg} = \beta_{kg} = 0$	(0.220)
Panel A: Gold and Islamic stock	
No causality-in-variance from $\mathrm{R_{gt}}$ to $\mathrm{R_{st}}$	1.425
$H_0: \alpha_{gs} = \beta_{gs} = 0$	(0.607)
No causality-in-variance from R_{st} to R_{gt}	2.993
$H_0: \alpha_{sg} = \beta_{sg} = 0$	(0.101)

Notes: This table shows the Wald test results of the joint null hypothesis of no volatility transmission between gold/sukuk and Islamic stock. The values in parentheses are p-values.
∗∗∗ $p < 0.01$.
∗∗ $p < 0.05$.
∗ $p < 0.1$.

Table 6: Hedge ratio and portfolio optimal weights computed from the DCC-GARCH model

	Hedge ratios	Portfolio optimal weights
Sukuk/ Gold	0.17	0.58
Islamic stock/Gold	-0.03	0.32

Notes: This table presents the average hedge ratios and optimal portfolio weights between gold and the two Islamic securities.

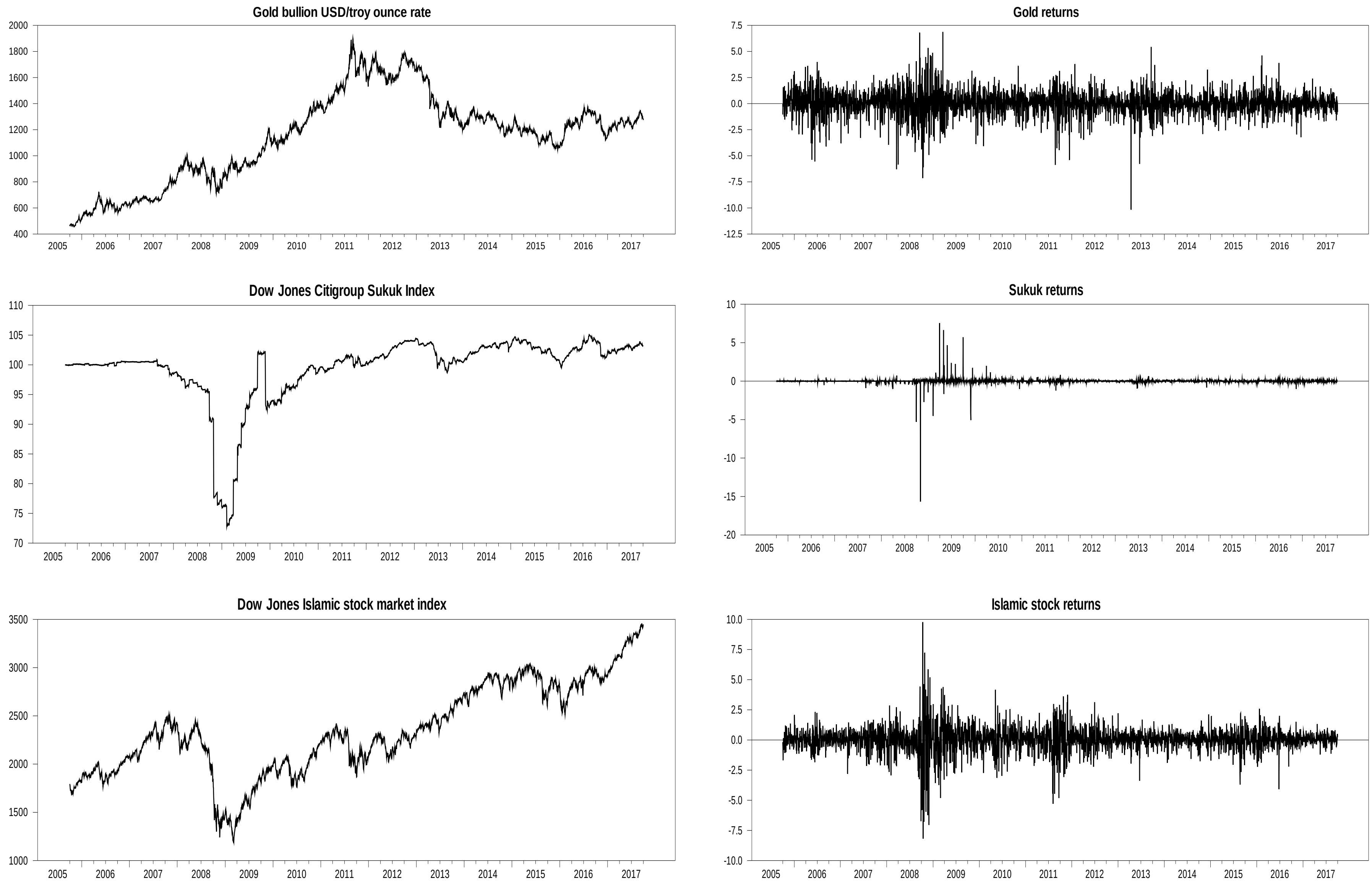

Figure 1: Daily plots of prices and returns for Gold, Sukuk and Islamic stock

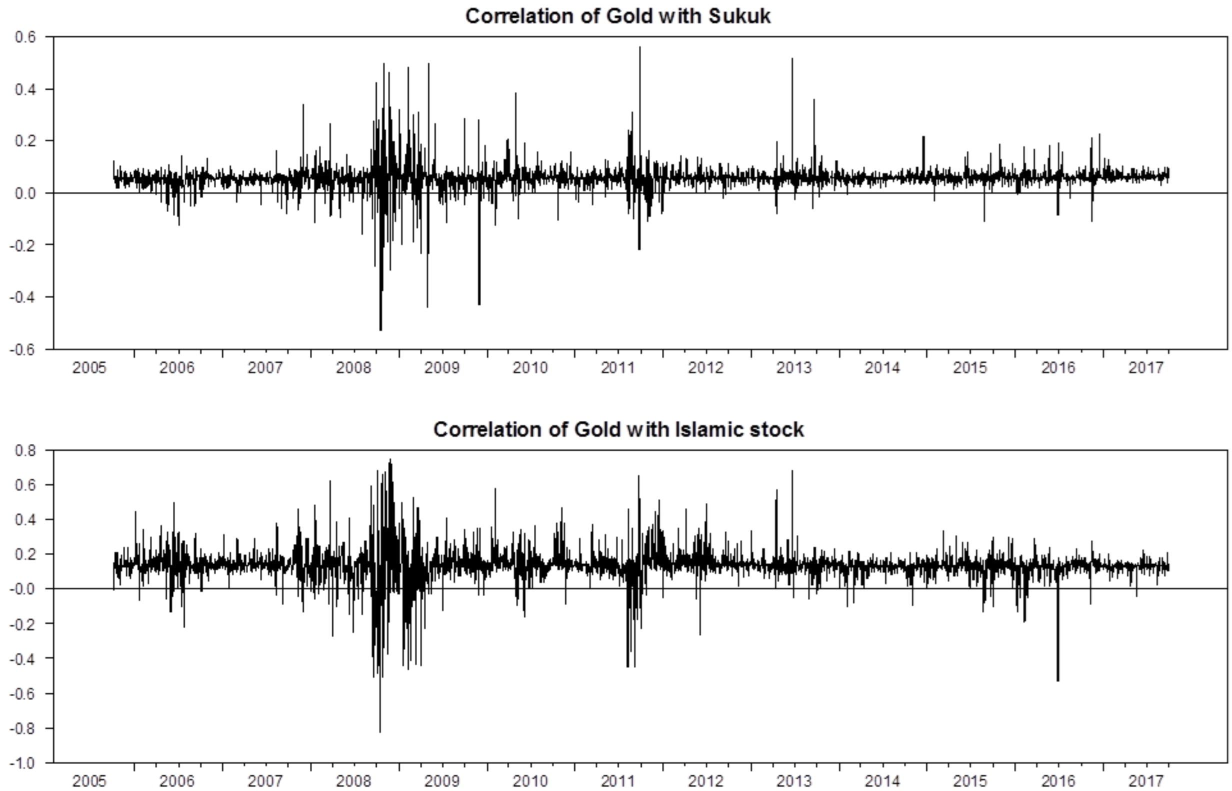

Figure 2: Dynamic conditional correlations from the DCC-GARCH model

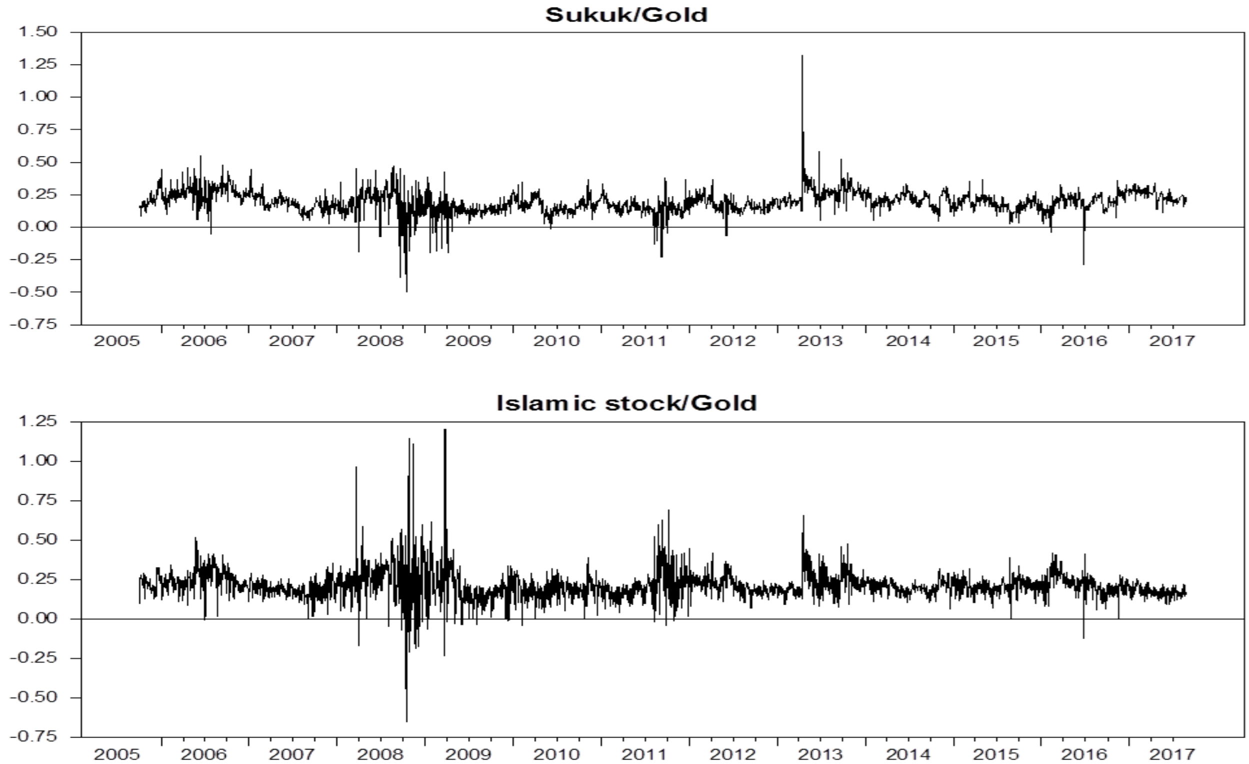

Fig. 3: Time-varying hedge ratios

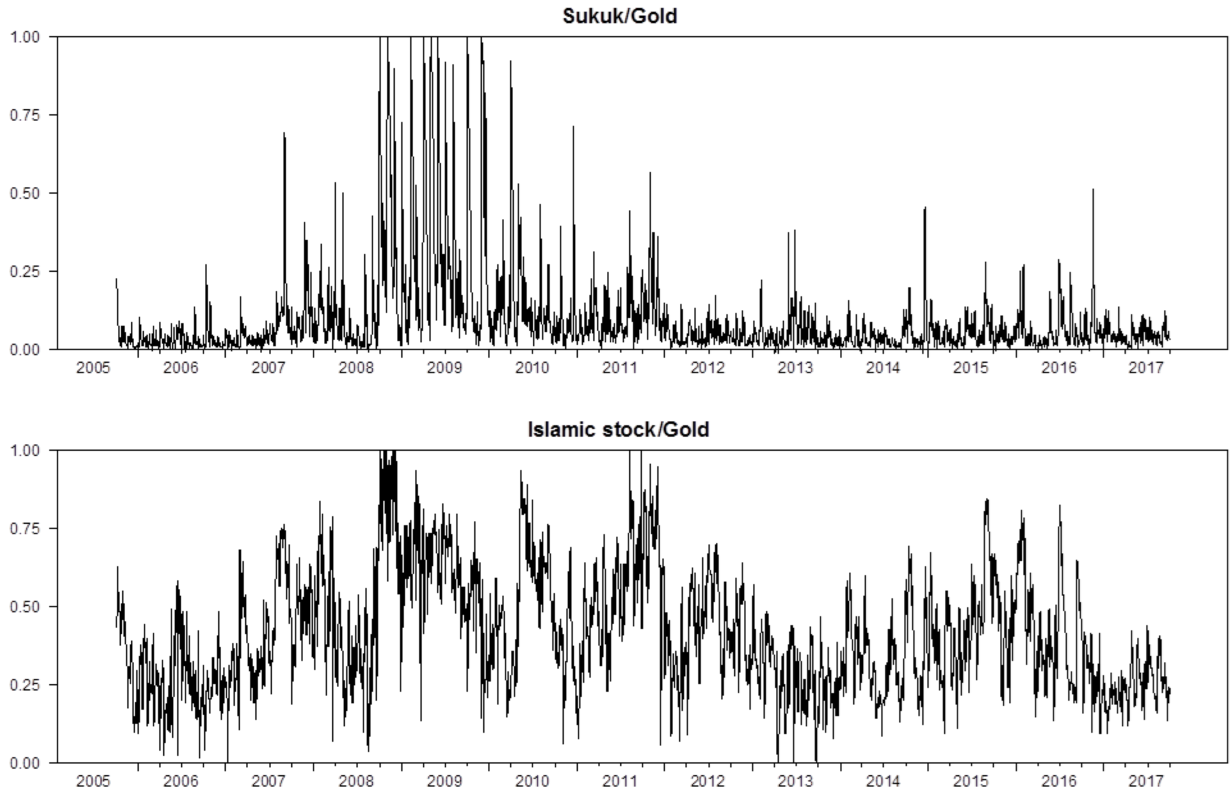

Fig. 4: Time-varying optimal portfolio weights

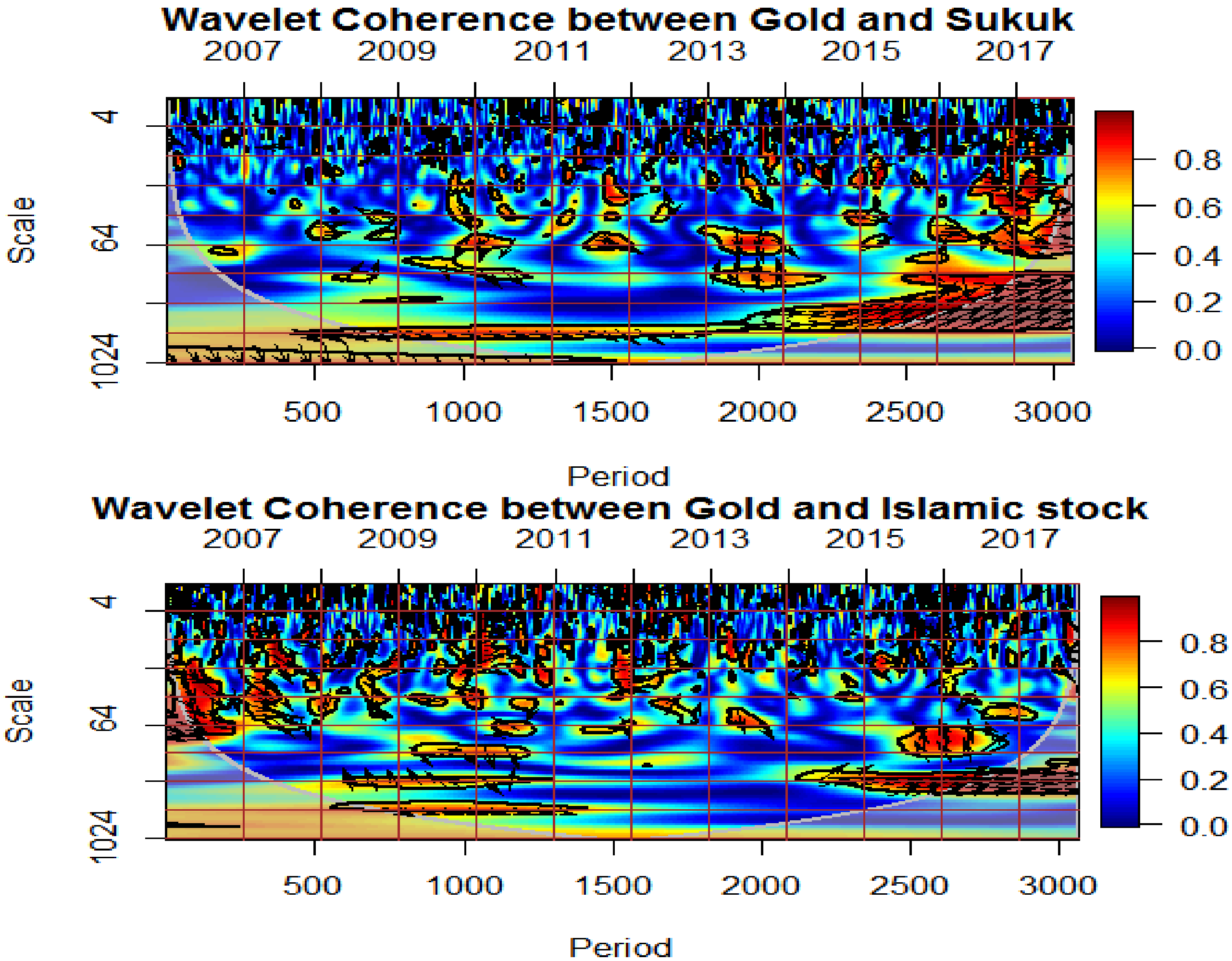

Figure 5: Wavelet coherence for Gold and Islamic securities

Notes: This figure plots the Wavelet coherence for pairs of gold Sukuk, and Islamic stock from the 30th of September 2005 to the 23th of august 2017, using daily sampling. Time is represented on the horizontal while the vertical axis shows the frequency (the lower the frequency, the higher the scale). Frequency is covered to days. The level of correlation is indicated by the color on the right side of the charts; the warmer the colors (red) the higher the absolute correlation between the pairs, while colder colors (blue) indicate lower dependence between the pairs. Cold regions beyond the significant areas represent time and frequencies with no dependence in the series. The warmer the colour of a region, the greater the coherence is between the pairs. The black solid line isolates the statistical significant area at the 5% significance level. An arrow represents the lead/lag phase relations between the two series. A zero phase difference means that the two time series move together on a particular scale. Arrows point to the right (left) when the time series are in phase (anti-phase). Arrows pointing to the right-down or left-up indicate that the first variable is leading, while arrows pointing to the right-up or left-down show that the second variable is leading.