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Interdependence between GCC stock market and oil prices and portfolio management strategies under structural breaks

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This paper empirically investigates the interdependence between GCC stock market and oil price by considering structural breaks in conditional volatility. The univariate and multivariate GARCH models are extended by including structural breaks which are determined endogenously by using ICSS algorithm proposed by Inclan and Tiao. Empirical results indicate that the inclusion of structural breaks in the model substantially reduces the volatility persistence and the estimated half-life of shocks. Hence, the conditional volatility of oil price and stock market are more affected by their own shocks and volatility when structural breaks are neglected. Likewise, our results are conclusive on conditional dependency between GCC stock market and oil price revealing that the volatility shifts reduce the shocks and volatility spillover effects. For the portfolio management, the empirical results show evidence of sensitivity of the optimal weight and hedge ratios to structural breaks in conditional volatility.

Key words: GCC stock market, oil price, dependency, multivariate GARCH, structural breaks, ICSS algorithm, portfolio implications.

INTRODUCTION

An abundant literature has investigated the volatility linkage between stock markets (Lieven, 2005; Kanas, 1998; Francis et al., 2001; Worthington and Higgs, 2004; John et al., 2010), and revealed that there is strong evidence of interdependency between stock market and suggested that shocks and volatility can be transmitted across market. Furthermore, a lot of empirical studies have investigated the volatility transmission between oil price and stock market such as those of Jones and Kaul (1996), Park and Ratti (2008), Apergis and Miller (2009) Nandha and Brooks (2009) and Sadorsky (1999, 2012). Their findings show evidence of stock market reactions to oil price changes. Guesmi and Fattoum (2014) examine the interdependence between oil price and stock market for five oil-importing countries (USA, Italy, Germany, Netherland and France) and four oil-exporting countries

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(United Arab Emirates, Kuwait, Saudi Arabia and Venezuela). They use asymmetric DCC-GARCH model and they conclude that dynamic conditional correlation does not differ for oil-exporting and oil-importing economies. However, only oil-exporting counties receive positive oil price shocks. Filis et al. (2011) provide the same results and conclude that time-varying correlations between oil prices and stock market on both oil-exporting and oil-importing countries depend on the origin of the oil shocks. For the GCC stock market, many studies include Hammoudeh and Choi (2006), Malik and Hammoudeh (2007), Lescaroux and Mignon (2008) and Arouri et al. (2011) have focused on the links between oil price changes and GCC stock market and revealed a strong interdependency between them. Hammoudeh and Choi (2006) examine the short- and long-run relationship between GCC stock market and oil price, S&P 500 and US interest rate using vector error correction model and cointegration techniques. The results based on impulse response analysis suggest that GCC stock market receives positive shocks from oil prices. Malik and Hammoudeh (2007) use trivariate GARCH model and make evidence of volatility spillover effects running from oil prices to GCC stock market and suggest that oil price receives volatility effects only from Saudi Arabia.

In the same context, Maghyereh and Al-Kandari (2007) investigate the causal links between oil price and four GCC stock markets (Bahrain. Kuwait. Oman and Saudi Arabia) based on daily data and nonlinear cointegration and conclude that GCC stock market responds to oil price shocks. Recently, Arouri et al. (2012) investigate the relationships between oil price and GCC stock market. The authors find evidence of short-run unidirectional causal links running from oil price to stock market. Awartani and Maghyereh (2013) examine shocks and volatility spillovers between GCC stock market and oil price over the period 2004-2012. They found bidirectional dependency between oil and GCC stock market and conclude that the global financial crisis of 2008 affects the estimated results. In the context of stock sector, Jouini (2013) investigates the volatility spillover effects between oil price and Saudi stock sectors using weekly data from January 10, 2007 to September 28, 2011 and VAR-GARCH model. The results show evidence of bidirectional volatility spillover effect between stock sectors and oil price. More recently Jouini and Harrathi (2014) examine the volatility interactions between GCC stock market and oil price using asymmetric BEKK-GARCH model and weekly data from June 24, 2005 to March 25, 2011. They found that the volatility spillover effects run more from stock markets to oil price, than from oil to stock markets for shocks spillover effects. Moreover, their findings are augmented by the causality test in conditional variance which confirms some evidence of bidirectional causality between GCC stock and oil markets.

Otherwise, many empirical studies such Hamilton and Susmel (1994) and Lamoureux and Lastrapes (1990) show that there was a considerable reduction in the estimated persistence of volatility when structural breaks were incorporated in the standard ARCH model and conclude that structural breaks should be included in the estimated conditional volatility. Hamilton (1994) also indicates that a good model should account for structural breaks. In the same line, Lastrapes (1989) and Lamoureux and Lastrapes (1990) argue that the volatility persistence is overestimated when structural breaks in variance are neglected in estimated GARCH model. Mikosch and Starica (2004) and Hillebrand (2005) found that ignoring structural breaks in the GARCH model induces upward biases in estimates parameters of the volatility persistence. Ewing and Malik (2005) investigate the existence of asymmetry in the predictability of the volatilities of small and large companies in the USA. They report that spillover effects between small and large cap stock returns disappear when volatility shifts are taken into consideration.

Additionally, Hammoudeh and Li (2008) examined the volatility of GCC stock market using weekly data from 1994 to 2001. They found that most of the GCC markets were more sensitive to major global events such as the 1997 Asian crisis and the September 11th attack than local and regional factors. Moreover, Marcelo et al. (2008) use Spanish stock market and weekly data from January 3. 1990 to January 5. 2005 and reveal that including structural breaks detected by using ICSS algorithm in estimated model reduce volatility persistence and shocks and volatility spillover effects. Kasman (2009) examines the impacts of the structural breaks on the volatility persistence in the BRIC stock market for the period 1990 to 2007. They find that the persistence of volatility is reduced significantly when volatility shifts are included in the GARCH model. More recently, Ewing and Malik (2013) use ICSS algorithm and BEKK-GARCH model to investigate the shocks and volatility spillovers between gold and oil futures including structural breaks in the conditional volatility based on daily data from July 1, 1993 to June 30, 2010. The authors make evidence of volatility spillover between gold and oil when structural breaks in variance are included in the model and conclude that the volatility shift reduce the estimated persistence of volatility.

The above empirical studies related to the causal links between GCC stock market and oil price ignore structural breaks in conditional volatility. Our study offers in fact more comprehensive analysis of the volatility dependence and volatility spillover effects between GCC stock market and oil price by including volatility shifts. Also, our findings are important for financial market participants to understand the behaviour of volatility and the volatility spillover between GCC stock market and oil price for portfolio decisions and hedging strategies.

The major objectives of this paper are twofold. The first objective is to examine the interdependence between GCC stock market and oil price incorporating the structural breaks in conditional volatility. The second is to use the estimated conditional volatility for portfolio decision and risk management. For this purpose, we use recent data and BEKK-GARCH model to investigate the causal links among GCC stock market and oil price. Furthermore, the volatility shifts are identified by using iterated cumulative sums of squares (ICSS) algorithms proposed by Inclan and Tiao (1994). The underlying idea in this paper is to examine the impact of structural breaks on the shocks and volatility spillover effects and the volatility dynamics.

We deem this research distinguishable from the related literature on the volatility dependency between GCC stock market and oil price for at least three points: *(i)* we use recent database covering GCC stock market and oil price; *(ii)* we include structural breaks in variance detected endogenously by ICSS algorithm to investigate volatility persistence and causal links between GCC stock market and oil price; *(iii)* we use the estimated conditional volatility for portfolio management. More precisely, we estimate optimal portfolio weights as well as the hedge ratio by considering structural breaks in conditional volatility.

The remainder of the paper is organized as follows: Section 2 covers econometric methodology. Section 3 describes the data and summary statistics. The empirical results are presented and discussed in section 4. Section 5 contains the portfolio management strategies and hedging while section 6 relates the main concluding comments.

ECONOMETRIC METHODOLOGY

The econometric technique employed in this paper to examine the interdependence between GCC stock market and oil price is the BEKK-GARCH model. First, the univariate GARCH model has been used to investigate the volatility persistence and half-life of shocks with and without structural breaks. The structural breaks in variance (volatility shifts) are determined endogenously by using ICSS algorithm developed by Inclan and Tiao (1994). Then, we employ the multivariate GARCH model to investigate the conditional dependency between GCC stock market and oil price. The BEKK parameterization of multivariate GARCH model proposed by Engle and Kroner (1995) allows to capture the shocks and volatility effect across return series. Finally, the estimated conditional volatility is used for portfolio decisions and risk management.

Detecting structural breaks in variance

Inclan and Tiao (1994) provide the iterated cumulative sums squares (ICSS) algorithm to detect structural breaks in the unconditional variance of return series due to a sudden shock. The ICSS algorithm is based on IT (Inclan and Tiao) statistics for testing the null hypothesis of constant unconditional variance against the alternative of a structural break in unconditional variance.

Let z_t denotes independent time series with zero mean and

unconditional variance σ_t^2 and the variance of each interval given by $\sigma_j^2, j = 1.2. \ldots . N_T$, where N_T is total number of variance change in T observations and $1 < k_1 < k_2 < \cdots < k_{N_T} < T$ are the set of change points. The unconditional variance over the N_T intervals is given by:

$$
\begin{aligned}
\sigma_t^2 &= \sigma_0^2 \quad 1 < t < k_1 \\
\sigma_t^2 &= \sigma_1^2 \quad k_1 < t < k_2 \\
&\vdots \\
\sigma_t^2 &= \sigma_{2N_T}^2 \ k_{N_T} < t < T
\end{aligned}
\tag{1}
$$

The cumulative sum of squares from the first observation to the kth point in time is used to detect the number of structural breaks in unconditional variance. Let $c_k = \sum_{t=1}^{k} z_t$. $k = 1. \ldots . T$. The test statistic is giver as:

$$
D_k = \frac{c_k}{c_T} - \frac{k}{T}
\tag{2}
$$

Where $c_0 = c_T = 0$ and c_T is the sum of the squared residuals from the whole period. The null hypothesis of constant unconditional variance is rejected if the maximum absolute value of D_k is greater than the critical value. Inclan and Tiao (1994) suggest that the critical value of 1.358 is the 95th percentile of the asymptotic distribution of $max_k\sqrt{(T/2)}|D_k|$. Besides, upper and lower boundaries are established at ± 1.358 in the D_k plot.

Univarite GARCH model without and with structural breaks

The univariate GARCH(1.1) model is used to investigate the volatility persistence. The GARCH model without volatility shifts is defined as follows:

$$
\begin{aligned}
R_t &= c_0 + c_1 R_{t-1} + \varepsilon_t , \\
\varepsilon_t / I_{t-1} &\rightsquigarrow N(0.h_t) \\
h_t &= c + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1}
\end{aligned}
\tag{3}
$$

Where R_t represents the stock market returns or the oil price returns. ε_t represents the residual term and h_t the conditional variance. The parameters α represents the own past shocks effects and β represents the own past volatility effects. The sum of the parameters α and β measures the volatility persistence.

In order to take into consideration the structural breaks in conditional volatility, the univariate GARCH model is augmented by including a set of dummy variables. The GARCH model with structural breaks is given as:

$$
h_t = c + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} + d_1 D_1 + \cdots + d_k D_k
\tag{4}
$$

Where $D_1 \ldots D_k$ is a set of dummy variables taking a value of 1 from each break point structural breaks detected by using ICSS algorithm and 0 elsewhere.

Bivarite GARCH model without and with structural breaks

The interactions between return series can be analyzed by using multivariate GARCH model. The BEKK specification of the conditional variance covariance matrix is more significant than univariate GARCH model to capture the linkage between return series. We present the first and second moments by bivariate VAR(1)-GARCH(1,1) model:

$$
\begin{aligned}
R_t &= \alpha + \beta R_{t-1} + \varepsilon_t \\
\varepsilon_t / I_{t-1} &\rightsquigarrow N(0, H_t)
\end{aligned}
\tag{5}
$$

With R_t a 2×1 vector of oil price returns and stock market returns, α a 2×1 vector of constant terms and β a 2×2 diagonal matrix of

autoregressive parameters. ε_t is a 2×1 vector of residual terms $\varepsilon_t = D_t \mu_t$ and has a 2×2 conditional variance-covariance matrix H_t. $\mu_t = (\mu_{1t}, \mu_{2t})'$ is a sequence of independently and identically distributed random vectors and $D_t = diag(h_{11,t}^{1/2}, h_{22,t}^{1/2})$ where $h_{11,t}$ and $h_{22,t}$ are the conditional volatility of oil price and stock market respectively. The market information available at time $t-1$ is represented by I_{t-1}. The BEKK parameterization for the bivariate GARCH(1,1) model is given as:

$$H_t = C'C + A'\varepsilon_{t-1}'\varepsilon_t A + B'H_{t-1}B \tag{6}$$

Where C is a 2×2 lower triangular matrix of constants, A and B are 2×2 square matrix. The diagonal parameters of matrices A and B measures the effects of own past shocks and past volatility of return indices on its conditional volatility. The off-diagonal elements in matrix A and B, a_{ij} and b_{ij} measures respectively the cross effects of shocks and volatility between returns series.

Following Ewing and Malik (2005), the BEKK parameterization given in equation (6) is augmented by including a set of dummy variables in order to include structural breaks. The bivariate GARCH (1.1) with structural breaks takes the following forms:

$$H_t = C'C + A'\varepsilon_{t-1}'\varepsilon_t A + B'H_{t-1}B + \sum_{i=1}^{n} D_i'X_i'X_iD_i \tag{7}$$

Where D_i is a 2×2 square diagonal matrix and X_i is a 1×2 row vector of dummy variables of cooresponding return series. The first element of matrix X_i represents the dummy variables of the first return series and the second elements represents the dummy variables of the second return series and n represents the total number of structural break points found in variance of the first and the second return series.

Portfolio designs and risk management

The estimated conditional volatility obtained from the bivariate BEKK-GARCH model can be used for the optimal portfolio designs and risk management. Following Kroner and Ng (1998), the risk minimizing portfolio optimal weight is given as:

$$w_{12,t} = \frac{h_{22,t} - h_{12,t}}{h_{11,t} - 2h_{12,t} + h_{22,t}} \tag{8}$$

Where $w_{12,t}$ is the portfolio weight of the oil relative to the stock market at time t and $h_{11,t}$ and $h_{22,t}$ are the conditional volatility of oil price and stock market respectively. $h_{12,t}$ is the conditional covariance between oil price and stock market. Assuming a mean-variance utility function, the optimal portfolio holdings of the oil portfolio is given as: 0 if $w_{12,t} < 0$, $w_{12,t}$ if $0 \le w_{12,t} \le 1$ and 1 if $w_{12,t} > 1$. The optimal weight of the stock market in the considered portfolio is $1 - w_{12,t}$.

In addition to that, the conditional volatility can be used to compute optimal portfolio hedge ratio. Kroner and Sultan (1993) show that to minimize the risk of the oil/stock portfolio an investor should shorten $\$\beta_{12}$ of the stock market that is $1 longer in the oil price. The hedge ratio is given as:

$$\beta_{12,t} = \frac{h_{12,t}}{h_{11,t}} \tag{9}$$

Data and summary statistics

We investigate the interactions between GCC stock market and oil price. Our sample covers the period from November 11, 2007 to September 18, 2012. All the data are from Datastream, sampled at a weekly frequency. The return index obtained as the first differen-

ce of the natural logarithm of the two successive weekly prices. Table 1 shows summary statistics on stock market and oil returns. This table provides that the highest weekly return is in crude oil and Saudi stock market while the highest volatility is in Qatar, Kuwait and Oman stock market. All return series, except Qatar, Kuwait and Oman are leptokurtic and skewed to the left, while the kurtosis statistics suggest the presence of asymmetry in all return series. As a consequence, the Jarque-Bera statistics reject the null hypothesis of normal distribution for all return under consideration. Furthermore, based on the Ljung-Box (LB) statistic of order 12, we can also reject the null hypothesis of white noise and assert that all series are autocorrelated. An application of the Lagrange multiplier test (ARCH-LM) shows strong evidence of ARCH effect suggesting that the ARCH model is appropriate to examine the volatility behaviour of return series.

Also, we find that the empirical unconditional correlation between GCC stock market and oil price are positive for all market. We also observe that Saudi, UAE and Bahrain stock market are more correlated with oil price, while Kuwait, Qatar and Oman have the lowest correlation with oil price.

As can be seen from Table 1, the results of the Augmented Dickey Fuller (ADF) test reject the null hypothesis of a unit root for all return series at the 1% significance level. As a result, we can conclude that all return time series are stationary. Furthermore, the dynamics of the weekly returns for GCC stock market and oil price plotted in Figures 1 and 2 show evidence of volatility clustering in all returns suggesting the presence of ARCH effect.

EMPIRICAL RESULTS AND DISCUSSION

In this section, we will discuss the empirical results of volatility persistence with and without structural breaks. We also estimate BEKK-GARCH model to examine the causal links between GCC stock market and oil price. The estimated conditional volatility obtained from the model is used for optimal portfolio allocation decisions.

Volatility shifts in unconditional variance

The estimated results reported in Table 2 indicate that the ICSS algorithm identifies four structural break points for the Bahrain stock market, three structural break points for Kuwait and Oman stock market, two structural break points for Saudi stock market and one structural break point for UAE stock market, Qatar stock market and oil price.

The empirical structural break points detected endogenously by using ICSS algorithm in unconditional variance can be caused by economic events or financial crisis[1].

Moreover, we observe that the most of structural breaks occurs during recent financial crisis (2008-2009) and there are common structural break points between returns series (Table 2).

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[1] In the present paper we do no attempt to investigate the real causes of the structural breaks but how break points affect volatility behaviour and shocks and volatility spillover effects.

Table 1. Summary of descriptive statistics of return series.

Return	Saudi Arabia	UAE	Bahrain	Qatar	Kuwait	Oman	Oil
Mean	0.13%	-0.72%	-0.57%	-0.18%	-0.48%	-1.34%	0.02%
Std.dev	0.039	0.048	0.017	0.249	0.211	0.238	0.063
Skew.	-1.108	-1.398	-1.166	0.497	0.267	0.234	0.346
Kurt.	4.177	6.069	4.425	80.338	83.637	-0.338	2.497
JB	161.122[*]	321.834[*]	180.404[*]	46531.572[*]	50425.219[*]	322.402[*]	148.401[*]
LB(12)	23.242	49.232	23.609	40.452	42.833	10.023	20.688
ARCH-LM	11.911[*]	14.320[*]	16.513[*]	41.136[*]	41.445[*]	1.249[*]	9.385[*]
ADF	-7.161	-5.466	-5.983	-12.628	-11.989	-8.884	-6.271
Corr. Stock /Oil	0.279	0.144	0.182	0.025	0.027	0.020	-

Notes: [*] denote the significant level at 1%; Std.dev is the standard deviation; JB is the Jarque-Bera normality test; LB is the Ljung-Box test for autocorrelation of order 12; ARCH-LM is the statistics test for conditional heteroskedasticity of order 2; ADF is the statistics test for unit root.
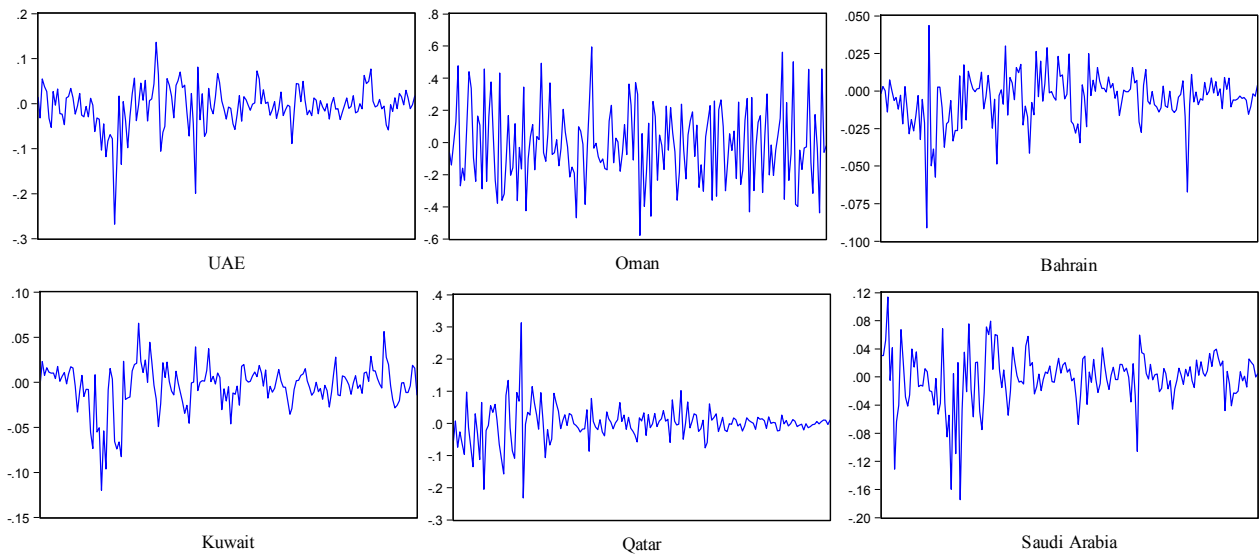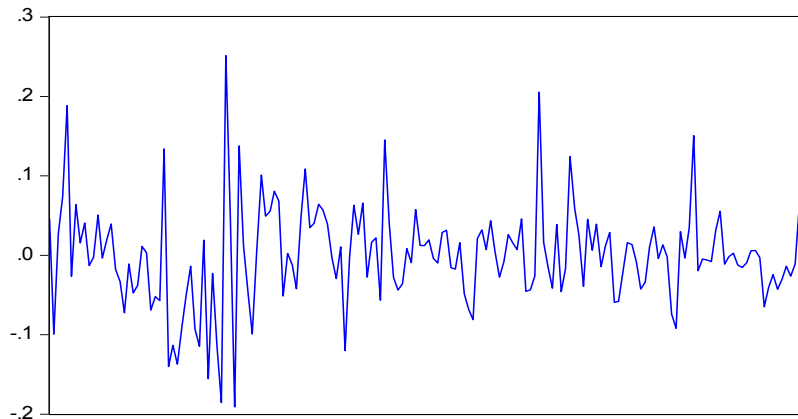

Figure 1. Weekly GCC stock market return

Figure 2. Weekly oil price return.

Table 2. Structural breaks in unconditional variance: The ICSS algorithms results.

Nb. Breaks	Bahrain	Kuwait	Oman	Saudi Arabia	UAE	Qatar	Oil
1	9-Jul-2008	18-Aug-2008	22-Apr-2008	26-Apr-2009	16-Sep-2008	16-Sep-2008	22-Jul-2009
2	16-Sep-2008	24-Jan-2011	18-Aug-2008	27-Sep-2009			
3	17-May-2010	8-Apr-2012	24-Jan-2011				
4	10-Aug-2011						

Table 3. Univariate GARCH(1.1) estimation result without and with structural breaks.

Return	Model	α	β	$\alpha + \beta$	Half-Life shocks	$logl$
UAE	without structural breaks	0.270	0.671[*]	0.940	11.224	308.923
	with structural breaks	0.267[***]	0.542[*]	0.809	3.276	309.728
Oman	without structural breaks	0.107	0.809[*]	0.916	7.938	6.479
	with structural breaks	0.054	0.507[**]	0.561	1.199	6.970
Bahrain	without structural breaks	0.502[**]	0.440[*]	0.942	11.617	471.875
	with structural breaks	0.079[*]	0.048[*]	0.126	1.177	482.175
Qatar	without structural breaks	0.723[**]	0.242[**]	0.965	19.650	188.374
	with structural breaks	0.375[*]	0.221[*]	0.596	1.339	251.681
Kuwait	without structural breaks	0.179[**]	0.729[**]	0.908	7.201	76.865
	with structural breaks	0.166[*]	0.330[*]	0.496	0.989	354.380
Saudi Arabia	without structural breaks	0.559[*]	0.419[*]	0.979	32.225	354.867
	with structural breaks	0.415[*]	0.360[*]	0.775	2.720	356.885
Oil	without structural breaks	0.323[*]	0.522[*]	0.845	4.110	248.364
	with structural breaks	0.258[*]	0.463[*]	0.720	2.112	249.033

Notes: The full set of results is available from the authors upon request. Reject of null hypothesis at 1%. 5% and 10% is denoted by *,**,***.

Volatility persistence without and with structural breaks

The above empirical results about structural breaks are used in order to investigate volatility shifts effects on volatility dynamics. The empirical results of univaraite GARCH(1,1) model[2] without and with structural breaks (Table 3) stress that all GARCH coefficients are highly significant, suggesting that the current values of conditional volatility of the GCC stock market and oil price are sensitive to their past own volatility with and without structural breaks[3]. Besides, except the UAE and Oman

stock market, the results indicate the past own shocks affect current conditional volatility when structural breaks are ignored. Furthermore, we observe that the current volatility is affected by its past own shocks, except Oman stock market after including structural breaks. Another interesting finding is that the past own volatility (GARCH coefficient) is greater than past own shocks (ARCH coefficient) for Bahrain, Qatar and Saudi stock market, suggesting that past own volatility is more important in predicting current volatility than past own shocks.

Otherwise, the estimated results in Table 3 offer some interesting insights. We observe that the estimated parameters of the univariate GARCH model with structural breaks are smaller than before including structural breaks for all return series. This fact implies that the volatility persistence drops substantially if structural breaks are included[4]. Accordingly, the degree of persistence declines in the model with structural breaks. In the same context, Lamoureux and Lastrapes (1990) show that the results of standard GARCH model indicate more volatility persistence if structural breaks are

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[2] The optimal lag length for the GARCH model was determined by using the AIC and BIC information criteria.

[3] The estimated results show that all dummy variables are statistically significant at conventional level, except one breaks point for Bahrain and Oman. However, the joint significance of structural breaks is supported by the likelihood ratio statistic (LR) given by $LR = 2[L(\hat{\theta}_1) - L(\hat{\theta}_1]$ where $L(\hat{\theta}_1)$ and $L(\hat{\theta}_0)$ are the maximum log likelihood values for the models with and without structural breaks, respectively. The LR statistic is asymptotically distributed as χ^2 with degrees of freedom equal to the number of restrictions. We find that the null hypothesis of no structural breaks is rejected at conventional level for all case. This fact implies that the model which incorporates structural breaks is more appropriate to depict the volatility dynamics over time. The result is not reported due to the large number of estimated parameter but available from the authors upon request.

[4] This finding is consistent with Kasman (2009) which reveal that the empirical results of previous studies could have overestimated the degree of the volatility persistence.

Table 4. Parameter estimates of bivariate GARCH (1.1) model.

Coef.	bivariate GARCH(1.1) model without structural breaks					
	Oil-UAE	Oil-Oman	Oïl-Bahrain	Oil-Qatar	Oil-Kuwait	Oil-Saudi Arabia
α	-0.002	-0.014	-0.002***	0.003	0.007	0.001
	(0.0023)	(0.0199)	(0.0009)	(0.0031)	(0.0062)	(0.0022)
β	0.317*	-0.159**	0.404*	-0.417***	-0.176***	0.339*
	(0.0778)	(0,0772)	(0.0792)	(0.2486)	(0.1029)	(0.0882)
a_{12}	-0.185	0.211	-0.005**	0.143	0.074	0.090
	(0.1027)	(0.1794)	(0.0023)	(0.1557)	(0.0649)	(0.0699)
b_{12}	0.154*	-0.844*	0.170	0.558*	0.176	-0.233*
	(0.0389)	(0.1541)	(0.2410)	(0.2078)	(0.5819)	(0.0692)
a_{21}	-0.532	0.005	-0.271	0.104	0.008*	-0.768
	(0.4181)	(0.0291)	(0.2059)	(0.1104)	(0.0022)	(0.5618)
b_{21}	-0.626*	-0.076	0.342*	-0.130*	-0.006	0.699*
	(0.1376)	(0.0733)	(0.0473)	(0.0372)	(0.0084)	(0.2422)
	bivariate GARCH(1.1) model with structural breaks					
α	-0.003	-0.016	-0.001	0.003	-0.002	0.004
	(0.0025)	(0.0193)	(0.0010)	(0.0023)	(0.0016)	(0.0025)
β	0.348*	-0.158***	0.410*	-0.223**	0.353*	0.253*
	(0.0892)	(0.0857)	(0.0820)	(0.1116)	(0.0679)	(0.0870)
a_{12}	0.061	0.217	-0.026	-0.142*	0.117*	0.037
	(0.0730)	(0.1575)	(0.0237)	(0.0416)	(0.0429)	(0.0641)
b_{12}	-0.275*	-0.913**	0.088*	0.174*	0.158*	-0.391*
	(0.0363)	(0.4181)	(0.0217)	(0.0572)	(0.0385)	(0.1270)
a_{21}	-0.171	-0.001	-0.279	-0.008	0.005***	0.649*
	(0.1253)	(0.0316)	(0.3438)	(0.0095)	(0.0027)	(0.1749)
b_{21}	0.381	-0.070	0.275*	0.033*	0.021**	0.563*
	(0.3260)	(0.0396)	(0.0612)	(0.0105)	(0.0104)	(0.2004)

Notes: The oil price return is denoted 1 and stock return is denoted 2. Standard errors are given in parenthesis. *, ** and *** denote rejection of the null hypothesis at 1%, 5% and 10% levels, respectively. The full set of results concerning the diagonal parameters c_{ii}, a_{ii} and b_{ii} are available from the authors upon request.

ignored and conclude that structural breaks should be incorporated into the estimated GARCH model. We also find that the maximum values of log likelihood are smaller than before including structural breaks. Consequently, the model with structural breaks provides a better fit and subsequently more appropriate than the model ignoring breaks.

Additionally, a high degree of persistence in volatility suggests that shocks on volatility die out slowly over time. The estimated results of half-life of shocks given by $(-\log(2)/\log(\alpha + \beta))$ change dramatically for all returns when we include structural breaks. The estimated half-life of shocks changes from 4 to 2 weeks for oil and from 11 to 3 weeks for UAE.

This fact implies that shocks lose their effect after a few weeks when structural breaks are included. Likewise, we find that the GCC stock market and oil price react relatively strongly to incoming news but absorb it fairly quickly. Our finding is consistent with Ewing and Malik (2013) who report that including structural breaks reduce

volatility persistence and the shock effects disappears rapidly.

Shock and volatility spillover effects between stock market and oil

We focus on the relationship between GCC stock market and oil price. The estimated results of the mean equation given by Eqs. 5 and reported in Table 4 indicate that all autoregressive parameters are statistically significant at the conventional levels. This fact implies that the current values of all returns are sensitive to their past own values with and without structural breaks. We also find evidence of short-term predictability in GCC stock market and oil price.

The estimated results of the oil-stock market model[5]

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[5] To the best of our knowledge, there is no empirical research that attempts to examine the interactions between GCC stock market and oil price by considering structural breaks in conditional volatility.

point out that the diagonal parameters a_{ii} and b_{ii} of conditional variance and covariance matrix without and with structural breaks are statistically significant at conventional levels. This fact implies that the conditional volatility is affected by its own past shocks and volatility for all return[6]. The results also indicate that the estimated parameters of past shocks and past volatility are smaller than before including structural breaks. This finding is consistent with the above empirical results of the univariate GARCH model who suggest that including structural breaks on the estimated model reduce the volatility persistence. But this is not all, the cross effects of shocks and volatility are of low importance compared to those obtained if structural breaks are included in the conditional volatility. The latter results are consistent with Marcelo et al. (2008) who reveal that volatility shifts reduce the volatility persistence and the shocks and volatility spillover impacts. Furthermore, the diagnostic tests based on standardized residuals (not reported to preserve space) such as Jarque-Bera test for normality, Ljung–Box tests for autocorrelations of order 12 applied to standardized residuals and squared standardized residuals and ARCH test for conditional heteroscedasticity of order 12 indicate that the model that incorporates structural breaks is suitable to investigate the conditional association between GCC stock market and oil price.

For the interactions between GCC stock market and oil price, the estimated results reported in Table 4 stress that the oil price volatility affects all GCC stocks market[7], except Bahrain and Kuwait, while only Bahrain stock market reacts negatively to oil price shocks when structural breaks are ignored. On the other hand, the empirical results after including structural breaks indicate that all GCC stock market are sensitive to the past oil price volatility, while oil price shock affects only Kuwait and Qatar stock market volatility. These findings can be explained by the contribution of oil revenues to GDP in GCC countries whose stock market's size indicator as measured by the market capitalization to GDP is positively correlated with the importance of oil in their economies.

Moreover, we find out that UAE stock market receives positive volatility effects when structural breaks are ignored and negative volatility effects when structural

breaks are included. Such results point out that the sign of shocks and volatility spillover effects between GCC stock market and oil price has reversed when the structural breaks are included in the model.

Furthermore, the empirical results for the model without structural breaks show evidence of volatility spillover effects running from GCC stock market to oil price, except Kuwait and Oman while only Kuwait stock market shocks affect oil price. Unlike the later results that exclude structural breaks, the results seem to change after including structural breaks that point out that oil price receives positive volatility spillover from GCC stock market except UAE and Oman. Our finding is more consistent than that of Malik and Hammoudeh (2007) who report that oil price receives volatility spillover effects only from Saudi stock market. Additionally, Arouri et al. (2011) conclude that the causal links are more apparent from oil price to GCC stock market. Moreover, our conclusion contradicts that of Arouri et al. (2012) who provide evidence of unidirectional causal links running from oil price to GCC stock market. A noticeable feature is that there is evidence of negative (positive) sensitivity of Qatar (Oman and Saudi) to oil price changes when structural breaks are included, whereas oil price receives positive shock from Kuwait and Saudi stock market.

To sum up, our results point out that there is evidence of bidirectional causal links between GCC stock market and oil price. These findings are in line with Awartani and Maghyereh (2013) and Jouini and Harrathi (2014) who reveal evidence of shocks and volatility spillover effects between GCC stock market and oil price. Additionally, the obtained findings indicate that the structural breaks change the direction of the causal links among GCC stock market and oil price, the sign of shocks and volatility spillover effects and the magnitude of the estimated parameters.

Portfolio decisions and hedging strategies

We discuss the financial implication for the portfolio decisions and risk management. The estimated results of the optimal weights (average value) for each oil-stock portfolio reported in Table 5 point out that Oman, Qatar and Kuwait stock market have the highest optimal weights. We also find that the estimated results of optimal weights change dramatically when we include structural breaks. As can be seen from Table 5, the optimal weights are increased for all portfolios after incorporating structural breaks in the conditional volatility.

For example, the result suggests that the optimal holding of oil in $1000 of oil-Kuwait stock market portfolio is $424, compared with $576 for the Kuwait stock market while the optimal holding of oil is $578, compared with $422 for the same market when we include structural breaks. Hence, the investors in Kuwait should own more stock (oil) than oil (stock) in the corresponding portfolio in

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[6] The best suited-model we obtain for all oil-stock market pairs by using the AIC and BIC information criteria is a VAR(1)-GARCH(1,1). It is shown in the literature that such model allows well capturing the conditional dependency across markets. We also use the quasi-maximum likelihood method to estimate the selected model since the normality hypothesis is rejected.

[7] The GCC countries account for 52% of the total OPEC oil reserves and 49% of the total OPEC crude oil production. Also, GCC countries produce about 20% of all the oil in the world, accounting for 35.7% of world oil exports, and have 47% of proven oil reserves in the world. Oil and gas represents approximately 73% of total export earnings, roughly 63% of government's revenues and 41% of its GDP. For the GCC countries, oil exports are the main sources of revenues, government expenditures and aggregate consumption demand.

Table 5. Optimal portfolio weight and hedge ratio.

Portfolio	Without structural breaks		With structural breaks	
	$w_{12,t}$	$\beta_{12,t}$	$w_{12,t}$	$\beta_{12,t}$
Oil - UAE	0.635	0.410	0.773	0.483
Oil - Oman	0.584	0.651	0.601	0.686
Oil - Bahrain	0.621	0.598	0.649	0.784
Oil - Qatar	0.783	0.369	0.785	0.513
Oil - Kuwait	0.424	0.433	0.578	0.470
Oil - Saudi Arabia	0.752	0.581	0.844	0.691

Notes: $w_{12,t}$ is the portfolio weight of oil relative to stock market at time t, while average $\beta_{12,t}$ is the risk-minimizing hedge ratio

order to minimize the risk without reducing the expected return if the structural breaks are ignored (included).

For the oil-Saudi stock market portfolio, an optimal portfolio weight of 75.2% implies that an investor willing to invest $1000 will get a minimum risk if the investor holds $752 in oil and $248 in stock market. The results show that the optimal weight becomes 84.4% after including structural breaks which implies that investor holds $844 in oil and $156 in stock market. We also find that investor should have more oil (stock) than stock (oil) in their portfolio for all GCC stock market.

From the estimated results reported in Table 5, we find out that the hedge ratios have increased after accounting for structural breaks. The results of the average values hedge ratios indicate that Bahrain, Kuwait and Saudi stock market have the highest hedge ratio. The hedge ratio of oil-Bahrain stock market portfolio implies that $1000 long in oil should be shortened by $598 of stock market when structural breaks are ignored compared with $649 after accounting for structural breaks. For the oil-Saudi stock market portfolio, we find that every dollar which is long in the oil the investor should short 58 cents when structural breaks are ignored and 69 cents after accounting of structural breaks. Our findings show how our estimated results could be used by financial market participants in GCC countries for making portfolio allocation decisions and risk management[8].

In the result, the obtained findings show that of the optimal weight and hedge ratios differs across GCC stock markets, which can be explained by the fact that GCC countries differ in their levels of dependency on oil price and in their efforts to diversify and liberalize their economies. To sum up, our findings show that the values of the optimal weight and hedge ratios increase when we include structural breaks in the estimated conditional

volatility. Indeed, the results show how structural breaks affect the estimated values of the optimal portfolio weight and the risk minimizing hedge ratios. This has important implications for portfolio selection in financial markets.

Conclusion

The paper aims to investigate the conditional dependency between GCC stock market and oil price and portfolio management strategies under structural breaks. The results suggest that structural breaks reduce the volatility persistence implying that the conditional volatility is more affected by their own past shocks and own past volatility when structural breaks are ignored. We also find evidence of causal links running from oil price to GCC stock market. Moreover, the estimated results show that oil price receives volatility spillover effects from the majority of GCC stock market. Besides, the obtained findings indicate that the sign of shocks and volatility spillover effects has reversed after including structural breaks in the estimated model, e.g. the oil price receives negative volatility spillover effects from Qatar before including structural breaks and positive volatility spillover effects after including structural breaks. The same findings are obtained for the shock spillover effects of Saudi stock market. We also conclude that the structural breaks affect both the causal direction among GCC stock market and oil price and the magnitude of the estimated parameters as well as the degree of persistence in conditional volatility.

Otherwise, the empirical results on the relationship between GCC stock market and oil price may offer insights to investors to know how the value of their portfolios will be affected by large variations observed in oil price. Hence, it is interesting to find that the model ignoring structural breaks gives an optimal weight and hedge ratios smaller than the model that incorporates structural breaks. Our findings show also evidence of sensitivity of optimal weight and hedge ratios to the structural breaks and GCC stock market. These findings can help financial market participants for portfolio

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[8] The slump in global oil market due to the global financial and economic crisis of 2007-2008 slowed the pace of investment, but the recent global economic recovery and the GCC economic reform program, focusing to attract domestic, regional and foreign private investment will result in a sharp rebound in the region's economic activities. Also, the recent economic reform program of the GCC countries could increase resilience against crises and their market transparency.

selection and risk management.

In this paper, we find that structural breaks reduce the volatility persistence on the one hand and affect the shocks and volatility spillover effects on the other hand. Our findings show that ignoring structural breaks in conditional volatility may lead to wrong results about the interdependency between GCC sock market and oil price and the portfolio decisions.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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