Volatility Spillovers across GCC Stock Markets

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Abstracts

The study of volatility transmission across markets commonly termed "volatility spillover" provides useful insights into how information disseminate across markets. Research results in this area have useful implications for issues such as international or regional diversification and market efficiency. This paper investigates volatility spillovers across GCC stock markets, namely Saudi, Abu-Dhabi, Dubai, Kuwait, Bahrain, and Muscat. The objective of the paper is to explore whether volatility surprises in one market influence the volatility of returns in another market in the group. The direction of variance causality in these markets indicates strong evidence of bi-directional volatility spillovers across four of GCC stock markets: Saudi and Kuwait; Kuwait and Abu-Dhabi; Abu-Dhabi and Dubai. This result implies that volatility surprises at any one of these markets influence volatility of returns in the other corresponding market. The other two markets, Muscat and Bahrain, are neither affected by each others' volatility nor influenced by volatility of other GCC markets.

1-Introduction

After the crash of October in 1987, the issue of volatility inter-dependence among capital markets gained momentum and become the subject matter of much research in financial economic literature. King and Wadhwani (1990) investigate a number of U.S markets after the crash and identify that markets overreact to the events of other markets, irrespective of the economic value of Information transmitted. Eun and Shim (1989) identify that about 26% of international stock markets variability can be explained by variability in return in other stock markets. Cheung and Ng (1996) show that variability of stock returns of Asian-Pacific markets closely associated with the variability of stock returns in the major U.S stock markets.

While substantial research efforts have taken place in the past few years on volatility spillovers across the developed and the emerging Asian stock markets, no prior research conducted on volatility

Inter-dependence of GCC stock markets.

The primary objective in this paper is to investigate the presence of volatility transmission across six of the GCC stock markets. They include Saudi, Dubai, Abu-Dhabi, Kuwait, Muscat, and Bahrain stock markets. There are some common characteristics identify these markets as a unique group. GCC countries have close and common economic, institutional, and cultural ties, a consequently these markets have common features and dual stock listings. More recently these markets have adopted structural reforms related to trading systems sophistication, including regulatory framework, trading rules, reporting, surveillance, settlements, and clearance systems. All these efforts come in conjunction with the newly adopted agreement obligating member GCC states equal treatment of all GCC nationals in all investment activities, including stock ownership and establishment of new business, and allow free mobility of capital and labor of GCC nationals in member countries. The new agreement also calls for integration of financial markets, and for harmonization of all investment related laws and regulations. GCC leaders also agreed to form a single currency by the year 2010.

To the best of my knowledge, no prior published research in volatility spillovers across GCC capital markets. However, this paper is motivated by the growing literature on the conditional variance a cross financial markets. In the literature, different methods adopted for measuring volatility spillover. Some of the methods include the cross-market correlation approach (Cheung and Ng, 1996); others adopt GARCH modeling approach (Hamae et al, 1990). In this paper we followed the latter approach. Two step procedure is employed to characterize the pattern of information flows based on variance causal relationships. The first step includes determining variability in return in each market as a function of its own lagged variability and variability of returns

of other GCC markets. In the second step we investigate variance causality between each two markets, to see if variability in one market can be explained by the variability of another market in the group.

The main contribution of this paper is that investigation of volatility inter-dependence among GCC equity markets renders better understanding of pricing of securities, trading strategies, risk management policies, and helps for regulatory purposes of GCC stock markets.

The reminder of the paper is structured as follows. Section two highlight growth indicators of GCC stock markets; Section three presents basic data analysis; Sections four and five respectively, investigate unit root tests and cointegration analysis. Sections six and seven conduct GARCH effects, and variance causality analysis; the final section concludes the study.

2-Market growth

Policy makers in GCC countries have realized that in order to achieve diversified economies, less dependent on oil resources, they must liberalize capital markets and remove res

trictions on foreign investments and mobilize domestic savings towards their economic development needs. Given that efficient and well-functioning capital markets are crucial for achieving such a goal, all GCC countries during the past five years embarked on new regulatory reforms that aim deepening their stock markets. Likewise, laws have been enacted to improve prudential regulations of commercial banks. As a result, all GCC countries opened up their equity markets to foreigners, and anti-money laundering policies adopted to safe guard against unwanted inflow of money to the region. Also restrictions have been eased for capital mobility between GCC countries. The outcome of these outward oriented investment policy is substantial surge in the liquidity of GCC stock markets as this can be shown from the significant rise in turn-over ratios and the expanding market capitalization for the past three years. Table (1) indicates that the size of GCC stock markets increased 514% during the period 2002 to 2006. During the same period the turn-over ratio increased from 25% to 124%, and the number of listed companies from 330 to 524 companies. The increase in the number of listed companies is mainly due to dual-listing[1].

It is important to realize that despite oil price rises considered a factor augmented the liquidity of GCC stock markets, the effect of new investment regulations including, dual-listing of companies and ease of restrictions on investment in equity markets, are most likely to have more direct impact on enhancing volatility spillovers across GCC markets.

[1] The apparent increase in the number of listed companies in Kuwait stock market is mainly due to dual-listing of companies from other GCC markets.

Table 1 Market growth

	Market Capitalization (million US$)		Turn-over ratio (%)		No. of Listed Companies	
	2002	2006*	2002	2006*	2002	2006*
Kuwait	26,926	106825	12.1	9.5	90	175
Bahrain	6765	21227	0.97	2.7	41	50
Muscat	3559	13089	2.3	3.5	95	119
Saudi	76,364	457381	8.8	81.9	76	81
Ab.Dhabi	6,224	93979	0.4	4.3	16	59
Dubi	8,456	95932	1.3	22.4	12	40

* To the third quarter of 2006.

Source: Arab Monetary Fund Data Base.

3-Data analysis:

Data employed in this study are daily closing stock price indices for GCC stock markets[2]. The sample period covers from May 2004 to Sept, 2006 (852 observations). Summary statistics for stock returns are presented in table (2).

Table 2.Basic statistics.

	Ab.Dhabi	Saudi	Dubai	Muscat	Kuwait	Bahrain
Mean	4.2	13.3	2.6	5.9	11.3	0.54
St.deviation:	90.1	307.6	93.8	104.6	182.2	24.7
Skewness:	1.45	-0.35	1.26	9.13	0.90	1.97
Kurtosis:	5.36	4.0	5.01	83.6	4.5	7.49
JB	115.5	49.7	97.4	22764	71.9	223
p-value	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

[2] Qatar stock market has not been included in the study due to its data mismatch with the sample size of the research data.

Analysis of the autocorrelation function (ACF), as indicated by the values of modified Box-Pierce statistic, shows at log levels, all markets exhibit statistically significant autocorrelation function (ACF) coefficients, while the log differences, or stock returns, shows insignificant ACFs. This result violates the finding by Bekaert and Harvey (1995), that ACFs have some significant lag effects in stock returns of emerging markets

Table 3 Autocorrelation function

		Log level				
Lag	Oman	Bahrain	Kuwait	Saudi	A.Dhabi	Dubai
1	0.97	0.98	0.99	0.99	0.99	0.99
2	0.94	0.97	0.99	0.99	0.99	0.99
3	0.91	0.96	0.99	0.99	0.99	0.99
4	0.89	0.95	0.99	0.98	0.98	0.98
5	0.86	0.94	0.98	0.98	0.98	0.98
		Log First-Difference				
1	-0.00	0.00	-0.01	0.00	0.00	0.00
2	0.00	0.00	.00	0.00	0.00	0.00
3	0.00	0.00	-0.00	0.00	0.00	0.00
4	0.00	0.00	-0.00	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00

Due to self-evidence of the results in the table, P-values for LJung-Box Pierce statistic are not reported.

4. Unit root tests

To test the order of integration for each market, the augmented Dickey-Fuller (ADF), and Phillips and Perron unit root tests employed. Since methodologies of these tests are well documented in the literature, we report in table (4) tests results for each market. The lag length parameter for ADF test is determined using the Akaike information criteria (AIC). Results of unit root tests in table (4) indicate that the levels of stock prices are non-stationary, while their first differences exhibit stationarity behavior. This result suggest that the order of integration of these markets is unity, I(1), which implies the first differenced series will be used in the upcoming cointegration and causality analysis.

Table 4 Unit root tests

	ADF test statistics	PP test statistics	5% critical values
	Log level:		
A.Dhabi	3.6	3.3	6.25
Saudi	14.4	13.5	6.25
Dubai	3.3	3.3	6.25
Kuwait	4.3	4.7	6.25
Oman	1.9	1.6	6.25
Bahrain	5.1	3.3	6.25
	Log difference:		
A.Dhabi	120	299	6.25
Saudi	143	426	6.25
Dubai	142	411	6.25
Kuwait	131	339	6.25
Oman	150	362	6.25
Bahrain	226	738	6.25

and volatility (as in table 2), in this paper Autoregressive Conditional Heteroskedasticity in Mean (ARCH-M) is employed to model the dynamic behavior of the residuals.

Given a time series {x(t)}, t=1,2,....N, a ARCH-M process is shown as:

$$x_t = a_0 + \sum_{i=1}^{k_1} a_i x_{t-i} + \log(h_t) + e_t \qquad (1)$$

$$\text{where} \quad e_t / I_{t-1} \sim N(0, h_t)$$

and

$$h_t = \beta_0 + \sum_{i=1}^{k_2} \beta_i e^2_{t-i} + \sum_{i=1}^{k_3} \alpha_i h_{t-i} \qquad (2)$$

Equation (1), describes the conditional mean dynamics, and equation (2) postulates GARCH process of the error terms, with conditional variance, h_t, and k_i (i=1,2) are lag parameters. Table (6), includes result of the Lagrange multiplier test and confirm that all markets, with exception of Muscat and Bahrain markets, exhibit significant autoregressive conditional hetroskedasticity.

Table 6 LM test statistic

	LM Statistics	Df	Critical values (5% significance level)
Dubai	165*	5	11.05
Saudi	164*	5	11.05
A.Dhabi	130*	5	11.05
Muscat	0.01	5	11.05
Kuwait	52.1*	5	11.05
Bahrain	0.006	5	11.05

Lag parameters in the LM statistic determined using AIC.

*** significant at 5% significance level.**

Given the evidence of GARCH-M effects in some of the data, study of causal link between stock markets' return volatility should take into account GARCH-M effects, where relevant.

7-Causality test

Given that, x and y are two variables and are cointegrated, we set up our error correction model as:

$$r_{xt} = \gamma_0 + \sum_{j=1}^{5} \gamma_{xt} r_{y(t-1)} + \lambda r_{x(t-1)} + \log(h_t) + e_t \qquad (3)$$

$$where,\ e_{jt(t-1)} \sim N(0, h_{jt})$$

$$h_{jt} = \beta_0 + \sum_{i=1}^{k1} \beta_i e^2_{jt-i} + \sum_{i=1}^{k2} \delta_i h_{jt-i} + \varepsilon_{jt} \qquad j = 1, \ldots\ldots 6$$

where j=1,..6, stand for the stock markets.

The set of equations in (3) represents GARCH-M model as $\log(h_t)$ is the error correction term represented by the logarithm of the conditional variance of residuals, and e_t is the residual term exhibiting a GARCH process with conditional variance function given by h_{it}.

Given volatility specification as in (3) we use variances from equations (3) to identify variance causality between each two markets as in (4):

$$h_{xt} = \alpha_{x0} + \sum_{i=1}^{p} \alpha_{xi} h_{x(t-i)} + \delta_y h_{yt} + \delta_{y1} h_{y(t-1)} + v_{xt} \qquad (4)$$

$$h_{yt} = \alpha_{y0} + \sum_{i=1}^{q} \alpha_{yi} h_{y(t-i)} + \delta_x h_{xt} + \delta_{x1} h_{x(t-1)} + v_{yt}$$

Estimation results of the set of equation in (4), as indicated in table (7), show that there is significant bi-directional feedback effects between volatility in Kuwait and Saudi stock markets; Kuwait and Abu-Dhabi; and Abu-Dhabi and Dubai stock markets. Also it can be verified from the tables in the appendix, there is significant one day lag effect of volatility in each of these four markets. The other two markets, Bahrain and Muscat, are neither affected by the volatility of other markets nor affect each other. The bootstrap method based on simulation of 2000 residual observations show that the parameter (δ), which estimates the association between volatilities of each two markets yield a very minimal bias in most of the cases.

Table 7 Causality test

H_0 :x does not cause y ($x \rightarrow y$)	estimated parameter ($\hat{\delta}$)	bootstrap simulation $E(\hat{\delta})$
$z \rightarrow m$	-0.23 (0.92)	-0.26
$m \rightarrow z$	-0.00005(0.91)	-0.0005
$d \rightarrow m$	-0.14 (0.96)	-0.06
$m \rightarrow d$	-0.00001(0.96)	-0.0001
$d \rightarrow s$	-0.03 (0.96)	-0.07
$s \rightarrow d$	-0.00006(0.96)	-0.0009
$d \rightarrow z$	0.23 (0.0001)*	0.07
$z \rightarrow d$	0.12 (0.0001)*	0.33
$z \rightarrow s$	0.55 (0.32)	0.86
$s \rightarrow z$	0.002 (0.32)	0.002
$d \rightarrow k$	-0.0002(0.99)	-0.016
$k \rightarrow d$	-0.0001(0.99)	-0.02
$s \rightarrow m$	-0.03 (0.83)	-0.026
$m \rightarrow s$	-0.001 (0.82)	-0.002
$s \rightarrow k$	0.01 (0.0001)*	0.02
$k \rightarrow s$	1.85 (0.0001)*	5.2
$z \rightarrow k$	0.13 (0.0006)*	0.006
$k \rightarrow z$	0.10 (0.0006)*	0.36
$b \rightarrow d$	-0.0001 (0.96)	-0.0005
$d \rightarrow b$	-0.03 (0.96)	-0.008
$m \rightarrow k$	-0.0001(0.96)	-0.0002
$k \rightarrow m$	-0.18 (0.92)	-0.26
$b \rightarrow s$	-0.007 (0.85)	-0.014
$s \rightarrow b$	-0.005 (0.85)	-0.004
$b \rightarrow z$	-0.0003(0.90)	-0.002
$z \rightarrow b$	-0.56 (0.90)	-0.07
$b \rightarrow k$	-0.0004(0.87)	-0.002
$k \rightarrow b$	-0.06 (0.87)	-0.09
$b \rightarrow m$	-0.005 (0.97)	-0.004
$m \rightarrow b$	-0.0002 (0.97)	-0.0004

Figures in parenthesis are p-values of Chi-square statistic for Wald test.

*significant at the 5% significance level.

8. Concluding remarks

This article examines volatility spillovers across six stock markets in GCC countries, namely, Dubai, Abu-Dhabi, Saudi , Kuwait, Muscat, and Bahrain stock markets.

Unit root tests indicate that all six markets are integrated of order one. Multivariate cointegration test results suggest there is at most two cointegrating vectors, or analogously there are two independent common stochastic trends tie individual series together.

Investigation of volatility structure in these markets show that with the exception of Bahrain and Muscat stock markets, volatility behavior in these markets exhibits GARCH effects. This implies that a proper account of conditional heteroskedasticity can have significant implication for the study of volatility spillovers among those markets.

The finding in this paper signify that there is volatility spillover across four of the six stock markets included in this study .There is evidence of bi-directional volatility spillover between Kuwait and Saudi stock markets; Kuwait and Abu-Dhabi; Abu-Dhabi and Dubai stock markets. This implies that any surprises originating at Kuwait stock market can reverberate to the other major markets in the region, via its influence on Saudi and Abu-Dhabi stock markets.

Bahrain and Muscat markets are insulated from volatility spillover effects, as they neither influence each other nor affect the other markets in the region.

It should also be noted that there is a significant one day lag effect of volatility in the four inter-dependent markets. More specifically, current day volatility in each market is affected by its own one day lag volatility. Such lag effect is not evidenced in the other two markets.

Existence of significant volatility lag effect for each market for the four inter-related markets support the evidence of volatility spillover among these

markets. The significance of one day lag volatility in a market is a result of spillover effect from another market responded to the initial volatility effect. Given the significance of volatility propagation among the inter-dependent GCC stock markets, systematic risks are expected to be higher in those markets as compared to the other two markets.

Appendix A

To illustrate the Johansen and Juseilus (1990) cointegration approach, consider first the univariate case:

$$y_t = a_1 y_{t-1} + a_2 y_{t-2} + ... + a_p y_{t-p} + e_t \qquad (1)$$

Equation (1) can be re-parameterized as[3]:

$$\Delta y_t = b_1 \Delta y_{t-1} + b_2 \Delta y_{t-2} + ... + b_{p-1} \Delta y_{t-p+1} - c y_{t-p} + e_t \qquad (2)$$

Where,

$b = -1 + a_1 + a_2 + ... + a_{p-1}$

$c = 1 - a_1 - a_2 - .... - a_p$

$\Delta = difference\ operator$

$p = lag\ length$

The multivariate analogy to equation (1) is:

$$Y_t = A_1 Y_{t-1} + A_2 Y_{t-2} + ... + A_{p-1} Y_{t-p+1} + A Y_{t-p} + e_t \qquad (3)$$

Equation (3) can also be re-parameterized as:

$$\Delta Y_t = \Psi_1 \Delta Y_{t-1} + \Psi_2 \Delta Y_{t-2} + ... + \Psi_{p-1} \Delta Y_{t-p+1} + \Pi Y_{t-p} + e_t \qquad (4)$$

There are three possibilities to consider. First, Π could be of full rank. In this case, the assumed stationarity of the error terms in equation (3) requires that the levels of the y_t process be stationary. This is contrary to the initial I(1) assumption. Second, Π could have rank zero, i.e., be a null matrix. In this case equation (4) reduces into standard VAR and there are no stationary long-run relations among the elements of y_t .The third case occurs when Π is of intermediate rank r (0<r<m). In this case, there exist, r ,

cointegrating vectors and Π can be factorized as follows: $\Pi = \theta H'$

[3] Equation (2) can be obtained from equation (1) by generalizing the following simplified illustration. Let
$y_t = a_1 y_{t-1} + a y_{t-2} + e_t$. Add and subtract from both sides of the equation y_{t-1} to get:
$\Delta y_t = (a_1 - 1) y_{t-1} + a_2 y_{t-2} + e_t$. Again add and subtract to the RHS of Δy_t equation, $(a_1-1)y_{t-2}$ and re-arrange terms.

where H is the co-integrating vector, and θ, reflect the speed of adjustment towards co-integration.

The empirical application of (JJ) test on I(1) process involves two stage regression analysis. We re-write equation (4) as:

$$\Delta Y_t = \delta + \sum_{i=1}^{p-1} \Psi_i \Delta Y_{t-i} - \Pi Y_{t-p} + e_t \qquad (5)$$

Where δ is a constant. The first stage involves getting the residual vectors, e_{ot} and e_{1t} from regression equations:

$$\Delta Y_t = \sum_{i=1}^{p-1} B_{0i} \Delta Y_{t-i} + e_{0t} \qquad (6-a)$$

$$\Delta Y_{t-p} = \sum_{i=1}^{p-1} B_{1i} \Delta Y_{t-i} + e_{1t} \qquad (6-b)$$

Where B_{0i} and B_{1i} can be estimated by OLS (Johansen & Jusilius, 1990).

In the second stage, we estimate the regression equation,

$$e_{0t} = \alpha e_{1t} + \eta_t \qquad for\ t=1,2,..T, \qquad (7)$$

Based on the estimated eigen values of equation (7), two likelihood ratio test statistics can be established. The trace statistic and the maximum eigen value statistic can help infer the number of co-integrating vectors. The hypothesis that there are at most, r, distinct co-integrating vectors can be tested by using the statistics:

$$s_{11} = (n-p)^{-1} \sum_{t=1}^{T} e_{1t} e'_{1t}$$

$$s_{22} = (n-p)^{-1} \sum_{t=1}^{T} e_{0t} e'_{0t}$$

$$s_{1t} = (n-p)^{-1} \sum_{t=1}^{T} e_{1t} e'_{0t}$$

Where, n, is the number of observations. We need to get the eigen values and the associated eigen vectors of $(s_{22})^{-0.5}(s_{21})(s_{11})^{-1}(s_{12})(s_{22})^{-0.5}$.

The first test statistic, known as the trace statistic, evaluates the null hypothesis that there are at most, r, co-integrating vectors against the alternative hypothesis that there are at most, r+1, co-integrating vectors, and is given by

$$L_{trace} = -(n-p)\sum_{i=r+1}^{p}\ln(1-\hat{\lambda}_i) \qquad (8)$$

Where $\hat{\lambda}_i$ are the eigen values (or the squared canonical correlations) between the two residual vectors, e_{0t} and e_{1t} . Alternatively, we can use the maximal eigen value test as follows:

$$L_{max} = -(n-p)\ln(1-\hat{\lambda}_{r+1}) \qquad (9)$$

Where $\hat{\lambda}_{r+1}$ is the largest eigen value.

To test, r+1, cointegrating vectors against no cointegrating vectors we use L_{max} test. The trace test provides more consistent way of testing the number of cointegrating vectors. It starts by testing for zero cointegrating vectors.

Since we have four variables, we compare the test statistic, $-(N-p)\sum_{i=1}^{4}\ln(1-\hat{\lambda}_i)$, with the relevant critical values. If we reject zero cointegrating vectors, then we test at most, 1, cointegrating vector by comparing the test statistic, $-N\sum_{i=2}^{4}\ln(1-\hat{\lambda}_i)$, to its critical value. If this is not rejected we stop and decide that r=1. If we reject this we move on until we can no longer reject and stop there.

Appendix B

Abu-Dhabi (Z) versus Muscat (M)

	H0: Z does not cause M	H0: M does not cause Z
α_0	1329 (1.19)*	422.5 (2.6)*
α_1	-0.001 (-0.04)*	0.91 (66.7)*
δ	-0.23 (2.3)**	-0.00005 (0.0005)**
δ_1	-0.19 (-0.08)*	-0.00004 (-0.08)*
Wald stat	0.01	0.01
p-value	0.92	0.91
R^2	0.0002	0.84
Dur h stat	-	0.4
Bootstrap;		
E(δ)	-0.26 (2.01)**	-0.0005 (0.004)**
Bias	0.03	0.000

*terms in parenthesis are t-ratios.

** terms in parenthesis are standard errors.

The same stars applies to all subsequent tables in this appendix.Dubai (D)

versus Muscat (M)

	H0: D does not cause M	H0: M does not cause D
α_0	11080 (1.1)	274.8 (2.6)
α_1	-0.001 (-0.04)	0.49 (16.3)
δ	-0.14 (3.5)	-0.00001 (0.0002)
δ_1	-0.21 (-0.06)	-0.00001 (-0.03)
Wald stat	0.002	0.001
p-value	0.96	0.96
R^2	0.0001	0.24
Dur h stat	-	9.6
Bootstrap:		
E(δ)	-0.06 (1.4)	-0.0001 (0.001)
Bias	-0.08	0.000

Dubai (D) versus Saudi (S)

	H0: D does not cause S	H0: S does not cause D
α_0	38645 (12.2)	30809 (2.1)
α_1	0.43 (13.7)	0.49 (16.4)
δ	-0.03 (0.75)	-0.00006 (0.002)
δ_1	-0.27 (-0.35)	-0.0004 (-0.3)
Wald stat	0.001	0.001
p-value	0.96	0.96
R^2	0.18	0.22
Dur h stat	-5.4	9.6
Bootstrap:	-0.07 (0.32)	
E(δ)	0.04	-0.0009 (0.004)
Bias		0.000

Dubai (D) versus Abu-Dhabi (Z)

	H0: D does not cause Z	H0: Z does not cause D
α_0	335 (2.1)	251 (2.2)
α_1	0.91 (67.4)	0.49 (16.4)
δ	0.23 (0.04)	0.12 (0.02)
δ_1	-0.07 (-1.66)	-0.11 (-4.7)
Wald stat	24.7	24.7
p-value	0.0001	0.0001
R^2	0.84	0.26
Dur h stat	0.10	8.9
Bootstrap:		
E(δ)	0.07 (0.04)	0.33 (0.07)
Bias	0.16	-0.21

Abu-Dhabi (Z) versus Saudi (S)

	H0: Z does not cause S	H0: S does not cause Z
α_0	38278 (11.6)	188.5 (0.85)
α_1	0.42 (13.7)	0.91 (66.7)
δ	0.55 (0.56)	0.002 (0.002)
δ_1	-0.49 (-0.89)	0.001 (0.65)
Wald stat	0.98	0.98
p-value	0.32	0.32
R^2	0.18	0.84
Dur h stat	-5.3	0.4
Bootstrap:		
E(δ)	0.86 (0.61)	0.0023 (0.005)
Bias	-0.31	0.000

Dubai (D) versus Kuwait (K)

	H0: D does not cause K	H0: K does not cause D
α_0	979.9 (5.3)	291 (2.56)
α_1	0.81 (79.3)	0.49 (16.3)
δ	-0.0002 (0.06)	-0.0001 (0.03)
δ_1	-0.01 (-0.27)	-0.002 (-0.13)
Wald stat	0.0001	0.0001
p-value	0.99	0.99
R^2	0.88	0.24
Dur h stat	-10.5	9.6
Bootstrap:		
$E(\delta)$	-0.016 (0.03)	-0.022 (0.12)
Bias	0.01	0.02

Saudi (S) versus Muscat (M)

	H0: S does not cause M	H0: M does not cause S
α_0	13786 (0.95)	38504 (12.3)
α_1	-0.001 (-0.04)	0.43 (13.7)
δ	-0.03 (0.14)	-0.001 (0.005)
δ_1	-0.01 (-0.07)	-0.001 (-0.18)
Wald stat	0.04	0.05
p-value	0.83	0.82
R^2	0.0001	0.18
Dur h stat	-	-5.3
Bootstrap:		
$E(\delta)$	-0.026 (0.16)	0.002 (0.009)
Bias	-0.004	0.001

Saudi (S) versus Kuwait (K)

	H0: S does not cause K	H0: K does not cause S
α_0	-123.4 (-0.51)	36810 (11.6)
α_1	0.80 (79.2)	0.39 (12.5)
δ	0.01 (0.002)	1.85 (0.5)
δ_1	0.008 (3.3)	-1.2 (-2.9)
Wald stat	14.7	14.6
p-value	0.0001	0.0001
R^2	0.88	0.20
Dur h stat	-11.7	-6.04
Bootstrap:		
E(δ)	0.023 (0.26)	5.26 (1.002)
Bias	-0.013	-3.4

Abu-Dhabi (Z) versus Kuwait (K)

	H0: Z does not cause K	H0: K does not cause Z
α_0	759 (3.8)	396 (2.3)
α_1	0.81 (79.9)	0.91 (66.8)
δ	0.13 (0.04)	0.10 (0.03)
δ_1	-0.09 (-2.3)	-0.09 (-3.6)
Wald stat	11.5	11.6
p-value	0.0006	0.0006
R^2	0.88	0.84
Dur h stat	-10.6	0.61
Bootstrap:		
E(δ)	0.006 (0.05)	0.36 (0.14)
Bias	0.12	-0.26

B ahrain (B) versus Dubai (D)

	H0: B does not cause D	H0: D does not cause B
α_0	274.9 (2.66)	2105 (1.1)
α_1	0.49 (16.3)	-0.001 (-0.04)
δ	-0.0001 (0.002)	-0.03 (0.6)
δ_1	-0.0001 (-0.05)	-0.03 (-0.05)
Wald stat	0.002	0.002
p-value	0.96	0.96
R^2	0.24	0.001
Dur h stat	9.6	
Bootstrap:		
E(δ)	-0.0005 (0.43)	-0.008 (0.002)
Bias	0.000	-0.02

Muscat (M) versus Kuwait (K)

	H0: M does not cause K	H0: K does not cause M
α_0	973 (5.3)	11937 (1.1)
α_1	0.81 (79.3)	-0.001 (-0.04)
δ	-0.0001 (0.001)	-0.18 (2.25)
δ_1	-0.0001 (-0.22)	0.01 (0.01)
Wald stat	0.008	0.08
p-value	0.92	0.92
R^2	0.88	0.0001
Dur h stat	-10.5	-
Bootstrap:		
E(δ)	-0.0002 (0.73)	-0.26 (4.65)
Bias	0.00	0.08

Bahrain (B) versus Saudi (S)

	H0: B does not cause S	H0: S does not cause B
α_0	38505 (12.3)	3833 (1.01)
α_1	0.43 (13.7)	-0.001 (-0.04)
δ	-0.007 (0.04)	-0.005 (0.03)
δ_1	-0.008 (-0.20)	-0.006 (-0.21)
Wald stat	0.03	0.03
p-value	0.85	0.85
R^2	0.18	0.0002
Dur h stat	-5.4	-
Bootstrap:		
E(δ)	-0.014 (0.04)	-0.004 (0.03)
Bias	0.007	-0.001

Bahrain (B) versus Abu-Dhabi (Z)

	H0: B does not cause Z	H0: Z does not cause B
α_0	420.8 (2.6)	2470 (1.15)
α_1	0.92 (66.7)	-0.001 (-0.04)
δ	-0.0003 (0.003)	-0.56 (4.6)
δ_1	0.0005 (0.19)	-0.02 (-0.04)
Wald stat	0.01	0.01
p-value	0.90	0.90
R^2	0.84	0.002
Dur h stat	0.40	-
Bootstrap:		
E(δ)	-0.0026 (0.71)	-0.066 (0.43)
Bias	0.0023	-0.49

Bahrain (B) versus Kuwait (K)

	H0: B does not cause K	H0: K does not cause B
α_0	973 (5.4)	2405 (1.13)
α_1	0.81 (79.3)	-0.001 (-0.04)
δ	-0.0004 (0.003)	-0.06 (0.38)
δ_1	-0.0004 (-0.16)	-0.01 (0.03)
Wald stat	0.03	0.02
p-value	0.87	0.87
R^2	0.88	0.0002
Dur h stat	-10.56	-
Bootstrap:		
$E(\delta)$	-0.002 (0.004)	-0.09 (0.85)
Bias	0.001	0.03

Bahrain (B) versus Muscat (M)

	H0: B does not cause M	H0: M does not cause B
α_0	10916 (1.07)	2074 (1.07)
α_1	-0.001 (-0.04)	-0.001 (-0.04)
δ	-0.005 (0.16)	-0.0002 (0.0001)
δ_1	-0.006 (-0.04)	-0.0003 (-0.04)
Wald stat	0.001	0.001
p-value		0.97
R^2	0.97	0.0001
Dur h stat	-	-
Bootstrap:		
$E(\delta)$	-0.004 (0.19)	-0.0004 (0.0002)
Bias	-0.001	0.000

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