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VOLATILITY SPILLOVERS BETWEEN STOCK MARKET RETURNS AND EXCHANGE RATE: EMPIRICAL EVIDENCE FROM SAUDI ARABIA AND EGYPT

Key Words

Volatility Spillovers; Stock Market Returns; Exchange Rates; VAR-GARCH Modle; Saudi Arabia; Egypt.

Abstract

This paper empirically investigates the volatility spillovers between exchange rate fluctuations and stock market returns in Saudi Arabia and Egypt over the period of 1st January 2007 to 30th December 2011. The paper employs a bivaraite vector autoregressive-generalized and autoregressive conditional heteroscedasticity model recently developed by Ling and McAleer (2003). The proposed model is estimated using the maximum likelihood method under the assumption of multivariate normal distributed error terms. The empirical results of the paper find that a one-period lagged exchange rate returns parameter, significantly affect the returns of Capital Market Authority general index which implies that past exchange rate returns can better be used to predict the future of returns of the Egyptian stock market. Furthermore, the results show that the shock (or volatility) originating from the Egyptian exchange rate market leads to increase stock market returns volatility. No volatility transmission is found between exchange rate and stock markets for Saudi Arabia.

Introduction

Over the past few decades, the interrelationship between stock market returns and exchange rate fluctuations has attracted significant attention from practitioners, academicians, and policy makers in both developed and developing countries, especially after the adoption of floating exchange rate regimes by many countries. A clearer understanding of the dynamic

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relationship and volatility spillovers between these two financial variables is very important particularly for policy makers, financial analysts, and investors due to the fact that these two variables play important roles in influencing the development of a country's economy, as well as their impact on portfolio diversification process and risk management.

Since the 1970s, this relationship has been the subject of many studies in the empirical finance literature. One of the earlier empirical studies that investigated this association was carried out by Frank and Young (1972) who employed six different exchanges rates with respect to US dollar to see their effects on the stock prices of selected US multinational companies included in the S&P 500 and Dow-Jones index. Based on a simple correlation and regression analysis, they concluded that there is no recognizable pattern of stock price reaction to the exchange rates. Since that time, there has been an ongoing debate over the empirical causal relations between these variables especially after the collapse of the Bretton Woods System in March 1973 and therefore, the correspondingly more volatile exchange rates which led many researchers, economists and policy makers to re-focus on this issue.

Theoretically, there are two portfolio models that have been proposed by classical economists to explain the interaction between stock market returns and exchange rate movements. Firstly, the "flow-oriented" models of exchange rate determination which assume that the currency fluctuations affect international competitiveness and the balance of trade position, and consequently the real income and output of an economy, which in turn affects current and future cash flows of companies and their stock prices. The exchange rate changes therefore should bear effects on stock returns (Gavin, 1989; Dornbusch and Fisher, 1980, and Mundell, 1963, 1964). On the other hand, Branson (1983) and Frankel (1983) have proposed the "stock-oriented" models which are based on the assumption that causality will run from stock prices to exchange rate changes as expectations of financial asset price movement affect the dynamics of exchange rates. In these models, exchange rates are viewed as equating the supply and demand for assets such as stocks and bonds.

Most of the empirical studies that investigated the volatility spillovers between stock market returns and exchange rate movements have focused on the US during the 1980s and 1990s or on South Eastern and South Asian countries particularly after the East Asian Financial crisis of 1997-1998. During this crisis peri-

od, financial economists have noticed that the markets collapsed - especially emerging ones - as a result of substantial depreciation of exchange rates in terms of US dollar as well as dramatic fall in the stock prices. In addition to that, emerging markets experienced huge volatility during that period because these markets are relatively risky as compared to the stock markets in the developed economy.

Although the issue is gaining increasing importance in recent years in different developed economies over the world, very little studies have emphasized on developing markets and to the best of our knowledge of the available literature, there is no evidence to date that this relationship has been empirically analyzed for the Saudi and Egyptian economies. Therefore, the main contribution of this paper is to fill the gap in the literature in this area by investigating this issue using daily observations of the two series over the period 1st January 2007 to 30th December 2011 by applying a bivaraite vector autoregressive-generalized autoregressive conditional heteroscedasticity (VAR-GARCH) model recently developed by Ling and McAleer (2003). The current paper will try to only investigate the interrelationship between the two variables during the world financial crisis period rather than testing the hypotheses assumed by the two portfolio models discussed earlier.

The stock markets in Saudi Arabia and Egypt can be considered among the largest markets in the Arab World. Accordingly, empirical research that links the performance of these markets with macroeconomic variables like exchange rate will be of great importance to the investment community. Although most variables that measure the performance of these markets have recently increased, stock markets in Arab world are more volatile than developed ones which might result in a differently patterned interrelationship between exchange rates and stock market performance.

The remainder of this paper is organized as follows: Section 2 contains a brief literature review. Section 3 provides a general overview of the Saudi and Egyptian stock markets. Section 4 describes the data and provides summary statistics. The methodology is presented in Section 5, while the results of the estimation are discussed in section 6. Finally, section 7 concludes the paper.

Literature Review

Considerable amounts of empirical research have been conducted to investigate the issue of volatility spillovers between stock market returns and exchange rate movements. How-

ever, the relationship still remains unresolved as to whether stock indices lead exchange rates, or vise versa. While some empirical studies found some relation and causality, other studies show no causality between the two variables. Aggarwal (1981) investigated the interrelationship between the effective exchange rates of the US dollar and changes of stock prices. Based on simple regressions, he found that the revaluation of the US dollar is positively correlated with stock market returns for the period 1974-1978. In the same track, Roll (1992) also found a positive relationship between the two markets using daily data over the period of 1988-1991. Some other studies found a negative relationship between the variables, such as, Soenen and Hennigar (1988) who discovered a strong negative relationship between these two variables when analyzed the above relation for a different time period, 1980 -1986. Bahmani-Oskooee and Sohrabian (1992) applied the co-integration analysis and the Granger causality test to analyze the long-run relationship between stock prices and exchange rates. They employed monthly data of the S&P 500 index and US dollar effective exchange rate for the period 1973-1988. The results indicated bi-directional causality in the short run. But they were unable to find any long run relationship between the two variables. By employing error correction model and causality test on daily closing stock market indices and exchange rates from 1985 to 1991 for eight advance economic countries, Ajayi and Mougoue (1996) displayed significant interactions between foreign exchange rates and stock markets.

In contrast, some studies find that there is no significant relationship between the two variables, among these, Solnik (1987), Chow *et al.* (1997), and Bhattacharya and Mukherjee (2003). Solnik (1987) examined the impact of several economic variables including the exchange rates on stock prices. Based on regression analysis, he concluded that real exchange rate movements do not have any significant impact over stock prices. Chow *et al.* (1997) also concluded no relationship for stock returns and real exchange rate returns by using monthly data for the period 1977-1989. But, after extending the period, they found that there is a positive relationship between a strong dollar and stock returns. Bhattacharya and Mukherjee (2003) found that there in no significant relationship between stock prices and exchange rates when investigating Indian markets using the data on stock prices and macroeconomic aggregates in the foreign sector including exchange rate.

After the Eastern Asian Financial Crisis, there were also various empirical studies about the interdependence between exchange rate movements and stock markets returns for Asian countries. Particularly important studies include that of Abdalla and Murinde (1997) who employed co-integration analysis and Granger causality test to examine the relationship between stock prices and real effective exchange rates for four Asian countries (India, Pakistan, South Korea and Philippines) for a period of 1985 to 1994. They detected unidirectional causality from exchange rates to stock prices for India, South Korea and Pakistan which is consistent with an earlier study by Aggarwal (1981). But, for the Philippines the stock prices lead the exchange rates. Meanwhile, Yu (1997) studied Hong Kong, Tokyo and Singapore markets by using daily data for a period of 1983-1994. Based on the Granger causality test, he showed that the changes in stock prices are caused by changes in exchange rates in Tokyo and Hong-Kong markets. However, no such causation was found for the Singapore market. On the reverse causality from stock prices to exchange rates, his results show such causation for only the Tokyo market. Therefore, for the Tokyo market there is a bi-directional causal relationship between stock returns and changes in exchange rates. Amare and Mohsin (2000) investigated the long-run relation between stock prices and exchange rates for nine Asian countries (Hong Kong, Indonesia, Japan, Malaysia, the Philippines, Singapore, South Korea, Taiwan and Thailand) for the period 1980-1998. They concluded that the long-run relationship between stock prices and exchange rates was found only for Singapore and the Philippines.

More recently, Kanas (2006) investigated the relationship for six developed countries. He found that volatility spillovers from stock market returns to exchange rates were significant for all countries except Germany, but there were no instances of significant spillovers in the reverse direction. Rahman and Jashimuddin (2009) found no cointegration as well as causal relationship between exchange rates and stock prices in three south Asian emerging economies.

In the case of Arab region, Alhayky and Houdou (2009) used an Error Correction Model (ECM) and the Granger causality test to examine the long-run and short-run relationship between Kuwait's stock prices and exchange rate for the period June 2001-December 2008. Under the co-integration test, it is found that there is a long-run equilibrium relationship between Kuwait Stock Price Index

(STIDX) and exchange rates for United States Dollar (USD), Japanese Yen (YEN), and British Pound (GBP), while there is no long-run linkage relationship between STIDX and EURO. Based on the Granger causality test, it is found that in the long run, there is a bilateral causality between STIDX and GBP, STIDX and exchange rate YEN, and STIDX and USD. Moreover, it is observed that in the short run, STIDX has no unidirectional or bidirectional causality with exchange rate GBP. However, there is evidence of only unidirectional causality from stock prices to exchange rate, which is significant for the YEN and USD.

In the light of the above discussion and with completely different methodology, this paper employs a bivaraite vector autoregressive-generalized autoregressive conditional heteroscedasticity (VAR-GARCH) model recently developed by Ling and McAleer (2003) model to investigate the volatility spillover effects between the stock market returns and the exchange rate movements in Saudi Arabia and Egypt.

Overview of the Stock Market in Saudi Arabia and Egypt

Saudi Stock Market

The Saudi Stock Exchange (SSE) dates back to the 1970s when it used to operate informally. In 1984, a Ministerial Committee comprising of the Ministry of Finance, Ministry of Commerce, and SAMA (Note 1) was formed to regulate the market. SSE which is known locally by its Arabic name Tadawul. The Saudi stock market has several unique characteristics that differentiate it from other stock markets in the world. Share-trading activity is executed through commercial banks that are responsible for the settlement of transactions between buyers and sellers. The market is also characterized by the absence of bourse and independent market-makers.

The overall performance of the SSE is measured by the Tadawul All Share Index (TASI) (Note 2), TASI reached its peak on 25th of February 2006, when it closed at 20,635. It was severely affected by the 2008 global crisis, like all the stock markets all over the world, and saw below 4000. The SSE currently lists 144 publicly traded companies divided into fifteen sectors (as of August 15, 2010), where the Financials and Basic Materials sectors are the most dominant sectors, accounting for around 70% of market capitalization. The biggest two companies by market share are Al RAJHI Bank and SABIC petrochemicals, both of which command around 11% of the market. The trading activity of the SSE can be considered very active with respect to the value of shares traded, the number of executed

transactions, and market capitalization (See Table 1), all which suggest an increase in investor confidence during this time period.

Today, the SSE is the largest market in the entire Arab World. Based on market capitalization, it ranks first in the Arab world with 319 billion U.S. dollars compared to an average of 65 billion dollars for the Arab countries participating in the Arab Monetary Fund Index (AMFI). Compared to the other Arab stock markets in the AMFI, the SSE had by far the largest market, with its value of shares traded amounting to 337 U.S. billion dollars in 2009 (Table 2). The second largest stock market is the Kuwaiti stock market, at 104 billion U.S. dollars. Additionally, the SSE is active and relatively liquid compared to the other markets in the AMFI, as measured by the market depth ratio, and the turnover ratio respectively. At the end of 2009, the depth of the SSE was 86% of GDP compared to an average of 57% of GDP for Arab share markets, and was one of the most liquid markets in the Arab world with a turnover ratio of 106% compared to an average of 54% for Arab share markets in 2009 (Table 2).

Egyptian Stock Market

In contrast to the SSE, the Egyptian stock exchange is one of the oldest stock markets established in the Middle East and Africa. Egypt's stock exchange has two locations: the main location is in Cairo (established 1903) and the other one is in Alexandria established (1883). These two exchanges were competing with each other before they merged in recent years. Today, both exchanges are governed by the same chairman and board of directors. They are commonly referred to as the Cairo and Alexandria Stock Exchange (CASE) and share the same trading, clearing and settlement systems, so that market participants have access to stocks listed on both exchanges.

The overall performance of the Egyptian stock market is measured by the Capital Market Authority (CMA) Index, which covers all listed stocks weighted in relation to their market capitalization. It can be viewed as an all share index that covers the broadest base of stocks. It is calculated and released daily by the CMA (Note 3).

Key Numbers of the *TADAWUL* and CASE

Table 1 provides some key figures for both markets. It is obvious that although CASE has a relatively large number of listed companies, whereas TADAWUL has a larger market capitalization, volume of trading, number of transactions, and number of

Table 1
Summary of Trading Activity in TADAWUL and CASE, 2007 - 2011

Year	Listed Companies	Value Traded ($ millions)	Market Capitalization ($ millions)	No. of Transactions	Shares Traded (In Million)
Saudi Stock Market (TADAWUL)					
2007	111	628,055.57	522,721.12	11343727	53,083.03
2008	127	483,122.22	246,809.85	11082545	54,441.98
2009	135	322,432.10	318,784.68	12197799	54,443.71
2010	146	192,445.39	353,419.01	16108992	31,555.34
2011	144	247,143.91	328,029.67	10356812	40,995.49
Egypt Stock Market (CASE)					
2007	435	49,388.19	134,903.52	8,161,607	10,512.79
2008	373	65,166.14	83,185.00	12,321,523	21,071.82
2009	306	50,812.70	86,267.22	13,300,653	28,243.25
2010	212	36,867.80	85,725.96	9,606,668	27,336.99
2011	213	18,081.29	48,679.23	5439868	16,669.04

Source: Compiled by the author based on data from the Tadawul website and AMF annual reports.

Table 2
Key Indicators of Arab World Share Markets, End of 2009

Capital Market	No. of Listed Companies	Market* Capitalization	Ratio to Total (%)	Value of Shares Traded*	Market Depth	Turnover Ratio
Saudi Arabia	135	318,803	35.29	337.070	86.3	105.7
Kuwait	205	93,824	10.38	103.772	73.5	110.6
Egypt	306	91,092	10.8	81.173	48.1	89.1
Qatar	44	87,930	9.73	25.317	106.8	28.8
Abu Dhabi	67	80,201	8.88	18.766	35.7	23.4
Morocco	73	74,186	8.21	16.226	80.0	21.9
Dubai	67	58,095	6.43	47.239	25.8	81.3
Jordan	272	31,889	3.53	13.641	105.8	42.8
Oman	120	23,616	2.61	5.905	44.5	25.0
Bahrain	49	16,263	1.80	473.0	75.2	2.9
Lebanon	11	12,843	1.42	1.038	39.9	8.1
Tunisia	52	9,237	1.02	1.360	24.5	14.7
Sudan	53	3,033	0.34	1.006	5.5	33.2
Palestine	39	2,377	0.26	500.0	Na.	21.0
Algeria	2	91	0.01	187.5	0.1	206.1

* Million of U.S. dollars.
Source: Quarterly Bulletin, Arab Monetary Fund, 2009.

shares traded during the period of the study.

Econometric Methodology

For a wide range of financial data series, time-varying conditional variances can be well explained through the use of the Autoregressive Conditional Heteroscedasticity (Note 4) (ARCH) of Engle (1982) and the Generalized ARCH (GARCH) developed by Bollerslev (1986) see for example (Agnolucci, 2009; Kang *et al.*, 2009; Hassan and Malik, 2007). However, it is commonly accepted that multivariate GARCH specifications such as BEKK model of Engle and Kroner (1995), CCC-GARCH model of Bollerslev (1990) or DCC- GARCH model of Engle (2002) are more relevant than univariate settings as far as we are concerned, by the volatility (Note 5) transmissions issue among multiple financial variables. To investigate the volatility spillover effects between the stock market returns and the exchange rate movements in Saudi Arabia and Egypt, this paper uses the VAR(1)-GARCH(1,1) model proposed by Ling and McALeer (2003). Apart from the fact that this model performs quite well in empirical modeling of volatility spillovers as noted by the aforementioned studies, one should note its two major advantages. First, it permits a multivariate analysis of conditional volatility of the studied series as well as of conditional cross effects and volatility spillovers between series. Second, it provides efficient estimates of the model's unknown parameters while avoiding the computational complications of some multivariate volatility models, such as the full-parameterized BEKK-GARCH, when the number of variables we consider becomes significant. This approach was applied by, among others, Chan *et al.* (2005), Chang *et al.*, (2011) and Hammoudeh *et al.* (2009) to various economic issues and appears to provide meaningful and interpretable coefficients.

The VAR(1)-GARCH(1,1) considered in this paper has the following specification for the conditional mean (Note 6):

$$\begin{cases} R_t = \mu + \Phi R_{t-1} + \varepsilon_t \\ \varepsilon_t = H_t^{1/2} \eta_t \end{cases} \qquad (1)$$

where

- $R_t = (r_t^s,\ r_t^e)'$ is the vector of returns on the stock market index and exchange rate respectively.
- Φ refers to a (2×2) matrix of coefficients of the form:

$$\Phi = \begin{pmatrix} \phi_1 & 0 \\ 0 & \phi_2 \end{pmatrix}$$

- $\varepsilon_t = (\varepsilon_t^s,\ \varepsilon_t^e)'$ is the vector of the error terms of the conditional mean

equations for stock and exchange returns respectively.

- $\eta_t = (\eta_t^s,\ \eta_t^{se})'$ refers to a sequence of independently and identically distributed (*i.i.d*) random errors; $H_t = \begin{pmatrix} h_t^s & h_t^{se} \\ h_t^{se} & h_t^e \end{pmatrix}$ is the matrix of conditional variances of stock market and exchange rate returns with h_t^s and h_t^e being the conditional variances of r_t^s and r_t^e respectively. Their time series dynamics are modelled as follows:

$$h_t^s = C_s^2 + \beta_{s1}^2 h_{t-1}^s + \alpha_{s1}^2 (\varepsilon_{t-1}^s)^2 + \beta_{s2}^2 h_{t-1}^e + \alpha_{s2}^2 (\varepsilon_{t-1}^e) \quad (2)$$

$$h_t^e = C_e^2 + \beta_{e1}^2 h_{t-1}^e + \alpha_{e1}^2 (\varepsilon_{t-1}^e)^2 + \beta_{e2}^2 h_{t-1}^s + \alpha_{s2}^2 (\varepsilon_{t-1}^s) \quad (3)$$

Obviously, Eqs. (2) and (3) assume that negative and positive shocks of equal magnitude have identical effects on conditional variances. The Eqs. also show how volatility is transmitted over time and across the two markets under investigation. The cross values of error terms, $(\varepsilon_{t-1}^e)^2$ and $(\varepsilon_{t-1}^s)^2$, represent the return innovations in the exchange rate market and to the corresponding stock market at time (t-1), and thus capture the impact of the direct effects of shock transmission, as well as those of lagged conditional volatilities, h_{t-1}^e and h_{t-1}^s, which directly accounts for the transfer of risk between markets. Under some regularity conditions, the roots of the equation $|I_2 - AL - BL| = 0$ must be outside the unit circle in order to guarantee stationarity, and the expression $(I_2 - AL)$ and BL satisfy some other identification conditions as proposed by Jeantheau (1998), where L is a lag polynomial, I_2 is a (2×2) identity matrix, and A and B are defined as:

$$A = \begin{pmatrix} \alpha_{s1}^2 & \alpha_{s2}^2 \\ \alpha_{e2}^2 & \alpha_{e1}^2 \end{pmatrix} \text{ and } B = \begin{pmatrix} \beta_{s1}^2 & \beta_{s2}^2 \\ \beta_{e2}^2 & \beta_{e1}^2 \end{pmatrix}$$

Let ρ be the constant conditional correlation (CCC); the conditional covariance between exchange rate returns and stock market returns is modelled as:

$$h_t^{se} = \rho * \sqrt{h_t^s} * \sqrt{h_t^e} \quad (4)$$

As specified previously, the empirical model simultaneously allows long-run volatility persistence as well as shock and volatility transmissions between the exchange rate and stock markets under consideration. Note that the CCC assumption can be viewed as restrictive given that correlation coefficient is likely to vary over time according to changes in economic and market conditions. Nevertheless, the statistical properties of a VAR-GARCH model accounting for dynamic conditional correlation have not yet been analyzed theoretically

(Chang *et al.*, 2011; McAleer *et al.*, 2009). Following Ling and McAleer (2003), the quasi-maximum likelihood estimation (QMLE) method of Bollerslev and Wooldridge (1992) is used to estimate the empirical model in order to take into account the fact that the normality condition is often rejected for the majority of macroeconomic and financial series.

Data and Preliminary Analysis

The time series data used for modelling volatility spillovers between exchange rate fluctuations and stock market returns in this paper are the daily closing prices of the Saudi Stock Market (SSM) index and the Capital Market Authority (CMA) index as well as daily exchange rate returns on the Egyptian Pound (EGP) and Saudi Arabian Riyal (SAR) against the US dollar over the period of 1st January 2007 to 30th December 2011. The closing prices of the general index of the two markets have been taken from the SSE website (http://www.tadawul.com.sa) and the CASE website (http://www.egyptse.com). While exchange rate data are extracted from (www.oanda.com/currency/realtime series). Unlike the majority of previous studies which employ low frequency data (yearly, quarterly, monthly, and weekly), this paper uses daily data in order to adequately capture the rapidity and intensity of the dynamic interactions between exchange rate and stock market returns. Daily returns are calculated from daily price data by taking the natural logarithm of the ratio of two successive prices. For both series, daily returns, in percentage, are defined as:

$$r_t = \log\left(\frac{P_t}{P_{t-1}}\right) * 100 \qquad (5)$$

where r_t is the return of the general market index (or exchange rate) at time t. P_t and P_{t-1} are the closing market index (or exchange rate) at the current day and previous day, respectively. Table 3 summarizes the returns of the general index of both markets along with the exchange rate returns.

The results in Table 3 show that the mean returns are negative for all series except of the exchange rate returns on the Saudi Arabian Riyal (SAR) against the US dollar. In view of the maximum and minimum values of both series it can be noted that fluctuations in stock market returns have been greater than of exchange rate returns over the period of study. In the same way, the value of standard deviation (an indication of unconditional variance in return series) regarding the value of mean is another proof for the high volatility and risky nature of the stock market in comparison with the exchange rate market. The results also indicate that both the

Table 3
Summary Statistics for Stock Market and Exchange Rate Returns

	Exchange rte returns		Stock market returns	
Statistics	**(USD /SAR)**	**(USD /EGP)**	**Tadawul Index**	**CMA Index**
Mean	0.000127	-0.002907	-0.019929	-0.102783
Minimum	-1.110799	-4.911629	-10.32845	-51.51038
Maximum	1.358440	4.493933	9.087370	27.11069
Std. dev.	0.113239	0.823577	1.679530	2.828784
Skewness	1.487539	-0.441858	-0.797523	-5.152991
Kurtosis	30.80687	11.45019	10.53532	106.0035
Jarque-Bera	42492.63***	3922.143***	3223.334***	582232.4***
ARCH(5)	275.9787***	7.913981	26.43570***	215.2402***
ARCH(30)	341.2769***	10.22787	42.92063**	431.1329***
Ljung-Box (30)	58.161**	40.489*	1403.8***	934.11***
Ljung-Box (30) on squared returns	1270.7***	10.496	57.904***	1450.4***

Note: *, ** and *** indicate significant at the 10%, 5% and 1% levels respectively.

returns series do not conform to normal distribution but display negative skewness (the distribution has a long left tail) for returns of stock market index and also for the exchange rate returns on the Egyptian Pound (EGP) against the US Dollar and positive skewness (the distribution has a long right tail) for the exchange rate returns on the Saudi Arabian Riyal (SAR) against the US Dollar. In addition to that, a highly leptokurtic distribution is also observed for both returns series. The Ljung-Box statistics for serial auto-correlations on return and squared return series indicate that the null hypothesis of no auto-correlations up to the 30th order is rejected and confirms the existence of auto-correlations in the two returns series. Finally, the results show strong evidence of ARCH effects for all series considered at 30 lags (except of the exchange rate returns on the Egyptian Pound (EGP) against the US dollar) which supports the decision to employ a GARCH approach to examine volatility spillovers between exchange rate fluctuations and stock market returns. Fig. 1, Fig. 2, Fig. 3 and Fig. 4 provide an illustration of the prices (returns) of the general market index, and for the exchange rate changes.

Empirical Results

As reported in the data description part when the residuals were examined for heteroscedasticity, ARCH-LM test (See an appendix) provided strong evidence of ARCH effects in the residual

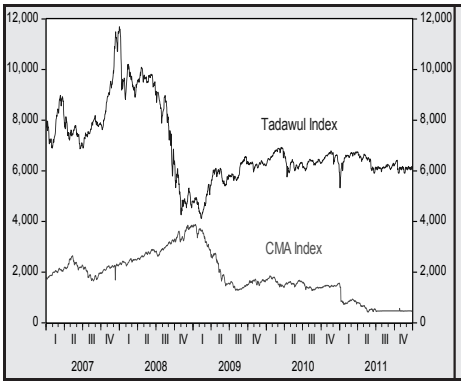

Fig. 1. Stock market index (2007- 2011)

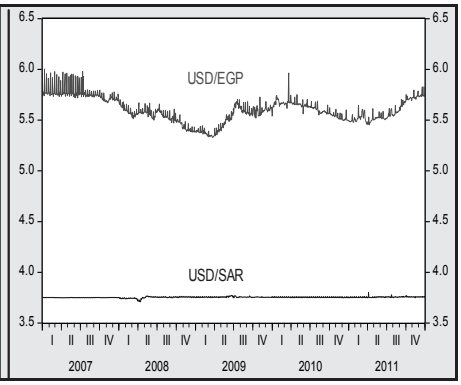

Fig. 2. Exchange rate (2007- 2011)

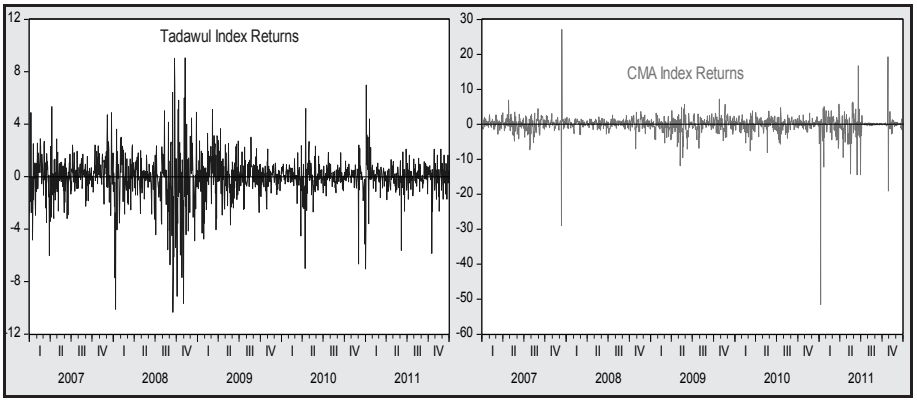

Fig. 3. Returns on stock market index (2007- 2011)

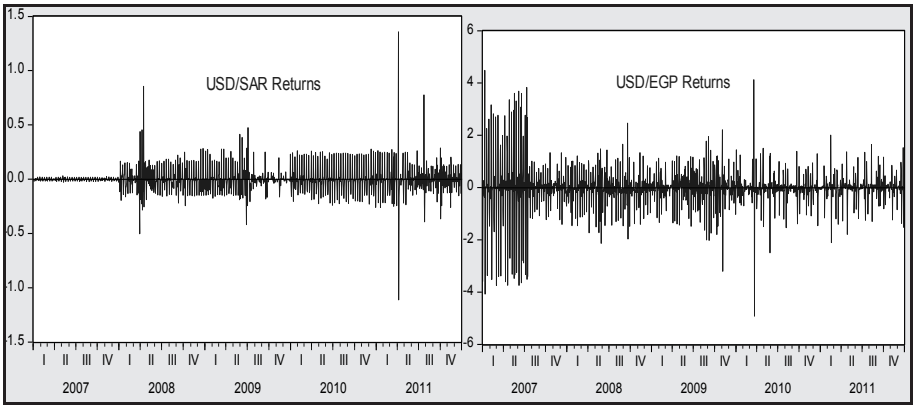

Fig. 4. Returns on Exchange Rate (2007- 2011)

series for both exchange rate and stock market returns, which indicates that it is possible now to proceed with modelling of the returns volatility by using GARCH framework. The proposed model is estimated using the maximum likelihood method under the assumption of multivariate normal distributed error terms. The log likelihood function is maximized using Marquardt's numerical iterative algorithm to search for optimal parameters. Besides the estimation output of the VAR(1)- GARCH(1,1) model, diagnostic test results were also provided to see whether there are any ARCH effects left in the estimated model (Note 7). Table 4 shows the parameter estimates of the model.

Estimation results for the return and volatility dependencies by applying VAR(1)-GARCH(1,1) model are reported in Table 4 for the stock and exchange rate markets. Regarding the interdependence of returns in mean equations, the results find that a one-period lagged exchange rate returns parameter significantly affects the index returns of Egyptian stock market which implies that past exchange rate returns can better be used to predict the future of the returns of the stock market. On the other hand, no sig-

Table 4
Estimation results of VAR(1)-GARCH(1,1) model for exchange rate and stock market returns

Variables	Stock Market Returns		Exchange Rate Returns	
	Tadawul Index	CMA Index	USD/SAR	USD/EGP
Conditional mean equation				
Constant	0.038194	0.155376	0.000297	0.008942
Exch(-1)	0.000156	-0.228334*	-0.082331	-0.000208
Conditional variance equation				
Constant	0.067462*	1.019001*	1.79E-06*	0.023354*
$(\varepsilon^{s}_{t-1})^2$	0.103760*	0.324240*	0.048564	0.007603*
$(\varepsilon^{e}_{t-1})^2$	0.048564	0.007603*	0.062861*	0.101228*
h^{s}_{t-1}	0.869074*	0.672325*	-0.295919	0.880719*
h^{e}_{t-1}	-0.295919	0.880719	0.950241*	0.849075*
Diagnostics				
$LB^2(30)$	28.961	50.812	60.691	136.55
ARCH(30)	26.91076	39.27633	46.19325	97.05887

- $LB^2(30)$ and ARCH(30) refer to the empirical statistics of the Ljung-Box test for autocorrelation of order 30 applied to the standardized residuals and the Engle (1982) test for conditional heteroscedasticity of order 30.
- * indicates the rejection of the null hypothesis of associated statistical tests at the 1% level.

nificant interactions between exchange rates and stock prices for Saudi Arabia.

As for the estimates of GARCH coefficients in the conditional variance equations, they are statistically significant for returns series. The significant of past own conditional volatility (GARCH-term) suggests that past values of the conditional volatility of stock market returns can be employed to forecast future volatility. The results also show that the current conditional volatility of the stock market depends on past shocks affecting return dynamics since ARCH-terms are highly significant. A closer inspection of the above coefficients reveals that in general; conditional volatility does not change very rapidly as the ARCH-terms measuring the impact of past shocks on conditional volatility are relatively small in size. On the other hand, the GARCH-terms, which capture the impact of past volatility on current volatility, are substantially large, indicating gradual fluctuations over time.

The empirical findings regarding the volatility transmission between exchange rate and stock markets in Table 4 indicate that the conditional volatility of the CMA index returns is affected by innovations in the exchange rate market as indicated by the significance of the coefficient on $(\varepsilon^{e}_{t-1})^2$. Apparently, a shock originating from the exchange rate market leads to increase stock market returns volatility. For the case of Saudi Arabia, no volatility transmission is found between exchange rate and stock markets. In addition, there is strong evidence to suggest that past volatility of the exchange rate market is transmitted to the Egyptian stock market because the coefficient associated with h^{e}_{t-1} is significant. On the other hand, the statistical significance of the coefficients of $(\varepsilon^{s}_{t-1})^2$ and h^{s}_{t-1} in the conditional volatility equation for exchange rate returns for Egypt suggests that stock market volatility behaves dependently on the changes (shock and volatility) taking place in the exchange rate market.

The residual diagnostic tests are reported in the last part of Table 4. The LB^2-statistic suggests that the null hypothesis of no autocorrelation cannot be rejected; thus, the residuals are free of autocorrelation. The ARCH-LM test suggests that the null hypothesis of no ARCH effects cannot be rejected; implying that the residuals do not suffer from the ARCH effects which imply that the conditional variance equation is well specified.

Conclusion

This paper tried to investigate the volatility spillovers between stock

market returns and exchange rates movements in Saudi Arabia and Egypt. Based on daily observations of general market index for the stock markets in the two countries and exchange rate of the SAR and EGP against the US Dollar over the period of 1st January 2007 to 30th December 2011, the paper employed a bivariate vector autoregressive-generalized autoregressive conditional heteroscedasticity (VAR-GARCH) model recently developed by Ling and McAleer (2003) to simultaneously estimate the conditional mean and conditional variance of exchange rate and stock market returns. The empirical results of the paper show that the shock originating from the exchange rate market leads to an increase in stock market returns volatility for Egypt. In addition, there is evidence to suggest that past volatility of exchange rate markets is transmitted to the stock market in Egypt during the period of the study. No volatility transmission is found between exchange rate and stock markets for Saudi Arabia.

The paper concluded that exchange rate shock (volatility) has a very serious implication on the Egyptian stock market. Hence, for any serious development of the stock market there is a need to stabilize the exchange rate movement. This is in line with Adjasi and Biekpe (2005) that exchange rate depreciation reduces stock market returns.

Notes

1 - The Saudi Arabia Monetary Agency (SAMA) was responsible for supervising the market from 1984 until 2003. In July 2003, authority was handed over to the newly formed Capital Market Authority (CMA). The CMA is now the sole regulator and supervisor of Saudi Arabia's capital markets, and issues the necessary rules and regulations to protect investors and ensure fairness and efficiency in the market (Talat *et al.*, 2011).

2 - The index was developed with a base value of 1000 in 1985 and it was restructured on 06/30/08.

3 - For a detailed discussion of the Egyptian Stock Market see for example, Mecagni and Sourial (1999) and Aly, *et al.* (2004).

4 - A time series is said to be heteroscedastic if its variance changes over time, otherwise it is called homoscedastic.

5 - In general terms, volatility refers to the fluctuations observed in some phenomenon over time. In terms of modelling and forecasting literature, it means "the conditional variance of the underlying asset return" (Tsay, 2010).

6 - The optimal number of lags for the VAR system will be chosen on the basis of commonly used information criterion.

7 - If the variance equation of the GARCH model is correctly specified, there should be no ARCH effect left in the residuals.

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Appendix

Testing for Heteroscedasticity (ARCH-LM test)

The ARCH LM test is used for testing the conditional heteroscedasticity in the residual series. Its commonly accepted in volatility modelling that one of the most important issues before applying the Generalized Autoregressive Conditional Heteroscedasticity (GARCH) methodology is to first examine the residuals for evidence of heteroscedasticity. To test for the presence of heteroscedasticity in residuals, the Lagrange Multiplier (LM) test for ARCH effects proposed by Engle (1982) is applied.

In summary, the test procedure is performed by first obtaining the residuals e_t from the ordinary least squares regression of the conditional mean equation which might be an autoregressive (AR) process, moving average (MA) process or a combination of AR and MA processes; i.e., an ARMA process. For example, in ARMA (1,1) process the conditional mean equation will be:

$$r_t = \phi_1 r_{t-1} + \varepsilon_t + \theta_1 \varepsilon_{t-1} \tag{1}$$

After obtaining the residuals e_t, the next step is to regress the squared residuals on a constant and q lags as in the following equation:

$$e_t^2 = \alpha_0 + \alpha_1 e_{t-1}^2 + \alpha_2 e_{t-2}^2 + ... + \alpha_q e_{t-q}^2 + v_t \tag{2}$$

The null hypothesis that there is no conditional heteroscedasticity (ARCH effect) up to order q can be formulated as:

$$H_0 : \alpha_1 = \alpha_2 .. = \alpha_q = 0$$

against the alternative:

for at least one i = 1, 2,..., q.

The test statistic for the joint significance of the q-lagged squared residuals is the number of observations times the R-squared (TR^2) from the regression (2). TR^2 is evaluated against the $\chi^2(q)$ distribution. This is an asymptotically locally most powerful test (Rachev *et al*., 2007)

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الملخص

التأثيرات غير المباشرة للتقلبات بين أسعار الصرف وعوائد الأسهم: دليل تطبيقي من المملكة العربية السعودية وجمهورية مصر العربية

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تختبر هذه الدراسة الآثار غير المباشرة بين تقلبات أسعار الصرف وعوائد الأسهم بأسواق الأوراق المالية في المملكة العربية السعودية وجمهورية مصر العربية للفترة من ١ يناير ٢٠٠٧م إلي ٣٠ ديسمبر ٢٠١١م. تستخدم الدراسة متجه الانحدار الذاتي الثنائي لنموذج اختلاف التباين الشرطي العام المنحدر ذاتياً (VAR-GARCH) الذي تم تطويره حديثاً بواسطة Ling and McAleer، في العام 2003. تم تقدير النموذج المقترح باستخدام طريقة الإمكان الأعظم تحت افتراض تبعية الأخطاء العشوائية للتوزيع الطبيعي المتعدد. أوضحت النتائج التطبيقية للدراسة أن سعر الصرف بإبطاء لفترة زمنية واحدة يؤثر معنوياً علي عائدات المؤشر العام لسوق الأوراق المالية بجمهورية مصر العربية، مما يعني أن عائدات سعر الصرف السابقة يمكن استخدامها للتنبؤ بعائدات السوق المستقبلية. علاوة علي ذلك تشير النتائج إلي أن الصدمات (التقلبات) الآتية من سوق سعر الصرف تؤدي إلي زيادة تقلبات عائدات سوق الأوراق المالية بالنسبة لمصر، بينما لم تشر النتائج التطبيقية للدراسة إلى وجود تأثيرات للتقلبات بين أسعار صرف الريال السعودي مقابل الدولار الأمريكي وعوائد المؤشر العام لسوق المال السعودية.

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