Volatility transmission in African foreign exchange markets

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Received 22 May 2015
Revised 3 September 2015
Accepted 14 September 2015

Abstract

Purpose – The concept of volatility transmission and co-movement has witnessed a resurgence in the international finance literature in recent years after the black swan events which gave evidence of financial market linkages. The purpose of this paper is to examine the dynamic sources of volatility transmission in the foreign exchange market in recent financial market integration in Africa.

Design/methodology/approach – A conceptual framework was adapted from the extant literature and was used as the basis of modeling exchange rate volatility transmission. This paper adopts a quantitative research approach and opts for augmented DCC model to empirically unearth the sources of exchange rate volatility transmission.

Findings – The key findings of the study are that, the African market is more prone to shock from outside than in the region. Macroeconomic news surprises influence volatility transmission and co-movements. Robust support is found for trade balance, interest rate and gross domestic product. These findings clearly demonstrate the low level of financial development and challenges that sometimes exist in exchange rate-policy implementation by policy makers.

Research limitations/implications – Interested academics and practitioners working in the area might incorporate bilateral investment into the model of exchange rate correlation in future research.

Originality/value – Unilaterally considering exchange rate volatility transmission and subsequent augmentation of the DCC model, this study makes a modest contribution to the examination of exchange rate correlations in Africa. This study makes an important contribution in not only addressing this imbalance, but more importantly improving the relative literature on exchange rate volatility transmission.

Keywords Augmented dynamic conditional correlation, Financial integration, Volatility transmission

Paper type Research paper

1. Introduction

Interactions among exchange rates pairs have been investigated in a considerable number of studies (Dornbusch and Fisher, 1980; Branson, 1983; Frankel, 1983; Karolyi and Stulz, 1996; Subramanian and Kessler, 2012; Cockerell and Shoory, 2012), where a majority of the works has focussed on assessing the degree of dependence in the foreign exchange and equity markets. An important and relatively unexplored issue in this context is to what extent the foreign exchange markets depend on how countries are, otherwise, financially or economically, integrated. Analyzing this issue may help us understand better the linkages that are important for risk spillover and contagion effects between exchangerate pairs. Several studies (Wei, 2008; Dijk *et al.*, 2011; Bautista, 2003; Baur, 2011; Christiansen and Ranaldo, 2009; Fry *et al.*, 2010) have investigated the importance of financial and economic integration on stock market co-movements using dynamic conditional correlation (DCC). In order to highlight the

African Journal of Economic and Management Studies
Vol. 7 No. 2, 2016
pp. 205-224

2040-0705
DOI 10.1108/AJEMS-05-2015-0056

spillover effect between exchange rate pairs, multivariate GARCH-type models have mostly been used in the literature on volatility transmission as they allow for the joint modeling of variances and covariances between different variables (Belgacem and Lahiani, 2012). In this study, the correlation in the foreign exchange markets is modeled using augmented DCC.

Advances in financial econometrics have provided a powerful tool for performing thorough analyses of the linkages that are important for the co-movements of financial markets. With a financial econometrics approach, we can investigate the foreign exchange market integration of different countries as defined by various financial and economic integration measures. The augmentation of the DCC model allows us to model direct and indirect effect of macroeconomic news surprises impact on volatility transmission. In addition, the DCC approach used is dynamic in nature, and makes it possible to investigate how shocks in returns or in macroeconomic variables in one country affect the currency markets of other countries.

The DCC model is widely used in the financial market empirical research (van Dijk *et al.*, 2005; Engle and Colacito, 2006; Cappiello *et al.*, 2006). Only recently some models which were developed include exogenous variables. Vargas (2008) extends the DCC model to allow for exogenous variables and introduces the DCCX model. Bali and Engle (2010) augment a capital asset pricing model with estimated correlations. The DCCX-MGARCH method can be quite useful to see what economic fundamental variables affect the cross-country correlations in order to identify the channels of contagion. For this purpose, a GARCHX model (Hwang and Satchell, 2005; Engle and Patton, 2001) is employed instead of the GARCH model used previously.

Although augmented DCC model of dependence structures has become very popular, it is hardly used in financial applications. Some of the few studies that employ augmented DCC model are the recent works by Bauwens *et al.*, 2006; Hong-Ghi and Young-Soon, 2012; Ehrmann *et al.*, 2011; Antonakakis, 2012; Belgacem *et al.*, 2014) these studies argue that augmented model has higher forecasting performance compared to a standard DCC model as well as being easily extended to incorporate exogenous variables. This methodology can estimate both the DCC and the impact of explanatory variables simultaneously in one framework.

These studies are closely related to this paper in that they add additional variables to mean and variance equations to explain volatility spillover. Moreover, like the various studies based on volatility spillover, they analyze pairwise correlations between energy market and equity market returns and inclusion of dummies. However, there are also crucial differences between their study and this paper. First, this study considers foreign exchange market only. This is important; since unilateral study of foreign exchange market may lead to improvement in the extant literature on volatility spillover. For instance, synchronized changes in inflation rates may indicate that different markets yield similar returns even if they are not economically integrated. Moreover, our regression approach makes it possible to investigate how changes in two economies' macroeconomic news affect the returns of a market and how these effects propagate throughout the foreign exchange market.

The current study therefore estimates a multivariate GARCH framework, to study volatility transmission in the foreign exchange markets among three African economies as well as UK and China that have strong trade ties with Africa. Three chosen African countries (South Africa, Egypt and Nigeria) are the top three economies in Africa and "most traded currencies" as defined by the daily trading volume and the size of the economy (BIS, 2007; AfDB, OECD, UNDP, and ECA, 2012;

World Bank, 2012). Chinese yuan is considered an international currency and might be the highest traded currency currently (Eichengreen, 2010a, b; Cockerell and Shoory, 2012). Furthermore, Subramanian and Kessler (2012) state that Chinese yuan has become the dominant reference currency especially in East Asia. Using monthly data over the period from January 1990 to December 31, 2013, it is revealed that African foreign exchange market is more prone to external volatility than intra-regional volatilities. This result may be attributed to the relatively low volume of trade among African countries themselves.

The rest of the paper is organized as follows. In Section 2, literature is reviewed, while Section 3 introduces the model. Section 4 presents the data and preliminary results and also discusses the main findings of the paper. Section 5 concludes the paper.

2. Literature

The existing literature in financial economics has provided two potential theoretical explanations for the interactions between exchange rates. The first is the Dornbusch and Fisher (1980) flow-oriented model. This model explains that domestic currency depreciation improves the competiveness of local firms, which in turn leads to increase in their exports and future cash flows. As a result, stock prices will move up in response to the increase in expected cash flows. The second is the stock-oriented models of exchange rate determination (also called the portfolio balance approach) which establishes a directional impact from stock prices to exchange rates (Branson, 1983; Frankel, 1983). Thus, the movements in exchange rates may be driven by changes in stock prices through the exchange rate adjustments to changes in supply and demand of foreign and domestic assets in internationally diversified portfolios.

Exchange rate volatility transmission studies started with Engle *et al.* (1990); two hypotheses, namely: the "heat waves" and the "meteor shower." The first refers to exchange rate volatility in one particular market having only country-specific effects, while the later refers to volatility being transmitted to other countries. The empirical evidence on these hypotheses fueled further studies (Bollerslev, 1990; Lee *et al.*, 2006; Billio *et al.*, 2006; Kearney and Patton, 2000; Melvin and Melvin, 2003; Black and McMillan, 2004; Calvet *et al.*, 2006) with numerous applications of multivariate GARCH models in multi asset volatility studies, which attested to its usefulness in studying volatility spillovers. These studies found strong support of co-movements and volatility spillover effects.

An empirical rejection of constant correlations model in certain classes of assets led to the metamorphosis of multivariate GARCH models (Tsui and Yu, 1999; Engle, 2002). For instance, the BEKK formulation of Engle and Kroner (1995), factor GARCH model of Engle *et al.* (1990), Alexander (2000) and Engle (2002), are a new class of estimators that has the capacity of preserving both the ease of estimating conditional correlations as well as allowing for non-constant correlations. Since then, Engle (2002) DCCs model has become a dominant model in volatility transmission studies as it has power to preserve the parsimony of univariate GARCH models of individual assets volatility like time-varying correlations (Engle and Sheppard, 2001). It has been recently employed in several studies (Dijk *et al.*, 2011; Diebold and Yilmaz, 2012; Bautista, 2003; Wei, 2008; Beine *et al.*, 2003).

In addition, a number of volatility transmission studies have also used various forms of copula approach in currency dependence modeling. For instance, Aloui *et al.* (2013) found evidence of significant and symmetric dependence for exchange rate pairs considered. Okimoto (2008) used copula approach to analyze the presence of two regimes in the UK and US stock markets. Jondeau and Rockinger (2006) used an exogenous variable to explain changes in the dependence structure between stock markets over time.

The empirical evidence on currency dependence has been documented by numerous studies. Safe arbitrage opportunities are immediately ruled out by other exchange rate movements (Haug *et al.*, 2000; Kühl, 2010). Kühl (2008) show that not only exchange rates share common stochastic trends but also cointegration between fundamentals across economies. According to Phengpis and Nguyen (2009) cointegration across countries might occur if monetary policies are coordinated to limit exchange rate fluctuations such that currency prices cannot permanently diverge from each other. The assumption of independence is usually not valid, in particular in the analysis of financial data that have strong inter-economy linkages (Urbain and Westerlund, 2006; Basher and Westerlund, 2009), such as exchange rates and income. Recently, Cerra and Saxena (2010) exploited the power of panel cointegration tests in a broad sample of 98 countries and found further evidence that monetary fundamentals play an important role for the nominal exchange rate. Nikkinen *et al.* (2006) examine currency options on the euro, British pound and Swiss franc exchange rates to the US dollar for volatility linkages. Currency options reflect markets' volatility expectations and concluded that the euro's volatility expectations have a significant impact on the currencies of GBP and CHF. Kocenda and Valachy (2006), examine the behavior of exchange rate volatility for Poland, Hungary, Slovakia and Czech Republic with TGARCH model. They found that volatility is greater under a floating exchange rate regime than under a fixed regime. Kobor and Szekely (2004) find exchange rate volatility (*vis-à-vis* the euro) in four CEE countries to be characterized by regime switching. Hau (2002) find a slight decrease in the euro/USD volatility as opposed to the DM/USD volatility, Malik (2005) and Wan and Kao (2008) observe significant evidence that the euro is much more volatile than the British pound and also find persistency of volatility to decrease for the euro but post euro era British pound volatility has increased. In univariate framework, Wan and Kao (2008) find no significant increase in the euro/USD volatility in post euro era. Furthermore, Subramanian and Kessler (2012) and Lien *et al.* (2013), argue that the Chinese yuan has become the dominant reference currency in East Asia. Lien *et al.* (2013) say this comes through the use of the yuan in NDF contracts to hedge their currency exposure, after the Chinese government reform of currency regime in 2005.

The financial sector's volatility has had a significant and negative impact on economic growth (Wang, 2010; Cheong *et al.*, 2011; Baur, 2011; Campello *et al.*, 2010). Recent studies (Wang, 2010; Cheong *et al.*, 2011) indicate that, financial sector's volatility leads non-financial sectors' in the USA and the UK. For example, financial crisis increased co-movement between financial sector and real economy (Baur, 2011; Campello *et al.*, 2010).

While these aforementioned studies focus on the increased importance of volatility transmission in stock markets, and real economy they provide little information about the volatility transmission and co-movement in the foreign exchange market. In the following sections we fill in this gap in the literature.

3. Data source and methods

The data frequency is monthly over the period of January, 1990-December, 2013. The exchange rates considered are the South African rand, Nigerian naira, Egyptian pound, the British pound and the Chinese yuan, all against the US dollar and some macroeconomic variables. The three chosen African countries are the top three economies in Africa and "most traded currencies" as defined by the daily trading volume and the size of the economy (AfDB, OECD, UNDP, and ECA, 2012; World Bank, 2012). Recent studies (Subramanian and Kessler, 2012; Eichengreen, 2010a, b; Cockerell and Shoory, 2012) consider Chinese yuan to be international currency and a dominant reference currency especially in East Asia. The long trade ties informed inclusion of pound sterling. The series were obtained from the International Monetary Fund and checked afterwards through central bank of each country.

The DCC-GARCH model is superior to the other multivariate GARCH specifications when studying financial markets dynamics as it takes into account dynamic correlation between financial data. Moreover, the conditional correlation between markets is shown to be time varying. Finally, DCC-GARCH presents the advantage of having less parameters to estimate, which allows us to augment the model by introducing a set of macroeconomic variables to test for the direct and indirect effects of macroeconomic news without burdening the estimation procedure (Belgacem and Lahiani, 2012).

The DCC model of Engle (2002) is defined as:

$$y_t = \mu_t(\theta) + \varepsilon_t, \quad \text{where } \varepsilon_t I \Omega_{t-1} \sim N(0, \mathrm{H}_t)$$

$$H_t = D_t R_t D_t \qquad (1)$$

where $y_t = (y_t, \ldots, y_{nt})'$ is a $n \times 1$ vector of exchange returns (specifically the rand, Egyptian pound, naira, pound sterling and yuan returns, thus $n = 5$), $\mu(\theta) = (\mu_t, \ldots, \mu_{nt})'$ is the conditional $n \times 1$ mean vector of y_t. $D_t = diag({h_{iit}}^{1/2} {h_{nnt}}^{1/2})$ is a diagonal matrix of square root conditional variances, where h_{iit} can be defined as any univariate GARCH-type model, and R_t is the $t \times \left(n(n-1)/2\right)$ matrix containing the time-varying conditional correlations defined as:

$$R = diag\left({q_{ii,t}}^{-1/2} \ldots {q_{nn,t}}^{-1/2}\right) Q_t diag\left({q_{ii,t}}^{-1/2} \ldots {q_{nn,t}}^{-1/2}\right) \text{ or}$$

$$\rho_{ij,t} = \rho_{ji,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t} q_{jj,t}}} \qquad (2)$$

$Q_t = (q_{ij,\, t})$ is a $n \times n$ symmetric positive definite matrix given by:

$$Q_t = (1-\alpha-\beta)\bar{Q} + \alpha \mu_{t-1} \mu'_{t-1} + \beta_i Q_t \qquad (3)$$

where $\mu_t = (\mu_{1t}, \mu_{2t}, \ldots, \mu_{nt})'$ is the $n \times 1$ vector of standardized residuals, $\overline{Q}$ is the $n \times n$ unconditional variance matrix of μ_t, and α and β are non-negative scalar parameters satisfying $\alpha + \beta < 1$.

In order to take into account the spillovers among foreign exchange markets, the basic model (2) is augmented so that it allows detecting not only the direct reaction of the African market to the release of China and UK macroeconomic announcements, but also the transmission effects (indirect) from Chinese and UK markets to the African foreign exchange market. To do so, DCC-GARCH model was augmented by macroeconomic variables in the variance equation of the foreign exchange market such that a test of volatility transmission between the markets can be done. Formally, the regression is as follows:

$$h_{S,t} = \gamma_S + \alpha_S \varepsilon^2{}_{S,t-1} + \beta_S h_{S,t-1} + \sum_{k=1}^{8} \delta_{S,k} S^U{}_{k,t} + \sum_{k=1}^{8} \delta_{S,k} S^C{}_{k,t} + \sum_{k=1}^{8} \theta_{S,k} D_k h^U{}_{t-1} + \sum_{k=1}^{8} \theta_{S,k} D_k h^C{}_{t-1} \tag{4}$$

$$h_{N,t} = \gamma_N + \alpha_N \varepsilon^2{}_{N,t-1} + \beta_N h_{N,t-1} + \sum_{k=1}^{8} \delta_{N,k} S^U{}_{k,t} + \sum_{k=1}^{8} \delta_{N,k} S^C{}_{k,t} + \sum_{k=1}^{8} \theta_{N,k} D_k h^U{}_{t-1} + \sum_{k=1}^{8} \theta_{N,k} D_k h^C{}_{t-1} \tag{5}$$

$$h_{E,t} = \gamma_E + \alpha_E \varepsilon^2{}_{E,t-1} + \beta_E h_{E,t-1} + \sum_{k=1}^{8} \delta_{E,k} S^U{}_{k,t} + \sum_{k=1}^{8} \delta_{E,k} S^C{}_{k,t} + \sum_{k=1}^{8} \theta_{E,k} D_k h^U{}_{t-1} + \sum_{k=1}^{8} \theta_{E,k} D_k h^C{}_{t-1} \tag{6}$$

$S_t{}^C$ and $S_t{}^U$ is the standardized surprise of the Chinese and UK macroeconomic announcements, D_k is a dummy variable taking the value 1 on the days of kth news announcements, and 0 otherwise. The terms $\sum_{k=1}^{5} \theta_{S,k} D_k h^C{}_{t-1}$ and $\sum_{k=1}^{5} \theta_{S,k} D_k h^U{}_{t-1}$ in Equations (4)-(6) help in detecting the volatility spillover from China and UK markets to the African foreign exchange market after the release of Chinese and UK macroeconomic indicators, while the terms $\sum_{k=1}^{5} \delta_{S,k} S^U{}_{k,t}$ and $\sum_{k=1}^{5} \delta_{S,k} S^C{}_{k,t}$ capture the direct effect of the Chinese and UK announcements on the volatility transmission in Africa. Similar specifications are given in (7)-(9) below to describe volatility transmission between African countries:

$$h_{S,t} = \gamma_S + \alpha_S \varepsilon^2{}_{S,t-1} + \beta_S h_{S,t-1} + \sum_{k=1}^{9} \delta_{S,k} S^N{}_{k,t} + \sum_{k=1}^{9} \delta_{S,k} S^E{}_{k,t} + \sum_{k=1}^{9} \theta_{S,k} D_k h^N{}_{t-1} + \sum_{k=1}^{9} \theta_{S,k} D_k h^E{}_{t-1} \tag{7}$$

$$h_{N,t} = \gamma_N + \alpha_N \varepsilon^2{}_{N,t-1} + \beta_N h_{N,t-1} + \sum_{k=1}^{9} \delta_{N,k} S^S{}_{k,t} + \sum_{k=1}^{9} \delta_{N,k} S^E{}_{k,t} + \sum_{k=1}^{9} \theta_{N,k} D_k h^S{}_{t-1} + \sum_{k=1}^{9} \theta_{N,k} D_k h^E{}_{t-1} \tag{8}$$

$$h_{E,t} = \gamma_E + \alpha_E \varepsilon^2{}_{E,t-1} + \beta_E h_{E,t-1} + \sum_{k=1}^{9} \delta_{E,k} S^U{}_{k,t} + \sum_{k=1}^{9} \delta_{E,k} S^C{}_{k,t}$$

$$+ \sum_{k=1}^{9} \theta_{E,k} D_k h^U{}_{t-1} + \sum_{k=1}^{9} \theta_{E,k} D_k h^C{}_{t-1} \quad (9)$$

The health of the DCC models was evaluated based on the standardized residuals and squared standardized residuals. Moreover, since these models are nested, other information criteria, namely, the Akaike Information Criteria, Schwartz Bayesian Criteria, Hannan-Quinn Criteria and the Shibata were applied to examine adequacy and appropriateness of the models. Having proved that conditional correlations do not remain constant over time, the BEKK model was also applied to test for the sensitivity of the results obtained from the DCC model. The full BEKK model of Engle and Kroner (1995) is defined as:

$$y_t = \mu_t(\theta) + \varepsilon_t$$

$$H_t = C'C + \sum_{i=1}^{q} \sum_{k=1}^{K} A'_i \varepsilon_{t-i} \varepsilon'_{t-1} A_i + \sum_{i=1}^{q} \sum_{k=1}^{K} B'_i H_{t-i} B_j \quad (10)$$

where $\mu_t(\theta)$ is as specified in (2), is an upper triangular matrix, A and B are $n \times n$ square matrices. The full BEKK is given by $(p+q)Kn^2 + n(n+1)/2$. In the application of the full BEKK, it is typically assumed that $p = q = K = 1$ such that if $n = 2$ variables, the number of estimated parameters equals to 11 but for $n = 4$ equals to 42. The flexible extensions of the MGARCH models proved that the full BEKK is able to ensure positive definiteness of the conditional variance matrix, and also more tractable.

Following (Harvey *et al.*, 1997; Fiorentini *et al.*, 2003), the Quasi-Maximum Likelihood estimator under a multivariate, student distribution is employed in the estimation of the multivariate GARCH models since normality assumption of the innovations is rejected in most empirical applications dealing with exchange rate data. The consequence is an addition of an extra parameter to the estimation of each model, thus the degree of freedom parameter, denoted by v.

4. Empirical results

This section provides the results of the study. It is divided into four sub-sections: descriptive statistics, volatility transmission, volatility spillovers and macroeconomic announcements, and evaluation of volatility transmission.

4.1 Descriptive statistics

Table I shows summary statistics for the returns of currency used in this study. All currency returns are averagely positive for the sample period 1990-2013 indicating possibility of depreciation. Comparatively, the volatility (standard deviation) in Africa is higher than those from outside. It is 34, 34 and 26 percent for Egypt, South Africa and China, respectively. The data are clearly skewed highlighting high probability of exchange rates to depreciate. The excess kurtosis coefficient is highly significant for each of the currencies indicating non-normality of returns. In addition, the Jarque-Bera statistic confirms the non-normality of returns as the hypothesis is persuasively rejected. The Ljung-Box Q statistic (up to eight lags) for returns and squared returns tests the null

	EGP	SAR	Nnaira	UKPS	Cyuan
Mean	0.00488	0.00486	0.01485	0.000325	0.000107
Max	0.18492	0.19153	0.14095	0.12769	0.13546
Min	−0.1979	−0.10467	−0.0162	−0.16246	−0.13537
SD	0.03368	0.03396	0.0227	0.02694	0.026543
Skewness	1.16373	1.13505	2.4441	0.90917	0.28215
Kurtosis	16.637	9.1156	10.3878	6.3712	1.5771
jb	2,240.88 (0.000)**	498.23 (0.000)**	918.82 (0.000)**	171.78 (0.000)**	265.25 (0.000)**
$Q(8)$	0.277 (0.000)**	0.310 (0.000)**	0.815 (0.000)**	1.422 (0.000)**	4.0038 (0.000)**
$Q(8)^2$	37.174 (0.000)**	36.12 (0.000)**	25.18 (0.000)**	13.326 (0.000)**	40.328 (0.000)**
ARCH	17.048 (0.000)**	25.917 (0.000)**	24.128 (0.000)**	13.638 (0.000)**	4.2426 (0.000)**

Notes: () denotes *p*-values. $Q()$ and $Q()^2$ is the Ljung-Box statistics for serial, correlation in raw returns and squared returns series. EGP is the Egyptian pound; SAR is the South African rand; Nnaira is the Nigeria naira; UKPS is the Great Britain pound sterling and Cyuan is the Chinese yuan. **Significance at 5 percent level

Table I.
Summary statistics for all returns

hypothesis of no serial correlation and homoskedastic, respectively. Table I reports the *Q* statistics to be insignificant at eight lags across each returns series, except the naira returns. This indicates that all returns but the naira can be characterized as random walk processes. However, the squared returns were significant for all returns series revealing strong non-linear dependencies. This is also supported by Engle's ARCH-LM statistic which also rejects the null hypothesis of no ARCH effects at 5 percent level of significance. The presence of ARCH effects in returns up to eight lags justifies DCC-GARCH as adequate to capture the heteroskedasticity in the volatilities series.

4.2 Volatility transmission

This sub-section analyses the empirical results with the aim of examining volatility transmission and spillover. Table II presents the results of the regressions that use exchange rate return. Following previous studies (Bauwens *et al.*, 2006; Hong-Ghi and Young-Soon, 2012; Ehrmann *et al.*, 2011; Antonakakis, 2012; Belgacem *et al.*, 2014), the estimated results include spillover effect with AR(3)-DCC-MGARCH(1,1) and a random walk DCC-MGARCH(1,1) models were chosen in order to remove any serial correlation in returns. The specification is adequate, as the diagnostic tests for serial correlation report no evidence of serial correlation. Hosking's (1980) and Li and McLeod (1981) multivariate versions of the Ljung-Box test statistics do not reject the null hypothesis of no serial correlation up to eight lags. There is strong evidence of significant DCCs.

The results show that the volatility spillovers are high between big economy size, namely, the pound sterling, the rand and the yuan. The strongest in magnitude of volatility spillovers occur between the rand-pound, and rand-yuan. Specifically, the estimated correlation coefficients between the rand-pound, rand-yuan and the naira-yuan are 0.8515, 0.8053 and 0.6656, respectively. The lowest corelations are between the Egyptian pound-naira, Egyptian pound-rand and the other three currencies. Specifically, the estimated correlation coefficients between the Egyptian pound-naira, and Egyptian pound-rand, are 0.0826, 0.1243 and 0.3030, respectively. This is in line with the literature that contagions are of intra-regional rather than inter-regional (Glick and Rose, 1999, 2002). These results show that the rand is the dominant currency in volatility transmission as the highest correlation is between currencies involving it. This means that the rand volatility significantly affects the

	SAR	EGP	Nnaira	GBP	CHRIM
Panel A: 1-step univariate GARCH estimates and diagnostic test					
Const (*m*)	0.0003	0.0003	0.0003	0.0003	0.0003
	6.58E−04	6.79E−06	8.46E−05	7.79E−05	8.26E−06
Const (*v*)	0.011	0.0009	0.0007	0.0024	0.0079
	0.0062	0.0009	(0.0006)	0.0006	(0.0030)
α	0.0426	0.0305	0.0344	0.0401	0.0412
	0.0113	0.0085	0.0078	0.0107	0.0109
β	0.9624	0.8542	0.9535	0.9374	0.9624
	0.0084	0.033955	0.0067	0.0136	0.0084
$Q(20)$	27.4653 {0.5988}	33.7972 {0.2890}	26.9527 {0.6258}	27.4653 {0.5988}	17.7635 {0.9622}
$Q(20)^2$	32.9728 {0.3237}	29.7339 {0.4793}	74.6051 {0.0000}**	5.3959 {0.9999}	0.0589 {1.0000}
Panel B: 2-step correlation estimates and multivariate diagnostic test					
ρSARRIM	0.8053 (0.0577)**				
ρSARGBP	0.8515 (0.0389)*				
ρEGPRIM	0.3190 (0.1147)**				
ρEGPGBP	0.3030 (0.1255)*				
ρNAIRARIM	0.6656 (0.0407)**				
ρNAIRABGP	0.4224 (0.0671)**				
ρNAIRASAR	0.3967 (0.0141)**				
ρNAIRAEGP	0.0826 (0.0666)				
ρEGPSAR	0.1243 (0.0694)				
α	0.0188 (0.0027)**				
β	0.9762 (0.0027)**				
df	7.8902 (0.5327)**				
Log Lik	36,944.3				
AIC	−33.405				
SBC	−33.342				
HQC	−33.382				
Shibab	−33.4052				
$H(8)$	506.319 {0.1706}				
$H(8)^2$	501.884 {0.2173}				
Li-McL(8)	506.081 {0.1725}				
Li-McL$(8)^2$	502.657 {0.2102}				

Notes: $Q()$ and $Q()^2$ are the Ljung-Box postmanteau tests statistics for serial correlation, in the univariate standardized and squared standardized residuals. $H()$, $H()^2$, Li-McL(), and Li-McL$()^2$ are the multivariate versions of the Ljung-Box statistics of Hosking (1980), Li and McLeod (1981), respectively. () and {} are standard errors and *p*-values, respectively

Table II. Estimation results of DCC model (DCC MGARCH (1,1))

volatility expectations of the naira, yuan and pound. Like the results of Nikkinen *et al.* (2006) where the euro significantly affects the volatility expectations of other currencies, it is established here that the rand is in a dominant position like the euro in volatility transmission probably because of the size of South African economy. Currencies in Africa received stronger volatility transmission and spillover from China and Britain than within the region. In this instance, meteor shower strongly works in Africa and signals vulnerability of African economy to the outside world. The evidence has serious implications for portfolio diversification and risk management. The lower volatility spillovers of the Egyptian pound to other currencies has obviously important implications since Egypt trades more with Arab nations than sub-Sahara African neighbors, but also for risk management, portfolio diversification and others, economies should include her in risk hedging.

4.3 Volatility spillovers and macroeconomic announcements

This section analyses how macroeconomic announcements is related to the volatility transmission in foreign exchange market. Table III presents the regression results that have exchange rate return as the dependent variable. The superscripts *c* and *u* stand for China and UK, respectively. The results of the augmented DCC-GARCH model as described by Equations (6)-(8) are reported in Table III below. The coefficients a_1 and b_1 of the DCC equation are highly significant, which confirm the adequate specification of the model and the existence of a time-varying correlation between the series.

To begin with, the results show evidence of the significant impact of the UK and Chinese macroeconomic surprises on African foreign exchange markets. The impact is divided into; direct effect (common response) and indirect effect (volatility transmission).

Table III. Estimation results of augmented DCC model (DCC MGARCH (1,1))

Variables	EGP	SE	SAR	SE	Nnaira	SE
Mean equation						
Constant	0.176**	(0.005)	0.074**	(0.004)	0.071**	(0.006)
Egp(1)	0.084**	(0004)	0.002	(0.012)	0.065	(0.069)
Sar(1)	−0.247	(0.294)	0.085**	(0.011)	0.025	(0.020)
Nnaira(1)	0.011	(0.024)	0.015	(0.023)	0.024**	(0.003)
UKPS(1)	0.025*	(0.024)	0.016**	(0.002)	0.041**	(0.003)
Cyuan(1)	0.012	(0.029)	0.006**	(0.003)	0.925*	(0.019)
Variance equation						
Constant	0.433*	(0.017)	0.440*	(0.016)	0.017	(0.004)
ε^2_{t-1}	0.032*	(0.018)	0.068**	(0.017)	0.261**	(0.004)
h_{t-1}	0.013	(0.027)	0.037*	(0.019)	0.253**	(0.003)
Direct effects						
GDP[a]	0.028**	(0.003)	0.883**	(0.088)	0.834**	(0.048)
GDP[b]	0.124**	(0.016)	0.487**	(0.054)	0.460**	(0.067)
Interest rate[a]	0.038	(0.040)	0.016	(0.029)	0.013	(0.051)
Interest rate[b]	0.048	(0.044)	0.016	(0.029)	0.025	(0.016)
Trade balance[a]	0.112*	(0.069)	0.195**	(0.054)	0.134**	(0.011)
Trade balance[b]	0.398**	(0.062)	0.394**	(0.063)	0.195**	(0.054)
CPI[a]	0.094**	(0.023)	0.026**	(0.008)	0.398**	(0.062)
CPI[b]	−0.042**	(0.010)	0.022	(0.060)	0.006	(0.054)
Indirect effects						
GDP[a]	0.022*	(0.010)	0.110**	(0.009)	0.120**	(0.012)
GDP[b]	0.053**	(0.017)	0.027**	(0.009)	0.055**	(0.011)
Interest rate[a]	0.005	(0.012)	0.162**	(0.073)	0.132**	(0.012)
Interest rate[b]	0.012	(0.012)	0.043**	(0.100)	0.036*	(0.021)
Trade balance[a]	0.028	(0.030)	0.026**	(0.008)	0.345**	(0.038)
Trade balance[b]	0.019	(0.020)	0.039**	(0.010)	0.470**	(0.042)
CPI[a]	0.026	(0.020)	0.014	(0.020)	0.055	(0.136)
CPI[b]	−0.014	(0.023)	0.488**	(0.035)	0.059**	(0.028)
DCC equation						
a	0.025	[3.467]				
b	0.972	[118.87]				
Log likelihood	2,093.183					
$Q(8)$	49.37	{0.41}				

Notes: () denotes standard errors, [] is *t*-value and {} is *p*-value. [a]China; [b]UK. *,**Significant at 5 and 1 percent levels, respectively

The direct effect of macroeconomic news on volatility transmission reveals increasing volatility recipient of South Africa and Nigeria markets significantly following a positive surprise in the Chinese CPI, trade balance and GDP announcements. Significant volatility spillovers from the UK market to the three markets in Africa is observed in interest rate, trade balance and GDP. Indeed, the common response leads to an increase in the volatility of the African markets. This result confirms the hypothesis that exchange rate prices are in some proportion driven by macroeconomics news (Belgacem and Lahiani, 2012).

Moreover, the results indicate that the volatility transmission from UK and China is significant. The volatility spillover effects from the two markets highlight an important integration between the UK, China and African markets. The volatility spillover effect supports the existing finding regarding spillover mechanisms of macroeconomic variables and the asymmetric unexpected effects of consumer price index on currency returns (Wang, 2010; Cheong *et al.*, 2011; Malik and Ewing, 2009).

However, the results of regional volatility transmission indicate that volatility transmission is insignificant from the Egyptian news to the Nigerian market. The significant volatility spillover effects from South Africa macroeconomic news to Egypt and Nigerian markets highlight an important integration between these economies. Thus GDP and trade balance are crucial in this circumstance. These findings are in contrast with those of Wang (2010) that volatility transmission is high in developing economies (Table IV).

4.4 Evaluation of volatility transmission

Evaluation of the conclusions is provided by the full BEKK model described in Section 3. The estimation results of the full BEKK model are reported in Tables AI-AIII. An AR(3) and a random walk full BEKK-MGARCH(1,1) is sufficient to filter any serial correlation in the conditional mean specification. The coefficients of matrices A and B indicate the innovations in each specific market and the persistence of news. The diagnostic tests of the model based on Ljung-Box test statistic shows absence of serial correlation as there is no evidence of multivariate serial correlation in the standardized and squared standardized residuals. All a_{11} a_{22} and b_{11}, b_{22} estimated coefficients are highly significant implying that past shock and volatility, respectively truly explain current conditions of shocks as well as volatility. However volatility and shock spillover coefficients (b_{21}, b_{12}, a_{12} and a_{21}) are insignificant except volatility from rand to naira which is significant at 5 percent level. This evidence reveals a weak regional volatility transmission effects. The unidirectional volatility spillover may come from marginal trade relation between Nigeria and South Africa. The results share with Glick and Rose (1999) conclusions that strong trade ties is an important factor in volatility spillover and high among economies with strong trade ties. The implication is that Nigerian policy makers should strictly watch economic activities in South Africa.

External volatility spillover effects from UK and China are presented in Tables AII and AIII. A close look at the cross-volatility transmission (b_{21}, b_{12}, a_{12} and a_{21}) shows that they are highly significant and that their values clearly indicate the existence of dependence. There is strong evidence of shock and volatility spillover effects from UK and China to foreign exchange market in Africa. The significant external mean and volatility spillover effects signify meteor shower hypothesis existence. Thus, a shock in UK or China surely is followed by one in Africa. Thus what happens in the UK or Chinese economy will have subsequent effects on African economies. These findings converge with those of Kitamura (2010), Perez-Rodriguez (2006) and McMillan and Speight (2010). The sensitivity test results confirms earlier findings

Variables	EGP	SE	SAR	SE	Nnaira	SE
Mean equation						
Constant	0.183**	(0.005)	0.924**	(0.019)	0.1037**	(0.035)
Egp(1)	0.470**	(0.042)	−0.046	(0.26)	0.026	(0.151)
Sar(1)	−0.247	(0.294)	0.032*	(0.017)	0.0832**	(0.0404)
Nnaira(1)	0.103	(0.106)	0.1136*	(0.034)	0.1540**	(0.0317)
Variance equation						
Constant	0.925**	(0.019)	0.9712**	(0.0492)	0.091**	(0.122)
ε^2_{t-1}	0.261**	(0.042)	0.204**	(0.024)	0.112**	(0.034)
h_{t-1}	0.245**	(0.036)	0.295*	(0.032)	0.154**	(0.032)
Direct effects						
GDP[a]	0.834**	(0.048)	0.221**	(0.027)	0.0111**	(0.0034)
GDP[b]	0.460**	(0.067)	0.244**	(0.023)	0.068	(0.049)
GDP[c]	0.345**	(0.038)	0.305**	(0.028)	0.7996**	(0.0576)
Trade balance[a]	0.084	(0.004)	0.080**	(0.013)	0.5985**	(0.056)
Trade balance[b]	0.025	(0.023)	0.098	(0.136)	0.0065	(0.0041)
Trade balance[c]	0.050	(0.073)	0.083	(0.277)	0.0418	(0.0510)
CPI[a]	0.035	(0.032)	0.032	(0.082)	0.3981**	(0.0558)
CPI[b]	0.134**	(0.011)	0.078	(0.182)	0.0113*	(0.0042)
CPI[c]	0.120	(0.012)	0.295**	(0.114)	0.3981**	(0.0558)
Indirect effects						
GDP[a]	0.071**	(0.031)	0.0149**	(0.0046)	0.0375**	(0.0049)
GDP[b]	0.132**	(0.012)	0.292	(0.199)	0.239	(0.109)
GDP[c]	0.040	(0.150)	0.036*	(0.021)	0.4819**	(0.0527)
Trade balance[a]	0.012	(0.051)	0.312**	(0.028)	0.1168*	(0.0542)
Trade balance[b]	0.025	(0.016)	0.1337	(0.0580)	0.026	(0.020)
Trade balance[c]	0.055	(0.136)	0.102**	(0.017)	0.7433**	(0.0603)
CPI[a]	0.059**	(0.028)	0.084**	(0.023)	0.0155**	(0.0051)
CPI[b]	0.3981**	(0.0558)	0.014	(0.020)	0.0550	(0.1360)
CPI[c]	−0.014	(0.023)	0.038	(0.040)	0.0590*	(0.0280)
DCC equation						
a	0.053	[3.735]				
b	0.827	[124.84]				
Log likelihood	2,192.263					
Q(8)	51.62	{0.43}				

Notes: () denotes standard errors, [] is *t*-value, and {} is *p*-value. [a]South Africa; [b]Egypt; [c]Nigeria. *,**Significant at 5 and 1 percent levels, respectively

Table IV. Estimation results of augmented DCC model (DCC MGARCH (1,1))

that foreign exchange market in Africa is more prone to external volatility transmission than inter-regional volatility transmission.

The implication of the volatility transmission and spillover in the foreign exchange market is that individual economies policy and efforts to stabilize the exchange rate would be futile since the volatility comes from outside. The dependence of the African economy on the outside world means that global crisis like the European Union's crisis would put severe financial stress on African's financial market. In this case, continental currency union would be critical because exchange rate stability would be managed at one central point. Though much of the shock comes from outside, shock within the region should not be underrated in transmitting volatility. It would be policy prudence to the global world to monitor African economies like South Africa since they are potential elements in volatility transmission.

5. Conclusion

This paper investigates the volatility transmission in the foreign exchange market using an augmented DCC model framework. The DCC model was estimated first followed by augmented version to allow for inclusion of macroeconomic factors. In addition, evaluation of the results was done with full BEKK.

The results show that volatility transmission in Africa follows meteor shower hypothesis and volatility spillover effect is strong from China and UK to African market. Regional volatility transmission and spillover seems not to be strong. However, it is only between the rand and the naira that signals volatility transmission and spillover. This result contrasts international evidence presented by Cockerell and Shoory (2012) and Glick and Rose (1999). It also finds both China and UK macroeconomic news to positively impact volatility transmission, especially GDP and trade balance. The findings show that the foreign exchange market in Africa has some significant dependence on the UK and Chinese macroeconomic variables.

On the policy implication, the fact that volatility transmission and spillover is marginal regionally, to some extent, should be of high relevance to policy makers, traders, investors and regulatory authorities. For policy makers and regulatory authorities, the paper has the following policy recommendations: first, high degree of trade openness does not only increase the foreign exchange co-movement, but it also increases currency risk exposure; the regulatory authority should introduce guidelines that enable investors to have a considerable level of currency stability. Considerable trade openness is needed because too much or too little trade openness will negatively affect investors and traders behavior and stability (Milesi-Ferretti and Tille, 2010).

Second, since macroeconomic announcements have direct and indirect impacts on asset prices. Global shock such as changes in trade balance has been found to play a significant role in volatility transmission, exchange rate co-movement and accelerating currency risk. Thus, regulatory initiative that allows investors to reduce currency risk exposure significantly for risk management purposes must be pursued. For investors, mechanisms should be put in place to measure the direct and immediate impact of news release and also be aware of the risk of transmission of volatility to other markets. Availing themselves of the investment opportunities and hedging against the risk of contagion are of great importance for the actors in the region, especially in the foreign exchange market.

Finally, the findings of this paper show that volatility transmission and spillover in Africa is characterized by meteor shower hypothesis, which could affect exchange rate co-movement and risk exposure. Therefore, regulatory, supervisory and monetary authorities should co-ordinate to put in place a comprehensive regulatory framework that would allow investors and traders to have a substantial amount of currency stability that is robust and consistent with any coordination policy. Currency union in the region would be prudent for exchange rate-policy coordination since management would be done at one central point.

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Appendix. Sensitivity test

Parameter	Egypt-South Africa	Nigeria-Egypt	Nigeria-South Africa
A		*Mean equation*	
$\alpha 1$	0.00292*	5.54E−04	0.00539***
$\alpha 2$	0.00329*	0.00528***	0.00227
$\beta 11$	0.41099**	0.40944***	0.46127**
$\beta 12$	0.03737	0.10784	−0.03457*
$\beta 21$	−0.00579	−0.03489	0.04218
$\beta 22$	0.37353***	0.45989***	0.37232***
R_1^2	0.16859	0.17495	0.33194
R_2^2	0.13147	0.33927	0.12828
B	*Kenya-South Africa*	*Volatility equation*	
c11	0.00941	0.01887	0.00372***
c21	−0.00129	−0.00126	0.00088
c22	0.00970**	0.00185	0.00712***
a11	0.58935*	0.74077**	0.46978***
a12	0.08999	0.0372	0.00642
a21	−0.09999	0.04469	0.02595
a22	0.49429***	0.56657*	0.50856**
b11	0.77709***	0.52895	0.88023***
b12	−0.05301	0.21271	0.85411**
b21	0.05971	−0.09274	−0.03263
b22	0.83353***	0.83103*	0.86312***
		Diagnostic test	
LB(4)	0.3459 (0.9867)	0.4354 (0.9795)	12.5595 (0.0136)
$LB(4)^2$	2.7604 (0.5987)	55.1238 (3.06E−11)	2.6539 (0.6173)
LB(8)	8.2378 (0.4106)	6.5145 (0.5898)	9.4392 (0.6528)
$LB(8)^2$	14.377 (0.0725)	104.5798 (0.000)	14.8356 (0.0624)
		Test of volatility spillover effects	
Wald (a12 = b12 = 0)	3.9406 (0.1394)	0.2378 (0.9956)	5.6744 (0.0586)*
Wald (a21 = b21 = 0)	0.2147 (0.8982)	0.0088 (0.8879)	0.4850 (0.7846)

Notes: LB (*n*) is the Ljung-Box of innovation series at the *n*th lag. While aii and aij represents own and cross-shocks spillover; bii and bij denotes effect of own volatility and its spillover to other markets. In parenthesis is probability of accepting the null hypothesis. *,**,***Significant at 10, 5 and 1 percent levels, respectively

Table AI. Estimation of the bivariate full BEKK model for regional volatility transmission

Parameter	Kenya-UK	Ghana-UK	South Africa-UK
		Mean equation	
$\alpha 1$	0.00291*	0.00563***	0.00378**
$\alpha 2$	−2.04E−04	−0.00144	−3.01E−04
$\beta 11$	0.41157**	0.45473***	0.346584***
$\beta 12$	0.11614**	0.03507	0.10692*
$\beta 21$	0.04569	0.15050*	0.14733**
$\beta 22$	0.12949*	0.12685*	0.09012
R_1^2	0.17712	0.33468	0.13411
R_2^2	0.02959	0.03439	0.0501
		Volatility equation	
c11	0.00655***	0.00329	0.00738***
c12	0.01741***	0.00107	−0.01104**
c21	−0.00251	0.01135	0.02343***
a11	0.56889***	0.40128***	−0.00149
a12	−0.12129*	−0.12491	−0.05277**
a21	0.03636	0.11246	0.05407***
a22	0.33443***	0.35851	0.06256*
b11	0.82698***	0.87071***	0.96982***
b12	−0.17049***	0.107065*	0.00035**
b21	0.00481	−0.03868	−0.00155***
b22	0.66719***	0.83182*	0.97007***
		Diagnostic test	
LM(4)	0.3915 (0.9832)	3.6711 (0.4523)	1.2841 (0.8641)
$LM(4)^2$	41.9429 (1.71E−08)	17.527 (0.0015)	2.2674 (0.6885)
LM(8)	7.2016 (0.5150)	13.0969 (0.1086)	8.8712 (0.3533)
$LM(8)^2$	19.1213 (0.0142)	19.4101 (0.0128)	18.2345 (0.0195)
		Test of volatility spillover effects	
Wald (a12 = b12 = 0)	0.1551 (0.9423)	0.1227 (0.9405)	2.74E + 04 (0.000)***
Wald (a21 = b21 = 0)	3.7277 (0.1551)	1.55E + 05 (0.000)***	456.6793 (0.000)***

Notes: The LB(*n*) is Ljung-Box innovation series at the *n*th lag length. While aii and aij represent the own and spillover shocks bii and bij denote volatility effect of own variance and volatility transmission. In parenthesis is the probability of accepting the null hypothesis. *,**,***Significant at 10, 5, and 1 percent levels, respectively

Table AII. Estimation of the bivariate full BEKK model for the UK volatility transmission

Parameter	Egypt-China	Nigeria-China	South Africa-China
		Mean equation	
$\alpha 1$	0.0471*	0.00356***	0.00728**
$\alpha 2$	−4.24E−04	−0.00164	−4.31E−04
$\beta 11$	0.3428**	0.5734***	0.6587***
$\beta 12$	0.32454**	0.05237	0.1699*
$\beta 21$	0.08765	0.1550*	0.1763**
$\beta 22$	0.21767*	0.2653*	0.06017
R_1^2	0.2568	0.3464	0.2641
R_2^2	0.0633	0.0749	0.0608
		Volatility equation	
c11	0.00357***	0.00392	0.00873***
c12	0.01821***	0.00306	−0.01045**
c21	−0.00534	0.02237	0.07345***
a11	0.5679***	0.6128***	−0.00193
a12	−0.1490*	−0.1495	−0.07275**
a21	0.05356	0.2412	0.04075***
a22	0.3476***	0.3854*	0.2569*
b11	0.7897***	0.7907***	0.9885***
b12	−0.1909***	0.1746*	0.00054**
b21	0.00758	−0.08367	−0.00167***
b22	0.2289***	0.1884*	0.7009***
		Diagnostic test	
LM(4)	0.4675 (0.8931)	2.7632 (0.5543)	1.804 (0.6481)
$LM(4)^2$	63.74 (1.51E−05)	19.547 (0.0072)	16.678 (0.8895)
LM(8)	6.7650 (0.6145)	9.065 (0.3068)	8.717 (0.5374)
$LM(8)^2$	17.384 (0.0864)	18.6501 (0.0173)	19.349 (0.0157)
		Test of volatility spillover effects	
Wald (a12 = b12 = 0)	0.5645 (0.8427)	0.1987 (0.9503)	3.64E + 05 (0.000)***
Wald (a21 = b21 = 0)	4.279 (0.2578)	1.54E + 05 (0.000)***	6.6795 (0.000)***

Notes: The LB(*n*) is Ljung-Box innovation series at the *n*th lag length. While aii and aij represent the own and spillover shocks bii and bij denote volatility effect of own variance and volatility transmission. In parenthesis is the probability of accepting the null hypothesis. *,**,***Significant at 10, 5, and 1 percent levels, respectively

Table AIII. Estimation of the bivariate full BEKK model for the China volatility transmission

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