Received 21 June 2021
Revised 18 August 2021
Accepted 29 August 2021

How does sovereign bond volatility interact between African countries?

Kalu O. Emenike
Department of Accounting and Finance, University of Eswatini, Kwaluseni, Kingdom of Eswatini

Abstract

The importance of sovereign bond as a source of financing revenue deficit, benchmarking for corporate bonds and debt management in Africa, calls for continual monitoring of its volatility dynamics. This study evaluates the nature of sovereign bond volatility interaction between African countries using bivariate BEKK-GARCH (1, 1) model. Based on a sample of eight African countries, the results show evidence of unidirectional volatility spillover from Morocco sovereign bond to Egypt sovereign bond. Next, the results show absence of volatility interaction between Ghana and Nigeria sovereign bonds. The results further show the existence of bidirectional volatility transmission between Uganda and Kenya. Finally, the results indicate evidence of bidirectional volatility interaction between Botswana and South Africa. Overall, the results show existence of full interaction between Uganda–Kenya and Botswana–South Africa sovereign bond returns, partial interaction between Egypt and Morocco sovereign bond returns and no interaction between Ghana and Nigeria sovereign bonds markets. Thus, these results provide valuable implications for sovereign and corporate credit risk management, as well as strategy for monitoring and minimising negative effect of sovereign bond volatility spillover in Africa.

Keywords Sovereign bond, Credit risk, Volatility interaction, African countries, BEKK-GARCH model

Paper type Research paper

1. Introduction

The importance of sovereign bond as source of financing revenue deficit, benchmarking for corporate bonds and debt management in African countries, calls for continual monitoring of its volatility dynamics. Sovereign bond offers an alternative source for financing infrastructure projects, social programs or other spending measures when tax revenue is not sufficient. Second, sovereign bonds represent benchmark securities for corporate bonds (Dittmar and Yuan, 2008; Arteta and Hale, 2008). Hence, a robust sovereign bond market provides the corporate sector with a reasonable basis for bond valuation and pricing. More so, active sovereign bond market expands international market access for firms thereby act as a catalyst for development of the country's corporate bond market. In addition to benchmarking and bond market development, sovereign bond can be issued to refinance

JEL Classification — F34, G12, H63, O57

The author would like to acknowledge the constructive comments received from reviewers, which helped to improve the paper.

Availability of data and material: The datasets analysed during the current study are available in the Standard & Poor database: https://www.spglobal.com.

Funding: No funding was received.

Journal of Derivatives and Quantitative Studies: 선물연구
Vol. 30 No. 4, 2022
pp. 246-259
Emerald Publishing Limited
e-ISSN: 2713-6647
p-ISSN: 1229-988X
DOI 10.1108/JDQS-06-2021-0015

older debts that may be maturing or to cover interest payments coming due including debt restructuring (Fabella and Madhur, 2003; Vellos, 2015). These numerous benefits of sovereign bond make it an attractive source of funding to propel economic growth and transformation, especially in the context of Africa where the need for funding for infrastructure and market development is dire.

Indeed in recent years, especially after the global financial crisis [1], African countries have made extensive use of the sovereign bond market to raise funds. At the end of 2011, bond issuance totalled $1 billion and by the end of 2014, it amounted to $6.2 billion. Africa had been ranked the fastest growing region for sovereign ratings over the last decade and a half (Vellos, 2015; Tafirenyika, 2015; World Bank, 2015). In 2016, S&P Global Ratings rated 17 sovereigns in sub-Saharan Africa, up from 12 ratings in 2008 and two ratings in 2000. Steady global market conditions and the potential for higher returns for investors have helped pave the way for more access to international markets, where the average return for these bond issuances is about 6.6%, with an average maturity of 10 years. Between 2013 and 2014, a total of 11 African countries accessed the sovereign bond market. By 2017, 21 African countries had outstanding foreign currency-denominated sovereign debt totalling $115bn, and this trend has accelerated since 2017 (Allen, 2018; Gross, 2020). Recent report from Fitch Ratings (2020) forecasts the median government debt/GDP ratio for 19 Fitch-rated Sub-Saharan Africa sovereigns to reach 71% at end-2020, from 57% at end-2019 and 26% in 2012. These statistics on fast-growing government debt burdens of African countries coupled with the global shock arising coronavirus pandemic have heightened currency risks, roll-over risks and greater macroeconomic volatility occasioned by sovereign bond (Velde, 2014).

Thus, the macroeconomic volatility resulting from sovereign bonds volatility could exacerbate uncertainty in the regional financial system; suppress vibrancy in domestic corporate bond pricing and significantly affect deficit financing. These outcomes contrast with the presumption that access to international bond markets should propel growth and transformation in developing countries (Kletzer, 2005; Arteta and Hale, 2008). More so, the presence of sovereign bond volatility has important implications for credit risk management and credit rating which can trigger sudden capital flow reversals and raise financial stability concerns (Lane, 2012; Zinna, 2014; Kirikkaleli and Gokmenoglu, 2020). Understanding the nature of sovereign bond volatility linkages among African countries therefore, is vital for credit risk management and for devising volatility containment policies in the continent. It could also provide guidance on valuation and pricing of corporate bond in the domestic markets as well enhance precision in Africa credit rating. These will in turn sustain the market for long-term financing, which is required to decimate infrastructure deficit in Africa as well boost financial market development.

Although numerous empirical studies using African data have investigated volatility linkages between international capital markets, majority of them concentrated on volatility spillover between international equity markets (see for example, Collins and Biekpe, 2003; Agyei-Ampomah, 2011; Boako and Alagidede, 2017; Panda *et al.*, 2019). These studies documented important evidence on shocks and volatility spillover among Africa and global equity markets as well as provide basis for risk hedging and portfolio diversification. This is not the case for sovereign bond volatility interaction in the African context. Hence, our understanding of sovereign bonds volatility interaction between African countries is still vague as a result of scant evidence. The few literature that dwell on Africa sovereign bond concentrated on investor herding in African debt markets as a result of high yield as well as debt risk reduction (see for example, Morsy and Moustafa, 2020; Griffiths *et al.*, 2020). There is therefore need to understand how sovereign bond volatility shocks are transmitted among African countries.

The purpose of this paper therefore was to analyse sovereign bond volatility interaction between African countries using bivariate BEKK-GARCH (1, 1) model. The findings from this study are vital for sovereign debt management by Africa debt management authorities who could formulate appropriate rescue policies to minimise anticipated macroeconomic instability resulting from sovereign bond volatility spillover. Similarly, investors could benefit through devising apt credit risk management strategy in response to expected changes in the sovereign bond environment. The study also expands existing knowledge on non-linear sovereign bond linkages between African countries.

Following the introduction is section two which discusses some characteristics of Africa sovereign bond and provides literature review. Section three focuses on econometric methodology and descriptive statistics. Section four interprets and discusses the empirical results, and section five is the conclusion.

2. Literature review

A considerable volume of the literature has concentrated on sovereign bond volatility spillover across international financial market but majority of them were motivated by financial liberalisation and financial crisis, especially the Eurozone crisis. In this section, we review some of the related literature in order to motivate our study. The first strand of the literature focuses on theoretical postulates in relation to empirical realities in Africa sovereign bonds. Theoretically, international capital inflows should permit developing countries to minimise the variability of private and public consumption in the presence of income volatility as well as enable foreign savings to finance domestic capital accumulation. Access to international financial markets should provide opportunities for the domestic private sector and government to diversify against aggregate country-specific income risk (Kletzer, 2005). In reality, however, international capital flows to emerging markets are themselves volatile and sometimes propagate external shocks to domestic consumption and investment or exacerbate domestic shocks. Velde (2014) outlined that sovereign bonds carry considerable risks for African countries, including currency risks, roll-over risks and greater macroeconomic volatility, especially when the proceeds are not used to plug economic and social infrastructure gaps as planned and manage macroeconomic conditions to reduce currency risks. Morsy and Moustafa (2020) reported amongst others that mispricing of Africa's sovereign risk is mainly due to discriminatory behaviour by international investors rather than to differences in the quality of macroeconomic fundamentals between Africa and non-Africa regions. Given the worsening debt sustainability and the possibility of a widespread debt crisis because of the COVID-19 pandemic, Griffiths *et al.* (2020) recommended amongst other options that multilateral institutions should accept the currency risks in sovereign bonds in order to reduce low-income country debt risk. The existence of sovereign bond risk is therefore not in doubt.

The second strand of the literature analyses the role of sovereign bond as benchmark securities for corporate bonds. A well-functioning and stable sovereign bond market provides the corporate sector with a reasonable basis for valuation and pricing of corporate bonds. Dittmar and Yuan (2008) reported amongst other that over one-fifth of the information in corporate yield spreads is traced to innovations in sovereign bonds; and that issuance of sovereign bonds, controlling for endogeneity of market-timing decisions, lowers corporate yield and bid-ask spreads. Similarly, Arteta and Hale (2008) reported evidence of a large and statistically significant decline in foreign credit to domestic private firms as a result of sovereign debt crisis. In a related study, Zinna (2014) showed amongst others that emerging market sovereign and corporate credit spreads differ because of their specific reactions to global risks namely, risk aversion, liquidity and US corporate risk. A recent study by Kirikkaleli and Gokmenoglu (2020) documented that changes in sovereign credit risk significantly lead to changes in economic risk, indicating the importance of sovereign credit risk for predicting economic risk. It is thus easy to notice that sovereign securities act as benchmarks and promote a vibrant corporate bond market.

The last strand of the literature measured volatility of sovereign bond. Claeys and Vašíček (2012) evaluated the strength and direction of sovereign bond volatility in Europe as well as the impact of rating news on sovereign bond volatility. They reported the presence of significant spillover between the sovereign bond markets of EU countries over the whole previous decade. They also reported existence of heterogeneity in the bilateral spillover sent and received between specific sovereign bond markets, and spillover is more important than domestic factors for all EMU countries, the European Union countries affect only each other, and Denmark, Sweden and the UK are insulated from the impact of other EU countries. They further reported that the overall effect of rating news on sovereign risk premia is limited, which is consistent with the claim that most rating actions do not come as a surprise for the markets. However, that the spillover of rating news is very heterogeneous, and it is substantially stronger for downgrades at lower grades. Afonso *et al.* (2012) also reported that rating downgrades during the crisis seem to have provoked turbulence on asset markets and higher financing costs for all sovereign bonds. Azis *et al.* (2013) reported the existence of threat of financial contagion to emerging Asian bond markets through shock and volatility spillovers from developed markets. In a later study, Claeys and Vašíček (2014) indicate substantial spillover, especially between EMU countries, with Belgium, Italy and Spain being key markets during the financial crisis; and that the frequent surges in market co-movement are driven by larger shocks rather than by contagion.

A similar study by Belke *et al.* (2018) showed amongst others that sovereign bond yields in emerging Asia market responded significantly to changes to US and Eurozone bond yields, although the magnitudes were heterogeneous across countries. Vizek (2019) analysed role of individual sovereign bond markets in international sovereign bond market volatility spillovers using daily data from 19 developed and developing countries and reported amongst others that innovations to the US sovereign bond market have the biggest influence on the return and volatility variance in other sovereign bond markets across the globe. A very recent study by Tsang *et al.* (2021) reported amongst others, evidence of bidirectional bond volatility spillover between the US and the ASEAN4 which include Indonesia, Malaysia, the Philippines and Thailand and a unidirectional spillover in bond return from the US. Thus, provide support to Vizek (2019) that US sovereign bond market influence the global sovereign bond markets.

3. Methodology, data and preliminary analysis

3.1 Data, characteristics of African sovereign bonds and preliminary analysis

3.1.1 Data. The dataset for this study consists of daily returns for eight Africa sovereign bond indices, namely, Botswana, Egypt, Ghana, Kenya, Morocco, Nigeria, South Africa and Uganda from 25 November 2014 to 31 December 2019 study period. The sample therefore consists of 1,321 observations for each country's time series. The sovereign bond series were sourced from Standard & Poor (S&P) and can be accessed online from www.spglobal.com. The S&P Africa sovereign bond indices track performance of country sub-level sovereign bonds as well as Africa as a unit. This study period was chosen because the launch date for the S&P Africa sovereign bond USD index was November 25, 2014. In addition, the study period captures only the period before COVID-19 pandemic. The sovereign bond series were transformed to percentage daily return as first difference of natural logarithm of the sovereign bond indices as follows:

$$SR_{i,t} = \text{Ln}(S_{i,t}) - \text{Ln}(S_{i,t-1}) * 100 \quad (1)$$

Where, $SR_{i,t}$ is daily percentage return of Africa sovereign bond from country i at time t, $S_{i,t}$ is current day index of sovereign bond from country i at time t, $S_{i,t-1}$ is previous day index of sovereign bond from country i at time $t-1$, and Ln is natural logarithm.

3.1.2 Characteristics of African sovereign bonds. Table 1 presents some characteristics of African countries' sovereign bonds as at April 30, 2020. Modified duration is the change in the value of a sovereign bond due to a change in interest rates. Notice that the modified duration for Southern Africa countries are higher than other regions in Africa. In the case of Southern Africa for example, a 100 basis point movement in interest rates, will cause an inverse movements of 6.35 and 6.02% for South Africa and Botswana, respectively. This implies that Southern Africa sovereign bonds have greater price volatility than other parts of Africa. Morocco is the next in ranking of high modified duration. Ghana (1.84) has the least modified duration followed by Egypt (2.37). The ranking of the modified duration for Africa mimics rating of Africa sovereign bonds. While Botswana has the highest rating of 70, Ghana has the least rating of 23 as of July 20, 2020. On the number of constituents, North Africa is on the lead with Egypt and Morocco having 73 and 67 components, respectively. Southern Africa on the other hand has the least number of constituents. The weighted average maturity values show that South Africa and Nigeria have the longest average amount of time until the maturities on their sovereign bonds, but Ghana and Egypt have the shortest maturity periods. The weighted average coupon rate for Africa is 9.82%. This rate is very high when compared to Eurozone, which is 2.37%, global average rate which is 2.13%, and China composite select bond index with par weighted coupon rate of 3.81%. While Morocco has the least weighted coupon rate of 3.84 in Africa, countries like Ghana, Egypt, Uganda and Nigeria have outrageous rates of 19.26%, 15.23%, 14.16% and 13.74%, respectively. The S&P rating column provides a scale of assessment for Africa sovereign bond market. Notice that Botswana possesses the strongest capacity to meet its financial commitment on the obligation followed by Morocco, whereas the least is Ghana.

3.1.3 Descriptive statistics. The preliminary analysis involved descriptive statistics and unit roots test. The analyses were conducted to describe the statistical properties of the sovereign bonds series. Figures 1–4 show line chart for the Southern Africa, West Africa, East Africa and North Africa sovereign bond return percentage series, respectively. An eminent characteristic of these charts is the general direction in which they changing over the time period of this study. The marked negative and positive fluctuations in all the series are suggestive of volatility and mean reversion attributes. More so, the spikes in the charts reflect

Variables	Mod	No const	PWC %	WAM years	S&P rating
Botswana	6.02	07	6.77	8.9	70 (A–)
Egypt	2.37	73	15.23	3.58	30 (BB)
Ghana	1.84	45	19.26	3.39	23 (B–)
Kenya	4.09	65	12.25	8.15	33 (B)
Morocco	5.17	67	3.84	6.66	53 (BBB–)
Nigeria	4.71	20	13.74	9.96	30 (B)
South Africa	6.35	13	8.41	13.92	46 (BB)
Uganda	3.07	27	14.16	5.75	31 (B)
Africa	4.62	642	9.82	8.52	–

Note(s): *Mod* is modified duration. *No const* is the number of constituents for market bond, and *PWC* is the par weighted coupon rate. WAM is the weighted average maturity, and *Mkt. value* is the market value of the sovereign bonds
Source(s): S&P sovereign bond index for various countries and regions

Table 1.
Characteristics of Africa sovereign bonds

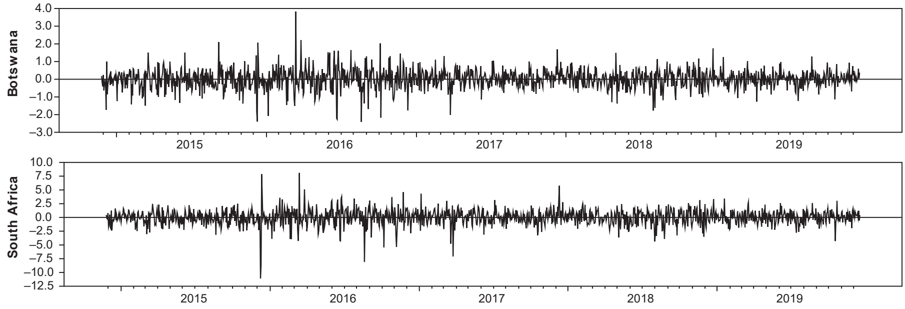

Figure 1.
Southern Africa

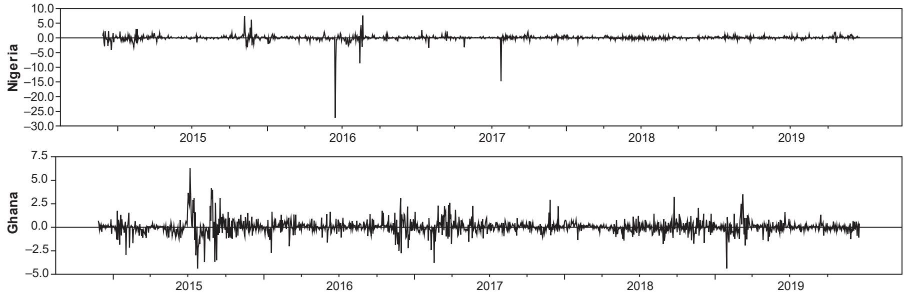

Figure 2.
West Africa

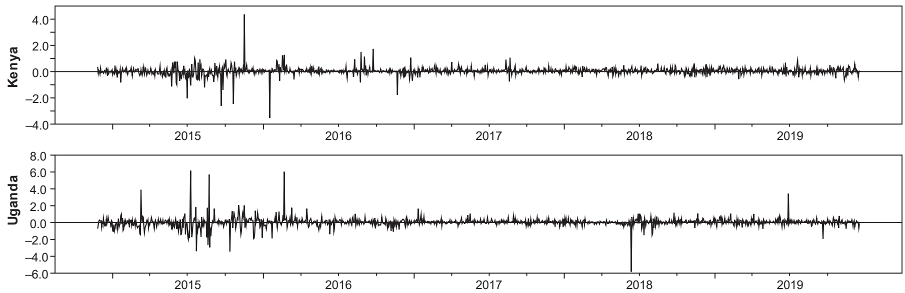

Figure 3.
East Africa

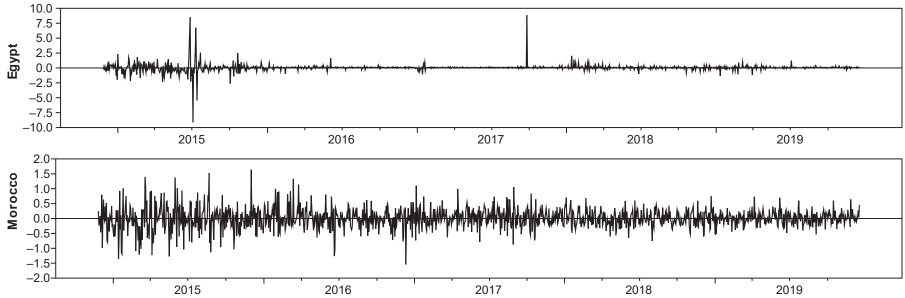

Figure 4.
North Africa

growing divergences in economic and financial fundamentals of each country as well as responses to movements in sovereign bond yields.

Table 2 provides summary statistics for Africa countries sovereign bonds percentage return series. The daily average returns for all the sovereign bonds are zero except for Kenya, Uganda and Ghana, which are significantly positive at the 5% level. The percentage daily standard deviation appears to be highest for Egypt, followed by South Africa and Nigeria. Thus sovereign bond returns from Egypt, South Africa and Nigeria exhibit high variability from expectation. Another measure of return stability is skewness. The skewness of a normal distribution is zero. A significant deviation from zero is an indication asymmetry in return distribution. Notice from Table 2 that Botswana, Kenya and Morocco are not skewed. The skewness for Egypt, Nigeria, Uganda, South Africa and Ghana, are significantly different from zero. While the sovereign bond returns for Uganda and Ghana are positively skewed, Egypt, Nigeria and South Africa are negatively skewed. Negatively skewed distribution of sovereign bonds returns is likely to deliver large negative returns and likely to be prone to less stability. The excess kurtosis values Africa countries' sovereign bonds returns are leptokurtic. In leptokurtic distributions, extreme observations are very likely to occur. The Jarque-Bera test results indicate absence of normal distribution in the West Africa stock markets returns.

3.1.4 Unit roots test for African and global sovereign bonds returns series. Table 3 displays unit roots tests estimates of the Africa sovereign bonds logarithmic level and return series. The augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) unit roots methods were applied. MacKinnon's (1991) critical values for no trend and with trend critical value were taken at the 5% level of significance to avoid the problem of accepting a false null hypothesis. Observe from the table that calculated values of the ADF test statistics are less than the theoretical critical tau value at 5% significance level, except for Morocco sovereign bond level series. This indicates that the Africa sovereign bond level series contain unit root at the 5% significance level. In other words, the Africa sovereign bond level series are not stationary, except for Morocco. Estimates from the PP tests are similar to the results from the ADF tests. Estimates from Africa sovereign bonds return series, however, indicate evidence of absence of unit root at the 5% significance level for both *no trend* and *with trend* series. The ADF and PP tests estimates hence show that Africa sovereign bonds return series are integrated of order one.

3.2 Methodology

In order to evaluate the nature of interaction between Africa sovereign bond volatility, we apply a simple methodological specification for conditional mean equation, excluding potential exogenous variables that could have an effect in the volatility of sovereign bonds for African countries being studied as follows:

Variables	Mean	Std. dev	Skewness	Kurtosis	JB stat
Botswana	0.011 (0.443)	0.558	−0.008 (0.899)	3.344 (0.000)	615 (0.000)
Egypt	−0.001 (0.963)	1.487	−19.988 (0.000)	549.194 (0.000)	1,667,673 (0.000)
Ghana	0.031 (0.144)	0.792	0.475 (0.000)	8.870 (0.000)	4,377 (0.000)
Kenya	0.038 (0.000)	0.313	−0.130 (0.052)	50.694 (0.000)	141,351 (0.000)
Morocco	0.010 (0.274)	0.346	−0.001 (0.980)	2.356 (0.000)	305 (0.000)
Nigeria	0.008 (0.785)	1.146	−11.854 (0.000)	268.00 (0.000)	398,129 (0.000)
South Africa	0.008 (0.818)	1.427	−0.601 (0.000)	6.545 (0.000)	2,435 (0.000)
Uganda	0.036 (0.021)	0.571	1.391 (0.000)	40.132 (0.000)	89,008 (0.000)

Note(s): Std. Dev. and JB Stat are the standard deviation and Jarque-Bera statistics for the Africa sovereign bonds return series. [.] and (.) are the *t*-statistic of means and *p*-value of the Jarque-Bera statistics, respectively

Table 2. Descriptive statistics for Africa sovereign bond returns

Table 3. Unit root tests results for Africa and global sovereign bonds

	Level series		Return series	
	No trend	With trend	No trend	With trend
ADF				
Botswana	−0.843	−2.806	−35.189*	−35.189*
Egypt	−1.436	−1.030	−15.418*	−15.484*
Ghana	−1.337	−3.053	−15.238*	−15.235*
Kenya	−1.619	−3.071	−34.999*	−35.156*
Morocco	−0.214	−3.717**	−36.881*	−36.912*
Nigeria	−1.207	−1.032	−31.873*	−31.929*
South Africa	−1.723	−2.916	−26.673*	−26.683*
Uganda	−0.698	−3.053	−34.756*	−34.817*
PP				
Botswana	−0.849	−2.826	−35.200*	−35.213*
Egypt	−1.438	−1.041	−26.797*	−26.829*
Ghana	−1.178	−2.386	−35.418*	−35.421*
Kenya	1.533	−3.048	−35.049*	−35.209*
Morocco	−0.199	−3.715**	−36.907*	−36.952*
Nigeria	−1.190	−1.012	−32.006*	−32.064*
South Africa	−1.756	−2.932	−33.050*	−33.066*
Uganda	0.681	−3.057	−34.758*	−34.833*

Note(s): * and ** refers to 1 and 5% statistical significance levels, respectively. ADF and PP are the augmented Dickey-Fuller and Phillips-Perron Unit root tests. MacKinnon's (1991) 1% critical values for no trend and with trend are −3.438 and −3.970, respectively

$$SR_{i,t} = \mu + \theta SR_{i,t-1} + \varepsilon_t$$
$$\varepsilon_t = \mathrm{H}_t^{1/2} I_{t-1} \tag{2}$$

where $SR_{i,t}$ is the vector of sovereign bond returns for African countries, μ is the vector of parameters that estimate the mean of the sovereign bond returns, θ is the vector of autoregressive terms that contain serial correlation in the return series, and ε_t is the vector of residuals with a conditional covariance matrix H_t given the available information set I_{t-1}.

We employ the unrestricted bivariate BEKK-MGARCH model of Engle and Kroner (1995), to specify the conditional variance-covariance equations. One of the major advantages of BEKK model is that it allows interactions between conditional variances and covariances of two or more time series (Emenike, 2018). Another advantage is that the conditional variance-covariance matrix is positive definite by construction. The BEKK model could be specified thus:

$$H_t = CC` + A\varepsilon_{t-1}\varepsilon`_{t-1}A` + B` H_{t-1}B \tag{3}$$

where H_t is the conditional variance matrix. C, A and B are parameter matrices. C is a 2×2 lower triangular matrix with three parameters, A is 2×2 square matrix that shows how conditional variances correlate with past squared errors, and B is 2×2 square matrix that measures the effect of past conditional variances on the current conditional variances and the degree of persistence in the volatility of the markets. The parameter matrices from Eq. (3) can be represented as follows:

$$\begin{bmatrix} h_{11,t} & h_{12,t} \\ . & h_{22,t} \end{bmatrix} = \begin{bmatrix} c_{11}^0 & c_{12}^0 \\ 0 & c_{22}^0 \end{bmatrix}' + \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{21}^* & a_{f22}^* \end{bmatrix}' \begin{bmatrix} \varepsilon_{11,t-1}^2 & \varepsilon_{11,t-1}\varepsilon_{22,t-1} \\ \varepsilon_{11,t-1}\varepsilon_{22,t-1} & \varepsilon_{22,t-1}^2 \end{bmatrix} \begin{bmatrix} a_{11}^* & a_{12}^* \\ a_{f22}^* & a_{22}^* \end{bmatrix} + \begin{bmatrix} b_{11}^* & b_{12}^* \\ b_{21}^* & b_{22}^* \end{bmatrix}' \begin{bmatrix} h_{11,t-1} & h_{12,t-1} \\ h_{21,t-1} & h_{22,t-1} \end{bmatrix}' \begin{bmatrix} b_{11}^* & b_{12}^* \\ b_{22}^* & b_{22}^* \end{bmatrix} \quad (4)$$

Where C, A and B are matrices of parameters with appropriate dimensions, with the diagonal elements of the three parameters matrices being restricted to be positive (Katsiampa *et al.*, 2019). Thus, $h_{11,t}$ denotes the conditional variance of sovereign bond for country i, $h_{12,t}$ is the covariance of sovereign bonds of countries i and j, and $h_{22,t}$ is the conditional variance of sovereign bond of country j. Statistical significance of the diagonal elements $a_{11,t}$ ($a_{22,t}$) would suggest that the current conditional variance of $h_{11,t}$ ($h_{22,t}$) is correlated with its own past squared errors, whereas significance of the lagged variance $b_{11,t}$ ($b_{22,t}$) indicate that the current conditional variance of $h_{11,t}$ ($h_{22,t}$) is affected by its own past conditional variance. Similarly, the statistical significance of the off-diagonal coefficients $a_{12,t}$ and $b_{12,t}$ will indicate evidence of shock and volatility interaction effects from the sovereign bond volatility of country i to the sovereign bond volatility in country j, whereas the statistical significance of the off-diagonal coefficients $a_{21,t}$ and $b_{21,t}$ will show evidence of sovereign bond volatility interaction effects from country j to country i (Emenike, 2021).

The matrix multiplication leads to eqs. (5) and (6) where $h_{11,t+1}$, and $h_{22,t+1}$ are conditional volatilities of sovereign bonds of country i and j respectively, $h_{12,t}$ is the conditional covariance, $\varepsilon_{11,t}^2$, $\varepsilon_{22,t}^2$ and $\varepsilon_{11,t}\varepsilon_{22,t}$ are the lagged own squared and cross-country random shocks.

$$h_{11,t+1} = c_{11}^2 + a_{11}^2\varepsilon_{11,t}^2 + 2a_{11}a_{12}\varepsilon_{11,t}\varepsilon_{22,t} + a_{21}^2\varepsilon_{22,t}^2 + b_{11}^2h_{11,t}^2 + 2b_{11}b_{12}h_{12,t} + b_{21}^2h_{22,t} \quad (5)$$

$$h_{22,t+1} = c_{12}^2 + c_{22}^2 + a_{12}^2\varepsilon_{11,t}^2 + 2a_{12}a_{22}\varepsilon_{11,t}\varepsilon_{22,t} + a_{22}^2\varepsilon_{22,t}^2 + b_{12}^2h_{11,t}^2 + 2b_{12}b_{22}h_{12,t} + b_{22}^2h_{22,t} \quad (6)$$

Eqs. (5) and (6) depict how sovereign bonds shock and volatility spillover among African countries. The maximum likelihood estimates of the parameters in bivariate BEKK-MGARCH model were obtained using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) algorithm. The likelihood element for an n-vector at time t can be estimated as follows:

$$\mathrm{L}(\theta) = -\frac{n}{2}\log 2\pi - \frac{1}{2}\log|\Sigma_t| - \frac{1}{2}\varepsilon'_{\mathrm{t}}\Sigma_t^{-1}\varepsilon_{\mathrm{t}} \quad (7)$$

where θ is the parameter vector to be estimated, Σ is the covariance matrix and ε is the vector of deviations from the means of the components.

4. Results of bivariate Africa sovereign bonds volatility spillover

Table 4 presents results of four bivariate BEKK-GARCH-(1,1) models estimated to analyse the direction and strength of sovereign bond volatility interaction between African countries. The models were estimated in regional pair as follows: Egypt–Morocco, Ghana–Nigeria, Uganda–Kenya and Botswana–South Africa. Notice from Table 4 that all the diagonal parameters are statistically significant, except for Morocco GARCH effect. In the Egypt–Morocco model for example, A_{11} captures Egypt sovereign bond's ARCH effects, while $A_{2,2}$

	Egypt/Morocco	Ghana/Nigeria	Uganda/Kenya	Botswana/South Africa
Panel A: Model estimates				
$C_{(1,1)}$	0.057 (0.139)	0.935 (0.000)	0.050 (0.059)	0.031 (0.041)
$C_{(2,1)}$	0.291 (0.051)	−0.025 (0.216)	−0.051 (0.000)	0.545 (0.000)
$C_{(2,2)}$	−0.000 (0.999)	0.143 (0.000)	−0.000 (0.999)	−0.086 (0.347)
$A_{(1,1)}$	1.296 (0.000)	0.414 (0.000)	0.454 (0.000)	−0.215 (0.000)
$A_{(1,2)}$	−0.020 (0.346)	0.018 (0.310)	0.033 (0.044)	−1.661 (0.000)
$A_{(2,1)}$	2.850 (0.000)	−0.021 (0.724)	−0.465 (0.000)	0.079 (0.000)
$A_{(2,2)}$	−0.009 (0.806)	0.511 (0.000)	0.104 (0.000)	0.738 (0.000)
$B_{(1,1)}$	0.407 (0.000)	0.485 (0.000)	0.506 (0.000)	−1.117 (0.000)
$B_{(1,2)}$	−0.003 (0.887)	0.009 (0.739)	−0.437 (0.000)	−3.324 (0.000)
$B_{(2,1)}$	0.016 (0.906)	0.041 (0.346)	1.223 (0.000)	0.058 (0.031)
$B_{(2,2)}$	0.564 (0.358)	0.863 (0.000)	0.670 (0.000)	0.611 (0.000)
Panel B: Wald test for volatility spillover				
1 → 2	1.10 (0.576)	0.90 (0.637)	1235.8 (0.000)	774.08 (0.000)
2 → 1	1033.51 (0.000)	4.43 (0.108)	1402.3 (0.000)	80.81 (0.000)
Panel C: Post estimation diagnostic tests				
MvLM (10)	19.11 (0.038)	0.70 (0.994)	0.17 (1.000)	2.32 (0.993)
MvQ (10)	1.36 (0.999)	0.03 (0.999)	0.45 (1.000)	20.22 (0.072)

Note(s): → indicates direction of volatility spillover. MvLM and MvQ are multivariate ARCH-LM and Ljung–Box *Q*-statistic for null hypotheses of no ARCH effect and no autocorrelation in multivariate GARCH model squared residuals and residuals, respectively. Lag lengths are displayed as (.)

Table 4. Results of bivariate BEKK-GARCH model for African countries

captures Morocco sovereign bond's ARCH effect. Significance of the diagonal parameters (A_{11}, $A_{2,2,}$ $B_{1,1}$ and $B_{2,2}$) thus indicate that each Africa country's sovereign bond past shock and volatility affect their current sovereign bond return volatility.

As defined in section 3.2, the off-diagonal elements of matrices A and B capture the shock and volatility interaction between Africa countries sovereign bonds. Notice from the off-diagonal elements of matrix A that a unidirectional shock spillover exists from Morocco sovereign bond to Egypt sovereign bond, but the response of Egypt sovereign bond to Morocco sovereign bond is not significant. The estimates from the off-diagonal elements of matrix B is however not significant for both of the North African countries. Estimates from the Ghana–Nigeria off-diagonal parameters of matrix A and B illustrate absence of any interaction between the sovereign bonds of the two West African countries. This is evidenced by insignificance of the A and B coefficient at conventional levels. Further, it can be seen from Table 4 that a bidirectional sovereign bonds interaction exist between Ugandan and Kenyan at the 5 and 1% significance level, respectively. It thus appears that shocks from Kenyan sovereign bond are stronger than those from Uganda. In the same vein, estimates from off-diagonal elements of matrix B suggest the existence of bidirectional volatility interaction between sovereign bonds of the two East African countries. Again, the magnitude of the effect is stronger in Kenya. The estimates from the Southern African region suggest existence of bidirectional shock and volatility interaction. This can be observed from significance of the off-diagonal elements of matrix A for Botswana and South Africa sovereign bonds at the 1% level. Similarly, the off-diagonal elements of matrix B are also significant at the 1 and 5% levels for Botswana and South Africa, respectively. The magnitude of shock and volatility spillover from Botswana appears stronger than those from South Africa, even though the latter is a dominant force in African financial markets. A possible but not empirical explanation of this finding might be the effect of sovereign bond rating. Botswana sovereign bond is the only upper-medium investment sovereign bond in Africa, whereas South Africa sovereign bond is rated as speculative grade. Similarly, Morocco sovereign bond hovers around lower-medium investment grade whereas Egypt sovereign bond is rated as highly speculative grade. It is thus possible that sovereign bond rating influences the direction and strength of sovereign bond volatility. A major implication of this finding is for African countries to devise strategies for increasing sovereign bond rating. One of such strategies could be to implement tenable fiscal adjustment plan that minimises liquidity pressure. This strategy will not only arrest deterioration in fiscal strength but will also stabilise government debt at lower levels.

Following Emenike (2021), Wald test was computed to evaluate consistency of estimates from BEKK-GARCH-(1,1) model. The null hypotheses of the Wald test for regional pairs of Africa countries sovereign bonds are: $A_{I,J} = B_{I,J} = 0$, indicates that absence of volatility interaction from sovereign bond of country I to sovereign bond of country J. conversely, $A_{J,I} = B_{J,I} = 0$, suggests that there is no volatility interaction sovereign bond of country J to sovereign bond of I. Rejection of one of the null hypothesis, would indicate evidence of unidirectional volatility interaction between countries I and J sovereign bonds. Similarly, rejection of both null hypotheses would indicate existence of bidirectional volatility interaction between countries I and J sovereign bonds. As can be seen from *Panel B* of Table 4, estimates from the Wald tests indicate evidence of unidirectional volatility spillover from Morocco sovereign bond to Egypt sovereign bond but volatility spillover from Egypt to Morocco sovereign bonds is not significant. In agreement with BEKK estimates, the Wald test estimates for Ghana and Nigeria sovereign bonds show absence of volatility interaction. It thus appears that the West Africa sovereign bond markets are segmented. The Wald tests estimates for East Africa and Southern Africa countries show evidence of bidirectional volatility interaction at the 1% significance level. These Wald tests results are consistent with the estimates from BEKK-GARCH-(1,1) model. The results suggest existence of full interaction between Uganda–Kenya and Botswana–South Africa sovereign bonds markets, partial interaction between Egypt and Morocco sovereign bond markets and no interaction between Ghana and Nigeria sovereign bonds markets. It seems possible that the regions with full integration have achieved higher levels of economic and financial integration than the regions with no interaction. This explanation is in line with Favero and Missale (2012), who opine that idiosyncratic shocks to a sovereign bond market have stronger spillover to markets when their mutual fundamental linkages are stronger. While the Southern Africa region, for example, has a functional common monetary area that links many countries in the region, West Africa is still struggling with the process of establishing one.

Multivariate ARCH-LM and multivariate Ljung–Box Q statistics were estimated to analyse adequacy of the BEKK-GARCH (1,1) model fitted to the Africa countries' sovereign bonds' squared residual and residual series, respectively. As can be seen from *Panel C* of Table 4, there is absence of heteroscedasticity and serial correlation in the squared standardised residuals and standardised residuals of the multivariate BEKK-GARCH model. Hence, the BEKK-GARCH (1,1) model is adequate to explain volatility transmission Africa sovereign bonds.

5. Conclusions

This study sets out to determine the nature of sovereign bond volatility interaction between African countries using daily sovereign bond indices from eight African countries: namely, Botswana, Egypt, Ghana, Kenya, Morocco, Nigeria, South Africa and Uganda. Analyses of some characteristics of African countries' sovereign bonds show that Southern Africa sovereign bonds have greater price volatility than other parts of Africa, and that Africa's weighted average coupon rate is outrageously high in relation to Eurozone, China and the global rates.

The summary statistics for Africa countries sovereign bonds show that daily average returns for all the sovereign bonds are zero except for Kenya, Uganda and Ghana, which are significantly positive. The percentage daily standard deviation appears to be highest for Egypt, followed by South Africa and Nigeria. Botswana, Kenya and Morocco sovereign bonds returns are not skewed, whereas Uganda and Ghana are positively skewed, but Egypt, Nigeria and South Africa are negatively skewed. The excess kurtosis values for all Africa countries' sovereign bonds returns are leptokurtic and non-normal.

The results from the diagonal parameter of BEKK-GARCH-(1,1) models estimated to analyse the direction and strength of sovereign bond volatility interaction between African countries show that each Africa country's sovereign bond market volatility is more determined by her own respective shocks and volatilities. Results from the off-diagonal parameters indicate evidence of a unidirectional shock transmission from Morocco sovereign bond to Egypt sovereign bond. Estimates from Ghana and Nigeria show absence of any volatility interaction between the sovereign bonds of the two West African countries. However, results from Ugandan and Kenyan indicate existence of bidirectional sovereign bonds shock and volatility interaction, but magnitude of the shock and volatility is stronger from Kenya. The estimates from Botswana and South Africa also indicate evidence of bidirectional sovereign bonds shock and volatility interaction, although the magnitude of shock and volatility spillover from Botswana appears stronger than those from South Africa. The results seem to suggest that countries with higher sovereign bond rating have stronger force in transmitting shocks and volatility in Africa, and that the countries within stronger integrated region, have stronger volatility interaction than countries within weaker integrated region.

Overall, this study strengthens the need for African countries to implement tenable fiscal adjustment policies that can minimise liquidity pressure in order to arrest deterioration in fiscal strength. There is equally need to maintain financial stability through monitoring of both national and regional monetary policies, especially for the integrated markets.

Note

1. The global financial crisis of 2007–2009 is arguably the first truly major global crisis since the Great Depression of 1929–1932 (Bekaert *et al.*, 2014). South Africa led the way for such borrowing in 1995, but since the global financial crisis in 2008, sovereign bond issuance has surged from many African countries. In 2013, the largest sovereign bond issuance shares were made by Gabon ($1.5 billion), Ghana ($1 billion) and Mozambique ($0.9 billion). In 2014, the largest issuances were made by Kenya ($2 billion), Ethiopia, Ghana and Zambia – all three at $1 billion each.

References

Afonso, A., FurceriI, D. and Gomes, P. (2012), "Sovereign credit ratings and financial markets linkages: application to European data", *Journal of International Money and Finance*, Vol. 31 No. 3, pp. 606-638, doi: 10.1016/j.jimonfin.2012.01.016.

Agyei-Ampomah, S. (2011), "Stock market integration in Africa", *Managerial Finance*, Vol. 37 No. 3, pp. 242-256, doi: 10.1108/03074351111113306.

Allen, K. (2018), "African debt markets thrive as investors hunt for yield", available at: https://www.ft.com/content/6e71b16a-17df-11e8-9e9c-25c814761640.

Arteta, C. and Hale, G. (2008), "Sovereign debt crises and credit to the private sector", *Journal of International Economics*, Vol. 74 No. 1, pp. 53-69, doi: 10.1016/j.jinteco.2007.05.008.

Azis, I.J., Mitra, S., Baluga, A. and Dime, R. (2013), "The threat of financial contagion to emerging Asia's local bond markets: spillovers from global crises", ADB Working Paper Series on Regional Economic Integration No.106, The Threat of Financial Contagion to Emerging Asia's Local Bond Markets: Spillovers from Global Crises (adb.org).

Bekaert, G., Ehrmann, M., Fratzscher and Mehl, M.A. (2014), "The global crisis and equity market contagion", *The Journal of Finance*, Vol. LXIX No. 6, pp. 2597-2649, doi: 10.1111/jofi.12203.

Belke, A., Dubova, I. and Volz, U. (2018), "Bond yield spillovers from major advanced economies to emerging Asia", *Pacific Economic Review*, Vol. 23 No. 1, pp. 109-126, doi: 10.1111/1468-0106.12256.

Boako and Alagidede, G.P. (2017), "Examining evidence of 'shift-contagion' in African stock markets: a CoVaR-copula approach", *Review of Development Finance*, Vol. 7 No. 2, pp. 142-156, doi: 10.1016/j.rdf.2017.09.00.

Claeys, P. and Vašíček, B. (2014), "Measuring bilateral spillover and testing contagion on sovereign bond markets in Europe", *Journal of Banking and Finance*, Vol. 46, pp. 151-165, doi: 10.1016/j.jbankfin.2014.05.011.

Claeys, P. and Vašíček, B. (2012), "Measuring sovereign bond volatility spillover in Europe and the impact of rating news", Research Institute of Applied Economics Working Paper 2012/19, p. 2.

Collins, D. and Biekpe, N. (2003), "Contagion and interdependence in African stock markets", *South African Journal of Economics*, Vol. 71, pp. 181-195, doi: 10.1111/j.1813-6982.2003.tb00077.x.

Dittmar, R.F. and Yuan, K. (2008), "Do sovereign bonds benefit corporate bonds in emerging markets?", *The Review of Financial Studies*, Vol. 21 No. 5, pp. 1983-2014, doi: 10.1093/rfs/hhn015.

Emenike, K.O. (2018), "Exchange rate volatility in West African countries: is there a shred of spillover?", *International Journal of Emerging Markets*, Vol. 13 No. 6, pp. 1457-1474, doi: 10.1108/IJoEM-08-2017-0312.

Emenike, K.O. (2021), "Interdependence among West Africa stock markets: a dimension of regional financial integration", *African Development Review*, Vol. 33 No. 2, doi: 10.1111/1467-8268.12575.

Engle, R.F. and Kroner, K.F. (1995), "Multivariate simultaneous generalized ARCH", *Econometric Theory*, Vol. 11 No. 1, pp. 122-150.

Fabella, R. and Madhur, S. (2003), "Bond market development in East Asia: issues and challenges", ERDWorking Paper No. 35, Asian Development Bank.

Favero, C.A. and Missale, A. (2012), "Sovereign spreads in the Eurozone: which prospects for a Eurobond?", *Economic Policy*, Vol. 27 No. 40, pp. 231-273.

Griffiths, J., Panizza and Taddei, U.F. (2020), "Reducing low-income country debt risks: the role of local currency-denominated loans from international institutions", *Briefing Note*, Overseas Development Institute. available at: https://cdn.odi.org/media/documents/reducing_low-income_country_debt_risks_v4.pdf.

Gross, A. (2020), "African countries face 'wall' of Sovereign debt repayments", available at: https://www.ft.com/content/8c232df6-4451-11ea-abea-0c7a29cd66fe.

Katsiampa, P., Corbet, S. and Lucey, B. (2019), "Volatility spillover effects in leading cryptocurrencies: a BEKK-MGARCH analysis", *Finance Research Letters*, Vol. 29, pp. 68-74, doi: 10.1016/j.frl.2019.03.009.

Kirikkaleli, D. and Gokmenoglu, K.K. (2020), "Sovereign credit risk and economic risk in Turkey: empirical evidence from a wavelet coherence approach", *Borsa Istanbul Review*, Vol. 20 No. 2, pp. 144-152, doi: 10.1016/j.bir.2019.06.003.

Kletzer, K. (2005), "Sovereign debt, volatility and insurance", Federal Reserve Bank of San Francisco Working Paper 2006-05, available at: http://www.frbsf.org/publications/economics/papers/2006/wp06-05bk.pdf.

Lane, P.R. (2012), "The European sovereign debt crisis", *Journal of Economic Perspectives*, Vol. 26 No. 3, pp. 49-68, available at: https://www.aeaweb.org/articles?id=10.1257/jep.26.3.49.

MacKinnon, J.G. (1991), "Critical values for cointegration tests", in Engle, R.F. and Granger, C.W.J. (Eds), *Long-run Economic Relationships: Readings in Cointegration*, Oxford University Press, New York, pp. 266-276.

Morsy, H. and Moustafa, E. (2020), "Mispricing of sovereign risk and investor herding in African debt markets", Working Paper Series No. 331, African Development Bank, Abidjan Côte d'Ivoire.

Panda, A.K., Nanda, S. and Paital, R.R. (2019), "An empirical analysis of stock market interdependence and volatility spillover in the stock markets of Africa and Middle East region", *African Journal of Economic and Management Studies*, Vol. 10 No. 3, pp. 314-335, doi: 10.1108/AJEMS-10-2018-0293.

Ratings, F. (2020), "Fitch: debt distress rising in Sub-Saharan Africa", available at: https://www.african-markets.com/en/news/africa/fitch-debt-distress-rising-in-sub-saharan-africa.

S&P Global Rating (2016), *Sub-Saharan Africa Sovereign Rating Trends 2017*, Standard & Poor Global.

Tafirenyika, M. (2015), "How healthy is Africa's sovereign bond debt? Analysts caution against accumulating too much", available at: https://www.un.org/africarenewal/magazine/april-2015/how-healthy-africa%E2%80%99s-sovereign-bond-debt.

Tsang, A., Yiu, M.S. and Nguyen, H.T. (2021), "Spillover across sovereign bond markets between the US and ASEAN4 economies", *Journal of Asian Economics*, Vol. 76, doi: 10.1016/j.asieco.2021.101343.

Velde, D.W.T. (2014), "Sovereign bonds in sub-Saharan Africa: good for growth or ahead of time?", *Briefing*, Overseas Development Institute, Vol. 87, available at: https://cdn.odi.org/media/documents/8883.pdf.

Vellos, R. (2015), "Sub-Saharan Africa's sovereign bond issuance boom", available at: https://blogs.worldbank.org/opendata/sub-saharan-africa-s-sovereign-bond-issuance-boom.

Vizek, M. (2019), "The sovereign bond markets return and volatility spillovers", *Economic Thought and Practice*, Vol. XXVIII No. 2, pp. 597-610, available at: https://hrcak.srce.hr/230541.

World Bank (2015), *International Debt Statistics 2016*, World Bank Group, doi: 10.1596/978-1-4648-0681-0.

Zinna, G. (2014), "Identifying risks in emerging market sovereign and corporate bond spreads", *Emerging Markets Review*, Vol. 20, pp. 1-22, doi: 10.1016/j.ememar.2014.05.002.

Corresponding author
Kalu O. Emenike can be contacted at: kalu@uniswa.sz