Examining volatility and spillover effects between markets for sovereign bonds of African countries and the world's long term interest rate

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Abstract

The study sets out to examine the existence of volatility and spillover effects between sovereign bond returns of South Africa and Ethiopia and the world's long term interest rate using weekly data in the period of 2014–2022. An MGARCH-DCC model is estimated to analyze the direction and strength of sovereign bonds' volatility interaction. The result indicated that volatility from the long-term world interest rate and South Africa's sovereign bond return affected the Ethiopian sovereign bond return negatively and positively, respectively. Then, it shows the existence of a bidirectional return spillover between Ethiopia's and South Africa's sovereign bond markets, and a unidirectional transmission from the US's long-term Treasury bond market to Ethiopia's sovereign bond market. Besides, the sum of ARCH and GARCH terms is very close to unity for both Ethiopia and South Africa, implying that both markets display high persistence in their volatilities. On the other hand, Ethiopia's and South Africa's sovereign bonds have weak or insignificant correlation with the world's long term interest rate. Besides, volatility in both markets is significantly affected by their own respective shocks and volatilities. The findings suggest that African financial policy makers should consider their own economies realities and specific reactions to volatility and spillover effects from the world's long-term interest rate. That means contextual policy workout is required to contain the negative impacts of the world's long-term world interest rates. Finally, the strong correlation between Ethiopia's and South Africa's sovereign bond market suggests the need to maintain financial stability through monitoring of both national and regional monetary policies.

Key words: *Africa; volatility; spillover; sovereign bond; long term interest rate; correlation.*

1. Introduction

The substantial increase in the flow of capital and financial information along with the globalized economy is attributed for the existence of interdependence between financial markets in various economies across the world. Moreover, the liberalization of capital movements, improvement in technology levels and the increase in the number of instruments in financial markets have caused financial instruments to rapidly react to new information from both domestic and global markets (Alkan and Cieck, 2020). In fact, liberalization has opened different sets of opportunities to investors, which provided investors the option to select and manage different portfolios around the globe. Jebran (2014) stated that the internationalization of financial markets gained considerable attentions from investors all over the world. Investors began to invest in different financial markets that can enhance their returns.

Sovereign bond offers an alternative source for financing infrastructure projects, social programs or other spending measures when tax revenue is not sufficient. So, interdependence in sovereign bond markets has the potential to enhance investment and in turn economic growth (Mishkin, 2005), especially for developing countries including Africa. Because, the interdependence facilitates access to the international market and serve as a source of finance to meet their huge demand for development projects.

Nevertheless, interdependence is accompanied with greater ease and speedy transmission of volatility shocks in the financial markets. Financial crisis, such as the 2008-09, which has adversely affected the global economy and financial markets especially the emerging and developing markets, has witnessed the strong interdependence of financial markets in the world. Since they became more integrated with developed financial markets, African markets have been hit by the financial crisis (Giovannetti and Velucchi, 2013) that was actually happening in the western part of the world.

The knowledge about spillover of financial information from one market to another gained a considerable attention over the last few decades. Worldwide, numerous studies have been made to examine the spillover effects of volatility between different financial markets. Most of them, however, are focused on the developed stock or equity markets, and skewed on the analysis between commodity prices and stock markets. Moreover, Alkan and Cieck (2020) stated that the literature generally is focused on volatility spillover rather than mean spillover to capture the interdependence between financial markets. The same study mentioned that most early studies of spillover across financial markets covered industrialized countries and most of them investigated the interdependence between foreign exchange and stock markets.

In Africa, a couple of 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. Our understanding of sovereign bonds volatility interaction between African countries themselves is still not clear due to the limited evidence available. The few literature that focus on Africa sovereign bond concentrated on investor herding in African debt markets as a result of high yield as well as debt risk reduction (Emenike, 2021).

On the other hand, Burger et al. (2017) suggested that a longstanding global factor, the level of US long-term interest rates, is an important factor in determining the effects of U.S. monetary policy on emerging market economies' sovereign and corporate bond markets. With respect to the African financial market, volatility spillovers between their sovereign bond markets and the US's bond market is not sufficiently explored. Giovannetti and Velucchi (2013) have made a general conclusion that South Africa and US shocks significantly affect African countries financial markets. To what extent and which African country is impacted by the shocks. This also worsened by the limited information available on how sovereign bond volatility shocks are transmitted among African countries.

Nowadays, some of African and the emerging economies financial markets are progressing and rapidly industrializing. As a result, investors across the world closely watch to sovereigns issued by the government of these nations so as to take advantage of the rapid growth occurring in their financial markets. Further, emerging African financial markets have been recently put forward as an interesting and profitable alternative to diversify risk for international investors. It is, therefore, highly relevant and justifiable to work out any financial information and make plausible assumptions and expectations by investors in a world where the economic systems are dynamic, and shocks occurred in one country transmits automatically to another.

Therefore, understanding transmission of return volatility and spillover effects from one market to another and future bond price developments is of paramount significance for the financial sector in the developing world in general and African economies in particular. With this background, this study is motivated and intended to examine the nature of return volatility and spillovers across markets for sovereign bonds between African and the FED's long term Treasury bond market.

The main objective of this paper is to explore the existence or otherwise of returns volatility spillover between selected African sovereign bond markets and the US's long-term interest rate. Specifically, the study aims to examine to what extent there are return and volatility spillovers across the African sovereign bond and US's long-term interest rate. Also, the paper analyzes sovereign bond volatility interaction between African countries themselves. Finally, it compares performance of variants of MGARCH model so as to identify the best model that can capture the return volatilities and spillover effects.

2. A Review of the Literature

The high practical relevance of the subject has led to a bunch of studies being carried out on the subject. There exists wide literature on volatility spillover dynamics across the world on various topics such as stock markets, bond markets, gold markets, and oil markets.

Regarding spillovers from the US markets to others, Albagli et al. (2018) studied the spillovers of US monetary policy to overseas bond markets and found that there are different channels of US spillovers for different types of economies. The channel is through risk-neutral rates for advanced economies, while it is through term-premia for emerging economies. Also, Burger et al. (2017) analyzed the effect of the US Federal Reserve's monetary policy on EMEs sovereign and corporate bond markets by focusing on two dimensions: the evolution of the structure (size and currency composition) of the bond markets and their allocations within the bond portfolios of US investors. *Global factors, particularly the level of long-term US Treasury bill yields, matte*r. Across all cases, when US long-term interest rates were low (i) EMEs issued more sovereign and private-sector local currency bonds and more private-sector foreign currency bonds and (ii) US investment in EME sovereign bonds (both local currency and USD-denominated) increased. In contrast, after controlling for the level of U.S. long-term interest rates, measures that attempt to isolate the effects of U.S. unconventional monetary policy are often statistically insignificant in the analysis.

Using data covering the period January 2002 to December 2011, Natarajana et al. (2014) fitted GARCH-M model and investigated the mean-volatility spillover effects that happen across international stock markets. The GARCH-M model provides useful insights into how information is disseminated across stock markets. In particular, the model examines the precise and separate measures of return spillovers and volatility spillovers. The analysis provides the evidence of strong mean and volatility spillover across some stock exchanges

Kang and Yoon (2020) examined the return links and volatility transmission between Chinese stock and commodity futures markets and draws implications for portfolio risk management. The study applied three VAR-MGARCH models - Diagonal (DIAG), Constant Conditional Correlation (CCC), and Dynamic Conditional Correlation (DCC) models – with which to model volatilities and conditional correlations between Chinese stock and three commodity futures markets. The empirical results reveal evidence of return linkage and volatility transmission between the Chinese stock and commodity futures markets.

Moreover, Yiu et al (2020) employed VAR-MGARCH model to investigate the spillover across the sovereign bond markets between the US and ASEAN+4 (Indonesia, Malaysia, the Philippines and Thailand) economies. The results confirm the return spillover from the US to ASEAN-4, while bidirectional influence in volatility exists between the US and ASEAN-4. Also, DCC analysis is employed to depict the changing correlation in the volatility. Besides, the study show that the yields of ASEAN-4 bonds increase with the emerging market risks and the exchange rate can act as a buffer to reduce spillover. Given that ASEAN-4 governments have issued large amount of government bonds to finance their large fiscal spendings amid the Covid-19 pandemic, the return and volatility spillovers from the US to ASEAN4 could be important factors to be mindful when the US unwinds its unconventional monetary policy and normalizes its interest rates in the medium to long term.

Using VAR and MGARCH, Li and Giles (2015) examined the linkages of stock markets across the U.S., Japan and six Asian developing countries, covering the period 1993 to 2012. The study finds significant unidirectional shock and volatility spillovers from the US market to both the Japanese and the Asian emerging markets. It is also found that the volatility spillovers between the US and Asian markets are stronger and bidirectional during the Asian financial crisis.

Abou-Zaid (2011) investigated the international transmission of daily stock index volatility movements from U.S. and U.K. to selected MENA emerging markets: Egypt, Israel, and Turkey. Employing a multivariate GARCH in mean technique, the study finds that Egypt and Israel are significantly influenced by the U.S. stock market while Turkey is not.Also, Mandigma (2014) studied the integration among the sovereign bond markets between ASEAN+5 countries (namely, Indonesia, Malaysia, the Philippines, Singapore and Thailand) and China. The paper found that ASEAN+5 and China were affected mainly by their own shocks with some impact to and from a few ASEAN+5 countries sovereign bond yields. This indicates that the spillover from China to the ASEAN sovereign bond market is still limited.

Moreover, Habibi and Mohammadi (2022) used weekly data on returns and range-based volatility over 2005–2017 to examine the interconnectedness in financial markets of eleven MENA and four Western economies. Using the methodology proposed by Diebold and Yilmaz (2009, 2012, 2014), it constructed a number of spillover indexes for stock returns and their volatilities. The findings suggest similar patterns of dynamic spillovers in both returns and in volatility. Both return and volatility spillover indices experienced significant bursts from 2008 to 2011 coinciding with the U.S. financial crisis. Also, financial markets of Israel, Saudi Arabia and the UAE are more closely integrated with Westerns markets and may serve as primary channels for transmission of Western shocks to the region. Also, shocks to these three markets have noticeable impacts on other MENA markets. Finally, the paper stated that shocks to the U.S. financial markets play a critical role in return and volatility of MENA markets.

Alkan and Cieck (2020) conducted a study to capture the spillover between financial markets in the Turkish economy and to investigate the effects of global markets on Turkish financial markets, since the spillover may arise from the global financial markets as well as the domestic ones. Employing BEKK parameterization of the multivariate GARCH model between 2006 and 2018, it found a strong mean spillover from global markets to domestic stock and bond markets, from stock and exchange markets to the bond market and from the dollar return to the stock market. For the volatility spillover, the results also supported strong spillover between each market pairs. These findings implied that the Turkish economy is well integrated into global markets and that a fluctuation in volatility in a global or domestic market immediately spreads to other domestic markets, regardless of borders.

Belke et al (2017) explores the extent to which changes to long-term interest rates in major developed economies have influenced long-term government bond yields in emerging Asia. To gauge long-term interest spillover effects, the paper uses vector autoregressive variance decompositions with high-frequency data. The results reveal that sovereign bond yields in emerging Asia responded significantly to changes to the United States and Eurozone bond yields, although the magnitudes were heterogeneous across countries. The magnitude of spillovers varied over time. The pattern of these variations can partially be explained by the implementation of different unconventional monetary policy measures in developed countries.

Finally, Bala and Takimoto (2017) studied stock returns volatility spillovers between emerging and developed markets using MGARCH models. Besides, they examined the impacts of global financial crisis on stock market volatility interactions and modify the BEKK-MGARCH model by including financial crisis dummies. Also, the study conducted unit root tests using ADF, and applied Inclan and Tiao's (IT) break test to identify the number and position of break points in variance of the returns. Moreover, they study applied the DCC-with-skewed-t density model so as to improve diagnostics by considering fat tails and skewed features of the series.

Regarding the African financial markets, Giovannetti and Velucchi (2013) analyses the relationship among mature financial markets (US and UK), China, some South Saharan African emerging markets (Botswana, Kenya, Nigeria and South Africa) and two North African countries (Egypt and Tunisia) over the period 2005–2012, focusing on the role of financial markets' volatility. With the help of a Multiplicative Error Fully Interdependent Model, it analyzed the dynamics of the financial market volatility (risk), and the interactions with other markets. Authors presented impulse-response functions with a time dependent profile to describe how a volatility shock from one market may propagate to other markets, increasing the fragility of African infant financial markets. The results show that South Africa and US shocks significantly affect African financial markets, and China has recently become more interconnected.

Furthermore, while US, Kenya and Tunisia are "net creators" of volatility spillovers, South Africa and China turn out to be net "absorbers".

Emenike (2021) evaluates the nature of sovereign bond volatility interaction between African countries using bivariate BEKK-GARCH 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.

On the market, Morema and Bonga-Bonga (2020) assessed the impact of gold and oil price fluctuations on the volatility of the South African stock market– namely, the financial, industrial and resource sectors. The paper applied a VAR-ADCC-GARCH modelling and intended to infer the link between the commodity and stock markets in South Africa. Moreover, the paper assesses the magnitude of the optimal portfolio weight, hedge ratio and hedge effectiveness for portfolios constituted of a pair of assets, namely oil-stock and gold-stock pairs. The findings of the study show that there is significant volatility spillover between the gold and stock markets, and the oil and stock markets. This finding suggests the importance of the link between the commodity and stock markets, which is essential for portfolio management. With reference to portfolio optimization and the possibility of hedging when using the pairs of assets under study, the findings suggest the importance of combining gold and stocks as the best strategy to hedge against stocks risk, especially during financial crises.

Ncube et al. (2012) investigated the impact of unanticipated United States bond yield increases, federal funds rate tightening, and monetary stimulus shocks on the South African economy using structural VAR models. Firstly, the US monetary stimulus shock leads to weak consumer price inflation, randdollar appreciation, real stock price revaluation, bond yield declines, decline in monetary aggregates and real interest rates in South Africa. Despite the weak trade channel evidence, the paper stated that the findings are consistent with predictions of a small open economy Mundell-Fleming model. Secondly, an unanticipated positive US medium-term bond yield shock leads to rand-dollar depreciation and rising bond yields as predicted by the portfolio balance exchange rate model. This same shock leads to significant real stock price declines, which is consistent with portfolio re-allocation driven by change in US bonds yields.

To sum up, this empirical literature review advocates the existence of interdependence between most emerging stock and/or bond markets and those of developed countries. In the era of globalization emerging countries, including Africa, are under market co-movement and volatility spillover pressure which is attributed by information flow from well-developed global markets more specifically from USA.

3. Research Methodology

3.1. Multivariate GARCH Models

Researches stated that data for returns on financial assets typically exhibits the so called volatility clustering (Fama, 1965; Mandelbrot, 1963). Such data series are better modeled using time-varying second-order moments. Therefore, Generalized Autoregressive Conditional Heteroskedasticity (GARCH) Models (Bollerlev, 1986) are developed to model such features of financial returns data. Multivariate GARCH models and their extensions are widely used by the applied financial researches (Bollerslev et al., 1988; Bauwens et al., 2006; Karolyi, 1995; Li, 2007; Worthington and Higgs, 2004).

Moreover, significant body of the literature suggests that MGARCH modeling is the most widely applied analytical method in assessing transmission or spillover of volatilities in financial assets' returns. As a result, this study fits two variants of MGARCH model: *Constant Conditional Correlation (CCC) Model and Dynamic Conditional Correlation (CCC) Model.* Operationally, this study focused on both mean and volatility spillover effects.

I. Constant Conditional Correlation (CCC) Model

The CCC-MGARCH model allows for time-varying conditional variances and covariance. Its conditional variance matrix is given by:

$$\boldsymbol{H_t = D_t R D_t = \rho_{ij}\sqrt{h_{ii,t}h_{jj,t}}}$$

where, D_t is (n×n) diagonal matrix that the diagonal elements are conditional standard deviations, and R is (n×n) time-invariant correlation matrix.

Then, conditional variance of the GARCH (1,1) specification is given by:

$$\boldsymbol{h_{ii,t} = c_i + a_i\varepsilon^2_{i,t-1} + b_i h_{ii,t-1}}$$

$$\boldsymbol{h_{ij,t} = \rho_{ij}\sqrt{h_{ii,t}h_{jj,t}}\ \ , i, j = 1 \dots\dots n,}$$

where c is a n×1 vector, α_i and bi are diagonal (n×n) matrices.

II. Dynamic Conditional Correlation (CCC) Model

This study applies the DCC approach developed by Engle (2002), which allows capturing the dynamic time-varying correlations across markets represented by the conditional covariance. In the multivariate case that we use, the variance – covariance matrix (H_t) of residuals is defined as:

$$\boldsymbol{H_t = D_t R_t D_t\,,}$$

where $D_t = diag\sqrt{\{H_t\}}$ is the diagonal matrix with conditional variances along the diagonal, and Rt is the time-varying conditional correlation matrix.

The diagonal matrix (D_t) is given by $\mathbf{D_t = diag\,(h^{1/2}_{11,t}, \dots, h^{1/2}_{44,t})}$

And, the time-varying conditional correlation matrix (Rt) is defined by

$$\boldsymbol{R_t = diag\,(q^{-\frac{1}{2}}_{11,t}\,,\ \dots\ ,\ h^{-1/2}_{44,t})\,Q_t diag\,(q^{-\frac{1}{2}}_{11,t}\,, \dots\ ,\ h^{-1/2}_{44,t})}$$

The systematic positive definite matrix Q_t is denoted as

$$\boldsymbol{Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1(\varphi_{t-1}\varphi'_{t-1}) + \theta_2 Q_{t-1}}$$

Where, $\bar{Q}$ denotes the 4×4 unconditional covariance matrix of φ_{it}. The coefficients θ_1 and θ_2 are non-negative with a sum of less than unity.

Then, the dynamic correlation is expressed as $$\boldsymbol{\rho_{ij,t}} = \frac{\boldsymbol{q_{ij,t}}}{\sqrt{\boldsymbol{q_{ii,t} q_{jj,t}}}}$$

3.2. Data, Estimation and Testing Mechanisms

The study utilizes a weekly time series data spanning the period 2014 to 2022 containing sovereign bond prices indices of Ethiopia and South Africa. Also, from the developed market, it includes US's Treasury 10-year bill rates relative to the 3-month bill's rate, which is taken as a proxy for the *world's long-term interest rate*. Since the data includes bond price indices for Ethiopia and South Africa, we calculate the continuously compounded weekly returns by taking the difference in the logarithms of two consecutive bond price indexes as shown below:

$$\boldsymbol{r_{i,t} = ln(P_{i,t}/P_{i,t} - 1) \times 100}$$

Where, $r_{i,t}$ denotes the continuously compounded percentage weekly returns for index i at time t and $P_{i,t}$ denotes the price level of index i at time t.

Because the data is non-stationary at level, first difference of natural logarithms of the bond price indices is utilized so as to make the series stationary. This conversion also helps to get the weekly bond yields/returns. Since the US long term interest rate is also non-stationary at level, its first difference is used so that it becomes stationary.

Then, stationarity of the data is tested using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. The data is also checked for normality and autocorrelation using histograms, autocorrelation function (ACF, afterwards) and partial autocorrelation function (PACF, afterwards) together with the Portmanteau (Q) test.

Finally, models are estimated using the Maximum Likelihood (ML) approach. After estimation, serial correlation (using Portmanteau (Q)) and normality (using Q-Q plots, and Kurtosis and Skewness) tests on the residuals and squared residuals are applied to check for model's adequacy. Also, Wald test is used to check for overall model's fitness. Finally, *Akaike's*

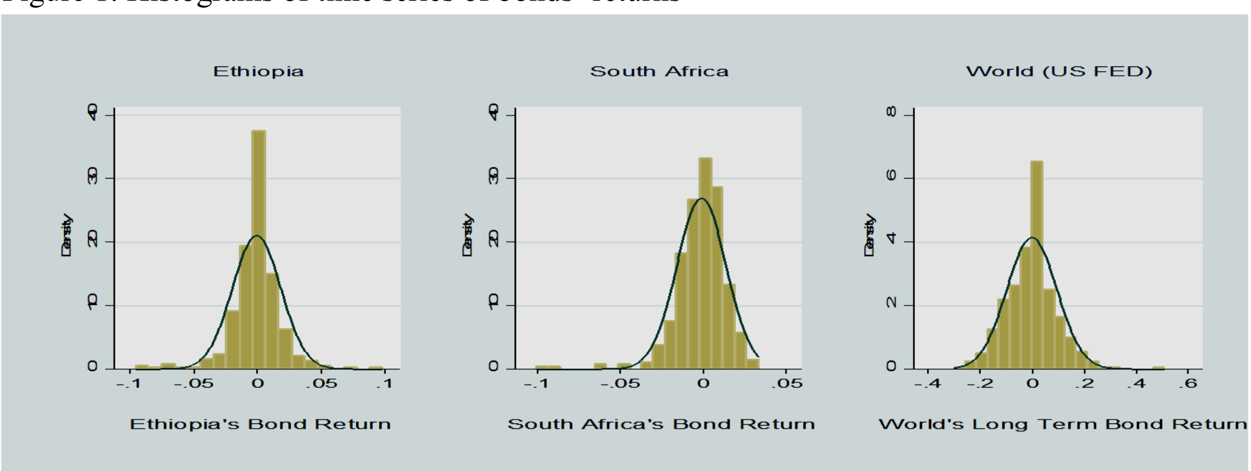
Information Criterion (AIC), Bayesian Information Criterion (BIC) and likelihood ratio tests are employed to select the best model that can capture the data.

Table 1: Descriptive statistics for each weekly sovereign bond return series

	Obs	Ethiopia	South Africa	USA
Mean	*373*	*-0.0006998*	*-0.0011858*	*-0.0016622*
Minimum	*373*	*-0.0956469*	*-0.1005821*	*-0.300000*
Maximum	*373*	*0.0983524*	*0.032866*	*0.5100000*
Standard Deviation	*373*	*0.0190048*	*0.0148423*	*0.0963468*
Variance	*373*	*0.0003612*	*0.0002203*	*0.0092827*
Skewness	*373*	*-0.5710646*	*-1.817192*	*0.4510238*
Kurtosis	*373*	*9.920984*	*11.75737*	*5.194609*

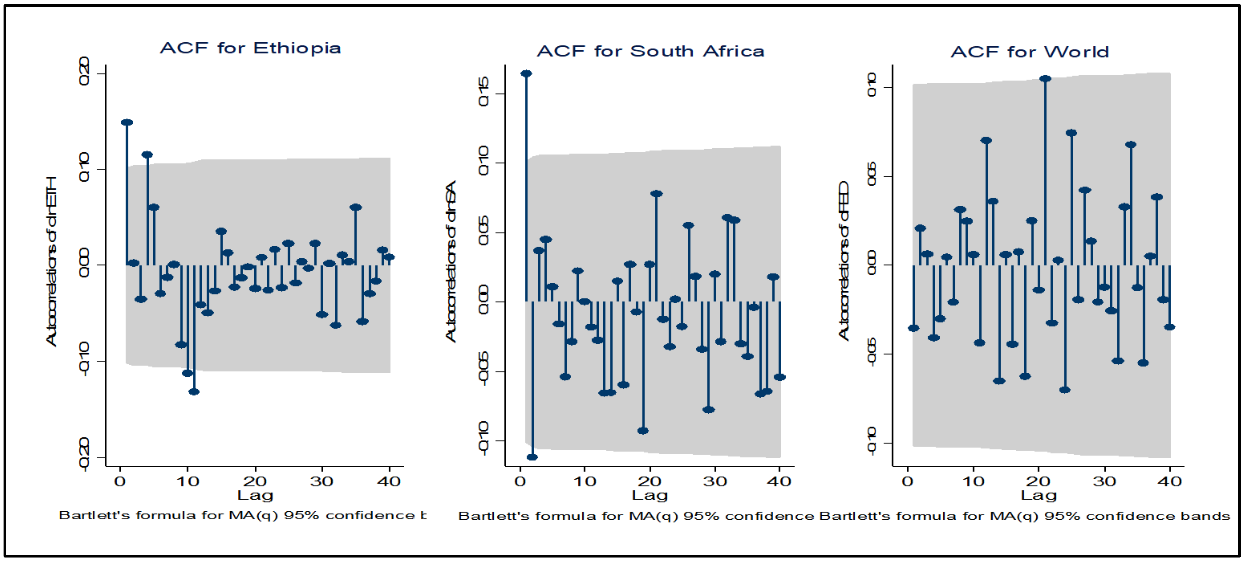
Table 1 presents descriptive statistics of the series. US's long term Treasury bill yields show the highest positive return along with the highest risk (standard deviation), while South Africa has the lowest risk. Ethiopia's and South Africa's return series shows negative skewness, with South Africa's being the most skewed, implying frequent small gains and extreme large losses. Kurtosis values for all series are above three, with South Africa having the highest, indicating the presence of peaked distributions and fat tails. That is, all return series display a leptokurtic distribution with a higher peak and a fatter tail than is the case in a normal distribution.

Figure 1: Histograms of time series of bonds' returns



The ACF functions together with the Portmanteau test show that no autocorrelation exists in the returns' series (figure 2).

Figure 2: Autocorrelation functions (ACF) of return series of each country

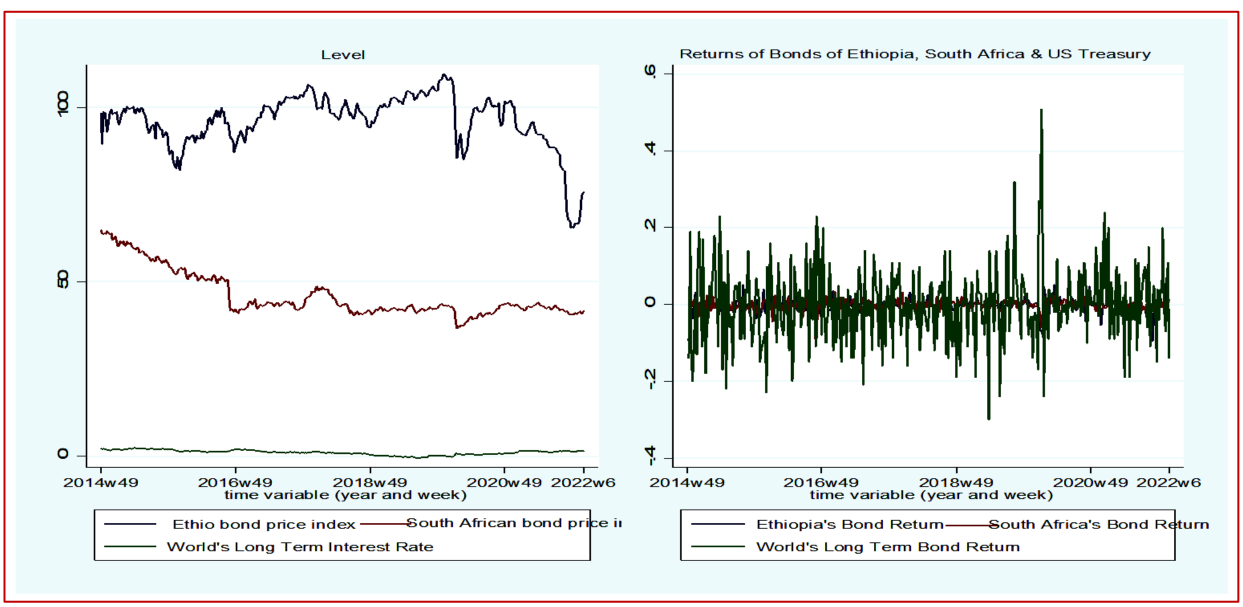


4. Results and Discussions

4.1. Testing for Stationarity

Visualizing time-series plots of the returns (Figure 3), it tells us that the data at level is non-stationary (first panel) and log price first differences (returns) and first difference of long term interest rate of the US looks stationary (second panel).

Figure 3: Graphical visualization of stationarity of bonds' returns series



Then after, stationary or unit root tests are made using the ADF and PP methods on the log price first differences (returns) series. Both the ADF and PP test results for unit root shows that the returns' series are stationary (table 2).

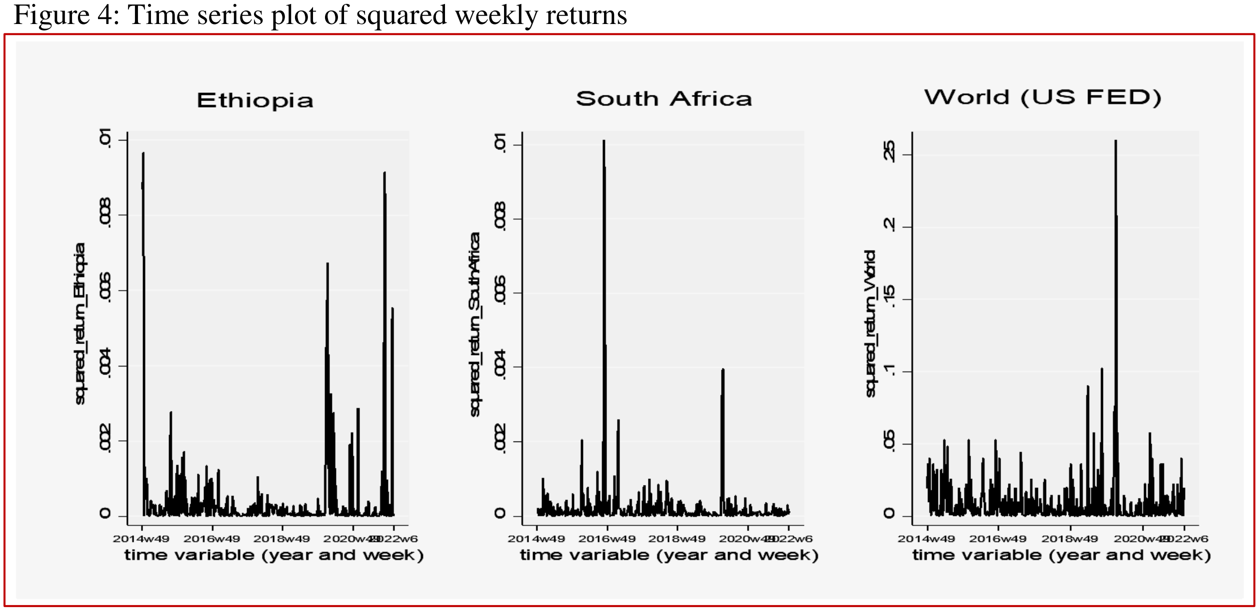
Table 2: ADF and PP test results for unit root test; Number of observations = 372

Augmented Dickey-Fuller (ADF) test statistic					***Phillips-Perron (PP) test statistic***			
	Test Statistic Z(t)	Critical Values			Test Statistic Z(t)	Critical Values		
		1%	5%	10%		1%	5%	10%
Ethiopia's bond return	*-17.126*	*-3.450*	*-2.875*	*-2.570*	*-17.256*	*-2.580*	*-1.950*	*-1.620*
South Africa's bond return	*-16.284*				*-16.135*			
FED's bond return	*-19.929*				*-19.954*			

4.2. Visual Inspection of Volatility in the Returns

Time-series plots of the squared weekly returns show the existence of volatility in the price returns of all the three bonds. In some cases, there is volatility clustering as periods of high volatility are followed by another period of high volatility (figure 4). These features of the financial returns data justify our selection of the Generalized Autoregressive Conditional Heteroskedasticity (GARCH) Models.

Figure 4: Time series plot of squared weekly returns



4.3. Model Estimation and Adequacy

The empirical analysis focuses on two multivariate GARCH (MGARCH) models to examine the volatility dynamics between bond returns of the modeled countries-Constant Conditional Correlation (CCC), and Dynamic Conditional Correlation (DCC). While our initial analysis suggests that Engle's (2002) DCC model may be the most appropriate model type for our data, we included CCC in our estimation just to allow for model comparison and robustness.

Using Maximum Likelihood (ML), parameters of four variants of the MGARCH model are estimated, assuming that the errors come from a multivariate normal distribution or student's t-distribution. As a result, two sub-models for each MGARCH model are estimated for each country (Ethiopia and South Africa): CCC with normal or Gaussian errors (model 1); CCC with student-t (7) errors (model 2); DCC with normal or Gaussian errors (model 3); and DCC with student-t (7) errors (model 4).

4.3.1. Model Adequacy

Suitability of each model for examining the return spillover effects is examined using serial correlation and normality tests on residuals and squared residuals of each model.

I. Test for Serial Correlation and Normality

The autocorrelation function for all models reveal that almost all lags of returns fall within 95% confidence bands, with a very few outliers on the series of squared residuals**.** Also, the Portmanteau test shows that we fail to reject the null hypothesis of no serial correlation among the standard errors and squared standard errors (annex). Overall, the tests reveal absence of serial correlation in the standard errors and only a very weak form of autocorrelation in the squared standard errors.

Regarding normality, the Q-Q plots of residuals appear that we have approximately normality distributed standardized errors, except for some lower tail deviations for the standard errors and upper tail deviations for squared standard errors. Also, the Kurtosis and Skewness test of normality confirms this because Prob>chi2 is 0.0000 for all models (annex). Therefore, all four variants of the MGARCH models that we have estimated seem adequate to modelling the return volatilities spillovers in our case.

II. Wald Test of Model's Fitness

Wald test rejects the null hypothesis all the coefficients on the independent variables in the mean equations are zero. Therefore, volatility of returns from all bonds has significant effect on the mean of returns evolutions and volatilities (table 3). This also confirms that all the models estimated are suitable to model the sovereign bond's returns data series.

Table 3: Wald test statistics of model fitness

Model	***Wald chi²***	***Prob > chi²***
CCC with normal or Gaussian errors (Model 1)	*51.10*	*0.0001*
CCC with student-t (7) errors (Model 2)	*47.01*	*0.0002*
DCC with normal or Gaussian errors (Model 3)	*52.82*	*0.0000*
DCC with student-t (7) errors (Model 4)	*48.28*	*0.0001*

4.3.2. Comparing Models' Performance

In order to compare models' performance and select the better one, Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and likelihood ratio tests are applied (table 4). AIC suggest model_4 (DCC with student-t (7) errors) is better than others; while the BIC suggests model_2 (CCC with student-t (7) errors) is better than others. Since model_2 and model 4 are nested models, we apply the likelihood ratio test to choose one of them.

Table 4: Information Criterion (*AIC, BIC and LR Test) Statistic*

Models	***AIC***	***BIC***
Model_1 (CCC with normal or Gaussian errors)	-4853.113	-4712.13
Model_2 (CCC with student-t (7) errors)	-4956.928	***-4815.945***
Model_3 (DCC with normal or Gaussian errors)	-4860.402	-4711.586
Model_4 (DCC with student-t (7) errors)	***-4959.104***	-4810.288
Likelihood-ratio test	LR chi(2)	Prob > chi2
(Assumption: model_2 nested in model_4)	6.18	0.0456

The *Likelihood-ratio test* rejects the restrictions imposed by the Constant Conditional Correlation (CCC) and favors Model_4 (Dynamic Conditional Correlation, DCC with student distribution), nearly at 5% level of significance (Table 4). Hence, the DCC with student-t (7) errors) is found better in examining the sovereign bonds' return volatility and transmission. Thus, analysis and discussion is made using the DCC model's results, while the CCC's results are also simultaneously presented, just to check for robustness of the estimates and compare the results.

4.4. Examining Volatility Spillovers in Returns

All models are suitable to analyze the volatility spillovers across sovereign bond markets of Ethiopia and South Africa, and the world's long term bond return (US's long term Treasury bill rate). Since the information criterions suggest that model_4 is better than the others, we base our analysis and interpretation using the DCC's (with student-t (7) errors) model results.

Estimated results of mean equations from both the CCC and DCC models are presented for Ethiopia, South Africa and the US-World's long term interest rate (Table 5). Looking at the mean equation of Ethiopia's sovereign bond return, the estimated coefficients on the first lag of South Africa (using CCC estimates[1]) and US's long term bong are statistically significant, implying that there is return spillover from South Africa's sovereign bond market (positive) and US's Treasury bond market (negative) to Ethiopia's sovereign bond market. For South Africa's return mean equation, the estimated coefficients on the second lag of Ethiopia is statistically significant, implying that there is return spillover from Ethiopia's to South Africa's bond market. And, the US's long term Treasury bond return mean equation, the estimated coefficients on the second lag of South Africa is statistically significant, implying that there is unidirectional return spillover from South Africa's bond market to US's long term Treasury bill market.

Hence, we find a bidirectional return spillover between Ethiopia's and South Africa's sovereign bond markets, and a unidirectional spillover from South Africa's financial market to US's long term market, and from the US to Ethiopia's market. Past returns of South Africa's bond have a positive influence on the returns of Ethiopia's sovereign bond, whereas the past returns of FED's long term Treasury bond have a negative impact on the returns of Ethiopia's sovereign bond. On

[1] *The IC tests suggest the DCC model with a very slight margin, using the CCC estimates in some situations will not change our interpretation. It is also backed by the literature.*

the other hand, there is statistically significant first lag own return spillover for Ethiopia's bond return and first and second lags own return spillover for South Africa's bond return.

Table 5: Empirical results of the CCC and DCC MGARCH models (mean equations)

Variable	CCC (Model_2)			DCC (Model_4)		
	Coefficient	**Z**	**P > |z|**	**Coefficient**	**Z**	**P > |z|**
Ethiopia's return mean equation						
Constant	.0002336	0.38	0.704	.0003673	0.60	0.550
ETH, L_1	.1217694**	2.23	0.026	.1227501 **	2.30	0.022
ETH, L_2	.007088	0.15	0.877	-.0016628	-0.04	0.971
SA, L_1	.0845238***	1.64	0.998	.0732718	1.44	0.151
SA, L_2	.0187126	0.40	0.690	.0182976	0.39	0.694
FED, L_1	-.020485*	-2.88	0.004	-.0218435 *	-3.12	0.002
FED, L_2	-.0056542	-0.82	0.415	-.0046349	-0.67	0.502
South Africa's return mean equation						
Constant	-.0001162	-0.19	0.850	-.0002251	-0.37	0.712
ETH, L_1	.0206438	0.57	0.567	.0261615	0.73	0.465
ETH, L_2	.0969134*	2.82	0.005	.1012856 *	2.96	0.003
SA, L_1	.0853662	1.56	0.118	.0951501***	1.77	0.077
SA, L_2	-.1748952*	-3.41	0.001	-.1670312*	-3.29	0.001
FED, L_1	.0008169	0.12	0.906	.0002669	0.04	0.969
FED, L_2	-.0030271	-0.45	0.650	-.0044552	-0.68	0.498
US's Long Term Treasury bill return mean equation						
Constant	*-.0045147*	*-0.98*	*0.326*	-.0052649	-1.14	0.254
ETH, L_1	*-.0445662*	*-0.17*	*0.867*	-.0096842	-0.04	0.971
ETH, L_2	*-.0811958*	*-0.31*	*0.755*	-.0698357	-0.27	0.789
SA, L_1	*-.2908198*	*-0.78*	*0.438*	-.2660836	-0.71	0.475
SA, L_2	*.6704928****	*1.93*	*0.054*	.6604246***	1.90	0.057
FED, L_1	*-.0959762****	*-1.76*	*0.079*	-.1083416**	-2.00	0.046
FED, L_2	*.0438833*	*0.87*	*0.383*	.0383531	0.76	0.445

Source: own presentation from STATA (, ** &*** refers to 1%, 5% & 10% significance levels, respectively)*

Results on the variance equations are presented in Table 6 below. The results show that the second lag GARCH effects of Ethiopia's sovereign bond return is statistically significant, indicating the presence of strong GARCH effects; that is, its own past volatility affects the conditional variance of its own sovereign bond market.

Furthermore, the ARCH effects that capture the past shock effect of the markets themselves are significant in both Ethiopia's and South Africa's market, which signals the existence of persistence in short-term volatility.

Besides, the sum of ARCH and GARCH terms is very close to unity for both Ethiopia and South Africa, implying that the bond markets display high volatility persistence. This finding suggests that investors in the financial markets of both countries remember shocks that happened a long time ago and that the effects of the shocks on volatility last for a long time in these markets.

Also, significance of second lag own conditional GARCH coefficients for Ethiopia indicates that long-term volatility persistence effects exist in its bond return, while no indication of existence of long-term volatility persistence effects in South Africa. Besides, coefficients on *lambda 1 and lambda 2 from the DCC model* are positive and statistically significant. The sum of these coefficients is nearly less than unity, which implies return volatility is persistent for all markets.

Overall, the findings suggest the existence of strong correlation between Ethiopia's and South Africa's Sovereign bond markets, indicating that choosing between Ethiopia's and South Africa's bond is not a good option for diversification benefits for investors who would like to decide in owning either of the two bonds. On the other hand, Ethiopia's and South Africa's sovereign bonds have weak or insignificant correlation with the US's long term Treasury bond return. This would imply that they are less integrated with world's markets, and thus appear to be less susceptible to international shocks. As such, they provide more portfolio diversification opportunities to international investors who are thinking of investing on financial assets in Africa.

Table 6: Empirical results of the CCC and DCC MGARCH models (variance equations)

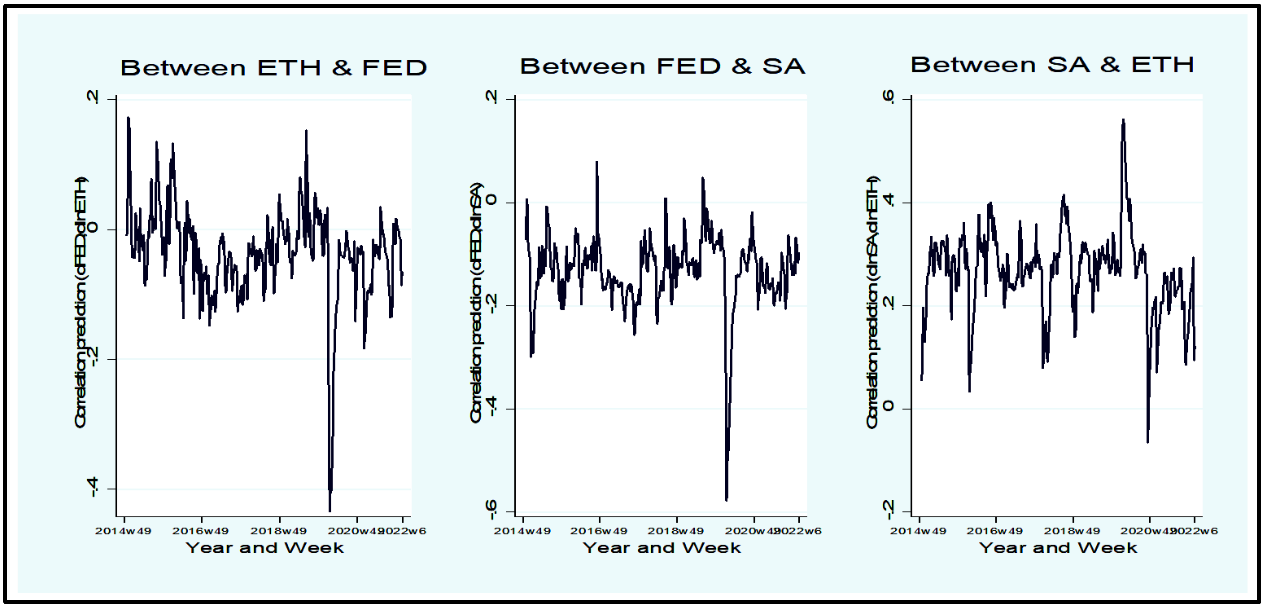
Variable		CCC (Model 2)			DCC (Model 4)		
		Coefficient	Z	P > |z|	Coefficient	z	P > |z|
Ethiopia's return variance equation							
ARCH_ETH, ARCH L1		.208959*	3.50	0.000	.1950348*	3.46	0.001
ARCH_ETH, GARCH L1		.0837629	0.79	0.430	.0840509	0.79	0.430
ARCH_ETH, GARCH L2		.602386*	5.25	0.000	.6180737*	5.45	0.000
Constant		.0000222 **	2.06	0.040	.0000206**	1.98	0.047
South Africa's return variance equation							
ARCH_SA, ARCH L_1		*.0904628***	*2.15*	*0.031*	.0899612**	2.22	0.026
ARCH_SA, GARCH L_1		*.3579998*	*0.95*	*0.343*	.3468574	0.97	0.330
ARCH_SA, GARCH L_2		*.4526663*	*1.29*	*0.198*	.4781312	1.42	0.154
Constant		*.0000167*	*1.31*	*0.190*	.0000142	1.30	0.195
US's Long Term Treasury return variance equation							
ARCH_FED, ARCH L_1		*.0777565*	*1.15*	*0.251*	.0715872	1.05	0.293
ARCH_FED, GARCH L_1		*.0186505*	*0.05*	*0.964*	.0337958	0.07	0.948
ARCH_FED, GARCH L_2		*.4116873*	*0.95*	*0.340*	.4090768	0.77	0.442
Constant		*.0044724****	*1.71*	*0.087*	.0044348***	1.69	0.091
CORR(ETH, SA)		*.2665622**	*5.03*	*0.000*	.2530601*	3.78	0.000
CORR(ETH, FED)		*.0310662*	*0.55*	*0.582*	.0424539	0.61	0.544
CORR(SA, FED)		*-.0730442*	*-1.30*	*0.194*	-.0382359	-0.55	0.583
Adjustment	*lambda 1*				.0392081***	1.84	0.066
	lambda 2				.7706153*	5.62	0.000

*Source: *, ** &*** refers to 1%, 5% & 10% significance levels, respectively.*

Finally, we presented the time-varying conditional correlation predictions in returns from the *DCC* model. It shows that conditional correlation between Ethiopia and FED is positive, but insignificant. The same is true between SA and FED, while Ethiopia and South Africa have stronger and significant predicted conditional correlation between their bond returns. And, this aligns with our analysis above using the results in Table 5, where the correlation coefficient between Ethiopia and South Africa's bond return is significant with a p-value of 0.000.

The correlation coefficients are not constant but vary greatly with time in all cases, meaning that investors frequently change their portfolio structure. More importantly, we observe a very low time-varying correlation in each case around the end of 2019 and beginning of 2020 (figure 5), which corresponds the Covid-19 pandemic.

Figure 5: Time-Varying Conditional Correlation Predictions in Returns from the DCC Model



The choice of sample period allows us to show that the correlation reaches to the very lowest level, a period associated with a Covid-19 induced crash in the financial instruments. This is not unusual event in the history of financial markets. During the financial crisis period, markets show rise in spillover and volatility in other markets (Aslam et al., 2021). Similar situation has been observed during Covid-19. Stock markets faced great decline during this pandemic. Besides, there has been a sharp increase in volatility of stock market during Covid-19 (Ali et al., 2020). Therefore, stock markets are witnessing high uncertainty and declines during pandemic times (Lyocsa et al., 2020).

5. Conclusions and Implications

The substantial increase in global capital flow along with the globalized economy is attributed for the existence of interdependence between financial markets which is more apparent than before. In the other side of the mirror, financial crisis was frequently happened and adversely affect the global economy and financial markets. This paper investigates weather there is market volatility and spillover effects between the US's long term interest rate (also known as world's long term interest rate), and Ethiopia and South Africa's sovereign bond markets return. Results of the Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) models revealed that correlations are varying and that both ARCH and GARCH effects play an important role in determining volatility and spillover effects among the markets. The results indicated the presence of unidirectional return spillover from the world's long term interest rate to Ethiopia's sovereign bond market, but no influence running in the other direction. There is a slight indication of the existence of a bidirectional return spillover between Ethiopia's and South Africa' sovereign bond returns. The analysis has also shown the existence of persistence in short term volatility in both Ethiopia and South Africa's financial market, while persistence in long term returns volatility exists in Ethiopia's sovereign bond market only. There is no such volatility persistence in the US financial market, world's long term interest rate bond market.

Moreover, the results reveal that sovereign bond yields in Ethiopia responded significantly to changes to the United States and South Africa bond yields. It also implies that the Ethiopian financial market is well integrated into global and South African markets. This is due to the existence of significant shocks and volatility spillovers from both the US (negatively) and from South African economies (positively) to Ethiopia. Thus, we can conclude that USA and South Africa have influential impact on the Ethiopian government bond return movement.

For the policy considerations, the paper suggest that financial policy makers in Africa have to beware of the spillovers in mean return as well as volatility in their respective sovereign bonds. The results suggest the existence of heterogeneous spillover effects of volatility from the US to Ethiopia and South Africa. It has unidirectional shock spillovers to Ethiopia's bond market, with no such effect on the South Africa's bond market. Considering its negative shocks separately, these unidirectional spillovers still exist significantly in both the short run and long run. It is also indicated that volatility in African economies sovereign bond markets are more determined by their own respective shocks and volatilities. Overall, the findings suggest that their financial policy makers should consider their economies realities and specific reaction to volatilities in the world interest rate. Adaptation of a certain financial policy measure from one African country to another is not commendable. Though most African economies share certain features with undeveloped financial markets, one-size-fits-all kind of intervention does not appear appropriate.

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