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Exploring Volatility and Spillover Effects between African Sovereign Bond Markets and Global Long-Term Interest Rates

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Abstract:

The study investigated 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 multivariate generalized autoregressive conditional heteroskedasticity model. The results showed that volatility from the long-term world interest rate negatively affects the Ethiopian sovereign bond market. The results also showed a one-way spillover from South Africa's market to the US long-term market, then from the US to Ethiopia's market, and further from Ethiopia's to South Africa's market. However, no bidirectional spillover was observed within these markets. Besides, both African markets display high volatility persistence. Besides, the markets have a weak or insignificant correlation with the world's long-term interest rate. Volatility in the markets is significantly affected by their respective past shocks or volatilities. Finally, it has forwarded policy inputs that should be tailored to the specific economic and financial context of each country.

Keywords: African markets; volatility analysis; spillover effects; sovereign bond; global long-term interest rate; financial integration.

JEL Classification: E47; E58; F36; G15; G28.

Introduction

The interconnectedness of financial markets globally is driven by increased capital flow and data, enabled by technological advancements and liberalized capital movements. This has led to responsive financial instruments influenced by both domestic and international information. Investors now diversify across global markets, seeking optimal returns. Sovereign bonds offer funding alternatives for various expenses when tax income falls short, especially benefiting developing nations like African countries. While interconnectedness enhances access to funds, it also transmits volatility shocks rapidly across markets, exemplified by the 2008-09 crisis impacting both developed and emerging economies. Recent research explores volatility transmission, often focusing on advanced economies. Little attention is given to African markets, their vulnerability to shocks, and spillover effects. As emerging economies industrialize, investors closely monitor their sovereign bonds for opportunities, making understanding volatility transmission crucial.

The main objective of this paper is to investigate the relationship between African sovereign bond markets and global long-term interest rates, with a specific focus on volatility and spillover effects using MGARCH models.

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Specifically, the study aims to examine to what extent there are return and volatility spillovers from the global long-term interest rate to Ethiopia and South Africa's sovereign bond markets. Also, the paper analyzes the volatility interaction between the two African countries themselves. The paper comprises sections on literature review, research methodology, results, and conclusions.

1. Literature Review

The significant rise in the flow of capital and financial data, coupled with the globalized economy, has been identified as the driving force behind the interconnectedness among financial markets across various economies worldwide. This trend is facilitated by the liberalization of capital movements, advancements in technology, and the proliferation of financial instruments. As a result, financial instruments now exhibit swift responsiveness to emerging information from both domestic and international markets (Alkan and Cieck, 2020). The process of liberalization has been accompanied by diverse opportunities for investors, granting them the flexibility to curate and manage portfolios spanning the global landscape. Jebran (2014) underscored the growing attention of investors worldwide toward the internationalization of financial markets. This phenomenon has motivated investors to diversify their investments in various financial markets, seeking avenues to optimize their returns.

Sovereign bonds offer an alternative way to fund infrastructure projects, social programs, or other expenses. This interlinkage in sovereign bond markets has the potential to boost investments and, subsequently, drive economic growth, particularly for developing nations like those in Africa (Mishkin, 2005). This is because such interconnectedness makes it easier for these countries to access the global market, providing them with the funds they require for their extensive development projects. However, this interconnectedness also brings about a downside in the form of rapid and widespread transmission of volatility shocks across financial markets. Instances like the 2008-09 financial crisis, which had severe repercussions on the worldwide economy and financial markets, especially in emerging and developing economies, highlight the strong interlinkage of global financial markets. As African markets have become more intertwined with developed financial markets, they too have been impacted by financial crises that originated in the Western parts of the world (Giovannetti and Velucchi, 2013).

In recent years, there's been a lot of interest in how financial information moves from one market to another. Many studies globally have looked into how volatility spreads between different financial markets, with a major focus on the developed stock markets and the relationship between commodity prices and stocks. Alkan and Cieck (2020) also noted that most of the focus has been on volatility rather than the average trends, which is important for understanding how markets are interconnected. They pointed out that earlier studies mostly looked at advanced economies and how foreign exchange and stock markets are linked. Also, Burger et al. (2017) suggested a longstanding global factor, the level of US long-term interest rates, is an important factor in determining the effects of US monetary policy on emerging market economies' sovereign and corporate bond markets. Concerning the African financial market, however, volatility spillovers between their sovereign bond markets and the US's bond market are 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 is also less known. This situation is worsened by the limited information available on how sovereign bond volatility shocks are transmitted among African countries.

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

Many studies have been conducted due to the practical importance of this topic. There's a lot of literature about how volatility spreads globally on various subjects, prices, and returns. The review begins with the most recent studies and completes by African case studies. Yadav et al. (2023) explored the dynamics of the Indian equity market, particularly the Sensex, and its relationship with global economies, particularly the Euro STOXX 50. The study used a DCC-GARCH model to analyze data spanning from April 2012 to March 2022 and looked at how volatility in global markets affects the Indian stock market. Their findings revealed that there is a short-term spillover effect from global markets to India. This means that, in the short term, Indian stock market investments can be influenced by global market volatility. However, for long-term investments, there seems to be a more stable situation with no significant volatility spillover from markets like Euro STOXX 50 and NASDAQ.

In another recent study, Hoque et al. (2023) explored the transmission of shocks from the US, China, and Japan to the stock returns and volatilities of fragile economies such as Colombia, Indonesia, Mexico, South Africa, and Turkey. They found that the USA and China primarily transmit shocks, while Japan acts as a receiver. Chinese shocks had the most significant impact, followed by the USA and Japan. Different statistical models, such as vector autoregression (VAR)-DCC-GARCH and VAR-ADCC-GARCH, were used to examine these effects, and the results showed that these shocks indeed affect stock market returns and volatility in these fragile economies. However, the direction and magnitude of these effects varied by country and its economic conditions.

In a broader context, Habibi and Mohammadi (2022) recently analysed the financial interconnectedness between eleven MENA and four Western economies using weekly data from 2005 to 2017. Through spillover indexes, they found similar patterns of dynamic spillovers in both returns and volatility. Significant bursts were observed during the U.S. financial crisis, and certain markets like Israel, Saudi Arabia, and the UAE were closely integrated with Western markets, acting as channels for transmitting Western shocks to the MENA region.

Ji et al. (2022) used a DCC-MGARCH model to study how the 2008 financial crises, including COVID-19, have affected the relationship between Chinese and US stock markets. Their findings showed that the financial crises and the COVID-19 strengthened the connection between these markets, with higher correlations during the pandemic. Investment patterns shifted toward Europe. Contagion effects were mainly from China to the US, with Hong Kong's stock market playing a role. This research suggests important considerations for financial regulators and risk-diversifying investors.

In their work, Yiu et al. (2020) used a VAR-MGARCH model to explore how spillovers happen in the sovereign bond markets between the US and ASEAN+4 economies (Indonesia, Malaysia, the Philippines, and Thailand). Their findings reveal that returns from the US influence ASEAN-4, and there's a two-way connection in terms of volatility. They used DCC analysis to showcase changes in volatility correlations. The study also highlights that ASEAN-4 bond yields increase when there are emerging market risks, and exchange rates can help mitigate these spillover effects. Given that ASEAN-4 countries issued a considerable amount of government bonds to manage Covid-19 impacts, it's important to consider the impact of returns and volatility from the US as it normalizes its monetary policy and interest rates over time.

When it comes to the effect of the US financial market on other countries' bonds and stocks, significant number of researches have undertaken in many parts of the world, especially in the developed and emerging economies in Asia. Albagli et al. (2018) found that the US monetary policy affects overseas bond markets differently based on the economy type. For advanced economies, it's about risk-neutral rates, while for emerging economies, it's about term-premia. Burger et al. (2017) focused on how the US Federal Reserve's monetary policy impacts EMEs sovereign and corporate bond markets. They looked at market structure changes and bond allocations within US investors' portfolios. Global factors, especially the level of US Treasury bill yields, played a key role. When US long-term interest rates were low, EMEs issued more bonds in different currencies, and US investment in EME sovereign bonds increased. However, the effects of US unconventional monetary policy weren't very significant once US long-term interest rates were considered.

Moreover, Bala and Takimoto (2017) focused on how volatility in stock returns spreads between emerging and developed markets. They used MGARCH models for their investigation. They also looked into how the global financial crisis influenced the way stock market volatilities interacted with each other. To do this, they adjusted their BEKK-MGARCH model by adding indicators for the financial crisis. The study also checked for certain statistical characteristics. They ran unit root tests using ADF and used Inclan and Tiao's (IT) break test to find out where and how many shifts occurred in return variance. To better understand the data, they used the DCC-with-skewed-t density model, which considers the unusual features of the series like fat tails and skewed distribution.

Likewise, Belke et al. (2017) explored the influence of changes in long-term interest rates in major developed economies on long-term government bond yields in emerging Asia. Using high-frequency data and vector autoregressive variance decompositions, they found that emerging Asia's sovereign bond yields significantly responded to shifts in U.S. and Eurozone bond yields, although the impact varied among countries and over time. These variations were partially attributed to different unconventional monetary policies in developed nations.

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.

Natarajana et al. (2014) conducted research between January 2002 and December 2011, using a GARCH-M model to explore how international stock markets influence each other in terms of both average returns and volatility. This model offers insights into the flow of information across these markets, dissecting the impact on returns and volatility separately. Their analysis provided strong evidence of notable effects in terms of both mean and volatility spillovers across specific stock exchanges.

In addition, Abou-Zaid (2011) delved into how the U.S. and U.K. stock markets impact selected MENA emerging markets - Egypt, Israel, and Turkey - through daily volatility movements. Using a multivariate GARCH in mean approach, the study showed that Egypt and Israel are notably influenced by the U.S. stock market, while Turkey isn't affected in the same way.

Shifting focus and scope, Gyamerah et al. (2022) investigated the interactions between green bonds and renewable energy stocks in terms of mean and volatility spillover globally. Using data spanning from 2011 to 2021 on the S and P green bond and global clean energy indexes, they identified a unidirectional causality from renewable energy stock prices to green bond prices. This means that changes in renewable energy stocks influenced green bond prices, but the reverse wasn't true. They also found a unidirectional volatility spillover from renewable energy stocks to green bond prices, indicating that the stock market had more influence on bond prices than the other way around. Notably, there were no significant shock spillovers in either direction, which implies a more stable relationship between the two markets.

Another study by Zhou et al. (2023) analysed information transmission and risk contagion between China's green bond market and its government bond market using advanced statistical models such as the VECM-DCC-VARMA-AGARCH model. Their results indicated that there's a significant dynamic correlation between these markets, with strong information transmission and risk contagion effects. The green bond market was found to be more sensitive to new information than the government bond market. They also identified a long-term equilibrium relationship between the two, suggesting that they tend to influence each other over time. And, there was a two-way risk contagion effect even though the intensity was uneven. These findings have implications for financial regulators and investors seeking to diversify their risk investments.

Moving to Istanbul, Kutlu and Karakaya (2023) conducted research on the asymmetric volatility spillovers in the stock and bond markets, using the data from 2003 to 2019, including the 2008 financial crisis period. It has used statistical models to assess volatility patterns such as GJR-GARCH and VARMA-AGARCH models. Their results revealed that during the entire period, there was negative volatility asymmetry in the bond market, while during the crisis, both markets showed positive volatility asymmetry. Return spillovers primarily occurred from the stock market to the bond market over the entire period, but during the crisis, this direction reversed. Moreover, volatility spillover was bidirectional under normal conditions but shifted during the global crisis, becoming bidirectional from stocks to bonds.

Kang and Yoon (2020) examined the connections between the Chinese stock market and commodity futures markets, specifically studying return links and volatility transfer. Their goal was to shed light on managing portfolio risks. They used three VAR-MGARCH models, Diagonal (DIAG), Constant Conditional Correlation (CCC), and Dynamic Conditional Correlation (DCC), to analyse volatility and conditional correlations between these markets. Their findings revealed clear signs of intertwined returns and the spread of volatility between the Chinese stock and commodity futures markets.

Besides, Alkan and Cieck (2020) investigated how financial markets within the Turkish economy interact and how global markets impact Turkish financial markets. By employing a multivariate GARCH model, the study demonstrated substantial mean and volatility spillovers between various markets, highlighting Turkey's strong integration into global markets and the swift transmission of fluctuations across domestic markets.

In addition, Mandigma (2014) examined the connections between sovereign bond markets in ASEAN+5 countries (Indonesia, Malaysia, the Philippines, Singapore, and Thailand) and China. The study revealed that each region was primarily affected by its own shocks, with limited spillover effects between them. This implies that spillovers from China to the ASEAN sovereign bond market remain restricted.

Focusing on African markets, Bossman et al. (2022) investigated the interplay between stock and government bond yields, especially in the context of the COVID-19 pandemic, in major sub-Saharan African markets. They employed various advanced statistical techniques to study this relationship and its impact on diversification during the pandemic. The findings suggested that the relationship between stocks and bonds in these markets is interdependent with multifaceted features. Interestingly, the study has found that COVID-19 pandemic did not significantly affect the co-movement of these assets. The research, however, has identified safe-haven benefits for short-term and medium-term investors during the pandemic but noted that the extent of connectedness between stocks and bonds is lesser in the long term.

Additionally, Emenike (2021) used a bivariate BEKK-GARCH model to explore sovereign bond volatility connections in African countries. Analysing eight nations, the study found one-way volatility influence from Morocco to Egypt's sovereign bonds. Ghana and Nigeria's bonds showed no interaction, while Uganda-Kenya and Botswana-South Africa displayed two-way interactions. In summary, full interaction was observed between Uganda-Kenya and Botswana-South Africa, partial interaction between Egypt and Morocco, and no interaction between Ghana and Nigeria sovereign bonds.

Also, Morema & Bonga-Bonga (2020) examined how changes in gold and oil prices impact the volatility of South African stock sectors: financial, industrial, and resource. Through VAR-ADCC-GARCH modelling, they aimed to reveal the relationship between commodity and stock markets in South Africa. Additionally, they measured the optimal portfolio weight, hedge ratio, and hedge effectiveness for asset pairs - oil-stock and gold-stock. Their findings indicated significant volatility transfer between gold-stock and oil-stock markets. This underscores the vital connection between commodity and stock markets, crucial for portfolio management. The study suggested combining gold and stocks as an effective strategy for hedging against stock risk, especially during financial crises.

Giovannetti and Velucchi (2013) examined links among established financial markets like the US and UK, China, emerging markets in South Saharan Africa, and North African countries from 2005 to 2012. They focused on how market volatility impacts these connections. Using a Multiplicative Error Fully Interdependent Model, they studied how volatility moves across markets and affects their interactions. The findings indicated that South Africa and the US significantly influence African financial markets, while China's influence is growing. It also highlighted that while the US, Kenya, and Tunisia tend to create volatility effects, South Africa and China absorb them.

Besides, Ncube et al. (2012) looked into how unexpected changes in United States bond yields, tightening of the federal funds rate, and monetary stimulus shocks affect South Africa's economy using structural VAR models. The study revealed that US monetary stimulus shocks resulted in weak consumer price inflation, rand-dollar appreciation, revaluation of real stock prices, lower bond yields, decreased monetary aggregates, and real interest rate drops in South Africa. Despite limited evidence from the trade channel, the findings aligned with predictions of a small open economy Mundell-Fleming model. Also, unanticipated positive medium-term US bond yield shocks led to rand-dollar depreciation and higher bond yields. These shocks also triggered significant declines in real stock prices, reflecting portfolio shifts driven by changes in US bond yields.

Furthermore, Emenike (2021) argued that, in Africa, a few studies have shown how shocks and volatility move between African and global stock markets, offering insights into risk management strategies like hedging and diversifying portfolios. However, our understanding of how volatility works specifically for sovereign bonds between African countries is still limited due to a lack of evidence. According to the study, the existing research on African sovereign bonds tends to centre on phenomena like investor behaviour in African debt markets, often driven by the appeal of high returns and managing debt risks.

Overall, the review showed that researchers have employed diverse methods to examine the complex interplay between various financial markets, exploring topics such as how global shocks impact stock markets and the links between government bonds in developing nations. The studies underscore the profound significance of these connections, and offer insights into the transmission of volatility, the influence of monetary policies, and strategies for effective risk management in today's highly interconnected financial landscape. Simply, it highlights diverse connections, from short-term spillovers to policy influences, aiding researchers, regulators, and investors. In essence, this body of work reveals the vital role these relationships play in shaping the world of finance.

However, it appears that while the review provides insights into African sovereign bond markets, there's room for in-depth analysis focusing specifically on different African regions or countries. It suggests exploring how the dynamics vary across various African economies, given their unique economic conditions and exposure to global shocks. Also, the review shows a potential gap in analysing the relationship between long term interest rate and many African markets, including Ethiopia and South Africa. So, it is worthy to investigate how changes in global long-term interest rates impact African sovereign bond yields. It also implies to consider conducting a comparative analysis across different emerging markets beyond Africa to understand how African sovereign bond markets differ or resemble others in terms of volatility and spillover effects.

Given that the literature review spans different time periods, it is vital to consider focusing on a specific time frame or updating the analysis with more recent data to capture any evolving trends or shifts in the relationship between African sovereign bonds and global interest rates. Moreover, the review suggests the presence of a potential research gap in investigating the specific risk factors that affect African sovereign bond markets, such as political instability, currency risk, and commodity price fluctuations. Understanding how these factors interact with global interest rates can provide a comprehensive view of market dynamics. Given these gaps in the literature shading light to future researches on the subject, this study intends to focus in providing insights into the dynamics of African sovereign bond markets and their relationship with global long-term interest rates. We believe the research has the potential to inform policymakers, investors, and financial institutions operating in the region.

2. Research Methodology

2.1. Multivariate Generalized Autoregressive Conditional Heteroskedasticity (MGARCH) Models

Studies have pointed out that returns on financial assets often show patterns of clustered volatility, where moments of change vary over time (Fama, 1965). This has led to the development of Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models to capture these features in financial data. Researchers working in financial markets have extensively used multivariate GARCH models and their variations to understand these complexities (Li and Giles, 2015). Additionally, a substantial body of literature suggests that one of the most prevalent analytical methods for examining the transmission or spillover of volatilities in financial returns is MGARCH modelling. Given this, the present study fits two variants of MGARCH models: the Constant Conditional Correlation (CCC) Model and the Dynamic Conditional Correlation (DCC) Model. In practical terms, this research explores both the effects of mean and volatility spillovers.

Constant Conditional Correlation (CCC) Model

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

$$H_t = D_t R D_t = \rho_{ij}\sqrt{h_{ii,t}h_{jj,t}} \qquad (1)$$

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:

$$h_{ii,t} = c_i + a_i\varepsilon_{i,t-1}^2 + b_i h_{ii,t-1} \qquad (2)$$

$$h_{ij,t} = \rho_{ij}\sqrt{h_{ii,t}h_{jj,t}} \ \ , i, j = 1 \dots \dots n, \qquad (3)$$

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

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:

$$H_t = D_t R_t D_t\ , \qquad (4)$$

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

$$D_t = diag\ (h_{11,t}^{1/2}, \dots, h_{44,t}^{1/2}) \qquad (5)$$

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

$$R_t = diag\ (q_{11,t}^{-\frac{1}{2}}, \ \dots\ ,\ h_{44,t}^{-1/2}) Q_t diag\ (q_{11,t}^{-\frac{1}{2}}, \dots\ ,\ h_{44,t}^{-1/2}) \qquad (6)$$

The systematic positive definite matrix Q_t is denoted as:

$$Q_t = (1 - \theta_1 - \theta_2)\bar{Q} + \theta_1(\varphi_{t-1}\varphi_{t-1}') + \theta_2 Q_{t-1} \qquad (7)$$

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

$$\rho_{ij,t} = \frac{q_{ij,t}}{\sqrt{q_{ii,t}q_{jj,t}}} \qquad (8)$$

2.2. Data, Estimation and Testing Approaches

The research employs a dataset of weekly time series spanning from 2014 to 2022, encompassing sovereign bond price indices for both Ethiopia and South Africa. It also includes data from the developed market, featuring the US Treasury's 10-year bill rates compared to the 3-month bill's rate, acts as a proxy for the global long-term interest rate. Utilizing these bond price indices for Ethiopia and South Africa, the study calculates the weekly returns by measuring the difference in the logarithms of consecutive bond price indexes, as illustrated below:

$$r_{i,t} = \ln(P_{i,t}/P_{i,t} - 1) \times 100 \tag{9}$$

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 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.

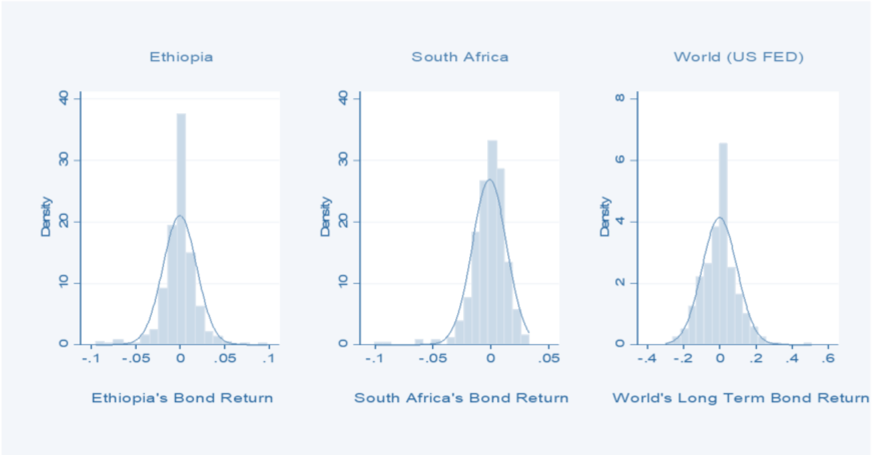
Table 1. Descriptive statistics for each weekly sovereign bond return series

Measures	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

Source: Author's computation using Stata 14

Besides, Figure 1 reveals that all return series display a leptokurtic distribution with a higher peak and a fatter tail than is the case in a normal distribution. That means, the centre of the histogram has a high peak and the tails are relatively heavy compared to the normal distribution (Figure 1), which is common in financial data. It affirms that our data is suitable in capturing volatility.

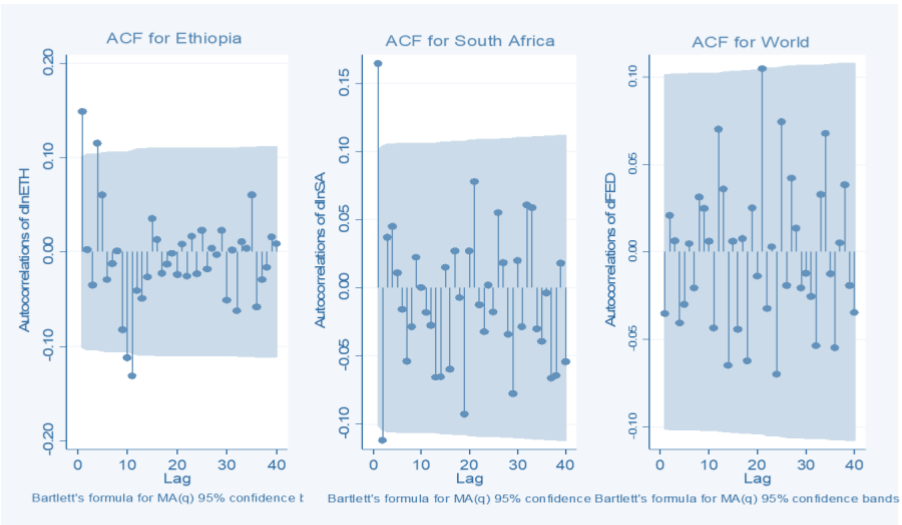
Figure 1. Histograms of time series of bonds' returns



Source: Author's analysis using Stata 14

The analysis of autocorrelation functions (ACF) in conjunction with the Portmanteau test indicates that there is no significant autocorrelation present in the series of returns (figure 2). This confirms the independence of residuals in MGARCH models, which is important for reliable parameter estimation in our study. Thus, our model can more efficiently estimate the conditional variances and covariance of the returns.

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



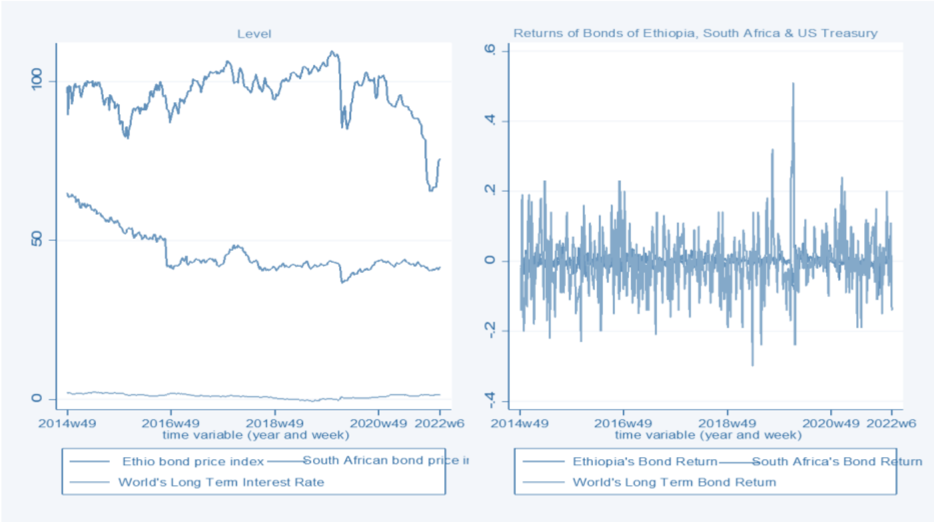
Source: Author's analysis using Stata 14

3. Results and Discussions

3.1. Stationarity and Visual Inspection of Volatility

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

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



Source: Author's analysis using Stata 14

Then after, stationary 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 (see Table 2).

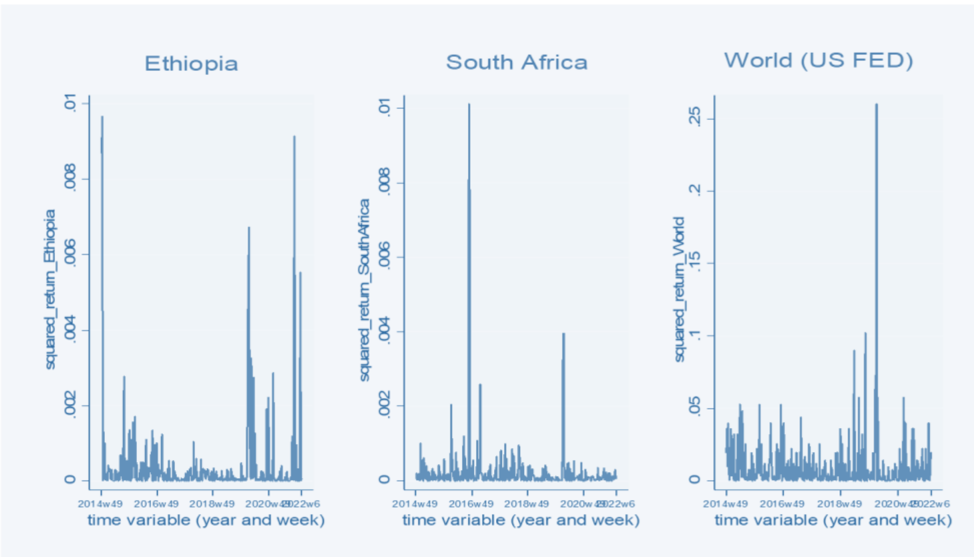
Table 2. ADF and PP test results for unit root test; Number of observations = 372

	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			

Source: Author's computation using Stata 14

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 heteroscedasticity (GARCH) models.

Figure 4. Time series plot of squared weekly returns



Source: Author's analysis using Stata 14

3.2. Model Estimation and Adequacy

The empirical analysis focuses on two multivariate GARCH (MGARCH) models to examine the volatility dynamics between bond returns of the modelled 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).

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. 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.

Moreover, Wald test of model's fitness 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 chi^2	Prob > chi^2
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

Source: Author's computation using Stata 14

Finally, the study has made comparison of the models' performance in capturing the data and subject of analysis. Thus, the Akaike's Information Criterion (AIC), Bayesian Information Criterion (BIC) and likelihood ratio (LR) 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 and 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 (Assumption: model_2 nested in model_4)	LR chi(2)	Prob > chi2
	6.18	0.0456

Source: Author's computation using Stata 14

The Likelihood-ratio test rejects the restrictions imposed by the Constant Conditional Correlation (CCC) and favours 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.

3.3. Examining Volatility and Spillovers in Returns

Although all models are suitable to analyse the volatility spillovers across sovereign bond markets of Ethiopia and South Africa, and the world's long term bond return (uses the US's long term Treasury bill rate), as mentioned above, we base our analysis and interpretation using the MGARCH DCC (with student-t (7) errors) model results. Results of the mean equations and variance equations are presented below in Table 5 and Table 6, respectively.

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

Variable[2]	DCC (Model_4)			CCC (Model_2)		
	Coefficient	Z	P > |z|	Coefficient	Z	P > |z|
Ethiopia's return mean equation						
ETH, L_1	.1227501**	2.30	0.022	.1217694	2.23	0.026
ETH, L_2	-.0016628	-0.04	0.971	.007088	0.15	0.877
SA, L_1	.0732718	1.44	0.151	.0845238	1.64	0.998
SA, L_2	.0182976	0.39	0.694	.0187126	0.40	0.690
FED, L_1	-.0218435*	-3.12	0.002	-.020485	-2.88	0.004
FED, L_2	-.0046349	-0.67	0.502	-.0056542	-0.82	0.415
South Africa's return mean equation						
ETH, L_1	.0261615	0.73	0.465	.0206438	0.57	0.567
ETH, L_2	.1012856 *	2.96	0.003	.0969134	2.82	0.005
SA, L_1	.0951501***	1.77	0.077	.0853662	1.56	0.118
SA, L_2	-.1670312*	-3.29	0.001	-.1748952	-3.41	0.001
FED, L_1	.0002669	0.04	0.969	.0008169	0.12	0.906
FED, L_2	-.0044552	-0.68	0.498	-.0030271	-0.45	0.650
Global long-term interest mean equation						
ETH, L_1	-.0096842	-0.04	0.971	-.0445662	-0.17	0.867
ETH, L_2	-.0698357	-0.27	0.789	-.0811958	-0.31	0.755
SA, L_1	-.2660836	-0.71	0.475	-.2908198	-0.78	0.438
SA, L_2	.6604246***	1.90	0.057	.6704928	1.93	0.054
FED, L_1	-.1083416**	-2.00	0.046	-.0959762	-1.76	0.079
FED, L_2	.0383531	0.76	0.445	.0438833	0.87	0.383

Source: Author's computation using Stata 14. Note: *, ** and*** refers to 1%, 5% and 10% significance levels, respectively.

Looking at the mean equation of Ethiopia's sovereign bond return, the lagged return of Ethiopia in the first period has a statistically significant coefficient at a 5% level. This indicates that an increase in the lagged return of Ethiopia in the previous period is associated with an increase in its mean return. The lagged return of Ethiopia's mean return in the second period has a negative, but statistically insignificant coefficient. Again, the coefficients of South Africa in both the first and second lags are not statistically significant, indicating that the lagged returns of South Africa in these periods do not significantly affect Ethiopia's mean return. The lagged U.S. long-term interest rates in the first period is statistically significant at 1% level, with a negative coefficient, which suggests that an increase in the lagged U.S. long-term interest rate in the first period leads to a decrease in the mean return of Ethiopia. And, the second lagged value's coefficient is not statistically significant. This suggests a potential negative impact of rising U.S. interest rates on Ethiopia's bond market returns. That means, there is a negative return spillover from the U.S.'s Treasury bond market to Ethiopia's sovereign bond market.

[2] ETH means Ethiopia, SA means South Africa and FED refers to US long term interest rate.

Focusing on South Africa's mean equation, coefficient of the first lag of Ethiopia's return is not statistically significant, while the second lagged value is statistically significant at the 1% level. This would imply that an increase in the lagged return of Ethiopia in the second period is associated with an increase in the current return for South Africa. South Africa's first and second lagged values are statistically significant at 10 % and 1% level, respectively. An increase in the first and second-lagged returns of South Africa bring about an increase and a decrease in its current return, respectively. Both FED's coefficients are statistically insignificant. So, 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. The significant negative coefficient for lagged return of South Africa suggests that negative returns in South Africa in the second period are associated with decreased returns in South Africa's current return. This could indicate a persistence in negative market sentiment.

Finally, in the world's long term Treasury bill return mean equation, none of these lagged returns or variables representing Ethiopia and South Africa are statistically significant, except the second-lag of South Africa. While the effect of the second lagged value is not strong, FED's first lag is statistically significant at the 5% level, with a negative coefficient, and this suggest that an increase in the lagged U.S. long-term interest rate in the first period is associated with a decrease in its mean return. And, the U.S. long term Treasury bond return, the estimated coefficients on the second-lag of South Africa is statistically significant.

Hence, the results suggest a unidirectional spillover from South Africa's financial market to U.S. long term Treasury market, and from the U.S. to Ethiopia's market and from Ethiopia's to South Africa' market. But we do not find a bidirectional return spillover in the markets. In conclusion, our research shows some dependencies between the bond markets of Ethiopia, South Africa, and global long-term interest rates. Changes in U.S. long-term interest rates can significantly impact Ethiopia's sovereign bond markets, while we have weak evidence of effect of change in the U.S. long-term interest rates on South Africa's market.

In Ethiopia's return variance equation (Table 6), the ARCH effect is statistically significant at 1% level of significance and it is positive. This indicates that the squared residual (volatility) of Ethiopia's return from the previous period (lag 1) positively impacts its own conditional variance. In other words, high volatility in the past leads to higher volatility in the current period. Also, 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. In South Africa's variance equation, first lag values ARCH effect has a positive and statistically significant coefficient at 5% significance level. This suggests that the squared residual (volatility) of South Africa's return from the previous period (lag 1) has a positive impact on its own conditional variance. South Africa has no statistically significant GARCH effect. In the variance equation of the global long term interest rate, none of the coefficients for squared residuals are statistically significant.

Examining the cross-correlation and adjustments, the correlation coefficient between Ethiopia and South Africa is statistically significant at 1% significance level, while it is insignificant for Ethiopia and FED, and for South Africa and FED. Both adjustment parameters, lambda 1 and lambda 2 are statistically significant, indicating their importance in capturing the dynamic correlations between the variables.

The ARCH term that captures the past shock effect of the markets are significant in Ethiopia and South Africa. This signals the existence of persistence in short-term volatility in the two African markets. The sum of ARCH and GARCH terms is very close to unity for both Ethiopia and South Africa, which supports existence of high volatility persistence in the markets. This finding suggests that investors in the financial markets of both countries remember shocks that happened some time ago and that the effects of the shocks on volatility last for a long time in these markets. Also, in Ethiopia, there exists long-term volatility persistence effects its bond return, while no indication 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.

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

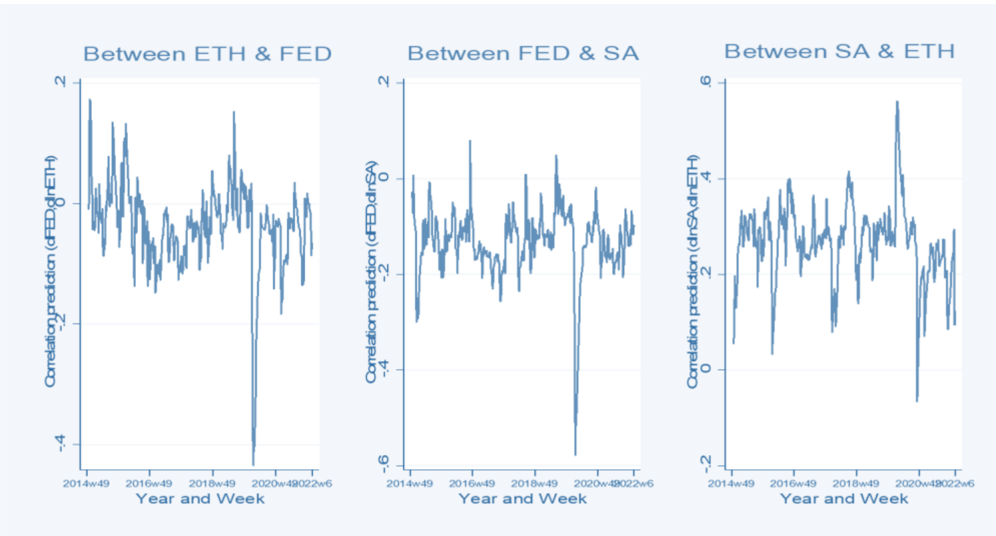
Variable	DCC (Model 4)			CCC (Model 2)		
	Coefficient	Z	P > |z|	Coefficient	z	P > |z|
Ethiopia's return variance equation						
ARCH_ETH, ARCH L1	.1950348*	3.46	0.001	.208959	3.50	0.000
ARCH_ETH, GARCH L1	.0840509	0.79	0.430	.0837629	0.79	0.430
ARCH_ETH, GARCH L2	.6180737*	5.45	0.000	.602386	5.25	0.000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

Source: Author's computation using Stata 14. Note: *, ** and*** refers to 1%, 5% and 10% significance levels, respectively.

Overall, the findings suggest the existence of strong correlation between Ethiopia's and South Africa's markets, indicating that choosing between Ethiopia 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. These correlations could be driven by factors like regional economic events, trade relationships, or similar market dynamics. 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. This would imply that they are less integrated with world's markets, and thus appear to be less susceptible to international shocks outside of the continent. As such, they provide more portfolio diversification opportunities to international investors who are thinking of investing on financial assets in Africa.

Finally, we presented the time-varying conditional correlation predictions in returns from the DCC model (Figure 5). We have seen that the 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.

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



Source: Author's analysis using Stata 14

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, which corresponds to the Covid-19 pandemic.

The choice of the sample period for the study allowed 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).

Conclusions

This paper investigates weather there is market volatility and spillover effects between the world's long term interest rate, and Ethiopia and South Africa's sovereign bond markets return. Results of the DCC MGARCH model 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 an indication of the existence of a unidirectional return spillover from Ethiopia's to South Africa's 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. Moreover, the results reveal that sovereign bond yields in Ethiopia responded significantly to changes to the United States. This is due to the existence of a negative significant shocks and volatility spillovers from the world's long-term bill market to Ethiopia's sovereign bond market. Thus, we can conclude that the world long term interest rate has an influential impact on the Ethiopian government sovereign bond return movement.

In terms of policy considerations, the paper highlights the need for financial policymakers in Africa to be cautious about the potential impact of spillovers in both average returns and volatility within their sovereign bond markets. The findings point to varying effects of volatility spillovers from the US to Ethiopia and South Africa. Specifically, Ethiopia experiences one-way shock spillovers to its bond market from the global market, while South Africa doesn't exhibit the same effect. Even when examining the negative shocks on Ethiopia separately, the one-way spillover persists significantly in both the short and long term. It is observed that volatility in the African economies' sovereign bond markets is largely influenced by their own unique shocks and volatilities.

Therefore, financial institutions, investors, and policymakers should take into account the potential for volatility clustering and the interdependencies between different assets or markets when making investment decisions or designing risk management strategies. Policy makers and investors in Ethiopia and South Africa should closely monitor events in both countries. Developments in one country's financial markets could have spillover effects on the other, impacting investment decisions and policy formulation. Given the interdependencies between Ethiopia and South Africa, policymakers should consider strengthening economic and trade partnerships. Collaborative efforts could lead to more stable economic conditions and reduced exposure to external shocks.

Finally, the results underline the role of African financial policymakers taking into account the individual realities and responses of their economies to global interest rate volatilities. Adopting a single financial policy approach from one African nation to another isn't advisable. Despite certain shared characteristics among African economies and underdeveloped financial markets, a universal intervention strategy might not be suitable. It is, therefore, important to tailor the recommendations to the specific economic and financial context of each country.

Credit Authorship Contribution Statement:

The author takes the sole credit for writing the paper, and drafting and modelling the theory, as to conceiving the idea of the paper, thus having played the full part in conducting the entire research.

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Conflict of Interest Statement

The research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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