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Methodological insights regarding the impact of COVID-19 dataset on stock market performance in African countries: A computational analysis

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Abstract — This research aims to evaluate the impact of the COVID-19 pandemic on stock markets in Africa. The study analyzes the stock market returns in nine selected African countries (South Africa, Morocco, Tunisia, Botswana, Nigeria, Uganda, Kenya, Mauritius, and Tanzania) before, during, and after the COVID-19 pandemic. We investigate the impact of COVID-19 on stock market returns and the effect of the worst-hit country's volatility on other African countries' stock market returns utilizing autoregressive conditional heteroscedasticity (ARCH), generalized ARCH (GARCH), and threshold ARCH (TARCH) tests. Additionally, we explore the implications for foreign investors in terms of portfolio diversification and risk management, contributing to the existing literature on the effects of the COVID-19 crisis on financial markets and investment risk. Thereby, we provide insights into African stock markets' interconnectedness and help foreign investors reduce their losses and manage risks associated with the COVID-19 pandemic. Finally, we discuss the need for further research.

Keywords: *Stock market, autoregressive conditional heteroscedasticity (ARCH), generalized ARCH (GARCH), threshold ARCH (TARCH), correlation matrices*

Subject Classification (2020): 62P20, 62P25

1. Introduction

There have been several studies on the impact of COVID-19 on the financial market. Studies have shown that COVID-19 has had a negative effect on stock markets across various countries, sectors, and emerging markets. Some studies have also shown that investor sentiment and country governance play a role in the volatility of stock markets during the pandemic. Other studies have shown that the COVID-19 pandemic has affected the financial markets in developed countries like the US, UK, Spain, Italy, France, and Germany, leading to deviations from market efficiency. The pandemic has disrupted global value chain production and caused investment decision delays. The financial system has also been strained by declining revenue and rising unemployment. The stock market holds immense significance in the financial world and plays a pivotal role in shaping investment decisions. Hence, analyzing the stock market's response to economic upheavals is crucial for gaining valuable insights. The COVID-19 pandemic has had a significant impact on economic indicators and financial markets around the world. While there has been a lot of research on the effects of the pandemic

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on developed countries and technologically advanced markets, there has been relatively little research on the impact on African countries. This study aims to fill this gap by examining the effects of the pandemic on the stock market returns in African countries.

Paul and Isaac [1] explored the impact of COVID-19 on stock market performance in thirteen African countries using a Bayesian structural time series approach. They found that COVID-19 had a major negative impact on the stock markets of ten countries while having no significant or temporary negative impact on the remaining three countries. The study concludes that there is no possibility of COVID-19 having a favorable effect on the performance of the African stock market during the sample period. According to a study by Ashraf [2], an increase in COVID-19 cases negatively affects the stock market performance across 64 countries, while there is little evidence to suggest that COVID-19 fatalities have a similar impact. Raifu et al. [3] found that lockdown policies and global COVID-19 cases and deaths negatively impacted Nigerian stock market returns more than local cases and deaths. The study also found that the effects of COVID-19 on stock returns swing between negative and positive before converging to equilibrium over the long term. However, important research questions remain, such as the economic impacts of national policy responses on the global stock market and how the stock market reacts differently to various policy types.

The literature review outlines the impact of the COVID-19 pandemic on the stock market in African countries. Research suggests that the measures taken to control the spread of the virus, such as travel restrictions, social exclusion, and economic lockdowns, have resulted in a significant socioeconomic cost in African countries. The study of the effect of COVID-19 on Ghana, Nigeria, and African economies showed a decline in GDP, an increase in poverty, and a loss of valuations in different sectors, with some industries potentially losing up to 60% of their worth. The UN Economic Commission for Africa reported instability in the regional economy and a slow recovery. The study highlights the need for structural reforms and diversifying the industrial base to make economies more resilient and reduce their reliance on primary commodities.

In addition, a vast body of literature has examined the response of stock markets during the pandemic. Alam et al. [4] found that the COVID-19 pandemic had a significant negative impact on the stock market in Bangladesh, as shown through their event study analysis of 55 companies listed on the Dhaka Stock Exchange. The study highlights the importance of policymakers implementing risk management strategies and providing liquidity support to companies to stabilize the stock market during crises. The pandemic resulted in an important decline in stock prices during the pandemic period, highlighting the need for policymakers to implement effective risk management strategies and provide liquidity support to stabilize the stock market during crises. The effect that the COVID-19 outbreak would have on the financial and stock markets is a major worry of financial experts and speculators, like the 2007–2009 Global Recession. A pandemic like COVID-19 referred to as a Black Swan event, might shock, frighten, and worry both domestic and foreign investors and trigger a rapid panic-selling reaction [5].

Furthermore, the general drop within the worldwide economy and budgetary markets has become an urgent concern for financial specialists concerning portfolio or risk and loss exposures. The impact of the novel COVID-19 epidemic on the interdependence of the financial market remains unclassified. Kayanula and Tumwebaze [6] look at the early evidence of the consequences of the pandemic on African stock markets, including market instability and price decreases. They also investigate potential affecting factors, such as investor sentiment, policy reactions, and industry variances. The report emphasizes the need for additional research to better understand the pandemic's long-term consequences on African stock markets and the broader economy.

While globalization is still being debated, the sad COVID-19 situation offered us a rare chance to assess how a sudden and terrifying sickness would affect the economies of impacted countries. China was the country where the COVID-19 virus initially surfaced and had a significant impact on its stock market. Due to the extent and level of economic interdependence in the modern world, changes in the Chinese stock market may impact other markets, leading to this study. It significantly adds to the knowledge of market correlations and the underlying investment strategy. Other research has revealed a weak relationship between African developing equities markets, leading some to believe they should still be treated separately [7- 9]. Andam et al. [10] used a multiplier model based on the 2018 Social Accounting Matrix for Nigeria to analyze the effects of the COVID-19 pandemic on the Nigerian economy. The study focused on the five-week lockdown imposed by the federal government in several states and estimated a loss of USD 16 billion, equivalent to 34.1% of Nigeria's GDP during the lockdown period. The services sector accounted for two-thirds of the losses, while the agriculture sector saw output decline by 13.1% (USD 1.2 billion). The study also found that the economic effects of COVID-19 resulted in a sudden 14 percentage point increase in Nigeria's poverty headcount rate, indicating that 27 million more people slipped into poverty during the lockdown. Volatility serves as a gauge of financial risk and uncertainty in operating financial markets. Financial sector regulators, mutual fund managers, individual investors, and legislators have a keen interest in volatility since it is essential to evaluate the level of uncertainty around investments in financial assets. Researchers have tried to prove a connection between the COVID-19 outbreak and the financial market's turbulence. The research focused on the financial market's effects of the COVID-19 epidemic. Evidence from various academic works demonstrates that COVID-19's impact on the financial markets is severe compared to other crises that have occurred in the past [11,12]. Baker et al. [11] tried to determine how the pandemic will affect stock market volatility. According to the report, the main causes of increased volatility are government limits on consumer freedom and economic activities. Zoungrana et al. [13] reported that rather than confirmed cases, the weekly death cases were the primary informational factor that caused a market disturbance. Finally, Investment opportunities assist investors, African firms, and entrepreneurs by enabling them to access finance to expand the continent's economies. However, significant issues remain, such as differences in economic development levels, a lack of a uniform regulatory framework, inconsistent accounting standards, etc.

The chosen stock exchange markets are advised to establish an efficient regulatory framework, expand and modernize their stock markets, and integrate them with those of other African nations. Shapiro-Wilk Test was used for the normality test. It tests the null hypothesis that a sample comes from a normally distributed population [14]. Sin and White [15] investigate different models to explain intraday return volatility in the stock market. It assesses the performance and suitability of various econometric models in capturing the characteristics of intraday volatility. Brooks [16] comprehensively introduces econometric techniques and their application in finance. It covers fundamental concepts, various econometric models, and practical applications, making it a valuable resource for students and practitioners in finance. Nelson [17] introduces the exponential generalized autoregressive conditional heteroscedasticity (EGARCH) model, which improves upon traditional generalized autoregressive conditional heteroscedasticity (GARCH) models by allowing for asymmetric effects of shocks on volatility. This paper is a seminal work in the field of volatility modeling. Glosten et al. [18] present the GJR-GARCH model, which incorporates leverage effects in modeling stock return volatility. The authors find a significant relationship between expected returns and volatility. Zakoian [19] introduces the threshold GARCH (TGARCH) model, which allows for different levels of volatility depending on the size and direction of past shocks. This model captures the threshold effects in financial time series. Bollerslev [20] develops the GARCH model, extending Engle's ARCH model by incorporating lagged conditional variances. The GARCH model has become a fundamental tool in modeling financial time series volatility. Engle [21] introduces the autoregressive conditional heteroscedasticity (ARCH) model, which models time-varying volatility in financial time series. This pioneering work laid the foundation for subsequent developments in volatility modeling. Engle and Ng [22] investigate how news impacts stock market volatility using the ARCH framework. The authors propose tests to measure the effect of news on volatility, providing insights into market reactions. Black [23] examines the changes in stock price volatility, highlighting the importance of understanding volatility dynamics for financial modeling and risk management. Bollerslev et al. [24] extensively review ARCH models, their extensions, and applications in econometrics. It is a comprehensive resource for understanding the development and implementation of these models. Zhang et al. [25] investigate the impact of the COVID-19 pandemic on global financial markets. The authors use various econometric models to analyze market reactions and volatility during the pandemic.

EGARCH and TARCH are both extensions of the GARCH model, used for modeling and forecasting financial time series with time-varying volatility. Each model addresses specific characteristics of financial data, such as asymmetry and leverage effects.

Significances of existing literature are as follows: Paul and Isaac [1]: COVID-19 had a major negative impact on the stock markets of ten African countries and no significant or temporary negative impact on the remaining three. Ashraf [2]: An increase in COVID-19 cases negatively affected stock market performance across 64 countries, but COVID-19 fatalities had little impact. Raifu et al. [3]: Lockdown policies and global COVID-19 cases and deaths negatively impacted Nigerian stock market returns more than local cases and deaths. Alam et al. [4]: The COVID-19 pandemic had a significant negative impact on the stock market in Bangladesh. He et al. [5]: COVID-19 caused a rapid panic-selling reaction in financial and stock markets, like the 2007–2009 Global Recession. Kayanula and Tumwebaze [6]: The pandemic led to market instability and price decreases in African stock markets, influenced by investor sentiment and policy reactions. Boako and Alagidede [7- 9]: The study highlights weak correlations between African developing equity markets and suggests they should be treated separately. Andam et al. [10]: The five-week lockdown in Nigeria caused a loss of USD 16 billion (34.1% of GDP) and increased the poverty headcount rate by 14 percentage points. Baker et al. [11]: Government restrictions on consumer freedom and economic activities were the main causes of increased stock market volatility during COVID-19. Zoungrana et al. [13]: Weekly death cases from COVID-19, rather than confirmed cases, were the primary factor causing market disturbances.

The EGARCH model, introduced by Nelson, captures the asymmetry and leverage effects often observed in financial time series, where negative shocks tend to increase volatility more than positive shocks of the same magnitude. The key feature of the EGARCH model is that it models the logarithm of the conditional variance, ensuring that the variance is always positive without imposing non-negativity constraints on the parameters.

The TARCH model, introduced by Zakoian [19] and Glosten et al. [18], also captures the asymmetry in volatility but does so differently than the EGARCH model. It allows for different responses to positive and negative shocks by incorporating a threshold term.

In practice, these models are used extensively in risk management, option pricing, and financial econometrics to capture the dynamic nature of volatility and improve the accuracy of volatility forecasts. Selecting between EGARCH and TARCH typically depends on the data's specific characteristics and the analysis's requirements.

During the COVID-19 crisis, financial markets experienced unprecedented volatility, which had significant implications for foreign investors regarding portfolio diversification and risk management – understanding how models like EGARCH and TARCH can help in this context.

Portfolio Diversification and its Volatility and Correlation: The COVID-19 crisis caused dramatic spikes in volatility across global markets, often accompanied by increased correlations between assets. This phenomenon, known as "contagion," can undermine the benefits of diversification. Typically, foreign investors diversify their portfolios across different asset classes and geographic regions to reduce risk. However, during periods of extreme market stress, correlations can rise, reducing the effectiveness of diversification strategies.

For portfolio diversification, the EGARCH model can help capture the asymmetric volatility dynamics, particularly useful during crises when negative news tends to increase volatility more than positive news. By understanding these dynamics, investors can adjust their portfolios to mitigate risks associated with adverse market movements.

The TARCH model helps identify how negative shocks (like bad news related to the pandemic) disproportionately affect volatility compared to positive shocks. This information is valuable for investors looking to rebalance their portfolios during periods of heightened market sensitivity.

In strategic Adjustments, investors can use these models to predict future volatility and adjust their portfolio weights accordingly, potentially increasing allocations to less correlated assets or hedging instruments during times of high market stress. By understanding the changing risk profiles, investors might reduce exposure to highly volatile markets or sectors and seek more stable investments.

In risk management, EGARCH and TARCH models provide more accurate volatility forecasts by accounting for asymmetries and leverage effects in financial returns. These models can offer early warnings of increased risk, allowing investors to take preemptive actions to protect their portfolios.

In summary, during the COVID-19 crisis, the EGARCH and TARCH models provided foreign investors with critical tools for managing increased market volatility and correlation. These models facilitated better portfolio diversification and risk management by offering insights into volatility dynamics, enabling more effective strategic adjustments, and supporting sophisticated hedging and risk mitigation strategies. In what follows the study is organized into the following sections: Section 1 discusses the introduction, overview of methods to be used, and detailed recent related work. Section 2 describes the data used for the research, considering the duration of the effect of COVID-19. It also contains the details of the model used in simulating the effect of COVID-19 on the African countries' stock market. The results of these effects on the African countries' stock market and their discussion were presented in Section while Section 4 details the conclusion, limitations and recommendations.

2. Data

This study uses daily data that covers the period from October 2019 to October 2022. The daily data of stock prices of 9 African countries are sourced from investing.com. For this research, the pre-COVID-19 case started on 1 October 2019 and continued until 28 February 2020. The heated period begins after the first month of African countries' contact with the virus, typically in March, and lasts until August 2020, following the lockdown period. The post period, which is the recovery period, starts from September 2020. The new coronavirus has so far been blamed for at least 12,423,000 confirmed infections and 256,000 recorded fatalities in Africa [26].

Table 1. Country, stock exchange, and COVID-19 statistics table

S/N	Country	Stock Price Index	First Case	Total Cases	Total Deaths
1	Nigeria	NSE All Share	28-Feb-20	258 934	3 144
2	Tanzania	Tanzania All Share	16-Mar-20	37 510	841
3	South Africa	South Africa Top40	5-Mar-20	3 999 345	101 915
4	Kenya	NSE 20	13-Mar-20	336 445	5 668
5	Uganda	Uganda All Share	21-Mar-20	167 503	3 626
6	Morocco	Moroccan All Shares	2-Mar-20	1 246 835	16 167
7	Tunisia	TUNINDEX	4-Mar-20	1 087 030	28 823
8	Mauritius	SEMDEX	18-Mar-20	61 390	986
9	Botswana	BSE Domestic Company	30-Mar-20	323 347	2 760

Table 1 shows nine randomly selected countries for further analysis, accounting for the average of the total cases and deaths recorded in Africa. The table lists the names of the stock exchanges in each African nation, the total number of COVID-19 confirmed cases and fatalities, and the day the virus's first case was identified. Moreover, the nine observations from Africa are recorded, including the first cases recorded, the first case was in February.

2.1. Empirical Econometric Model

This study uses a variety of data analysis methods obtained from [16], including generalized autoregressive conditional heteroscedasticity (GARCH), Autoregressive conditional heteroscedasticity (ARCH) tests, Threshold ARCH (TARCH) models, correlation matrices, and descriptive statistics. The correlation matrix was chosen to understand the linear relationships between multiple variables over specific dates. This method provides a straightforward measure of how closely related different variables are, which is crucial for identifying potential multicollinearity issues and understanding the interdependencies in the dataset.

We can initially dismiss the data with the aid of descriptive statistics analysis. The correlation matrix displays the historical correlation between several stock indices. Finally, we conduct the ARCH test, the first presumption to run the ARCH family models, to meet the study's goal. We can deploy ARCH family models to the analysis if this assumption is true. We chose the GARCH because, particularly in financial applications, the ARCH and GARCH models have grown in importance as time series data analysis tools. When forecasting and analyzing volatility is the study's main objective, these models are very helpful.

The ARCH autoregressive model is estimated as follows:

$$X_t = e_t\sigma_t\sigma_t^2 = \omega + \alpha_1\chi_{t-1}^2 + \cdots + \alpha_\rho\chi_{t-\rho}^2$$

The GARCH (1,1) model is estimated as follows:

$$X_t = e_t\sigma_t$$
$$\sigma_t^2 = \omega + \alpha_1\chi_{t-1}^2 + \cdots + \alpha_\rho\chi_{t-\rho}^2 + \beta_1\sigma_{t-1}^2 + \cdots + \beta_q\sigma_{t-q}^2$$

In the GARCH (1,1) model, each term can be defined as follows:

X_t =The observed time series data at time t, often representing financial returns or other economic variables.

e_t = The error term or innovation at time t, which is assumed to be independently and identically distributed with zero mean and finite variance.

σ_t = The conditional standard deviation or volatility of X_t at time t, which is modeled to capture the time-varying volatility in the data.

σ_t^2 = The conditional variance of X_t at time t, which is the square of the conditional standard deviation σ_t.

ω =The constant term or intercept of the GARCH model, representing the long-term average volatility.

$\alpha_1, \alpha_2, \dots, \alpha_\rho$ are the coefficients associated with the squared-lagged error terms $\chi_{t-1}^2, \chi_{t-2}^2, \dots, \chi_{t-\rho}^2$, where ρ is the order of the ARCH process. These coefficients capture the short-term impact of past squared innovations on the conditional variance.

$\beta_1, \beta_2, \dots, \beta_q$ are the coefficients associated with the lagged conditional variances $\sigma_{t-1}^2, \sigma_{t-2}^2, \dots, \sigma_{t-q}^2$ where q is the order of the GARCH process. These coefficients capture the long-term impact of past conditional variances on the current conditional variance.

The GARCH (1,1) model specifies the conditional variance σ_t^2 as a function of past squared innovations χ_{t-i}^2 and past conditional variances σ_{t-j}^2, where i ranges from 1 to ρ and j ranges from 1 to q. This model allows for short-term and long-term volatility persistence, capturing the conditional variance's autocorrelation structure over time.

3. Results and Discussion

3.1. Results of Descriptive Statistics and Correlation Matrix

The summary statistics of the sample data are described in Tables 2–9. The whole dataset contains 765 observations for each country, and the average value of Tunisia's return is 7068.9, South Africa has 58163.03, Kenya has 1963.06, Mauritius is 1897.69, Moroccan is 11779, Nigeria has 1488.85, Tanzania has 1896.91, Tunisia has 7068.93, Uganda has 1416.27. These are the mean index value stock returns for three years for the selected countries. The results also show that the standard deviation is larger in South Africa, Moroccan, and Tunisia.

Table 2. Full sample descriptive statistics (10 October 2019 to 31 October 2022)

	Botswana	Kenya	Mauritius	Moroccan	Nigeria	South Africa	Tanzania	Tunisia	Uganda
Mean	7096.308	1963.065	1897.7	11779.64	1488.86	58163.054	1896.919	7068.936	1416.27
Median	7098.375	1889.575	1970.67	11955.63	1593.995	60113	1884.85	7048.36	1370.7
Maximum	7608	2766.77	2304.13	13991.47	2065.62	71034	2136.52	8351.17	1861.26
Minimum	6521.68	1563.68	1455.21	8987.89	871.26	36490	1697.65	6116.16	1130.12
Std. Dev	311.2366	267.538	257.499	1176.3665	309.126	6656.3348	90.184	432.233	164.956
Skewness	-0.114	1.61	-0.22567	-0.40823	-0.35593	-0.457	0.544331	0.70999	1.117
Kurtosis	1.952	4.6884	1.423	2.4079	1.745	2.6965	2.6193	3.76103	3.5413
Observation	765	765	765	765	765	765	765	765	765

Table 3. Full sample descriptive statistics of the pre COVID-19 period (10 October 2019 to 28 February 2020)

	Botswana	Kenya	Mauritius	Moroccan	Nigeria	South Africa	Tanzania	Tunisia	Uganda
Mean	7529.164	2589.116	2160.993	12004.048	1166.300	52180.250	2035.376	7015.582	1755.704
Median	7525.99	2608.995	2147.5	12057.7	1136.560	52757.0	2052.635	6993.61	1775.969
Maximum	7608.7	2766.77	2247.73	12633.570	1320.02	54950.0	2130.390	7204.390	1861.26
Minimum	7451.89	2337.03	1895.69	10806.41	1063.97	41631.0	1763.57	6811.72	1531.06
Std. Dev	39.769	94.271	61.096	374.037	82.424	2302.02	74.232	83.906	86.938
Skewness	0.535	-0.673	-1.121	-0.322	0.495	-2.523	-1.317	0.296	-1.395
Kurtosis	2.394	2.755	6.319	2.456	1.957	10.761	4.890	2.505	3.929
Observation	104	104	104	104	104	104	104	104	104

Table 4. Descriptive statistics of the heated COVID-19 period (1 March 2020 to 30 August 2020)

	Botswana	Kenya	Mauritius	Moroccan	Nigeria	South Africa	Tanzania	Tunisia	Uganda
Mean	7294.148	1940.753	9890.02	1031.39	48863.24	1825.42	6525.741	1358.881	1626.03
Median	7275.890	1954.930	10113.990	1044.92	49978.0	1805.22	6574.870	1331.25	1611.91
Maximum	7605.0	2400.56	11339.46	1158.820	54341.0	2079.140	6863.44	1742.29	1885.22
Minimum	7054.03	1723.96	8987.89	871.26	36490.0	1739.63	6116.160	1200.360	1455.210
Std. Dev	180.697	121.712	454.491	64.284	4281.011	84.458	183.696	106.164	71.0
Skewness	0.269	0.758	-0.357	-0.642	-0.868	1.757	-0.40	1.827	0.913
Kurtosis	1.759	5.499	2.602	2.799	3.239	5.085	2.010	6.520	4.332
Observation	123	123	123	123	123	123	123	123	123

Table 5. Descriptive statistics of the post-COVID-19 period (1 September 2020 to 30 October 2022)

	Botswana	Kenya	Mauritius	Moroccan	Nigeria	South Africa	Tanzania	Tunisia	Uganda
Mean	6969.944	1850.938	1910.4349	12170.6952	1654.136	61411.85	1887.53	7203.1	1366.08
Median	6952.07	1866.27	2008.855	12176.11	1682.545	61820	1883.39	7149.74	1358.47
Maximum	7546.49	2066.46	2304.13	13991.47	2065.62	71034	2136.52	8351.17	1607.93
Minimum	6521.68	1563.68	1459.41	9952.63	1079.43	48385	1697.65	6535.74	1130.12
Std. Dev	263.562	101.6553	249.103	952.6838	195.60	4531.869	63.6	411.878	99.24
Skewness	0.0751	-0.35638	-0.4078	-0.3045	-1.017	-0.495	0.209	0.866	0.232
Kurtosis	2.075	2.8989	1.64	2.504	4.423	3.19	2.55	3.461	2.341
Observation	538	538	538	538	538	538	538	538	538

Tables 3 and 4 show the descriptive statistics of sample data during the COVID-19 heated period, including 123 observations. The results show that variations in stock markets during COVID-19 are greater in South Africa. South African stock market is ranked number one in Africa. The rest of the analyses will consider it a factor when comparing the volatility of other stock markets. The worst-hit country will also be considered as a factor.

Table 6. Pairwise correlation coefficient of the full sample COVID-19 (10 October 2019 to 31 October 2022)

	Nigeria	Kenya	Tunisia	Botswana	Mauritius	Uganda	Tanzania	Moroccan	South Africa
Nigeria	1								
Kenya	-0.49641	1							
Tunisia	0.643568	-0.23641	1						
Botswana	-0.3368	0.434233	0.02978	1					
Mauritius	0.491103	0.300599	0.57883	0.435802	1				
Uganda	-0.36179	0.922259	-0.13605	0.230869	0.2972	1			
Tanzania	0.055611	0.6502	0.2618	0.220015	0.571814	0.478461	1		
Moroccan	0.750036	0.061034	0.519677	-0.20089	0.740445	0.201286	0.478461	1	
South Africa	0.864504	-0.40842	0.526411	-0.45745	0.415523	-0.29298	0.03199	0.76287	1

Table 7. Correlation matrix of the sample pre-COVID-19 (10 October 2019 to 28 February 2022)

	Nigeria	Kenya	Tunisia	Botswana	Mauritius	Uganda	Tanzania	Moroccan	South Africa
Nigeria	1								
Kenya	-0.116594	1							
Tunisia	0.478053	-0.22714	1						
Botswana	0.3965564	-0.24162	0.457967	1					
Mauritius	0.63008	0.4974	0.453229	-0.00151	1				
Uganda	0.648458	0.612849	0.205574	0.395602	0.610572	1			
Tanzania	0.649814	0.080153	0.298978	0.58367	0.379097	0.688647	1		
Moroccan	0.762987	0.366405	0.425838	0.121694	0.83279	0.74089	0.593037	1	
South Africa	0.042673	0.596778	0.071378	-0.47389	0.634928	0.200624	-0.16081	0.359268	1

Table 8. Correlation matrix of the sample during COVID-19 (1 March 2020 to 31 August 2020)

	Nigeria	Kenya	Tunisia	Botswana	Mauritius	Uganda	Tanzania	Moroccan	South Africa
Nigeria	1								
Kenya	0.025918	1							
Tunisia	0.586395	-0.59772	1						
Botswana	-0.43224	0.743158	-0.82876	1					
Mauritius	-0.0707954	0.614099	-0.26742	0.32562	1				
Uganda	0.2678	0.823171	-0.41291	0.650801	0.29369	1			
Tanzania	0.163776	0.554833	-0.34382	0.599575	0.0987	0.77539	1		
Moroccan	0.68012	-0.26453	0.755065	-0.62084	-0.07117	-0.08164	0.085077	1	
South Africa	0.260198	-0.78688	0.788153	-0.94184	-0.31487	0.75756	-0.67395	0.512648	1

Table 9. Correlation matrix of the sample post-COVID-19 (1 September 2020 to 31 October 2022)

	Nigeria	Kenya	Tunisia	Botswana	Mauritius	Uganda	Tanzania	Moroccan	South Africa
Nigeria	1								
Kenya	0.21218	1							
Tunisia	0.463177	0.40204	1						
Botswana	0.444266	-0.60718	0.530303	1					
Mauritius	0.827254	-0.12804	0.572886	0.625829	1				
Uganda	-0.23927	0.865614	-0.2253	-0.66847	-0.11476	1			
Tanzania	0.292407	0.497077	0.345989	-0.16512	0.456098	0.635671	1		
Moroccan	0.687401	0.378168	0.184032	0.096942	0.764656	0.344101	0.578451	1	
South Africa	0.707454	0.126737	0.187191	0.125044	0.611444	0.078842	0.416768	0.724827	1

The results of the correlation matrix of the sample countries' stock marks are given in Tables 6–9. The results show that the stock market of South Africa has a strong correlation with Nigeria, Tunisia, Morocco, and Mauritius, in the full sample. It had a negative correlation with Kenya in the full sample but a positive correlation with Kenya in the pre-COVID-19 sample.

3.2. Results of Model Selection (ARCH, GARCH, EGARCH, and TARCH)

Before using the ARCH family models, we validate the dataset's presumptions. Applying ARCH family models has two approaches to test their underlying presumptions. The first one involves utilizing residual plotting to examine the clustered volatility of stock returns. The second confirms the ARCH effect's presence [27].

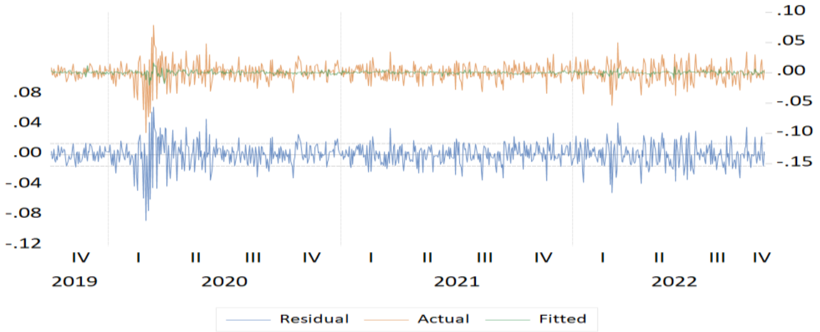

Figure 1. Results of the ARCH effect test

Table 10. Results of diagnostic statistics

F-statistic	447.72922	Prob.F (1,762)		0.000
Obs*R squared	282.761	Prob.Chi-Square (1)		0.000
Included Observation: 764 after adjustments				
Variable	Coefficient	Std.Error	t-Statistic	Prob.
C	8.52E-06	2.78E-06	3.0651777	0.0023
RESID^2(-1)	0.6083635	0.028751164	21.159613	0.000

We apply the ARCH effect test to decide robustness. The statement "There is no ARCH effect" serves as the test's null hypothesis. The results of the ARCH effect test are shown in Figure 1, and the Probability value of observed R squared is less than 0.05, rejecting the null hypothesis and accepting the alternate hypothesis that there is an ARCH effect (Table 10).

We use the model selection method to estimate the right GARCH model. The data rules are common hypotheses of the standard rules based on evaluating the Kullback-Leibler data measure [16]. However, they consider the heteroscedastic concept of the information that more boundaries are evaluated for AR-GARCH models than for AR models.

3.3. Results of GARCH Models

In this subsection, Tunisia and South Africa were chosen as focal points due to their high fatality rates. At the same time, Nigeria was randomly selected from the country's top 5 most robust stocks.

3.3.1. Pre-COVID-19 Period

The model result for the pre-COVID period shows an insignificant impact on the volatility of various stock returns in Africa using South Africa, Tunisia, and Nigeria as dependent variables during estimation and other countries' stock market returns. Only Tunisia significantly impacted the stock returns of Nigeria in Table 11. For that estimation, the GARCH and ARCH are significant.

Table 11. GARCH model test 1

GARCH model results for a pre-COVID period				
Dependent Variable: Nigeria				
Included observations: 104				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	-0.0013	0.0006	-2.0447	0.0409
Variance Equation				
C	0.0000	0.0000	0.8705	0.384
RESID(-1)^2	0.5462	0.2329	2.3449	0.019
GARCH(-1)	0.5938	0.1448	4.0996	0.0000
TUNISIA	-0.0036	0.0017	-2.1196	0.034

3.3.2. During the COVID-19 Period (Heated Period)

Model results for the heated period from Tables 12-20, in which South Africa, Tunisia, and Nigeria were dependent variables and other African stock returns were variance regressors. The results show that ARCH and GARCH terms are significant in the full sample. Kenya, Mauritius, and Tunisia's stock returns significantly affected the volatility of South African stock returns during the heated period. Morocco, Tanzania, and Uganda's stock returns significantly affected Tunisia.

Table 12. GARCH model test 2

GARCH model result for heated COVID-19 period
Dependent Variable: South Africa
Included observations: 123

Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.001	0.001	-2.0447	0.0409
Variance Equation				
C	0.0000	0.0000	5.456	0.000
RESID(-1)^2	-0.093	0.001	-78.262	0.000
GARCH(-1)	1.037	0.000	177.0	0.000
KENYA	0.003	0.001	3.877	0.000

Table 13. GARCH model test 3

GARCH model result for heated COVID-19 period
Dependent Variable: SOUTH_AFRICA
Included observations: 123

Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0011	0.0014	0.7916	0.4286
Variance Equation				
C	0.0000	0.0000	4.3023	0.0000
RESID(-1)^2	-0.0979	0.0003	-58.7540	0.0000
GARCH(-1)	1.0381	0.0001	155.2919	0.0000
MAURITIUS	0.0010	0.0005	2.1526	0.0314

Table 14. GARCH model test 4

GARCH model result for heated COVID-19 period
Dependent Variable: SOUTH_AFRICA
Included observations: 123

Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0014	0.0014	1.0001	0.3173
Variance Equation				
C	0.0000	0.0000	1.3384	0.1808
RESID(-1)^2	-0.0886	0.0058	-15.2014	0.0000
GARCH(-1)	1.0352	0.0002	114.000	0.0000
TUNISIA	0.0051	0.00017	2.9999	0.0027

Table 15. GARCH model test 5

GARCH model result for heated COVID-19 period
Dependent Variable: TUNISIA
Included observations: 123

Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.001	0.000	3.623	0.000
Variance Equation				
C	0.000	0.000	6.492	0.0000
RESID(-1)^2	-0.147	0.000	-109	0.0000
GARCH(-1)	1.016	0.000	201	0.0000
SOUTH_AFRICA	0.0010	0.000	1.563	0.118

Table 16. GARCH model test 7

GARCH model result for heated COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 123				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0008	0.0004	2.1073	0.0351
Variance Equation				
C	0.0000	0.0000	7.1486	0.0000
RESID(-1)^2	-0.1512	0.0002	-67.1925	0.0000
GARCH(-1)	1.0227	0.0000	115.5000	0.0000
KENYA	- 0.0001	0.0001	-0.8678	0.3855

Table 17. GARCH model test 8

GARCH model result for heated COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 123				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0008	0.0004	1.7530	0.0796
Variance Equation				
C	0.0000	0.0000	13.3690	0.0000
RESID(-1)^2	-0.1422	0.0024	-58.4285	0.0000
GARCH(-1)	1.0190	0.0000	151.5000	0.0000
MOROCCAN	0.0002	0.0001	2.1177	0.3855

Table 18. GARCH model test 9

GARCH model result for heated COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 123				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0008	0.0004	1.9351	0.0530
Variance Equation				
C	0.0000	0.0000	19. 6361	0.0000
RESID(-1)^2	-0.1468	0.00017	-87.9828	0.0000
GARCH(-1)	1.0199	0.0000	204.0300	0.0000
NIGERIA	0.0001	0.0001	1.0776	0.2812

Table 19. GARCH model test 10

GARCH model result for heated COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 123				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0009	0.0004	2.2629	0.0236
Variance Equation				
C	0.0000	0.0000	18.1811	0.0000
RESID(-1)^2	-0.1439	0.0000	-69.5200	0.0000
GARCH(-1)	1.0195	0.0000	207.1000	0.0000
NIGERIA	0.0002	0.0001	3.3747	0.0007

Table 20. GARCH model test 11

GARCH model result for heated COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 123				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0007	0.0004	1.9582	0.0502
Variance Equation				
C	0.0000	0.0000	16.9498	0.0000
RESID(-1)^2	-0.1451	0.0014	-102.4796	0.0000
GARCH(-1)	1.0188	0.0000	308.4000	0.0000
UGANDA	0.0002	0.0001	2.6588	0.0078

3.3.3. Post-COVID-19 Period

Finally, Tables 21–26 show that Tunisia's stock returns were significantly impacted by Kenya, Tanzania, and South Africa's stock returns after the heated period of COVID-19. The Post COVID-19 periods show an insignificant impact on the Africa Stock Return in South Africa and Nigeria.

Table 21. Significance of stock returns of the post-COVID period for Kenya against Tunisia

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.3348	0.0196
Variance Equation				
C	0.0000	0.0000	4.4266	0.0000
RESID(-1)^2	0.2819	0.0491	-5.7395	0.0000
GARCH(-1)	0.3511	0.0998	3.5185	0.0004
KENYA	- 0.0003	0.0001	-2.8063	0.0050

Table 22. Significance of stock returns of the post-COVID period for Tunisia against Morocco

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.1763	0.0196
Variance Equation				
C	0.0000	0.0000	4.1084	0.0000
RESID(-1)^2	0.2930	0.5222	5.6145	0.0000
GARCH(-1)	0.3383	0.1103	3.0670	0.0022
MOROCCAN	0.0000	0.0001	-0.3197	0.7492

Table 23. Significance of stock returns of the post-COVID period for Tunisia against Nigeria

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.1562	0.0311
Variance Equation				
C	0.0000	0.0000	3.8689	0.0001
RESID(-1)^2	0.2683	0.0475	5.6474	0.0000
GARCH(-1)	0.4279	0.0971	4.4066	0.0000
NIGERIA	0.0001	0.0000	1.1781	0.2388

Table 24. Significance of stock returns of the post-COVID period for Tunisia against South Africa

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.3348	0.0196
Variance Equation				
C	0.0000	0.0000	4.4266	0.0000
RESID(-1)^2	0.2819	0.0491	-5.7395	0.0000
GARCH(-1)	0.3511	0.0998	3.5185	0.0004
SOUTH_AFRICA	- 0.0003	0.0001	-2.8063	0.0050

Table 25. Significance of stock returns of the post-COVID period for Tunisia against Tanzania

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.2171	0.0266
Variance Equation				
C	0.0000	0.0000	4.1686	0.0000
RESID(-1)^2	0.2948	0.0529	5.5760	0.0000
GARCH(-1)	0.3285	0.1105	2.9733	0.0029
TANZANIA	0.0000	0.0001	0.1166	0.9072

Table 26. Significance of stock returns of the post-COVID period for Tunisia against Uganda

GARCH model results for the post-COVID-19 period				
Dependent Variable: TUNISIA				
Included observations: 538				
Variable	coefficient	Std. Error	z-Statistic	Prob.
C	0.0003	0.0001	2.3313	0.0257
Variance Equation				
C	0.0000	0.0000	5.2493	0.0000
RESID(-1)^2	0.3104	0.0569	5.4519	0.0000
GARCH(-1)	0.2582	0.1016	2.5422	0.0110
UGANDA	0.0001	0.0000	1.9167	0.0553

4. Conclusion

Economists are investigating how the coronavirus's global spread may affect economic indicators, including the financial sector, focusing on how it would affect the largest, most developed, and most affected countries. Little research has been conducted on the performance of the stock returns in African countries and their interconnectedness, even though several have been done on the effect of COVID-19 shocks on the volatility of stock markets in technologically advanced countries. Considering this, this study is being undertaken to determine how the volatility of the stock market returns in the worst-hit country by COVID in the observation and the best-performing stock return in Africa affect the stock market returns in 9 African countries. We highlight the key conclusions here. Despite the influence of the COVID-19 crisis, the ARCH family model research shows that the interaction between emerging African stocks is generally minimal, suggesting that the emerging equity markets are still a long way from connecting.

This study has proven that grouping nations together and examining how the COVID-19 pandemic has affected the economy's fundamentals, including financial market indicators, can be deceptive and result in policy bias. When formulating policies to address the afflicted sectors or industries in each country, policymakers may find it extremely helpful to analyze the socioeconomic responses of various nations to the COVID-19 pandemic. These results suggest significant implications for foreign investors looking to reduce losses and risk exposures, particularly regarding portfolio diversification and hedging techniques. Intriguingly, during the continuing COVID-19 issue, investors looking to diversify their portfolio risks or losses resulting from advanced market assets could retain holdings in Nigerian shares in the short term.

The study's limitations include limited availability and reliability of financial data from some African countries, a focus on only nine countries, a constrained time frame that may not capture long-term effects, and the potential inadequacy of GARCH, ARCH, and TARCH models to capture all market behavior nuances fully. The study did not account for other concurrent global events or economic policies affecting the stock markets independently of the pandemic. Therefore, future research should include a broader range of African countries, extend the analysis period to capture long-term impacts, improve data collection methods, and employ advanced econometric and machine learning models. Comparative studies with other global regions are also recommended to understand the unique and shared impacts of the pandemic on different stock markets.

Author Contributions

All the authors equally contributed to this work. The author read and approved the final version of the paper

Conflicts of Interest

All the authors declare no conflict of interest.

Ethical Review and Approval

No approval from the Board of Ethics is required.

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