COVID-19 Pandemic and Stock Market Linkages in Southern African Customs Union

Emenike, Kalu O.

University of Eswatini

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Kalu O. Emenike
Department of Accounting and Finance,
University of Eswatini
Private Bag No. 4, Kwaluseni M201
Kingdom of Eswatini.
kalu@uniswa.sz
https://orcid.org/0000-0002-3599-0281

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Abstract
Stock market linkage broadens the range of investment opportunities available to market participants, strengthens the expansion of the component market, fosters healthy competition in the provision of financial services, and exacerbates vulnerability to volatility contagion. The objective of this study was to evaluate the linkages between stock markets in the Southern African Customs Union (SACU) before and during the COVID-19 pandemic using the bivariate Baba-Engle- Kraft-Kroner (BEKK) GARCH model and correlation analysis. Pre-COVID-19 results show that there is no correlation between the stock markets of Eswatini and any other SACU country; Botswana and Namibia stock markets exhibit a weak relationship, but South Africa and Namibia stock markets have a strong linkage. The COVID-19 results show evidence of a bidirectional volatility spillover between the SACU stock markets, suggesting increased linkage during the COVID-19 pandemic era. The COVID-19 pandemic has had a significant impact on the linkage of stock markets within the SACU region. For effective volatility transmission management, we recommend that policymakers and investors closely monitor and analyse the component markets during the crisis period. More so, the influence of the regional shocks should be considered in the formulation of investment and regulatory policies. This will help to ensure a more resilient and stable financial system in the face of future crises.

JEL Classification Numbers: F36, G15, I18.

Key Words: Stock market linkage, regional integration, COVID-19 pandemic, volatility spillover, South African Customs Union

Introduction

The COVID-19 virus has undeniably left an indelible mark across the globe, reshaping the financial system, public healthcare, and lifestyle in ways previously unimaginable (Zhang et al., 2020; Hasan et al., 2021; Jareño et al., 2023; Gil et al., 2023). Goodell (2020) notes that the pandemic heightened the risk levels in financial markets, which resulted in huge investment losses. As the global economies grappled with the multifaceted challenges posed by the pandemic, one area of profound impact was the global financial market, particularly the linkage of stock markets. In the Southern African Customs Union (SACU)[1], comprising Botswana, Eswatini, Lesotho, Namibia, and South Africa, the pandemic's effects reverberated through financial markets, offering a compelling case study on the linkage between regional economies and their stock exchanges amidst crisis. The reverberation was exacerbated in the wake of the declaration of COVID-19 as a pandemic, as investors scrambled to diversify their portfolios to minimize risk exposures.

The advent of the COVID-19 pandemic prompted unprecedented volatility in global markets, triggering sharp declines followed by erratic rebounds as investors navigated the uncertainty surrounding the pandemic's trajectory and its economic ramifications (Emenike, 2021b; Youssef et al., 2021). The economic repercussions echoed more in Africa than any other continent because of the potential financial stability issues, health sector constraints, and scarcity of liquidity resulting from large negative shocks (Emenike, 2021b). Within SACU, this volatility was keenly felt as member states grappled with not only the public health crisis but also its cascading effects on trade, investment, and fiscal policy. The intricate web of linkages[2] within the SACU region meant that disruptions in one member state reverberated across borders, affecting the financial stability and performance of stock markets regionally. The SACU and Common Monetary Area (CMA) arrangements, according to Kalenga (2019), strengthen the zonal linkage by minimizing transaction costs for cross-border trade and investment, as well as contributing to the preservation of price and financial stability in the zone.

Stock market linkage increases the variety of assets and investment options accessible to domestic market players, fortifies the development of the component market, reduces capital costs, promotes healthy competition in the financial services industry, and ultimately opens up global risk-sharing opportunities to shield investors from domestic financial cycles (Bekaert, 1995; Park, 2013; Dorodnykh, 2014; Feng and Stewart, 2015 Kikuchi et al., 2018; Emenike, 2021a). Vo and Tran (2020) observe that the effectiveness of a diversification strategy depends on the nature of the linkage between markets. Hence, evidence-based knowledge of the nature of SACU stock market linkage is the basis for diversification. A strong linkage, for example, discourages diversification, whereas the absence of linkage enhances diversification opportunities. In other words, the more correlated the markets are, the less benefit there is to diversifying investments across them.

Numerous research studies have been carried out to determine the ways in which negative information and the ensuing volatility are disseminated among global stock markets during times of crisis as well as investment positions that can counteract possible losses that may be sustained

[1] One of the compelling justifications for establishing the SACU was to promote economic development through sub-regional linkage.

[2] Four of the five member countries formed a common monetary area (CMA) alliance, which is characterized by a 1:1 peg between the South African Rand and the currencies of Eswatini, Lesotho and Namibia (Biekpe and Motelle, 2013). The purpose of CMA, therefore, is to enhance sub-regional integration and for all of the SACU countries to have similar development and equitable economic advancement (Zyi, 2003; Patroba and Nene, 2013). The SACU and CMA arrangements, according to Kalenga (2019), strengthen zonal linkage by minimizing transaction costs for cross-border trade and investment, as well as contributing to the preservation of financial stability in the zone.

during such times (see, for example, Jefferis and Okeahalam, 1999; Li and Giles, 2015; Guo and Ibhagui, 2019; Caporale et al., 2019; Choudhary and Singhal, 2020). Contrastingly, research on how the COVID-19 pandemic has affected relationships between international stock markets is expanding quickly (see, for example, Zhang et al., 2020; Pardal et al., 2020; Youssef et al., 2021; Emenike, 2021b; Jareño et al., 2023). In these growing literature, evidence of the SACU stock market linkage before the coronavirus and the fundamental changes in the market linkage during the COVID-19 pandemic is scarce. More so, there is a considerable knowledge gap on the behavior of small stock markets in SACU, such as those of Eswatini and Botswana. An understanding of the nature of linkage among the SACU stock markets will help to improve the markets' policy coordination and capacity to manage stock investment risk in the zone. This understanding is crucial for investors looking to diversify their portfolios across the region.

In this paper, we delve into the intricate relationship between the COVID-19 pandemic and stock market dynamics within the SACU. Through the multivariate BEKK GARCH model and correlation analysis, we investigate daily and monthly stock returns from Botswana, Eswatini, Namibia, and South Africa, with the intention of elucidating the nature and direction of linkage across SACU in order to contribute an evidence-based understanding of the mechanisms through which shocks propagate across the member states' stock markets. To our knowledge, this sample represents the largest number of markets covered thus far in empirical research on the nature of linkage among SACU stock markets. Most of the studies on market linkage in Southern Africa largely ignored the Eswatini and Botswana stock markets, which are very small. This omission is surprising, given the potential impact of these markets on regional integration efforts.

The results of this study contribute to the literature in two ways. First, we provide evidence on the linkage between the small stock markets (Eswatini and Botswana) in the SACU zone before and during the COVID-19 pandemic. These small markets remain comparatively under-researched relative to the South African market, which is one of the largest markets in Africa. Second, we analyze the nature of the linkage between the small markets and the South African stock market before and during the COVID-19 pandemic. Hence, this study documents evidence on the nature and magnitude of the linkage between stock markets in the SACU zone, which provides support for the markets' policy coordination, managing portfolio risk, and diversification. The remainder of this paper is structured as follows: Section 2 primarily reviews related literature on stock market linkages. Section 3 provides a succinct overview of data and methods. Section 4 presents the empirical results, and Section 5 concludes the paper with a few policy implications.

Literature review

The SACU is one of the sub-regional integration arrangements in Africa. Although, it is the oldest customs union in the world, founded in 1910, the stock markets have different stages of development and varying degrees of activity. The oldest and most advanced stock market in the sub-region is the South African one, which was founded in 1887. The markets that are currently in place in Namibia, Botswana, and Eswatini were founded in 1989, 1990, and 1992, respectively. According to the African Securities Exchange Association annual report 2018–2019, as of 2019, there are 317, 34, 07, and 39 listed stocks in the stock markets of Johannesburg, Botswana, Eswatini, and Namibia. With a market capitalization of $253.3 million and a 52-week turnover of $1 million, the Eswatini stock exchange has the lowest figures. According to the African Securities Exchange Association annual report 2018–2019, the capitalizations of the stock markets of South Africa, Botswana, and Namibia, as well as their 52-week turnover, are $977.5 billion ($301.6 billion), $38.7 billion ($154.9 million), and $148 billion ($746.2 million), respectively. Even

though the Eswatini stock market was founded almost simultaneously with the Botswana stock exchange and before the Namibian stock exchange, the characteristics of SACU markets indicate that it is the smallest in the region.

There is a wealth of empirical research on the strength and direction of global stock market linkage. The first strand of studies analyzed stock market linkage in a tranquil economic environment. Most research that looked at the relationship between developed stock markets, developing markets, and certain African stock markets came to the conclusion that there was very low linkage among the markets (see, for example, Jefferis and Okeahalam, 1999; Gil-Alana et al., 2018). In a comparable study, Choudhary and Singhal (2020) found evidence of a significant long-run linkage between India and the international stock markets, except the Eurozone market, and a short-run bidirectional causal relationship with the US stock markets. On the nature of risk sharing across international markets, Yépez (2020) reported that advanced economies tend to share risk better in international markets than emerging economies do.

The second strand of studies investigated stock market linkage during financial crisis periods. The majority of the international studies on the nature and causes of stock market linkage during crisis periods reported, amongst others, that stock market linkage was higher during financial crisis periods but that the speed of convergence decreased after the crisis periods, although linkage remained above pre-crisis levels (see, for example, Narayan et al., 2014; Li and Giles, 2015; Caporale et al., 2019; Zhang et al., 2020). This conclusion thus implies that economic and financial conditions have an explanatory influence on the nature and degree of markets' linkage, as evinced by return correlation and volatility spillover. The international evidence on increased linkage during economic and financial crises is similar to those documented using sub-Saharan African and developed stock market data (see, e.g., Bundoo, 2017; Guo and Ibhagui, 2019).

The third strand of studies examined stock market linkage during the COVID-19 pandemic, and the literature is fast growing. Many of studies that analysed the impact of the COVID-19 pandemic on financial markets across the globe reported that the Pandemic harmed the markets' returns and exacerbated stock market volatility (Zhang, et al., 2020; Emenike, 2021b; Kusumahadi and Permana, 2021). Pardal et al. (2020), Zhang et al, (2020) and Youssef et al. (2021) also reported that the majority of the regional financial markets were highly linked during the entire lockdown period as returns became negative while volatility was positive, but that few of the regional markets did not show any evidence of linkage. Zhang et al. (2020) further reported that the global stock markets linkage displayed different patterns before and during the pandemic announcement, and that some of the markets transmitted more volatility than others. These observations therefore imply that the nature of market linkage requires empirical verification since not all the markets were linked during the pandemic, and also because of the different behaviour of the markets before and during the pandemic.

Further studies on how linkage measures change over time and the impact of various policy stimuli on the pandemic reported that linkage measures change over time and that COVID-19-induced policy responses by countries moderated the negative impact of the pandemic on financial markets and industrial productivity (see, for example, Bernard et al., 2021; Rizvi et al., 2021; Jareño et al., 2023; Abdi et al., 2023). In addition, Li et al. (2021) provided a review of the objective lessons learned from market failure during COVID-19.

Evidence from extant empirical studies summarizes that the international stock market linkage becomes stronger during the financial crisis, but some of the markets are segmented. Hence, there is a need for evidence-based knowledge on the nature of markets' linkage.

Data and Methods

Data. Two datasets were used in the study in this paper. The first dataset included monthly all share indexes for South Africa (FTSE/JSE), Namibia (FTSE/NSX), Botswana (BSE Domestic Company), and Eswatini, the four SACU nations studied. The period covered by the data was January 2010–December 2019. The Eswatini Stock Exchange, which lacks a daily stock price index, was not included in the second dataset, which consisted of daily observations on the same markets. The daily data was collected over two periods, from November 1, 2013, to January 29, 2021, in order to determine the nature of the relationship between the stock markets prior to and during the COVID-19 pandemic. While the coronavirus era dataset covered the period from January 2, 2020, to January 29, 2021, the pre-coronavirus dataset covered the period from November 1, 2013 to December 31, 2019. The amount of time allotted to studying for the daily dataset was determined by the availability of data. On October 14, 2013, the Namibian FTSE NSX overall index was released. The investing.com database was used to gather the indices for Botswana, Namibia, and South Africa, while the Eswatini Stock Exchange provided the indexes for that country. The first difference in the natural logarithm of the indices was transformed into a percentage return as follows:

$$Rt = \big(Ln(I_t) - Ln(It-1)\big) * 100 \quad (1)$$

Where, R_t is a vector of percentage stock indices returns at time *t*, I_t is the current day stock indices at time *t*, $I_{,t-1}$ is the previous day stock indices at time *t*-1, and *Ln* is the natural logarithm.

The augmented Dickey-Fuller (ADF) unit roots test was estimated, according to Fuller (1995) and Dickey and Fuller (1979), to test for unit root in the SACU stock markets' return series. This is to ensure that the return series do not have a unit root because estimating with a unit root series is difficult to generalise to other time periods. The ADF test was computed as follows:

$$\Delta Y_t = c_t + \beta_c Y_{t-1} + \sum_{t=1}^{n} \varphi \Delta Y_{t-i} + \varepsilon_t \quad (2)$$

Where, c_t is a deterministic function of the time index *t* and ΔY_t is the differenced series of Y_t. The null hypothesis to be tested is that Y_t is *I*(1) with drift (i.e., β_c = 0), against the alternative that Y_t is *I*(0) about a deterministic time trend (i.e., β_c < 0) (Dickey & Fuller, 1979; Tsay, 2005).

Methods. This study employed the Pearson correlation coefficient to analyze the nature of the linear linkage between SACU stock markets. The correlation coefficient measures the association between two stock markets by estimating the degree and direction of the association between them. Following Emenike (2021a), the population Pearson correlation coefficient is measured, thus:

$$\rho_{XY} = \frac{\sigma_{XY}}{\sigma_X \sigma_Y} \quad (3)$$

where, ρ_{XY} is the correlation coefficient for markets x and y, σ_X and σ_Y are the standard deviations, and σ_{XY} is the covariance. A value of ρ_{XY} close to zero (0) would show that the linear linkage is weak but a value of ρ_{XY} close to one (1) would indicate a strong linkage between the two markets. The absence of a linear relationship would not indicate lack of linkage since correlation

coefficients measure only linear relationship. There may be a nonlinear linkage in the absence of linear linkage.

To determine whether there is non-linear linkage between SACU stock markets, the bivariate BEKK-GARCH model described in Engle and Kroner (1995) was calculated. The BEKK model is supported by the fact that it assesses the relationship between the volatilities and co-volatilities of two or more variables and that it automatically verifies, without parameter constraints, that the variance-covariance matrix is positive definite, making it appropriate for estimation (MacDonald et al., 2018; Emenike, 2021a). The squares and cross products of innovation (ε_t) are necessary for the conditional variance-covariance matrix equations in the BEKK model. These can be obtained using the mean equation that follows:

$$Rt = \mu + \delta Rt - i + \mu t, \mu_t | \Omega_{t-1} \sim N(0, H_t) \quad (4)$$

where, $R_t = (R_t^B, R_t^N, R_t^S)`$ is a vector of stock returns for the SACU markets, $\delta$ is a vector of autoregressive parameters that restrain serial correlation in the average market returns in Botswana, Namibia and South Africa, $\mu_t = (\mu_t^B, \mu_t^N, \mu_t^S)`$ is the $n \times 1$vector of random errors, and represents the innovation for each stock market's return at time t with their corresponding 3×3 conditional variance-covariance matrix H_t. The market information available at time $t-1$ is denoted as Ω_{t-1}.

In accordance with the BEKK models of Engle and Kroner (1995) and Emenike (2020), the conditional variance-covariance equation is as follows:

$$Ht = \mathrm{CC}` + \mathrm{A}\varepsilon\mathrm{t\text{-}1}\varepsilon`\mathrm{t\text{-}1A}` + \mathrm{BHt\text{-}1B}` \quad (5)$$

where, the conditional variance matrix is represented by *Ht*. The three matrices parameters are *C*, *A*, and *B*. A is 3x3 square matrix that illustrates the relationship between conditional variances and past squared errors, B is a 3x3 square matrix that quantifies the impact of previous conditional variances on the current conditional variances and degree of persistence in the volatility of the stock returns, and C is a 3x3 lower triangular matrix.. In accordance with Emenike (2021a), we provide the following standard BEKK parameters for the three-variable multivariate GARCH (1,1) model:

$$H_t = \begin{bmatrix} h_{B,B,_t} . h_{B,N,_t} . h_{B,S,_t} \\ h_{N,B,_t} h_{N,N,_t} . h_{N,S,_t} \\ h_{S,B,_t} \; h_{S,N,_t} \; h_{S,S,_t} \end{bmatrix}$$

$$= \begin{bmatrix} c_{B,B} & 0 & 0 \\ c_{N,B} c_{N,N} & 0 \\ c_{S,B} \, c_{S,N} \, c_{S,S} \end{bmatrix} + \begin{bmatrix} a_{B,B} a_{B,N} a_{B,S} \\ a_{N,B} a_{N,N} a_{N,S} \\ a_{S,B} \; a_{S,N} \; a_{S,S} \end{bmatrix} + \begin{bmatrix} b_{B,B} b_{B,N} b_{B,S} \\ b_{N,B} b_{N,N} b_{N,S} \\ b_{S,B} \; b_{S,N} \; b_{S,S} \end{bmatrix} + \begin{bmatrix} \varepsilon_{BB} \varepsilon_{B,N} \varepsilon_{B,S} \\ \varepsilon_{N,B} \varepsilon_{NN} \varepsilon_{N,S} \\ \varepsilon_{S,B} \; \varepsilon_{S,N} \; \varepsilon_{SS} \end{bmatrix} \quad (6)$$

where,$h_{B,B,_t}$, $h_{N,N,_t}$ and $h_{S,S,_t}$ denote the conditional variance of the stock exchanges in Botswana, Namibia, and South Africa, respectively; $h_{B,N,_t}$ and $h_{B,S,_t}$ the of the stock returns in Botswana and Namibia, as well as the stock returns in Botswana and South Africa; $h_{N,B,_t}$and $h_{N,S,_t}$ are the covariance of Namibia and Botswana stock returns, and Namibia and South Africa stock returns; $h_{S,B,_t}$ and $h_{S,N,_t}$ are the covariance of South Africa and Botswana stock returns, and South Africa and Namibia stock returns. The statistical significance of the off-diagonal coefficients $a_{B,N,_t}$ &

$b_{B,N,t}$, and $a_{B,S,t}$ & $b_{B,S,t}$ show evidence of shock and volatility linkages from Botswana to Namibia and South Africa stock exchanges; whereas the significance of the off-diagonal coefficients $a_{N,B,t}$ & $b_{N,B,t}$, and $a_{N,S,t}$ & $b_{N,S,t}$ show evidence of shock and volatility linkages from Namibia to Botswana, and South Africa stock exchanges at time *t*. Similar evidence of shock and volatility linkages from South Africa to the bourses of Botswana and Namibia is shown by the significance of the off-diagonal coefficients $a_{S,B,t}$ & $b_{S,B,t}$, and $a_{S,N,t}$ & $b_{S,N,t}$ at time *t*.

The statistical significance of the off-diagonal parameters would demonstrate a linkage between the SACU stock markets. To assess the multivariate BEKK-GARCH model's robustness, diagnostic tests for heteroscedasticity and multivariate autocorrelation were employed.

Results

Descriptive Statistics. The descriptive statistics for the monthly and daily returns of the SACU stock markets before and during the COVID-19 pandemic are displayed in Table 1. Prior to the COVID-19 pandemic, all of the SACU stock markets had positive monthly mean returns, as indicated in *Panel A* of Table 1. South Africa and Eswatini had the highest returns. However, compared to other SACU stock markets, there is a greater variance in the monthly return of the Namibian stock market. A very interesting feature of *Table 1* is the skewness coefficient. A normal distribution has zero skewness. Positive skewness denotes a greater proportion of positive than negative changes in returns. Note that each SACU market's skewness coefficient was notably positive prior to the coronavirus outbreak, but turned negative throughout the coronavirus era, as Panel C illustrates. This suggests that during the coronavirus era, there was a greater likelihood of negative returns. A leptokurtic return distribution is also suggested by the excess kurtosis coefficient for the SACU stock markets prior to and during the coronavirus outbreak. Given the negative skewness during the coronavirus pandemic period, the leptokurtic distribution suggests that investors were exposed to large amounts of losses.

It is also evident from *Panel A* of *Table 1* that not all SACU stock markets have significant findings from the Ljung-Box and McLeod-Li tests. These demonstrate the homoscedasticity and serial dispersion of the monthly return series for the markets. However, the daily return series shown in *Panels B* and *C* of *Table 1* for both the pre-coronavirus and the during-coronavirus pandemic eras are heteroscedastic and serially correlated. It is necessary to find evidence of heteroscedasticity in order to estimate GARCH family models.

Furthermore, the results of the ADF test indicate that the return series are integrated of order 1, indicating that they are all stationary at the first difference.

Table 1. Summary statistics for SACU stock markets returns

	Botswana	Namibia	South Africa	Eswatini
Panel A. Monthly observations before Coronavirus				
Mean	0.018	0.478	0.628	0.598
Std. dev.	2.1026	4.339	3.691	1.422
Skewness	-0.596*	0.063	0.181	4.413*
Kurtosis	5.449*	-0.337	-0.461	26.564*
JB Stat.	154.281*	0.6450	1.709	3885.30*
LB Q(21)	24.059	21.889	27.237	21.554
McL(21)	21.261	27.635	25.895	2.458
ADF	-9.399*	-11.516*	-13.818*	-10.794*
Panel B: Daily observations before Coronavirus				

Mean	0.009	-0.016	-0.014	
Std. dev.	0.363	1.277	1.006	-
Skewness	0.736*	0.260*	0.142**	-
Kurtosis	78.002*	2.440*	1.394	-
JB Stat.	389536*	398.603*	129.564*	-
LB Q(78)	166.843*	108.083*	113.224*	-
McL(78)	269.614*	788.069*	376.426*	-
ADF	-13.003*	-38.798*	-39.986*	-
Panel C: Daily observations during Coronavirus				
Mean	-0.032*	-0.024	0.039	-
Std. dev.	0.145	2.446	1.910	-
Skewness	-2.307*	-0.428*	-0.661*	-
Kurtosis	10.985*	4.111*	7.884*	-
JB Stat.	1603.129*	199.215*	721.702*	-
LB Q(32)	82.315*	92.103*	88.180*	-
McL(32)	72.872**	287.167*	319.550*	-
ADF	-15.261*	-16.779*	-10.326*	-

Note: * refers to 1% statistical significance level. The ADF is the augmented Dickey-Fuller Unit root test. The critical values for the monthly and daily ADF tests before COVID-19 at 5% are -2.885 and -2.863 respectively; and daily ADF test during COVID-19 pandemic is -3.427. Lag lengths for the ADF tests are selected using Schwarz information criterion (SIC). LBQ and McL are Ljung-Box and McLeod-Li tests for serial correlation and autoregressive conditional heteroskedasticity in stock returns up to the selected lag order (.).
Source: Author's computation

Correlation Analysis. Table *2* shows the correlation results for the monthly and daily SACU stock market return series before and during the coronavirus pandemic. The Eswatini stock market is unrelated to any of the SACU stock markets prior to the COVID-19 pandemic, according to the correlation coefficient of the monthly data displayed in Panel A. The lack of market activity in the Eswatini stock market, which is caused by the small number of listed securities, could provide an explanation for this. It also raises the possibility that Eswatini may not have fully explored the advantages of the stock market in terms of raising private cash to support development and investment. The stock markets of Namibia and Botswana are negatively correlated, but not with any other SACU stock market. The shaky connection between the Botswana and Namibia stock markets is important for portfolio diversification. Low market correlation is crucial for international diversification, and portfolio risk is reduced by diversifying across markets with low return correlation, according to Solnik et al. (1996) and Emenike (2021a). Conversely, there is a strong correlation (0.72) between the stock markets in Namibia and South Africa. This is comparable to the strong association seen in Biekpe and Motelle's (2013) analysis between the Treasury bill rates in Namibia and South Africa. The high degree of correlation between Namibian and South African stock markets indicates that they may not be a suitable option for portfolio diversification.

From *Panel B* of *Table 2*, the Namibian stock market maintained a strong relationship (0.81) with the South African stock market before the coronavirus pandemic. There is, however, no significant relationship between Namibia and Botswana stock markets, nor was there one between South Africa and Botswana stock markets before the coronavirus pandemic period. Similarly, the correlation coefficients displayed in *Panel C of Table 2* show the absence of any relationship between Botswana and other SACU stock markets. However, a weak relationship

existed between the Namibian and South African stock markets during the coronavirus pandemic period. This result contradicts our expectation of increased stock return correlation during the crisis period. Pardal et al. (2020), for example, reported that the short-term relationship among central European stock markets strengthened during the coronavirus pandemic.

Table 2. Correlation results

	Panel A: correlation results for monthly data			
	Botswana	Eswatini	Namibia	South Africa
Botswana	1			
Eswatini	0.127	1		
	(0.169)			
Namibia	-0.165	0.021	1	
	(0.073)***	(0.821)		
South Africa	-0.123	0.010	0.720	1
	(0.184)	(0.916)	(0.000)*	
	Panel B: correlation results for before-coronavirus daily data			
Botswana	1	-		
Namibia	0.024	-	1	
	(0.347)			
South Africa	0.045	-	0.811	1
	(0.076)***		(0.000)*	
	Panel C: correlation results for during-coronavirus daily data			
Botswana	1	-		
Namibia	-0.027	-	1	
	(0.659)			
South Africa	-0.096	-	0.136	1
	(0.116)		(0.025)**	

* , ** and *** refers to 1%, 5% and 10% statistical significance levels, respectively .

Volatility spillover between SACU stock markets. The multivariate BEKK-GARCH (1,1) model findings, which were calculated to determine the nature and direction of volatility spillover among SACU stock markets prior to and during the COVID-19 pandemic, are presented in Table 3. Squared standardized residuals and standardized residuals of the multivariate BEKK-GARCH model exhibit no signs of heteroscedasticity or serial correlation, according to estimates from the multivariate ARCH-LM and multivariate Ljung-Box Q statistics, which are shown in Panel D of Table 3. These indicate that the BEKK model can explain the volatility relationships among SACU stock markets.

As you can see from Panel A, there are shock and volatility links among the SACU stock markets in the off-diagonal elements of matrices A and B. The Wald test was used to determine the significance of the A and B matrices estimated from the BEKK-GARCH (1,1) model. The null hypotheses of the Wald test for pairings of SACU stock markets are: $A_{I,J} = B_{I,J} = 0$, which shows that there is no volatility correlation between country I's and country J's stock markets. On the other hand, $A_{J,I} = B_{J,I} = 0$, demonstrating that there is no volatility correlation between the stock markets of country *J* to the stock market of country *I*. Should any of the null hypotheses be disproved, it would suggest that there is a unidirectional volatility relationship between the countries *I* and *J* stock markets. Similarly, the evidence of bidirectional volatility linkages between

the stock markets of countries I and J would be revealed by the failure of both null hypotheses (Emenike, 2021a).

Estimates from the Wald test results presented in *Panel A* of *Table 3* suggest evidence of unidirectional volatility spillover from Botswana to Namibia stock markets before the COVID-19 outbreak. This suggests that, prior to the coronavirus pandemic, there was a partial volatility correlation between the stock markets in Namibia and Botswana. Prior to the coronavirus pandemic, there was evidence of bidirectional volatility links in the stock markets of Namibia and South Africa. On the other hand, the South African stock market's Wald test coefficient is higher than Namibia's. This implies that the stock market in South Africa is leading the correlation between volatility and the stock market in Namibia. Additionally, it raises the possibility that there is a preferred attachment between the stock markets in Namibia and South Africa. According to Vyrost et al. (2015), there is a greater chance of spillover effects the more connected any two are. Because of their shared colonial past, it is therefore not unexpected that Namibian and South African markets are linked in the first and second moments.

The volatility of the South Africa and Botswana stock market returns, on the other hand, was completely segmented before the coronavirus pandemic, as there is no evidence of shock and volatility linkages between them. Thus, the results suggest that linkages among the SACU stock markets before the coronavirus pandemic were weak. This finding is similar to Gil-Alana et al. (2018), who analyzed linkages between nine African stock markets and concluded that the degree of linkage among the markets is very low.

The nature of linkages among the SACU stock markets during the coronavirus pandemic displayed in *Panel B* of *Table 3* is revealing. The Wald test results show that, at the 1% significance level, there is a bidirectional volatility linkage between Botswana and Namibia, Botswana and South Africa, Namibia and South Africa, and vice versa. These findings demonstrate the presence of bidirectional volatility linkages between the SACU stock markets throughout the coronavirus era and imply that the degree of linkage between the SACU financial markets was amplified by the coronavirus pandemic. This finding may be explained by the sharp increase in stock market volatility and the fall in returns as skittish investors strive to factor in the new risks posed by the coronavirus pandemic.

The increased linkage between the SACU stock markets during the COVID-19 pandemic partly resembles the results of Guo and Ibhagui (2019), who reported, among others, that the linkage between China and five African stock markets became stronger during the global financial crisis period. Bundoo (2017) and Caporale et al. (2019) also reported that the extent of regional and international stock market linkages strengthened during the global financial crisis period. The few studies that have investigated the nature of stock market linkage during the coronavirus pandemic have largely reported evidence of positive stock return volatility and increased levels of linkage among the regional and global markets. Youssef et al. (2021), for example, documented that volatility spillover reached unprecedented heights during the COVID-19 pandemic in the first quarter of 2020. Zhang et al. (2020) also demonstrated that there were observable differences in the patterns of the global stock market linkage before and following the declaration of the pandemic. In general, the finding of increased volatility linkage among SACU stock markets during the coronavirus period aligns with the empirical literature on the efficacy of financial crises in exacerbating market linkages.

The major outcome of this study is that there was a weak linkage among the SACU stock markets before the emergence of the coronavirus. But during the COVID-19 pandemic, the relationship strengthened significantly, resulting in a bidirectional volatility spillover between the

zonal stock markets. Since the markets tend to become closely linked during times of crisis, authorities overseeing the SACU stock market should take the initiative to develop rules to reduce the negative impacts of shock and volatility spillover that may occur during such times, as well as collaborate with regional partners and international organizations to develop effective strategies for managing cross-border financial contagion.

Table 3: Multivariate BEKK-GARCH(1,1) results for SACU stock markets

	Panel A. Before Coronavirus		*Panel B. During Coronavirus*	
Parameters	Coefficient	*t*-statistic	Coefficient	*t*-statistic
$C_{(B,B)}$	-0.148	-4.461	0.492	2.026
$C_{(N,B)}$	-0.033	-0.374	0.111	0.987
$C_{(N,N)}$	0.252	21.659	0.000	0.005
$C_{(S,B)}$	-0.066	-1.266	0.291	1.667
$C_{(S,N)}$	-0.003	-0.078	-0.000	-0.006
$C_{(S,S)}$	-0.093	-2.956	-0.000	-0.005
$A_{(B,B)}$	0.233	6.372	-0.272	-5.284
$A_{(B,N)}$	0.042	3.786	0.022	4.642
$A_{(B,S)}$	-0.004	-0.156	-0.245	-6.076
$A_{(N,B)}$	0.062	0.646	0.265	0.221
$A_{(N,N)}$	0.920	9.588	0.145	1.013
$A_{(N,S)}$	0.136	1.519	-0.380	-0.633
$A_{(S,B)}$	-0.061	-1.373	-0.977	-10.375
$A_{(S,N)}$	-0.109	-7.633	0.021	3.305
$A_{(S,S)}$	0.175	5.216	-0.146	-2.307
$B_{(B,B)}$	0.963	63.197	0.308	3.846
$B_{(B,N)}$	-0.025	-1.408	-0.013	-2.475
$B_{(B,S)}$	0.007	0.501	-0.292	-5.736
$B_{(N,B)}$	-0.183	-1.473	7.947	7.407
$B_{(N,N)}$	-0.010	-0.312	0.147	2.159
$B_{(N,S)}$	-0.236	-2.371	5.898	6.571
$B_{(S,B)}$	0.013	0.703	-0.227	-2.354
$B_{(S,N)}$	0.039	1.398	-0.020	-3.376
$B_{(S,S)}$	0.970	60.945	0.812	13.618
Panel C. Wald test results for volatility linkages among SACU stock markets				
	Test statistic	*p*-value (χ^2)	Test statistic	*p*-value (χ^2)
Botswana → Namibia	14.750	0.000*	23.861	0.000*
Botswana → South Africa	0.396	0.820	74.819	0.000*
Namibia → Botswana	3.654	0.160	57.392	0.000*
Namibia → South Africa	6.919	0.031**	43.358	0.000*
South Africa → Botswana	2.094	0.350	135.993	0.000*
South Africa → Namibia	58.774	0.000*	17.662	0.000*
Panel D. Robustness tests for BEKK-GARCH model				

MV ARCH-LM	0.65	1.000	48.96	0.279
MV LBQ	47.655	0.997	34.194	0.362

Note: *. ** and *** refers to 1%, 5% and 1% statistical significance levels respectively. → indicates direction of volatility spillover. MV ARCH-LM and MV LBQ are multivariate ARCH-LM and Ljung-Box Q-statistic for null hypotheses of no ARCH effect and no autocorrelation in multivariate GARCH model squared residuals and residuals, respectively. SIC selected lags 32 and 78 for coronavirus period and before coronavirus period respectively.

Conclusion

This study examines the linkage between SACU stock markets before and during the COVID-19 pandemic. Using monthly and daily datasets covering the period from January 2010 to January 2021, this article specifically aimed to determine the relationship between stock returns and volatility spillover between the stock markets of Botswana, Eswatini, Namibia, and South Africa prior to and during the coronavirus pandemic. The daily dataset was divided into two periods to capture the nature of linkage between the markets before and during the COVID-19 pandemic.

The estimates on the nature of the return relationship between SACU stock markets before the coronavirus pandemic show that the Eswatini stock market is not related to any of the SACU stock markets. Botswana's stock market has a very weak relationship with the Namibian stock market, but not with any other SACU stock market. The Namibian stock market, on the other hand, had a high degree of relationship with the South African stock market before the COVID-19 pandemic period. During the coronavirus period, the Namibian stock market maintained its relationship with the South African stock market, with the absence of a relationship with other SACU markets.

The estimates on the direction and magnitude of volatility spillover among the SACU markets before the COVID-19 pandemic show evidence of unidirectional volatility spillover from Botswana to Namibia stock markets as well as bidirectional volatility linkages between South Africa and Namibia stock markets before the COVID-19 pandemic era. During the coronavirus pandemic, however, we recorded evidence of bidirectional volatility spillover between all the SACU stock markets. Consequently, the findings imply that there existed a weak volatility correlation between SACU stock markets prior to the coronavirus pandemic but that this linkage strengthened during the epidemic.

These findings have important implications for stock market regulation and risk management in the SACU zone. Stock market integration policies in SACU should take into account the spillover risk and measures to contain such risks as a means of ensuring financial stability. More so, there is a need for the capital market authorities to identify policy measures that would mitigate adverse effects from shock and volatility spillover that might occur during crisis periods. A risk management implication would be for investors to continually monitor changes in the SACU financial market environment to adjust their portfolios in response to shock and volatility transmissions that are exacerbated during crisis periods. Monitoring the SACU financial market environment would help investors mitigate potential losses and optimize their investment strategies.

Future research in this area of study could analyze the effectiveness of different policy interventions in mitigating the effects of volatility transmission during crisis periods in the SACU zone. In addition, this study can be extended by modeling asymmetric volatility transmission among the SACU markets as well as between the SACU and the international stock markets.

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