A study measuring the connectedness of African and advanced financial markets using spillover indices.

A Research Report submitted in partial fulfilment of the Degree of Master of Economic Science in the School of Economics and Finance,
University of the Witwatersrand

By
Kelebogile Mabitsi
Student No: 1644683
Supervised by Professor Farrell
Word Count: 12 731
Date: 02 April 2024

Abstract

Investors are always searching to diversify their portfolios and manage risks. South Africa, Kenya, Egypt and Nigeria are African frontier and emerging market economies that are potentially attractive to such investors. This study examines whether African equity markets are suitable for investment diversification amongst themselves and advanced market investors from countries such as the United States and the United Kingdom. The paper uses Diebold and Yilmaz (2012) spillover indices to make this determination, by measuring the connectedness of the returns and volatilities, for the period 2008 to 2022 using both weekly and daily data. The daily and weekly results show that advanced and African markets have low interdependence, except for South Africa, that shows stronger connectedness with advanced markets. South African policymakers can consider developing policies that are responsive to advanced market shocks. Additionally, African policymakers can consider developing policies that promote a Pan-African market that has consistent regulatory, listing and trading requirements to promote African economic growth. The diversification opportunities that are present may have limited efficacy due to the composition of African stock markets. The volatility spillover plots display more sensitivity to market dynamics than the returns, as significant cycles and bursts are identifiable.

Key words: Interdependence, connectedness, spillovers, transmissions, innovations, Generalised variance decomposition, markets, diversification

Table of Contents

List of Tables

List of Figures

1. Introduction

Countries are interconnected when the effects of events occurring in one country spread to another country. These are known as spillovers. Spillovers can carry adverse effects or positive effects, depending on the nature of the event, and their magnitude may be time varying, increasing in crisis periods. This research report seeks to examine the interdependence of the equity markets of a group of African economies amongst themselves and with advanced economies by investigating spillovers. The purpose is to assess the nature of the connectedness of these markets, to identify if these spillovers differ for returns and volatilities, across types of economies and whether they are constant over time. A significant sub-question that this research will answer is, which countries provide the best diversification benefits for investors?

Most of the existing literature examines the interdependence[1] between advanced markets such as the US and European countries only (Fasanya, Oyewole, & Agbatogun, 2019). There is minimal literature available about advanced and African markets. This is an area of interest following the relaxing of trade barriers due to the inception of the African Continental Free Trade Act (AfCFTA), technological development, improvements in the governance of African financial markets, less stringent capital flows, diversification purposes and policy implications to combat regional shocks.

The African economies chosen are from the Northern and Sub-Saharan regions and comprise of both emerging and frontier economies, namely South Africa, Kenya, Egypt and Nigeria. These are some of the leading economies in the region (de Wet, 2022) and are potentially of interest to foreign investors seeking to diversify into Africa. African asset markets may offer opportunities for higher returns on investments, an increasingly diverse sector-based equity market as more foreign investors look to set up shop in the region, opportunities for ESG investments and faster growth due to rapid economic growth prevalent in emerging and frontier markets – Africa is the second-fastest growing continent by GDP growth rate (African Development Bank , 2024). The US and the UK are included in the study to capture the linkages with markets in advanced economies.

African countries generally have low trading volume because of them being illiquid – South Africa is an outlier in this case (The African Development Bank, 2014). According to Claassen

[1] Interdependence is used interchangeably with contagion, spillovers and connectedness. This refers to the measure of relation or association between variables (markets).

(2019), the lack of liquidity is a potential deterrent because securities are not easily traded. Bello et al. (2022) note that African markets are different from other markets because of regulatory and institutional hindrances. This is due to most of these African countries developing significantly later than their advanced market counterparts.

This study will focus on the six major indices of these markets: the Johannesburg Stock Exchange (JSE) All Share index, Nairobi All Share Index (NASI), Nigerian Stock Exchange (NGX) Index, Egyptian Exchange (EGX), Financial Times Stock Exchange (FTSE) Index, and Standard & Poor's 500 Index (S&P 500). Spillovers between these indices are investigated over a fourteen-year period, from January 2008 to January 2022 for daily data and February 2008 to December 2022 for weekly data. The connectedness of both returns and their volatilities will be considered, using the 2012 version of the Diebold and Yilmaz spillover model, which employs forecast error variance decompositions from generalised vector autoregressions (VARs). I will consider both static (full sample) and dynamic (rolling-windows) spillovers to assess the time-varying nature of connectedness. The importance of comprehending the extent of connectedness between financial markets is mainly for diversification and risk management purposes. Diversification of stocks helps to minimize losses and increases the chances of positive returns.

2. Literature review

This section provides an overview of existing literature that discusses interdependence in financial asset markets. It provides a review of studies that discuss financial market spillovers and existing methodologies to measure these spillovers. It pays particular attention to research on African markets. The following key contributions to the literature informing this research report will be reviewed: Diebold and Yilmaz (2009, 2012), Fasanya et al. (2019), Boakye et al. (2023), and Mensah and Alagidede (2017).

Spillover effects occur when a crisis or boom in one asset market leads to a crisis or boom in another country's asset market (European Central Bank, 2005). Some authors believe it should be narrowed to periods of crises, while others extend the definition to include non-crises periods.

We explore early investigations of connectedness by Hilliard (1979). The author uses correlation and covariance methods to analyse the connectedness between equity indices around the world for the daily period of 7 July 1973 to 30 April 1974 – the period is selected due to the 18 October 1973 OPEC embargo which the author views as an external variable that should introduce co-movement between global indices. He compares the correlation coefficients between 10 indices from exchanges located in Paris, Amsterdam, Milan, London, Frankfurt, New York, Tokyo, Sydney, Zurich and Toronto. The authors conclude that there is significant intra-continental connectedness between Northern American and European markets. This is expected as these exchanges are more developed and integrated. The authors provide the following as reasons for the integration; countries with positively correlated income tend to generate similar share price movements due to investor confidence and expectations; and multinational representation in these indices results in similar price behaviour. Indices in Sydney and Tokyo exhibit low coherence with other markets – this is due to Tokyo's stringent capital flow restrictions and Sydney's geographic location causing delayed reaction to global shocks. This approach only shows a static view of connectedness, it does not account for dynamic changes between markets over time, nor does it show causality. On the other hand, the Diebold-Yilmaz approach provides the direction and magnitude of the connectedness between markets and captures time-varying connectedness.

Diebold and Yilmaz develop measures of connectedness in a series of literature. Diebold and Yilmaz (2009) look at returns and volatility spillovers with application to nineteen advanced and emerging equity markets. They conduct a static (full sample) and a dynamic (rolling-window) analysis to measure these spillovers. They find that the nature of spillovers differs for both volatility and returns. The returns spillovers display no bursts, and an increasing trend - this is attributed to increasing global financial relations due to technological development and declining barriers of entry. The volatility spillovers are more reactive to crises, but they display no clear trends. For the full sample analysis, they find that approximately 40% of the forecast error variances emerge from spillovers for both returns and volatility. They also find that the US is the most independent market - contributions from other markets to the US amount to 6.4% which is the lowest value. Conversely, the US accounts for most of the contributions to other markets. This shows that the US is an exporter of spillovers to the rest of the world.

Diebold and Yilmaz (2012) use generalised forecast error variance decompositions (GFEVD) to measure the total and directional volatility spillovers of US stock, foreign exchange, bonds and commodities markets for the period January (1999 to 2010). The results show that the total and directional spillovers between the asset classes are low. The largest net volatility transmissions were from stocks to other markets, this peaked during the GFC in 2008. This is expected as stocks are highly volatile due to their nature of having potential high returns. The GFEVD method was taken up following the limitations of using Cholesky-decomposition to identify VARs, where variance decompositions are dependent on variable ordering. The variance decompositions produced from using the updated generalised VAR method are not sensitive to variable ordering. Unlike Cholesky decomposition, that attempts to orthogonalize shocks, the GFEVD permits for correlated shocks – this results in the total contributions of the forecast error variance not being equal to one. Additionally, generalised forecast error variance decompositions allow researchers to assess directional spillovers. Directional spillovers measure the directional component of spillovers. This is done to quantify the information contained in the historical volatility of one market for predicting the future direction of other markets (Diebold and Yilmaz, 2012).

Fasanya et al. (2019) use Diebold and Yilmaz (2012) spillover indices to assess the volatility and return spillover sectoral effects in the Nigerian equity market between January 2007 and December 2016. They find that both returns and volatilities show evidence of trends and bursts. Ndlovu (2020) applies Structural VAR and Diebold-Yilmaz (2009, 2012) spillover methodologies to determine if South African monetary policy shocks spillover to its neighbouring countries. The author finds that South African monetary policy shocks significantly impact its neighbouring countries - the monetary policy factors of these countries begin to move in alignment to South Africa. Boakye et al. (2023) employs similar techniques from the Diebold and Yilmaz approach to study the return spillovers and connectedness amongst African foreign exchange markets. The total spillover is low at 13.9% which provides evidence of opportunities for diversification amongst the markets. The rand, Moroccan dirham and CFA francs are the largest net transmitters - this aligns with previous findings that South African financial market shocks spillover to other African markets.

Balli et al. (2015) studies the spillovers between developed equity markets (Europe, Japan and US) and emerging equity markets in Asia, the Middle East and North Africa (MENA). The study finds that Asian markets experienced both return and volatility spillovers from the US. Japan exerted significant spillovers to markets such as Kuwait, Qatar and UAE – the authors expect this due to the strong trading relations between the regions. Ultimately, the study finds that US spillovers are larger and more persistent to emerging markets.

Following the joint financial losses experienced by advanced economies during the GFC, Mensah and Alagidede (2017) explore the interdependence between advanced and African emerging equity markets to assess the feasibility of investing assets in Africa for diversification purposes. They use a copula approach to consider the dependence structures between these stock markets, rather than the Diebold-Yilmaz approach that is proposed for this research report. Their results show that South Africa has the strongest association to advanced markets. The authors attribute this to the following, South Africa being the largest trading partner to the UK, being part of BRICS, and it being an emerging economy unlike its counterparts. The results also reveal that the nature of dependence changes based on the period, and there is weak tail dependence for Egypt, Nigeria and Kenya - meaning that these stock markets are less susceptible to spillovers from advanced economies. Secondly, they find that the returns co-movement differs in bullish and bearish markets. Lastly, they find little evidence of interdependence between these markets when advanced markets are going through extreme downturns. Therefore, frontier African markets appear as suitable investment havens for diversification.

Frontier markets are an investment magnet because they have higher growth prospects, low input costs, and low levels of leverage. This is corroborated by Sivabalan (2018)'s findings that frontier markets have consistently delivered good performance for risk-adjusted returns. Thomas et al. (2022) conducts a study on how frontier markets can provide diversification benefits in the Asian-Pacific and European region. The authors find that frontier markets in the Asian-Pacific region provide better diversification potential than European frontier markets. This is because Asian-Pacific frontier markets are less matured than European frontier markets, hence they are less likely to move in alignment to developed stock markets. These authors also find that Nigeria, South Africa, and Kenya are the best investment opportunities - this makes them suitable countries to look at in my study.

Spillovers mostly emerge from larger economies since these are generally big exporters to the rest of the world - they set the international economic tone. The GFC emerged from the US - it was one of the top three global exporters at the time (Workman, 2021). The crisis instantly spread throughout the rest of the world due to tighter global relations. This crisis significantly constrained investor diversification efforts. Globalisation has since led to financial deregulation and increased technological developments, which has led to increased equity market integration across different countries (Jebran, Chen, Ullah, & Mirza, 2017). This makes equity markets more vulnerable to global macroeconomic shocks causing their volatility to increase. This can lead to tighter correlations between markets especially during periods of global economic downturns. Tighter correlations between asset markets might inversely affect diversification opportunities. As a result, investors' risk exposure is expanded, and they may face greater losses due to this interdependence. This shows that increasing financial globalisation will lead to systemic risk which can leave all financial markets vulnerable and volatile simultaneously.

Antonakakis et al. (2020) enhance Diebold and Yilmaz (2012, 2014) by using time-varying parameter (TVP) VARs to measure interdependence between foreign currencies – these are the USD, EUR, GBP, CHF, and JPY currencies. Diebold and Yilmaz use a constant-parameter rolling-window VAR style; this modified approach has a TVP-VAR with a time-varying covariance structure. This model's benefits are that it can capture changes to coefficients more accurately than rolling-window analysis; not extremely sensitive to outliers; researchers do not have to randomly select the rolling-window length therefore there is no loss of observations. The results show that most shocks emanate from the EUR and CHF; and the GBP and JPY are the highest recipients of shocks. Thus, showing that there is tighter interdependence between advanced markets. This model is a great enhancement; however, Diebold and Yilmaz's approach is still a preferred choice because it has been widely used throughout existing literature. As a result, to follow on the trajectory of prominent papers, this paper will use the Diebold-Yilmaz approach.

Other common methods used to measure connectedness are Probability analysis, VAR models, GARCH, Cross-market correlations, and Extreme value analysis (Forbes, 2012). Initially researchers would use correlation-based models to measure for interdependence, then limitations about linear correlation developed, that is, that stock returns' co-movement is time-varying. Multivariate GARCH models became popular for measuring time-varying stock connectedness. Over time researchers found a limitation in the method, that is, the assumption that stock returns are symmetric normally or Student-t distributed - they are non-linear and asymmetric (Mensah & Alagidede, 2017). An alternative method to address these drawbacks is the copulas method. Copulas are functions that merge multivariate distributions to their one-dimensional margins. (Sklar, 1959). They give a practical view of the structure of dependence between random variables over their entire range of variation, as well as linear and non-linear relation, symmetric and asymmetric relation, and extreme or tail dependence. Diebold and Yilmaz (2023) reflect on the trajectory of the measure of spillovers moving from measuring total spillovers to directional spillovers and now using networks to visualise variance decomposition. This latest iteration to the method makes it easy to assess the connectedness of large and small network dimensions.

3. **Methodology**

This section outlines the methodology that will be used to measure the connectedness amongst the African and advanced stock markets under study for the period 2008 to 2022. This methodology follows the spillover approach of Diebold and Yilmaz (2012), rather than the Cholesky-based identification approach used in Diebold and Yilmaz (2009). Diebold and Yilmaz (2012) use the generalised identification method of Pesaran and Shin (1998), following Koop et al. (1996). This generalised identification approach is intended to avoid the variable ordering problems associated with Cholesky identification.

The generalised forecast error variance decomposition measures the contribution of markets to the forecast error variance of other markets. This method allows researchers to assess total and directional spillovers. It produces four spillover types, these are, directional, total, net, and net pairwise spillovers. These spillover indices are used to explore returns and volatility interdependence. This will reveal any spillover trends, bursts and cycles between these equity markets. Both static (full) and dynamic (rolling-window) sample analyses are being assessed.

Diebold and Yilmaz (2012) proceed as follows:

Consider a covariance stationary N-variable VAR (p),

$$z_t = \sum_{i=1}^{p} \varphi_i z_{t-i} + \varepsilon_t \qquad (1)$$

where, $\varepsilon_t \sim (0, \sum)$ is a vector of independently and identically distributed disturbances, and φ_i are coefficient matrices. Z represents a vector of the returns or of volatilities.

Equation (1) is a covariance stationary process thus the infinite moving average is,

$$z_t = \sum_{i=0}^{\infty} B_i \varepsilon_{t-i} \qquad (2)$$

where $B_i = 0$ and B_0 is an N x N identity matrix.

The coefficient matrices of B_i follow this recursion,

$$B_i = \varphi_1 B_{i-1} + \varphi_2 B_{i-2} + \cdots + \varphi_p B_{i-p}$$

for i = 1,2, …

The benefit of using variance decompositions is that we can break up the forecast error variances of each variable into separate sections that are due to the numerous system shocks.

We can determine how much of the H-step-ahead forecast error variance in z_i is due to shocks to z_j, for all i≠j, for each *i*. This study uses generalised impulse response functions to identify the VAR to obtain variable ordering-invariant variance decompositions. Hence the shocks to each variable are not orthogonalised, the total of the contributions to the variance of forecast error is not equal to unity - $\sum_{j=i}^{N} \theta_{ij}^{g}(H) \neq 1$

The H-step-ahead forecast error variance decomposition is denoted by, $\theta_{ij}^{g}(H)$, for H=1,2,…, we get $\theta_{ij}^{g}(H) = \frac{\sigma_{ii}^{-1} \sum_{h=0}^{H-1} (e_i' B_h \Sigma e_j)^2}{\sum_{h=0}^{H-1} (e_i' B_h \Sigma B_h' e_i)}$

$\sum$ is the variance matrix for the error vector ε, σ_{ii} is the standard deviation of the error term for the *i*th equation and e_i is the selection vector with one as the *i*th element and zeros otherwise.
We define "own variance portion" as the fractions of the H-step-ahead error variances in forecasting z_i due to shocks to z_i, for i= 1, 2,…N and the "cross variance portion" shares, or spillovers, as the fractions of the H-step-ahead error variances in forecasting z_i due to shocks to z_j, for i, j = 1,2,..N, i ≠ j.
The available information in the variance decomposition matrix is used to generate the spillover index by normalising each entry of this matrix by the row sum as:

$$\theta_{ij}^{g}(H) = \frac{\theta_{ij}^{g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{g}(H)}$$

Where $\sum_{j=1}^{N} \theta_{ij}^{\sim g}(H) = 1$ and $\sum_{i,j=1}^{N} \theta_{ij}^{\sim g}(H) = N$

Total spillovers index is $S^{g}(H) = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \theta_{ij}^{\sim g}(H)}{\sum_{i,j=1}^{N} \theta_{ij}^{\sim g}(H)} \times 100 = \frac{\sum_{\substack{i,j=1 \\ i \neq j}}^{N} \theta_{ij}^{\sim g}(H)}{N} \times 100$

The total spillover index measures the contribution of spillovers for volatility or return shocks across all the stocks to the total forecast error variance.
This directional spillover is used to measure spillovers received by market i from all other markets j, it is:

$$S_{i.}^{g}(H) = \frac{\sum_{\substack{j=i \\ j \neq i}}^{N} \theta_{ij}^{\sim g}(H)}{\sum_{j=1}^{N} \theta_{ij}^{\sim g}(H)} \times 100$$

This directional spillover is used to measure spillovers from market i to all other markets j, it is: $S_{.i}^{g}(H) = \frac{\sum_{\substack{j=i \\ j \neq i}}^{N} \theta_{ji}^{\sim g}(H)}{\sum_{j=1}^{N} \theta_{ji}^{\sim g}(H)} \times 100$

The net spillover from market i to all other markets j is, $S_i^g(H) = S_{.i}^g - S_{i.}^g$. It is the difference between gross volatility/return shocks transmitted to and received from all other markets.
This is the net pairwise spillover between markets *i* and *j*, it is the difference between gross volatility/return shocks from market *i* to *j* and gross volatility/return shocks from *j* to *i*,

$$S_{ij}^g(H) = \left[\frac{\theta_{ij}^{\sim g}(H)}{\sum_{k=1}^N \theta_{ik}^{\sim g}(H)} - \frac{\theta_{ji}^{\sim g}(H)}{\sum_{k=1}^N \theta_{jk}^{\sim g}(H)}\right] \times 100$$

The continuously compounded returns are calculated as the difference in the log of equity market prices multiplied by 100. To compute volatility, Diebold-Yilmaz, use weekly high, low, opening and closing prices obtained from underlying daily high, low, open, close data to estimate volatility:$\sigma^2 = 0.511\,(H_t - L_t)^2 - 0.019[(C_t - O_t)(H_t + L_t - 2O_t) - 2(H_t - O_t)(L_t - O_t)]$.

Full and Rolling-window sample analyses

The full sample gives a general perspective of the measure of connectedness. The benefit of spillover indices is that they provide a tabular view of contributions going to and from a specific market which makes it simpler to interpret findings. Diebold and Yilmaz (2012) went on to conduct a rolling-sample analysis to investigate the effect of certain events on financial markets. The rolling-sample analysis considers that a fixed parameter cannot be constant throughout time, given the integration of financial markets over the recent years to date. The rolling-window analysis, using a window of 200 days and 200 weeks, provides a time-varying perspective in spillovers. The purpose of this is to identify any significant movements in the spillovers following significant events occurring in the period of study such as the GFC. The rolling-window analysis expresses any changes in much more detail using spillover plots.

Diebold and Yilmaz (2012) include total dynamic spillover plots to graphically explain the nature of interdependence between financial markets. These plots are derived from estimating 200-day (200-week) rolling samples and 10-day (10-week) forecast horizon – researchers can assess significant trends, dynamic and cyclical movements in the spillover over time.

Volatility computation

To compute volatility in this paper we will use GARCH estimates. Fasanya et al. (2019) and Bahloul and Khemakhem (2021) use a GARCH (1,1) model to determine the volatility series. This study uses Bahloul and Khemakhem's AR (1) GARCH (1,1) model to find conditional variance. It is expressed as:

$r_t = a_0 + a_1 r_{t-1} + \varepsilon_t$;

$e_t / \Omega_{t-1} \sim N.(0, \sigma_t^2)$;

$\sigma_t^2 = \omega + \alpha\varepsilon_1^2 + B\sigma_{t-1}^2$;

with conditions that $\beta, \alpha \geq 0$ and $\alpha + \beta < 1$.

r_t represents the daily/weekly index return at time (t), ω is a constant term, ε_t represents the error term and σ_t^2 represents the conditional variance of the residuals of the mean equation. The GARCH model is used to estimate financial markets' volatility. It is used to model historical and predict future volatility levels of variables. The model caters for time-varying volatility that financial markets exert, and it can model non-normal distribution data.

4. Data and Preliminary Analysis

This study uses daily and weekly stock exchange data over a fourteen-year period from January 2008 to January 2022 for daily data, and February 2008 to December 2022 for weekly data. The data is retrievable from Bloomberg. The sample period contains numerous critical historical events, namely, the GFC, Brexit, national elections and the Covid-19 pandemic, that might be expected to impact the analysis.

The following indices are included; JSE, S&P 500, FTSE 100, NGX, EGX and NSE. The prices have been converted to returns by taking log-differences. An AR (1) GARCH (1, 1) model has been used to measure volatility in the study.

4.1. Daily Returns Analysis

Table 1 - Descriptive Statistics: Daily data

The average ranges from -0.01% (NGX) to 0.03% (S&P 500). Therefore, for the sample period, the NGX market experienced a decline in its returns; while the other markets experienced positive returns – this suggests that the NGX may have been subject to adverse economic and market conditions that led to its underperformance. Standard deviation ranges between 0.89% (NSE) and 1.54% (EGX) - the EGX is the most volatile by standard deviation. The daily returns are all excess kurtosis (leptokurtic), meaning that they have fatter tails than normal and sharper peaks around the average. This shows that there is a strong likelihood of extreme price fluctuations, resulting in greater possibility for extreme returns or losses. Most of the returns are skewed negatively, except for the NSE and NGX. The positively skewed return distributions show that the NGX and NSE markets experience smaller stable returns with a chance of occasional large gains. While the remaining negatively skewed return distributions experience more regular stable returns and have a small probability of significant losses.

Index	Mean	Standard Dev.	Min.	Max.	Skewness	Kurtosis
NSE	0.0001	0.0089	-0.0567	0.0748	0.0638	8.5856
JSE	0.0003	0.0130	−0.1045	0.0790	-0.2487	5.7402
S&P	0.0003	0.0128	−0.1277	0.1095	-0.5653	13.8410
FTSE	0.00004	0.0120	−0.1151	0.0938	-0.3644	10.1078
NGX	-0.0001	0.0102	-0.0503	0.0798	0.2582	4.0840
EGX	0.00002	0.0154	-0.1799	0.0783	-1.0329	10.1520

Table 2 - Unit root tests on the daily stock exchange returns

The indices are tested for stationarity using the Elliot, Rothenberg and Stock (DF-GLS) Unit Root Test. The tests included a constant term for all the series, refer to the time series plots for motivation. The results show that all the daily returns are stationary series.

Index	NSE	JSE	S&P	FTSE	NGX	EGX
DF-GLS	-13.160***	-21.064***	-28.437***	-12.194***	-10.593***	-22.871***

*, **, *** denote 10%, 5% and 1% level of significance respectively.

Table 3 - Linear correlations using Spearman method.

To provide a preliminary assessment of the connectedness between the markets over the full sample, Table 3 presents the Spearman linear correlation coefficients, which are suitable for non-normally distributed data. The US and the UK are mostly correlated to South Africa. The ascending order of the US pairs are US-Nigeria, US-Kenya, US-Egypt and US-South Africa. In a similar fashion for the UK pairs, the order is as follows, UK-Kenya, UK-Nigeria, UK-Egypt and UK-South Africa. In terms of African markets, the least and most correlated are Kenya-South Africa and Egypt-South Africa respectively.

The advanced markets have a moderate correlation with the JSE, which is consistent with existing literature. The remainder of the African stock markets have a low correlation with advanced stock markets. While the JSE is the most correlated to the EGX – this is likely due to how much further developed these stock markets are in comparison to their sister-countries. These results suggest potential diversification benefits for foreign investors, in other words, advanced market investors may see opportunities to diversify their portfolios in low correlated advanced-African markets.

Correlation tests are limited in that, they are unable to measure nonlinear relations between markets and do not show directional relations. These limitations support the use of the Diebold and Yilmaz methodology in this study.

Returns	**S&P 500**	**FTSE 100**	**JSE**	**NSE**	**NGX**	**EGX**
S&P 500	1					
FTSE 100	0.4932	1				
JSE	0.3355	0.5848	1			
NSE	0.0148	-0.0077	0.0063	1		
NGX	0.0005	0.0468	0.0297	0.1229	1	
EGX	0.0944	0.1678	0.1674	0.0458	0.0626	1

4.2. Daily Volatility

Table 4 - GARCH estimates parameters of AR (1) GARCH (1,1) model.

Conditional variances estimated from the below GARCH model have been used to estimate volatility.

	S&P 500	FTSE 100	JSE	NSE	NGX	EGX
Mean Equation						
A_0	7.39×10^{-4} (0.00) **	3.03×10^{-4} (0.02) **	5.17×10^{-4} (0.00) **	3.73×10^{-4} (0.02) **	-2.04×10^{-4} (0.27)	5.25×10^{-4} (0.04) **
A_1	-6.63×10^{-2} (0.00) **	-3.44×10^{-2} (0.05) **	5.01×10^{-3} (0.77)	3.23×10^{-1} (0.00) **	3.13×10^{-1} (0.00) **	1.98×10^{-1} (0.00) **
Conditional Variance equation						
C_o	3×10^{-6} (0.00) **	3×10^{-6} (0.01) **	2×10^{-6} (0.00) **	6×10^{-6} (0.00) **	8×10^{-6} (0.00) **	1.1×10^{-4} (0.00) **
α	1.55×10^{-1} (0.00) **	1.10×10^{-1} (0.00) **	8.06×10^{-2} (0.00) **	2.02×10^{-1} (0.00) **	1.88×10^{-1} (0.00) **	1.02×10^{-1} (0.00) **
β	8.27×10^{-1} (0.00) **	8.69×10^{-1} (0.00) **	9.05×10^{-1} (0.00) **	7.13×10^{-1} (0.00) **	7.21×10^{-1} (0.00) **	8.47×10^{-1} (0.00) **

Notes: This table gives a view of the model estimations of the AR (1) GARCH (1,1) model for all six equity markets. The sample period is daily from January 2008 to January 2022. ** and * denote level of significance at 5% and 10% level respectively.

Table 5 - Linear Correlations of volatility (conditional variances)

The US and the UK are mostly correlated to South Africa. The ascending order of the US pairs are US-Nigeria, US-Kenya, US-Egypt and US-South Africa. The UK pairs are as follows, UK-Nigeria, UK-Kenya, UK-Egypt and UK-South Africa. The least and most correlated African markets are Kenya-Egypt and Egypt-South Africa respectively.

The conditional variances of the advanced stock markets and the JSE are highly correlated. The remainder of the African stock markets have a low to moderate correlation with advanced stock markets. This suggests that the JSE is expected to move in tandem with advanced stock markets when experiencing volatility shocks.

Volatility	S&P 500	FTSE 100	JSE	NSE	NGX	EGX
S&P 500	1					
FTSE 100	0.8189	1				
JSE	0.7385	0.7723	1			
NSE	0.2083	0.2095	0.2677	1		
NGX	0.1969	0.2093	0.2075	0.1440	1	
EGX	0.4063	0.4516	0.4386	0.0577	0.1610	1

4.3. Weekly Returns Analysis

The empirical analysis in this section is conducted on weekly data ranging from February 2008 to December 2022.

Table 6 - Descriptive Statistics: Weekly data

The average ranges from -0.03% (NGX) to 1.4% (S&P 500). This is consistent with the findings from the daily return analysis, implying that the NGX market experienced a downward trend over the sample period which was likely due to country-specific challenges such as oil price volatility, foreign currency liquidity challenges and political instability. Standard deviation ranges between 2.53% (NSE) and 3.98% (EGX) - the EGX is the most volatile by standard deviation. The returns are all excess kurtosis (leptokurtic), meaning that they have fatter tails than normal and sharper peaks around the average. This shows that there is a strong likelihood of extreme price fluctuations, creating a greater possibility for extreme returns or losses. All the returns are skewed negatively – the returns are more likely to be stable with a likelihood of experiencing a few significant losses.

Index	Mean	Standard Dev.	Min.	Max.	Skewness	Kurtosis
NSE	0.0003	0.0253	-0.1556	0.1531	-0.3559	4.7509
JSE	0.0011	0.0276	-0.1693	0.1792	-0.1865	5.8826
S&P 500	0.0014	0.0265	-0.2008	0.1142	-0.9579	8.0745
FTSE	0.0003	0.0258	-0.2363	0.1258	-1.5550	14.5777
NGX	-0.0003	0.0317	-0.1449	0.1562	-0.1444	4.4062
EGX	0.0003	0.0398	-0.2196	0.1913	-0.8405	5.4899

Table 7 - Unit root tests

The indices are tested for stationarity using the Elliot, Rothenberg and Stock (DF-GLS) Unit Root Test. The tests included a constant term for all the series, refer to the time series plots for motivation. The results show that all the weekly returns are stationary series.

Index	NSE	JSE	S&P	FTSE	NGX	EGX
DF-GLS	-3.791***	-11.468***	-4.554***	-4.032***	-7.159***	-10.930***

*, **, *** denote 10%, 5% and 1% level of significance respectively.

Table 8 - Linear Correlation tests using Spearman method.

The ascending order of the US pairs are US-Nigeria, US-Kenya, US-Egypt and US-South Africa. The UK pairs are as follows, UK-Kenya, UK-Nigeria, UK-Egypt and UK-South Africa. The least and most correlated African markets are Nigeria-South Africa and Nigeria-Kenya respectively. The advanced stock markets have an above moderate correlation with the JSE, which is consistent with existing literature. Contrary to this, the remainder of the African stock markets have a low correlation with advanced stock markets.

Returns	S&P 500	FTSE 100	JSE	NSE	NGX	EGX
S&P 500	1					
FTSE 100	0.7276	1				
JSE	0.5781	0.6635	1			
NSE	0.0654	0.0303	0.0531	1		
NGX	0.0192	0.0431	0.0525	0.1987	1	
EGX	0.1980	0.1915	0.1616	0.1848	0.1066	1

4.4. Weekly Volatility

Conditional variances estimated from the below GARCH model have been used to estimate volatility.

Table 9 - GARCH estimates parameters of AR (1) GARCH (1,1) model.

	S&P 500	FTSE 100	JSE	NSE	NGX	EGX
Mean Equation						
A_0	3.27×10^{-3} (0.00) **	1.19×10^{-3} (0.08) *	1.75×10^{-3} (0.02) **	1.34×10^{-3} (0.11)	8.77×10^{-4} (0.39)	1.1×10^{-3} (0.43)
A_1	-5.72×10^{-2} (0.14)	-3.52×10^{-3} (0.93)	-5.22×10^{-2} (0.18)	1.13×10^{-1} (0.01) **	1.5×10^{-1} (0.00) **	1.26×10^{-1} (0.00) **
Conditional Variance equation						
C_o	4.1×10^{-4} (0.00) **	3.8×10^{-5} (0.00) **	4.1×10^{-5} (0.00) **	1.09×10^{-4} (0.00) **	8.4×10^{-5} (0.00) **	1.73×10^{-4} (0.00) **
α	3.51×10^{-1} (0.00) **	2.06×10^{-1} (0.00) **	1.08×10^{-1} (0.00) **	3.02×10^{-1} (0.00) **	3.21×10^{-1} (0.00) **	1.83×10^{-1} (0.00) **
β	6.25×10^{-1} (0.00) **	7.54×10^{-1} (0.00) **	8.28×10^{-1} (0.00) **	5.46×10^{-1} (0.00) **	6.34×10^{-1} (0.00) **	7.21×10^{-1} (0.00) **

Notes: This table gives a view of the model estimations of the AR (1) GARCH (1,1) model for all six equity markets. The sample period is weekly from February 2008 to December 2022. ** and * denote level of significance at 5% and 10% level respectively.

Table 10 - Linear Correlation of volatility (conditional variances)

The ascending order of the US pairs are US-Nigeria, US-Kenya, US-Egypt and US-South Africa. The UK pairs are as follows, UK-Kenya, UK-Nigeria, UK-Egypt and UK-South Africa. For African stock markets, the least and most correlated are Nigeria-Kenya and Nigeria-South Africa respectively. The advanced stock markets are highly correlated to the JSE. Conversely, the remainder of the African stock markets have lower correlation with the advanced stock markets.

Returns	S&P 500	FTSE 100	JSE	NSE	NGX	EGX
S&P 500	1					
FTSE 100	0.7612	1				
JSE	0.7132	0.7017	1			
NSE	0.3009	0.2697	0.3400	1		
NGX	0.2789	0.3765	0.3552	0.1504	1	
EGX	0.3683	0.4364	0.3064	0.1523	0.1971	1

5. The Results

We estimate a VAR model as the foundation for the Diebold-Yilmaz spillover measures. The VAR model is then used to compute Generalised Forecast Error Variance Decompositions (GFEVDs), which explain how different shocks impact the various variables within the VAR, i.e., it assesses the strength of interdependence between variables within the system. Identifying the VAR model using the generalised identification methodology allows for the measurement of total and directional spillovers, as explained in Section 3. The lag length for the VAR is selected using the Akaike Information Criterion (AIC) and the Final Prediction Error (FPE) criterion. The results are as follows; 7 for daily returns, 12 for daily volatility, 3 for weekly returns and 6 for weekly volatility.

This section reports results for both daily data (sections 5.1 –5.4) and weekly data (sections 5.5 –5.8). In each case, the analysis of returns spillovers is presented first (spillover indices and plots), followed by that of volatility spillovers.

5.1. Daily Total and Directional Returns spillovers

Table 11 - Spillover Table

We begin by interpreting the gross directional spillovers. The “gross directional spillovers to others” from each of the six markets is highest in the FTSE followed by the S&P 500 with 61% and 57% respectively - this is expected given that these are advanced markets with the highest trading volume, strong trade linkages with other markets, and global footprint in terms of stocks in specific industries. In terms of the African markets, we see a large difference between the contributions of the markets. South Africa exerts the highest contribution to other markets while Egypt follows second with a lesser 10% contribution.

The gross “directional spillovers from others” column shows that the gross directional spillovers from others to the FTSE market is the largest at 48%, followed by the JSE having spillovers from other markets explaining 44% of its forecast error variance. The largest net directional spillovers are from the S&P 500 market to others (57.04 – 41.38 = 15.66%) and from others to the NSE market (2.21 – 13.92 = -11.71%). The total spillover is calculated as (178.68/6= 29.78%). Therefore, for our whole sample, 29.78% of the returns’ forecast error variance in all six indices emanates from spillovers.

With respect to advanced markets, the return spillovers from the UK to South Africa (24%) are higher than return spillovers from the US to South Africa (17%). With respect to African markets, the stock markets have very little connectedness with each other - the most notable interdependence is between South Africa and Egypt with innovations to South Africa accounting for 5% of the 10-day ahead forecast error variance of Egyptian returns. International investors and policymakers who are interested in diversification and risk management strategies should consider expanding their portfolios into the frontier African markets because there is low connectedness between these markets and advanced markets.

Overall, the total spillover is moderate at 29.78%. The directional spillovers between the advanced markets and the JSE are just below moderate. This shows that the more sophisticated and integrated financial markets are, the more they are susceptible to innovations from other markets. The magnitude of spillovers between the advanced markets and the remaining African markets is low; therefore, opportunities of diversification are encouraged between these markets. The key is to assess sector-specific diversification opportunities between the regions.

	S&P	FTSE	JSE	NSE	NGX	EGX	C. from others
S&P	58.62	24.29	14.03	0.26	0.24	2.57	41.38
FTSE	24.24	51.41	21.73	0.12	0.29	2.20	48.59
JSE	17.09	24.19	55.76	0.18	0.46	2.32	44.24
NSE	4.96	3.77	2.67	86.08	0.58	1.94	13.92
NGX	2.17	2.70	2.04	1.064	90.81	1.22	9.19
EGX	8.58	6.38	5.50	0.59	0.31	78.64	21.36
C. to others	57.04	61.33	45.96	2.21	1.88	10.25	29.78
Contributions including own	115.66	112.74	101.72	88.29	92.70	88.88	600.00

Notes: The underlying variance decomposition is based upon a daily returns VAR of order 7, identified using Generalised Impulse Response Functions. The ijth entry of the 6x6 matrix is the estimated contribution to the forecast error variance of market i coming from innovations to market j. The “from others” column compromises of row sums excluding the diagonal entries, it shows the total directional spillover from all others to market i. The “to others” row is made up of the column sums sans the diagonal entries, it provides the aggregate directional spillover from market j to others. The difference between these directional spillovers (‘‘from minus to’’) gives net spillovers. The total spillover index is provided in the bottom right entry of the table. It is obtained by dividing the sum of the last column (“from others”) by the total markets (6 in this study) and it is expressed as a percentage (Diebold and Yilmaz, 2012).

5.2. Daily Returns Rolling window analysis – Spillover Plots

As stated by Diebold and Yilmaz (2009) it is unlikely that the parameters of this model would be constant throughout time, considering the multitude of events that happened during the period, 2008 to 2022, that may have had an impact on financial markets. These are namely, the GFC, Euro debt crisis, Covid-19 pandemic, and Brexit. The rolling window analysis is based on a 200-day window for analysis with a 10-day horizon forecast (H=10).

Figure 1- Total returns spillovers.

This is a generalised spillover plot inspired by the Diebold and Yilmaz (2012) approach. It provides an average view of interdependence between all the variables. It gives us a time-varying and dynamic view of how financial markets are affected by shocks over time. This will reveal the nature of connectedness of the entire sample as market conditions change over time. This plot is based on a 200-day rolling sample. The plot ranges between 35% to 48% from 2008 to 2012. During this period, financial integration was becoming prominent. Bursts are seen around 2015 to 2018; and 2020 to 2021 where spillover levels peaked above 60% - this is a result of the unexpected pandemic.

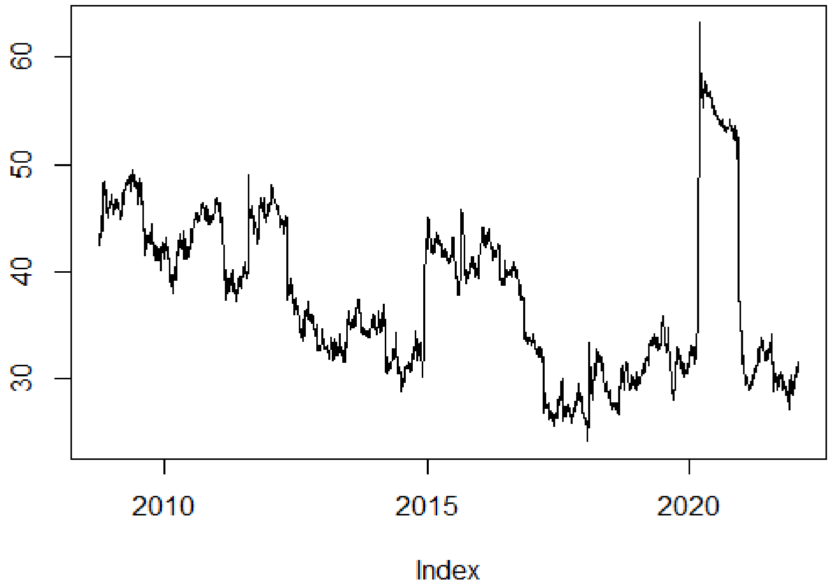


Figure 2 - Directional returns spillovers, from six equity markets

During the tranquil periods, the spillovers from each index are below 5%, during volatile periods the FTSE, JSE and S&P directional spillovers exceed 10%. The directional returns spillovers from the NSE are smallest. The return spillovers from the FTSE and S&P 500 are the largest.

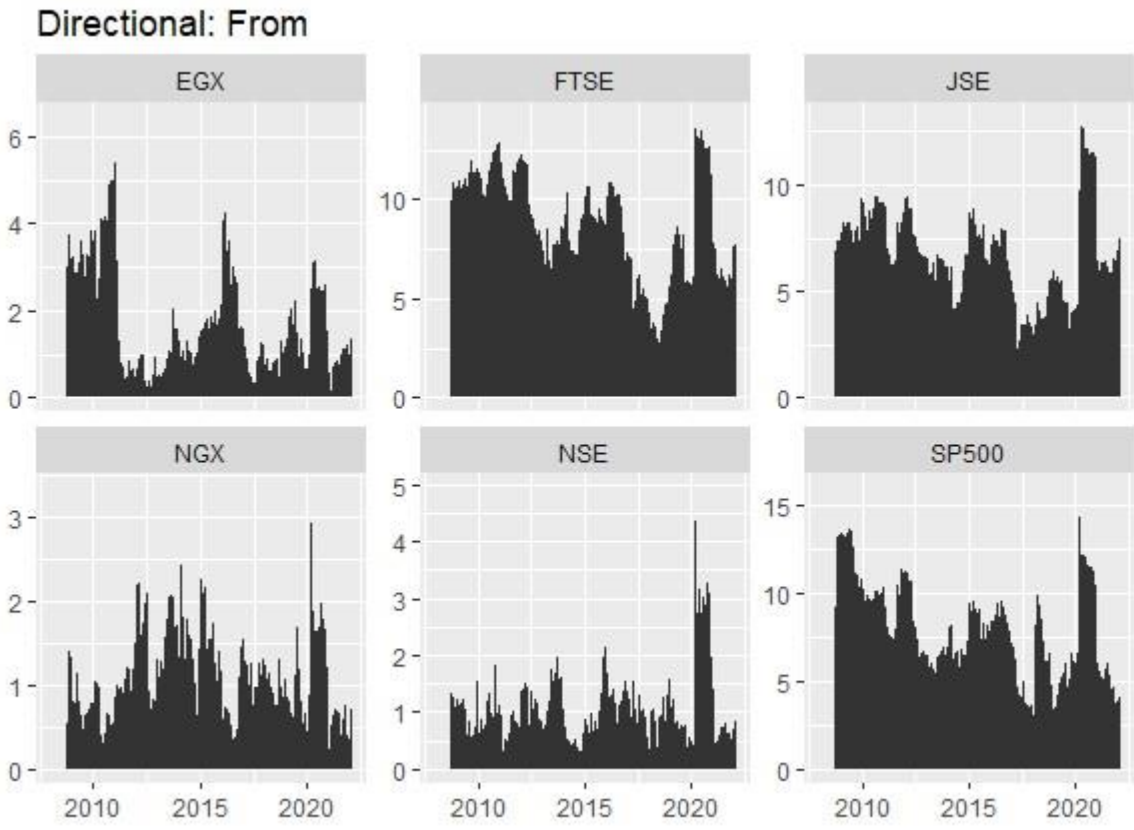


Figure 3 - Directional returns spillovers, to six equity markets

The S&P, FTSE and JSE are the highest recipients of gross directional spillovers with peaks exceeding 10% during volatile seasons such as the GFC and the recent pandemic. The EGX and NSE peaked above 5% during the GFC, and the NGX did so during the pandemic. The frontier African markets receive spillovers at a lower magnitude, this may be due to limited global financial integration with advanced markets, restricted capital flows, illiquidity, differences in sector composition.

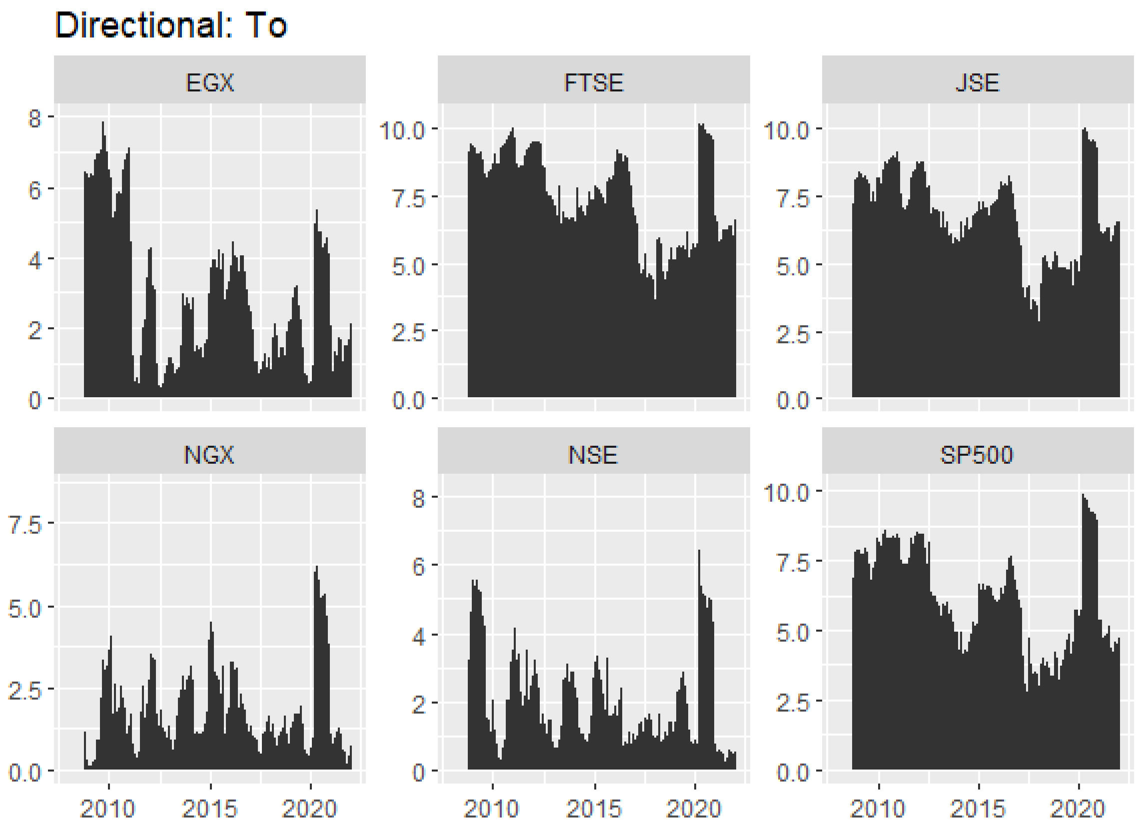


Figure 4 - Net spillovers, six equity markets

The net returns spillovers are mostly negative for the African markets. The JSE's lowest point is -2% in 2014, when the country was vulnerable to severe political instability. The net returns spillovers are mostly positive for the advanced markets. The FTSE's low is around 2018/2019, which is in the tenure of the Brexit. The S&P is barely a net-recipient of external shocks, it only experiences minor negative spillovers after 2020.

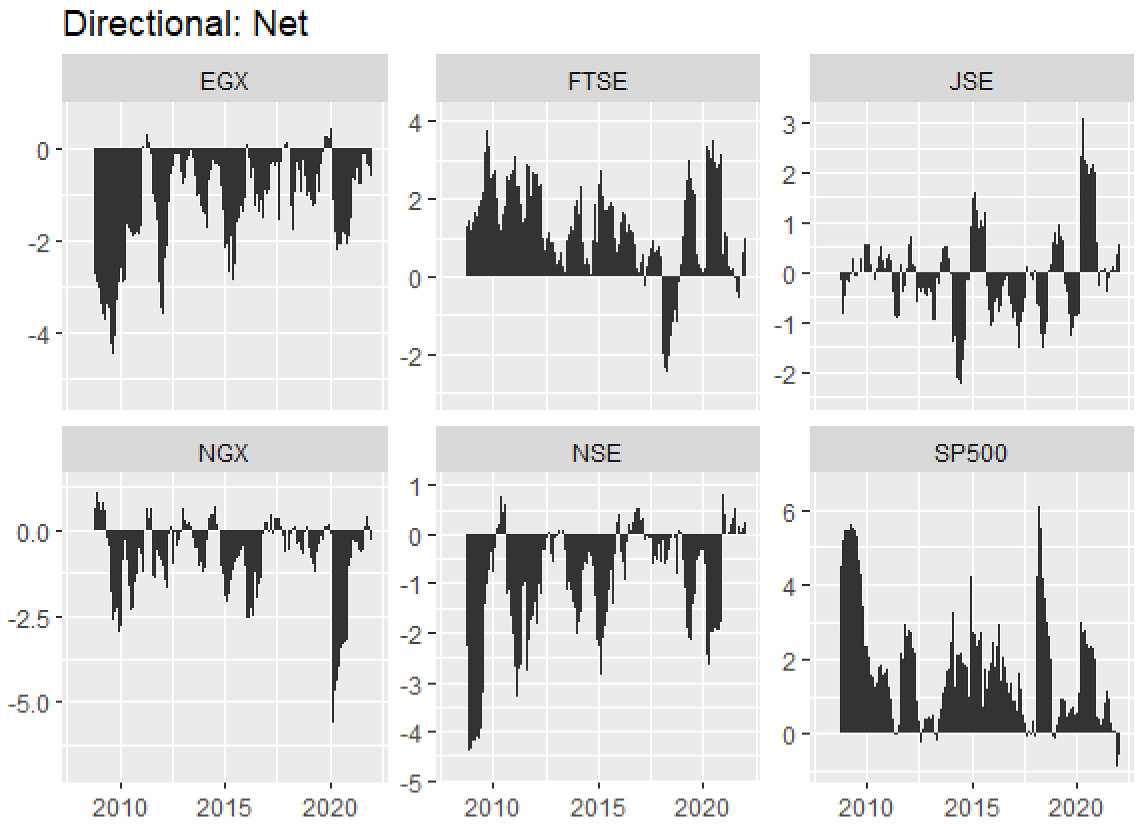
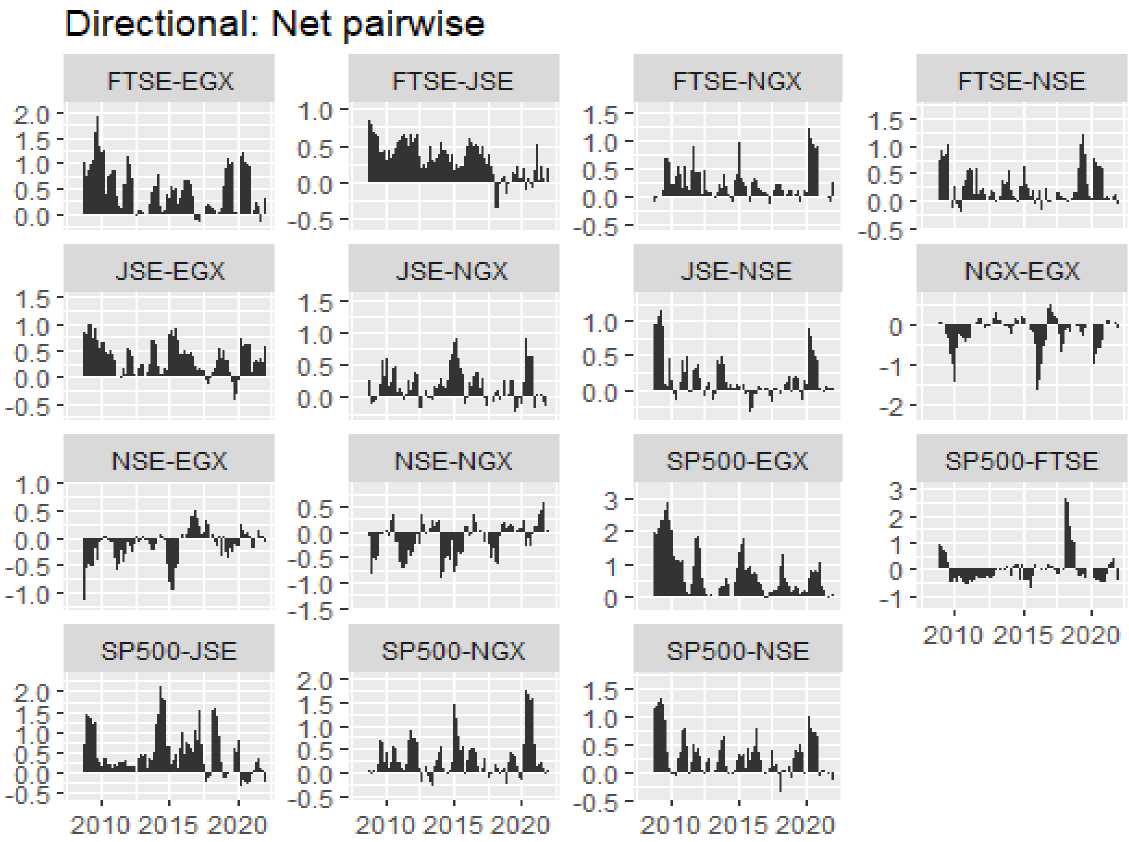


Figure 5 - Net pairwise

The innovations to the FTSE mostly spilled to the African markets for most of the period with spillovers to Egypt peaking at 2%. Around 2018, the shocks to the S&P spilt over to the FTSE – the FTSE was sensitive due to the Brexit. The JSE is a net transmitter to all other African markets with most of its shocks spilling over to Egypt. The NGX is a net recipient of innovations from the EGX. The S&P is mostly a net transmitter to all the markets, with it being a net recipient to the FTSE between 2010 and 2015, and in 2020.



As expected, the advanced markets exert higher spillovers to other markets, this is due to their strong international trade and financial linkages with the rest of the world, many African countries are dollar dependent for trade and that makes their markets susceptible to dollar movements. The S&P, FTSE and JSE have a higher market size and liquidity which in turn makes them attractive to global investors and thus increases their connectedness. This also means that they are vulnerable to global shocks and are likely to respond in the same manner to shocks due to their heightened connectedness. With respect to African markets, the JSE exerts the highest contribution to other markets followed by Egypt. As Africa’s most advanced index, the JSE has a pivotal role in Africa’s financial market ecosystem. It is regarded as the entry point for many foreign investors looking to invest in African markets. This means that regional markets are closely affected by the JSE's behaviour. This explains why its innovations impact its sister countries.

5.3. Daily Total and Directional Volatility spillovers

Table 12 - Volatility Spillover Table

The "gross directional volatility spillovers to others" from each of the six markets is highest in the S&P followed by the FTSE with 63.7% and 58% respectively – this is consistent with returns findings that innovations to advanced markets are most likely to spillover to other markets. In terms of the African markets, South Africa and Egypt exert the highest contributions to other markets with 35.8% and 12% respectively.

The gross "directional spillovers from others" column shows that the gross directional volatility spillovers from other markets are the largest to the JSE at 51.7%, followed by the FTSE having the transmissions from other markets explaining 45.7% of its forecast error variance. The largest net transmissions are from the S&P market to others (23.98%). The largest net receiver is the JSE (-15.91%). For our whole sample, 29.33% of the volatility forecast error variance in all six markets results from spillovers which is significant.

With respect to advanced markets, the volatility spillovers from the UK to South Africa are equal to those from the US to South Africa. With respect to African markets, the stock markets have very little interdependence with each other – this presents diversification opportunities amongst the African markets. This low interdependence between African markets can be attributed to the following reasons:

- Low levels of intra-Africa trade - most African markets trade with leading global markets this results in declined levels of African market financial linkages.
- Heavily concentrated sector compositions on exchanges, for example, NGX is concentrated in oil and gas, banking and consumer goods; JSE in mining, financial services, telecommunications and consumer goods; NSE in financial services, agriculture and telecommunications; and EGX in real estate, tourism and industrial sectors. The difference in sector dominance means that African stock markets are unlikely to move simultaneously hence the low levels of connectedness.
- Market barriers - low levels of liquidity and trading volume.
- Inconsistency in regulatory and political frameworks across African countries which can limit regional capital flows.

	S&P	FTSE	JSE	NSE	NGX	EGX	C. from others
S&P	60.28	22.67	12.24	0.95	0.07	3.78	39.72
FTSE	26.54	54.31	14.16	0.58	0.178	4.23	45.69
JSE	23.33	23.49	48.26	1.63	0.31	2.98	51.74
NSE	2.36	4.64	2.03	89.63	0.74	0.59	10.37
NGX	2.50	0.61	1.25	0.65	94.51	0.47	5.49
EGX	8.97	7.03	6.14	0.21	0.60	77.04	22.96
C. to others	63.70	58.45	35.82	4.03	1.90	12.06	29.33
Contributions including own	123.98	112.76	84.07	93.66	96.42	89.10	600.00

Notes: The underlying variance decomposition is based upon a daily volatility VAR of order 12, identified using Generalised Impulse Response Functions.

5.4. Daily Volatility Rolling window analysis – Spillover Plots

Figure 6 - Total Volatility Spillover Plot

This plot is based on a 200-day rolling sample. There are no trends in sight, there are a couple of cycles and bursts. The plot ranges between 20% and 70%. The plot peaks at 60% in 2012 which coincides with the Euro debt crisis, it peaks at 70% in 2020 during the recent pandemic. A brief downward cycle is seen in 2018, this may be due to the Brexit.

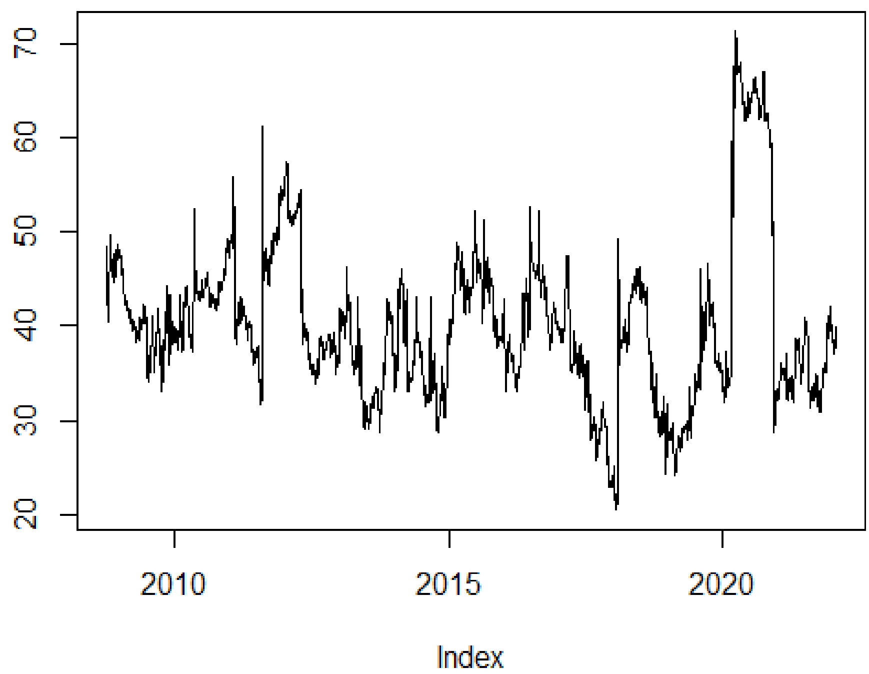


Figure 7 - Directional volatility spillovers, from six equity markets

During tranquil periods, spillovers from each index are below 5%, during volatile periods the directional spillovers exceed 10% - a notable peak is 22% for the JSE in 2020 during the pandemic. The directional volatility spillovers from the NSE, EGX and NGX are the smallest due to these indices having a limited effect on leading financial markets. The advanced markets exert the largest directional volatility spillovers.

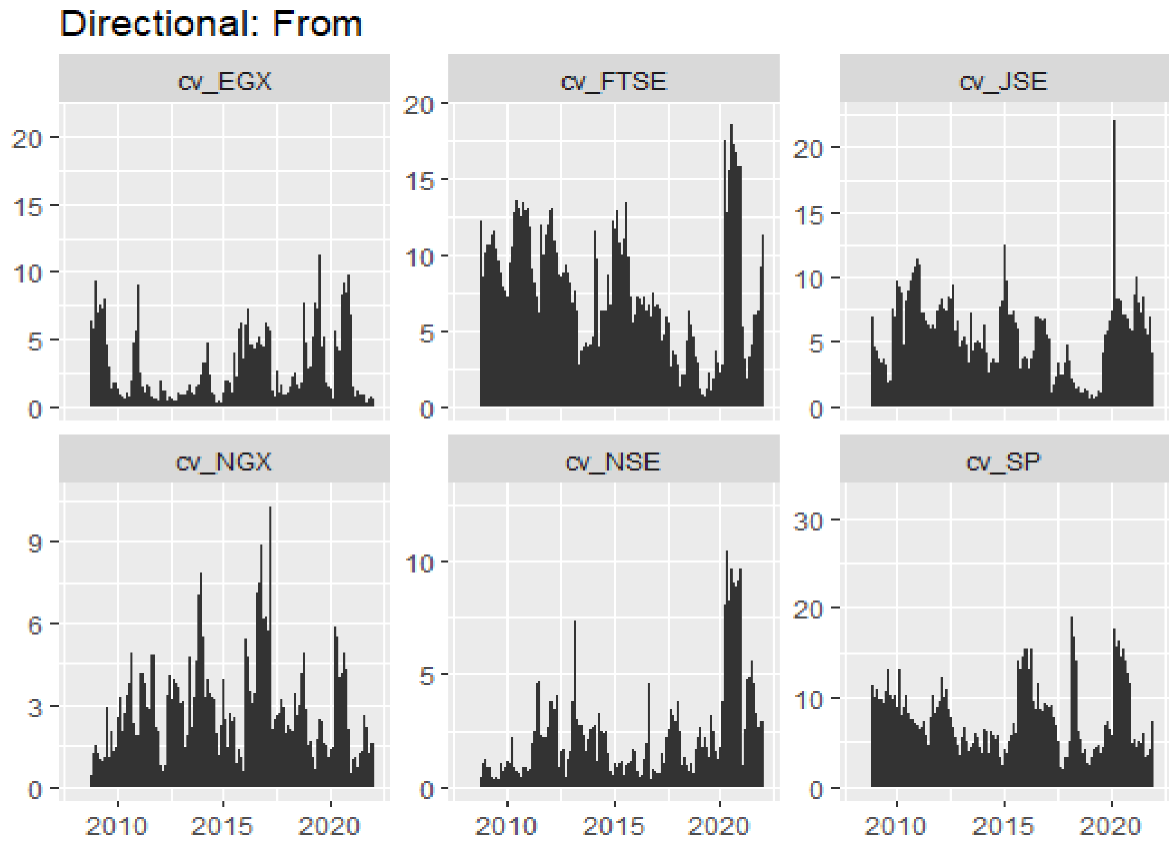


Figure 8 - Directional volatility spillovers, to six equity markets

The S&P, FTSE and JSE are the highest recipients of directional spillovers with peaks exceeding 10% during volatile seasons such as the GFC, Brexit and the recent pandemic. The NGX and NSE are the least affected by transmissions from other markets.

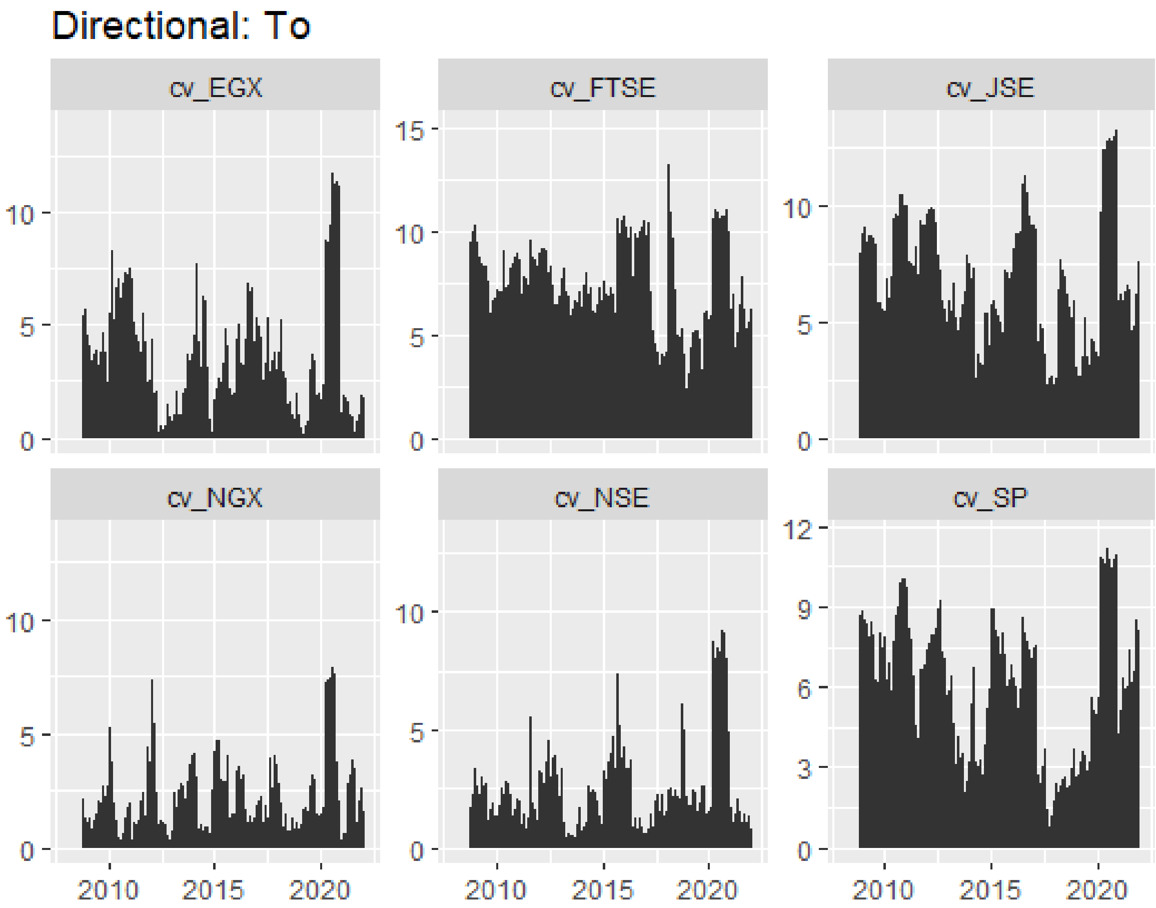


Figure 9 - Net spillovers, six equity markets

Net volatility spillovers fluctuate between positive and negative spillovers for all the markets. The EGX is mostly a net recipient with exceptions in 2009 and 2019. The FTSE mostly experiences positive net volatility with its highest peaks around the 2020 pandemic. The JSE is a net recipient of volatility shocks with notable extreme lows during 2009, 2016 and 2021 resulting from the GFC, political instability and the pandemic. The S&P 500 reached lows of (-5%) in 2015 but picked up thereafter to peak above 15% in 2018 where its innovations mostly influenced other markets.

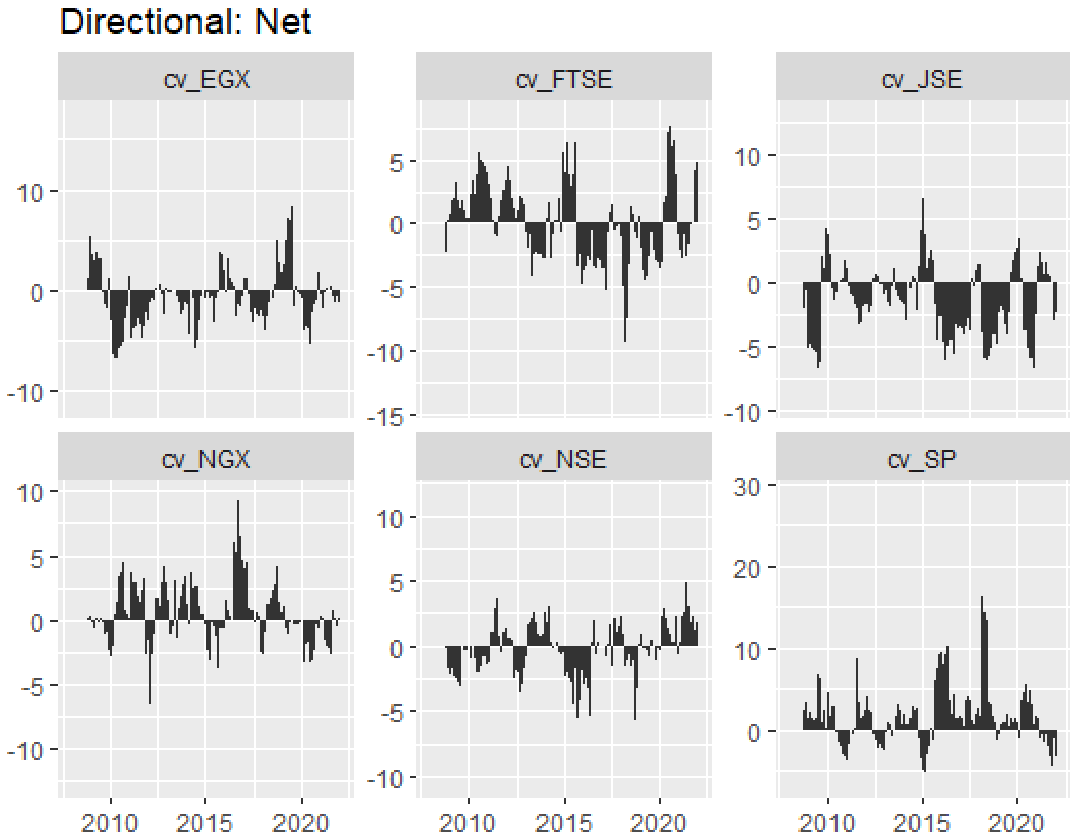
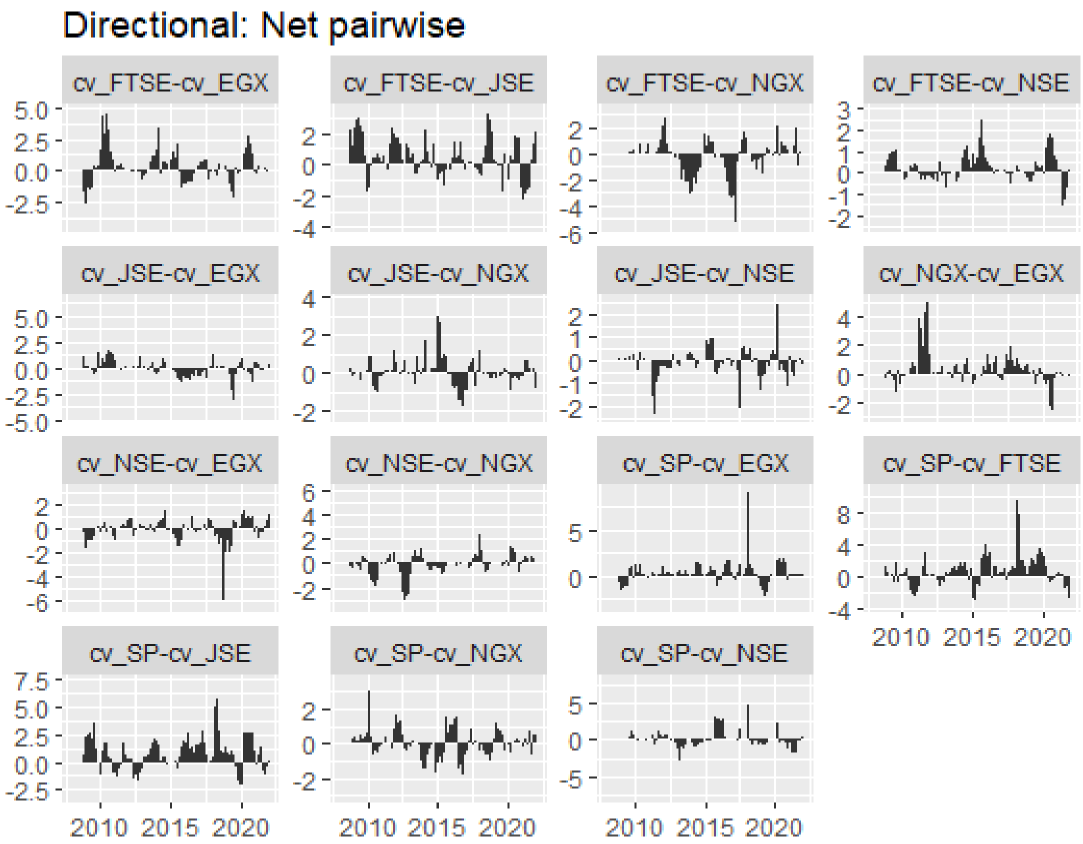


Figure 10 – Net pairwise

Innovations from the FTSE spilled to the JSE, EGX and NSE. The S&P is a net transmitter to the JSE with peaks exceeding 5% in 2018. Around 2011 to 2013, Nigerian innovations spilled over to the EGX and FTSE.



5.5. <u>Weekly Total and Directional Returns Spillovers</u>

Table 13 - Spillover Table

The "gross directional spillovers" to others from each of the six markets is highest in the FTSE followed by the S&P 500 with 79.6% and 73.2% respectively. For African markets, South Africa exerts the highest contribution to other markets while Egypt follows second with a lesser 19% contribution.

The gross "directional spillovers from others" are the largest to the FTSE market at 57%, closely followed by the S&P 500 having spillovers from other markets explaining 56% of its forecast error variance. The largest net transmissions are from the FTSE market to others (79.65 – 57.28 = 22.37%) and the largest net receiver is the NSE market (8.84 – 28.95 = -20.11%). The total spillover is calculated as (249.71/6= 41.62%). Therefore, 41.62% of the returns' forecast error variance in all six markets result from spillovers which is very significant. This result indicates high levels of connectedness between the markets, which increases the likelihood of systemic risk.

With respect to advanced markets, the return spillovers from the UK to South Africa are greater than return spillovers from the US to South Africa. The African markets display low interdependence amongst themselves. This provides evidence of diversification opportunities for both international and African investors.

The magnitude of the directional spillovers is low to moderate for the African markets excluding South Africa that has high directional spillovers. Opportunities of diversification are most suitable between advanced markets and the frontier markets.

	S&P	FTSE	JSE	NSE	NGX	EGX	C. from others
S&P	43.85	28.57	20.58	1.45	0.38	5.16	56.15
FTSE	27.67	42.72	22.91	1.10	1.02	4.57	57.28
JSE	22.07	26.01	45.66	1.14	1.22	3.90	54.34
NSE	8.58	8.25	6.50	71.05	2.21	3.41	28.95
NGX	4.13	5.97	3.77	2.48	81.39	2.25	18.61
EGX	10.74	10.85	9.22	2.66	0.91	65.62	34.38
C. to others	73.20	79.65	62.98	8.84	5.75	19.29	41.62
Contributions including own	117.05	122.37	108.64	79.89	87.14	84.92	600.00

Notes: The underlying variance decomposition is based upon a weekly returns VAR of order 3, identified using Generalised Impulse Response Functions

5.6. Weekly Returns Rolling Window Analysis

Figure 11 – Total Returns Spillover Plot

This plot is based on a 200-week rolling sample. Downward trends are visible between 2012 and 2016, there is a slight pick-up just after 2016 that soon returns to a downward trend until 2020. The total spillover ranges between 26% and 52% - the total returns spillover plot peaks above 50% in 2012, 2020 to 2022 - this could be due to the Euro debt crisis, 2012 American elections and the 2020 pandemic. In periods of global crises, there is clear interdependence between the markets as spillovers tighten.

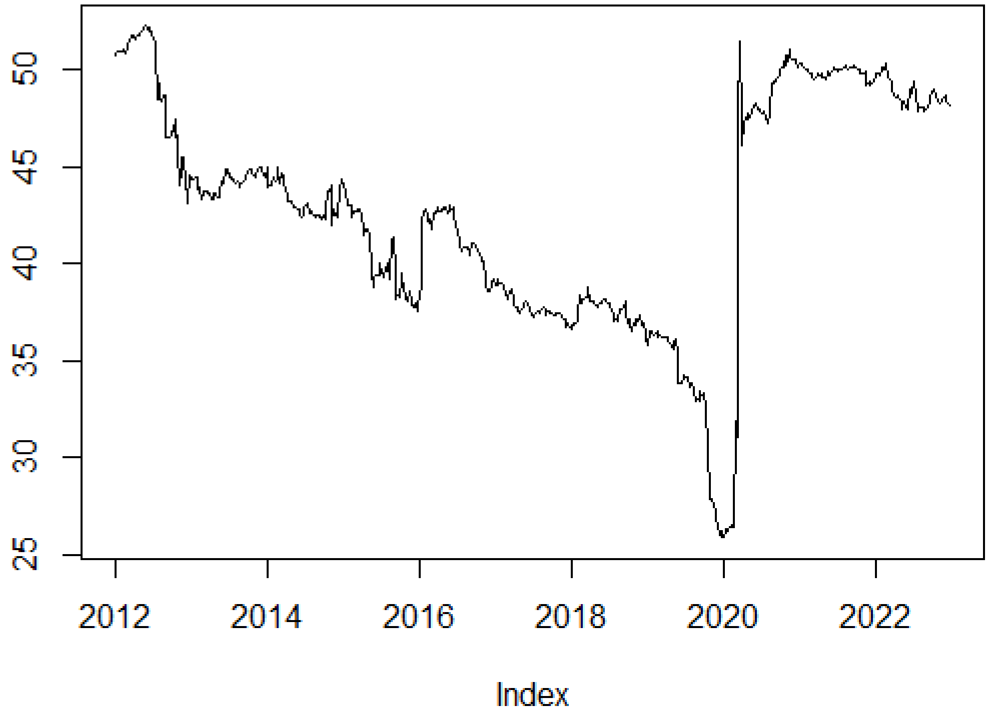


Figure 12 - Directional spillovers, from six equity markets

During tranquil periods, spillovers from the NSE, EGX and NGX are below 3%; for the JSE, FTSE and S&P 500, they are below 10%. During volatile periods the directional spillovers exceed 10% for the more sophisticated markets and peak at 5% for the lesser developed markets. The directional returns spillovers from the FTSE, JSE and S&P 500 are consistently high in the period of study, with peaks exceeding 10% in 2012 and the 2020.

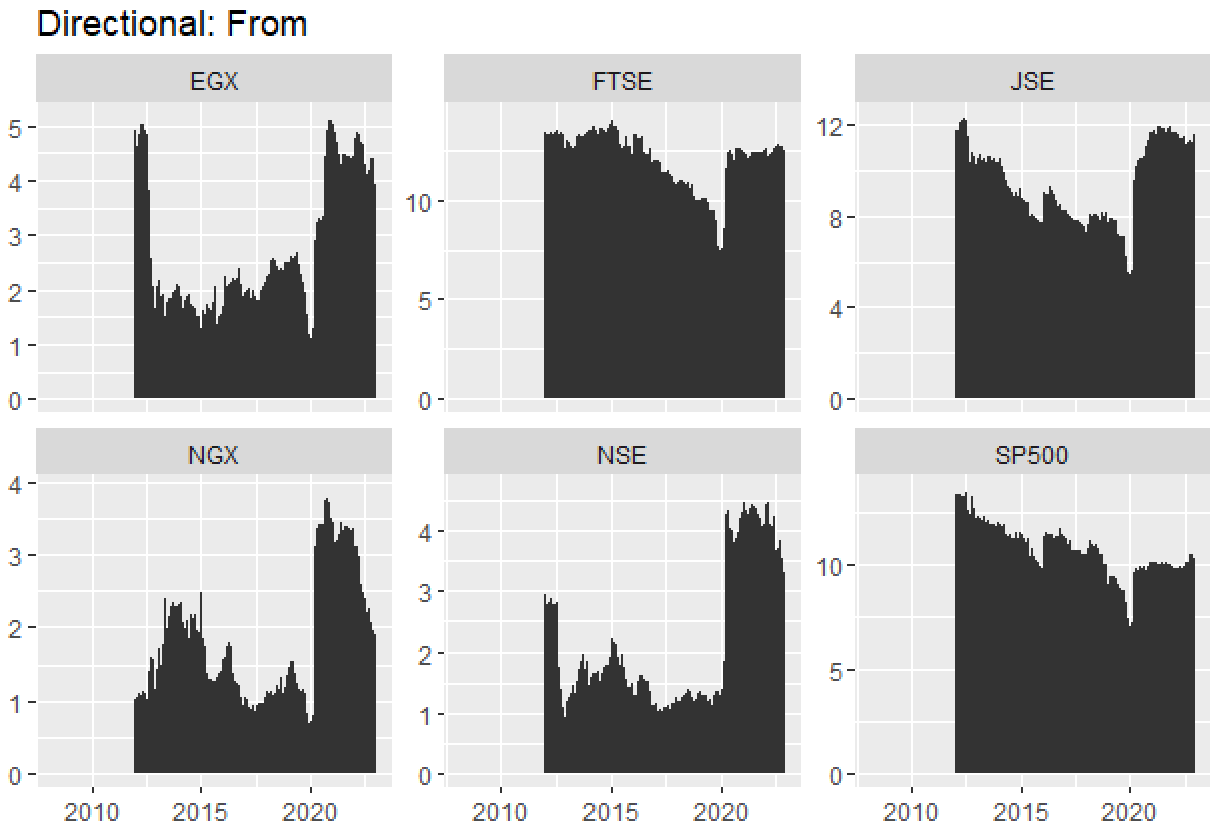


Figure 13 - Directional spillovers, to six equity markets

The S&P, FTSE and JSE are the highest recipients of gross directional spillovers with peaks reaching 10% in 2012 and 2020 due to the Euro debt crisis and the pandemic. Spillovers to the EGX, NGX and NSE collectively reached highs during the pandemic – the NSE had its highest peak at 7% in 2015.

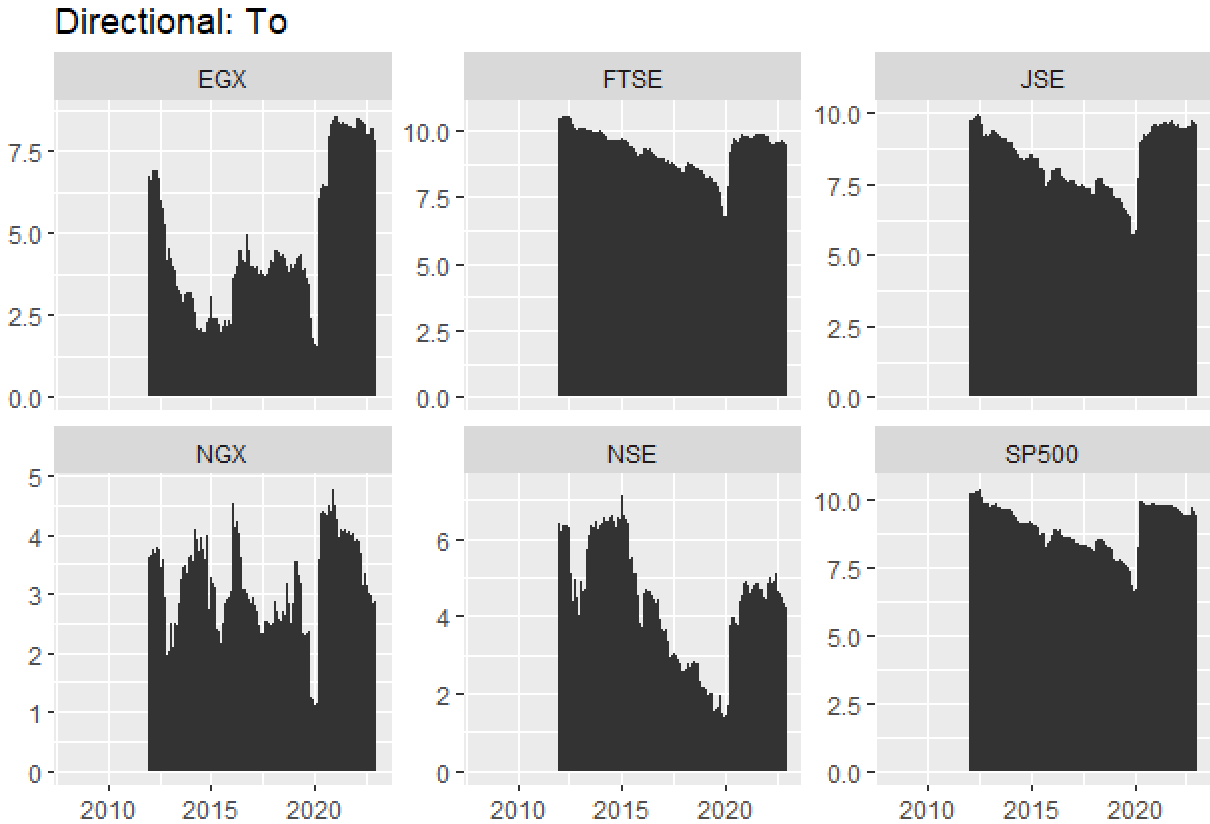


Figure 14 - Net spillovers, from six equity markets

The net returns spillovers are mostly negative for the EGX, NGX and NSE. The NSE and NGX experienced extreme lows in 2012 and 2015 due to country-specific factors, while the EGX experienced its severe lows during the pandemic. The FTSE, JSE and S&P 500 mostly display positive net returns spillovers (net transmitters), with peaks in 2012, 2015 and 2020 owing to Brexit, Eurozone debt crisis and the recent pandemic.

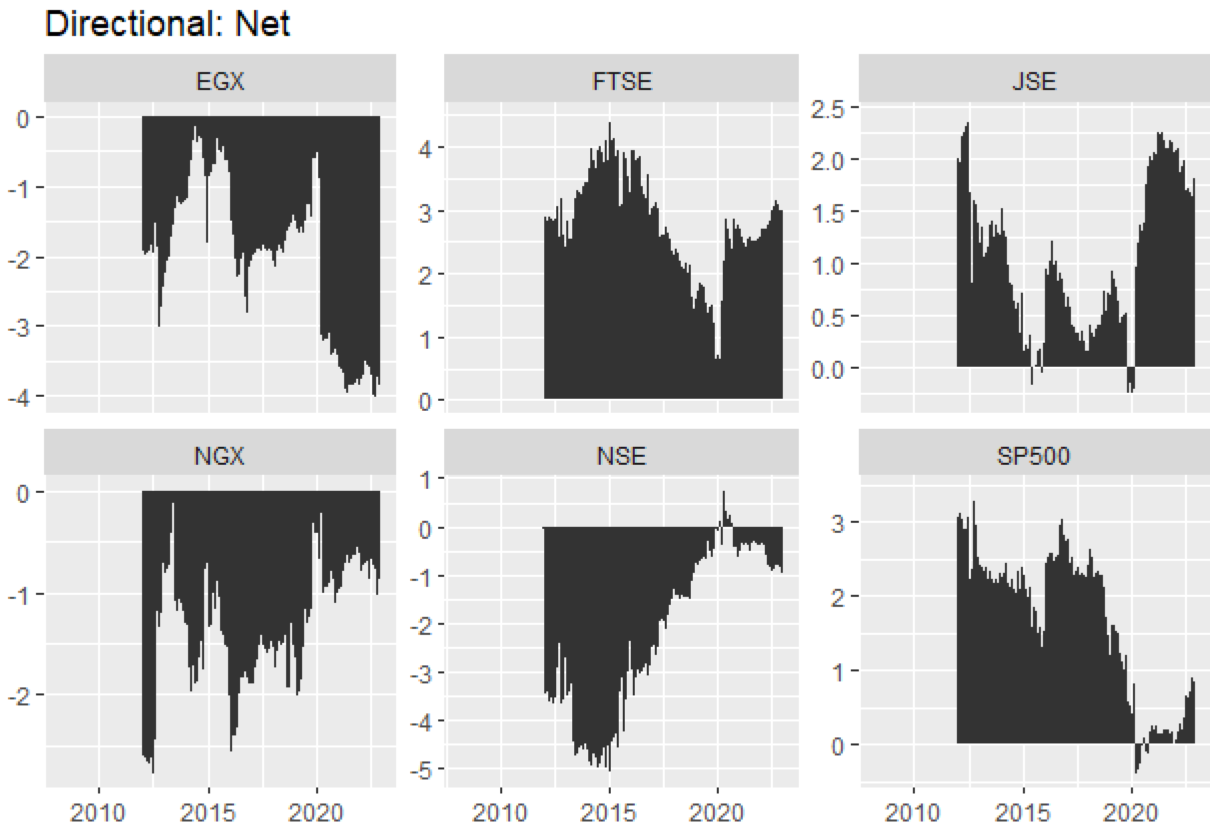
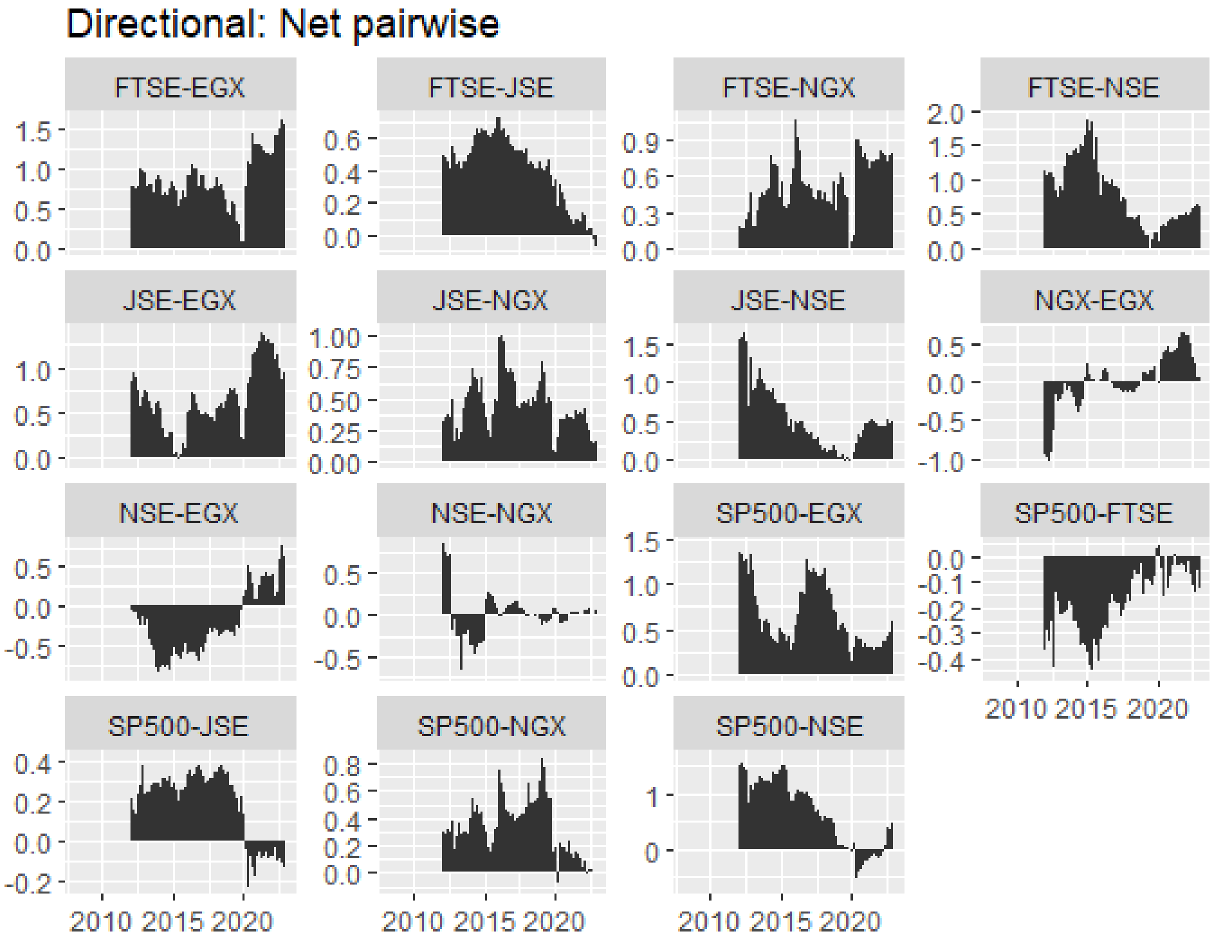


Figure 15 - Net pairwise

The FTSE is a net transmitter to all markets for the period analysed. The JSE is a net transmitter to all other African markets with peak transmissions to the EGX after 2020 and NSE in 2012. The S&P is mostly a net transmitter.



5.7. Weekly Total and Directional Volatility Spillovers

Table 14 – Volatility Spillover Table

The "gross directional volatility spillovers to others" from each of the six markets is highest in the FTSE followed by the JSE with 97% and 87% respectively. Innovations to the NSE volatility explain 28% of the forecast error variance in all other markets, making it the second largest African gross transmitter to other markets.

The gross "directional spillovers from others" column shows that the gross directional volatility spillovers from others to the FTSE market is the largest at 62%, followed by the JSE having spillovers from other markets explaining 59.7% of its forecast error variance. The largest net transmitter to other markets is the FTSE (35.11%); the largest net receiver of shocks from other markets is the EGX (-48.28%). 52.04% of the volatility forecast error variance in all six markets result from spillovers, this shows high levels of connectedness between the markets – this is higher than the weekly returns total spillover. This is because volatility transmits quicker than returns, has persistent effects, and it captures wider market responses to shocks.

With respect to advanced markets, the volatility spillovers from the US to South Africa are less than those from the UK to South Africa. African markets have extremely low volatility interdependence amongst themselves. Investors and policymakers who are interested in diversification and risk management should look to expand their interests into emerging and frontier African markets.

	S&P	FTSE	JSE	NSE	NGX	EGX	C. from others
S&P	40.61	25.38	24.95	5.91	0.78	2.37	59.39
FTSE	27.53	37.85	25.07	5.77	1.56	2.22	62.15
JSE	20.71	25.89	40.32	9.412	2.39	1.28	59.68
NSE	15.58	16.48	17.48	48.23	0.75	1.47	51.77
NGX	4.323	8.99	6.86	1.61	77.31	0.91	22.69
EGX	15.83	20.52	12.66	5.30	2.22	43.47	56.53
C. to others	83.98	97.26	87.02	28.00	7.70	8.25	52.04
Contributions including own	124.59	135.11	127.33	76.23	85.01	51.72	600.00

Notes: The underlying variance decomposition is based upon a weekly returns VAR of order 6, identified using Generalised Impulse Response Functions

5.8. Weekly Volatility Rolling window analysis

Figure 16 -Total Volatility Spillover Plot

This plot is based on a 200-week rolling sample. There are no trends, but a few bursts, especially during global crisis periods. The total spillover ranges between 30% and 80% - the volatility spillover plot peaks above 60% in 2012 and 2020 to 2022. The index has remained constant around 70% from 2020 to 2022 showing high levels of volatility spillovers during the period, which is consistent with existing evidence given the impact of the recent pandemic.

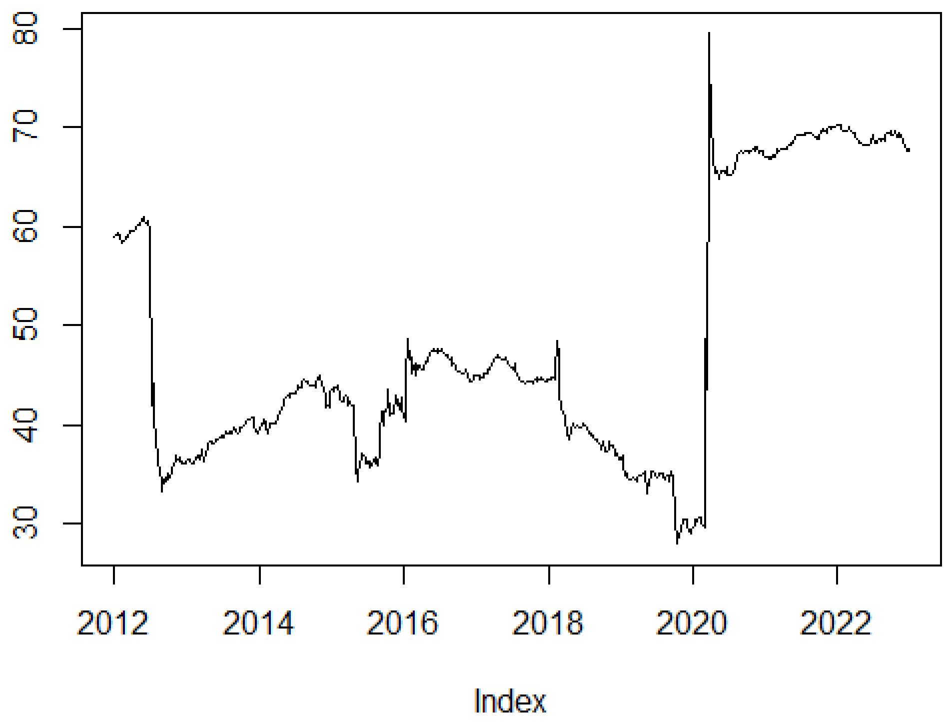


Figure 17 - Directional volatility spillovers, from six equity markets

Spillovers from the FTSE, JSE and S&P to other markets are the largest - the JSE and FTSE spillovers peak above 15% during the inception of the 2020 pandemic. Of the remaining African markets, the NSE exerted the most directional spillovers in 2020.

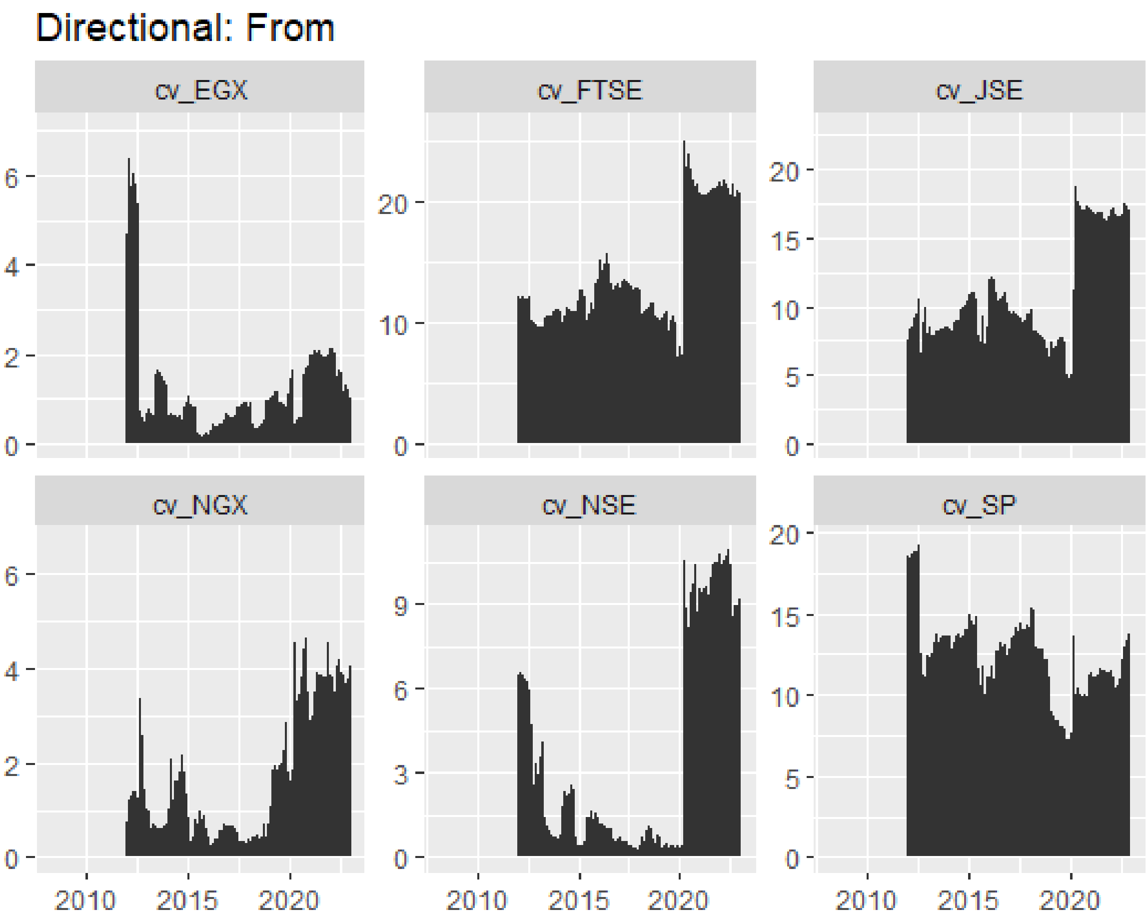


Figure 18- Directional volatility spillovers, to six equity markets

Spillovers from other markets to the S&P, FTSE and JSE are high between 2012 and 2022 with peaks exceeding 10%. Spillovers to the EGX, NGX and NSE peaked above 5% in 2012 and 2020.

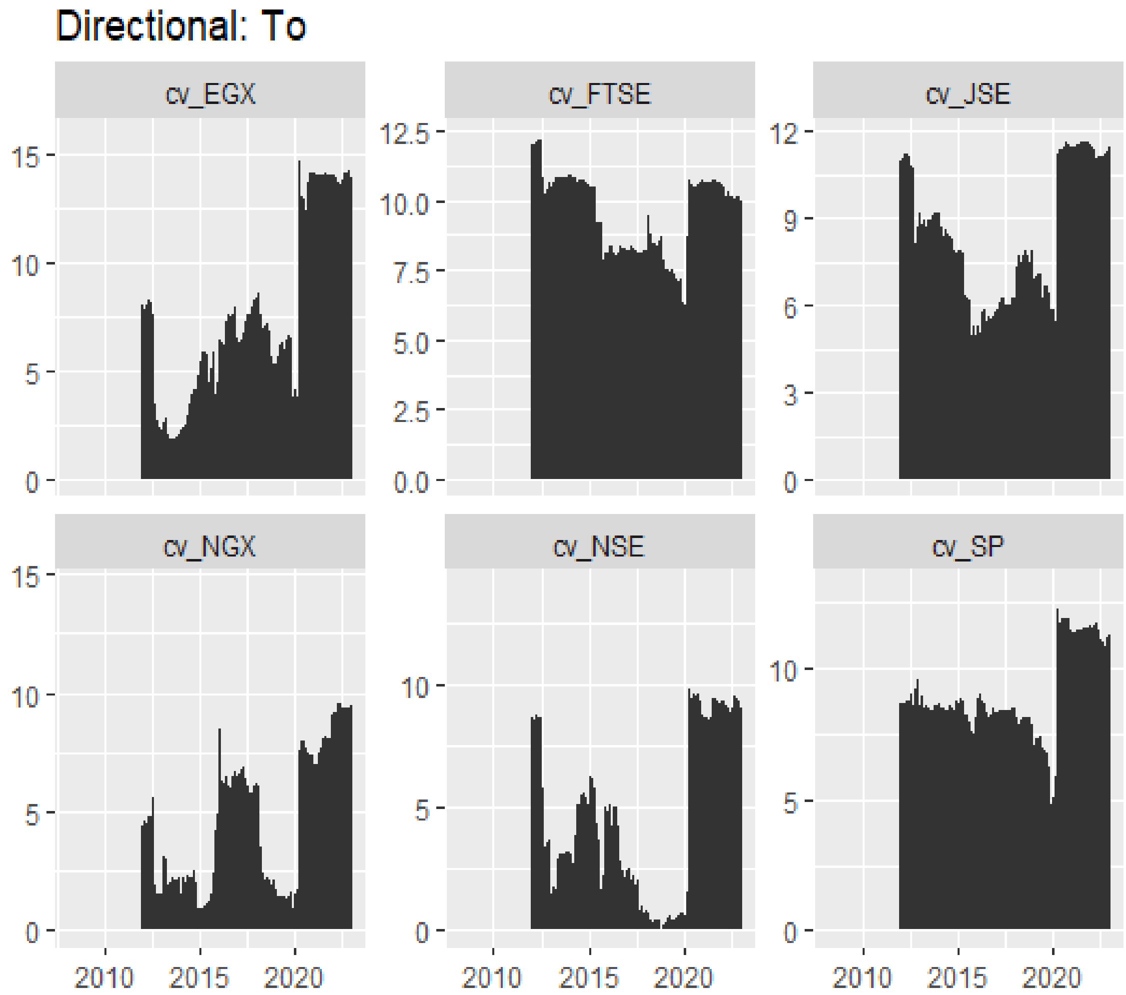


Figure 19- Net volatility spillovers, from six equity markets

The net volatility spillovers are mostly negative for the EGX, NGX and NSE making them net recipients. The FTSE, JSE and S&P 500 mostly display positive net volatility spillovers, with peaks in 2012, 2015 and 2020.

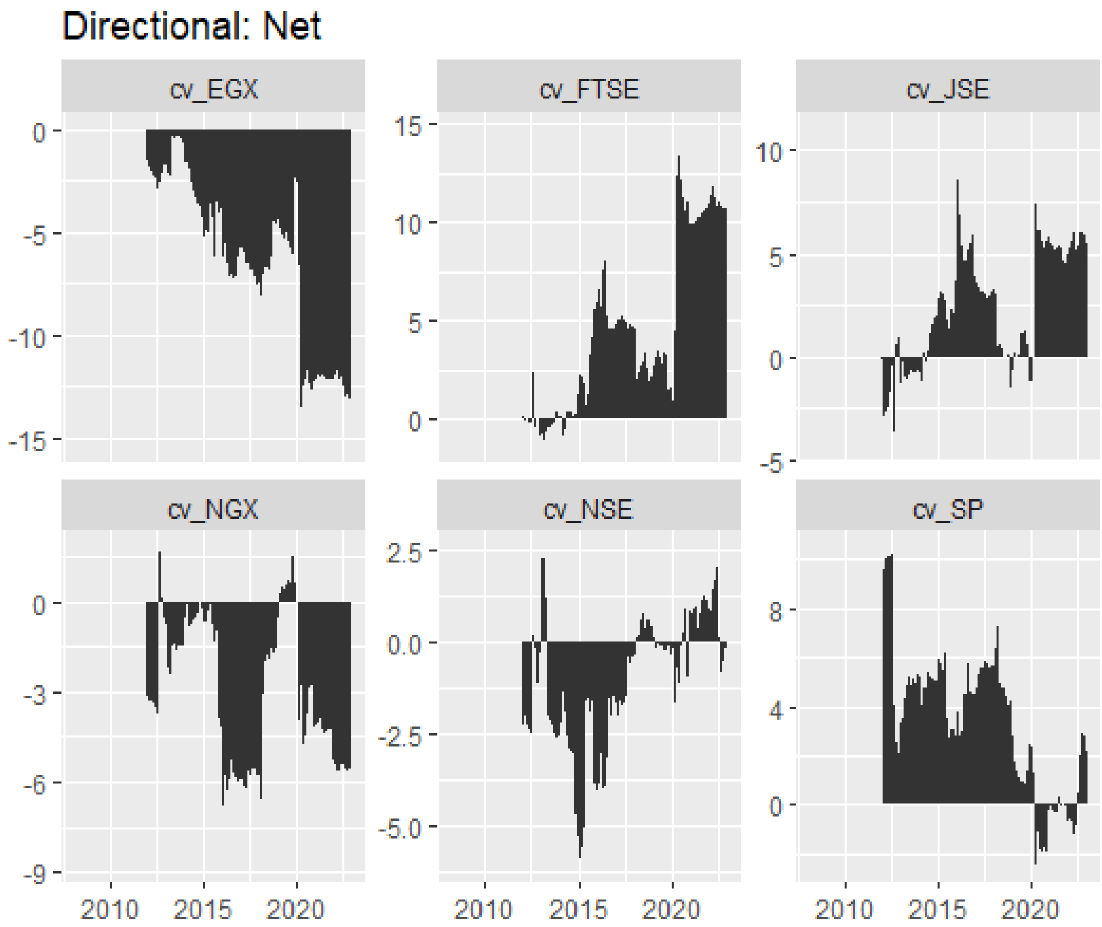
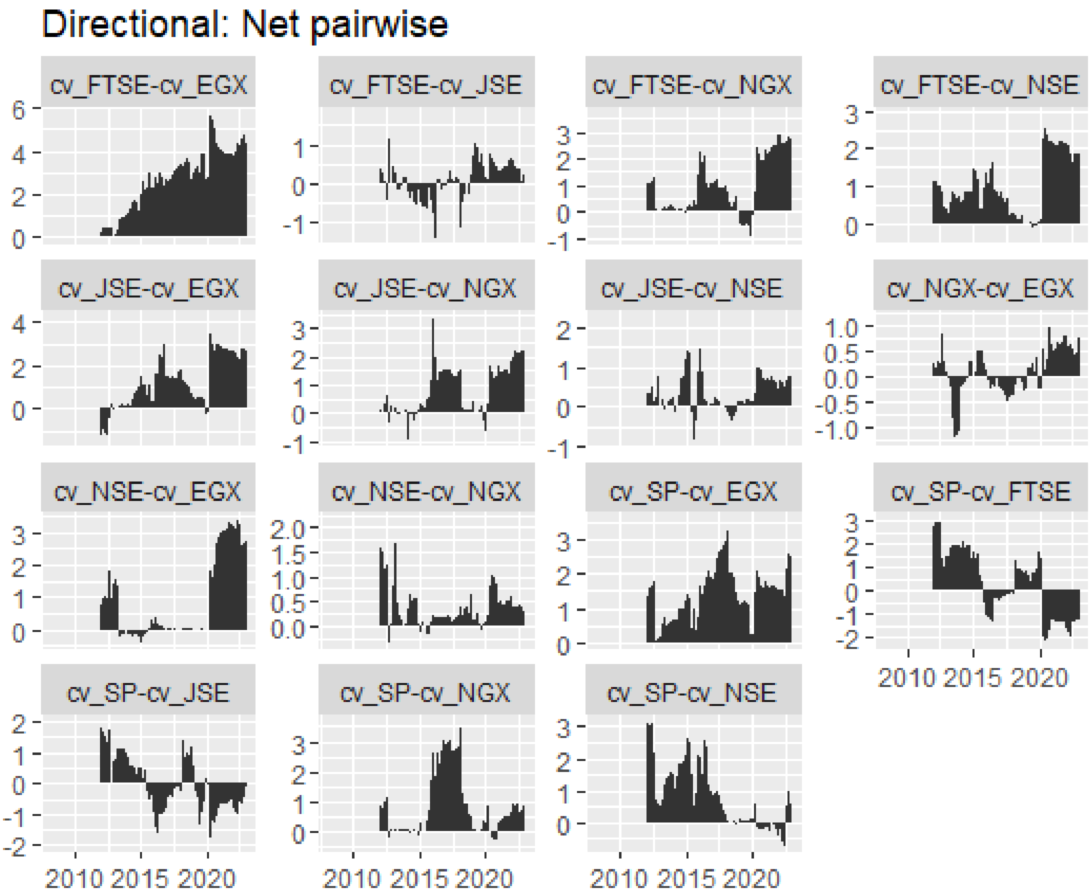


Figure 20 – Net pairwise

The FTSE is a net transmitter to the EGX, NGX and NSE. It spilt over innovations to the S&P during the pandemic, and to the JSE between 2016 and 2022. The JSE is a net transmitter to all other African markets. The S&P transmits its innovations to the JSE and FTSE between 2012 and 2015 and again in 2018, to the EGX, NGX and NSE.



6. Answering research question and Conclusion

This paper has assessed the nature of connectedness between advanced and African stock markets. It reports total, directional, net and rolling window interdependence. The total daily returns and volatility spillovers are moderate at 29%. Daily returns and volatility directional spillovers exhibit low interdependence for the NSE, NGX and EGX; however, displaying high connectedness for the FTSE, S&P and JSE. The total weekly returns and volatility spillovers are high at 41% and 52% respectively. Weekly directional spillovers for both returns and volatility are high for the JSE, FTSE and S&P which is expected given the maturity of these indices. For the remaining African countries, weekly directional spillovers fluctuate between low to moderate connectedness – deviations are seen for the weekly directional volatility spillovers from others to the NSE and EGX.

For daily returns and volatility, the highest net transmitter is the S&P 500, and the net receivers are the NSE and JSE respectively. For weekly returns and volatility, the net transmitter is the FTSE, and the net receivers are the NSE and EGX respectively. As expected, the innovations from advanced markets contribute the most to the forecast error variance decomposition of other markets. Innovations travel speedily from advanced markets, because of their global footprint and highly efficient markets. The African markets have very little interdependence amongst themselves – meaning that diversification benefits exist amongst themselves.

The nature of connectedness is similar between daily returns and daily volatilities, whereas it slightly differs for weekly returns and weekly volatilities. The results show that weekly volatilities exhibit higher connectedness between the markets than weekly returns. Overall, the connectedness is tighter between advanced markets and South Africa, while the remainder of the African markets show little connectedness with advanced markets. Based on the rolling window analyses, the spillovers are not constant over time. All the total spillover plots show no trends but display cycles and bursts. The daily and weekly returns display bursts during the GFC, Eurozone crisis, and the Covid-19 pandemic. The daily volatility displays many cycles, it is clearly sensitive to shocks and information. The weekly volatility peaked above 70% during the Covid-19 period. We can conclude that spillovers are not constant over time.

The results indicate that there are possible diversification opportunities between advanced markets and African markets, excluding South Africa, that more closely resembles the advanced markets. The results align with the findings of Mensah and Algaidede (2017) obtained using the copula methodology for a similar group of countries. That is, there is weak interdependence between advanced and African markets, except for South Africa. In terms of African markets interdependence, South Africa and Egypt display the highest level of interdependence – although it is low.

An important caveat to this finding of diversification benefits is that they may be limited in efficacy. If investors in advanced markets are seeking higher and stable returns, they can consider diversifying their portfolios into African markets where fast growth may be expected – in markets that show little connectedness to advanced markets. The limitation is that some of these African stock markets are heavily concentrated on specific sectors and have a significant portion of their index being composed of international companies which may make them increasingly sensitive to changes in international markets.

Data availability constraints continue to hinder progress in the study of contagion in African markets. Given that the observation size is small, the Diebold and Yilmaz methodology is suited. If I was to include more observations, I would recommend using a different model such as copulas – this is better suited for larger datasets and caters for the short comings of the Diebold and Yilmaz model.

Policymakers should consider the following in managing spillover effects:

- During periods of high spillover effects between markets, policymakers should consider strengthening financial buffers, i.e. foreign currency reserves or stabilisation funds to mitigate these spillover effects
- African policymakers can enhance their regional financial stability coordination models to manage spillovers within the region – although our findings prove these spillovers to be low
- Considering the high sensitivity of the JSE to advanced market spillovers, South African policymakers should create policies that are responsive to advanced financial market conditions
- Following the pandemic, policymakers should increase stress testing for multinational firms that are listed on global exchanges and consider tightening these organisations' capital controls

Policymakers should consider the following to improve the development and performance of African stock markets:

- Standardise regulations and financial market practices - ensure that there is consistency in listing, trading and reporting requirements across the continent
- Develop regional trading platforms
- Promote cross-listing of companies across African exchanges
- Introduce policies that will enhance market liquidity and encourage cross-border investment
- Encourage domestic participation from retail investors by lowering trading costs
- Improve trading platform infrastructure/technology
- Support continental initiatives such as the AfCFTA to promote financial market integration and growth

7. References

Adelegan, O. (2004). How efficient is the Nigerian Stock Market? Further evidence. *African Review of Money Finance and Banking, 8(2)*, 145-165.

Adenomon, M. O., Maijamaa, B., & John, D. O. (2022). The effects of Covid-19 outbreak on the Nigerian Stock Exchange performance: Evidence from GARCH models. *Journal of Statistical Modeling and Analytics (JOSMA), 4(1)*, 25-38.

African Development Bank . (2024, February 16). *African Development Bank Group*. Retrieved from African Development Bank Group - Africa dominates list of the world’s 20 fastest-growing economies in 2024: https://www.afdb.org/en/news-and-events/press-releases/africa-dominates-list-worlds-20-fastest-growing-economies-2024-african-development-bank-says-macroeconomic-report-68751#:~:text=The%20top%2011%20African%20countries,%2C%20and%20Uganda%20at%206%25.

Alber, N. (2013). Industry effect and stock market reaction to global financial crisis: A comparative analysis. *Journal of Applied Finance & Banking, 3(3)*, 29-43.

Antonakakis, N., Chatziantoniou, I., & Gabauer, D. (2020). Refined Measures of Dynamic Connectedness Based on Time-Varying Parameter Vector Autoregressions. *Journal of Risk and Financial Management , 13*(4), 1-23.

Bahloul, S., & Khemakhem, I. (2021). Dynamic return and volatility connectedness between commodities and Islamic stock market indices. *Resources Policy, 71*, 101993.

Balli , F., Hajhoj, H. R., Basher, S. A., & Ghassan, H. B. (2015). An analysis of returns and volatility spillovers and their determinants in emerging Asian and Middle Eastern countries. *International Review of Economics & Finance, 39*, 311-325.

Baoko, G., & Alagidede, P. (2017). Currency price risk and stock market returns in Africa: Dependence and downside spillover effects with stochastic copulas. *Journal of Multinational Financial Management , 41*, 92-114.

Bello, J., Guo, J., & Newaz, M. K. (2022). Financial contagion effects of major crises in African stock markets. *International Review of Financial Analysis, 82*, 102128.

Boakye, R. O., Mensah, L. K., Kang, S. H., & Osei, K. A. (2023). Foreign exchange market return spillovers and connectedness among African countries. *International Review of Financial Analysis, 86*, 102505.

CenterPoint Securities . (2022). *CenterPoint Securities: The interconnectedness of markets* . Retrieved July 2022, from https://centerpointsecurities.com/interconnectedness-of-markets/

Claassen, C. (2019). *Connectedness of the African Equity Markets: A Time-Frequency Spillover Analysis.* Cape Town: University of Cape Town.

de Wet, P. (2022). *Business Insider South Africa: Africa's fastest growing companies are in Kenya and Nigeria...* Retrieved July 2022, from https://www.businessinsider.co.za/africas-fastest-growing-companies-ft-ranking-shows-kenya-and-nigeria-are-booming-2022-5

Diebold, F. X., & Yilmaz, K. (2009). Measuring Financial Asset Returns and Volatility Spillovers, with Application to Global Equity Markets. *The Economic Journal, 119*(534), 158-171.

Diebold, F. X., & Yilmaz, K. (2012). Better to Give than to Receive: Predictive Directional Measurement of Volatility Spillovers. *International Journal of Forecasting, 28*, 57-66.

Diebold, F. X., & Yilmaz, K. (2015). *Financial and Macroeconomic Connectedness: A network approach to measurement and monitoring.* Oxford University Press.

Diebold, F., & Yilmaz, K. (2023). On the past, present, and future of the Diebold and Yilmaz approach to dynamic network connectedness. *Journal of Econometrics, 234*, 115-120.

El-Shal, A. (2012). *The spillover effects of the global financial crisis on economic activity in emerging economies -investigating the Egyptian case using the financial stress index.* In Economic Research Forum Working papers (Vol.737).

European Central Bank. (2005). *Financial Market Contagion.* Financial Stability Review.

Fasanya, O. I., Oyewole, O., & Agbatogun, T. (2019). Measuring Return and Volatility Spillovers among Sectoral Stocks in Nigeria. *Zagreb International Review of Economics & Business , 22*(2), 71-93.

Forbes, K. (2012). *'The Big C': Identifying contagion.* NBER Working Papers, no 18465.

FTSE Russell. (2023). *FTSE UK Index Series*. Retrieved from FTSE Russell: https://www.lseg.com/en/ftse-russell/indices/uk

Gandolfo, G. (2016). *International Finance and Open Economy Macroeconomics.* Springer. 2nd ed.

Hilliard, J. E. (1979). The Relationship Between Equity Indices on World Exchanges. *The Journal of Finance, 34(1)*, 103-114.

Jebran, K., Chen, S., Ullah, I., & Mirza, S. S. (2017). Does volatility spillover among stock markets varies from normal to turbulent periods? Evidence from emerging markets of Asia. *The Journal of Finance and Data Science, 3(1-4)*, 20-30.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, 74(1), 119-147.

Kumaresan, S. (2020, December 31). *Reuters.* Retrieved from FTSE 100 wraps up worst year since 2008 financial crisis: https://www.reuters.com/article/idUSKBN2950P4/

Mensah, J. O., & Alagidede, P. (2017). How are Africa's emerging stock markets related to advanced markets? Evidence from copulas. *Economic Modelling, 60*, 1-10.

Ndlovu, D. (2020). *Monetary policy spillovers in the SACU area.* Free State: University of Free State.

Oberholzer, N., & von Boetticher, S. (2015). Volatility spill-over between the JSE/FTSE indices and the South African Rand. *Procedia Economics and Finance* (24), 501-510.

Partington, R., & Wearden, G. (2020). *The Guardian* . Retrieved September 2023, from https://www.theguardian.com/business/2020/mar/09/global-stock-markets-post-biggest-falls-since-2008-financial-crisis

Pesaran, H. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economic Letters*, 58(1), 17-29.

Sivabalan, S. (2018). *Bloomberg: If you thought frontier investing was high risk, here's comfort.* Retrieved August 2022, from https://www.bloomberg.com/news/articles/2018-02-22/if-you-thought-frontierinvesting-was-high-risk-here-s-comfort

Sklar, A. (1959). Fonctions de repartition a n dimensions et Leurs Marges. *Publications de l'Institut de Statistique de l'Universite de Paris, 8*, 229-331.

Statista. (2022). Retrieved from Change in performance of S&P 500 during Covid-19 pandemic vs previous major crashes as of August 2020: https://www.statista.com/statistics/1175227/s-and-p-500-major-crashes-change/

Thomas, N. M., Kashiramka, S., Yadav , S. S., & Paul, J. (2022). Role of emerging markets vis-`a-vis frontier markets in improving portfolio diversification benefits. *International Review of Economics and Finance, 78*, 95-121.

Uyaebo, S., Atoi, V., & Usman, F. (2015). Nigeria Stock Market Volatility in comparison with some countries: Application of asymmetric GARCH models. *CBN Journal of Applied Statistics, 6(2)*, 133-160.

Workman, D. (2021). *World's Top Export Countries*. Retrieved July 2022, from https://www.worldstopexports.com/worlds-top-export-countries/

World Bank. (2020). *The African Continental Free Trade Area*. Retrieved July 2022, from https://www.worldbank.org/en/topic/trade/publication/the-african-continental-free-trade-area

World Health Organization. (2020). *World Health Organization*. Retrieved from World Health Organization Emergencies: https://www.who.int/europe/emergencies/situations/covid-19

8. Appendix

8.1. Background on equity markets

United States and United Kingdom

The S&P 500 was established in 1957. The index is regarded as a good indicator of the American economy. The index experienced declines during the GFC, where its value declined by 56.8% for the period between the end of 2007 and March 2009 – the declines experienced during this period are regarded as the largest since the second World War (Statista, 2022). The index has shown a positive trend post-GFC to the Covid-19 pandemic – the market had bullish trends, positive investor confidence, resilience due to its rate of recovery after the economic downturns. The index began to recover from the pandemic in late 2020. This is due to the efforts made by the government to stimulate the economy, these are, providing financial aid to corporates, lowering interest rates, and government stimulus.

The FTSE 100 index was established in 1984. It was bullish between the 1980s and 1990s (FTSE Russell, 2023). It is used as an indicator for the British economy. That is, when share prices are on a positive trajectory, this translates to economic growth. The index is recorded to have earned an annual average return of 5.4% between 2011 and 2020, with the peaks being in 2013 and 2016. The GFC and the Covid-19 pandemic resulted in a 31% and 14.3% drop on the index's value respectively (Kumaresan, 2020). This is consistent with the behaviour exhibited by the S&P 500. The decline in the index's performance during the 2020(1) period was exacerbated by the recession, the stringent conditions of the lockdowns and the Brexit.

African Markets

African countries are considered emerging and frontier economies. These are an investment favourite due to opportunities for spurts in returns. Contrastingly, due to some of these countries receiving emancipation in recent years, they are in the infant stages of defining and developing their economies. This phase of economic development often comes with multiple macroeconomic challenges, mostly political and social ones. These include minimal dollar liquidity, less sophisticated financial markets, volatile currencies, political instability and underdeveloped infrastructure - these challenges may negatively impact investor confidence in African stock markets.

South Africa

The JSE was established in 1887. It has the largest market capitalisation amongst African countries. Prior to South Africa experiencing political emancipation in 1994, the country experienced numerous social and political challenges. These challenges include capital flow restrictions, economic sanctions on trade and foreign investments (Oberholzer & von Boetticher, 2015). As a result, the index may have displayed an irregular relationship to other equity markets around the world. Post 1994, South Africa became an attractive investment haven to foreign investors for diversification purposes, given that it was an emerging economy that presented low risk and potential for fast and large returns. Uyaebo et al. (2015) conducts a volatility cross comparison using GARCH models, one of the markets studied is the JSE for the period February (2000 to 2013), of which the authors find that it is moderately volatile to market shocks. This is likely due to its sophisticated market infrastructure. South Africa is generally regarded as a net transmitter in Africa.

Nigeria

The Nigerian exchange came into existence in 1960. Historically, the exchange has faced challenges of thin trading, low market capitalisation and liquidity challenges (Adelegan, 2004).

In 1986, the Nigerian exchange underwent deregulation to modernise it and to promote free capital flows (Uyaebo, Atoi, & Usman, 2015). The deregulation included the introduction of an electronic trading system, demutualising the exchange to a public limited company, increasing competition by revising the listing requirements and by introducing additional brokerage firms and traders to the market. The exchange is noted to have gone through foreign investment capital reversals to the value of NGN113 billion during the GFC – this was likely due to declining investor confidence, herding behaviour and investors wanting to diversify into less volatile asset markets (Uyaebo et al., 2015). The GFC resulted in a drop in Nigerian stock prices which diminished investor wealth. This gave rise to the reduction of market capitalisation, disinvestment from foreign investors which was likely due to herding behaviour and low investor confidence in the region. Adenomon et al. (2022) finds that, during the first four months of 2020, the pandemic resulted in higher volatility in Nigerian stocks and ultimately led to a sharp decline in stock prices.

Kenya

The Nairobi stock market was established in 1954 while it was still under colonisation. Hence trading on the exchange was limited. The country received its independence from Britain in 1963, this allowed for liberalisation of capital markets. Early studies on the financial market found that it is not efficient – this is because it only met the weak form of efficiency condition (Adelegan, 2004).

Egypt

The Egyptian exchange was originally established in 1883 – it underwent many name iterations over the years - the current Egyptian stock market was established in 1997. It monitors performances of the first 30 listed companies. The effects of the GFC crisis are investigated by Alber (2013), who finds that the stocks that experienced the most negative spillovers from the crisis were the insurance and real estate stocks. El-Shal (2012) investigates the spillover effects of the GFC on economic trading in Egypt, the findings show that the effects were transmitted to Egypt through its trade partners. The Egyptian stock market's volatility increased, foreign investors disinvested from the financial market, exports to the European Union declined, inflation became persistent, it later became manageable through monetary policy hikes.

8.2. Data Analysis continued

Daily Returns Time Series Plots

The below plots display the behaviour of daily returns over the period of study.

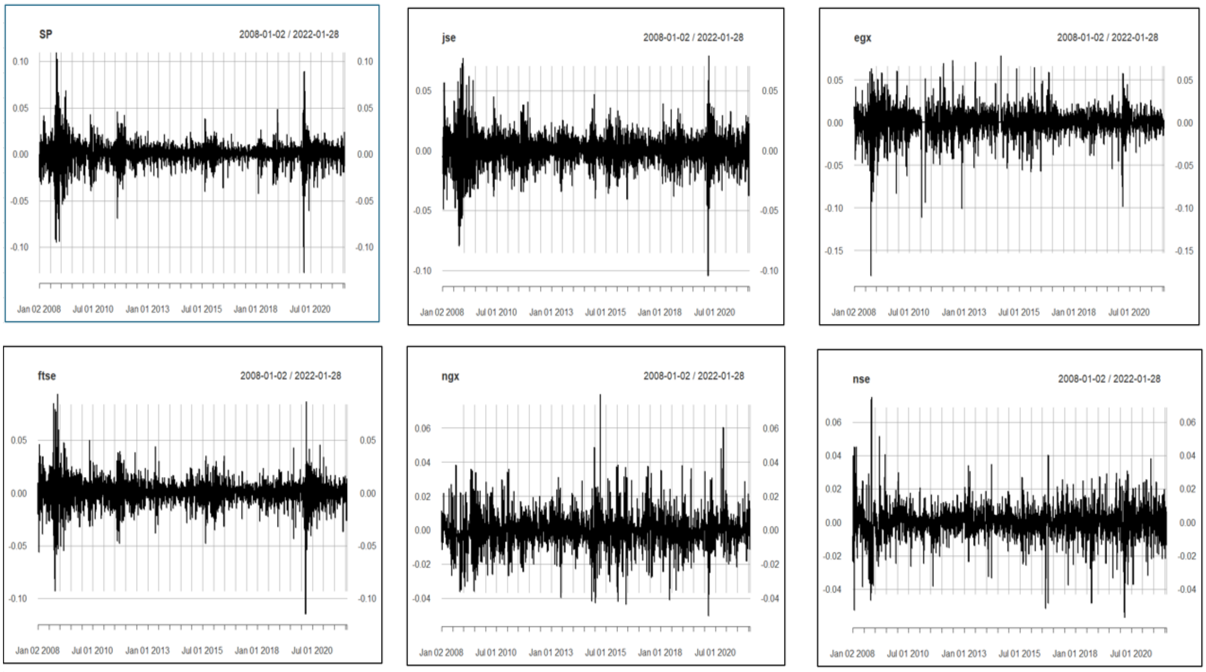


Figure 21 - Daily Stock Market Returns

The daily S&P 500 displays large spikes during 2008 and 2020, these are linked to the GFC and the 2020 pandemic - the spikes reach around 10% but soon decline to hover around zero. The daily JSE displays deviations during the same time with less volatile spikes. There are some spikes seen in 2015 which may have been a result of political instability as there were numerous protests in that year. For most of the period, the returns display low volatility. The daily FTSE spikes massively during 2008 and 2020 as expected, these are attributed to the GFC and the 2020 pandemic – the pandemic seems to have had the most impact on the series, this is because of the uncertainty and restrictions posed by the pandemic. The daily NGX displays large spikes during 2015 and 2020, these are likely due to country-specific factors such as the Nigerian general election, and Covid-19. The daily NSE displays large sensitivity during 2008, 2016, and 2020. The daily EGX displays notable spikes during 2008, 2010, 2013 and 2020. This is due to the GFC, country-specific factors and the Covid-19 pandemic.

Daily Volatility Plots

The below graphs provide a view of observed volatility, that is, squared returns.

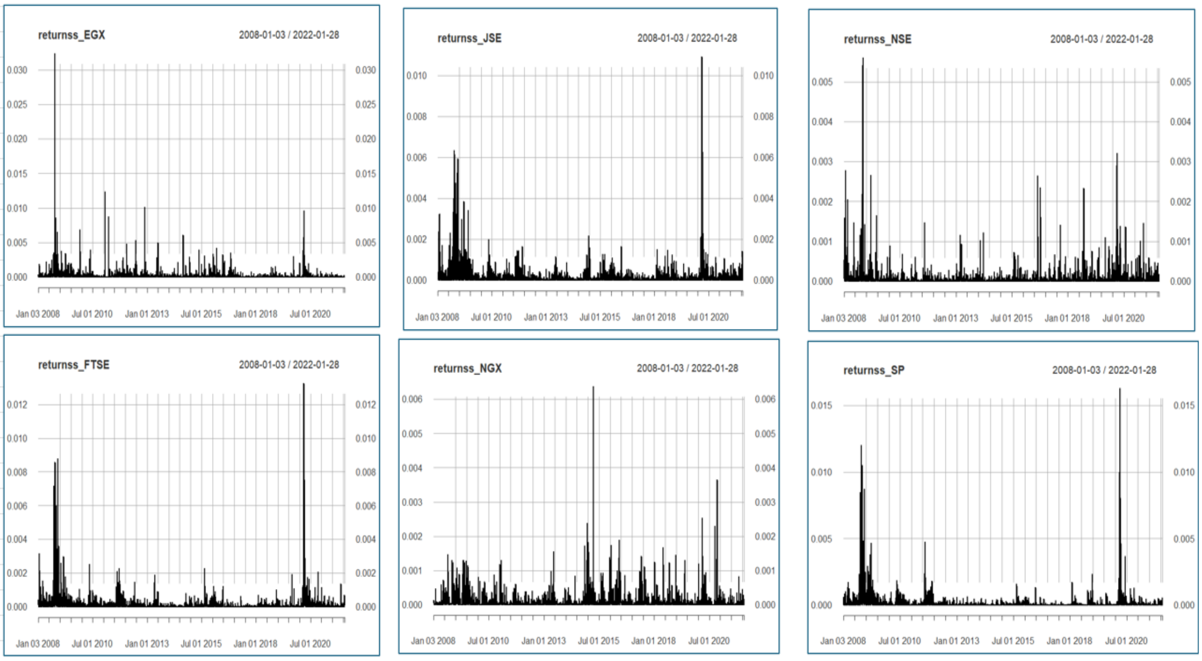


Figure 22- Observed volatility.

EGX displays minimal fluctuations - Sharp spikes are noted in 2008, 2010/13 and 2020.The FTSE, S&P 500 and JSE display persistent spikes in 2008 and 2020 due to the GFC and the Covid-19 pandemic. During 2008, South Africa experienced political and social instability in the form of the inception of loadshedding, national elections and xenophobic attacks. For the NGX, large spikes are noted in the national election year of 2015 and the Covid-19 pandemic in 2020. The NSE displays large spikes in 2008, 2015, 2018 and 2020.

Weekly Returns Time Series Plots

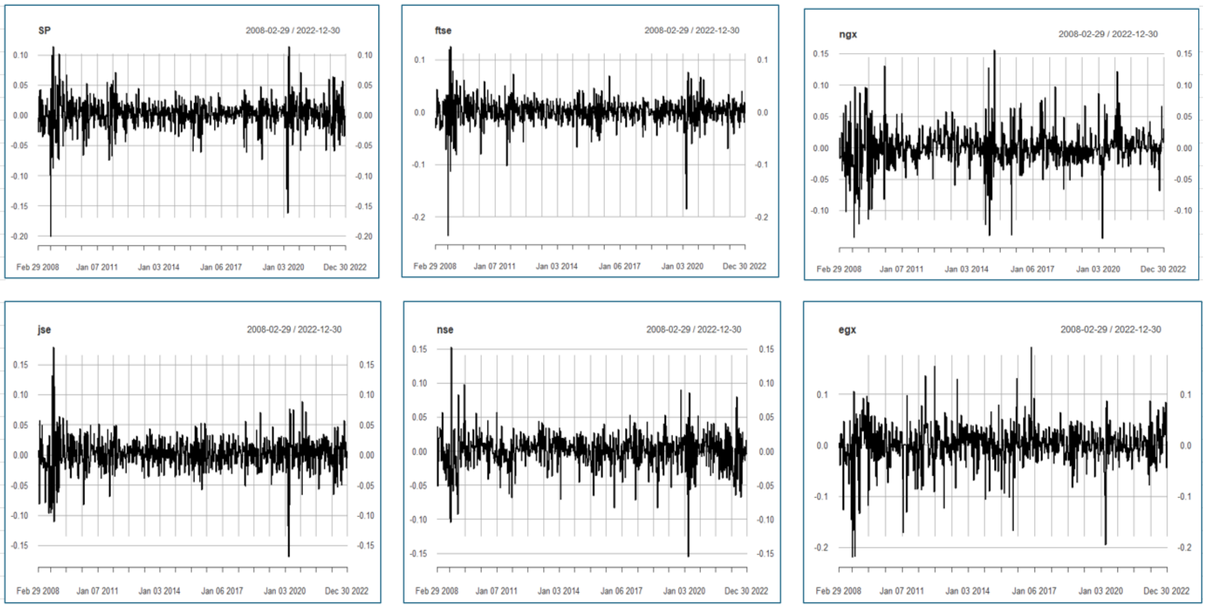


Figure 23 – Weekly returns.

The S&P 500, FTSE, NSE and JSE returns average slightly above zero, the points of large deviation are during 2008 and 2020 which are due to the GFC and the Covid-19 pandemic. The weekly returns show more evidence of fluctuations than the daily returns. The NGX has several periods of spikes evident during the period. Deviations are seen throughout the GFC crisis in 2008, 2014/15 when the country had political protests and election uncertainty, and in 2020 due to the pandemic. The EGX returns display signs of volatility in 2008, 2011, 2014/5 and 2020.

Weekly Volatility

The below graphs provide a view of observed volatility, that is, squared returns.

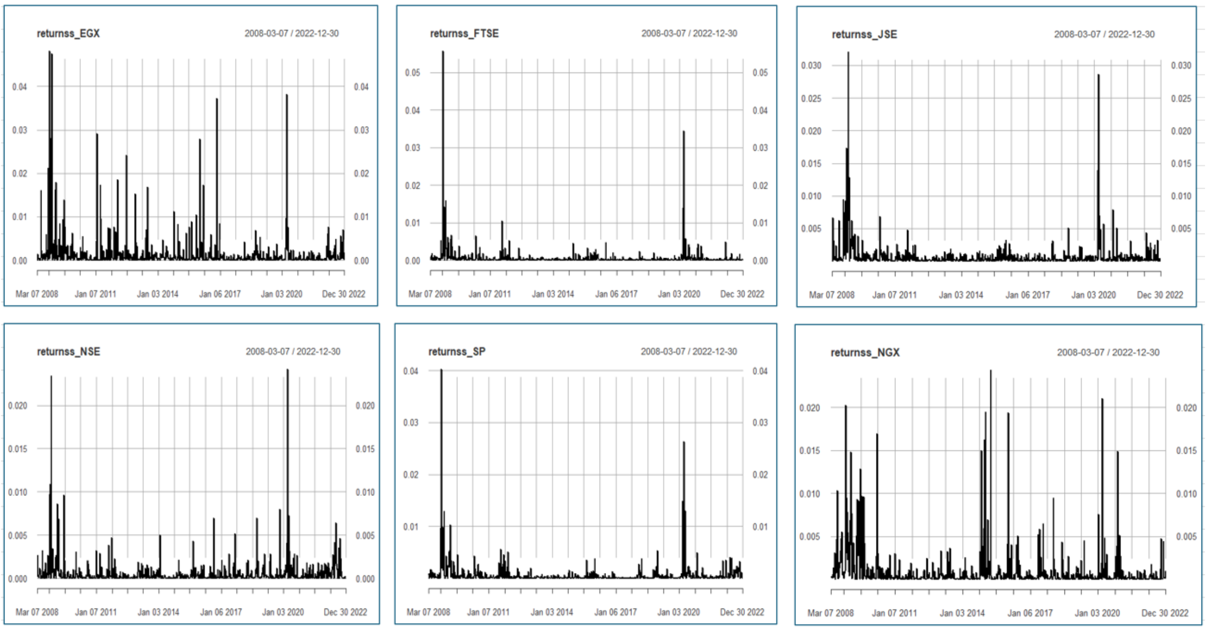


Figure 24 – Observed volatility.

The NSE, JSE, FTSE, S&P 500 and EGX observed volatility experienced some fluctuations, with extreme spikes noted in 2008 and 2020. The NGX observed volatility experienced frequent fluctuations, with extreme spikes noted in 2008/9, 2015, and 2020/1.