ADFJ ISSN 2522 - 3186.

African Development Finance Journal

VOLUME 5 (3)

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Date Received: February, 13, 2023

Date Published: June, 12, 2023

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Abstract
With the economic relevance of the relationships among emerging and frontier equity markets becoming increasingly significant, this paper investigates co- movement among returns from six African stock markets Botswana, South Africa, Egypt, Kenya, Mauritius, Morocco, Nigeria) and also with the U.S. S&P 500 Composite index. In part, we employ principal component analyses, to account for the maximum portion of the variance present in the returns by examining rolling windows with 8- , 6- , 4- , 3- , and 2 - year periods. We also investigate the incidence of structural breaks and co- movement, aiming to uncover the dynamics in co- movements among these markets. We find evidence of high co- movement among the African markets, and also with the U.S. markets. Botswana and South African's equity markets are at the extremes. However, our results do not corroborate findings of clear evidence, reported in previous studies, of the United States having a leading role in the region.

Keywords: *co-movement, correlation, African stock markets, portfolio diversification, stock markets*

Introduction

Financial contagion has been viewed in the literature as mainly a concern for emerging markets. However, the global financial crisis of 2007 confirmed that financial crisis is not limited to certain groups of markets such as developed or emerging markets, because it is assumed that rescue plans were already put in place to insulate many developed countries during the 2007 financial crisis. Interestingly, the situation actually differs from African markets as no African country announced a bank rescue plan as observed in many developed countries. Africa being a developing region has not been an exemption to the movement toward the full financial integration being experienced in the world. However, in spite of several financial reforms being undertaken to promote financial integration in Africa, her macroeconomic fundamentals remain weak and the process of financial integration is relatively slow compared to that of emerging countries in Asia and Europe.

Instinctively, analyses of co- movement between African markets should hold huge interest for risky averse investors aiming to hold well-diversified portfolios. When investors' appetite for risk fall, they immediately

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reduce their exposure to risky assets and consequently fall in value together whereas when the appetite for risk rises, demand for risky assets in increasing in their value rises simultaneously. More specifically, this article aims to address a number of questions: First, do African stock markets commove and how do these markets commove with South Africa stock market which is the largest in Africa? Secondly, across these markets, is there either a contagion or an interdependency? In order to address this issue, it is important to clarify the impact of shock returns during normal periods, which is interdependence, from augmented effect originated from contagious periods. The term interdependence, as defined by (Forbes and Rigobon, 2002), refers to co - movement during stable periods driven by strong linkages among markets. Here, in this paper, we consider the consensus definition of contagion as a change in the international propagation of shocks caused by some countries' specific factors. In the other words, we adopt definition of contagion as increase in cross-country correlations during crisis times. Therefore, this type of contagion runs along the lines of risks and ignores fundamentals trade and exchange rate arrangements (Kumar and Persaud, 2001).

In this study, we provide three empirical implementation examples to investigate the co-movement among returns from seven African stock markets (South Africa, Botswana, Egypt, Kenya, Mauritius, Morocco and Nigeria). First, we employ a principal component analysis (PCA), which offers a natural metric to gauge the extent of convergence between African equity markets. Second, to determine the similarity or difference in parameter instability and structural change across the market returns over time, we also perform a multiple structural break test by (Bai and Perron, 2003a). Third, following (Yetman, 2011a, 2011b), we investigate the co-movement between each possible pairing of the market returns by constructing the co-movement between each pair of market returns and, crucially at each point in time by computing a z score of each market's returns. Furthermore, we include U.S. equity market in our study to verify if this market drives the African stock markets in general, and in particular during the crisis period. The consensus of our results underscores our findings and provides several insights into the co - movement between United States equity and equity markets of Africa.

Nowadays, the word is becoming more and more globalized, such that it has become practically impossible for countries to operate in isolation. Integrated financial markets facilitate inter-temporal capital flows and portfolio diversification but at the same time may increase the probability of financial crisis and the contagion of crisis across the market. With increased economic and financial integration globally, and significant increases of investors in emergent and frontier equity markets, have equity markets in Africa become more similar? Are they moving together with the U.S. equity markets? Is there a clear lead-lag relationship? We address the above issues in an easily assessable manner and contribute to the still ongoing debate regarding to what extent equity markets in Africa co - move.

Literature Review

There are a number of studies on co-movement of financial markets since the recent episodes of financial crisis. One strand of studies has focused on whether and how the transmission of economic and financial events like crisis from one country's to other countries stock markets occur. The other strand of the literature is concerned with the portfolio diversification. The portfolio theory states that, the expected benefit of diversification exists only when assets included in an investor's portfolio have negative or nearest zero correlations among them. Consequently, international portfolio diversification is advantageous to investor only if stock markets in different countries do not commove in the same direction. Furthermore, others investigate how stock markets may present lead-lag relationships between two different markets, which may then allow an investor to exploit abnormal returns by trading shares from the lagging market, based on the behavior of share prices in the leading market. Following the controversy surrounding the definition and the nature of contagion, geographical and economic closeness of countries, as well as the limitations of some models to tackle the issue, authors have used different methodologies such as spillover model, factor models, co-integration and vector error correction, correlation model, regime switching models. In addition, as it is the case in finance, the findings from the existing studies varied widely and are often different per country, sample period as well as the methodologies used.

For instance, study by Bekaert *et al*., (2014) who utilized the factor model to investigate evidence of contagion and channels of contagion in 415 country-sector equity portfolios across 55 countries during the global financial crisis (GFC) present these particularities. The results show small evidence of contagion from the US and the global market to other markets. However, there is a strong evidence of contagion from the domestic markets to individual domestic portfolios. Following a similar approach, Baur (2012) examined contagion in 25 developed and emergent markets during the GFC. The finding shows increase of co-movement of returns among the financial sector stock across countries and between financial sector stocks and real economy.

The seminal studies of the topics focus on several strands. A first wave focuses on investigating co-movements between developed stock markets. The second wave of studies concentrates on co-movement between developed and emerging stock markets where they explored the interrelationships between these two groups. A third group has been concerned with co-movement between emerging markets, generally belonging to a common continent and geographical region.

Among the existing studies above, a number of empirical studies has revealed the existence of contagion in the advance markets. For instance, King and Waddhani (1990) tested for contagion of New York, London and Japan during the 1987 US market crash. Based on correlation coefficient, the analysis suggest that cross market correlations increased significantly during the crisis. Similarly, Masih and Masih (1997) tested the relationship among six stock markets of developed nations (US, Japan, Canada, Germany and UK), before and after the stock market crash of 1987. It was found that the crash brought about a greater interaction among markets and evidence of single co-integration vector over each of the pre-crash and the post-crash samples.

In the same vein, Missio and Watzka (2011) examined financial contagion in a sample of seven countries, namely, Germany, Greece, Portugal, Spain, Italy, Netherlands, Belgium and Austria, between 2008 and 2010. The results indicated that there was occurrence of contagion in Portugal, Spain, Italy and Belgium. Likewise, Syllignakis and Kourectas (2011) studied the emerging stock markets of central and Eastern Europe for the period 2007-2009, the results indicated that the emerging markets were exposed to external shocks with a substantial regime shift in the conditional correlations. Also, corbert and Twoney (2015) revealed the evidence of contagion mechanics attributed to herding behavior in Europe markets between 2007 and 2013 to the G7 countries market examined. Tiwari et al. (2016) found a short run correlation during the period of financial distress and comovement among markets in the long run. However, karanasos *et al*., (2014) reported time-varying correlation and volatility spillover effects between the returns of the markets examined.

In the case of emerging markets, Aresti et al. (2005) test for contagion in the four largest emerging markets of Asia, namely; Thailand, Indonesia, Korea and Malaysia against a set of developed markets, viz, Japan, UK, Germany, and France (major lender) during the 1997 East Asian crisis. Evidence of contagion was found between the major lenders to the emerging markets. This was attributed to the reduction in bank lending from the major international lenders. Wand and Thi (2006) examined the impact of financial crisis on China Economic Area (CEA) between 1992 and 2002. Conditional correlation coefficients were found positive, and comovement existed among the Thailand and CEA markets. For all the markets, the variances were higher in the post-crisis than in the pre-crisis period, indicating an evidence of contagion.

Similarly, Chiang et al. *(*2007) revealed the evidence of contagion effect from the Asian crisis of 1997 in Thailand, Malaysia, Indonesia, Philippines, South Korea, Taiwan, Hong Kong and Singapore from 1990 to 2003. The first phase of the crisis displaying a process of increasing correlation (contagion), while the second phase investor behavior converged and correlations were significantly high (herding behavior) across the Asian countries.

Meric et al. (2001) examine the stability of correlations and the benefits of international portfolio diversification for an American investor by investing in the four largest Latin American markets (Argentina, Brazil, Chile and Mexico), during and after, the 1987 stock market crash – when the Dow Jones Industrial Averages fell by 508.32 points (or 22%) and lost approximately US $500 billion in 1 day, the largest 1-day percentage drop in history. They use PCA to study changes in co-movement patterns of the selected equity markets from the pre-crash period to the post-crash period and during the post-crash period. Coleman et al. (2018) inspired by Harrisson and Moore (2010) employ the PCA to account for the maximum portion of the variance present in the returns by examining rolling windows with 8-,6-,4-,3-2 and 1 years periods. They also investigate the incidence of structural breaks and co-movement, aiming to uncover the dynamics in co-movements among these markets. They find evidences of high co-movement among the Latin American markets, and also with the U.S markets.

In Africa, Collins and Biekpe (2003) examined the existence of contagion between African equity markets and global emerging during the Asian crisis of 1997. Evidence was found that the larger and more integrated markets in Africa (Egypt and South Africa) suffered from contagion during the Hong Kong crisis of 1997. Morales and O'callaghan (2014) reports no evidence of contagion in 58 countries between 2003 and 2009. It was revealed that markets suffered mostly from the US.

Meanwhile, Bouri (2014) reports a sudden increase in conditional volatilities during financial crisis and a dynamic conditional correlation of equity markets returns of 12 equity markets in MENA between 2005 and 2013. Boako and Alagidede (2017) examined the evidence of shift-contagion in African stock markets using conditional value at risk (CoVaR) between 2003 and 2016. The studies found that global shock propagation to developing markets stagger during the global financial crisis of 2007 but becomes more pronounced after the crisis.

Offiong et al. *(*2018) examined financial contagion and its impact on the Nigerian stock market using Bayesian VAR model in period before, during and after the global financial crisis. The findings showed that American and Chinese markets negatively affected the Nigerian stock markets, with a pronounced effect as a result of the fall of the naira exchange rates.

In a recent study, Anyikwa and Leroux (2020) investigated evidence of integration and contagion between major African stock markets (ASMs) and developed stock markets during the global financial crisis and Euro-zone sovereign debt crisis. Specially, they examine whether the co-movement between ASMs and developed stock markets during the two-crisis period is related to their level of financial integration or due contagion. The authors find limited evidence of integration between ASMs and developed markets. However, the analysis of dynamic correlations show that the conditional correlations are typically positive and higher during the period of crisis and indicating substantial evidence of contagion.

Aderajo and Olaniran (2021), assess the dynamic correlation of financial contagion with evidence from five African countries (South Africa, Nigeria, Egypt, Kenya and Tunisia). The authors analyzed monthly stock prices indices from 2004 to 2018 and they use dynamic conditional correlation multivariate GARCH model to ascertain the contagious effect of the U.S to the selected African markets. Their study revealed that a significant relationship exists between the returns of U.S market and African markets. The inspection of the pre-crisis, crisis, post-crisis mean and variance estimation shows that the crisis period is characterized by substantial increases in volatility, establishing that the shock experienced in the U.S pose a threat of the African markets being examined. Further evidence revealed that in the crisis period, an increase in correlation (contagion) existed, while a continued correlation (herding) existed in the post-crisis period.

We can observe that only few studies investigated can be linked to Africa as most of them have concentrated on Europe and Asian countries. This therefore, suggests for further investigation on the dynamic analysis of financial contagion in African stock markets.

Research Methodology

Principal components

In this study, we first investigate co-movement on the eight stock markets investigated using common factor analysis. The approach finds structure in the covariance and correlation matrix and uses this structure to locate low-dimensional subspaces containing most of the variation in the data. It is worth noting here that the Principal Component Analysis (PCA) has often been referred to in many statistical texts as a special case of factors analysis. However, PCA and factor analysis, as usually defined, are quite different techniques. The confusions may be related to the fact that both PCA and factor analysis aim to reduce the dimensionality of a set of data, but they differ in the techniques employed to achieve this goal.

The PCA is concerned with explaining the variance –covariance structure of data through a few linear combinations of original variables. Its general objectives are twofold that is data reduction and data interpretation. Although the original data set contains k variables often much of the variability can be accounted by a small number m of principal components, where there is almost as much information in the new m variables (principal components) as in the original k variables. Thus, data reduction means that the original data set consisting of n observations on m variables is reduced to one consisting of n observations on k principal components. In general, k components are necessary to represent the total system variability, but there are many situations where much of the variability can be represented by a reducer number of m components. If so, there is nearly as much information in the m components as in the original k variables. The m principal components can then substitute the original k variables so that the original data set of n measurements on m principal as stated by Tsay (2005).

Let $y = \{y_{it}\}$ be a vector of stock market index for country $i = 1, \dots, n$ for period $t = 1, \dots, T$, which are determined by a set of factors (components) f.

$$y_{it} = \sum_{j=1}^{r} \lambda_{ij} f_{jt} + \varepsilon_{it} \qquad y_{it} = \lambda_i f_{it} + \varepsilon_{it} \quad (1)$$

Where λ_i is the factor loading coefficient associated with each of the f and ε_{it} is a white noise identically and independently distributed error term.

Becker and Hall (2009) show that a set of variables are convergent if the general factor representation given in equation (1) can be restricted to a single factor. In this study, we obtain each of the r common factors by PCAs that represent the maximum portion of the variance for the selected stock exchanges. Using the calculated monthly returns, we employ PCA to test for convergence over the sample period considered. We follow the definition of convergence from Becker and Hall (2009), which is based on the value of the $\%R^2$ of the first principal component, this value measures the total variation of the returns explained by the first factor. The closer this value is to one, the greater the degree of convergence between the returns. In addition, if $\%R^2$ over the first period is less than that in some subsequent Period 2, then convergence has accelerated over the selected interval. Thus, the convergence is used as a measure of co-movement.

Multiple Structural Breaks Test

The testing for parameter instability and structural change in regression models have been fundamental in applied econometric work, dating back to (Chow, 1960), who tested regime change at a priori known dates using a F statistic. As a priori known dates may not be clear to relax the requirement that the candidate break date be known, (Quandt, 1960) modified the Chow framework to consider F statistic with the largest value over all possible break dates. Others, including (Andrews, 1993) and (Andrews and Ploberger, 1994), deducted the limiting distribution of the Quandt tests statistics.

On the basis of those previous methodologies, (Bai, 1997) and (Bai and Perron, 1998, 2003a, 2003b) determined theoretical and computational results that further extend the Quandt-Andrews framework by allowing to test for multiple unknown breakpoints.

We consider the case of pure structural change regression model with T periods and m potential breaks (resulting $m + 1$ regimes), for observations $T_j, T_j + 1, \ldots, T_{j+1} - 1$ for the regimes $j = 0, \ldots, m$ given by

$$y_t = Z_t'\delta_t + \varepsilon_t \qquad (2)$$

The Z variables have coefficients that are regimes specific. In such cases, computation of the estimates of the Equation (2) can be completed by simply employing the ordinary least square approach, segment by segment without constraints. Bai and Perron (1998) depict global optimization procedures for distinguish the m multiple breaks that minimize the sum of square of residuals (SSR) of the equation model of equation (2). The multiple breakpoint tests may be broadly separated into three categories: firstly, tests that use global maximizers for the breakpoints; secondly, tests that employ sequentially defined breakpoints, and finally, hybrid tests that combine the two approaches. The tests can be performed allowing differential serial correlation in the errors, different distributions for data, and errors across sections or stating a common structure. In this study, we apply the global maximizer approach in line with the recommendation of Bai and Perron (2003a): the problem is that, in the present of multiple breaks, certain configurations of changes are such that it is difficult to reject the null hypothesis of 0 versus 1 break, but it is not difficult to reject the null of 0 versus a higher number of breaks (this occurs, for example when 2 changes are present and the value of the coefficient returns to its original value after the second break). In such cases, the sequential procedure breaks down.

In sum, for a specific set of m breakpoints, such as $\{T\}\ m = (T_1, \ldots, T_m)$, we minimize

$$S(\beta, \delta|\{T\}) = \sum_{j=0}^{m} \left\{ \sum_{t=T_1}^{T_{t+1}-1} y_t - X_t'\beta - Z_t'\delta_j \right\} \qquad (3)$$

Using standard least square regression to find the estimates $\hat{\beta}, \hat{\delta}$ in the case of the partial structural model or $\hat{\delta}$ for a pure structural change model. Bai and Perron show that the number of comparison models increases rapidly in both m and T and derived practical algorithm for computing the global optimizers for multiple breakpoint models. These global break point estimates are then utilized as the benchmark for several breakpoint tests.

Bai and Perron (1998, 2003a) present a further generalization of the Quandt-Andrews tests (Andrews,1993) in which tests for equality of the across multiple regimes. For the test of the null of no breaks against an alternative of breaks, an F statistic is applied to assess the null hypothesis that $\delta_0 = \delta_1 = \cdots = \delta_{l+1}$ as below:

$$F(\hat{\delta}) = \frac{1}{T}\left(\frac{T - (l+1)q - p}{kq}\right)(R\hat{\delta})'\left(R\hat{V}(\hat{\delta})R'\right)^{-1} R\hat{\delta}$$

Where $\hat{\delta}$ is the optimal $l - break$ estimate of δ, $(R\delta)' = (\delta_0' - \delta_1', \ldots, \delta_l' - \delta_{l+1}')$, and $\hat{V}(\hat{\delta})$ is an estimate of the variance covariance matrix of δ that may not suffer from serial correlation and heteroscedasticity depending on the assumptions regarding the distribution of the data and the errors across segments.

A singular test of no breaks versus an alternative of l breaks assumes that the alternative number break points, l, is predetermined. As is often the case, the precise number of breaks is not known; Bai and Perron (BP) approach proposes the double maximum tests – two tests of the null hypothesis of no structural breaks against an alternative of an unknown number of breaks, given some upper bound M. The first, UD_{max}, an equal weighted version of the test, choose the alternative that maximizes the statistic across the number of break points. The second test, WD_{max} , employs weighs to the individual test such that the marginal p values are equal across values of M. BP recommend the five breaks should be sufficient for most empirical applications and provide the appropriate critical values for $M = 5$ and also options of 5%, 10% and 15% sample trimming. BP also show that critical values appear to vary little when the upper bound M is greater than 5. In this study, we test the individual stock market returns for multiple structural breaks using the global L breaks versus none option and explore similarity in the number of breaks and, as consequence, infer some form of evidence of comovements across these markets. Recent empirical applications relevant to this current work include (Cuesta et al. 2015) and (Coleman et al. 2018).

Dynamic co-movement

To analyze the co-movement between markets, we proceed contrarily to the existing literature which widely used Pearson correlation coefficient, which albeit simple has majors' shortcomings with high frequency data, in particular due to the narrowness of the time specific information it provides. In this article, we follow Yetman (2011b) by constructing the co-movement between each pair of markets, but at each point in time. In sum, the co-movement at time t, between the return R of markets i and j can be estimated by the product of their respective z scores

$$\rho_t^{ij} = \frac{(\Delta R_{it} - \Delta \bar{R}_i)}{\sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(\Delta R_{it} - \Delta \bar{R}_i)^2}} . \frac{(\Delta R_{jt} - \Delta \bar{R}_j)}{\sqrt{\frac{1}{T-1}\sum_{t=1}^{T}(\Delta R_{jt} - \Delta \bar{R}_j)^2}} = z_{it}.z_{jt} \qquad (4)$$

We estimate equation (4) for each possible pairing that is, the different African stock markets plus the U.S markets: we come out with 28 pairs of ρ^{it} across time. Positive estimate of ρ^{it} implies co-movement, whereas negative values imply decoupling or movement in the opposite directions. In any one case, the relative size of the z score indicate the strength of the co-movement. Following the objective of this study, we are also interested in the proportion of the time that we observe co-movement between each market pair. For our purpose, we use simple events study methods. We consider for periods. Two pre-event period 2005 to 2006 and 2017 to 2018 and two events period 2007 to 2008 and 2019 to 2021. The proportion of times that the positives estimates of the co-movement is observed is calculated and reported in Table 7, and on the basis of this, we are able to posit on whether there is any noticeable change in the periods of co-movement across any market pair.

Data and Descriptive Statistics

The study uses monthly closing stock price indices from July 2005 to December 2021 for seven stock markets (seven African stock exchanges: namely Botswana (BOT), Egypt (EGY), Kenya (KEN), Mauritius (MAU), Morocco (MOR), Nigeria (NIG), South Africa (SAF) and the U.S stock exchange. All stock price indices are denominated in local currency and into monthly stock returns as $ln(P_t/P_{t-1})$, where P_t is the closing stock index on month t and P_{t-1} is the closing stock index on month $t-1$. The dataset was obtained from the Bloomberg database. We report summary statistics in the Table 2. Here we lay out a few notable observations. South Africa and Egypt exhibit the highest means return 0.83 % and 0.56 %, respectively, whereas the lowest return where in Kenya -0,37 %. The results suggest that for African countries, opportunities exist for international portfolio diversification between their returns. United States S&P composites index yields a return of 0.70%, which it is the second highest return when the whole sample are considered. The highest volatilities, measured by the standard deviation are observed in Nigeria (7.33 %) and in Egypt (8.47 %), whereas the lowest volatilities are found in the Botswana (3.2 %) and in the United States (4.3 %). Therefore, the higher risk can be inferred to the former two markets and lower to the associated risk to the latter. We note that the adage stating that the high returns are followed by high risk is not respect.

With respect to the return distribution, all of the selected markets present non-normal returns, according to the Jarque-Bera test. A majority of these markets, during the analyzed period exhibit negative skewness, suggesting that the proportion of months with negative returns tends to be higher than those with positive returns. The exception is Botswana which have positive skewness. We also see from Table 2 that the data highlight that all these markets have leptokurtic distributions, suggesting “fat tail risk “in their returns.
Finally, the correlation matrix reported in Table 3 suggest that the potential of the countries in the sample for diversification with the Botswanan market is the most promising one due to its lowest correlation with the other markets. We note that, with the exceptions of Egyptian and South African stock markets, the correlation coefficients of the individual countries with the United States composite index are all below 0.50.

Table 1: **Descriptive statistics of monthly returns of African stock markets and United States stock exchanges (July 2005 to December 2021)**

	BOT	EGY	KEN	MAU	MOR	NIG	SAF	USA
full sample period								
Mean	0.0038	0.0056	-0.0037	0.0053	0.0053	0.0034	0.0083	0.0070
Median	0.0017	0.0012	0.0034	0.0034	0.0036	0.0025	0.0010	0.0012
Max	0.147	0.311	0.144	-0.326	0.181	0.329	0.129	0.119
Min	-0.1069	-0.394	-0.256	0.153	-0.233	-0.365	-0.161	-0.185
Std.Dev	0.0320	0.0847	0.0543	0.0474	0.0432	0.0733	0.0464	0.0430
Skew	0.4752	-0.5036	-0.9694	-1.9263	-0.5115	-0.4381	-0.2924	-0.9093
Kurtosis	7.1599	5.8258	6.0756	17.184	8.3038	7.7862	3.8516	5.3040
Jarque-Bera	150.22	74.251	109.06	1782.4	240.72	195.33	8.8066	71.085
Probability	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0122	0.0000
observations	198	198	198	198	198	198	198	198

Note. In this table, BOT, EGY, KEN, MAU, MOR, NIG, and RUSA, represent returns for the stock markets in Botswana, Egypt, Kenya, Mauritius, Morocco, and the United States, respectively

Table 2: Correlation Matrix

	BOT	EGY	KEN	MAU	MOR	NIG	SAF	USA
BOT	1.00							
EGY	-0.0746	1.00						
KEN	0.0648	0.3778	1.00					
MAU	0.1475	0.4160	0.4675	1.00				
MOR	0.0388	0.3374	0.1638	0.3568	1.00			
NIG	0.1304	0.2955	0.3044	0.3370	0.2633	1.00		
SAF	-0.0328	0.5200	0.4008	0.4095	0.2249	0.3010	1.00	
USA	0.0131	0.5230	0.4030	0.4573	0.2343	0.2899	0.6502	1.00

Note. In this table, BOT, EGY, KEN, MAU, MOR, NIG, and RUSA, represent returns for the stock markets in Botswana, Egypt, Kenya, Mauritius, Morocco, and the United States, respectively

Empirical Results

Principal Component Analysis

In this section we report our analysis from applying principal component analysis to the database of African stock market returns over the whole sample and for 8-,6-, and 4-year rolling windows. For the whole sample period, the first principal component is able to explain about 47.94% of the variance in the data when only African stock markets are considered, and 47.53% with United States markets. These results suggest that most of the variance in the stock market return indices in African markets analyzed cannot be attributed to one factor over the whole sample period. Furthermore, the inclusion of the United States appears to have no substantial effect the increment is less than 1% for the U.S market. One clear implication is that there is an incomplete convergence over the period and as, a result, the study attempts to assess whether convergence has been period specific or increasing over time.

To identify whether stock market co-movement is episodic, we provide a series of rolling windows periods (8,6,4,3 and 2 years) for the first component for African stock exchanges without and with the inclusion of the US market. For the 8-,6- and 4-years rolling windows, it appears to have an indication of increasing convergence peaking when episodes of crisis and international macroeconomic policy instability are included in the rolling window. For instance, for the 8-year rolling window, the highest periods of convergence can be observed in the interval 2008-2016 and 2009-2017. Notably, both periods contain major economic shocks such as the 2008-2009 Global financial crisis, and the more recent 2011-2012 Greek Sovereign debt crisis, the 2014 Nigerian stock market slump and the Kenyan foreign exchange market crisis in 2015. The 6- and 4-year rolling windows appear to confirm this pattern of increasing co-movement since the highest point is reached during periods of economic and financial distress. These findings seem to be in line with studies from Anyikwa and Le Roux (2020), Collins and Biekpe (2003) and Jin and An (2015) who identified a similar patterns for African stock markets. When we include U.S in our analysis, we observe that the co- movement between the seven stock exchanges presents marginal differences being noticeable when analyzing the rolling windows.

Table 4 summarizes the results for the shorter periods rolling windows, that is, 3 years. By examining these windows, we may expect the episodic periods of increasing and decreasing co - movement and their links with the occurrence of economic and financial shock to be more prominent. It is fairly evident that the initial pattern of increasing convergence peaking during times of economic and financial distress is also repeated for shorter periods rolling windows suggesting the link with 2008-2009 Global financial crisis, and the more recent 2011-2012 Greek Sovereign debt crisis, the 2014 Nigerian stock market slump and the Kenyan foreign exchange market crisis in 2015 and 2018 South Africa recession Akunga et al. (2022) provide the same findings. As noted by Agyei-Ampomah (2011), the wave of financial sector liberalization in African stock markets in the few past years might have contributed to these findings.

The factor analysis model described earlier indicates the extent to which fluctuations in the returns in our sample have common features. It is also of interest, however, to identify how independently the other country's returns a particular exchange returns fluctuate about common factor. With complete convergence, these factor loadings will be equivalent to 1 for all exchanges in our sample.

Full sample 2005 m07-2021 m21

Table 3 R^2 first principal component NoUSA and USA (8-, and 6-, year rolling windows)

No USA (Full sample)				0.4794							
USA (Full sample)				0.4753							
8 years windows		**2005 2013**	**2006 2014**	**2007 2015**	**2008 2016**	**2009 2017**	**2010 2018**	**2011 2019**	**2012 2020**	**2013 2021**	
NoUSA		0.6099	0.6063	0.5952	0.7305	0.7447	0.6885	0.6539	0.5403	0.5171	
USA		0.5984	0.5986	0.5886	0.7257	0.7416	0.6881	0.6550	0.5413	0.5190	
6 years window	**2005 2011**	**2006 2012**	**2007 2013**	**2008 2014**	**2009 2015**	**2010 2016**	**2011 2017**	**2012 2018**	**2013 2019**	**2014 2020**	**2015 2021**
No USA	0.6089	0.5326	0.6141	0.7027	0.7356	0.7744	0.8227	0.5710	0.5964	0.5917	0.6018
USA	0.5840	0.5250	0.6067	0.6929	0.7297	0.7739	0.8229	0.5714	0.5971	0.5936	0.6040

Table 4 R^2 first principal component NoUSA and USA (4-, and 3-year Rolling Windows)

4 years windows	**2005 2009**	**2006 2010**	**2007 2011**	**2008 2012**	**2009 2013**	**2010 2014**	**2011 2015**	**2012 2016**	**2013 2017**	**2014 2018**
NoUSA	0.74087	0.6296	0.5115	0.7404	0.7598	0.7554	0.8450	0.7774	0.6108	0.6416
USA	0.70248	0.61171	0.5035	0.7293	0.7533	0.7535	0.8451	0.7811	0.6108	0.6435

4 years Windows	**2015 2019**	**2016 2010**	**2017 2021**							
NoUSA	0.6691	0.41862	0.5473							
USA	0.6702	0.41595	0.5457							

3 years windows	**2005 2008**	**2006 2009**	**2007 2010**	**2008 2011**	**2009 2012**	**2010 2013**	**2011 2014**	**2012 2015**	**2013 2016**	**2014 2017**
NoUSA	0.7811	0.7744	0.6603	0.6884	0.7836	0.7732	0.8884	0.8421	0.8650	0.6780
USA	0.7477	0.7460	0.6432	0.6741	0.7757	0.7714	0.8884	0.8450	0.8674	0.6785

3 years windows	**2015 2018**	**2016 2019**	**2017 2020**	**2018 2021**						
NOUSA	0.7419	0.5153	0.5470	0.6865						

Structural Break Analysis

This section focusses on the results of multiple break point tests developed by (Bai and Perron, 2003a, 2003b). In order to apply the tests, we specified a multiple regression equation (5) for each the seven African stock markets over the whole sample with and without United States stock market.

$$Y_{jt} = \alpha_t + \sum_{k=1}^{6} \beta_{kt} X_{kt} + \varepsilon_t \qquad (5)$$

In equation (5) Y_j is the return in country j in which the multiple break test is considered, and X_k is the return in the other countries $k = 1, \ldots, 6$.

In order to overcome potential problems of heteroscedasticity and serial correlation, we employ the Newey-West (1987) estimator of the covariance matrix.

In total we allowed a maximum number of five breaks based on the sample size; we also employed 15% trimming and 5% significance level. As described in the Section 3, we apply the global L Breaks versus none approach, using the F statistic and the double maximum test, which involve maximization both for a given number of breaks l across various values of the test statistic for l. The hypothesis can be summarized as H_0, no structural breaks, versus H_1, alternative number of unknown breaks up to an upper bound ($m = 5$). Table 5 below summarizes the results. The specific dates at which the breakdown occurs are identified for each country as the month in which the break commenced, and identified in a graph when that ends. Note that the breakpoint started in that month, so a researcher should consider controlling the impact at this month in order to neutralize the breakpoint impacts.

The test statistics reported underneath the specification are used to determine the number of breaks for each country, as can be verified by the significance of operator $SupF_T(k)$, where k denotes the number of breaks. $SupF_T$ type test considers the hypothesis of no structural break ($m = 0$ versus $m = k$ breaks. In the tests of this study, the maximum of 5 breaks were noted.

The number of breaks found range from 1 to 5 with Botswana having the lower number of breaks identified. The double maximum statistics (UDmax and WDmax, with number of the breaks in the brackets) are used to test the null hypothesis of no structural break against an alternative of an unknown number of breaks.

Given the significance of all double maximum statistics, as denoted by star (*), the presence of at least one break is confirmed. The statistics would have us believe that all the countries experienced a structural break at date around the global financial crisis, that is, in 2007-2009. The other important breakdown is related to the period 2011-2013. Finally, we find a break point related around the middle of 2019 both for the S&P 500, among the African countries;

Table 5 Bai and Perron (2003a) Multiple Breakpoint test results

	Specification						
Countries	$\boldsymbol{q = 1}$		$\boldsymbol{p = 0}$	$\boldsymbol{h = 15}$		$\boldsymbol{m = 5}$	
	Tests						
South-Africa	$SupF_T(1)$ 60.17*	$SupF_T(2)$ 26.57*	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 80.52* (5)**	**WDmax 131.42*(5)**
South-Africa-USA	$SupF_T(1)$ 30.18*	$SupF_T(2)$ 38.68*	$SupF_T(3)$ 31.90*	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 172.61* (5)**	**WDmax 276.97*(5)**
Botswana	$SupF_T(1)$ 117.88*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 117.88* (1)**	**WDmax 131.82*(5)**
Botswana - USA	$SupF_T(1)$ 176.65*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 294.34* (5)**	**WDmax 472.30*(5)**
Egypt	$SupF_T(1)$ -	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 90.91* (5)**	**WDmax 148.37*(5)**
Egypt -USA	$SupF_T(1)$ 29.89*	$SupF_T(2)$ 42.28*	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 101.73* (2)**	**WDmax 145.61*(5)**
Kenya	$SupF_T(1)$ 28.36*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 63.42* (3)**	**WDmax 80.50*(3)**
Kenya – China	$SupF_T(1)$ 27.07*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 84.94* (5)**	**WDmax 136.30*(5)**
Kenya -USA	$SupF_T(1)$ 32.44*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 88.82* (5)**	**WDmax 142.52*(5)**
Mauritius	$SupF_T(1)$ 137.78*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 454.86* (5)**	**WDmax 742.38*(5)**
Mauritius - USA	$SupF_T(1)$ 173.79*	$SupF_T(2)$ 37.20*	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 846.85* (5)**	**WDmax 1358.87*(5)**
Morocco	$SupF_T(1)$ 46.34*	$SupF_T(2)$ 43.21*	$SupF_T(3)$ 31.15*	$SupF_T(4)$ 24.12*	$SupF_T(5)$ -	**UDmax 186.47* (5)**	**WDmax 304.35*(5)**
Morocco - USA	$SupF_T(1)$ 55.52*	$SupF_T(2)$ 43.69*	$SupF_T(3)$ 50.74*	$SupF_T(4)$ 44.30*	$SupF_T(5)$ 30.80*	**UDmax 242.78* (5)**	**WDmax 339.26*(5)**
Nigeria	$SupF_T(1)$ -	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 105.22* (5)**	**WDmax 171.73*(5)**
Nigeria -USA	$SupF_T(1)$ -	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 178.62* (5)**	**WDmax 286.62*(5)**
USA	$SupF_T(1)$ 75.18*	$SupF_T(2)$ -	$SupF_T(3)$ -	$SupF_T(4)$ -	$SupF_T(5)$ -	**UDmax 111.57* (5)**	**WDmax 179.03*(5)**

Note: Maximum Breaks = 5= m; Trimming Percentage = 15 = critical number of observations as defined in the model; Significance Level = 0.05; *p* and *q* are respectively vectors of covariates.

An important observation is that, in general, the breaks are similar across the major part of the markets and the inclusion of the US as with the PCA analysis does not appear to have a clear distinctive effect. This is quite an interesting and important result in this study, as there is full body of literature that states be the U.S market the leading market in term of co-movement within the region. The findings so far from convergence and structural break analyses appear to suggest that this may not be the case, and the whole of these African markets tend to be synchronized without a distinct lead-lag relationship.

The analysis was only conducted on monthly data to improve the precision of test results. If the annual data series were used the years identified in this paper would prominently be identified as the years of the breakdown.

Correlations dynamics

We summarize our analysis on co-movement as follows: Table 6 presents descriptive statistics of ρ_t^{ij} ; Table 7 summarizes the proportion of positive co-movements; Figure 1 illustrates how these co-movement have evolved over time.

By using the equation (4), we estimate all possible pairings of the ρ_t^{ij}, for the eight markets. following this, we are then able to graphically illustrate and examine the behavior of this cross markets co-movements over time see figure 1 (due to space availability, we only provide the figure of South Africa and others markets, others graphics are available under request). Positive entries ($\rho_t^{ij} > 0$) represent comovement, whereas negative entries ($\rho_t^{ij} < 0$) imply the markets move in the opposite directions. Table 6 suggest some interesting patterns we highlighted the salient ones below. Over the entire sample, South Africa exhibits higher co-movement with U.S, Egypt, Mauritius and Kenya, with average ρ_t^{ij} exceeding 0.39. This is particularly noteworthy, since by contrast and interestingly, South Africa stock market display significantly less co-movement with that of its geographically closer neighbor with coefficient of -0.032 with Botswana and a correlation of only 0.29 with Nigeria which it is the second biggest economy of Africa. This finding suggests that geographical proximity, economic ties, and even trading link do not infer similar stock markets behavior. Furthermore, we find weak co-movement between Botswana and the others African stock markets. As noted before, Botswana stock market commove less with the other markets in the sample. The estimate z scores appear to show stronger co-movement during the period of economic crisis. For example, the 2007/2008 and the euro-zone sovereign debt crisis are captured across all possible as period of higher co-movement, which corroborate the results found in the PCA above. This buttress the support of the earlier findings by Forbes and Rigobon (2001), Coleman et al. 2018) with regarding the impacts of the transmission of shocks from one to another market, particularly in times of turbulence. Furthermore, across all the 28 possible pairings, the markets appear to be fluctuating around the zero mark over most of the period. The relevance of this co-movement for investors is crucial, so in order to ascertain the proportion of the sample period over which co-movement is found between any pair, Table 7 reports the percentage of positive entries. The findings of this exercise suggest that, typically, there is over co-movement between the markets in about 50 per cent of the time analyzed. The exception, though, appear to be the Botswanan stock market that seems to commove the least with the others, that is, around 50 per cent of the entire period. This feature can be observed in the Table 7 of stock return correlations. This means that, the risk-averse investors in these African markets may, in theory, include the Botswanan market in their portfolios to improve the diversification.

Table 6 Descriptive statistics of returns co-movements

Country pair	**Mean**	**SD**	**Maximum**	**Minimum**
Number observation	**198**			
South-Africa-Botswana	-0.032	1.072	4.092	-9.656
South-Africa-Egypt	0.517	1.503	14.139	-1.123
South-Africa-Kenya	0.398	1.657	12.335	-2.267
South-Africa-Mauritius	0.407	1.969	19.049	-1.808
South-Africa-Morocco	0.223	1.616	15.071	-5.853
South-Africa-Nigeria	0.299	1.475	9.986	-5.004
South-Africa-U.S	0.646	1.692	13.424	-2.390
Botswana- Egypt	-0.074	0.980	2.985	-4.767
Botswana- Kenya	0.064	1.219	7.353	-6.381
Botswana- Mauritius	0.146	1.213	9.410	-4.136
Botswana- Morocco	0.038	1.104	5.239	-7.263
Botswana- Nigeria	0.129	0.939	5.911	-2.007
Botswana- USA	0.013	1.015	4.435	-6.274
Egypt- Kenya	0.375	1.674	17.967	-3.170
Egypt- Mauritius	0.413	2.127	22.409	-1.827
Egypt- Morocco	0.335	1.710	17.729	-3.393
Egypt- Nigeria	0.293	1.637	15.717	-4.174
Egypt- USA	0.520	1.899	21.127	-2.27
Kenya- Mauritius	0.465	2.466	21.757	-2.942
Kenya- Morocco	0.162	1.759	17.214	-10.295
Kenya- Nigeria	0.302	1.574	12.690	-5.408
Kenya- USA	-0.001	0.012	0.013	-0.141
Mauritius-Morocco	0.354	2.966	38.627	-9.825
Mauritius – Nigeria	0.335	2.070	20.121	-6.578
Mauritius – USA	0.455	2.300	22.852	-1.851
Morocco- Nigeria	0.261	1.593	15.919	-2.839
Morocco- USA	0.233	1.672	18.080	-6.344
Nigeria- USA	0.288	1.721	14.922	-3.967

Notes: Summary statistics are presented for the pairwise comovements, $\boldsymbol{\rho_t^{ij}}$, of each month stock return, over the full sample.

Analysis of the pre-crisis and post-crisis period did not show a clear pattern about the co-movement for all the markets. However, on the other hand, an indicative observation is that the larger market of South Africa and Egypt appear to commove even more following the crisis and these findings corroborate the results of Collins and Biekpe (2003). On the other hand, we notice that, the small markets, particularly Botswana seem to demonstrate rather less co-movement with other markets following the crisis. This observation confirms the statement made earlier that risk-adverse investors can improve their portfolio diversification by combining Botswanan equity with other African assets. These results show that there is an evidence of contagion in African markets from the global to the emerging markets crisis only in the largest and most traded markets, namely Egypt and South Africa. One interpretation of this result may be that African equity markets offer a true source of diversification to asset managers. Given the small size of most of these markets, however, that is hardly significant for asset manager with more valued portfolio under management.

Table 7 percentage of positive of ρ_t^{ij} (comovement) – Full sample, precrisis, and postcrisis

Country pair	Full sample [%]	Precrisis [%]	Postcrisis [%]
South-Africa-Botswana	52.02	56	**46.66**
South-Africa-Egypt	61.61	56	60
South-Africa-Kenya	57.07	36	57.33
South-Africa-Mauritius	53.53	44	48.66
South-Africa-Morocco	56.56	64	**53.33**
South-Africa-Nigeria	56.56	44	58
South-Africa-USA	68.18	76	**66**
Botswana- Egypt	43.93	60	**42**
Botswana- Kenya	53.53	68	**52.66**
Botswana- Mauritius	58.80	76	**58.66**
Botswana- Morocco	0.5	72	**47.33**
Botswana- Nigeria	57.07	68	**53.33**
Botswana- USA	51.51	56	**52**
Egypt- Kenya	61.11	60	**58.66**
Egypt- Mauritius	59.59	52	56.66
Egypt- Morocco	57.57	56	58.66
Egypt- Nigeria	52.52	60	**48.66**
Egypt- USA	63.13	56	63.33
Kenya- Mauritius	61.11	60	60.66
Kenya- Morocco	57.07	64	**57.33**
Kenya- Nigeria	58.08	44	60.66
Kenya- USA	57.57	68	**56.66**
Mauritius-Morocco	61.61	72	**59.33**
Mauritius - Nigeria	58.58	60	**56**
Mauritius - USA	56.06	56	**54**
Morocco- Nigeria	54.54	48	52.66
Morocco- USA	61.11	76	**59.33**
Nigeria- USA	55.05	32	60

Note. For each batch of pairings, the entry in bold indicates the country-pair with the lowest percentage within that batch of pairings.

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ISSN 2522-3186

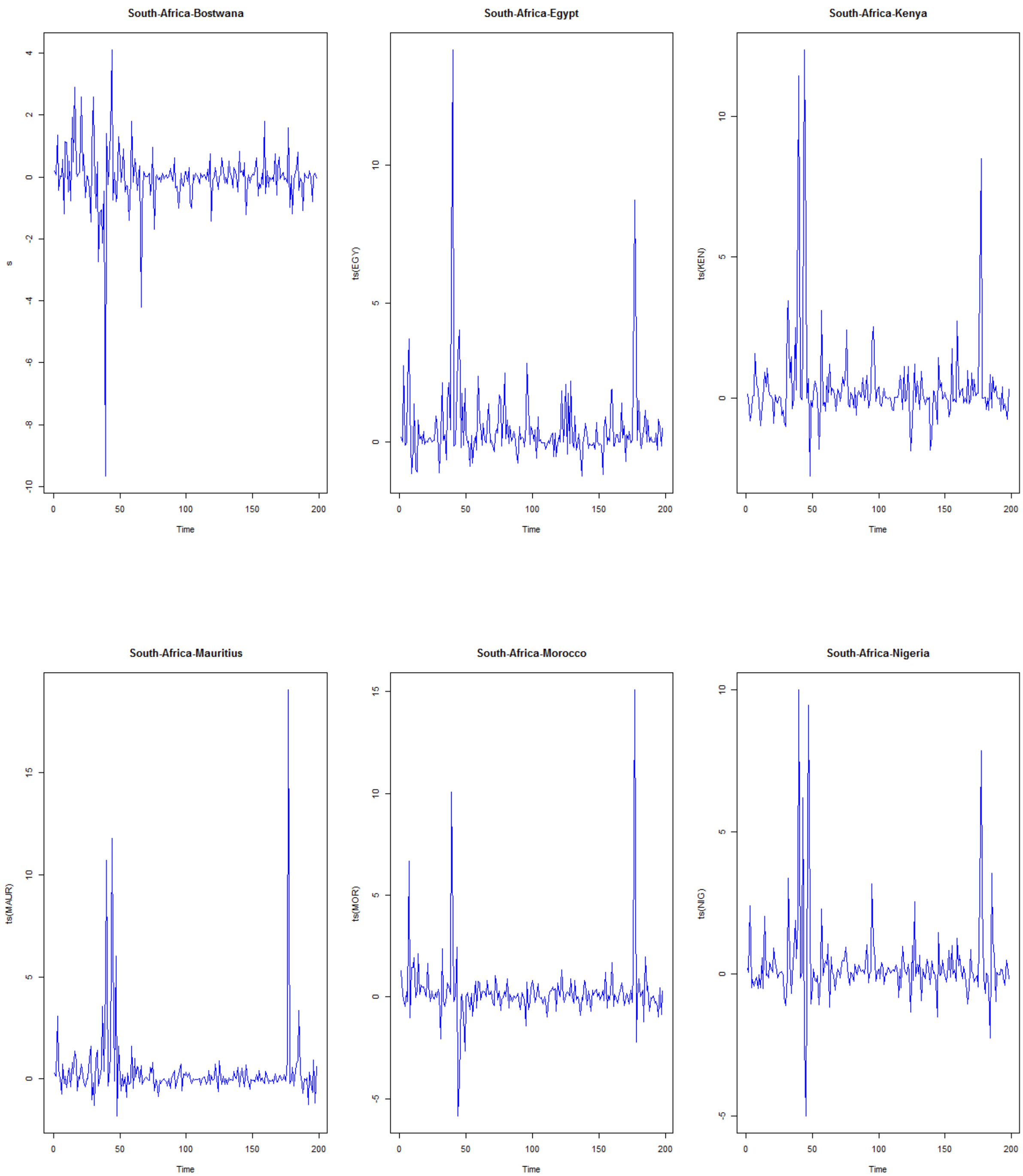

Figure 1: Estimates of co-movement ρ_t^{ij} (South Africa and other markets)

Conclusions and Recommendations

In this study, we used monthly returns, constructed from monthly closing price indices from seven African stock exchange markets (Botswana, South Africa, Egypt, Kenya, Mauritius, Morocco, Nigeria, and the US S&P 500 index market to examine to what extent the African equity markets commove with each other and also with the U.S equity market. The first important results suggest that, irrespectively of the equity market choice, an inclusion of Botswana equity market in investor portfolios is likely to increase the benefit of diversification. South Africa and Egypt on the other hand, appear to commove the most with the other markets, implying least portfolio diversification. Secondly, we notice that after the Global Financial Crisis (GFC) period, with the exception of Botswana and Mauritius, the African stock markets commove with the U.S about 60% of the time with the high degree of co-movement being with the South Africa. Thirdly, we find that in the GFC post-crisis period, co-movement across the different stock markets appears to have decreased for all countries compared with the pre-crisis period.

In era of easier large capital inflows, this study underscored the importance of understanding interdependencies among African markets and also with U.S in order to make a reliable and profitable portfolios decision.

For policymakers, the observed level of co-movement between, U.S and these African equity markets underscore the relevance of considering and being prepared for contagion effects when formulating policies relating to financial regulation and international capital flow controls.

This suggests that equity market disturbance in the United States and certain African countries are more likely to be transmitted to the other countries which may then have adverse consequences for the stability of the financial system. This is the case of South Africa and Egypt. The investigation of the co-movement of African countries and developed stock markets will give more insight in global portfolio management with African stock markets, this issue is left for future researches.

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