

# Africa Stock Markets Cross-Market Linkages: A Time-Varying Dynamic Conditional Correlations (DCC-GARCH) Approach

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## ABSTRACT

*This article investigates stock return volatility and contagion among the five African countries (Zimbabwe, South Africa, Egypt, Kenya, and Nigeria) and the United States of America for the period between 1998 and 2015. Engle (2002)'s Dynamic Conditional Correlation multivariate generalized autoregressive conditional heteroscedasticity model was adapted to explore the time-varying conditional correlations to capture the contagion behavior of these financial markets over time. In this article the researchers observe that South African Stock returns are highly correlated to NYSE stock returns and the coefficients are significant for all periods under consideration. Additionally, the South African stock returns are significantly negatively related to Zimbabwean stock returns. An analysis of correlation confirms what most scholars found, that the correlations amongst markets tend to increase during the time of crises and weaken during periods of stability with an exception of Egypt whose results indicate an insignificant negative correlation during the 2007/9 crisis. It is recommended that future research in this area should focus on the potential contagion mechanisms between African countries and European countries especially looking at what transpired during and after the sovereign debt crisis.*

**Keywords:** Stock Market Returns; Volatility; Contagion; Inter Linkages; Global Crisis; Portfolio Diversification; GARCH; Dynamic Conditional Correlations

## 1. INTRODUCTION

The past three decades have been characterized by a number of unsettling commodities and forex crises. Beginning with the 1992/93 forex crises, followed by the devaluation of the Mexican peso which led to financial market crisis of 1994, and then the Asian crisis in 1997, followed by the 1998 Russian financial crisis, after which the Brazilian currency crisis of 1999 was witnessed, then the dot-com bubble bust in 2000. More recently the global financial crisis of 2007/9 and the Greek sovereign debt crisis of 2010 whose aftermath is still with us. The global financial crisis of 2007/9 has amplified curiosity in the understanding of the importance of market contagion and systemic risk.

Dimitriou, Kenourgios and Simos (2013) revealed that the global financial crisis had the most damaging effects worse than those of the great depression of 1929 because of cross-market linkages. One remarkable distinguishing outcome of these predicaments was how a shock in one country was swiftly transferred from one financial market to another around the world (Forbes and Rigobon, 2002). The connections between stock market and financial markets in general resulted in an increase in systemic risk between countries as correlations significantly increased between markets beyond any fundamental linkages a phenomenon generally known as market contagion (Kenourgios, Samitas & Paltalidis, 2011). Market contagion is defined by Forbes and Rigobon (2002) as “a significant increase in cross-market linkages after a shock to an individual country (or group of countries)”. Recently financial markets research has refocused their efforts to understanding the nature of linkages across markets especially after the financial turmoil. However, many studies confirmed the existence of financial contagion during the periods of stock market crashes.

Reinhart, Kaminsky and Vegh (2003) gave detailed chronological events that related to the market contagion from 1982 to 2000. Other scholars like King and Wadhvani (1990) realised an increase in correlations of stock returns during the stock market crises of 1987 and the increase in correlations were significant, while Calvo and Reinhart (1996) identified a change in correlations during the Mexican Crisis. Yang and Lim (2004), Agenor, Miller, and Vines (2006), and Sander and Kleimeier (2003) also confirms the contagion effect during the East Asian Crisis. Longin and Solnik (2001) and Ang and Bekaert (1999) found out that correlations tend to increase during the crash or bear markets and decline during the bull market. Lin, Engle and Ito (1994) indicate that correlations between markets also increase during times of increased volatility.

Most of the literature explores the linkages in developed stock markets and recently others are researching on the nexus between developed markets and emerging markets. However, most literature explored and a couple of it discussed here discusses the integration developing markets and well developed markets yet there is very little if any empirical research that was done to investigate the contagion effects amongst the African markets. The research on systemic risk amongst financial markets has been put into perspective once again mainly after the global financial crisis of 2007/9. An investigation on stock market linkages is important for the investors as it provides information on diversification and risk management. A better understanding on the linkages of capital markets of various countries is crucial in the diversification of risk to derive high return (Bakar and Masih, 2014). This paper provides new knowledge through modeling and approximating the degree of financial markets integration in the African countries. The investigation of integration amongst financial markets is very important because of its catastrophic consequences to the global economy, mainly, within the context of long-term asset allocation, the valuation and pricing of assets, the monetary and fiscal policy articulation, and last but not least the risk management (see Kaminsky & Reinhardt, 1999; Longstaff, 2010, among others). Due to recent global financial crisis, the examination of cross market linkages amongst international markets become a fertile research terrain (Ahmad, Sehgal & Bhanumurthy, 2013). The present study adds to the body of knowledge by: Examining the time-varying correlation dynamics of stock returns among African countries during different phases of pre-crisis (before 2007), during crisis (2007-2009) and post-crisis (After 2009); providing a detailed investigation of time varying linkages in stock market returns, which is a deeper scrutiny of correlations overtime. The present work utilizes the generalized autoregressive conditional heteroscedasticity (GARCH (1,1)) model to capture the inter linkages of these markets overtime.

This paper investigates the existence of a contagion among the five African countries (Zimbabwe, South Africa, Egypt, Kenya, and Nigeria) and the United states of America as it is the source of crisis. The study is carried out from the 1<sup>st</sup> of January 1998 to 31<sup>st</sup> of April 2015. The study employs Engle (2002)'s Dynamic Conditional Correlation (DCC) multivariate GARCH model. The model was adapted to explore the time-varying conditional correlations in order to capture the financial markets integration over time. Some of the results reported in this study supports the notion that there is cross market inter-linkage between developed and emerging stock markets. The study also found insignificant relationship amongst the volatility of JSE and other African countries.

The layout of the present paper is as follows: In Section 2 literature on financial markets linkages is reviewed. Then followed by section 3 where the researcher discusses the model specification and estimation techniques that were employed to address the main question of cointegration of African markets and the United States. Section 4 will display, analyze and discuss empirical results, while Section 5 reports the concluding remarks.

## **2. LITERATURE REVIEW**

The intergration between markets is becoming tighter due to increased international financial transactions amongst different countries (Rezayat and Yavas, 2006). The opening up of financial markets as a result of financial liberalization coupled with the re-emergence of the stock market crashes and forex crises have made the issue of global financial market integration important especially in the context of risk management and asset allocation (Bakar & Masih, 2014). The foundation of this investigation is the theory of investments portfolio diversification and financial market contagion/ integration. The financial market contagion/ integration is defined by Menezes, Andreia Dionisio and Hassanic (2010) as the extent to which price and returns are closely related and the causality between them over time. There are many theories that try to model and explain the causes of the association in international financial market returns over time.

Reinhart, Kaminsky and Vegh (2003) propose a couple of scenarios that try to explain the integration between markets. They point the issue of irrational exuberance by investors as the main factor that can be understood by an economist as this will affect how money and capital markets operate and thereby increasing volatility. Other models which were emphasized on were through trade or finance. The more appealing theory is one in which they suggest that the way in which this phenomenon is transmitted is consequence of global diversification of investments within a context of limited information.

The benefits of international diversification have been demonstrated theoretically and recognized empirically for decades. The pioneering work on the theory of portfolio diversification was done by Markowitz (1959). This theory suggests that risk can be significantly reduced through proper asset allocation, where unsystematic risk can be eliminated through diversification. Unsystematic risk can be reduced significantly by formulating a portfolio of securities with negative correlation. This means that to maximize return for every unit of risk you need to combine assets in a portfolio which are not highly correlated with each other. Recently, the analysis of correlations within the international market context has been of great importance with regard to cross-country optimal portfolio allocation and diversification (Ahmad et al., 2013).

There are various studies that were carried out on financial markets contagion (see for example Aloui, Aissa, & Nguyen, 2011., Samarakoon, 2011 and, Bakar & Masih, 2014). Some of these researchers investigated the process of time varying correlations amongst different financial markets during the period of crisis emanating from a shock from other markets. Dooley and Hutchison (2009) in their study found out that the United States of America(US) financial crisis has no repercussion on emerging markets. Yiu, Alex Ho, and Choi (2010) investigated the dynamics of cross market correlations in developed markets and developing markets. They revealed that there was a significant evidence of contagion between the US and the Asian markets during the 2007/9 global crisis. Yiu et al. (2010) further indicates that there is no integration between the American financial markets and Asian financial markets in crisis periods.

More recently, Loh (2013) indicates markets have become more integrated particularly the stock markets. In line with Loh (2013), Ding and Pu (2012) reports that contagion increased in line with the increase in volatility coupled with deteriorating capacity to owner obligations as they fall due. Aloui et al. (2011) analysed the BRICS countries stock markets along with USA. Their results indicate a strong contagion between the US and each of the BRIC countries. The correlations were found to be persistent in both upward and downward trending markets. In the study by Kenourgios et al. (2011) where they examined the BRIC countries, they also found the effects of contagion from countries that were in turmoil to fairly stable markets during periods of financial market crisis.

Among the other recent study on stock market contagion are Horvath and Petrovski (2013), Ahmad et al. (2013), Kenourgios (2014), Luchtenberg and Vu (2015). These researchers observed that during the periods of market turmoil the correlation between international stock markets increased significantly. More interesting revelation was proposed by Ding and Pu (2012) who pointed out that there has been a dramatic change in the correlation structure before and after the crisis leading to a suggestion that financial market integration should be conceptualized differently after the 2007/9 global financial crisis. Substantial cross market inter-linkages among international stocks will inevitably result in spillover effect to other markets. Chiang, Jeon and Li (2012) asserts that it is financial market liberalization that allowed for the connection of the Chinese markets to the whole world and these reforms will allow spillovers from China to the international markets.

In their study of emerging and developed market Ahlgren and Antell (2010) found no evidence of contagion, rather they found evidence of short-term linkages during times of crisis. Contrary to the existence of short-term inter linkages, Awokuse, Chopra, and Bessler (2009) show that the substantial surge in market connections due to globalization and liberalization of financial markets came to a halt, in fact there was some structural decrease in some of the markets during the Asian financial crisis of 1997. Xu and Hamori, (2012) suggests that the stock market inter-connection between the BRICs and the US sapped in both the average return and the volatility in times of market turmoil. Horvath and Petrovski (2013) confirm the same findings suggesting that the deterioration in stock market correlations during trending and prolonged bearish markets could be a consequence of decreased market capitalization.

In the analysis of US financial shocks Samarakoon (2011) reports the existence of bi-directional, yet asymmetric, interdependence and contagion in emerging markets. Specifically, the study indicates the interdependence and

contagion between US and developing financial markets while the frontier markets and the American markets are also cointegrated. Kenourgios and Padhi (2012) employed the Conventional cointegration and vector error correction analysis to examine the contagion effects on emerging markets during the Russian and Asian crises as well as the subprime crisis. Their findings show that there is both short and long run dynamics only amongst emerging markets during Russia and the Asian crises. They then indicate that financial markets tend to be significantly integrated in times of trouble. Informed by literature reviewed in this study, one can conclude that there is almost a conclusive determination of the nexus between emerging and developed markets. However, studies that examine contagion in African markets are still rare. The analysis of inter-connection between African stock markets is meager despite the importance of understanding how financial market are integrated particularly in a generation where crisis in financial markets are persistent.

The mixed results in the study of financial markets contagion were dictated by ever changing correlation between financial market through time. Mandeleno and Pinho (2012) indicate that correlation between markets changes over time as the financial crisis occurred at different time periods. There is time variation and scale variation in correlation across the different times of the financial crises (Loh, 2013). Azdemir and Cakan (2007) found that there is a significant two-way non-linear cointegrating association between the American markets and other markets. There is a plethora of evidence that indicate to the fact that stock markets in general are correlated in terms of price level and returns. The linkages have been shown to change overtime where strong correlations are reported in times of crises.

### 3. DATA, EMPIRICAL MODEL SPECIFICATION & ESTIMATION TECHNIQUES

In this section the researcher discusses the model specification and estimation techniques that were employed to address the main question of Cointegration of African markets and the US. In this research, the researcher employed quarterly time series data for the period between 1998 and 2015. The data used in this study was all gotten from the Bloomberg and McGregor data base. The time-varying dynamic conditional correlations is estimated among the 5 selected African countries and examine the dynamic patterns of correlation changes across three periods, the initial time period comprises of the period prior to the 2007/9 global financial crisis, followed by the most critical period during the financial crisis and finally the third being the period post 2007/9 global financial crisis. To improve on existing empirical studies this study employs Engle (2002)'s dynamic conditional correlation (DCC) GARCH model in a bid to examine the cross-market linkages on financial markets. The advantage of the GARCH (1,1) model of Engle (2002) used in this paper is its flexibility, since it includes the ARCH and GARCH specifications. This methodology, according to Dimitriou et al. (2013), and Kenourgios et al. (2011), provides a thorough scrutiny of how markets are connected through time by considering temporary disproportionateness in both volatilities and correlations, while investigating the second order moments dynamics of financial time-series and is also meant to solve the problem of heteroscedasticity.

Initially the Engle (2002)'s dynamic conditional correlation (DCC) GARCH models were employed in order to investigate how correlations change through time between the five selected African stock markets and the US stock market. Let  $r_t$  represent a vector with two series of returns that is,  $r_t = (r_{1t}, r_{2t})$  If this was to be shown as the lag polynomial  $A(L)$  we end up having:

$$A(L)r_t = \mu + e_t$$

Where  $e_t$  is the residual of the vector.

The underlying assumption of the dynamic conditional correlation model is that the conditional returns are normally distributed with zero (0) mean and conditional covariance matrix  $H_t = \epsilon (r_t, r_t' | I_{t-1})$ . Generally, the covariance matrix is presented as follows:  $H_t = D_t R_t D_t$

and  $D_t = \text{diag}[\sqrt{h_{1t}}, \sqrt{h_{2t}}]$  becomes the standard deviation that is time variant gotten from the approximation of univariate GARCH (1,1) progressions:  $h_t = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \beta_1 h_{t-1}$  and  $R_t$  is the conditional correlation matrix of the standardized returns  $\epsilon_t$ , with  $\epsilon_t = D_t^{-1} r_t$

$$R_t = \begin{bmatrix} 1 & q_{12t} \\ q_{21t} & 1 \end{bmatrix}$$

The matrix  $R_t$  is decomposed into:

$$R_t = Q_t^{*-1} Q_t Q_t^{*-1}$$

Where  $Q_t$  is shown as positive non-variant matrix that includes conditional dependent volatility of  $\varepsilon_t$ , and  $Q_t^{*-1}$  is the inverted transverse matrix which contains the root of the transverse elements of  $Q_t$ :

$$Q_t^{*-1} = \begin{bmatrix} 1/\sqrt{q_{11t}} & 0 \\ 0 & 1/\sqrt{q_{22t}} \end{bmatrix}$$

The DCC(1,1) model is then given by:

$$Q_t = \omega + \alpha \varepsilon_{t-1} \varepsilon'_{t-1} + \beta Q_{t-1}$$

Where  $\omega = (1 - \alpha - \beta)\bar{Q}$ . In this study  $Q$  is taken to represent the second moment of the residual  $r\varepsilon_t$ , and is estimated by the sample moment calculated returns from a huge market. Aielli (2011) realized that the equation  $\bar{Q} = E[\varepsilon_t \varepsilon'_t]$  in general cases equilibrium may not hold, and hence the analysis of  $\bar{Q}$  plus the calculation are not to be taken for granted (see Aielli, 2011 for some examples).

The dynamic conditional correlations are finally given by:

$$\rho_{12t} = \frac{q_{12t}}{\sqrt{q_{11t}q_{22t}}}$$

In the estimation of the dynamic conditional correlation model, Engle (2002) employs the two step maximum likelihood method. The estimation is given as follows:

$$L = \frac{1}{2} \sum_{t=1}^r (2 \log(2\pi) + 2 \log|D_t| + \log|R_t| + \varepsilon'_t \varepsilon R_t^{-1} \varepsilon_t)$$

The multivariate DCC-GARCH model of Engle (2002) was used in the analysis of stock market interlinkages because it has the following strengths: Firstly, it enables one to get all potential conditional correlations of financial instruments returns of the countries being investigated. Secondly, one can study possible behavior of correlations during bullish, stable or bearish, such as periods of before 2007-2009 financial crisis, during the financial crisis of 2007-2009, and period post 2009. Lastly, the researcher was able to look at possible market interlinkages between South Africa and the US plus selected African financial markets particularly countries that were affected during the global financial crisis. The variance equation is given as follows and the ARCH and GARCH test results are provided subsequently.

$$\delta_t^2 = \phi + \beta \delta_{t-1}^2 + \gamma \varepsilon_{t-1}^2 + \varphi \sum_{j=1}^n OM_j$$

Where  $\delta_t^2$  is the variance of the residual (error term) derived from the A(L) which is the lag polynomial,  $\phi$  is a constant,  $\delta_{t-1}^2$  is the previous period's squared residual derived from the A(L) model which is the previous month's stock returns volatility of south African stock market i.e. the ARCH term, and  $OM_j$  is the return of other markets under investigation. Three types of distribution were used to estimate the Z-statistic and they are: Normal Gaussian distribution, Student's t with fixed df., and the Generalized Error Distribution assumption. The results of this equation are presented in Table 1.

4. RESULTS, DISCUSSION AND ANALYSIS

Table 1. Z-statistic for ARCH and GARCH test: Dependent variable (JSE All-share index)

Country/ Index	Coefficient	z-statistic Normal distribution	z-statistic Student's t distribution	z-statistic Generalized error distribution
NYSE	$\phi$	-1.6988*	-1.3871	-1.551432
	$\gamma$	2.5649**	2.1424**	2.2390**
	$\beta$	6.0833***	5.8565***	5.5829***
	$\varphi$	-2.5139**	-2.3326**	-2.3526**
	Robust test	NS/NA	NS/NA/RN	NS/NA
Kenya	$\phi$	-0.8297	-0.8297	-0.8372
	$\gamma$	1.1907	0.1934	2.1242
	$\beta$	3.2533***	0.1877***	8.1391***
	$\varphi$	-0.1750	0.0024	-0.2902
	Robust test	NS/NA	NS/NA	NS/NA
Nigeria	$\phi$	-0.7168	-0.7153	-0.9216
	$\gamma$	1.2117	1.2104	1.4921
	$\beta$	3.2319***	3.2286***	5.6712***
	$\varphi$	0.3723	0.3719	-0.5078
	Robust test	NS/NA	NS/NA	NS/NA
Egypt	$\phi$	-0.6542	-0.6542	-0.1223
	$\gamma$	1.0612**	1.0296**	2.1042**
	$\beta$	1.4948***	1.4948***	2.8343***
	$\varphi$	-0.5494	-0.5471	-0.352078
	Robust test	NS/NA	NS/NA	NS/NA
Zimbabwe	$\phi$	-1.0514	-0.9332	-0.8133
	$\gamma$	1.2540	-2.6784***	1.4815
	$\beta$	0.7687	19.604***	-0.6951
	$\varphi$	0.2678	3.1122***	-1.5041
	Robust test	NS/NA	NS/NA	NS/NA

\*\*\* Represents 1% level of significance, \*\* Represents 5% level of significance, and \*Represents 10% level of significance

NS-No serial correlation

NA- There is no ARCH effect

RN-Residual is normally distributed using Jarque-Bera statistic

Table 1 shows the Z-statistic for ARCH and GARCH test for five markets under consideration relative to the South African market. The coefficient ( $\beta$ ) for GARCH under all the distribution models are significant. This shows the persistence of the GARCH effect indicating that the previous month South Africa stock returns volatility can also influence the current stock returns volatility. The coefficient ( $\gamma$ ) for ARCH under all the distribution models is significant meaning that the previous month stock returns can influence current month stock returns. The results for the coefficient ( $\varphi$ ), which shows the contagion effects between returns of JSE and other stock markets is inconsistent across markets. The JSE stock returns volatility is dependent on the Zimbabwe stock returns and NYSE stock returns. This confirms the proposition that most emerging markets are interlinked with the US markets, a confirmation why the crash in the US stock markets almost affected all markets in the world.

Table 2. Dynamic Conditional Correlations Coefficients (DCC)

Countries/ Indices	Pre 2007/9 crisis	2007-2009 crisis	Post 2007/9 crisis
JSE and NYSE	0.6013***	0.7605***	0.7603***
JSE and KENYA	-	0.6676	0.3561
JSE and NIGERIA	-	0.3110	0.2512
JSE and EGYPT	-	-0.1742	0.4057
JSE and ZIMBABWE	-	-	-0.1829***

\*\*\* Represents 1% level of significance, \*\* Represents 5% level of significance, and \*Represents 10% level of significance



Most of the studies (e.g. Forbes and Rigobon (2002)) in the determination of the degree of integration between financial markets utilized simple correlation. However, correlations were found not to be static but highly dynamic as they varied through time. Hence, in this study we employed the DCC model in order to capture the time variant behavior of the correlation matrix thereby overcoming the major weakness of simple correlation analysis. Table 2 reveals the results of the dynamic conditional correlation between the stock market returns of South African stock returns and other markets. It is duly highlighted that the African financial markets particularly stock markets are weakly correlated with each other. The correlation coefficient is negative for Egypt and during crisis while the correlation is negative and significant at 1% level of significance for Zimbabwe post financial crisis. However, South African Stock returns are highly correlated to NYSE stock returns and the coefficients are significant.

## 5. CONCLUSION

This article contributes to existing empirical literature on financial market contagion especially on US and African stock markets. Particularly, the article draws its main conclusions from the changes in correlation coefficients through the global financial crisis as the analysis was done using period before, during and after the crisis. To measure the potential contagion phenomenon in this article, the inter-linkage between the five African countries stock markets and the US stock market was investigated using the DCC – GARCH (1, 1) approach. Some of the results found in this article are in line with the observation that there is cross market inter-linkage between developed and emerging stock markets. South African Stock returns are highly correlated to NYSE stock returns and the coefficients are significant for all periods under consideration. Furthermore, the South African stock returns are significantly negatively related to Zimbabwean stock returns. The researcher also found insignificant relationship amongst the volatility of JSE and other African countries. An analysis of correlation confirms what most scholars found. Correlations amongst markets tend to increase during the time of crises and weaken during periods of stability with an exception of Egypt whose results indicate an insignificant negative correlation during the 2007/9 crisis and an insignificant positive correlation post 2007/9 financial crisis. These results are contrary to widely referenced conclusions by Forbes and Rigobon (2002) where they report that stock markets across the world are not cointegrated neither is there any contagion, however, they found that markets are interdependent. An area for further studies would be to investigate the potential contagion mechanisms between African countries and European countries especially looking at what transpired during and after the sovereign debt crisis.

## AUTHOR BIOGRAPHY

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