# RISK TRANSMISSION OF STOCK MARKET MOVEMENTS: EVIDENCE FROM THE US AND SELECTED AFRICAN COUNTRIES

BY

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**DECLARATION**

I, **Trevor Tatenda Chatukuta**, hereby declare that this research report is my own work except as indicated in the references and acknowledgements. It is submitted in fulfilment of the requirements for the award of Master of Management in Finance and Investments degree at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in this or any other university.

*Trevor Tatenda Chatukuta*

Signed at …***Wits Business School (WBS)***……………………

On the …26th………. day of …………***November***……… ***2020***

# Dedication

*This thesis is dedicated to my family; Brighton Chatukuta, Byron Chatukuta, Pamela Chatukuta and my mother Mrs Sophie Zindi-Chatukuta.*

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# Abstract

Risk spillover and contagion studies have recently gathered momentum especially with the continuous recurrence of financial and economic crisis globally. Nonetheless, the financial world tends to lack unanimous view on how to properly define contagion. Many studies on risk transmission, spillover and contagion focused mainly on first and second order moments which does not fully consider market traits such as asymmetry. Moreover, the literature on spillover and contagion in Africa is relatively scanty despite the continent being home to only emerging market economies.

This study sought to examine the sources and mechanisms of connectedness and risk propagation by applying a technique proposed by Baruník and Krehlík (2018) which advocates for the study of pairwise and inter-national higher order moments. In addition, the technique is based on the premise that innovations or shocks to a market impact variable at numerous frequencies with varying strengths and therefore short-, medium-, and long-term frequencies are used. An inherent merit of using frequencies is that they work on the premise that economic players operate using varying investment horizons which is captured by time-varying frequencies.

By studying risk transmission between the United States of America (the US) and selected African markets (Egypt, Nigeria, Kenya and South Africa), this study observed that, except South Africa, these elected African markets were less impacted by the shocks that originated in the US. This was observed from the higher moment skewness based on the weekly data between 25 November 2001 and 30 December 2018. The conclusion is that stronger spillover of shocks is evident among these selected markets (pairwise spillover).

Also, by examining the higher moment measures on absolute, net spillover and the within spillover transmission, this study contributed to the literature by concluding that most of the selected African markets recorded strong net risk recipients and net risk transmission at times adrift from the common global crisis periods such as the 2007 to 2009 crisis. This partially concurs to the recent notion of post-crisis contagion.

# Risk transmission of stock market movements: Evidence from the US and selected African countries

## Chapter 1: Introduction

### 1.1 Motivation

The most recent global financial crisis of 2007-2009 originated in the United States of America (US) with the impact of the volatility spilling over to all the global economies. The global spread of volatility and risk was mainly catalysed by the rising inter-connectedness of the global markets which brought a need to model, measure and quantify the systemic risk inherent in the global markets. In addition, this contagion effect of financial risks heightened the need for research that assesses the transmission mechanism of extreme downside market risk. In as much as stock market volatility modelling is vital, the volatility which is of most concern to portfolio managers, investors, investment practitioners and regulators such as the Basel Committee on Banking Supervision is the downside market risk which has a negative impact on asset values. Modelling and forecasting volatility is a fundamental aspect of option pricing (Huang, Wang, & Hansen, 2017), risk management (Chiarella, He, & Wei, 2015), portfolio optimization, hedging strategies, risk management or valuation of financial derivatives and portfolio allocation (Adballa & Winker, 2012). Put differently, Shahzad, Hernandez, Rehman, Al-Yahyaee and Zakaria (2018) states that this situation of global stock market inter-connectedness has increased concerns about the threat of global systemic risk and financial spillover domino effects among stock markets and economies, a risk which is intensified during times of financial crisis. This is further corroborated by Shen (2018) who states that understanding the international risk-transmission mechanism will assist in both portfolio allocation strategies for investors pursuing cross-border investment opportunities, and also, it leads to the best policy reactions by the regulatory institutions and local governments, in order to control market stability.

Over the past couple of decades, there has been significant growth in the studies of inter-national links in stock market returns. This is not unanticipated and empirical modelling of such relations is pertinent for trading and hedging strategies and provides insights into the transmission of shocks across markets (Beirne, Caporale, Schulez-Ghattas, & Spagnolo, 2010). A series of studies that examined the inter-dependence or relationship between national stock markets include Baur et al., 2012; Mensah and Alagidede, 2017; Eun and Shim, 1989; Engel and Susmel, 1993; Huo and Abdullahi, 2017. However, most of these studies focus on the market inter-dependency within first and second moments and use volatility as a measure of market risk (Shen, 2018). In addition, the concept of variance decomposition and frequencies is not independently taken into consideration in these studies, especially in the context of Africa.

Volatility explains the general extent of the tendency of financial time series data to change or vary and is a vital tool across all assets. To be more specific, by saying volatility this study refers to total risk as measured by standard deviation which weights the volatility symmetrically thereby giving lesser weight to the downside risk which is of most concern in risk management. This means volatility as measured by standard deviation is enough as a risk measure only when financial returns are normally distributed as standard deviation is one of the parameters of a normal distribution. In other words, a special feature of stock volatility is that it is not directly discernible. However, the assumption of normality for returns is violated for most financial returns, and this means the use of volatility as a risk measure can lead to distorted conclusions (Danı´elsson, 2011). Put differently, using volatility to determine the riskiness can result in indifference between assets as each may easily plot on the same place on a mean-variance frontier suggested by Harry Markowitz (1952) regardless of varying degrees of risk.

Investment practitioners are more concerned about the extreme downside risk as it results in loses while on the other hand, the upside dispersion is a part of the asset price increase or capital gains. This research seeks to develop the above literature with a focus on investigating risk transmission mechanism between the US and selected major African stock markets from 2000 to 2018.

The main objective of investing in financial markets and in financial assets is to earn a return. Investments are taken for reasons ranging from earning capital gains, dividends, coupons, wealth creation, and store of value and purely as an inter-temporal exchange. Since most investors are interested in the upside of volatility, it makes them put more focus on the upside volatility, which is mainly a source of gains and pay less attention to the downside risk. Most literature on stock market volatility is based on the market volatility and co-movements on the stock markets paying less attention to the left tail of stock market volatility. Holding other factors constant, investors seek to maximize returns and minimize risk. The recent increase in globalization, dual and multi-listing of companies as well as the recent bubbles and financial crises such as the Dot Com bubble of the late 1990s and the global financial crisis of 2007-2009 has increasingly revealed the need for prudent risk management measures to be taken by all the stakeholders including the regulators such as the Basel Committee on Banking Supervision. Furthermore, the global financial crisis of 2007-2009, as well as the Greece debt crisis's impact in the Eurozone (of around 2010), shows the need for analysts and regulators to monitor risk. These motivations make risk modelling and measurement an indispensable exercise in every investment decision making. It is therefore, against this background that this study seeks to investigate the international risk transmission of stock market movements between the US and major African stock markets**.**

Most of the prior literature on stock market volatility focused on total volatility as measured by variance or standard deviation, which has a main weakness of giving less weight to the left tail, i.e. the downside risk. This is a more important aspect in the regulatory, investment, finance and banking fields where rational investors are assumed to have varying degrees of risk aversion. To be more specific, a risk-averse investor is more sensitive to the downside risk. On the other hand, prior literature such as Kuttu (2014) have observed that African equity market exhibit unique traits than those of developed markets such as the US. This observation necessitates the need to investigate the risk transmission between Africa and the US since the results will help investment practitioners in hedging strategy decisions, diversification strategies and portfolio management between these two markets.

The objective of this study is to investigate the risk transmission mechanism between the US equity market and the African equity market given the uniqueness of each market. In other words, this includes investigating the effect of shocks in one market on another. Another perspective in this study is to observe the structure of risk interdependence or inter-connectedness across the study period. This will be done by employing a new framework suggested by Baruník and Krehlík (2018) to investigate if risk spillover exists between the US and four major stock markets in Africa during the period between 2000 and 2018. This technique has more benefits over other volatility modelling methods in that it accommodates the relatively short life of many African stock exchanges using short-, medium- and long-term frequencies. In addition, to approximate connectedness in short-, medium-, and long-term financial cycles, a technique that is based on the spectral depiction of variance breakdowns is applied. Finding all this information helps investors in risk management and portfolio allocation especially inter-national investors. Portfolio managers will also benefit since this information will help in asset allocation decisions including hedging.

## 1.2 Background

The New York Stock Exchange (NYSE) is by far the world's largest stock exchange by market capitalization with a market cap of US$28.5 trillion as of 30 June 2018 ( (New York Stock Exchange, 2019). Shahzad, Hernandez, Rehman, Al-Yahyaee and Zakaria (2018) observed that the significance of the NYSE in the global network of securities exchanges and markets suggests that only the US equity market can trigger systemic risk on a global scale. This observation is in line with many prior studies which argue that spillover impacts are significant only from the dominant market to the smaller market and that the volatility spillover from only one direction. However, studies such as Bala and Permaratne (2003) concludes that it is possible for there to be reverse volatility spillover, that is, from the smaller market to the major market. Commonly these studies are vital in risk management as they prevent oversight.

On another note, the origin of the global financial crisis of 2007-2009 is credited to the failure of the US financial system. This underlines the importance of the US in the shock and risk transmission on a global scale. Put differently, the size, efficiency, diversity, and liquidity of the US financial markets coupled with the systematically important financial institutions make it a good proxy to examine its risk transmission impact on the African markets. Also, given the importance of the US market and its strategic position in virtually all the asset classes including the foreign currency market, it is safe to take the US as a proxy of the developed market. In terms of trade, the past two decades saw the US and Africa signing significant trade deals such as the Africa Growth and Opportunity Act (AGOA) of 2000 which is a law enacted to enable Africa to export non-oil goods to the US, duty-free. These trades are increasingly improving the economic inter-connectedness of the US and Africa. In other words, the interdependence and co-movement of equity markets among different countries have been growing in leaps and bounds in recent years, mainly due to the integration of financial markets and increasing globalization. It is against this background that this research seeks to evaluate the risk transmission between the US and Africa.

By observing the relationship between Japan and the two markets of the US and UK, Hamao, Masulis and Ng (1990) applied the daily and intraday price and return data. Their study concluded that there is an existence of significant spillover effects from the US and the UK markets to the Japanese market but not the reverse effect. On the contrary, Bala and Permaratne (2003) observed that cross-market interdependence in returns and volatilities is bi-directional between the US and Japan. This contradicting view motivates this research to confirm whether there is an existence of risk spillover from the US (big market) to major African stock markets (small market) as well as to test for any the feedback effect.

Mlambo and Biekpe (2005) assert that African markets exhibit the traits of illiquidity, weak investor base, low market capitalization, poor regulatory framework and poor accounting and reporting standards. Furthermore, Assaf and Cavalcante (2005) point out the uniqueness of African markets relative to advanced markets such as industrial structure. These unique traits underlying African equity markets may contribute to different dynamics driving the returns and volatility (Kuttu, 2018). This difference in market characteristics warrants the need to investigate co-movement and spillover between US (a developed market) and Africa (an emerging market) especially considering the most recent global financial crisis.

Another trait of some of the African equity markets is that their volatility is asymmetric. This evidence is well documented by Appiah-Kusi and Menyah (2003), Kuttu (2014) and Kuttu (2018) who show that there is volatility asymmetry in the African equity market. This means that studying African equity market needs more attention or weight to be given on the left tail to incorporate this characteristic.

Baruník and Krehlík (2018) further suggest a framework to quantify connectedness among financial variables which, unlike most studies that assume homogenous frequency responses to shocks, it assumes heterogeneous frequency responses to shocks. Also, to model connectedness in short-, medium-, and long-term financial cycles, they presented a technique based on the spectral depiction of variance. They found significant time-frequency exhibitions of volatility connectedness in the U.S. financial institution. This angle of study has not been carried out in the context of Africa. In addition, the uniqueness of African markets as predominantly emerging markets with unique traits warrants a heterogeneous approach to frequency responses to shocks and this study seeks to investigate risk spillover between the U.S. markets and a selected African market. This study seeks to achieve the following research objectives.

### 1.3 Research Objectives

- **i.** To examine the extent of the risk spill over from the US to major African stock markets and to examine the existence of the feedback effect between these markets.
- **ii.** To examine whether risk interdependence change over time during the period under study.
- **iii.** To investigate the asymmetric responses of gains and losses transmission between the equity markets of US and Africa.

### 1.4 Significance of the study

This study fills a gap in that, it covers inter-national risk transmission and interconnectedness of stock market movements between the US and major stock markets in Africa, not only focusing on co-movement of the markets. In addition, it seeks to extend on the study by Forbes and Rigobon (2002) in which they posit that connectedness rather than contagion is prevalent in the United States during the period under study. In addition to presenting frequency aspects into the quantification of connectedness, this study examines how cross-sectional linkages affect the connectedness. A greater connection does not essentially imply connectedness in the way the literature attempts to quantify it. Shen (2018) further argues that the common feature of the prevailing literature is that they put emphasis on the market interdependency structure within the first and second moments and use volatility to measure the market risk despite the apparent weaknesses of volatility as a measure of portfolio risk. This research mitigates this by focusing on the decomposition of variance than the absolute variance itself.

Also, by using the technique applied by Baruník and Krehlík (2018), this study adds to the literature by not only investigating the risk spill over from the US to Africa but also investigating the feedback effect between these markets and the US.

Furthermore, this study uses some of the most recent test statistics and models by combining them to quantitatively establish the stock market movement patterns. Understanding these patterns help in hedging, portfolio allocation, and investment analysis, managing offshore investments and forecasting risk by using other markets as 'leading indicators. The information from this study will also help to explain the degree to which a 'mistake' in one market can be transmitted to other markets (King & Wadhwani, 1990).

### 1.5 Limitations

The methodology in this study will consider only 4 major stock markets in Africa namely, South Africa, Egypt, Kenya, and Nigeria which may not be a full representation of risk transmission between the US and Africa. This opens this research to a sample selection bias. Another potential weakness in this study is that the data collected is based on weekly timeframes. The use of weekly closing prices to eliminate market noise can have a downside of resulting in the biased observation of the actual behaviour of the stock market price movements. Furthermore, African equity markets are generally less liquid and characterized by thin trading which can hinder the accuracy of the results of the study.

### 1.6 Conclusion

The study seeks to investigate the risk transmission between the US and four major African markets as well as the feedback effect. This will help in explaining the impact of the US on the performance of African markets and will also provide a channel through which a shock in one market is transferred to another market.

# Chapter 2: Literature Review

## 2.1 Introduction

This chapter builds up from the previous chapter where the main highlights of this study were laid out by presenting the theoretical background which underpins this research. Following the Great Depression of the 1930s and its effects on the global economy and the stock markets, there was an increasing need to model stock market volatility among academics. Stock market volatility is a vital part of portfolio management, regulatory framework and risk management across asset classes, investor profiles and financial institutions. Volatility in the stock markets is a challenge that affects policymakers, market analysts, corporate managers, and economists. This is further exacerbated by the fact that financial markets and stock exchanges have over the years introduced complex and synthetic instruments such as futures and option contracts on interest rates, stock indices and foreign exchange rates which have been growing exponentially until their impact was questioned following volatility-induced market crashes for instance, that of 2007-2009. This chapter begin by extensively covering the main literature underpinning this study; this is followed by some of the recent studies on stock market volatility in developed markets; after that follows literature on stock market volatility in emerging markets and finally, literature on stock market volatility in the African context.

The concept of risk transmission and/ or contagion across markets has been a subject of various studies with some studies focusing on addressing the contentious concept of defining the term contagion (Forbes and Rigobon, 2001).Other studies focus on theoretical models and empirical analysis of contagion such as the theoretical conduits through which contagion can happen such as Claessen and Forbes ( 2001), Pritsker (2000) while other studies focus on the mechanisms driving contagion such as, De Gregorio Valdés (2000), Eichengreen, Hale and Mody (2000), Kaminsky, Lyons and Schmukler (2000) and Schinasi and Smith (2000). On the other hand, other studies focus on comparative significance of real connections such as trade against financial links such as investor behaviour or investor sentiment and herd instinct. Forbes and Rigobon (2001) also suggest the classification of contagion as “crisis-contingent” and “non-crisis contingent”.

Previously, studies on contagion have been subject to a major question of determining the best definition of contagion. Forbes and Rigobon (2001) proposed an insightful definition of contagion as a significant increase in cross-market linkages following a shock. This is vital in that it seeks to distinguish between existing linkages between countries such as trade which prevail in times of stability and of turbulence. This contribution is vital in the study of contagion and it avoids dwelling much on the cause and conduit of contagion whilst focusing on the measurement or quantification of contagion and/ or risk transmission between countries.

The definition of contagion therefore categorises numerous risks spread structures as "crisis-dependent" or "non-crisis dependent". Forbes and Rigobon (2002) further state that heteroscedasticity gives more weight to correlation coefficients when testing for contagion. This is mainly because testing for contagion using the correlation coefficients between markets bring challenges owing to the bias driven by varying volatility in market returns i.e. heteroscedasticity (Forbes and Rigobon, 2002). In other words, where correlation exist during tranquil times, it tends to proportionally increase during turbulent times which simply represents pre-existing linkages and not necessarily translate to contagion. This, therefore, makes correlation coefficient biased in measuring contagion between countries.

In addition to showing that standard tests for contagion are biased due to heteroscedasticity, they also identify endogeneity and omitted variables as some of the reasons why some tests for contagion are biased. The correlation coefficient is observed to be conditional on the volatility of the period under tests. They assumed the definition of contagion as a substantial surge in market co-movement after a shock to one country or a group of countries. Put differently, this study defines contagion as a substantial increase in cross-market linkages following a shock to one country or group of countries. Based on this assumption, their study has shown that correlation coefficients are conditional on market volatility. Under these specific assumptions, they argue that it is possible to adjust for this bias towards correlation coefficient.

After adjusting for the bias by using the unconditional correlation coefficients, their findings show that there was no increase in unconditional correlation coefficients, that is, there was no contagion during the 1997 Asian crisis, 1994 Mexican devaluation and 1987 U.S. market crash.

They further posit that there is evidence of a high level of market co-movement in all periods however, which they refer to as interdependence. This argument is profound however, it does not fully take into consideration the fact that globalisation and trade deals have seen all countries interconnected to varying degrees. In general, the argument of interdependence against contagion, in its strict sense, does not recognise the existence of contagion.

One of the key arguments by Forbes and Rigobon (2002) however, is that if the market co-movement does not rise substantially, then any sustained high-level of market correlation indicates robust linkages between two economies that occur in all states of the world- tranquil and turbulent times. This definition is quite simple and insightful and has a broader scope, however the meaning of “significant or substantial” has not been clearly defined and therefore fails to deal with the contentious topic of the narrow definition of contagion. Another argument they put forward is that, if two markets show a high degree of co-movement during tranquil periods, the continuation of high correlation of markets following a shock to one market may not signify contagion. This assertion, however, does not fully account for the tendencies of investors to exhibit the herd behaviour where they pull funds from one country as a result of actions by major investors such as banks and open-ended hedge fund managers from the affected country as pointed out in the study by Eichengreen, Hale and Mody (2000).

In attempting to study the channels for financial contagion Pritsker (2000) first defined contagion as a scenario that happens after a shock to one market or to a group of markets, nations, or organizations, extends to other markets, nations, or organizations. This is a broad definition of contagion and has a main merit of avoiding the debatable concept of choosing suitable fundamentals which are required to narrow the definition Pritsker (2000). One of the main arguments in this study is that, in as much as there is a difficulty in identifying the propagation channels for market shocks, Pristker (2000) posit that this difficulty can also highlight that there is a need for more propagation channels to be theoretically modelled and empirically tested.

In addition, Pritsker (2000) identified at least five distinct ways through which real shocks are spread from one nation to another. These include contagion through real links, through a mutual financier, through financial markets, through financial organizations, and through the dealings of financial organizations and markets. This interaction of financial institutions and markets is asserted by Eichengreen, Hale and Mody (2000) as a factor causing the decrease in financial markets liquidity and the flight to quality. The results from this study supports the notion that neither of these contagion channels require irrationality for shocks to be spread. However, owing to market shortcomings concerning information asymmetries, the price actions that occur in one market or country due to contagion from somewhere else can at times be extreme in comparison to full-information fundamentals (Pritsker, 2000).

### 2.2 Crisis-contingent contagion theories

Crisis-contingent theories of how shocks are spread globally can be classified into three methods: multiple equilibria; endogenous liquidity; and political economy (Forbes & Rigobon, 2002). Crisis-contingent theories argue that, following a crisis in one country, investor expectations tend to change and as a result, transmit the shock through systems or structures that do not exist during times of market tranquillity (Forbes & Rigobon, 2002).

Masson (1999) argue that models that assume only one equilibrium conditional on the macroeconomic fundamentals are not ideal to capture all kinds of contagion. He further motivates that it is beneficial to create macro models that accommodate multiple equilibria and self-fulfilling outlooks. One of the major contributions by Masson (1998) is the categorisation of macroeconomic links behind contagion into three, namely; monsoonal effects, spillovers, and jumps between multiple equilibria (Masson, 1999).

Monsoonal effects originate from the global environment mainly policies from developed nations and spill over to developing countries to varying degrees. Spillover effects provides the reason for a crisis in one nation to influence other emerging markets through connections such as trade, economic activity, or competitiveness. Jumps between multiple equilibria is considered complementary in that, if the first two fail to describe the transmission of crises, it is argued that there is a role for expectation in which perception with respect to a particular nation varies entirely as a consequence of a crisis in another nation.

In this study, Masson (1999) introduced a simple balance of payments model where multiple equilibria are enabled through the belief that expectations affect interest rates on external borrowing, and also the probability that reserves will decrease below a required minimum level, triggering a crisis. This study avoids the challenge of quantifying investor behaviour by using macroeconomic indicator as a proxy. The result of this study is based on the assertion by Masson (1999) that some aspects of the contagion are difficult to describe using macroeconomic factors which necessitated the use of a multiple equilibria model.

Another study by Mullainathan (1998) argues that investors imperfectly recall past experiences which affect their behavioural reaction during a crisis. A crisis in one nation could trigger a recall of past crises, which would cause investors to reimagine the past and assign higher probability to a bad state Mullainathan (1998), Forbes and Rigobon (2002). The negative price co-movements would then be a as a result of positive relationship between memories rather than the correlation of the fundamentals (Forbes & Rigobon, 2002). This means that investor sentiment overrules real linkages in such times. These models are insightful in establishing how risk is transmitted, however, modelling or quantifying human behaviour is a huge challenge.

Another crisis-contingent theory is the argument of endogenous liquidity shocks where the authors posit that the occurrence of a crisis in one country negatively affects the liquidity of market players. For example, Valdés (1996) developed a model in which investors could be forced to 'rebalance' or reconstitute their portfolios and dispose assets in other nations so as to remain functioning in the market or to comply with margin calls or to meet regulatory requirements (Valdés, 1996) and (Claessens & Forbes, 2001).

Calvo (1999) also developed a model on endogenous liquidity shocks in which the capital market has two categories of investors: the informed and the uninformed investors. The uninformed try to obtain knowledge from the trades by informed investor. This creates the prospect that if informed investors are forced to sell emerging market assets to meet requirements such as margin calls, this act could be misinterpreted by the uneducated investors as implying low returns in emerging markets. This theory means Africa and emerging markets can be prone to be affected by this crisis-dependent theory of uninformed investors due to relatively lower market efficiency which means there may be information asymmetry in African markets. This is identical to the argument by Kuttu (2017) who states that African emerging markets are unique and have traits such as lack of liquidity and market inefficiency. The paper presents a simple model in which this type of market misunderstanding may result in a breakdown in the performance of emerging markets (Calvo, 1999).

The third propagation method under crisis-dependent is political contagion. By studying the devaluations in Europe between 1992 and 1993, Drazen (1998) created a model that presumed that central bank governors are under political influence to retain their nations' fixed exchange rates. When one nation opts to leave its peg, it lowers the political costs to other nations of ditching their own pegs, which raises the probability of these nations altering exchange rate regimes. Consequently, exchange rate shocks may be clustered collectively, and the spread of the original shock happens through a process that was not present before the original crisis (Claessens & Forbes, 2001). However, Drazen (1998) concluded that these political effects can only be limited to explicit monetary unions. All these crisis-dependent theories have a common denominator, that is, they focus on the method of shock transmission.

### 2.3 Non-Crisis-Contingent Contagion theories

On the other end of the spectrum there are contagion studies that focus on non-contingent theories. These theories argue that there is no significant disparity on the transmission methods before and after the shocks. Claessens and Forbes (2001) states that, any large intermarket connections following a shock are an extension of connections that prevailed prior to the crisis. These propagation methods are often called "real linkages" because many (albeit not all) are built on economic tenets.

These theories can be categorised into four comprehensive routes: trade; policy management; nation re-assessment; and arbitrary cumulative shocks. Trade as a propagation mechanism could have a ripple effect for example, if country X devalues its currency, this will cause exports from this country to be relatively "cheaper" or increase the competitiveness of country X's exports. In other words, exports to a second country Y could increase in that way harming local sales within the second country Y. The original devaluation could also have a subtle impact of decreasing export sales from other nations that compete in the same markets. None of these impacts could not only have an explicit effect on a nation's sales and output, but if the loss in affordability is severe enough, it could raise anticipations of an exchange rate devaluation and result in an attack on another nation's currency (Forbes & Rigobon, 2002).

According to Forbes (2002) the second propagation mechanism policy management connects economies because one nation's reaction to an economic shock could force another country to pursue comparable policies. Country reassessment is the third transmission mechanism. Forbes and Rigobon (2002) argues that investors may apply the lessons realized following a shock in one nation to other nations with comparable macroeconomic forms and policies. Lastly, non-crisis-dependent spread mechanism contends that random cumulative or global shocks could concurrently affect the fundamentals of several economies.

### 2.4 Methodological literature

One of the most popular and early studies on the concept of modelling stock market volatility in the literature of finance is the study by Robert Engel (1982). In his paper, Engel (1982) seek to address one of the major challenges in the traditional econometric models which assumed a constant one-period forecast variance. By assuming a constant one-period forecast variance, these traditional models were falling short in predictive power, robustness and consistency in modelling variance or risk. Engle (1982) therefore attempted to address this relatively weak assumption of constant variance by introducing a new class of stochastic processes called autoregressive conditional heteroscedastic (ARCH) processes on the inflation rates of the United Kingdom from 1958 to 1977.

These ARCH processes have a mean of zero, serially uncorrelated processes with nonconstant variances conditional on the past, but constant unconditional variances. The rationale for this kind of process is that the most recent past gives information about the one-period forecast variance. The process that is serially uncorrelated results in improved efficiency of the estimators. Further, nonconstant variances allow the process to be more realistic by assuming that variances are not constant.

However, the major weakness of the ARCH model is that it accepts that positive and adverse shocks have similar effects on volatility. Bollerslev (1986), however addressed this limitation by introducing the GARCH (Generalized Autoregressive Conditional Heteroskedastic) which permit for a significantly more variable lag arrangement. The expansion of the ARCH procedure to the GARCH procedure carries many similarities to the expansion of the standard time series Auto Regression (AR) procedure to the general ARMA procedure and allows a more prudent explanation in many situations Bollerslev (1986).

Despite the continued growth of modelling of stock market volatility, the major challenge remained, which is to establish the best way of measuring risk in the stock markets as well as a better definition of risk. The challenge of risk is epitomised by Harry Markowitz (1952)'s failure to specify risk in his modern portfolio theory which has become the fundamental theory in finance and investments. However, one of the breakthroughs in risk measurement came in 1994 in the form of value-at-risk (VaR) as proposed by J.P. Morgan.

The value-at-risk has become a standard measure of risk used by financial institutions both in the private sector and among regulatory organisations such as the Basel Committee of Banking Supervision. VaR summarizes the worst expected loss over a target horizon within a given confidence interval (Jorion, 1996). One of the main reasons of the widespread use of VaR as a risk measure is that it focuses on the downside of risk or the left tail of risk, that is, the worst-case scenario of losses per given degree of confidence. This is a favourable trait of VaR as investors are concerned about the probability of losing their investments. Put it differently, rational investors are generally assumed to be risk-averse to varying degrees, and this makes VaR one of the best risk measures.

Engle and Manganelli (2004) proposed the use of conditional autoregressive value-at-risk (CAViaR) model to address the weaknesses and challenges inherent in the VaR at the same time capitalising on the strengths of VaR as a risk measure. The CAViaR as introduced by Engle and Manganelli (2004) infers the VaR as the quantile of forthcoming portfolio values dependent on present information. This means that the conditional autoregressive value at risk (CAViaR) model specifies the progression of the quantile over time by means of an autoregressive process and estimates the parameters with regression quantiles (Engle & Manganelli, 2004).

The CAViaR improved on the VAR in that instead of modelling the whole distribution first and recover quantiles indirectly, it focuses on modelling the quantile directly. This allows the model to focus specifically on the quantiles of interest and in the case of downside risk, it focuses on the lower quantiles or the left tail risk. It is against this background that this research seeks to model stock market volatility or risk transmission of stock market movements using the multiple quantile approach: -the cross-quantilogram as suggested by White, Kim, & Manganelli (2015).

Furthermore, in their study, Engle and Manganelli (2004) applied the condition that each period the probability of greater than the VaR must be independent of all the previous information. Their study is based on a sample of 3392 daily prices for General Motors, IBM, and the S&P500 from April 7, 1986 to April 7, 1999. This evaluation of the performance of the quantile models was done by presenting a new test of model adequacy: - the dynamic quantile test. They further contend that empirical evidence points to volatilities of stock returns clustering over time which may be translated to mean that distribution is autocorrelated. As a result, the VaR which they posit to be strongly related to the standard deviation of the distribution argued that it therefore must exhibit similar behaviour. This trait of VaR is therefore characterised by using CAViaR.

The unknown parameters of the VaR are estimated by minimising the regression quantile (RQ) loss function. The findings of this study further suggest that the process governing the traits of the tails might be different from that of the rest of the distribution. This acts as an underpinning point to research on the downside risk transmission between stock markets.

The work of Koenker and Bassett (1978) ushered in an era of increasing quantile regression model use in various academic literature due to the fact that these models enable one to study the relationship between variables across the entire distribution not only at the centre of the distribution (White, Kim, & Manganelli, 2015).

Also, Linton and Whang (2007) introduced a concept of quantilogram which can be used to provide an inference tool to measure directional predictability of time series data. By applying the quantilogram approach on the S&P500 stock index data, the empirical results suggest some directional predictability in returns. Furthermore, this evidence was found to be strongest in mid-range quantiles for instance the 5-10% and for daily data. The quantilogram method helps to quantify the directional predictability and to test for the hypothesis that a given time series has no directional predictability. The test is based on relating the correlogram of quantile hit to a specific confidence interval (Linton & Whang, 2007). Put differently, this study contributed immensely in literature of finance in that it seeks to quantify predictability in the direction of stock prices.

The main merit of the quantilogram approach relative to the usual correlogram is that it can be used in circumstances where the usual correlogram is unreliable (Linton & Whang, 2007). Further, the results of this study show strong evidence of predictability in daily stock index returns at many different quantiles, especially in the lower tails. This motivates a strong need to use quantilogram approach to investigate the risk transmission between stock markets indices focusing mainly on the left tail.

Building on the work by Linton and Whang (2007) of quantilogram approach, White, Kim and Manganelli (2015) proposed methods of estimation and inference in multivariate, multi-quantile models. Unlike the previous approaches, this model is an improvement in that it can concurrently put up models with numerous random variables, numerous confidence levels and several lags of the related quantiles. In other words, this framework can be viewed as vector autoregressive (VAR) expansion to quantiles (White, Kim, & Manganelli, 2015). In general, vector autoregressive means that the current value of a variable depends on its own prior value or lag value of a given order. The study was done by applying this model on market equity returns data to analyse spillovers in the value-at-risk (VaR) between market index and financial institutions. Using the value-at-risk as a volatility or risk measure enables their study to explicitly focus on the probability of extreme losses given a confidence interval. They constructed impulse-response functions for the quantiles of a sample of 230 financial institutions around the world. In addition, they also posit that the institution-specific and system-wide shocks are absorbed by the system.

These inherent qualities make this VAR for VaR framework one of the improved most recent framework to model the downside risk spillovers between assets for instance, its ability to incorporate the strengths of value-at-risk as a risk measure and applying the quantilogram function on multiple lags and multiple confidence levels as well as multiple variables. The results of the study showed that the largest and most leveraged financial institutions exhibit high sensitivity to market-wide shocks in situations of financial distress.

Forbes and Rigobon (2002) however, argue that strong cross-sectional correlations significantly biased the observed contagion effects identified by many researchers. This is mainly because Forbes and Rigobon (2002) argue that higher degree of correlation does not necessarily translate to contagion or connectedness. It is against this background that Baruník and Krehlík (2018) studied how cross-sectional correlations affect the connectedness and introduced frequency dynamics with take into consideration the differences in response to shock among market variables.

### 2.5 Stock market volatility in Developed markets

In the wake of the 1987 market crush, there was an exponential increase in the studies on the issue of stock returns transmissions. Some of the focus of these studies include financial market interdependence. Some of the pioneering studies include studies by Eun and Shim (1989), Hamao, Masulis and Ng (1990) and Becker, Finnerty and Tucker (1993).

Eun and Shim (1989) studied the international transmission process of stock market developments by assessing a nine-market vector autoregression (VAR) system. They applied modelled outcomes of the projected VAR approach. They sought to (i) uncover all the major avenues of connections among national stock markets, and (ii) observe the active reactions of one market to shocks in another. Their findings show that there was a significant amount of multi-dimensional connection is found among national stock markets. Shocks in the U.S. are quickly spread to other markets in an evidently recognizable manner, whereas they argue that no single foreign market can considerably explain the U.S. market movements. Likewise, the dynamic reaction trend is observed to be normally in agreement with the idea of informationally efficient international stock markets (Eun & Shim, 1989).

By applying the autoregressive conditionally heteroskedastic (ARCH) model, Hamao, Masulis and Ng (1990) investigated pricing interactions between three main stock exchanges, Tokyo, London, and New York in the short run. In other words, they investigated the inter-connection of prices and price relationships across three key international stock markets. The results of this study show that there is indication of price volatility spillovers from New York to Tokyo, London to Tokyo, and New York to London, however, no price volatility spillover effects in the opposite directions were found for the period prior to October 1987.

Using the recent multivariate quantile model and impulse-response functions, Wen, Wang, Ma, and Wang (2019) explored the risk spillover using different quantiles on daily data over the period from January 2000 through August 2018. The study was carried out on developed countries namely, United States of America, Japan, France, Italy, German, Canada, and the United Kingdom (the G7 group). They used the multivariate regression quantile model (the VAR for VaR approach) proposed by White, Kim and Manganelli (2015) to examine the risk spillover effect in these markets. This model is a generalisation of the original CAViaR model of Engel and Manganelli (2004). In other words, this model is a VAR extension to quantile models (Wen, Wang, Ma, & Wang, 2019). This approach is successful in addressing some of the main weaknesses of the prior literature which studied stock market spillover based on multivariate GARCH which do not differentiate the cases of upside and downside quantiles (Wen, Wang, Ma, & Wang, 2019). Their findings indicate that the risk spillovers are asymmetric which is not the usual case on the downside quantiles but rather has been documented to happen on the upside quantiles.

Leverage effect in brief is the increased sensitivity of time series data on the downside than on the upside. In other words, it means that their findings were contrary to the conventional notion of leverage effect in financial time series data because the leverage effect in financial markets indicates the increased risk at the downside quantiles. In addition, they established that there is an existence of significant positive risk spillover effects between stock market and crude oil market. Between countries also the risk spillover was found to be significantly present.

By studying predominantly developed markets, Rejeb (2017) investigated the structure and extent of interconnectedness with regards to volatility, that is, transmission, between Islamic and conventional stock markets during periods of excessive shocks such as during crisis as well as during periods of calmness in the markets. They incorporated quantile regression into GARCH model to create a Quantile Regression-based GARCH model. The study is based on daily frequency data covering the period spanning from January 1, 2001 to January 18, 2016. The results revealed that Islamic stock markets are not totally immune to the global financial crisis. In addition, this study found out that there is a very strong interdependence between the conventional and the Islamic stock markets with results more robust from the conventional developed markets to the Islamic Emerging and Arab markets as well as to the Islamic developed markets. Furthermore, Rejeb (2017) observed that the interdependencies from conventional to Islamic markets are also transmitted between Islamic markets. In other words, the quantile regression approach enabled this study to uncover the risk transmission among Islamic markets and between Islamic markets and the conventional developed markets. Because of the strong interconnectedness of Islamic markets with conventional markets, Rejeb (2017) opines that the Islamic finance industry does not seem able to provide protection against economic and financial shocks that affect conventional markets.

The main contribution of this study is that many of preceding studies on the interdependencies between variables are largely based on econometric approaches which only considers symmetric linear relations between variables and fail to provide the difference between dependence during up and down markets or between large and small stock price movements (Rejeb, 2017).

Shen, Shi and Variam (2018) carried out a study in Europe and Asia. They examined the risk spread mechanism between the oil and natural gas markets. This was done by using the newly familiarised test statistics built on cross-quantilogram function and the multivariate quantile regression model (VAR for VaR) to the US oil and natural gas prices which are independently formed. From the results they posit that the shocks in the oil market substantially increase the value-at-risk (VaR) in the natural gas market, but the reverse effect is not evident. In addition, they highlighted the significant asymmetric response of gains and losses transmission in energy markets with risk transmission more evident in extreme market risk compared to moderate risks. In other words, the recent method enabled the construction of a dynamic tail-interdependence system and to quantitatively trace out the risk transmission behaviour between energy markets.

As further evidence of the robustness of the new approach to modelling volatility transmission across markets- the cross-quantilogram, Lyócsa, Vašaničová, & Litavcová (2019) applied the cross quantilogram approach to study the interconnectedness of international tourism demand variations among thirty European countries. They projected the strength of the directional (lead or lag) relations of the international tourism demand of European countries in percentiles of 10th, 50$^{th}$ and 90th. They observed noticeable asymmetries across percentiles, where demand behaves much more similarly during times of crisis ( the 10th percentile) relative to calm phases (50th percentile).

Based on thir study they posit that there is an inverse relationship between international demand for tourism and the interconnectedness of these markets. In other words, they argue that the interconnectedenss among these countries declines as the international demand for tourism increase abruptly. This can be expected bacause, holding other factors constant, with higher variability, the degree of connectedness tend to diminish. In addition, one of the major interesting findings of this study is that, that they observe a tendency for the relationships of the international tourism demand among the various countries to be bidirectional. This is in agreement to the observation by Bala and Permaratne (2003) who stated that the risk transmission or interconnectedness among markets at times exhibit the feedback effect.

### 2.6 Stock market volatility in Emerging markets

Harvey (1994) studied risk and return traits of emerging market equity markets in Africa, Europe, Latin America, and Middle East. He posits that these markets display high expected returns as well as high volatility. Notably, he argues that the low linkages of emerging markets with equity markets in developed markets substantially lowers the absolute portfolio risk of an international investor. Nevertheless, he contends that normal global asset pricing models, which assume total integration of financial markets, fall short in explaining average returns in emerging countries. The main contribution of this study is that he found out that emerging market returns are more prone to be affected by local information than developed countries. This result is profound however, with information asymmetries and market inefficiency prevalent in some emerging markets, measuring the impact of information on equity market performance with accuracy may be challenging.

Mensi, Hammoudeh, Nguyen, & Kange, (2016) and Ji, Bouri, & Roubaud (2018) studied risk spillover effects and transmission among the US and BRICS markets. The former study applies the bivariate Dynamic Conditional Correlation Fractionally Integrated Asymmetric Power ARCH (DCC-FIAPARCH) model, the modified ICSS algorithm and the value-at-risk (VaR) to examine volatility spillovers, identify structural breaks and evaluate the portfolio market risks. The main highlight from this study is that BRICS markets were found to be deeply influenced by the global financial crisis which backs the proposition of recoupling while the premise of decoupling or disengaging is evidenced from the Russian stock market only. South Africa being part of BRICS, this study shows that these select emerging markets are influenced by global economic crisis. However, South Africa alone cannot be representative of Africa.

The uniqueness of the African markets coupled with the opaqueness of most stock exchanges in Africa, lack of liquidity (Kuttu, 2014) and market inefficiency warrants a further study covering the African context. In addition, the results from the study below done by Mensah and Alagidede (2017) established that only South Africa was affected by risk spillover in Africa during the global financial crisis. Ji, Bouri and Roubaud (2018) on the other end implemented the graph theory approach that incorporates a dynamic conditional correlation model to disclose the dynamics of information integration and investigate the impact of events such as political, war and financial events on changes in information flow among implied volatility indices. Their findings agree with Mensi, Hammoudeh, Nguyen, & Kange, (2016) that events can affect the degree of comovement among markets. However, they argue that the impact of events on the integration structure among market volatilities is limited.

The Chinese economy has been growing in leaps and bounds in recent years and has been one of the fastest growing emerging economies in the world. This prompted a lot of studies to focus on the Chinese economy. Jian, Wu and Zhu (2018) are among many researchers who studied stock market volatility and risk spillovers between the Chinese stock market and index futures market using the conditional value at risk (CoVaR) which was proposed by Adrian and Brunnermeier (2016). The CoVaR is briefly defined as the value-at-risk of a specific market which depends on the fact that the other market is under certain adverse events and the tail dependence is shown in the difference between the CoVaR conditional on an extreme event and the CoVaR conditional on conventional scenarios (Jian, Wu, & Zhu, 2018). This study analyses the bidirectional and asynchronous extreme risk spillover based on the CoVaR.

In addition, one of the contributing factors of this study is that it addresses the one-period CoVaR prediction under the multivariate conditional autoregressive value at risk (MV-CAViaR) model proposed by White, Kim and Manganelli (2015). To further shed light using the intraday high-frequency data, they extended the MV-CAViaR model to directly and jointly estimate the bidirectional spillover effects captured by intraday difference in CoVaR measures (Jian, Wu, & Zhu, 2018). Their findings reveal the presence of asymmetric spillover under various market conditions, various trading rules and various confidence levels. Put differently, they assert that there is a presence of substantial downside spillovers and immaterial upside spillovers. Moreover, the stock futures (stock) market appeared to be significant in risk transmission during bearish (bullish) market periods.

Xu, Ma, Chen, and Zhang (2019) sought to focus on studying time-varying asymmetric volatility spillover. They applied a recent spillover directional measure and asymmetric spillover measures to investigate the dynamic asymmetric volatility spillover between oil and stock markets during the period of 2007 to 2016. Based on the WTI futures prices, the S&P 500 index, and the Shanghai stock market composite index, they observed that there exists an asymmetric spillover effect between the oil market and the stock markets. In addition, downside spillovers were found to dominate upside spillovers for most of the period under study. Put differently, this study observes the behaviour of realised volatility components separately as positive (good) and negative (bad) volatility. Further, the major contribution of their study is the use of asymmetric generalised dynamic conditional correlation (AG-DCC) model which reveals a strong evidence of asymmetries in volatility shocks between the oil and stock markets due to downside or negative volatility.

Xiao, Hu, Ouyang, and Wen (2019) further examined the effects of shifts in implied volatility index of oil market (OVX) on the shifts in the implied volatility of the Chinese stock market (VXFXI). In other words, they studied the co-movement between the oil market and the stock market. They applied the quantile regression approach on their empirical study. The underpinning reason in using quantile regression in this study is that it accomplishes a more detailed analysis under various market conditions. Further, this study examines whether the Chinese stock market shifts would react with lags and asymmetry to the oil market shifts. The results of the study show that the impact of the oil market changes on the stock market changes are positive and tend to be stronger in bearish markets. In addition, the findings of examining lagged outcomes show that robust connections between the two variables are temporary in distinct market conditions, which does not endorse the hypothesis of steady information transmission very well. Xiao, Hu, Ouyang, and Wen (2019) further observed that the oil market changes can asymmetrically affect the stock market changes. Put differently, the adverse oil market shifts have greater impact under bullish market conditions and the vice-versa is true for the bearish market.

## 2.7 Stock market volatility in Africa

By applying the contagion categorisation identified by Forbes and Rigobon of “crisis-contingent” and “non-crisis contingent”, Pretorius and de Beer (2004) studied the possibility of contagion between South Africa and Zimbabwe which is in economic turmoil. The motivation of their study was based on the notion that South Africa has encountered significant currency volatility in recent years, regardless of strong economic fundamentals. Their study empirically examines the presence and the scope of contagion in justifying volatility of the South African Rand. Economic challenges in Zimbabwe and other emerging-market countries (such as Argentina) have often been attributed to the recent volatility. In this study, two alternative contagion channels were investigated namely, real interdependence, that is, trade links through bilateral trade and trade competition in third markets and financial contagion. Their findings confirm the presence of financial, but not trade contagion. These results are insightful as they can mean Zimbabwe is a net importer and therefore trade contagion is expected from South Africa without a feedback effect from Zimbabwe.

Despite an increasing study on the interdependence of stock markets between countries, very few studies were carried out on Africa. Kuttu (2014) investigated return and volatility dynamics among four African equity markets. They employed a multivariate vector autoregressive-exponential general autoregressive conditional heteroscedasticity (MVAR-EGARCH) to examine the returns and volatility dynamics between thin-traded and daily-adjusted equity returns from Ghana, Kenya, Nigeria, and South Africa from 1 August 2005 to 31 December 2010. Their findings suggest an existence of feedback effect between Ghana and Kenya and between Nigeria and South Africa. In addition, they assert that Nigeria appears to be the source of volatility innovations in Ghana, Kenya, and South Africa. The main contribution of this study is that it extends the literature on African market interdependency in numerous directions such as accounting for thin trading and in so doing, eliminating potential biases related to empirical work on thin trading. Also, contrary to prior studies on African market connectedness which use univariate models to model the first and second moments, they examined the return and volatility dynamics concurrently on African stock exchanges in the MVAR-EGARCH framework.

Ahmadu-Bello and Rodgers (2016) examined financial contagion from the U.S. to eight African national markets during the 2007–09 financial crisis employing a dynamic conditional correlation (DCC)-based methodology. The crisis was studied from the view of it being a single long-period event as well as a series of cumulative short-sub-periods. To put into perspective, contagion from the U.S. to seven developed markets was also examined. The results reveal a strong indication of contagion in African national markets during the initial stages of the crisis. On the contrary, contagion in developed markets was seen to happen more gradually. They posit that the disparities observed concur with herding behaviour taking place at a quicker rate in the Africa national markets than in their developed market counterparts.

Boako and Alagidede (2017) modelled the extreme downside currency risk spillover effects to Africa's equity markets using value-at-risk (VaR) and conditional value-at-risk (CoVaR) based on stochastic copulas. This study attempted to highlight the potential of Africa's stock markets to acts as sustainable investment alternatives for international portfolio investors both during calm and turbulent times. In other words, their study was concerned with capturing the likelihood of possible joint movement of extreme events given by high or low values.

Their findings revealed the existence of non-homogenous weak negative dependence between stocks and the US dollar (USD) and the Euro (EUR) exchange rates which suggests that higher equity prices are accompanied by depreciation of domestic currencies and the vice versa. They further posit that foreign currency exchange price risk may command premium in some African equity markets especially during market turbulence to reduce any hedge capabilities of domestic stock markets for investors.

Further, by using both VaR and conditional VaR to model, this study captures the effect of the extreme downside risk using the most common risk measure of VaR. In addition, Boako and Alagidede further combined VaR with the recently growing concept of copulas. Copulas allows the joint modelling of random events and the main contribution of this study is that copulas exhibit superiority over other traditional methods. In addition, it has the capacity to offer information on typical dependence as well as the tails of joint distribution centred on the marginal models of the distribution (Boako & Alagidede, 2017). In brief, Boako and Alagidede (2017) argue that the use of copula to estimate CoVaR has key merits relative to other parametric bivariate functions for instance, it permits a lot of flexibility in modelling marginals as it permits distinct modelling of the marginal and dependence structures. This flexibility enables unique and different tail dependence features affecting CoVaR to be captured.

The benefit of copulas was also highlighted in a study by Mensah and Alagidede (2017) where they studied the dependence structure between Africa's emerging markets and the advanced markets. They found the evidence of asymmetric dependence which indicates that stock return co-movement differs in downtrend and uptrend markets. In addition, they observed that extreme downside stock price movements in advanced markets do not have substantial spillover effects on Africa's emerging markets. This means that African markets, excluding South Africa were observed to be relatively immune to risk spillover from advanced markets. This finding agrees with the findings by Tony-Okeke, Ahmadu-Bello, Niklewski and Rodgers (2018).

The unique nature of African emerging markets such as lack of liquidity motivated a study by Kuttu (2017) in which he studied the impact and behaviour of time-varying conditional discrete jumps in emerging African equity markets. This is motivated by the fact that volatility is generally not conditional and continuous which can allow its trajectory to be predicted, but rather the discreet jumps are problematic to forecast therefore, the need for them to be studied. He used the autoregressive jump intensity-EGARCH model which combines the conditional discrete jump with the frequently applied GARCH models into an ARJI-Exponential-GARCH. Kuttu (2017) argue that, despite the GARCH in the ARJI-GARCH model allowing for volatility clustering, it has a weakness of being unable to distinguish sign-bias irregularity and the non-negativity which means the invertibility limitations on the coefficients have the potential to limit the use of the model. This, according to Kuttu (2017) highlights the need to combine the ARJI with the EGARCH model of Nelson (1991).

The focus of this study is on Egypt, Nigeria, and South Africa. The findings suggest that conditional discrete jump is both changing-with-time and sensitive to past shocks for Egypt and South Africa except for Nigeria. In addition, conditional discrete jump sensitivity was found to be persistent in all the markets and only South Africa exhibit the likelihood of asymmetric conditional jump volatility. Further, Kuttu (2017) posit that the existence of thin trading exaggerates the economic implication of the conditional discrete jump dynamics.

In agreement with a study by Kuttu (2017) on the existence of unique traits in African markets such as the presence of asymmetries, Gkillas, Vortelinos and Suleman (2018) investigate the asymmetries in the African financial markets of Botswana, Egypt, Kenya, Mauritius and South Africa from January 1, 2001 to January 20, 2018 using the daily data. They applied an asymmetric threshold approach with an error-correction model using four dummy variables for both positive or negative and small or large news. They observed that the foreign exchange markets in Africa are statistically more predisposed to larger-scale news. They also observed a direct reaction to short-term positive/negative stock market news after the global financial crisis.

Tony-Okeke, Ahmadu-Bello, Niklewski and Rodgers (2018) added to the literature by extending the explanation of financial contagion outside that of the market correlation approach promoted by Forbes and Rigobon (2002). They focused on the consequence of contagion on the conditional sector-risk beta of the African emerging natural resource market. They established a multi-factor capital asset pricing model (CAPM) within a DCC-MGARCH framework to estimate time varying beta. The results show that excluding South Africa, the 2007-2009 crisis had no substantial influence on Beta. This result concurs with the findings by Mensah and Alagidede (2017) who stated that only South Africa showed a significant impact from global financial crisis among African markets. Tony-Okeke, Ahmadu-Bello, Niklewski and Rodgers (2018) further assert that the disparities found can be ascribed to the various ways in which contagion events influence individual markets. From this they determined that a universal approach to correlations-based contagion analysis is not the best way.

## 2.8 Conclusion

Studies on stock market volatility have grown in scope and depth over the years with various models and frameworks used by researchers in a bid to accurately model stock market volatility. The need to model stock market volatility was further strengthened by the recent global financial crisis of 2007-2009 which pointed to the increased globalisation and increased risk transmission across stock exchanges. However, many studies, particularly in the context of Africa did not consider the causality of contagion and the heterogeneous responses to shocks among market variables. The following chapter explains the methodology to be used in this study as well as the potential limitations and challenges in carrying out the study.

# Chapter 3: Methodology

## 3.1 Overview

This chapter builds on the literature presented in the preceding chapter with emphasis on the methodology applied in this study. This methodology is a replication of the methodology applied by Baruník and Krehlík (2018) with a focus on broadening their study to cover international risk spillover rather than focusing on financial institutions in the U.S. alone. The approach taken in this study puts more emphasis on the risk transmission between economies under study. By applying the Baruník and Krehlík (2018) technique, this study examines the extent of the risk spillover from the U.S. to major African stock markets and also examine if there is an existence of the feedback effect between these markets. In addition, the rolling window aspect of this technique enables the examination of the behaviour of risk interdependence over time during the period under study. In other words, the rolling window aspect allows this study to investigate whether risk interdependence vary over time. To investigate the asymmetric responses of gains and losses transmission between equity markets of the U.S. and Africa, the methodology applied in this study has frequency-dependent component which mitigates challenges that arise from these responses.

## 3.2 Data description

The data for this study is extracted from Bloomberg and is based on the weekly closing prices of the stock market indices namely; the Standard & Poor 500 Composite Index (S&P 500), for the US, and 4 major African indices: the FTSE/JSE All Share index (JALSH), for South Africa; the Hermes Financial, for Egypt; Nigeria All share index, for Nigeria and Nairobi Securities Exchange, for Kenya. The weekly data timeframe helps to minimise market noise associated with relatively smaller timeframes such as hourly and daily and thereby smoothing the data. This enables this study to focus on the impact of risk transmission in other countries. These markets are chosen in this study because they are the largest in their respective regions of the African continent, that is, South Africa has the largest stock exchange by market capitalization of ZAR 13.96 trillion [approximately US$1 trillion] (Bloomberg Terminal, 2019) in southern African region. Egypt acts as a proxy for North Africa with a market capitalization of approximately US$ 44.61 billion, whilst Nigeria is a proxy for West Africa with a market capitalization of approximately US$ 39.28 billion and Kenya represents East African region with a market capitalization of approximately US$ 25.06 billion (Stock Market Clock, 2019).

The S&P 500 is chosen as it represents 500 largest companies across all industries listed on the NYSE and therefore is a better proxy for the US market. Further, Cheung, Fatum and Yamamoto (2019) postulate that the U.S. is viewed as the source of the 2007-2009 global financial crisis. This makes the inclusion of the U.S. in this study of paramount relevance.

The data period in this study is from 25 November 2001 to 30 December 2018. It is also selected to include the 2007-2009 global financial crisis and the 2009-2012 Eurozone crisis which Ahmed et al (2013) posit that they are vital periods to assess spillovers in financial. The study period is divided into three sub-periods: 2001-2007 to investigate the impact of the bullish market on international risk transmission; 2008-2009 to investigate the impact of the bearish market trend during the global financial crisis and 2010-2018 to investigate the bullish market during the recovery from the financial crisis. This period is from the recovery of the dot com bubble in 2000 as well as including one of the greatest financial crises in the world: -the global financial crisis of 2007-2009. In other words, the period under study allows this study to investigate risk transmission during both bull and bear markets as well as during periods of tranquil and turbulent times. Put differently, these periods are chosen to allow a better analysis of the risk transmission behaviour before the crisis and during the acute downside risk as well and during the post financial crisis.

The optimal lag applied in this study is one week. In addition, the forecast length applied is 12 weeks which is equivalent to a quarter of a year. The frequencies applied are 1 to 4 weeks for short-term (monthly). This period is chosen because the data is based on weekly and a maximum of a month enables significant observations to be observed across markets and to identify any connectedness. The medium-term ranges from 4 to 52 weeks (a maximum of 1 year). Annual observations allow any relationships to be observed in an annual cycle. The long-term frequency is from 52 weeks to infinity and allow a long-run observation during the time under study.

### 3.3 Estimation techniques

Diebold and Yilmaz (2009) posit that variance breakdowns permit us to divide the estimate error variances of each variable into parts ascribable to the numerous system shocks. Baruník and Krehlík (2018) further state that the breakdown of variance offers valuable insights about how much of the future uncertainty of a given variable is ascribed to shocks in another variable. In addition, Diebold and Yilmaz (2014) contend that variance breakdown is closely related to recent measure of systematic risk such as expected shortfall (Acharya et al., 2017), CoVaR (Adrian and Brunnermeier, 2016) and VAR for VaR (White, Kim, & Manganelli, 2015). This view makes the following methodology ideal in achieving the objectives of this study. Also, a simplified narrative of frequency dynamics, i.e. long-, medium- or short-term, of connectedness is to take into account the spectral depiction of variance decomposition centred on frequency reactions to shocks (Baruník & Krehlík, 2018).

GFEVDs is a method of measuring connectedness in line with the argument raised by Forbes and Rigobon (2001) that connectedness is more prevalent across markets rather than contagion across various market conditions of tranquil and volatile. It is constructed on the matrix of a vector autoregressive (VAR) model in (1) of local covariance stationarity. However, this study, rather than applying in locally as in Baruník and Krehlík (2018), it will apply this model inter-nationally between the US and selected African markets. Let $K$-variate process $Y_t=(y_{1,t},\ldots,y_{K,t})'$ at t=1, …, T a VAR(ρ) be represented as

$$Y_t=\sum_{i=1}^{p} \emptyset_i y_{t-i} + \epsilon_t \qquad \ldots\ldots\ldots (1)$$

where $\phi i$ and $\epsilon i$ are coefficient matrices and white noise with covariance matrix Π. The use of a $(K \times K)$ matrix $(\boldsymbol{I}K - \emptyset 1L - \ldots - \emptyset pLp)$ with identity $\boldsymbol{I}K$ is more ideal in this case. If the roots of the characteristic equation $|\theta(z)|$ lie outside of the unit circle, the VAR system has a moving average $MA$ (∞)

$$Y_t=\psi(L)\epsilon_t \qquad \ldots\ldots\ldots. (2)$$

with $\psi(L)$ being an infinitely lagged polynomial. The GFEVD, the contribution of the $kth$ variable to the variance of forecast error of the element $j$ can be written as

$$(\Theta_H)_{j,k} = \frac{\sigma_{kk}^{-1} \sum_{h=0}^{H} \left( (\psi_h \Pi)_{j,k} \right)^2}{\sum_{h=0}^{H} (\psi_h \Pi_h)_{j,k}} \qquad \text{………. (3)}$$

where $h$ = 1, …, $H$ and $\sigma kk$ = ($\Pi kk$). This is likely since the connectedness measure is contingent on variance breakdowns, being the transformations of $\psi h$ and functions as inputs of the shocks to the system. Since rows do not amount to unity, the matrix $\Theta H$ is given as

$$\left(\widetilde{\Theta}_H\right)_{j,k} = \frac{(\Theta_H)_{j,k}}{\sum_{k=1}^{N} (\Theta_H)_{j,k}} \qquad \text{……….. (4)}$$

Diebold & Yilmaz, (2012) argues that, for measuring the overall connectedness, the pairwise connectedness in (4) can be combined, and specified as the share of variance in the estimates contributed by disturbances other than own disturbances or the ratio of the totality of the off-crosswise elements to the totality of the complete matrix as

$$C_H = 100 * \frac{\sum_{j \neq k} \left(\widetilde{\Theta}_H\right)_{j,k}}{\sum \widetilde{\Theta}_H} = 100 * \left(1 - \frac{Tr\{\widetilde{\Theta}_H\}}{\sum \Theta_H}\right), \qquad \text{…….. (5)}$$

In which $Tr\{.\}$ is the trace operator, and the denominator represents the totality of all components in the matrix. The dual-directional ("to" market i from all other markets $k$, and the reverse effect ("from") of connectedness can be quantified. This means that the these "net" connectedness is also quantified as the distinction between "to" spillovers and "from" spillovers (the feedback effect). Consequently, a market with a positive net spillover is a net source while the one with a negative spillover is a net receiver of shocks, according to Owusu Junior and Alagidede (2019). The net volatility spillover is generally the distinction between the aggregate volatility shocks transmitted to and the ones received from all other markets (Diebold & Yilmaz, 2012).

In the delineation of the spectrum, a frequency response function $\psi(e - i\omega)= \sum_h e^{-i\omega h}\psi_h$ of Fourier convertible coefficients $\psi_h$ with $i = \sqrt{-1}$, a density of $Yt$ at frequency $\omega$ can be defined as $MA(\infty)$ filtered series

$$S_y(\omega) = \sum_{h=-\infty}^{\infty} E(Y_t Y_{t-h})e^{-i\omega h} = \psi\left(e^{-i\omega}\right)\Pi\psi'\left(e^{+i\omega}\right) \text{ ………. (6)}$$

The spectral power, $Sy(\omega)$ depicts the dispersal of the variance of $Yt$ over the frequency factors $\omega$. The causation spectrum over $\omega \in (-\pi, \pi)$ is characterized as

$$(\mathcal{F}(\omega))_{j,k} = \frac{\sigma_{kk}^{-1}|\psi(e^{-i\omega})\Pi_{j,k}|^2}{\left((\psi(e^{-i\omega})\Pi\psi\prime(e^{+i\omega})\right)_{j,j}}, \qquad \text{……….. (7)}$$

Observant of the fact that $(\mathcal{F}(\omega))_{j,k}$ signifies the part of the $ith$ variable owing to shocks in the $kth$ variable at a specific frequency $\omega$. In that case $(\mathcal{F}(\omega))_{j,k}$ can be understood as to be within-frequency causation on account of the denominator.

Owusu Junior and Alagidede (2019) further concur with Baruník and Krehlík (2018) that it is nobler to measure connectedness over time horizons (i.e. bands $d = (a,):a,b \in (-\pi, \pi), a < b$)) contrasted with just a single frequency point. A scaled breakdown over $d$ can be specified as

$$\left(\tilde{\Theta}_d\right)_{j,k} = (\Theta_d)_{j,k} / \sum_k (\Theta_\infty)_{j,k} \qquad \text{........... (8)}$$

Following this, the *within-frequency* and frequency connectedness are specified in (9) and (10), correspondingly.

$$(\mathrm{C}_{\mathrm{d}}^{\mathrm{W}})=100*\left(1-\frac{\mathrm{Tr}\{\tilde{\Theta}_{\mathrm{d}}\}}{\sum \tilde{\Theta}_{\infty}}\right) \qquad \text{.......... (9)}$$

$$C_d^F = 100 * \left(\frac{\sum \tilde{\Theta}_d}{\sum \tilde{\Theta}_\infty} - \frac{Tr\{\tilde{\Theta}_d\}}{\sum \tilde{\Theta}_\infty}\right) = C_d^W * \left(\frac{\sum \tilde{\Theta}_d}{\sum \tilde{\Theta}_\infty}\right) \qquad \text{......... (10)}$$

### 3.4 Limitations

The concept of contagion and its definition is a debatable concept and the challenge in coming up with a universally agreed definition brings limitations in terms of scope, research period and concepts to focus on.

Biases, as a result of sample selection have the potential of resulting in inaccurate empirical results. This has a negative impact on the robustness and the applicability of both in-sample and out-of-sample results. One of the possible biases in this research study is the possible misrepresentation and selection bias in the initial research database. This occurs when a part of the initial database is systematically excluded due to an attribute. In the case of this study, Kenya's actual national index values prior to 2008 are not available which is poised to influence the statistical significance of the test or produce distorted results. To remedy this, the earliest available weekly data is used as standard proxy value for all periods prior. This approach gives an idea but does not fully solve the challenge of missing information and therefore it means the observations for Kenya are likely to influence the results or cause the results to be biased.

Another common bias is the time bias which is evident when the results produced are specific or unique to a certain examination period. If the examination period for instance has a single business cycle such as a bullish only, the results will contain time bias. However, in this study, the time bias is mitigated by including both bullish and bearish business cycles to test for the robustness of the findings.

### 3.5 Conclusion

In concurrence with the main objectives of the study, this chapter exhibited the comprehensive process to be pursued to carry out the risk transmission modelling. It is vital to emphasise that a couple of measures are applied to efficiently measure these important tests, however, this research adopted the approach of Baruník and Krehlík (2018). Mimicking this study did not only apply to the methodological procedure but also informed the type of data attributes that must be extracted. Having known these research methodological procedures, Chapter 4 will capture the findings of the risk transmission and the inter-national connectedness.

# Chapter 4: Results Analysis

## 4.1 Introduction

The continuous occurrence of financial crisis across continents, financial systems and national boundaries has led to an increase in studies on connectedness and contagion (Claessens and Forbes, 2001; Diebold and Yilmaz, 2012; Forbes and Rigobon, 2001, 2002; Pritsker, 2001). This is expected as countries are increasingly categorised using certain traits for instance in terms of blocs such as European Union, BRICS (Brazil, Russia, India, China, and South Africa), continental location, economic development such as emerging markets and developed markets. The existence of these strong inter-national transactions exposes economies to higher degree of connectedness and contagion. However, the literature on higher moments studies on inter-dependence and contagion is also still new and relatively sparse.

The significance of investigating higher moments in inter-dependence and contagion cannot be underestimated due to the distributional traits originating from the stylised facts of time series returns (Ding and Granger, 1996; Cont, 2001; Brooks, 2014). These traits are paramount in risk management, investment analysis and diversification of portfolios. In addition, higher moment studies in emerging markets are relatively scant and more so, in the context of Africa. In other words, by investigating higher moments in the context of Africa, this study is adding to the literature. This means that this study investigates interdependence and contagion through higher moments of a selected African equity markets which are typical emerging market economies. An in-depth understanding of this concept in the context of Africa is vital for policy making, portfolio management, diversification, and risk management.

Forbes and Rigobon (2001) argue that substantial surging of the correlation implies that the transmission process between two markets could have risen after the shock and contagion happened. In other words, the description of contagion has recently expanded to consist of a period after a shock has happened. Further, Forbes and Rigobon (2001) provided a simple definition of shift contagion which they defined as a change in cross market linkages across times of tranquil market conditions and turbulent market conditions. However, despite the broadening of the meaning of contagion to include post-shock periods (Boako and Alagidede, 2017) and the substantial variability in correlation between different market conditions, the main drawback of this concept of shift contagion is that it is mainly premised on heteroscedasticity bias adjustment (Baruník & Krehlík, 2018). By applying the technique by Baruník and Krehlík (2018), this study side-steps the heteroscedasticity bias inherent in the shift contagion proposed by Forbes and Rigobon (2001). This chapter provides an analysis of the results obtained in this study as well as establishing whether there is interconnectedness and/or contagion existing between the U.S. and selected African markets. In addition, by applying the Baruník and Krehlík (2018) technique and the higher moments this study investigates the risk transmission mechanism between these economies.

Time and frequency domain spillovers explain frequency bands and are chosen to account for short-, medium-, and long-term dynamics. These are chosen to correspond with Baruník and Krehlík (2018) framework as shown in Table 4.1. In othert words, frequency dynamics of connectedenss ($d_i$) according to the concept by Baruník and Krehlík (2018) are used in this study to signify variance breakdown dependent upon frequency reactions to innovations as opposed to impulse reactions to innovations. Also, the bands are applied to assist in establishing the strength of connectedness across the three frequencies instead of a single frequency. Put differenlty, one of the significant contributions by Baruník and Krehlík, (2018) is that innovations to economic activity affect variables at numerous frequencies as compared to a single frequency.  As shown in table 4.1, the notion is that economic agents or players operate at under diverse investment horizons which is represented by frequencies. In this study, $d_1$ represents the short-term horizon of weekly, while $d_2$ represent the medium-term investment horizon which ranges from 4 to 52 weeks (a month to a year) and $d_3$ represents the long-term horizon of greater than 52 weeks (one year). Further, these frequencies are represented by frequency bands as shown in the table 4.1 below.

**Table 4.1: Clarification of timescales & frequencies**

| **Frequency** | **Band** | **Weeks** | **Interpretation** |
|---|---|---|---|
| $d_1$ | 3,14 to 0,79 | 1 to 4 | Weekly |
| $d_2$ | 0,79 to 0,06 | 4 to 52 | Monthly |
| $d_3$ | 0,06 to 0,00 | 52 to infinity | Annually |

## 4.2 Descriptive statistics

The Appendices section shows the price and log-return plots of the selected African equities market and the US equities. The significant variations in the weekly prices is apparent in figure 4.1 especially during the global financial crisis of 2007-2009 across markets. In addition, figure 4.2 shows the log-return plots for all the markets under study. The log-return plots exhibit volatility clustering as anticipated due to the stylised facts of financial time series or asset returns as revealed by Cont, (2001).

Table 4.2 exhibits the summary of statistics for the markets under study and during the period under study. The skewness values observed shows non-normality across board with South Africa exhibiting a skewness close to normality of 0.0134. On the other hand, kurtosis values further show leptokurtic behaviour in the values across all markets. In terms of the stationarity test, the Augmented Dicky-Fuller (ADF)-Generalised Least Squares (GLS) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) is used. The observations from both the ADF-GLS and the KPSS reveals that all the data series explicitly fulfil the stationarity requirements. This is in line with assumptions of various autoregressive studies such as (Engle, 1982; Engle & Manganelli, 2004) which assumes global stationarity. However, this study circumvents the global assumption by employing the Baruník and Krehlík (2018) technique which assumes the local stationarity rather than the global stationarity.

## 4.3 Frequency-domain (static) analysis

Many studies on risk spillover concluded that risk propagation tends to originate from the bigger to a smaller economy for instance from an economy such as the US to a less developed economies or emerging markets for example studies by (Boako & Alagidede, 2017; Boako & Alagidede, 2017; Mensah & Alagidede, 2017; Mlambo & Biekpe, 2005). However, Bala & Permaratne, (2003) argues that there tends to be feedback effect on risk transmission between economies. In this segment the total two-directional spillovers in the frequency domain within markets is analysed. This is a static analysis with the three frequency bands as shown in Table 4.3. for skewness. The corresponding values shown in table 4.3 highlight the approximate contribution to the forecast error variance market *i* originating from shocks to market *j* (that is, ‘global’ shocks). On the other hand, the diagonal value (the economy to its own as shown from top right to bottom left in each panel) records the forecast error variance contribution of market *i* that is originating from its own shocks (that is, local shocks). From the evidence presented, it is apparent that these values are the largest and this result is logical.

One of the main information contained in table 4.3 is the total connectedness of these markets. More specifically, the *within* (WTH) connectedness is of more interest in that is uses the weighting of the power of the series based on frequencies. The apparent benefit of using frequencies is that, as stated by Baruník and Krehlík (2018), innovations to economic activity influence variables at numerous frequencies with various strengths which is captured through frequency dynamics of the connectedness. Put differently, they posit that varied frequency reactions to innovations are basically aggregated through frequencies. In other words, the WTH (*within* connectedness) connectedness is special in this study in that it captures and highlights causality as it matches to every ABS (absolute connectedness) connectedness value observed. This means that the forecasting horizon increases; the causality tends to also increase. On the other hand, a notable observation is that the absolute connectedness (ABS) is decreasing or decomposing with the frequency bands. Also, across board, the ABS connectedness is significantly lesser than the WTH connectedness suggesting lower correlations influencing ABS connectedness. The WTH (*within* connectedness) values are higher than the ABS (*absolute* connectedness) values across all three panels and across all frequency ranges in table 4.3.

The spillover observed in table 4.3 shows that spillover is dominant in the short- and medium-frequencies across a selected four African markets and the US based on the FROM ABS values of 10.13 and 2.42 which matches to frequency bands 1 and 2 correspondingly. South Africa and the US have dominant spillovers across all three frequencies of short-, medium-, and long-term. This result is in line with the observation by Mensah and Alagidede (2017) who observed that during the global financial crisis, except South Africa, most of the African markets were insignificantly impacted by the risk spillover. The relatively weak spillover recorded for other African markets have implications such as diversification in that, excluding South Africa, Nigeria, Egypt, and Kenya have weak spillover effect with the US and therefore have potential diversification benefit to inter-national investors. Another notable observation is that the US does not always dominate in terms of the spread of spillover based on the causal effect as shown by WTH connectedness. In other words, in the short-term South Africa has a marginally stronger WTH connectedness of 6.07 while the US dominates in the medium- and long-term. This observation is contrary to many studies which argue the dominance of a larger market in risk transmission or innovation propagation for instance a study by Mensi, Hammoudeh, Nguyen, and Kange, (2016). On the other hand, this evidence of the feedback effect corroborates with the findings by Bala & Permaratne, (2003) who argued that in some cases there is not only one way trisk transmission from a bigger market to a smaller market but there is also a return effect. Also, this weak WTH connectedness can be used to conclude that there was generally a lesser effect of the global financial crisis of 2007-2009 on these selected African markets or these emerging markets. In other words, the greatest portion of spillover observed in the African emerging markets can be ascribed to the spillover asymetric returns within each other coupled by the lack of liquidity and market ineffieincy in African markets.

In table 4.3, the information on net spillovers (**Net**) for each market is shown. Net spillover, as highlighted in the previous chapter is the disparity between *TO* and *FROM* spillovers per each given market. The positive sign on net spillover means the market is a **net transmitter** while the opposite is true for **net receiver**. In other words, there are mainly two categories of markets, those that are the net receivers and those that are the next transmitters of skewness or kurtosis innovations across the given frequency bands, except very limited ones that are neither of the aforementioned.

Figure 4.3 therefore shows that across the short-, medium- and long-term frequency bands, the US is a net receiver rather than a net transmitter. It is vital to note that this observation is in contrast to the notion of big market only transmitting risk to smaller markets and can best be explained by the fact that African markets exhibit unique traits such as lack of liquidity, market inefficiencies which can limit the impact of the US on these markets. Nigeria and Kenya are the net transmitters cross all frequency bands while Egypt, and South Africa are the net recipients. Since this data includes the period of global financial crisis, the time period is the appropriate to capture the global financial crisis and confirms that the impact on the selected African markets was limited but rather can be significantly explained by propagation of spillover among these emerging market African countries.

Table 4.5 provides another perspective in terms of pairwise net directional spillover of skewness while confirming the existence of time varying **net recipients** and **net transmitters** according to Baruník and Krehlík (2018) which reveals the relationship between selected African markets and the US. Connectedness is stronger in the short-term compared to the long-term. In the short-term, Egypt-Nigeria recorded the largest negative net spillover of -2.613 recorded in 2008 while South Africa-US is observed as the strongest net transmitter with net pairwise spillover of 1.321 in 2007.

In the medium-term, Kenya-Nigeria recorded the highest net connectedness spillover of contagion of 1.098 in 2009 while there is a record of net connectedness spillover reception across the market pairs. In band 3 (the long-term frequency), Egypt-Nigeria had the strongest recording of net connectedness spillover or contagion of 0.0515 witnessed in 2004 while South Africa-US records net connectedness spillover reception of -0.402 in 2003.

**Table 4.2: Summary statistics**

| | Egypt | Kenya | Nigeria | South Africa | USA |
|---|---|---|---|---|---|
| Obs. | 937 | 937 | 937 | 937 | 937 |
| Min | 0.7867 | 0.9044 | 0.8667 | 0.8951 | 0.8331 |
| Max | 1.2693 | 1.1661 | 1.1763 | 1.1613 | 1.1102 |
| Range | 0.4826 | 0.2617 | 0.3096 | 0.2662 | 0.2771 |
| Sum | 940.4507 | 937.5704 | 938.8714 | 939.0898 | 937.8667 |
| Median | 1.0051 | 1 | 1.0014 | 1.003 | 1.002 |
| Mean | 1.0037 | 1.0006 | 1.002 | 1.0022 | 1.0009 |
| SE.mean | 0.0013 | 0.0006 | 0.001 | 0.0008 | 0.0008 |
| CI.mean.0.95 | 0.0025 | 0.0012 | 0.002 | 0.0016 | 0.0015 |
| Variance | 0.0015 | 0.0003 | 0.001 | 0.0006 | 0.0005 |
| Std.deviation | 0.0391 | 0.0185 | 0.0315 | 0.0254 | 0.0234 |
| Coef.var | 0.039 | 0.0185 | 0.0314 | 0.0254 | 0.0233 |
| Skewness | -0.1632 | 0.2566 | 0.1388 | 0.0134 | -0.5955 |
| Skew.2SE | -1.0212 | 1.606 | 0.8687 | 0.0836 | -3.727 |
| Kurtosis | 5.4081 | 11.587 | 3.9653 | 3.3145 | 5.0668 |
| Kurt.2SE | 16.9407 | 36.296 | 12.4212 | 10.3827 | 15.8716 |
| Normtest.W* | 0.9452 | 0.8225 | 0.9371 | 0.965 | 0.9434 |
| ***Unit Root Tests*** | | | | | |
| ADF-GLS | -29.95*** | -27.44*** | -29.33*** | -33.32*** | -34.00*** |
| KPSS | 0.16*** | 0.13**** | 0.37*** | 0.13*** | 0.23*** |

*Note: Normtest.W* show that normality is rejected at all standard levels of significance. [***] indicate significance at 5% levels.*

**Table 4.3 Total spillover and Net spillover indices between higher moments of select African equities and the US**

| | | Panel A | | | | | |
|---|---|---|---|---|---|---|---|
| **A** | Egypt | Kenya | Nigeria | South Africa | US | FROM_ABS[a] | FROM_WTH[b] |
| | | *Band 1: 3,14 to 0,79; Corresponds to 1 to 4 weeks* | | | | | |
| Egypt | 71,9 | 0,49 | 0,52 | 0,45 | 0,38 | 0,37 | 0,49 |
| Kenya | 0,06 | 68,11 | 1,41 | 0,12 | 0,38 | 0,39 | 0,52 |
| Nigeria | 0,81 | 1,2 | 70,9 | 0,18 | 0,08 | 0,45 | 0,6 |
| South Africa | 0,27 | 1,57 | 0,68 | 56,37 | 20,25 | ***4,55*** | ***6,07*** |
| US | 0,24 | 2,04 | 0,22 | 19,3 | 56,81 | ***4,36*** | ***5,82*** |
| TO_ABS[a] | 0,28 | 1,06 | 0,57 | 4,01 | 4,22 | **10,13** | |
| TO_WTH[b] | 0,37 | 1,41 | 0,75 | 5,35 | 5,63 | | **13,51** |
| **Net** | -0,091 | 0,666 | 0,113 | -0,545 | -0,142 | | |
| | | Panel B | | | | | |
| **B** | | *Band 2: 0,79 to 0,06; Corresponds to 4 to 52 weeks* | | | | | |
| Egypt | 16,43 | 0,25 | 0,4 | 0,07 | 0,15 | 0,17 | 1,05 |
| Kenya | 0,05 | 18,63 | 0,93 | 0,01 | 0,03 | 0,21 | 1,24 |
| Nigeria | 0,41 | 0,4 | 16,87 | 0,03 | 0 | 0,17 | 1,01 |
| South Africa | 0,08 | 0,58 | 0,21 | 9,64 | 3,44 | ***0,86*** | ***5,2*** |
| US | 0,16 | 0,86 | 0,13 | 3,89 | 9,25 | ***1,01*** | ***6,08*** |
| TO_ABS[a] | 0,14 | 0,42 | 0,34 | 0,8 | 0,72 | **2,42** | |
| TO_WTH[b] | 0,85 | 2,53 | 2,02 | 4,82 | 4,36 | | **14,58** |
| **Net** | -0,033 | 0,214 | 0,167 | -0,063 | -0,285 | | |
| | | Panel C | | | | | |
| C | | *Band 3: 0,06 to 0,00; Corresponds to 52 weeks to infinity* | | | | | |
| Egypt | 8,48 | 0,14 | 0,23 | 0,03 | 0,08 | 0,1 | 1,13 |
| Kenya | 0,03 | 9,7 | 0,53 | 0,01 | 0,01 | 0,12 | 1,36 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Nigeria | 0,22 | 0,22 | 8,68 | 0,01 | 0 | 0,09 | 1,08 |
| South Africa | 0,04 | 0,31 | 0,11 | 4,75 | 1,69 | ***0,43*** | ***5,09*** |
| US | 0,09 | 0,47 | 0,08 | 1,93 | 4,54 | ***0,51*** | ***6,05*** |
| TO_ABS[a] | 0,08 | 0,23 | 0,19 | 0,4 | 0,36 | **1,25** | |
| TO_WTH[b] | 0,92 | 2,69 | 2,23 | 4,68 | 4,19 | | **14,71** |
| **Net** | -0,018 | 0,113 | 0,097 | -0,035 | -0,157 | | |

Note: [a] *To Absolute* (TO ABS) quantifies skewness/kurtosis spillovers from one country j to other countries. *From Absolute* (FROM ABS) quantifies skewness/kurtosis spillovers from other nations to nation j. [b]*Within to* (TO WTH) quantifies skewness/kurtosis spillovers from nation j to other nations, considering from own innovations to nation k. *Within from* (FROM WTH) measures skewness/kurtosis spillovers from other countries to country j, including from own innovations to country k. The biggest influences of markets per frequency band are emphasised in bold italics.

**Table 4.4 Pairwise net directional spillover between higher moments of select African equities and the US**

*Band 1: 3,14 to 0,79; Corresponds to 1 to 4 weeks*

| | | | | |
|---|---|---|---|---|
| Egypt-Kenya | Egypt-Nigeria | Egypt-South Africa | Egypt-US | Kenya-Nigeria |
| 0,087 | -0,059 | 0,036 | 0,028 | 0,043 |
| Kenya-South Africa | Kenya-US | Nigeria-South Africa | Nigeria-US | South Africa-US |
| -0,29 | -0,331 | -0,1 | -0,029 | 0,19 |

*Band 2: 0,79 to 0,06; Corresponds to 4 to 52 weeks*

| | | | | |
|---|---|---|---|---|
| Egypt-Kenya | Egypt-Nigeria | Egypt-South Africa | Egypt-US | Kenya-Nigeria |
| 0,04 | -0,002 | -0,003 | -0,002 | 0,107 |
| Kenya-South Africa | Kenya-US | Nigeria-South Africa | Nigeria-US | South Africa-US |
| -0,114 | -0,167 | -0,037 | -0,026 | -0,09 |

*Band 3: 0,06 to 0,00; Corresponds to 52 to infinity weeks*

| | | | | |
|---|---|---|---|---|
| Egypt-Kenya | Egypt-Nigeria | Egypt-South Africa | Egypt-US | Kenya-Nigeria |
| 0,022 | 0,001 | -0,002 | -0,003 | 0,061 |
| Kenya-South Africa | Kenya-US | Nigeria-South Africa | Nigeria-US | South Africa-US |
| -0,062 | -0,091 | -0,02 | -0,015 | -0,049 |

The general conclusion of these observations is that connectedness was strong and weak at various periods in pairwise connectedness in the markets under study and not only during the global financial crisis of 2007-2009. In addition, based on these observations, these selected African markets do not clearly and significantly concur with the conclusion made by Boako and Alagidede (2017) who argued for post crisis contagion or connectedness.

### 4.4 Conclusion

This study, rather than merely acknowledging higher moments in the explanation of risk transmission propagation mechanism as most of the studies in risk transmission and contagion, seek to quantify connectedness and the significance of spillover between US and selected African markets as well as among African markets. The results observed in this study concurs with the finding by Mensah and Alagidede (2017) which have shown that there is indeed a strong spillover effect from the US to a select African markets, however, South Africa exhibited a relatively less impact during the period under study. The observations from the spillover table 4.2 contrast with most of the studies which show that indeed the US is a net transmitter of spillover. This may be due to the unique nature of the African markets such as lack of liquidity and relatively less trading deals with the US. The findings also reveal that most of the contagion took place in periods away from the global financial crisis. This further strengthen the concept of post crisis contagion in the literature.

# Chapter 5: Conclusion and Recommendations

## 5.1 Background Summary

Although there has been a significant growth in the literature covering African equity markets and economy in recent years, the studies investigating the behaviour, risk transmission mechanism and propagation methods of spillover or contagion in African are still relatively scanty compared to the other emerging market regions and countries. In addition, the past decade has seen African countries emerging as the fastest growing economies in the world. This has also resulted in an increase in investment interests from global investments towards some of these African markets. Further, this warrant more interest to be raised in studying risk transmission techniques and mechanisms in Africa.

Another reason for interest in Africa stems from conclusions by Assaf and Cavalcante (2005) and Kuttu (2018) point out the uniqueness of African markets relative to advanced markets such as industrial structure. These unique traits underlying African equity markets may contribute to different dynamics driving the returns and volatility. This difference in market characteristics warrant the need to investigate co-movement and spillover between US (a developed market) and Africa (an emerging market) especially considering the most recent global financial crisis. Even the few studies on Africa such as by Mensah and Alagidede (2017) pointed out that the extreme stock price movements in the advanced market did not exhibit spill over effects on Africa’s emerging stock markets. These results gave an opinion that, apart from South Africa, African markets are immune to risk spill over from advanced markets. These unique and rather “Afro-centric” traits add to the need to investigate more on African markets.

Another perspective on African equity markets is that, studying these markets is vital for risk management, portfolio diversification and policy creation and implementation. In addition to the motivations for this study on African markets, the concept of defining risk contagion has been contentious among economists and across finance literature. Forbes and Rigobon (2001;2002) contributed significantly to the definition of contagion by attempting to highlight the difference between contagion and connectedness. In other words, they argue that connectedness is more prevalent across markets rather than contagion across various market conditions of tranquil and volatile. This contribution further motivated this study to identify the risk propagation mechanism.

Shen (2018) also pointed out that most studies on volatility and risk transmission focus on first and second order moments which does not take into consideration the third and fourth order moments. This study attempted to go beyond these first and second order moments as well as going beyond just correlation by using higher order moments to identify the propagation mechanisms. Moreover, the observation by Mensah and Alagidede (2017) , of asymmetric dependence which suggested that stock return co-movement varies in bearish and bullish markets further strengthened a need to investigate spillover in Africa along this direction using frequencies to account for time-varying and higher order spillovers to account for asymmetric dependence.

## 5.2 Summary of the key findings

This study intended to examine interdependence and the roots of contagion in African (emerging markets) equities markets through higher moments. Moreover, interdependence and contagion are studied through investigating the behaviour of distribution among and between markets. One of the key approaches used is the pairwise spillover skewness measures which assisted in establishing the connectedness in these markets. We compute weekly time series and estimates of weekly skewness. The data period is from 25 November 2001 to 30 December 2018. This period covers some of the most recent financial crisis such as the global financial crisis of 2007 to 2009 as well as the Eurozone crisis of 2011 to 2012. By covering these periods, it became easier to investigate the recent notion of post crisis contagion such as the one suggested by Boako and Alagidede (2017). The time-varying frequency-domain technique by Baruník and Krehlík (2018) is applied to investigate spillovers in these markets.

The results showed that except South Africa, there is less influence from the US in terms of risk transmission and spillover, in line with the observation by Mensah and Alagidede (2017). Based on frequency weighted spillover, the results showed that risk propagation to Africa is weak across all three frequency bands of short-, medium- and long-term. In fact, in isolation this spillover data has shown weak feedback effect from these selected African markets during the time under study. In other words, the spillover skewness measures indicated that US was a net recipient. These results are in contrary to the notion of many studies that risk can only be transmitted from a bigger to smaller market. However, the pairwise higher moment values indicated that indeed South Africa was influenced by shocks in the US while the rest of the selected African markets did not exhibit any significant impact. This may be explained by the notion of the uniqueness of African markets and the degree of development of these markets.

## 5.3 Recommendations

The increasing inter-connectedness among the global markets due to inter-national transactions, trans-frontier investments and trading means that not only is there a risk (downside) transmission only but also an 'upside' transmission. This study applied a methodology by Baruník and Krehlík (2018), however the technique used only focus on spillovers without breaking down the cause of these spillovers. The contingent theories such as the one suggested by Forbes and Rigobon (2001;2002) attempted to identify the specific origin of risk propagation, however, this topic of breaking down spillover to specific causations such as event studies is still contentious. This study therefore did not do justice in establishing whether this spillover was a constructive or adverse one especially that the results showed some of the significant net receipt and transmissions taking place in periods far from the known crisis for example in 2003 as noted in the preceding chapter. By looking into the causes of net recipient and net transmission of spillover, this study can be improved significantly and that will result in a better understanding of the cause of spillover propagation.

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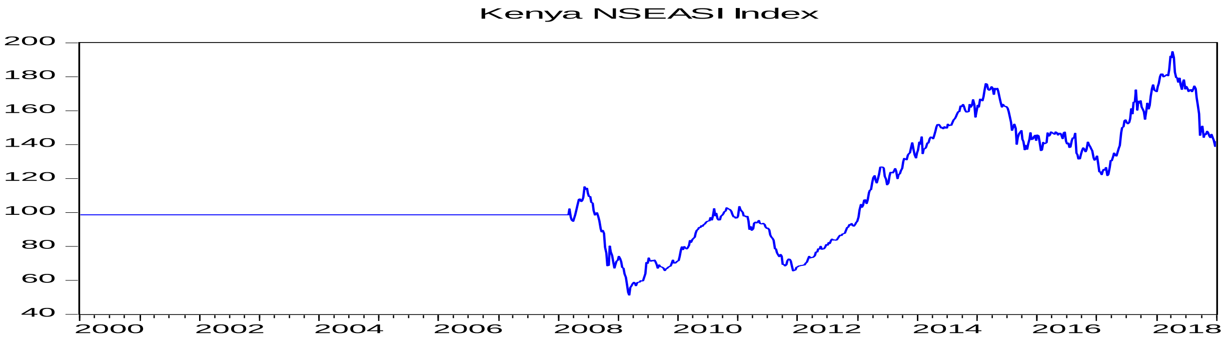
## Appendices

### Figure 4.1 Price Series: Select African markets and the U.S.

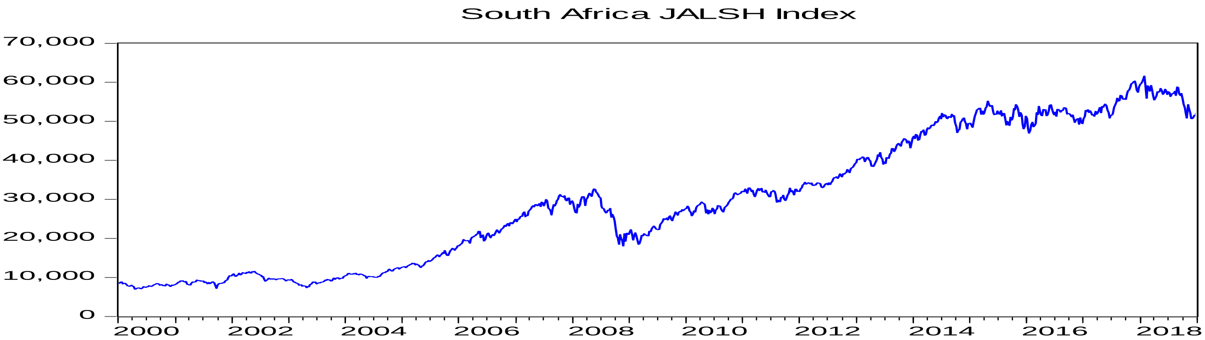
Egypt


Kenya




Nigeria

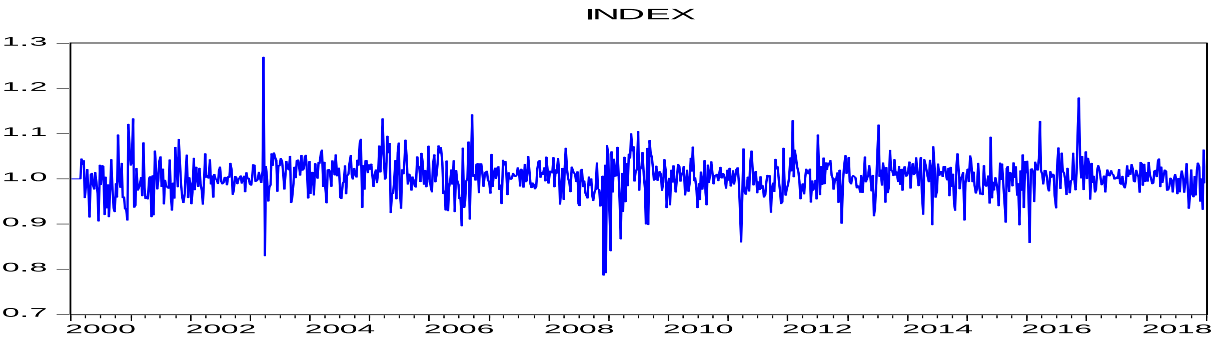

South Africa



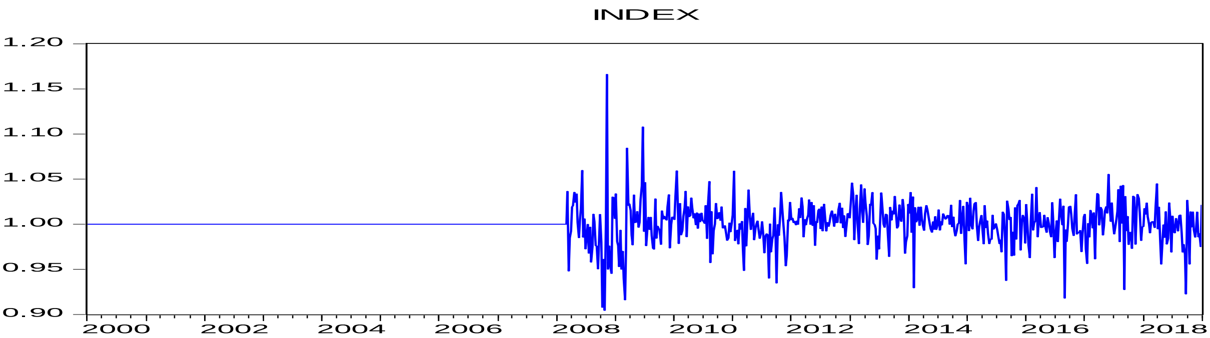
United States of America (U.S.)


**Figure 4.2 Log-return series: Select African markets and the U.S.**

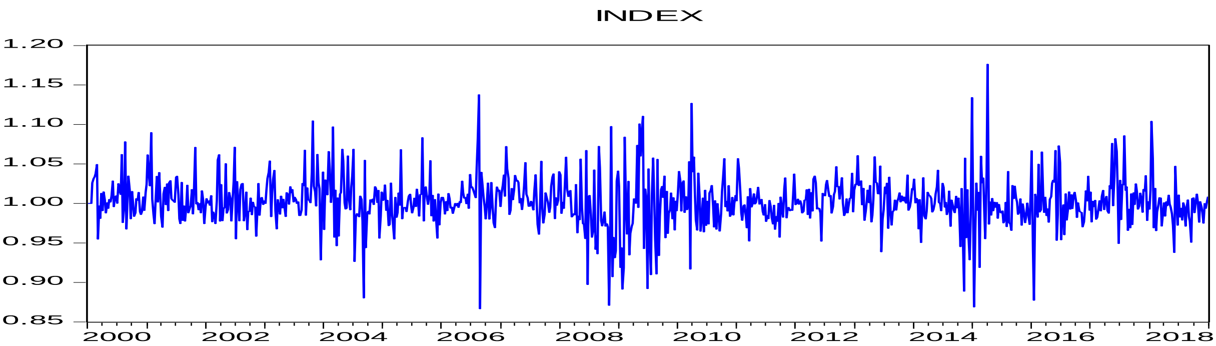
Egypt



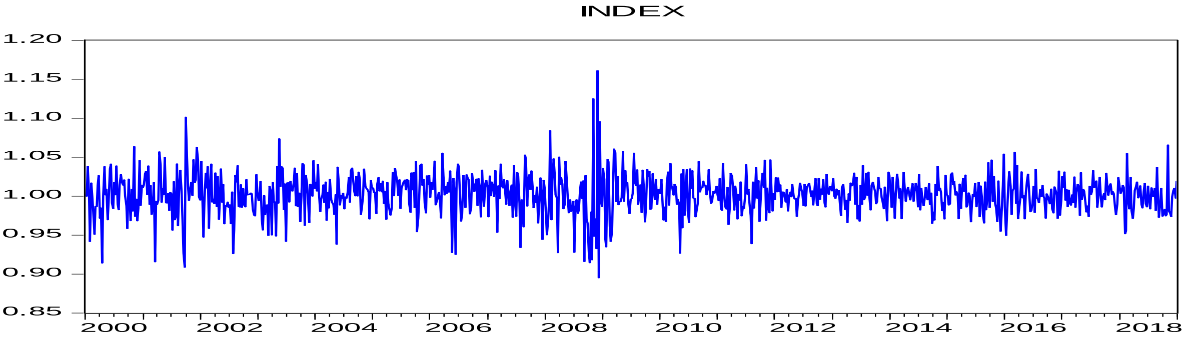

Kenya




Nigeria



South Africa




U.S.