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**ANALYSIS OF VOLATILITY SPILLOVER FROM MARKET TO MARKET IN
THE EAST AFRICA CAPITAL MARKETS**

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101817



**Submitted in partial fulfillment of the requirements for the Degree of Master of
Commerce at Strathmore University**

Strathmore University Business School

Strathmore University

Nairobi, Kenya

May 2020


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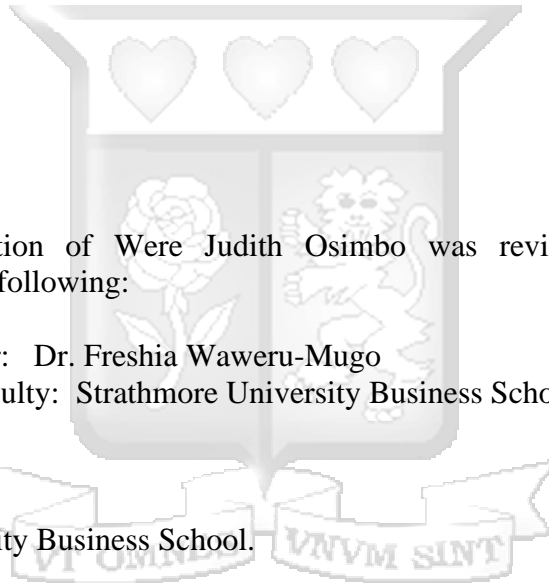
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Abstract

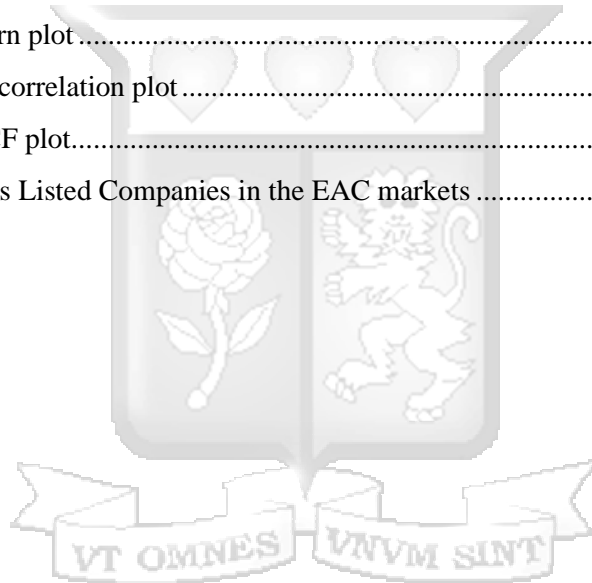
The existence of spillover effects is created by co-movement in the international stock prices and for international portfolio diversification to be considered effective, the level of spillovers among stock markets need to be so low or close to nonexistent so that one national market that is performing poorly can be hedged by the international market. The study purposed to model volatility effects between stock markets in the East African securities markets and analyze the behavior of volatility spillover and volatility persistence. The study was guided by three theories, the Efficient Markey Hypothesis, Random Walk Hypothesis, and the Arbitrage Pricing Theory. Four markets in East Africa were studied namely NSE, USE, DSE and RSE. Data comprising of the closing daily stock indices was obtained from secondary sources for the sample period of 2009 to 2019. The Exponential Generalized Autoregressive Conditional Heteroscedastic (E-GARCH 1,1) model and the Glosten, Jagannathan and Runkle Generalized Autoregressive Conditional Heteroscedastic (GJR-GARCH 1,1) model were used to model the asymmetric volatility and volatility persistence between the markets and was estimated using R. These models were selected based on empirical results which showed the GJR-GARCH model as the best fit for RSE and the E-GARCH model as the best fit for NSE, DSE, and USE. The findings show existence of volatility asymmetry in NSE, USE, and DSE, RSE. NSE, USE, and DSE showed positive volatility asymmetry with fat right tails. For RSE, bad news has larger effects than good news. Further, the results also show the presence of volatility persistence in the four markets, with some experiencing larger persistence than others. This indicates that turbulence takes a long duration to settle down in these markets. The study recommends regime specific volatility spillover modelling or Granger causality models for further analysis.

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List of Abbreviations

| | |
|----------|---|
| ARCH | Autoregressive conditional heteroskedasticity |
| BRIC | Brazil, Russia, India, China |
| BRVM | The Bourse Régionale des Valeurs Mobilières |
| CEE | Central and Eastern Europe |
| CMA | Capital Markets Authority |
| DFI | Direct Foreign Investment |
| EAC | East African Community |
| EASEA | East African Stock Exchange Association |
| EASRA | East African Securities Regulatory Authority |
| E-GARCH | Exponential Generalized Autoregressive conditional heteroskedasticity |
| EMH | Efficient Market Hypothesis |
| EU | European Union |
| GARCH | Generalized Autoregressive conditional heteroskedasticity |
| GCC | Gulf Cooperation Council |
| GFC | Global Financial Crisis |
| GJRGARCH | Glosten, Jagannathan and Runkle-GARCH |
| MENA | Middle East and North Africa |
| OECD | Organisation for Economic Co-operation and Development |
| UK | United Kingdom |
| US | United States of America |
| VAR | Value at Risk |
| NSE | Nairobi Securities Exchange |
| USE | Uganda Stock Exchange |
| RSE | Rwanda Stock Exchange |
| DSE | Dar-Es Salaam Stock Exchange |

Acknowledgements

I am grateful to God for His grace throughout the entire journey. To my supervisor Dr. Freshia - Mugo Waweru, I am sincerely grateful for your support, guidance, and patience during the study. Many special thanks to Jael, Teresia and Kevin for supporting me in one way or another and finally, thanks to my mother Jane Muthoni Wachira for your prayers. Many thanks to my workmates, fellow classmates, and friends for the encouragement.

May the Lord bless all of you abundantly.



Dedication

This project is dedicated to my mother, Mrs. Jane Muthoni Wachira for believing in me when I had doubt, for her love, prayers, and support.



Chapter 1 : Introduction

1.1 Background of the Study

The recorded number of financial crises over time has raised concerns over the intensity and extents to which shocks emanating from one market are transmitted across the world. Considering the range of crises that have hit the worldwide financial markets since the Second World War to present, the 2007 US credit score crisis is viewed as the most critical with the largest magnitude that meets the canons of being named a Global Financial Crisis, therefore marking the start of the crisis whose effects became contagious throughout the global financial markets (Reinhart et al., 2008). Exponential increase in the degree of economic market integration arising from various factors like economic ties, financial deregulation, capital movement liberalization and increased international trade led to interlinking among developed markets and emerging markets (Huen et al., 2014; Jebran et al., 2017).

These processes of financial liberalization relaxed restrictions for ownership of assets by foreign investors which facilitated growth and development of capital markets. In conjunction to this, other measures such as trade and macro-economic reforms provided access to foreign capital in form of Portfolio investments and direct foreign investments into developing countries. This has contributed to the integration of the capital markets which play a very crucial role in development. Removing investment restrictions has allowed for international risk sharing and diversification (Giovannetti & Velucchi, 2013). According to EMH, integrated markets are more efficient than segmented markets whereby they are more responsive both to global and local events. Further interlinking between various markets allowed for sentiment and information sharing from market to market. Advancements in computerized technology and rapid methods of information processing and synthesis led to liberalization of domestic markets, which opened them up to vulnerably react promptly to shocks and news originating from the rest of the globe. This resulted to the development of strong linkages between stock markets around the world to grow. Strong linkages reduced the protection of local markets from any global external shifts whereas weak linkages between markets offered potential diversification gains to foreign investors (Choudhry & Jayasekera, 2014).

Hamao et al., (1990) assert that robust interdependence among economic markets could fundamentally adjust investor positions regarding the significance of foreign financial news, thereby increasing the correlation in volatility experienced within the markets and stock returns permanently. Relatedly, Engle et al., (1990) claim that close trade and investment links among other factors such as, growing financial market integration, market contagion, and international asset-pricing models may contribute to correlation between volatility and returns of two equity markets. In reference to movements in volatility, a financial market in one country might receive various effects from alterations in volatility of financial markets in other countries, a matter that is referred to as volatility spillover effects (Kalemli-Ozcan et al., 2014). Volatility describes the deviation of market returns from the expected value and can be either unconditional or conditional. Unconditional volatility means that the measure of dispersion is time-invariant; meaning the values of the variables will be the same no matter when they were observed. Conditional or stochastic volatility on the other hand implies that the measure of variability itself changes over time, and is randomly distributed (Daly, 2011).

Volatility is a fundamental notion in the discipline of finance and is synonymous with the measure of risk; hence, high volatility is perceived as a symptom of market disruption which depicts that securities are priced unfairly and the capital market is experiencing some anomalies. Due to this, a sound knowledge of volatility and its estimation is desirable for estimating the expected returns from a risky asset. Volatility has numerous financial applications; it plays a pivotal function in asset allocation under the mean-variance framework and is an important factor in derivatives market. Furthermore, volatility modeling gives a simple method for calculating value-at-risk of a financial position in risk management as observed by Matei (2009). With respect to time series data, modeling of volatility improves the efficiency of estimation of parameters and the accuracy of regime forecast. Volatility spillover happens when the price volatility in a particular market affects the price volatility in the rest (Trujillo-barrera et al., 2012).

Abhyankar (1995) stated that global volatility spillover and mean returns volatility analysis is essential due to several rationale. First, this analysis is necessary for the identification of the reasons behind the transfer of a market's financial disturbances to other related markets. Second, the systems of international price co-movements are of

interest to investors who invest in securities, which are traded across geographical boundaries. Third, electronic trading systems provide the opportunity for traders to trade securities from one exchange, outside of regular trading window, and trading on another national securities market located in a different country and time zone. Abhyankar, also says that the benefit or the possibility for global investors to gain from international portfolio diversification can be wiped out by co-movement in the international stock prices which creates the existence of spillover effects. For international portfolio diversification to be considered effective, the level of spillovers among stock markets need to be so low or close to nonexistent so that one national market that is performing poorly can be hedged by the international market.

Giovannetti and Velucchi (2013) conducted a study on the select emerging African markets namely Botswana, Kenya, Tunisia, Nigeria, Egypt, and South Africa on spillover effects of shocks from US, UK and China. They observed that new financial markets in Africa present attractive and profitable alternatives for international investors to diversify risk. At the same time, they have become more integrated with first-world financial markets, such that despite various claims that Africa would not get affected by the volatilities in the western world because they were at the edge of the globalization process, they also suffered from the effects of the 2008–09 crisis. This study portrayed the African Market as an avenue for international investors seeking to diversify their risk with Kenya and the US being termed as “volatility creators” and South Africa and China “volatility absorbers”. However, this study focused on a selection of African markets and did not include Tanzania, Uganda, and Rwanda, which in addition to Kenya are the focus of this study.

In a sectoral study in MENA (Middle East and North Africa), Hammoudeh et al., (2009) found that the banking sector was the least sensitive to own spillover. This could indicate opportunities for diversifying into the banking sector to minimize risk. An excellent reason for stakeholders to acquire cross- border securities is the potential for spreading portfolio risk, which can be heightened if investors have a decent comprehension of the origins and contributors of volatility between local markets and cross-market correlations (Balli et al., 2013). Few studies conducted on African markets mainly focused on the

highly capitalized markets like South Africa and Namibia (Humavindu & Floros, 2006). Their findings show low correlation between the two markets and no spillover effects suggesting that Namibian Stock Exchange, NSX is an attractive risk diversification tool in the regional markets. Li and Giles (2015) argued that if emerging markets were only slightly connected with the developed markets, external market movements may have reduced influence on the new markets, while those investors in developed market can take advantage of integrating emerging market securities in their portfolio, as diversification is a tactic which minimizes the exposure to market risk.

Other sub regions that have been integrated their market exchanges in Africa such as MENA, South Africa region, and BRVM have paved way for East Africa to incorporate an integrated platform which is being spearheaded by EASRA (East African Securities Regulatory Authority) for the East Africa region. EASRA was set up in 1997 with the mandate of developing a centralized marketplace for the East African Capital Markets and to shape the regulatory framework aimed at harmonizing integrated trade platforms to encourage cross-border trading. To this regard, the East African Stock Exchange Association (EASEA), was formed to champion this agenda among others such as restructuring IPOs within the region, to harmonize transaction costs and exchange rate risks for regional IPOs.

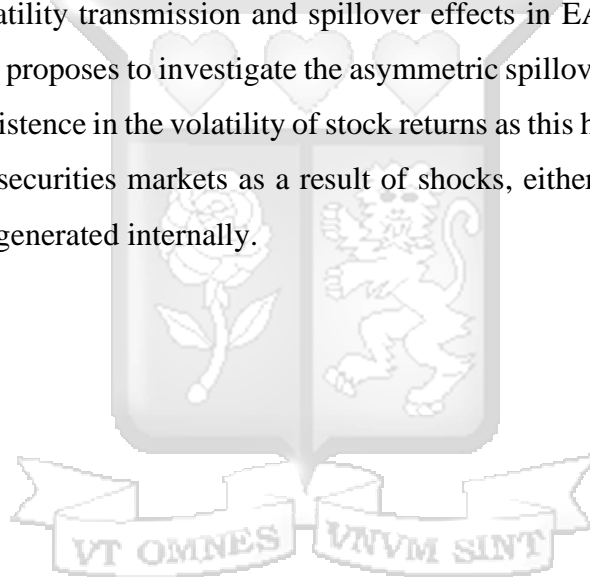
These integration developments trigger a few captivating questions. Have these integration efforts generated the anticipated outcome for investors, policy makers and their respective national governments? Can foreign investors from developed markets benefit by securing portfolios in these emerging markets for diversification? Lastly, from these developing countries perspective, what is the implications of relaxed policies, demutualization, direct foreign investments on the financial markets and ultimately on economic growth? Bekaert and Harvey, (2003) argue that the entry of foreign investors into these local markets will bid up the local stocks' prices. Another impact could be herding by foreign investors into these markets for diversification potential while rational investors will avoid inefficient sectors. On the upside, this can reduce the cost of equity capital which in turn may upsurge investment and in the long run increase economic welfare.

1.2 Problem Statement

Co-movement in the prices of securities which are the origin of the spillover effects across the markets has been attributed to several factors such as cross-listing of companies and entry of foreign investments into local markets. The skill of creating a good diversified portfolio requires that the impact of spillovers among stock markets gets minimized or eliminated such that poor stock performance in a single stock market can be hedged by other securities in the rest of the markets in which one is invested. Therefore, theory on market spillovers is at the core of interest for investors and policy makers because such knowledge of the international financial exchanges is useful for making decisions to reduce portfolio risk exposure (Huen et al., 2014).

The focus on past studies has been in developed markets such as the United States, Japan, and the United Kingdom. Asian markets have also received a fair share of attention but the African market, particularly East Africa has not been studied as much. Yunvirusaba et al., (2019) conducted a similar study on the linkage's dynamics using the VAR and DCC - GARCH models on three East African securities exchanges, NSE, DSE and USE. They found existence of bi-directional causality between NSE and DSE and unidirectional causality between USE and DSE, with no evidence of co-integration among the three indices. This indicates that these three exchanges depict a relationship in the short run however, in the long run the relationship fades and ceases to exist. The use of the DCC model has been challenged by Caporin & McAleer, (2013) who have cited ten limitations of applying the Dynamic Conditional Correlation (DCC) for estimating time varying conditional correlations. They show how the DCC model is useful as a diagnostic check and it should not be used as a model. (Marselline, 2019) Studied co-integration and volatility in the East African markets, using South Africa as a benchmark on performance for African markets with the aim of determining the level of integration in terms of least integrated to completely integrated markets as well as the causal relationship of volatility spillover between the Johannesburg Exchange and the East African markets. They found that shocks emanating from JSE have exceptionally low impact on the East African markets and vice versa. This indicates that these markets are independent therefore providing avenues for portfolio diversification opportunities. According to the East Africa

Securities Regulatory Authority (EASRA), these markets even when combined are small compared to others in Africa like South Africa and Nigeria, which can provide insight as to why studies have not been extensive in these markets due to their size and liquidity challenges. The impact from the 2007-2009 crisis on the East Africa market shows the need for market players to understand the impact of volatility spillover effects to their investment (Drummond & Ramirez, 2009). Results from empirical and theoretical literature are mixed, some pointing to interdependence of markets and some pointing to non-existence of dependency implying minimal market integration. The East Africa markets integration has been an ongoing initiative to harmonize regulations and unify the markets, which has not been short of its fair share of challenges yet limited literature is available on volatility transmission and spillover effects in EAC markets (ESMID_IFC 2007). The study proposes to investigate the asymmetric spillover effect in the East Africa markets and persistence in the volatility of stock returns as this has a major effect on future volatility of the securities markets as a result of shocks, either originating from another market or being generated internally.



1.3 Research Objectives

1.3.1 General Objective

To assess the behavior of asymmetric volatility of stock returns in the East Africa capital markets in Kenya, Tanzania, Rwanda, and Uganda.

1.3.2 Specific objective

- i. To assess spillover effect between NSE, USE, DSE, and RSE markets
- ii. To assess the extent of volatility persistence in the East Africa stock markets
- iii. To evaluate the leverage effect in the East Africa stock markets

1.3.3 Research Questions

- i. Is there evidence of asymmetric volatility spillover on the East Africa market returns?
- ii. Do the East African markets exhibit volatility persistence?
- iii. To what extent is volatility asymmetry in the East Africa stock markets?

1.4 Scope of the study

The study sought to analyze volatility spillover effects on four main capital markets in East Africa namely NSE, USE, DSE, and RSE. The independent variables are the stylized facts of time series data, asymmetric volatility, and volatility persistence. The study used market share indices from Kenya – NSE All Share Index, Tanzania – DSE All Share Index, Uganda – USE All Share Index and Rwanda – RSE All Share Index. See Appendix A. The secondary data used for the study was collected for the period of January 2009 to December 2019 for NSE, USE, and DSE and from 2013 to 2019 for RSE. RSE is the youngest among the four markets therefore the data available was limited in comparison to the rest. The period covered is characterized by internal and external shocks in the four countries which contribute to volatility in the four markets. The four markets have also experienced market reforms during this period, championed by EASRA to expedite their

integration.

1.5 Significance of the study

Findings from this study will be beneficial to several market participants according to the findings and conclusions of this study.

1.5.1 Market regulators

The findings of the study will be of importance to the regulatory bodies and policy makers in the EASA. It will shed light into how the performance of the markets will be impacted by integration thereby formulate conducive practices and policies to favor standard practices capable of improving joined market performance. Policy makers and regulators are reliant on market estimates of volatility as a gauge or benchmark for the vulnerability and exposure of the financial markets and the economy to externalities.

1.5.2 Fund managers

Fund managers are analysts of global financial trends in emerging markets. Portfolio managers can use this to develop their trading strategies as well as construct portfolios (Soler, 2009). First, forecasting of volatility of financial assets is necessary for these fund managers who are representative economic agents as it assists with decisions on portfolio risk management decisions by rational investors. Volatility is critical to fund managers because it gives a measure of risk exposure for their investments in the markets. Finally, volatility affects the economy as a whole and understanding it is an advantage for any investor. Portfolio managers in developing markets need to adjust diversified portfolios in times of high volatility in the markets from which there is a high volatility spillover.

1.5.3 Investors

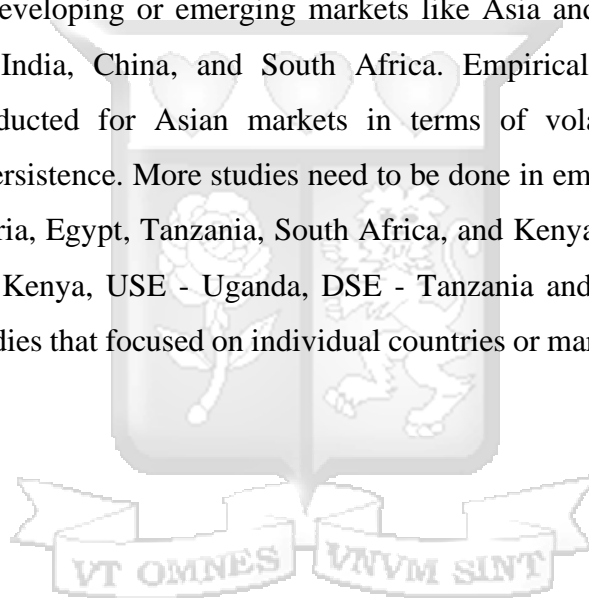
Investors can use this as a source of information for international portfolio diversification and as a guide to asset allocation strategies. Additionally, since the release of the first Basle accord in 1996, volatility forecasting is at the core of risk management. It is useful to know the volatility of the underlying asset of an option because theoretically, it is vital in pricing of derivative securities.

1.5.4 Academicians

Researchers can benefit from the study by getting more information on volatility effects in the East Africa markets that will serve as a reference for further research. Different models other than the ones utilized in this study can be employed. The findings of the study bridge the knowledge gap on volatility spillover effects in the East African markets by informing empirical literature on volatility spillover in these markets.

1.6 Chapter Summary

Volatility spillover effects is a broad area that has been widely studied. The focus has been on developed markets like the United States, Europe, Japan (also known as OECD countries) and developing or emerging markets like Asia and BRIC countries –that is Brazil, Russia, India, China, and South Africa. Empirical studies have also been extensively conducted for Asian markets in terms of volatility spillover volatility clustering and persistence. More studies need to be done in emerging stock exchanges in Africa like Nigeria, Egypt, Tanzania, South Africa, and Kenya. This study focused on 4 markets, NSE - Kenya, USE - Uganda, DSE - Tanzania and RSE - Rwanda and will contribute to studies that focused on individual countries or market segments within these countries.



Chapter 2 : Literature Review

2.1 Introduction

Extensive work on research conducted on asymmetric volatility spillover effects were in developed markets, developing markets and emerging markets. The theories considered for this research are Efficient Market Hypothesis, Random walk Hypothesis and Arbitrage Pricing Theory. Research work regarding volatility spillover effects on markets as done by other researchers is also reviewed together with volatility persistence. This chapter identifies the research gap and identifies the relationship between variables using a conceptual framework as well as a summary of the findings of empirical studies.

2.2 Theoretical Framework

2.2.1 *Efficient Market Hypothesis*

The Efficient Market theory indicates that stock prices echo both publicly available and private information in the market. It was first propositioned by Fama (1965) by noting that current information is instantly incorporated in prices of shares such that no investor can use private information to have an advantage over others and make gains using this information. The random walk theory dictates that successive future price changes are variables that are randomly distributed and independent. Independence in statistical terms means that the probability distribution during period t of price change is autonomous from price changes in past periods. The simple implication of this is that consecutive price changes have no memory, therefore past news cannot be utilized to predict the future prices of a security. New information such as new developments in research, tariff imposition on industries or countries by foreign countries, or trends in the market can affect intrinsic values of securities, however actual market prices may not necessarily correspond to intrinsic values hence intrinsic value is treated as noise in the market. Fama (1970) advanced on this previous work by his article Efficient Capital Markets where he categorized the market in three subsets of efficiency namely the weak, semi-strong and strong form of efficiency. In the weak form efficiency, historical information is reflected in the prices. The semi-strong form of efficiency reflects both current information that is

available publicly such as stock splits announcements, dividend announcements and so on together with historical information in the security prices. The strong form of efficiency incorporates historical information, current information that is publicly available as well as private information, which implies that both expert and novice investors, will earn comparable returns despite their different levels of expertise. For price adjustments to be considered efficient, the following conditions should be in place. Firstly, there are no transaction costs in market securities, secondly, all market participants have access to information at no cost and lastly, all market participants are in a consensus on the implications of current news on current security prices and the distribution of future security prices. All conditions held constant; such a market is considered efficient as the current price fully reflects all available information. Since in practice these conditions may be violated for one reason or another, it is fortunate that these conditions create a favorable environment sufficient for an efficient market but are unnecessary.

In his sequel on efficient capital markets, Fama (1991) states that literature of market efficiency should be evaluated based on how it progresses the ability of an investor to describe the behavior of returns over time such as seasonality like the January effect and volatility. In the sequel, Fama says that event studies stipulate more accurate signals on efficiency. On volatility tests, Fama asserts that volatility tests are a useful mechanism of demonstrating that returns are variable over time. Through EMH, rationality is applied to the pricing of assets in the markets (Malkiel, 2005). Opportunities for abnormal profits are eliminated because prices of all securities include all available information in a financial market that is regarded as efficient. It is however important to note that the theory has its shortcomings such as its inability to incorporate investors behavioral patterns. This implies that investors' decisions tend to be influenced more by emotions rather than rationality (Malkiel, 2003). In this era of multiple sources of information including social media, it is challenging for investors to keep up with information. Literature demonstrated that the effect of good news is shorter than that of bad news, meaning that the market's reaction to news is reliant on the type of news and the transmission tends to be more lagged for bad news. Critics also ride on the notions that it is also not able to explain speculative bubbles, volatility clustering and excess volatility.

The extent of co-movement of stock price of indices in developed and emerging countries is of relevance to individual investors, the policy makers, forecasters, the researcher and more lastly but not least by investment banks that are specializing in new financial innovations to minimize risk (Natarajan et al., 2014). They support that there's existing interdependence among national stock markets where news received in one market is perceived to be fundamental to prices in other markets. Firstly, the transmission mechanism presents essential awareness about market efficiency. In an efficient market, and in the absence of time varying risk premium, it should be impossible to forecast the value of returns of a particular stock using the lagged returns of another (Harris & Pisedtasalasai, 2006). A spillover effect evident in returns suggests the existence of an exploitable trading opportunity and, if this opportunity provides profits that exceed transaction costs, potentially signifies evidence against market efficiency (Choudhry & Jayasekera, 2012). Secondly, transmission mechanisms may be valuable for portfolio asset allocation owing to its inherent implications of risk. Engle et al., (1990) claim that market inefficiency may be reflected through meteor showers. Meteor showers represent a phenomenon of intra-day volatility spillovers from one market to another market. The reasons for occurrence of meteor showers on financial assets are linkage of economies through global news, gradual dissemination of private news by rational investors, stochastic policy coordination among industrialized countries where a policy change or announcement in one country causes another country to respond causing volatility spillover. This is experienced in countries that have elements of political rivalry as observed by Choudhry (2004) in their study on volatility transmission. On the other hand, countries that are friendly experience no meteor shower effect but only experience heat waves since the effect of policy change is known to the involved governments which adjust accordingly to experience pareto gains from the policy change or announcement. Choudhry, therefore recommends deterministic coordination when setting policies between countries to minimize negative effects of news and policy change to other countries. As long as the countries are geographically close and have existing trade links, it is possible for mistakes in one market that may be brought about by trends, herding, speculative and noise trading to be transmitted to other markets when the price movements are impacted. Results from his study shows unidirectional volatility and mean return

spillover from the US to the smaller emerging markets and little evidence of volatility and mean return spillover from the six emerging markets to the US. These may be due to increased integration of financial markets, policy coordination, economic, investment and trade links between countries.

The relevance of the theory for this study is that it describes the different forms of market efficiencies, which are relevant in signaling the level of financial market integration. In strong form of efficiency, all information is incorporated in the prices of securities therefore it is unlikely for investors to make any gains by either using past information to predict the future behavior of prices or to use private information to make abnormal returns.

2.2.2 Arbitrage Pricing Theory (APT)

The Arbitrage Theory was introduced as a substitute to the asset pricing model (mean variance model) presented by Sharpe, Treynor and Lintner which asserts that the expected returns are linearly related to a number of systemic factors (k) and the exposure to these factors is measured by factor betas.

$$E(r_i) = r_f + \lambda_1\beta_{i1} + \dots + \lambda_k\beta_{ik} \quad (1)$$

Where:

β_{ik} is the beta or risk exposure on the k th factor

λ_k is the factor risk premium for $k = 1, 2, 3, \dots, k$

When $k=1$ and f_1 is the market portfolio factor, the APT implies the 'Capital Asset Pricing Model.

If the first asset has only a unit beta risk on the second factor, i.e $\beta_2 = 1$ and zero betas on all the other factors, then its expected return will be:

$$E(r_i) = r_f + \lambda_2 \quad (2)$$

This implies that mispriced securities present short-term, risk-free profit opportunities Ross (1976). If the assets are mispriced so that the expected returns of these assets deviate from what is accounted for by their beta risk, smart investors can construct an arbitrage

portfolio and make abnormal returns. Unlike the Capital Asset Pricing model which uses a single factor, APT is a multifactor model that incorporates some underlying assumptions such as homogeneity of expectations, liability limitations, among others. Arbitrage Pricing Theory's ability to include multiple factors in the model has made it influential in the pricing of assets. APT is one of the tools used in asset pricing which has a number of assumptions where first, there is a risk free interest rate with which individuals can lend and borrow freely, agents cannot influence the prices, a security can be sold short with the seller receiving all the proceeds, there are no taxes and no transaction costs (Cox & Ross, 1976). This theory however has limitations which include not explicitly stating which factors affect returns therefore leaving it open to individuals to determine them and interpret them.

Choudhry and Jayasekera (2012) examined asymmetric volatility in the US and UK where they found that the market efficiency level declined significantly as the economies slid into a recession during the crisis period. This decline implied that prices delayed converging to their intrinsic values which suggests to investors arbitrage opportunities especially for hedge funds and speculations. On the other hand, studies like (Malkiel, 2003; 2005; Natarajan et al., 2014) are strong proponents of the Efficient Market Theory. Malkiel (2005) points out that if markets were unpredictable and if prices were irrational then there professionally managed investment funds would outperform passive index funds every time. He asserts that new information that is developing randomly will be matched with the price as well which will follow a similar pattern therefore no investor will be able to make above average returns at a lesser level of risk. In the African markets context, Appiah-Kusi and Menyah (2003) evaluated 11 African countries whereby their model accounted for time varying risk premium out of which the Nigeria, Ghana, Ivory Coast and Swaziland market's results indicated that they are not efficient. They however pointed out that after investors account for transaction costs and taxes, the opportunity of exploiting inefficiencies diminishes and therefore eliminating arbitrage. Piesse and Hearn (2005) cite evidence of financial markets intergration in Sub Saharan Africa, they also cite evidence of unidirectional and bidirectional spillovers between different countries. These observations indicate opportunities for arbitrage especially for cross listed companies exhibiting price differentials in rival stock markets. However, they also point out that these

markets are faced with challenges like weakness in broker capitalizaion which reduces the ability of investors to quickly respond to arbitrage opportunities.

Despite complaints by policy makers on negative effects of foreign investments resulting from liberalization Bekaert & Harvey (2003) were intrigued by the absence of evidence for negative implications of foreign investments made. Rational international investors are advised to be conscious of the effect of market integration which could potentially decrease their expected returns raise correlations between emerging market and global market returns. The proposition of the theory is that if the assets are mispriced so that the expected returns of these assets deviate from what is accounted for by their beta risk, smart investors can construct an arbitrage portfolio and make abnormal returns. Therefore, price differentials in rival markets indicate arbitrage opportunities for investors especially for cross listed companies which is also a signal of market efficiencies or the lack thereof.

2.2.3 The Random Walk Hypothesis

The Random Walk Hypothesis was introduced by (Bachelier, 1964). A sequence of random variables is referred to as a random walk if the increments of the variables are independently distributed. The theory holds that for a security price to exhibit randomness, the security price changes be independent and constitute a probability distribution. Fama, (1965) later took up the study of the behavior of prices on the normality of the distribution of share price changes found that there is no dependence among share prices. On the other hand Praetz, (1969) found some dependence in distribution but it was not large or widespread to be gainfully exploited. Highly non-normal and well-defined price distributions implies greater risk to the investor compared to normal price distributions. Market participants also contribute to the behavior of price distribution behavior, securities are not independent of the market participants behavior therefore they d not possess a “rational” value (Kassouf, 1968). Investors decisions are made using average estimates therefore a satisfactory price theory for liquid assets should incorporate individual behaviors of investors operating in varying levels of anticipation. An investor may be rational in his investment decisions but the collective action of other investors resulting to changes in prices should also be considered when investing in highly liquid assets.

The theory proposes that when prices are exhibiting randomness and independence, investors will not be able to beat the market. The importance of this to regulators and policy makers is to ensure that these markets are continuously monitored to increase efficiency levels.

2.3 Empirical Framework

Empirical studies on volatility spillover have been carried out on a multidimensional manner by different researchers; while some test spillover on markets in relation to their geographical setting; others focus on market size classification such as developed, emerging, frontier, developing and undeveloped financial markets. This section discusses various literature on some stylized facts of time series data, volatility modelling and an overview of the East African markets featured in this study.

2.3.1 Asymmetric volatility spillover in developing and emerging markets

Cox and Ross (1976) pioneered the modelling of stock return volatility as being negatively correlated with stock returns. Further, Christie (1982) based their explanation of the asymmetric volatility properties of individual stock returns on leverage supporting the leverage hypothesis. Christie explained that once the value of a stock drops indicating undesirable returns, the financial leverage goes up. This makes the security riskier which in turn increases its volatility. On the contrary, asymmetric volatility became synonymous with leverage effects. However, the nature of asymmetry of the return shocks response to volatility could simply be reflecting the presence of time varying risk premia (Campbell & Hentschel, 1992). The leverage theory argues that the changes in conditional volatility are caused by return shocks, while the time varying risk premium hypothesis claims that return shocks are caused by changes in conditional volatility which indicates that there is no clarity on which effect determines asymmetric volatility as both camps can only account partially for the volatility responses. To explain these contending arguments, Bekaert and Wu (2000) developed an experimental framework to simultaneously study volatility asymmetry at the market and portfolio level. Their findings showed that returns and conditional volatility are negatively correlated which means that volatility in equity markets is asymmetric which is explained by leverage effects and volatility feedback. They also affirmed that asymmetry is an important feature of stock market volatility in

both the US and Japan markets (Bekaert & Wu, 2000).

Engle et al., (1990) also early pioneers of the analysis of volatility spillover by defining and testing for dexterity, a form of market efficiency that requires instantaneous adjustment of asset prices in response to new information. If there is no new information, then there is no change in price experienced in an efficient market and old information cannot be used to forecast future asset prices. Explanations for volatility processes lie between entrance of shocks caused by new information and the speed of processing the information by the market. Depending on the transmission mechanism, information coming in in clusters may exhibit ARCH tendencies even in a perfect market. Their results indicated the existence of volatility spillovers between the US and Japan markets which could either be due to volatility clustering or stochastic policy coordination.

Developed markets are characterized by being highly liquid, diversified, and well-integrated with global financial markets and therefore tend to share information more intensively, compared to developing and emerging markets which are on average smaller. It is interesting to note that the proportion of internal shocks within the EU increased by the end of the 1990's which suggested that the degree of market integration increased which indicated that the local equity market returns can be explained by local factors as opposed to global market volatility spillover. This observation suggested reduced potential for international diversification Baele (2005).

Choudhry (2004) investigated the transmission of international stock market volatility and mean returns spillover from the US, a developed market and between the stock markets of long political rival countries in Europe, Asia, and the Middle East. The paired rivals, Jordan- Israel, Turkey- Greece and Pakistan- India are geographically close to each other and over the years have managed to maintain economic and trade links among them despite being in different continents across the globe. These emerging markets are considered as small based on their market capitalization and the US, a developed market which is large in comparison has historically maintained strong financial and economic links with all these six rival countries.

Volatility is a fundamental notion in the discipline of finance and is synonymous with the measure of risk; hence, high volatility is perceived as a symptom of market disruption which depicts that securities are not being valued equitably and the capital market is

experiencing some anomalies (Daly, 2011). Due to this, a sound knowledge of volatility and its estimation is desirable for estimating the expected returns from a risky asset. According to Abhyankar (1995), global spillover in and mean returns and volatility is important for numerous reasons. Firstly, it is instrumental in identifying the underlying factors that contribute to transfer of financial disturbances from one market to other markets, secondly, investors are keen on the dynamics of international price movements of securities traded across national exchanges and thirdly, with technological advancements in electronic exchange systems, investors have access to exchanges outside their normal trading time located in different time zones which has enabled them to trade in assets in a different exchange market. The analysis of volatility inter-dependence offers valuable insights into how information is conveyed and spread across markets including its inferences for portfolio choice and risk management (Natarajan et al., 2014). Globally, the subject of volatility spillover has sparked a lot of interest where inventions in one market gets transmitted to other markets and numerous studies were conducted in the US, Europe, and Asian markets on the spillover effects among international stock markets.

Soler (2009) focused on volatility in financial markets, using three special objectives. First, volatility transmission incurred in various financial markets and different asset categories, both in periods of financial stability and turmoil. Second, trading strategies influenced by the volatility spillovers, and lastly, the effect of monetary policy on intraday volatility. These varied but related issues were addressed taking into account the phenomenon of asymmetric volatility. In the last few decades, focus has shifted from the study of means of asset market returns to one which is interested in the return volatilities. The world is now more interested in modeling the conditional variance and developing various models which can address the issue of high levels of volatility. Unprecedented movements in the international stock markets now feature important news events that create disturbance in the domestic stock markets as news revealed in one country affects the stock prices in another country. The reason for this predicament is the real, productive, and financial linkage of economies. Additionally, the overreaction and noise trading are transmissible across geographical borders into foreign markets. Advanced computer technology and improved worldwide networking also produce similar effects as well as faster dissemination and quick processing of “news”. This has led to domestic markets to

react promptly to new information from international markets. Therefore, volatility becomes closely synchronized across national stock markets.

After studying the mean, volatility persistence and volatility spillover relationships between the stock indices in two developed countries; Japan and the US and two developing countries; Malaysia and China, Huen et al., (2014) findings showed a significant mean spillover that is bilateral between larger developed markets and smaller developing markets. It also showed that volatility spillover and-persistence within the developed markets was smaller compared to developing markets.

Similarly, Natarajan et al., (2014) examined mean and volatility spillovers between Germany, the USA, Brazil, Hong Kong and Australia and noted there existed a level of interdependence among national stock markets and highlighted innovations as a key source of stock market volatility. Their findings showed significant negative own spillovers in all five markets with the US market being the most influential among the markets. Other older studies that supported that markets influence each other include (Engle et al., 1990; Hamao et al., 1990; Booth et al., 1997) where they found mixed results of both unidirectional volatility spillovers from the larger markets to the smaller markets and own spillover in the smaller markets.

Özer et al., (2016) examined the German stock market and sixteen 'European stock markets using frequency domain causality approach. Their results indicated existence of both unidirectional and bidirectional volatility spillovers that varied across different periods. Another dimension of volatility transmission across markets is illustrated using a third-party trade perspective under volatility spillover theories. In this channel a crisis can be transmitted from one market to another even though the two countries are not linked directly through direct trade.

2.3.2 Volatility persistence and its impact to stock returns

This line of research also gained prominence due to the recurrent financial crises, which took a global toll. The most recent of them being the Subprime crisis of 2007-2008 and Eurozone crisis of 2009-2012. The impact of these studies is on international portfolio diversification, assessment of global risk, and working towards integration of global markets. In their IMF report, Drummond and Ramirez (2009) looked at the effect of the

global recession on East Africa Community countries, Kenya, Uganda, Tanzania and Rwanda and indicated that the crisis slowed down the economies of these countries, with the downturn mostly pronounced in Kenya resulting from decreased foreign direct investments. These countries responded to the crisis by easing monetary and fiscal policies.

Engle, (1982) pioneered the model for time varying trends of volatility in stock markets as conditional variance using the GARCH framework by introducing a maximum likelihood technique to estimate the ARCH model parameters and ratio test to ARCH effects which was later generalized to allow for a more flexible lag structure such that past conditional variances flow through to current conditional variances by (Bollerslev, 1986) and (Engle & Kroner, 1995). Al Janabi et al., (2010) study revealed that volatility fluctuates over different time periods (there is volatility persistence or time varying volatility) in both the GCC and MENA portfolios but it is not significant in explaining the expected returns outcome, implying that that stock returns are negatively correlated with volatility stock returns. Similarly to studies on stock return volatility and contagion, (Caceres, 2019) analyzed volatility spillover across exchange markets. Volatility spillovers were found to be asymmetric such that bad news in one market impacted the other market. They therefore recommended a multilateral monitoring mechanism that can prevent crisis from spillover effects to be designed.

Financial crises have also contributed to increased studies on stock markets volatility. The global, the Asian financial crisis, the Mexican crisis, the Russian debt crisis, Brazilian currency crisis were studied by Bala and Takimoto (2017) using various GARCH models observed that the global financial crisis did not significantly impact cross-market volatility in emerging markets, but had minor influence on own-volatility. These findings support the idea that investors can explore the option of diversifying their portfolios by investing in emerging markets to cushion their investments. Aggarwal et al., (1999) studied shifts in volatility of emerging markets stock returns and the events related with the increased volatility. They showed that big variations in volatility related to important country specific political, economic, and social events. These findings are important because they signify that unexpected events in emerging markets pose a threat to investors' portfolio returns. Wu (2001) investigated the determinants of asymmetric volatility in equity

markets and observed that asymmetric volatility is more prevalent during stock market crashes, volatility feedback is large during volatile periods and that combined with leverage effect they play a major role in generating asymmetric volatility. In contrast, Jebran et al. (2017) studied volatility spillover from calm to turbulent periods in Asian markets, their findings pre crisis and post crisis varied. Their results highlighted that volatility varied from calm to turbulent seasons, markets were more integrated in a crisis and negative shocks generate more volatility than positive shocks of the same scale. A study by Baillie and Bollerslev, (1990) looked at informational efficiency of markets to know whether news integration was immediate in major global foreign exchange rate markets, and the comparative importance of news associated with particular currencies and markets. They found out that there was volatility clustering caused by traders with diverse information trading at the same period causing high volumes of trade and price volatility. While a majority of the studies focused on entire markets, some ventured into sectors within the markets such as Choudhry and Jayasekera (2014) who looked at the banking sector in large and small economies between the US and the UK, which offers a proxy of a country's economic performance. They compared spillover effects of the large economies in Europe and US and the smaller economies in Europe. Their findings showed indications of spillover from major economies to the smaller economies pre-global financial crisis and spillover from the small economies to the major economies during and post crisis. Ito and Roley (1987) studied the transmission mechanism of news in foreign exchange markets and noted that there was volatility clustering. Bad news assimilates longer than good news. These findings indicated that significant spillovers reduce the benefit of portfolio diversification for international investors; however, the knowledge of the spillover effects may be useful for the international investors in diversifying their portfolios.

Angabini and Wasiuzzaman (2011) analyzed the stock markets of Malaysia for two periods: one from June 1, 2000 to December 31, 2007 and the second from June 1, 2000 to March 16, 2010 (including the crisis) using ARMA, ARIMA, ARCH-LM and GARCH (1, 1) models. On comparison, it was observed that volatility went up by 24.5% yet the persistence of volatility went down by 2.16% in the crisis duration. In a different part of the globe, Sed'a (2012) surveyed the impact of crisis on Czech and Poland stock markets

using various GARCH models with heteroscedasticity. The results showed no statistically significant increase in both markets pre- crisis, but the opposite was found during the crisis. This corresponds with Choudhry and Jayasekera (2014) who found minimal evidence of a substantial spillover from the smaller economies to the major economies during the global financial crisis period. They found that return and volatility transmission mechanisms between the major economies and the smaller EU countries are asymmetric during the crisis period.

Baele, (2005) also examined the extent of market globalization, liberalization, and regional integration to the European capital markets at the height of extensive efforts to integrate the economic market. Globalization and regional integration through economic integration by importing and exporting, monetary integration by currency exchange and currency union and financial integration may affect equity market correlations via convergence of flow of funds in these markets. The shock spillover intensity in the European Union were caused by factors such as equity market growth, increased trade integration, equity market development, and low inflation. During periods of high global markets volatility, there is evidence of contagion from the US market which was used as a proxy for the global market to some of the EU markets. Economies with strong bilateral trade links and financial integration are exposed to common shocks and higher returns correlations with each other.

Bala and Takimoto (2017) used the DCC-MGARCH with skewed t-density approach to analyze the developed markets and Emerging markets during the financial crisis. The markets under evaluation were Nigeria, Japan, USA, UK, Brazil, and China. The results showed Correlations in Developed markets are higher compared to correlations in Emerging markets suggesting greater interactions in developed markets than among Emerging markets. They also observed that past shocks play more crucial role in the volatility of Emerging markets than those in the volatility of developed markets. This suggests that the more advanced a market is, the less affected it is by its own past shocks. It can also imply that Emerging markets are less efficient than developed markets as the effects of the shock takes longer time to dissipate. These finding has financial implications and can help guide investors in their investment decisions. In addition, it was also evident that the GFC was not influential to cross-market volatility in emerging markets but had

little evidence of own-volatility influence. It was observed that these markets were more integrated during the crisis period.

In emerging markets of Asia, Jebran et al., (2017) examined the volatility spillover effect prior to and after the 2007 financial crisis between 2001 and 2013 using the E-GARCH model. They recognized that volatility spillover varies from calm periods to turbulent periods. They also agree that the stock market signifies more integration and volatility spillover increases during turbulent periods and negative shocks generate more volatility than positive shocks of the same magnitude also known as volatility clustering. The integration levels suggest low potential diversification opportunities for investors.

Despite facing liquidity challenges African financial markets such as Kenya, Ghana, Uganda, Egypt, Nigeria, Mauritius, and Zambia have been listed on the top ten best performing markets in the world and they continue to offer attractive returns to investors. In the past, African capital markets were highly regulated, but they have since then undergone financial reforms in the last two decades that relaxed controls around Direct Foreign Investments (DFIs), liberalization of capital accounts and free capital flow. This has contributed to the integration of the capital markets which play a very crucial role in development. Removing investment restrictions has allowed for international risk sharing and diversification (Giovannetti & Velucchi, 2013). According to EMH integrated markets are more efficient than segmented markets whereby they are more responsive both to global and local events. On the flip side, Kim and Singal (2000) contend that increased levels of market integration increase risk levels which consequently affect the cost of capital which will in turn have negative ramifications to companies' ability to raise financing and in the long run, impede economic growth. Coffie (2015) similarly observed that the cost of capital, specifically equity is high in African markets because investors need to be compensated for taking on additional volatility risk. Companies in these markets are faced with stringent regulatory frameworks which are costly to meet due to requirements such as constant audits which force these companies to raise capital locally at higher costs compared to their counterparts in developed markets which puts them at a disadvantage. In terms of volatility persistence, Coffie's findings show that some African countries experienced higher volatility persistence compared to others although the reaction is less intense compared to the US and UK. Positive premiums suggest that

investors are compensated for taking up additional volatility risk. On the other hand, the markets are characterized by high transaction costs resulting from weak regimes of corporate governance and weak market integration. This would hinder international investors from joining and leaving markets freely.

2.3.3 Volatility Modelling review

Modelling of volatility is important because it is instrumental in forecasting risk. Value at Risk (VAR) statistic measure is used to measure the level of financial risk of a firm or a portfolio as well as chance of occurrence of the defined loss in a set period. Predominantly, a majority of these studies utilized variations of the GARCH model with some combining them with Markov switching models and regime switching models. The selection of model affects the outcomes of the studies differently because each model has a set of specifications to apply as we observed in the outcomes of the studies. Abou-Zaid (2011) examined spillover from the US and UK to MENA markets using a univariate GARCH model and evaluated their volatility performance using market indices. Hammoudeh and Li (2008) focused on unexpected shifts in volatility and analyzed these shifts' impacts on the estimated persistence of volatility by employing the iterated cumulative sums of squares (ICSS) algorithm. They found that most of these stock markets are more sensitive to major global events than to local and regional factors meaning that some spillover effects result from country specific internal shocks. The CGARCH model developed Zarour and Siriopoulos (2008) was used to investigate the existence of volatility decomposition into short run and long run components. Their findings are similar to others on volatility persistence.

Hammoudeh et al., (2009) used the VARMA- GARCH model to examine the conditional volatility correlation cross effects. They were able to estimate with minimal challenges with less computational hitches. The BEKK model of Engle and Kroner (1995), a multivariate GARCH (1,1) model has also been utilized in other studies but has a disadvantage when the variables are too many with dynamic covariance and dynamic correlations. Similarly, Bekaert et al., (2015) are proponents of the E-GARCH and the GJR-GARCH models due to its variance response of the conditional variance of shocks following positive versus negative innovations which is one key feature of these models that enables it to better fit many economic time series.

The frequency domain causality approach which is a Granger causality test was used by Özer et al., (2016) and they found that the transmission is unidirectional from Germany to some CEE markets and other CEE markets do not experience any spillovers from Germany. Using a different method of quantile regression to analyze volatility persistence and asymmetry Baur and Dimpfl (2019) challenge some of the empirical studies by claiming that volatility asymmetry and persistence is only present in high volatility regimes and that there is no asymmetry in low volatility regimes suggesting markets are unstable in high volatility regimes. They also propose using an alternative framework for estimating volatility persistence for regime specific volatility spillovers.

Spillover analysis is important for the identification of the factors underlying the transfer of national financial disturbances to other markets. Furthermore, the dynamics of international price movements is of interest to those who invest in securities, which trade across national exchanges. Electronic exchange systems in emerging markets have enabled investors to trade in assets from one exchange, outside of normal trading time, by trading on another exchange located in a different time zone (Abhyankar, 1995). Non parametric methods for measuring leverage effects have also been employed which is different from what other studies have employed. Ederington and Guan (2010) reported that the GARCH models place a lot of weight on outliers or extreme observations and on the likelihood specifications, claiming that the E-GARCH and GJR models are possibly mis-specified.

Emerging markets in Africa were considered as being fairly independent and were presented as frontier markets before the sub-prime crisis by *The Economist* as opportunities that would provide profitable investment alternatives and therefore be of interest to international investors for diversification of risk because it was believed that they were sheltered from external shocks. Prior to the global financial crisis, African financial markets had expanded rapidly and exponentially within a short period of time with the number of operational exchange markets increasing by 65% between 1989 and 2007 from eight to twenty-three. However, in the recent years due to globalization and liberalization of financial markets, African markets become more and more integrated with developed financial markets which was demonstrated by the global financial crisis from 2007-2009 which originated from the US. Giovannetti and Velucchi (2013) analyzed

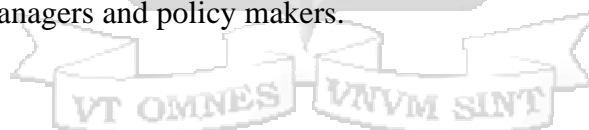
the relationship between developed financial markets – US, UK and China and emerging financial markets in Africa – Kenya, Nigeria, South Africa and Botswana in relation to markets volatility and how volatility shocks from one market are propagated to other markets. Their findings show that shocks from the US and SA radically affected the other African markets with China being more interconnected with the African markets over time. The US and Kenya propagated shocks while South Africa and China absorbed the volatility shocks.

The increasing role of emerging markets is becoming more important for investors and policy makers (Li & Giles, 2015). The information about linkages between the emerging markets will provide valuable information to investors, which may help in portfolio formulation and diversification. Information about volatility spillover effects are useful for applications in finance, such as option pricing, portfolio optimization, value at risk and hedging as they rely on estimates of conditional volatility. In portfolio management practice, studying the direction of volatility spillover on stock returns could provide better diversification benefits (Özer et al., 2016). This study proposes to provide information on the effects of volatility spillovers in USE, NSE, DSE and RSE.

2.3.4 Overview of the East African Exchanges

There are four operational stock exchanges in the East Africa Capital markets: NSE (Kenya), DSE (Tanzania), RSE (Rwanda) and USE (Uganda), with a total of 114 listed companies. The breakdown of the listed companies is as follows; 27 on the DSE, 62 on the NSE, 8 on the RSE and lastly 17 on the UGE. A total of 10 companies have been cross listed across the four exchanges as shown on Appendix H. The market infrastructure comprises of four trading platforms, trading in both fixed income securities and equity. All four security exchanges have CSD - Central Securities Depositories for clearance and settlement of securities. Considering the existing of trade and financial linkages between these markets, it stands well to deduce that there exists some interdependence between the markets in the region. The total market capitalization for East African markets is about \$28.5 billion, Kenyan market constituting the largest percentage followed by Tanzania, Uganda then Rwanda (The Exchange, July 2016). Ensuing the global trends across the

markets, such as integration and demutualization, the securities have followed suit. The Kenyan market was the second to demutualize and self-list in Africa after Johannesburg exchange. Tanzania and Uganda followed the precedent as well in the last few years. Just like other sub-regions in Africa, the BRVM, MENA and South African block of exchanges that have established regional or integrated markets, the East African regional markets are in the process of having an integrated market platform in the region. East African Securities Regulatory Authorities (EASRA) was established in 1997 with the mandate of developing a common market for the East African Capital markets and to harmonize the legal and regulatory framework structure to realize shared trading system merging markets, boost cross-border investments and enhance growth and development of the regional exchanges (CMA). In 2004 the East African Stock Exchange Association (EASEA) was formed to foster the integration agenda. The association is spearheading several initiatives, notably: streamlining regional IPOs to mitigate related challenges such as exchange rate risk, transaction cost and bank transfer charges while paying for shares during regional IPOs, EASEA is also pushing for recognition of East African Stock Broker unit (EASB) to ease the operations of stockbrokers across markets (ASEA). This study analyzed volatility spillover effects in these four markets, this aims to build on the information on the relationship that exists between these four markets for investors, students, fund managers and policy makers.



2.4 Conceptual Framework on volatility behavior

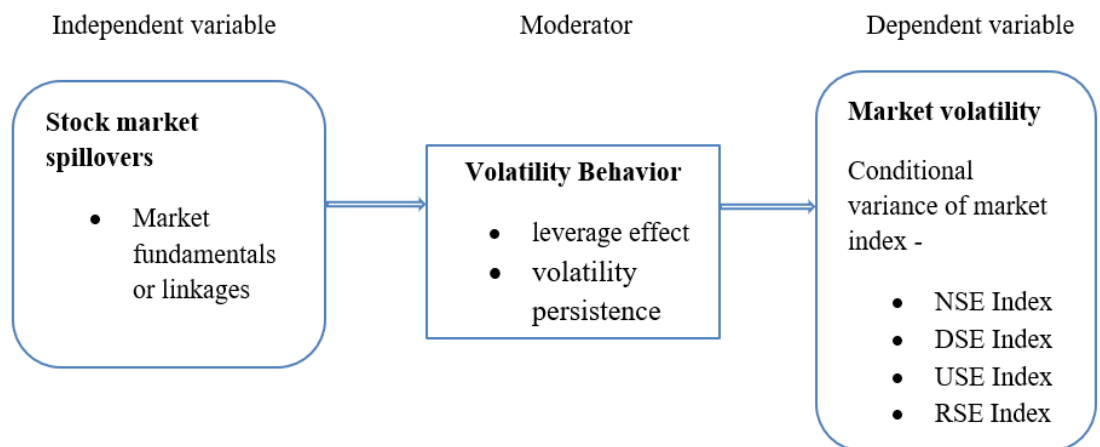


Figure 2.1 Conceptual Framework

2.4.1 Stock market spillovers and leverage measurement

Spillovers refer to shocks that transmit from one market to the other any time as result of market fundamentals or linkages. These economic factors include inflation, international capital flow, latest news, supply, and demand, among others. Volatility spillover is an independent variable measured by the ratio of lagged index returns.

Volatility behavior is represented by volatility persistence and volatility asymmetry also known as leverage effects. Volatility persistence explains the length of duration that positive or negative shocks take to decay off a market. This is determined by summing up the ARCH and GARCH terms and is measured by the range of the sum of these coefficients. Good news Shocks or news can either be positive or negative. Positive shocks or good news is typically observed when the previous period's stock return is exhibiting an upward trend and negative shocks, or bad news is observed when the previous period's stock return is exhibiting a downward trend. Volatility asymmetry represents the impact of news, whether positive or negative on to the market returns. This is measured by the difference between absolute residuals and expected residuals of the market return. The study applied the E-GARCH and GJR GARCH models to capture asymmetric shocks and volatility persistence. Volatility persistence explains the length shocks take to decay off from the affected market. Both the E-GARCH model by Nelson (1991) and the GJR-

GARCH model by Glosten et al., (1993) are popular because they are capable of capturing asymmetry and leverage (Beg & Anwar, 2012; McAleer & Hafner, 2014).

The EGARCH model specification is stated as follows:

$$\text{Log}(\sigma_t^2) = \beta_0 + \alpha \log(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta_1 \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] \quad (1)$$

Where asymmetry exists if $\gamma \neq 0$ and leverage exists if $\gamma > 0$ and $\gamma < \alpha < -\gamma$.

The specification of the GJR-GARCH model is as follows:

$$\sigma_t^2 = \beta_0 + \sum_{j=1}^q \beta_j u_{t-j}^2 + \sum_{j=1}^p \alpha_j \sigma_{t-j}^2 + \gamma u_{t-1}^2 \quad (2)$$

Where $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$

And the ε_{t-1} dummy variable $\varepsilon_{t-1} = \begin{cases} 1 & \text{if } \varepsilon_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$

Leverage effect is present if γ is positive and statistically significant.

Positive shock (good news) has an impact of β_i and negative shock (bad news) has an impact of $\alpha + \gamma$.

2.5 Summary of Literature Review

The common findings to the above studies can be summed up as follows: the return volatilities and the stock market volatilities of different countries depict significant correlations in general. Additionally, volatilities of stock market prices are time varying. Lagged spillovers have been confirmed to exist in developed stock markets while correlations in stock returns have a causal and effect relationship with their volatilities from one country to another, in particular from US to others (unidirectional spillover) (Huen et al., 2014). The financial crisis, which originated from the U.S, was transmitted to other large markets and then cascaded to emerging markets leaving significant losses for investors, which in turn led to bankruptcies of many financial institutions. This eroded

investor confidence with consequent negative impact on the global economy.

Risk is essential for evaluating financial assets, gauging regulatory proposals, and executing hedging tactics and strategies with the aim of inhibiting capital flows. Therefore, the correlation between the return of a financial asset and its volatility as a measure of risk is especially important in financial markets for restricting international investors from pulling out their investments (Al Janabi et al., 2010). The relationship between returns from volatility and financial assets play a pivotal role in Black Scholes option pricing, hedging strategies, calculations of Value at Risk (VaR), portfolio selection and asset pricing. With some markets like NSE implementing derivative exchanges for commodity trading and financial trading, studies on the interconnection between expected returns and volatility are timely to propel the development of these advanced products for the purposes of hedging such as structuring optimal hedge ratios in relation to volatility. The literature reviewed asymmetric volatility spillover effects, volatility persistence and the volatility models in line with analyzing the stylized facts of time series data. The E-GARCH and the GJR-GARCH models have the capability of capturing these features, to analyze asymmetry in volatility and volatility persistence. The variations of the findings could be attributed to the different models used in these studies together, data frequency used, market size and market location. More so, the studies also used the various financial crises as the basis of their analysis from large markets to other large markets in Europe, US, Asia, and the Middle East. The African market received very little attention and some authors sighted liquidity challenges, market size, inadequate data and lack of proper governance structures as some of the reasons why little markets in Africa were excluded in earlier studies. This study shows the existence of asymmetric volatility in the East African markets and provides insight of what this means to investors who experience challenges in making investment decisions.

Chapter 3 : Research Methodology

3.1 Introduction

This chapter highlights the approach that the study used to answer the research objective. The chapter is organized as follows, research philosophy, research design, population sampling, data collection, research quality and ethical considerations.

3.2 Research Philosophy

This study is inclined to the post-positivism school of thought -a reflection after positivism (Clark, 1998). Post-positivism views that observations or measurements are imperfect, besides the study may be largely affected by the researcher's contextual characteristics. Therefore, there is need for considerable number of studies in an area of interest from which objective conclusions can be drawn. It is in the view of this study that few available literature on volatility modeling in the East African region in light of volatility spillover is not only contradictory but it has also been done on selective markets based on market capitalization which ignored critical markets that if looked at could alter or give more meaning to conclusions we already have in the literature.

3.3 Research Designs

Kothari (2004) explains research design as a scheme of those procedures employed by a researcher for testing relationships between variables; explains the framework of activities to be completed, scheme of integrating the variables under investigation and methodology used to conduct research analysis. There exist several classifications of research designs by different authors. This is a quantitative, explanatory study, making use of GARCH time-series models to determine the effects of volatility spillover in EAC capital markets. The market indices of four markets were employed and thereafter analyzed using the GARCH models to create estimates for the mean and variance equations. Finally, we tested model parameters using a hypothesis testing approach, to determine the significance of the model parameters that indicate volatility spillover and persistence in order to answer the research objectives.

3.4 Target Population

The target population of the study entailed specific elements with the desired information (Kothari, 2004). This study sought to investigate the volatility spillover dynamics between the selected East African stock markets which are USE, DSE, NSE, and RSE. This study used daily data consisting of 5 trading days namely Monday to Friday for analysis because by using daily data, we can capture more information.

3.5 Population Sampling

The total population consists of the four EAC markets members NSE, USE, DSE, and RSE except for Burundi. Burundi is relatively small; having only two listed companies so far and does not have a market index yet. The total population was examined because the population size is small therefore sampling was not applied. Creswell and Creswell (2017) recommends the use of the entire population when the size is manageable.

3.6 Data Collection

The data collected forming the basis for analysis of this study comprised of secondary data sourced from Thompson Reuters DataStream of the daily closing stock market indices for Kenya (NASI), Tanzania (DSEI), Uganda (ASIUG), and Rwanda (ASIRW), for the period between January 2009 and December 2019. Daily closing equity market index prices were used for working days only, that is, weekends excluded from the data sample. For missing values due to holidays in one market, while the other markets are open, the previous day's closing price was used. The secondary data was sourced from Thompson Reuters DataStream. The type of data used for this study is numerical/quantitative comprising of daily share indices which is secondary data.

3.7 Data Analysis

The study aimed to investigate the dynamics of volatility spillovers between NSE, USE, DSE, and RSE financial markets. The stock market indices used for this study are

summarized on Appendix A. To test for the accuracy of the models the variations of the error terms were observed using the ARCH model (Engle, 1982). This model assumes a time varying variance. To start off, the log returns for all the indices were computed. The market index returns for each of the four markets, defined by the first difference of logs of daily closing stock indices which have been computed as:

$$R_t = \text{Log} \left[\frac{P_t}{P_{t-1}} \right] \quad (3)$$

Where P_t indicates the price at time t and P_{t-1} is the price at time $t-1$.

Volatility in the stock returns were captured by using a linear regression model:

$$R_t = \beta_0 + \beta_1 P_{t1} + \beta_2 P_{t2} + \beta_3 P_{t3} + \mu_t, \mu_t \sim N(0, \sigma_t^2) \quad (4)$$

To test for ARCH effects that is the presence of auto correlation, the Lagrange Multiplier (LM) was used.

$$H_0: \beta_0 = \beta_1 = 0$$

$$H_a: \beta_1 \neq 0$$

The test statistics is given as:

$$LM = qR^2 \sim \chi^2_m \quad (5)$$

Where q represents the number of observations and R^2 is a squared correlation coefficient multiple. The test statistic follows a Chi square distribution. The value of the R^2 will be high if one of the variables is statistically significant. The null hypothesis is rejected if the test statistic is greater than the table values.

The asymmetric volatility spillover was explored by using variations of GARCH models as suitable namely Exponential Generalized Autoregressive Conditional Heteroskedasticity (E-GARCH) model and the GJR-GARCH model. The focus on asymmetric volatility spillovers is because it is most widely argued that asymmetric (negative) shocks generate more volatility than symmetric (positive) shocks of the same magnitude.

The study applied the E-GARCH and GJR GARCH models to capture asymmetric shocks and volatility persistence using R. Volatility persistence explains the length shocks take to decay off from the affected market. Both the E-GARCH model by Nelson (1991) and the GJR-GARCH model by Glosten et al., (1993) are popular because they are capable of capturing asymmetry and leverage (Beg & Anwar, 2012; McAleer & Hafner, 2014).

The EGARCH model specification is stated as follow:

$$\text{Log}(\sigma_t^2) = \beta_0 + \alpha \log(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta_1 \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] \quad (1)$$

Where asymmetry exists if $\gamma \neq 0$ and leverage exists if $\gamma > 0$ and $\gamma < \alpha - \gamma$.

The specification of the GJR-GARCH model is as follow:

$$\sigma_t^2 = \beta_0 + \sum_{j=1}^q \beta_j u_{t-j}^2 + \sum_{j=1}^p \alpha_j \sigma_{t-j}^2 + \gamma u_{t-1}^2 \quad (2)$$

Where $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$

And the ε_{t-1} dummy variable $\varepsilon_{t-1} = \begin{cases} 1 & \text{if } \varepsilon_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$

Leverage effect is present if γ is positive and statistically significant.

Positive shock (good news) has an impact of β_i and negative shock (bad news) has an impact of $\alpha + \gamma$.

To answer the first objective the hypothesis is shown as:

H_0 : There is no asymmetry in volatility on returns

H_a : There is asymmetric volatility on market returns

The answer the second objective the hypothesis is shown as:

H_0 : The stock market returns do not exhibit volatility persistence

H_a : There is presence of volatility persistence in the stock market returns

The model selections were based on the best fit by using Akaike Information Criterion (AIC) and the one with the lowest value was selected. A model with a low AIC and BIC

is preferred these ensure that there is a reduced risk of overfitting the model.

The study also used the Jarque Bera test to test for normality because it considers skewness and kurtosis of the data. Skewness measures the degree of asymmetry of a probability distribution whereas Kurtosis measures the degree of peakedness relative to tails.

Ho: The data is normally distributed

Ha: The data is not normally distributed

The computation of the test statistic is as illustrated below:

$$JB = N \left[\frac{S^2}{6} + \frac{(K-3)^2}{24} \right] \quad (6)$$

3.8 Research Quality

Quality research adheres to the scientific process covering all the aspects of study design which pertains to the decision regarding the mapping of methodology, subject selection, questions and measurement of outcomes between the methods to ensure protection against systematic, non-systematic bias, and inferential errors (Kothari, 2004). The study quality was observed by ensuring that the secondary data was sourced from a reputable source and was sufficient to answer the objective interpretation of the study results. Diagnostic tests were conducted to ensure that the appropriate GARCH model was selected for the analysis – these included tests for normality, autocorrelation, multi-collinearity, and heteroscedasticity.

3.8 Ethical considerations in Research

Ethics are norms or standards of behavior that guide moral choices about our behavior and relationship with others. No one was harmed or suffered adverse consequences from the research activities undertaken during the study. Ethical standards in the study was maintained by ensuring that information obtained from all sources is fully acknowledged. Permission to collect data was sought from the university and other relevant sources. All information obtained will be used only for academic purposes and will be treated with

confidentiality. The researcher will further ensure that nobody or organization or any party is harmed by this study. Participation will also be voluntary without coercion or enticement and privacy will be ensured throughout the study period.



Chapter 4 : Data Analysis and Presentation

4.1 Introduction

The chapter presents the application of the methodology presented in the previous chapter using exploratory data analysis to meet the objectives of the study. The statistical package used for the analysis is R. The general focus of the study was to model the effect of volatility between a selection of East African markets namely NSE, USE, DSE, and RSE from 2009 to 2019. This section reports the findings obtained from the data analysis and the interpretation with regards to the objectives of the study. Panel data was used for this secondary data analysis.

4.2 Descriptive Statistics

The section highlights basic data characteristics such as mean, median and standard deviations to evaluate the distribution properties of the dependent and independent variables of this study. The findings are presented in *Table 4.1*

Table 4. 1 Descriptive Statistics

| Variables | USE | DSE | RSE | NSE |
|-----------|---------|---------|--------|--------|
| N | 2812 | 2812 | 1686 | 2812 |
| Mean | 1737.97 | 2213.57 | 133.91 | 149.10 |
| SD | 199.62 | 326.53 | 12.27 | 17.20 |
| Median | 1735.00 | 2258.89 | 132.23 | 147.39 |
| Minimum | 1331.00 | 1490.14 | 121.74 | 104.92 |
| Maximum | 2270.00 | 2850.15 | 563.59 | 196.57 |
| Range | 939.00 | 1360.01 | 441.85 | 91.65 |
| Skewness | 0.37 | -0.40 | 26.21 | 0.06 |
| Kurtosis | -0.49 | -0.49 | 896.25 | -0.37 |
| SE | 4.86 | 7.95 | 0.30 | 0.42 |

From the descriptive statistics in *Table 4.1*, it is observed that DSE has the highest mean of 2213.57, followed by USE with a mean of 1737.97. NSE and RSE had lower means of 133.91 and 149.10, respectively. The range between the minimum and maximum prices of the indices is wide for all the countries, with some countries having a wider dispersion compared to the others leading with DSE having a maximum 2850.15 then USE with a maximum of 2270. RSE has a minimum of 121.74 and NSE has 121.74 which is the lowest

in the group. The range of dispersion is widest for DSE with a range of 1360.01 and NSE has the narrowest dispersion with a range of 91.65. The standard deviation for DSE is 326.53 which is the highest, USE has the second highest standard deviation of 199.62 then NSE with a standard deviation of 17.20 and the lowest standard deviation is for RSE at 12.27. Standard deviations are far from the sample mean. Skewness is positive for USE, RSE, and NSE but negative for DSE. USE, DSE, and NSE mirror normal distributions with skewness of 0.37, -0.40 and 0.06, respectively. RSE has a positive skewness of 26.21 which indicates long right tail. USE, DSE, and NSE are all platykurtic, $-0.49 < 3$ for USE and DSE, $-0.37 < 3$ for NSE. RSE is leptokurtic with kurtosis of $896.25 > 3$. The charts on Appendix B also provide additional visuals to the descriptive statistics of the variables of the East Africa markets. NSE, DSE and USE display peaks and troughs around similar periods while RSE remains relatively calm.

4.2.1 Normality Tests

To analyze the series of the stock markets, we first observe the features of financial time series data for clustering, outliers, and kurtosis. The values of kurtosis, and skewness from Jarque Bera statistics on *Table 4.2* reveal that the indices are not normally distributed since the P values are significant and kurtosis is greater than 3.

Table 4. 2 Jarque Bera Statistics

| | Jarque Bera test | df | P. value | Skewness | Kurtosis |
|-----|------------------|----|----------|----------|----------|
| USE | 79867.82 | 0 | 0 | 0.92 | 33.68 |
| DSE | 815546.80 | 0 | 0 | 3.53 | 107.55 |
| RSE | 111216900.00 | 0 | 0 | 32.80 | 1256.90 |
| NSE | 2086.27 | 0 | 0 | -0.35 | 5.40 |

For USE, the skewness is 0.92 which indicates a normal distribution but the Kurtosis of $33.68 > 3$, similar to DSE, $107.55 > 3$, RSE $1256.9 > 3$ and NSE $5.4 > 3$ all indicate excess kurtosis. The probability distribution for these East African markets are all positively skewed indicating fat right tails. From these results, we reject the null hypothesis and conclude that the data is not normally distributed.

The charts displayed on Appendix C show that NSE, DSE, and USE experienced instability in 2013, mid 2015 and 2017. Periods of stability were experienced in 2014, mid 2017 to 2018 then we can see another trough towards 2019.

The next step is to check for the presence of heteroskedasticity after testing for normality. The variance series is calculated by squaring the corresponding return series for each stock market using second order moments.

4.2.2 Correlation Analysis

Summary of correlation values of East Africa stock market indices is provided in *Table 4.3* below. All the markets exhibit positive relationships, some strongly compared to others. USE and NSE have the highest correlation coefficient of 0.86. USE and DSE also a strong correlation with a correlation coefficient of 0.58 together with DSE and NSE with a correlation coefficient of 0.57.

Table 4. 3 Correlation summary of stock indices

| | USE | DSE | RSE | NSE |
|-----|------|------|------|------|
| USE | 1.00 | | | |
| DSE | 0.58 | 1.00 | | |
| RSE | 0.05 | 0.04 | 1.00 | |
| NSE | 0.86 | 0.57 | 0.12 | 1.00 |

Comparatively, USE and RSE have a weak positive correlation with a coefficient of 0.05 while DSE and RSE have a coefficient of 0.04 and NSE and RSE having a correlation coefficient of 0.12.

4.2.3 Autocorrelation function (ACF) analysis

The autocorrelation function is used to check for linear dependence of a variable at different lags. From Appendix F, the sample ACF shows significant correlation at different lags for all the stock market returns. In Kenya stock market, NSE returns displays significant correlation with increasing lags. Ljung- Box test developed by Ljung and Box (1978) was used to check whether auto correlation with different lags are zero.

Ljung Box test statistics is defined as follows:

$$Qlb = n(n + 2) \sum_{h=1}^H \frac{\hat{\rho}e^2(h)}{n-h} \quad (7)$$

where $\hat{\rho}e^2(h)$ is auto correlation function at lag h, and H is the quantity of auto correlations that have been tested. For a significant level, we reject the H0 if:

$$Qlb(k) > x_{1-\alpha}^2(k)$$

The output from the Ljung box test in *Table 4.4*, show that there is a strong statistical evidence of rejecting the null hypothesis, this implies presence of auto correlation at 5% confidence level in all stock markets returns. The P values are all statistically significant for USE, DSE, RSE and DSE.

Table 4. 4 Ljung Box Test

| | Box. Stats | df | P.value |
|-----|------------|----|---------|
| USE | 13.4598 | 0 | 0 |
| DSE | 122.8388 | 0 | 0 |
| RSE | 102.1088 | 0 | 0 |
| NSE | 124.892 | 0 | 0 |

Partial auto-correlation function (PACF) is also used to check for linear dependence at different lags, but it removes the effect of intervening correlations. From the charts on Annex G, all the stock returns appear to be serially correlated. For USE, we observe a large spike at lag 1 followed by a damped wave that alternates between positive and negative correlations. This indicates a higher order moving average term in the data. In NSE, we observe significant correlations at the first or second lag, followed by correlations that are not significant, this indicates an autoregressive term in the data. In DSE, we observe a large spike at lag 1 that decreases after a few lags, this indicates a moving average term in the data. Lastly for RSE we also observe significant correlations at the first or second lag, followed by correlations that are not significant, this indicates

an autoregressive term in the data

4.2.4 Preliminary Tests

Due to the salient features of time series data, preliminary tests this section presents results on the tests that were carried out before the model estimation. In estimating a GARCH-type model, it is necessary to determine whether the ARCH effect is present as a precondition to ensure that GARCH model is suitable for the data.

We started by computing the natural logarithm of daily index returns. Secondly, tests were conducted for serial correlation in the absolute value of daily returns as well as the squared value of daily returns and these confirmed that the existence of conditional heteroskedasticity in the daily equity index returns is highly likely. This justified the use of ARCH models. It is important to test for ARCH effects prior to estimating ARCH models. In testing for the presence of ARCH effects in the residuals, the generalized autoregressive presentation of the residuals is given as:

$$\hat{u}_t^2 = b_0 + b_1 \hat{u}_{t-1}^2 + b_2 \hat{u}_{t-2}^2 + b_3 \hat{u}_{t-3}^2 + b_q \hat{u}_{t-q}^2 + e_t \quad (6)$$

If parameters b_1, b_2 are statistically significant, this indicates the presence of conditional volatility (ARCH effects) under the null hypothesis of no ARCH effects:

$$b_1 = b_2 = b_3 = \dots = b_q = 0$$

Therefore, testing for ARCH (1) effects

$$\hat{u}_t^2 = b_0 + b_1 \hat{u}_{t-1}^2 + e_t \quad (7)$$

Where:

Ho: $b_1 = 0$ (homoskedasticity)

Ha: $b_1 \neq 0$ (heteroskedasticity)

Table 4. 5 Lagrange Multiplier test for ARCH effects on daily stock returns

| Stock | Arch1 | df 1 | P.value |
|-------|------------|------|---------|
| USE | 249.294327 | 1 | 0.00 |
| DSE | 20.509193 | 1 | 0.00 |
| RSE | 5.690013 | 1 | 0.02 |
| NSE | 134.112193 | 1 | 0.00 |

The results from *Table 4.5* indicate that we reject H_0 for presence of ARCH effects at level of 5% significance for all the four countries. There is evidence of conditional heteroskedasticity in the mean of the East Africa market returns therefore a GARCH model that accounts for volatility needs to be employed to model the returns in the East African markets. All the P values are statistically significant at 5% level of significance for NSE, DSE, USE and RSE. We therefore reject the null hypothesis.

4.3 Analysis of Volatility Asymmetries in the EAC Markets

To test for asymmetries (leverage effects) we estimate an E-GARCH (1,1) model for NSE, USE, and DSE. The parametrization of the model is as follows:

$$\text{Log}(\sigma_t^2) = \beta_0 + \alpha \log(\sigma_{t-1}^2) + \gamma \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \beta_1 \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] \quad (1)$$

$$H_0: \gamma_1 = \gamma_2 = \dots = 0$$

$$H_a: \gamma_1 < 0 \text{ or } \gamma_1 > 0$$

For Rwanda, we estimate a GJR-GARCH model (1,1), the specification of the GJR-GARCH model is as follow:

$$\sigma_t^2 = \beta_0 + \sum_{j=1}^q \beta_j u_{t-j}^2 + \sum_{j=1}^p \alpha_j \sigma_{t-j}^2 + \gamma u_{t-1}^2 \quad (2)$$

Where $I_{t-1} = 1$ if $\varepsilon_{t-1} < 0$

And the ε_{t-1} dummy variable $\varepsilon_{t-1} = \begin{cases} 1 & \text{if } \varepsilon_{t-1} > 0 \\ 0 & \text{otherwise} \end{cases}$

Leverage effect is present if γ is positive and statistically significant.

To measure the asymmetric effects, we are interested in parameter γ on *Table 4.6* for USE, RSE, DSE, and NSE.

Table 4. 6 Estimates of the GARCH (1,1) parameters under various specifications for each of the stock returns

| Returns & Model | Parameters | Estimate | Std.Error | t value | Pr(> t) | |
|-----------------|-----------------|------------|-----------|---------|----------|--------|
| USE | E-GARCH (1,1) | μ | 0.0357 | 0.0262 | 1.3633 | 0.1728 |
| | | α | 0.1876 | 0.0308 | 6.0962 | 0.0000 |
| | | α_1 | -0.0997 | 0.0315 | -3.1687 | 0.0015 |
| | | β_1 | 0.4205 | 0.0692 | 6.0733 | 0.0000 |
| | | γ_1 | 0.4609 | 0.0400 | 11.5234 | 0.0000 |
| DSE | E-GARCH (1,1) | μ | 0.0241 | 0.0129 | 1.8643 | 0.0623 |
| | | α | 0.1270 | 0.0097 | 13.0531 | 0.0000 |
| | | α_1 | -0.1064 | 0.0169 | -6.2991 | 0.0000 |
| | | β_1 | 0.9706 | 0.0049 | 198.9945 | 0.0000 |
| | | γ_1 | 0.3821 | 0.0211 | 18.0720 | 0.0000 |
| RSE | GJR-GARCH (1,1) | μ | 0.0050 | 0.0079 | 0.6248 | 0.5321 |
| | | α | 0.1016 | 0.0037 | 27.2325 | 0.0000 |
| | | α_1 | 0.1521 | 0.0514 | 2.9603 | 0.0031 |
| | | β_1 | 0.0000 | 0.0000 | 0.0000 | 1.0000 |
| | | γ_1 | 0.5946 | 0.1232 | 4.8253 | 0.0000 |

| | | | | | | |
|-----|---------------|------------|---------|--------|---------|--------|
| NSE | E-GARCH (1,1) | μ | 0.0479 | 0.0178 | 2.6888 | 0.0072 |
| | | α | -0.1311 | 0.0374 | -3.5008 | 0.0005 |
| | | α_1 | -0.0135 | 0.0234 | -0.5784 | 0.5630 |
| | | β_1 | 0.7420 | 0.0569 | 13.0411 | 0.0000 |
| | | γ_1 | 0.3999 | 0.0442 | 9.0444 | 0.0000 |

The null hypothesis is stated as follows:

$$H_0: \gamma = 0$$

$$H_a: \gamma < 0$$

In the variance equation 1 above the variable of interest for leverage effect is denoted by γ . If the parameter γ is negative that is $\gamma < 0$ and statistically significant, it implies that, bad news (negative shock) generates larger volatility than good news (positive shock) of the same magnitude. In other words, it is an indicator of whether a market exhibits leverage effects or otherwise. It can be observed that the leverage effect for all the returns are positive and statistically significant at 95% confidence interval. From *Table 4.6* the γ results are as follows for each market, USE ($\gamma = 0.4609$, $P < 0.05$), DSE ($\gamma = 0.3821$, $P < 0.05$), RSE ($\gamma = 0.5946$, $P < 0.05$), NSE ($\gamma = 0.3999$). The coefficient of the asymmetric term denoted by γ are all positive for NSE, USE, RSE and DSE and statistically significant at 95% confidence level.

Since we used different models, the computation of leverage effects or asymmetry will be done separately because of the model specifications. To derive the total leverage effects for USE, DSE, and RSE:

$$\text{If } u_{t-1}^2 < 0, \text{ the total effect of } u_{t-1}^2 \text{ on } \text{Log}\sigma_t^2 \text{ is } 1 - \gamma_1 [u_{t-1}^2] \quad (3)$$

or

$$\text{If } u_{t-1}^2 > 0, \text{ the total effect of } u_{t-1}^2 \text{ on } \text{Log}\sigma_t^2 \text{ is } 1 + \gamma_1 [u_{t-1}^2] \quad (4)$$

Since the coefficients for the asymmetric terms is positive for all the markets, we will use equation 4 to derive the total leverage effects/asymmetry for NSE, USE and DSE. The results of this computation are presented below:

Leverage effects results

| | |
|-----|--------|
| USE | 1.4609 |
| DSE | 1.3821 |
| NSE | 1.3999 |

We conclude there is presence of positive asymmetry in NSE, USE and DSE.

This implies that positive innovations are more destabilizing than negative innovations.

To derive the asymmetry for RSE for the GJR-GARCH model, for positive shocks, the estimate of the time varying volatility is given as:

$$\sigma_t^2 = 0.1016 + 0.1521 \sigma_{t-1}^2 + 0.0000 u_{t-1}^2 = 0.2536$$

For negative shocks, the estimate of the time varying volatility is given as:

$$\sigma_t^2 = 0.1016 + 0.1521 \sigma_{t-1}^2 + (0.0000 + 0.5946) u_{t-1}^2 = 0.8482$$

The difference between the good news and bad news on the RSE stock is 0.5946 which is the coefficient of the asymmetric term γ . We conclude that there is presence of asymmetry in Rwanda and that negative shocks have larger effects than positive shocks.

4.4 Analysis of Volatility persistence in the EAC Markets

Volatility is persistent if $\alpha_1 + \beta_1 = 1$, if $\alpha_1 + \beta_1 < 1$ it is less persistent and explosive if $\alpha_1 + \beta_1 > 1$. Using the output from *Table 4.6*, we generate the GARCH (1,1) models for each stock return as follows:

USE – E-GARCH (1,1) Model

$$R_t(USE) = 0.0357 + 0.0262 + \varepsilon_t$$

$$\begin{aligned} \text{Log}(\sigma_t^2) = & 0.1876 (\mp 0.0308) - 0.0997 (\mp 0.0315) \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] + 0.4205 (\mp 0.0692) \sigma_{t-1}^2 \\ & + 0.4609 (\mp 0.0400) \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} \end{aligned}$$

Volatility persistence – USE ($\alpha_1 + \beta_1 = 0.3208 < 1$, $P < 0.05$). Volatility is less persistent at 95% confidence interval.

DSE – E-GARCH (1,1) Model

$$R_t(DSE) = 0.0241 \mp 0.0129 + \varepsilon_t$$

$$\begin{aligned} \text{Log}(\sigma_t^2) = & 0.1270 (\mp 0.0097) - 0.1064 (\mp 0.0169) \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] + 0.9706 (\mp 0.0049) \sigma_{t-1}^2 \\ & + 0.3821 (\mp 0.0211) \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} \end{aligned}$$

Volatility persistence – DSE ($\alpha_1 + \beta_1 = 0.8642 < 1$, $P < 0.05$). Volatility is less persistent at 95% confidence interval.

NSE – E-GARCH (1,1) Model

$$R_t(NSE) = 0.0479 \mp 0.0178 + \varepsilon_t$$

$$\begin{aligned} \text{Log}(\sigma_t^2) = & -0.1311 (\mp 0.0374) - 0.0135 (\mp 0.0234) \left[\frac{|u_{t-1}|}{\sigma_{t-1}} - \sqrt{\frac{2}{\pi}} \right] + 0.7420 (\mp 0.0569) \sigma_{t-1}^2 \\ & + 0.3999 (\mp 0.0442) \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} \end{aligned}$$

Volatility persistence – NSE ($\alpha_1 + \beta_1 = 0.7285 < 1$, $P < 0.05$). Volatility is less persistent at 95% confidence interval.

RSE – GJR-GARCH (1,1) Model

$$R_t(RSE) = 0.0050 \mp 0.0079 + \varepsilon_t$$

$$\sigma_t^2 = 0.1016 (\mp 0.0037) - 0.1521 (\mp 0.0514) \varepsilon_{t-1}^2 + 0 + 0.5946 (\mp 0.1232) \varepsilon_{t-1}^2 I_{t-1}^2$$

Volatility persistence – RSE ($\alpha_1 + \beta_1 = 0.1521 < 1$, $P < 0.05$). Volatility is less persistent at 95% confidence interval.

We conclude that volatility is less persistent in all the markets, with DSE and NSE having the highest volatility persistence at 0.8642 and 0.7285 and USE and RSE having lower levels of volatility persistence of 0.3208 and 0.1521, respectively.

4.5 Analysis of spillover effect in the EAC Markets

Table 4. 7 Estimates of the mean parameters under various specifications for each of the stock returns

| Returns & Model | Parameters | Estimate | Std.Error | t value | Pr(> t) |
|-----------------|-----------------------------|----------|-----------|---------|----------|
| USE | μ | 0.0357 | 0.0262 | 1.3633 | 0.1728 |
| | E-GARCH (1,1) α | 0.1876 | 0.0308 | 6.0962 | 0.0000 |
| DSE | μ | 0.0241 | 0.0129 | 1.8643 | 0.0623 |
| | E-GARCH (1,1) α | 0.1270 | 0.0097 | 13.0531 | 0.0000 |
| RSE | μ | 0.0050 | 0.0079 | 0.6248 | 0.5321 |
| | GJR-GARCH (1,1) α | 0.1016 | 0.0037 | 27.2325 | 0.0000 |
| NSE | μ | 0.0479 | 0.0178 | 2.6888 | 0.0072 |
| | E-GARCH (1,1) α | -0.1311 | 0.0374 | -3.5008 | 0.0005 |

From the *Table 4.7*, μ represents the average stock return for each of the indices, all the coefficients are positive for USE, DSE, RSE and NSE and are statistically insignificant for USE, DSE, RSE but statistically significant for NSE at 95% confidence interval. The μ results are as follows for each market, USE ($\mu = 0.0357$, $P > 0.05$), DSE ($\mu = 0.0241$, $P > 0.05$), RSE ($\mu = 0.0050$, $P > 0.05$), NSE ($\mu = 0.0479$, $P < 0.05$).

For the index returns, α represents the past value of the market return of the indices. The coefficients of USE, DSE and RSE are all positive, with NSE having a negative coefficient which are statistically significant at 95% confidence interval. The α results are as follows

for each market, USE ($\mu = 0.1876$, $P < 0.05$), DSE ($\mu = 0.1270$, $P < 0.05$), RSE ($\mu = 0.1016$, $P < 0.05$), NSE ($\mu = -0.1311$, $P < 0.05$). This shows that past value of the stock predicts the current value of the stock.



Chapter 5 : Discussion

5.1 Introduction

The study sought to assess the behavior of asymmetric volatility of stock returns in the East Africa capital markets as well as volatility persistence. This section discusses the findings of this study by presenting the summary of the findings and a discussion of the findings as well.

5.2 Discussion of the findings

The primary objective of the study was to analyze the behavior of in the East African capital markets. The summary of the key findings is presented below according to the specific objectives of the study.

5.2.1 *Volatility spillover analysis in the East African markets*

The study investigated the presence of asymmetric volatility spillover in the East African markets. The study found the presence of positive volatility asymmetry in NSE, USE and DSE which indicates that these markets are characterized by fat right tails. The positive volatility asymmetry is also an indication that the downside for investors in these markets is limited but the upside is unlimited, meaning that the potential or realized reward is greater than the potential or realized loss. These findings are in line with Christie (1982) Bekaert & Wu (2000), Hamao et al., (1990) and Wu (2001) who all unanimously acknowledge the existence of leverage effects on stock returns. Coffie (2015) similarly observed that the cost of capital, specifically equity is high in African markets because investors need to be compensated for taking on additional volatility risk. An increase in volatility should correspond to a high (Christie, 1982) This is supported by Campbell & HentSchel (1992) on the nature of asymmetry of the return shocks response to volatility being an indication of the presence of time varying risk premia. A spillover effect evident in returns suggests the existence of an exploitable trading opportunity and, if this opportunity provides profits that exceed transaction costs, potentially signifies evidence against market efficiency (Choudhry & Jayasekera, 2012). In the African markets context, Appiah-Kusi and Menyah (2003) evaluated 11 African countries whereby their model

accounted for time varying risk premium out of which the Nigeria, Ghana, Ivory Coast and Swaziland market's results indicated that these markets provided opportunities of high returns. They however pointed out that after investors account for transaction costs and taxes, the opportunity of exploiting inefficiencies diminishes and therefore eliminating arbitrage. Results for Rwanda shows that negative shocks have larger effects than positive shocks. Baur and Dimpfl (2019) challenge some of the empirical studies by claiming that volatility asymmetry and persistence is only present in high volatility regimes and that there is no asymmetry in low volatility regimes suggesting markets are unstable in high volatility regimes. They also propose using an alternative framework for estimating volatility persistence for regime specific volatility spillovers. Choudhry and Jayasekera (2012) cited existence of arbitrage opportunities resulting from decline in market efficiency levels caused asymmetric volatility. This decline implied that prices delayed converging to their intrinsic values which suggests to investors arbitrage opportunities especially for hedge funds and speculations.

5.2.2 Volatility persistence in the East African markets

The study investigated the levels of volatility persistence in NSE, USE, DSE and RSE. The findings show the presence of volatility persistence in all the markets, although the degree varies with Kenya and Tanzania exhibiting high levels of persistence and Uganda and Rwanda exhibiting lower levels of persistence. Volatility is less persistent in all the four markets. Similarly, Coffie (2015)'s findings show that some African countries experienced higher volatility persistence compared to others Positive premiums suggest that investors are compensated for taking up additional volatility risk

These findings contradict with Huen et al., (2014) where volatility spillover and persistence within the developed markets was smaller compared to developing markets because these East African markets are categorized as emerging markets yet they exhibit less volatility persistence. Aggarwal et al., (1999) study showed that big variations in volatility related to important country specific political, economic, and social events. These findings are important because they signify that unexpected events in emerging markets pose a threat to investors' portfolio returns. Ndwiga & Muriu (2016) concluded that there is no evidence of volatility persistence in NSE and that there's presence of

volatility clustering indicating the volatility is time varying and is not constant. This contradicts with the findings of this study. (Baele, 2005) examined the extent of market globalization, liberalization, and regional integration to the European capital markets at the height of extensive efforts to integrate the economic market. Globalization and regional integration through economic integration by importing and exporting, monetary integration by currency exchange and currency union and financial integration may affect equity market correlations via convergence of flow of funds in these markets. The shock spillover intensity in the European Union were caused by factors such as equity market growth, increased trade integration, equity market development, and low inflation. Economies with strong bilateral trade links and financial integration are exposed to common shocks and higher returns correlations with each other.

The economic and market reforms in these markets, along with integration efforts and cross listed companies can also explain the volatility persistence result. NSE, USE and DSE have the greatest number of cross listed companies as shown on Appendix I. This can provide insight on the volatility persistence findings.

Lastly, the study investigated the volatility spillover in the East African markets, USE, DSE, RSE and NSE. The findings show that the past values have a strong predictive ability on the current stock. The findings establish the presence of mean spillover or time varying conditional volatility of the index returns for USE, RSE and DSE, which means that the three markets were influenced by events within these markets. However, the NSE was not influenced by events in these other markets. The findings for NSE align with (Yunvirusaba et al., 2019).

5.3 Summary

The primary objective of the study was to assess the salient features of volatility spillover and volatility persistence in the East African capital markets. The preliminary analysis is first conducted on the four markets – USE, NSE, DSE and RSE market returns to test for normality, skewness, and kurtosis. The values of kurtosis, Jarque Bera and skewness reveal non normal distribution. Prior to fitting the GARCH models, Ljung box tests were done to check the presence of ARCH effects. The key findings were discussed and summarized to answer the objectives of the study.

The key findings show the existence of asymmetric volatility and volatility persistence in East Africa markets. NSE, USE and NSE exhibit fat right tails with positive volatility asymmetry while RSE shows negative asymmetry where bad news has larger effects than good news. This is an indication of non-randomness as well as a weak form of efficiency. Volatility is less persistent in all four markets as it is less than 1 although Tanzania and Kenya show a higher threshold of volatility persistence which is closer to explosive volatility persistence compared to USE and RSE.

5.4 Limitation of the Study

The study utilized secondary data of four market indices, data was limited for Rwanda which was incorporated later than the other three markets therefore data that was available was from 2013 onwards meaning Rwanda had fewer observations in comparison to the rest of the markets. The study did not get qualitative input from the investors and other market participants, as secondary data was the data that was used for this study. Lastly, other than price volatility, other variables like interest rates, inflation, currency exchange rates among other economic variables affect stock market performance. The study variables only explain a fraction of the stock market performance therefore, there are more variables that can be included in future studies.



Chapter 6 Conclusion and Recommendations

6.1 Conclusion

6.1.1 Asymmetric volatility spillover and volatility persistence in the East Africa markets

The study found positive volatility spillover in NSE, DSE and USE. This implies that investors potentially have higher upside than downside, they earn higher returns for higher levels of risk. Volatility persistence was higher in Kenya and Tanzania, which can be categorized as near explosive meaning the volatility in these markets takes a longer duration to decay from these markets. This implies that turbulent times last longer and it takes a while for the market to stabilize.

With continued developments on volatility modelling such as regime specific volatility spillover modelling proposed by Baur and Dimpfl (2019), there is room to revisit the stylized facts of volatility persistence and volatility clustering to shed more light on their behavior.

6.2 Recommendations for Further Research

To further elaborate the understanding on the East African interconnectedness and available diversification opportunities, the study suggests use of additional models such as Cointegration and Granger causality to better clarify on the direction of stock market predictability in the region. Moreover, a study on impact of foreign market restrictions on market volatility should be undertaken in order to disclose whether market restrictions to foreign traders help to curb higher volatility during periods of global crises.

6.2.1 Recommendations to Market regulators

The findings of the study will be of importance to the regulatory bodies and policy makers in the EASA. It will shed light into how the performance of the markets will be impacted by integration thereby formulate conducive practices and policies to favor standard practices capable of improving joined market performance. Policy makers and regulators are reliant on market estimates of volatility as a gauge or benchmark for the vulnerability and exposure of the financial markets and the economy to externalities.

6.2.2 Recommendations to Fund managers

Analysts of global financial trends in emerging markets. Portfolio managers can use this to develop their trading strategies as well as construct portfolios (Soler, 2009). First,

forecasting of volatility of financial assets is necessary for these fund managers who are representative economic agents as it assists with decisions on portfolio risk management decisions by rational investors. Volatility is critical to fund managers because it gives a measure of risk exposure for their investments in the markets. Finally, volatility affects the economy as a whole and understanding it is an advantage for any investor. Portfolio managers in developing markets need to adjust diversified portfolios in times of high volatility in the markets from which there is a high volatility spillover.

6.2.3 Recommendations to Investors

Investors can use this as a source of information for international portfolio diversification and as a guide to asset allocation strategies. Additionally, since the release of the first Basle accord in 1996, volatility forecasting is at the core of risk management. It is useful to know the volatility of the underlying asset of an option because theoretically, it is vital in pricing of derivative securities.

6.2.4 Academicians

Researchers can benefit from the study by getting more information on volatility effects in the East Africa markets that will serve as a reference for further research. Different models other than the ones utilized in this study can be employed. The findings of the study bridge the knowledge gap on volatility spillover effects in the East African markets by informing empirical literature on volatility spillover in these markets.

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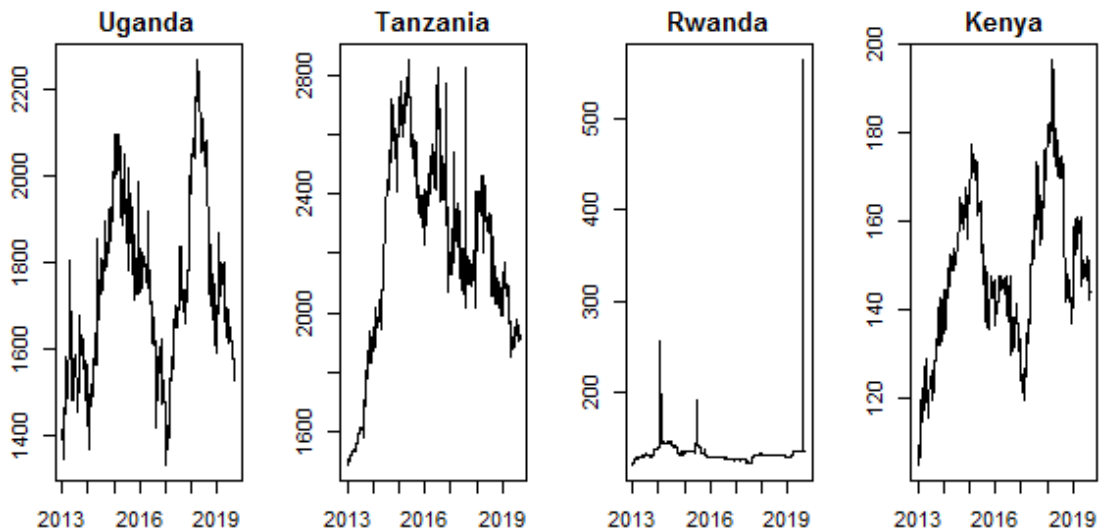
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Appendices

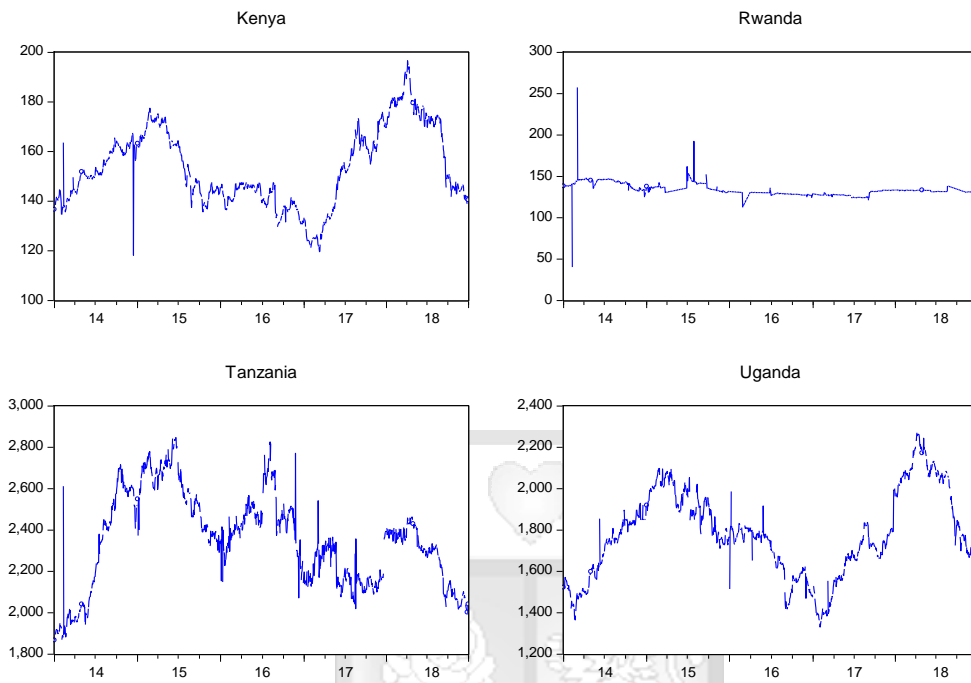
Appendix A: Stock market profiles

| Country Market | Index name | Index abbreviation | Currency | Period of data |
|----------------|---------------------|--------------------|---------------------|----------------|
| Kenya (NSE) | NSE All Share Index | NASI | Kenyan shillings | 2009 - 2019 |
| Tanzania (DSE) | DSE All Share Index | DSEI | Tanzanian shillings | 2009 - 2019 |
| Uganda (USE) | USE All Share Index | ALSIUG | Ugandan shillings | 2009 - 2019 |
| Rwanda (RSE) | RSE Share Index | ALSIRW | Rwandan Franc | 2013 - 2019 |

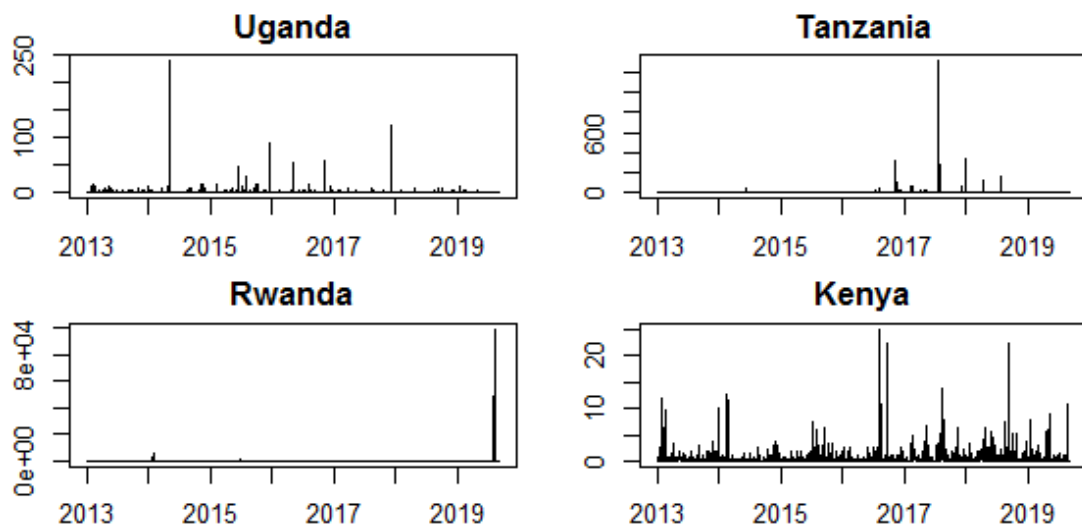
Appendix B: Time series plot



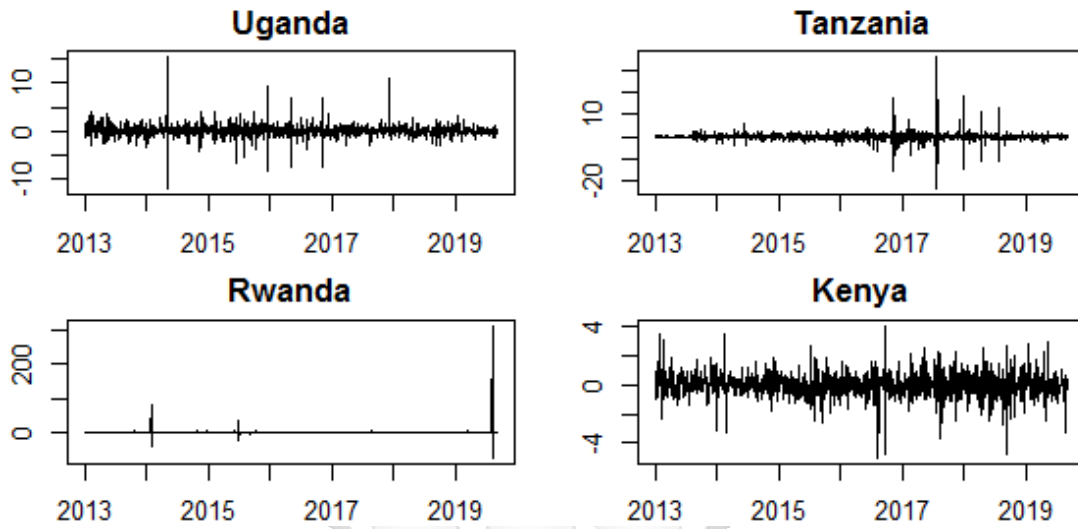
Appendix C: Returns Plot



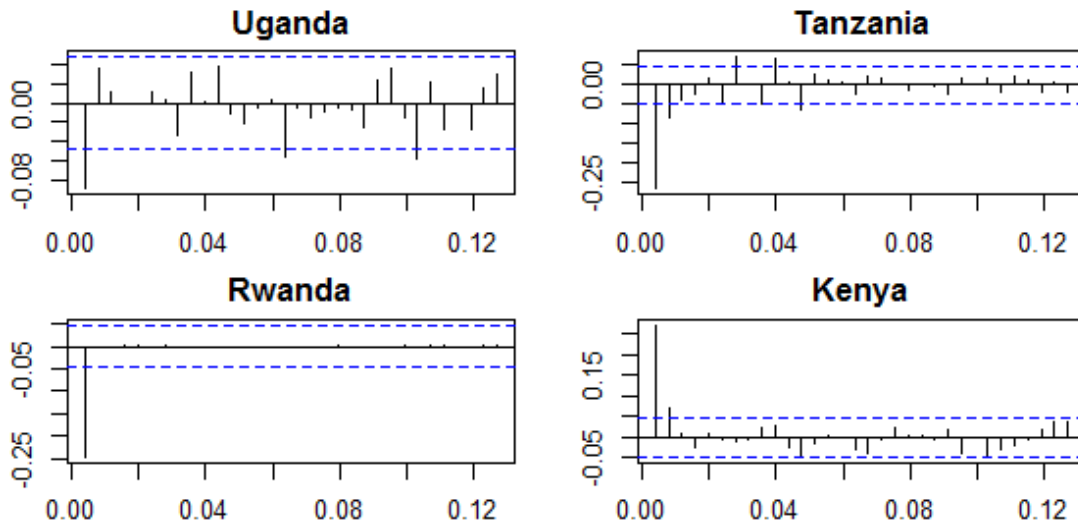
Appendix D: Squared returns plot



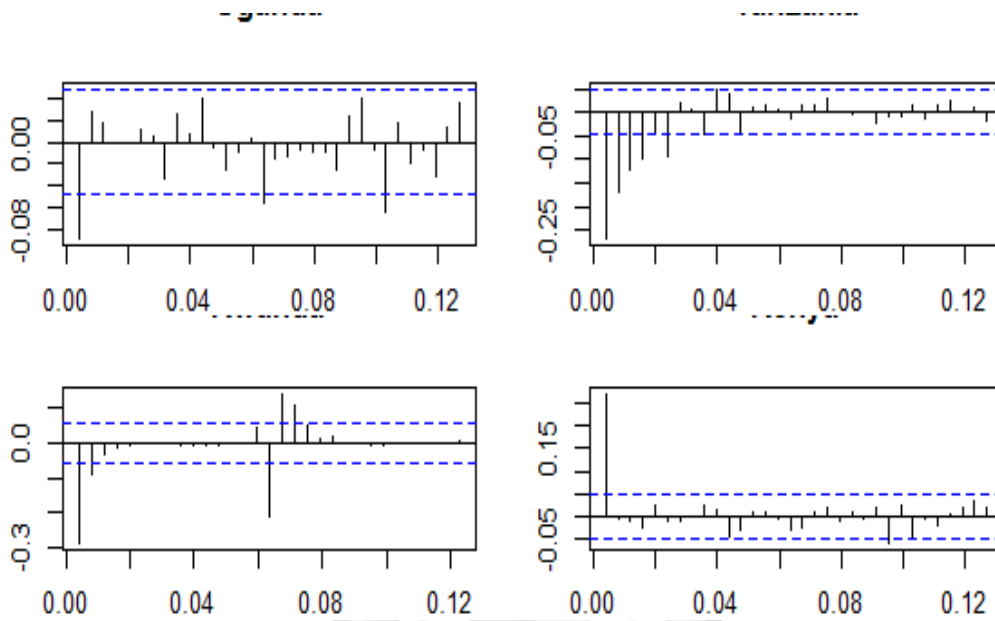
Appendix E: Return plot



Appendix F: Autocorrelation plot



Appendix G: PACF plot



Appendix H: Cross Listed Companies in the EAC markets

| Cross Listed Companies | Kenya | Uganda | Tanzania | Rwanda |
|--------------------------|-------|--------|----------|--------|
| British American Tobacco | ✓ | ✓ | | |
| Centum Investment | ✓ | ✓ | | |
| East African Breweries | ✓ | ✓ | ✓ | |
| Equity Group | ✓ | ✓ | | ✓ |
| Jubilee | ✓ | ✓ | ✓ | |
| KCB Group | ✓ | ✓ | ✓ | ✓ |
| Kenya Airways | ✓ | ✓ | ✓ | |
| Nation Media | ✓ | ✓ | ✓ | ✓ |
| Uchumi Supermaket | ✓ | | ✓ | ✓ |
| Umeme | ✓ | ✓ | | |