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**Inter-sector Volatility Spillover among Equities on the
Nairobi Securities Exchange**

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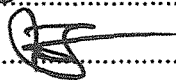
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ABSTRACT

This paper investigates the existence and magnitude of volatility spillovers among equities on the Nairobi Securities Exchange. The multivariate VARMA-GARCH model is used to test for spillover effects between four broad sectors of the NSE: Agricultural, Financial, Commercial and Services and Industrial. The significance of the parameters of the model are used as an indicator of the spillover effect between sectors. Based on the empirical results, the biggest volatility spillover is from the commercial and services sector to the broad industrial sector. There are also significant spillovers from the industrial and agricultural sectors to the financial and commercial and services sectors, as well as from the financial and commercial and services sectors to the broad industrial sector.

Key words: Volatility Spillovers, NSE, VARMA-GARCH

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List of Abbreviations

NSE	Nairobi Securities Exchange
ASEAN	Association of Southeast Asian Nations

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1. Introduction

1.1 Background of the Study

In order to clearly define volatility spillover, the term 'volatility' must first be defined. Schwert (1990), defines stock market volatility as a measure of the changeability or randomness of asset prices. He further states that volatility is commonly measured as the standard deviation of prices or rates of return. Therefore a higher standard deviation would indicate higher volatility, while a lower standard deviation would indicate lower volatility. According to Natarajan, Singh, & Priyac (2014), "Market volatility is inevitable: it is the nature of markets to move up and down over the short term". Following the same line of reasoning, and based on the work of Hammoudeh, Yuan, & McAleer (2009), volatility spillover can be defined as transmission of volatility in one sector of the stock market to another sector i.e. volatility in one sector resulting in volatility in another sector.

There are various ways in which equities on a stock market can be grouped or subdivided. One common method of subdivision of equities is based on the sectors in which the relevant company operates. In Kenya, for example, the equities on the Nairobi Securities Exchange are sub-divided into 11 sectors¹, which include: Agricultural, Automobile & Accessories, Banking, Commercial & Services, Construction & Allied, Energy & Petroleum, Insurance, Investment, Investment Services, Manufacturing & Allied, and Telecommunication & Technology².

Dividing the stock market based on the industrial sector in which the company operates allows companies which have similar operations, regulation and

¹ A full list of NSE companies by sector is given in Appendix I

² Nairobi Securities Exchange - *Listed Companies*. Retrieved June 15, 2015, from <https://www.nse.co.ke/listed-companies/list.html?start=50>

governance issues to be grouped together. These companies are likely to be affected in the same way, if industry conditions, regulations, or economic conditions change. For example, if insurance regulation in Kenya changed significantly, insurance companies in Kenya, including those listed on the Nairobi Securities Exchange would be affected. Therefore, the grouping of companies by sector in this way allows the analysis of individual industrial sectors.

With any investment, there is always a risk on one hand, and on the other hand, a return that is ideally meant to reward the investor for the risk taken. "It has been shown, that the crucial factor determining portfolio risk for a given level of return is the correlation between the returns of the securities that make up that portfolio," (Bartram & Dufey, 2001). Stock groupings by sector have been used as a basis for some portfolio diversification strategies. The key indicator in the formulation of these strategies is the extent of covariation between stocks of different sectors. Various studies into the factors driving covariation of stock returns have been done. These include studies done by King (1966), Lessard (1974, 1976), Heston & Rouwenhorst (1994) and Griffin & Karolyi (1998) all of whom concluded that country diversification was a superior strategy as compared to industry diversification. However, against the backdrop of this series of studies, Ehling & Ramos (2003), using a mean-variance spanning approach, concluded that a superior diversification strategy is one which is based on country as well as industry motivated portfolios. This indicates that industry diversification plays some role in portfolio risk management. If investors ideally diversify based on industrial sector, the main goal being to reduce the covariance between the stocks in their portfolio, a key issue to consider would be whether the volatility spillover between sectors is substantial enough to impact their initial estimates or assumptions about this covariance. The existence of significant volatility spillover between sectors would imply that there is some degree of integration between sectors.

Hammoudeh, Yuan, & McAleer (2009) argue that investors and portfolio managers should pay attention not only to the individual volatilities of the sectors in the stock market, but also the interactions and volatility transmissions between sectors. In addition, according to Harris & Pisedtasalasai (2006), information about volatility spillover effects is useful for applications in finance that rely on estimates of conditional volatility, for example option pricing, portfolio optimization, value at risk and hedging. Based on this it would be reasonable to check if volatility spillovers do exist; and if they do, a portfolio manager would need to consider whether it would impact their portfolio or risk management strategy significantly. A study of the existence and magnitude of these spillovers in the Kenyan market could provide useful additional information that could improve portfolio management practices in Kenya.

In their study, Hammoudeh, Yuan, & McAleer (2009) were able to examine the extent to which the volatility in one sector of the stock exchange can result in volatility in another sector within a certain period. In addition, they were able to show the extent to which past volatility of a sector can result in volatility of the sector in the current period. The approach taken by Hammoudeh, Yuan, & McAleer (2009) in their study was to put all the individual sectors into major sector groupings (Service, Industrial and Banking) rather than studying each individual sector in the market. This was done perhaps to take into account the possible integration that is known to already exist between some sectors. Based on the results of previous studies, evidence of some integration between some sectors has been found. A good example of this type of integration is in the financial sector. Cummins, Wei, & Xie (2011), in their study of U.S. Banks and Insurers were able to show that there are significant information spillovers between the two sectors, implying that there is some level of integration between them. This research will attempt to take a similar approach, putting the individual

sectors into broader sector groupings rather than the 11 individual sectors on the NSE.

This research attempts to examine the existence of volatility spillover on the Nairobi Securities Exchange, and if it does exist, the magnitude of the spillover between sectors. In addition, it attempts to identify the sectors between which volatility spillover is the highest.

1.2 Problem Statement

There has been evidence of volatility spillovers in stock markets other than the Nairobi Stock Exchange. Hammoudeh, Yuan, & McAleer (2009) were able to show evidence of this in their study of the Gulf Arab Stock markets. This study attempts to contribute to stock market volatility spillover literature, focusing specifically on the Nairobi Securities Exchange. A study of the existence and magnitude of these spillovers in the Kenyan market could provide useful additional information to portfolio managers or investors who diversify based on industry/sector.

1.3 Research Objectives

The objectives of this research are as follows:

- i. To determine the existence and magnitude of volatility spillover between sectors on the Nairobi Securities Exchange
- ii. To identify the sectors between which volatility spillover is the highest on the Nairobi Securities Exchange

1.4 Research Questions

The research questions are as follows:

- i. Is there any volatility spillover between sectors on the Nairobi Securities Exchange?
- ii. To what extent/magnitude does volatility spillover occur between sectors on the Nairobi Securities Exchange?
- iii. Between which sectors on the Nairobi Securities Exchange is volatility spillover the highest?

1.5 Scope of Research

This research focuses on volatility spillover between sectors on the Nairobi Securities Exchange. The period of study is from January 2007 to November 2014.

1.6 Significance of Research

This research attempts to contribute to literature on volatility spillover specifically on the NSE. The main beneficiaries of this research are likely to be portfolio managers who to whatever extent diversify portfolios based on industries/sectors. With information on volatility spillover, they would be able to identify between which sectors volatility can spill over, allowing them to select securities that take this possible spillover into account, and avoid the adverse effects of high volatilities in their portfolios.

2. Literature Review

2.1 Introduction

There has been extensive research done on stock market volatility as well as the econometric time series models used in modelling the volatility. The various sections of the literature review give a discussion of literature dealing with the topics related to the subject of study. There is a discussion on stock market volatility in general, followed by diversification, volatility spillover between similar sectors in different countries, volatility spillover between sectors in the same market, and finally volatility spillover between large and small cap stocks. Finally, the research gap that the study attempts to fill is discussed briefly, and the conceptual framework is formally presented.

2.2 Stock Market Volatility

In one of the seminal works on stock market volatility, Schwert (1990), defined volatility as a measure of the changeability or randomness of asset prices.. He went on to identify standard deviation as the most common measure of volatility because it summarizes the probability of seeing extreme values of return. His study was based on stock market volatility in the U.S. It provided an overview (at that point in time) of stock market volatility and some of the issues that may have an impact on it such as computerized trading, trading in futures and options and trading volumes.

Similarly, Haugen, Talmor, & Torous (1991), studied volatility on the U.S. stock markets. However, they focused on the effect of volatility changes on stock prices and returns. Their approach focused on the present value model of calculating share prices, more specifically, the discount rate that is used in the model. They were able to provide evidence that increases in volatility caused a decline in stock prices and a consequent increase in realized future returns, whereas a decrease in volatility resulted in a rise in stock prices and a lower realized future return. The

implication of this study is that volatility is one of the factors that may contribute to the level of stock prices. Therefore an investor with equities in their portfolio should be wary of the impact that a significant increase or decrease in volatility can have on his/her portfolio.

2.3 Diversification

“There is little disagreement that diversification is a worthwhile activity,” (Chance, Shynkevich, & Yang, 2011).

This section presents a discussion on the country versus industry effects debate, to which various scholars have contributed. The debate is mainly driven by the search of a superior diversification strategy between one based on country effects and one based on industry effects. The section ends with a short discussion on human biases in security selection and diversification.

2.3.1 The country versus industry effects debate

In one of the seminal works on the industry versus country effects discussion, Heston & Rouwenhorst (1995) presented a simple model to measure country and industry effects in international stock returns. Their study was based on total returns of 829 firms that were included in the Morgan Stanley Capital International (MSCI) of twelve European countries from 1978 through 1992. The proposed model was a simple linear factor model for the return on a stock which had a common factor, a parameter for industry effects, another one for country effects, and an error term. Based on the model, they were able to conclude that country effects dominated industry effects. The implication was that a portfolio manager should give more preference to geographical composition when deciding a portfolio diversification strategy. This was one of the earlier works that sparked the debate on country versus industry effects.

In their study of the European equity markets, Adjouate & Danthine (2004) analysed the consequences of the process of financial and economic integration

on the European Equity markets. They concluded that finding diversification opportunities at a disaggregated level (at the level of country sectors) is important due to changes in factors such as fundamentals in the markets. The key fundamentals they highlighted were increased synchronization of macro-economic activities and a non-negligible evolution in pricing. Therefore the impact of the change in fundamentals calls for a slightly different diversification strategy to that proposed by Heston & Rouwenhorst (1995). Diversification at a disaggregated level appears to be a middle ground between diversification based on industry effects and country effects. Furthermore, Adjouate & Danthine (2004) highlight some deficiencies in the methodology used by Heston & Rouwenhorst (1995). The first of these deficiencies are that it imposes restrictions that a firm belongs to one country and one industry only and that it is not sensitive to other countries or industries. This is due to the increased influence of multinational firms or firms that operate in multiple industries. A second deficiency that was identified is that the methodology assumes that all stocks from the same industry or country have the same sensitivity to the industry or country effects.

As a contribution to the debate on country versus sector effects in equity returns, De Moor & Sercu (2010) undertook a study to investigate the effect of considering emerging markets. They propose that based on earlier works e.g. Heston & Rouwenhorst, (1994) inclusion of emerging markets (EMs) into the sample under study would have an impact on the ratio of country related variance to industry related variance in stock returns. In their approach they sought to investigate to what extent the effect of adding emerging markets is attributed to the impact of small firms. The reason for this was that emerging markets have a higher variability, and are less connected to the global market and global industry news. After adding both emerging markets and small firms to the data, they concluded that adding small firms to the data has little impact on the effect of adding

emerging markets and that the role of the emerging markets cannot be reduced to just a small-firm phenomenon.

Dou, Gallagher, Schneider, & Walter (2014) carried out a study on cross-region and cross-sector asset allocation on developed equity markets in six regions (North America, UK, Japan, Large European Countries, Small European countries and the Pacific ex-Japan). In their study, they utilised a regime switching model across both regions and sectors. The model considered two regimes: A bull market with high returns and low volatilities, and a bear market with low returns and high volatilities. Their justification for using the regime switching model was that static mean-variance analysis fails to account for multiple regimes i.e different market or economic conditions. From their study, they concluded that diversification across sectors was superior to regional diversification. This was explained by the increased level of global market integration. In addition they concluded that the regime switching model gives a more realistic representation of equity returns as compared to the static mean-variance analysis. The conclusions of this study contradict the conclusion of the seminal works of Heston & Rouwenhorst (1995), indicating that perhaps markets had significantly evolved since the earlier work was done.

Hwang & Sitorus (2014) studied the impact of country and industry effects in optimal diversification strategy. Their study was based on the Association of Southeast Asian Nations (ASEAN) member countries: Indonesia, Malaysia, Phillipines, Singapore and Thailand. They found that the country effect still dominates the industry effect in explaining equity return variation of the counties under investigation. The implication of this result is that international portfolio managers should put more emphasis on country effects as opposed to industry effects when seeking a diversified ASEAN portfolio.

2.3.2 Human biases in security selection and diversification

In their study on security selection and portfolio construction, Chance, Shynkevich, & Yang (2011), endeavoured to test the previously debated hypothesis that no more than 30 securities are required for effective diversification of a portfolio. The approach they took was to compare the security selections of a portfolio of a sample of investors to security selections driven by a random number generator. Their conclusion was that there is no arbitrary number of securities required to achieve full diversification. Another supplementary conclusion that was made was that diversification was improved when investors held smaller portfolios. The explanation given was that these investors selected portfolios with stocks that were familiar to them. This familiarity can be identified as a human bias since familiarity is a unique experience to every human being. The results of this study highlight the impact that human biases can have on security selection during the diversification process, contributing towards behavioural finance theory.

2.4 Volatility Spillover

2.4.1 Volatility Spillover between countries

Engle & Kroner (1995) developed theoretical results for the multivariate simultaneous generalized ARCH model, also known as the BEKK model. Singh, Kumar, & Pandey (2010) used the BEKK model to investigate volatility spillovers between the Indian markets and the Hong Kong, Korea, Japan, Singapore and US markets. In this case spillover between the stock markets was of interest. Their study found that there is a positive volatility spillover between the Indian and the other markets, whereas there was a negative spillover between the Indian and US and Pakistan markets. An interesting observation from this study was that the volatilities of particular indices were affected most by those markets that opened just before them. This implies that the differences in the opening times of the stock

markets is one of the factors to consider when analysing volatility spillover between markets.

Similarly, Kouki, Harrathi, & Haque (2011), used this BEKK model in their study of volatility spillover among sectors of international stock markets. Unlike Singh, Kumar, & Pandey (2010) their study focused on spillover between similar sectors across multiple stock markets. More specifically, they analyzed volatility among five main sectors: Banking, Financial Service, Industrial, Real Estate and Oil. Their findings were that there was significant spillover among the Banking, Real Estate and Oil sectors. The results of this study appear to support the hypothesis that the level of stock market integration among countries, between these three sectors is relatively higher when compared with that of the industrial and financial services sectors. Furthermore, the results of the study contribute to the debate on country diversification versus sector diversification. This is because they call into question the universal applicability of the top-down approach to diversification, where assets are selected based on country first, then on sectors as a secondary criterion.

Taking a similar approach to Singh, Kumar, & Pandey (2010), Natarajan, Singh, & Priyac (2014), studied mean and volatility spillovers among five major national stock markets: Australia, Brazil, Germany, Hong Kong & USA. However, they used a GARCH-M model instead. They found that past-market volatility shocks in the USA influenced current volatility in the Australian and German market with varying degrees of intensity. Not only were they able to show that volatility spillovers occurred, but they were also able to show the existence and extent of mean spillovers between the stock markets. The study of volatility spillovers between countries, could be used as a measure of which of the countries is the most influential. As an example, Natarajan, Singh, & Priyac (2014) were able to conclude that the US market is the most influential market among the markets under study.

2.4.2 Inter-sector volatility spillover

Using the VARMA-GARCH model developed by Ling & McAleer (2003), Hammoudeh, Yuan, & McAleer (2009) were able to study shock and volatility spillovers among equity sectors of the Gulf Arab Markets. Focusing only on three major sectors (Service, Industrial and Banking), they were able to conclude from their findings that volatility spillovers were more widespread from the industrial sector to the service sector of the Saudi Arabia, Kuwait and Qatar markets.

The possibility of volatility being transmitted from one equity sector to another calls into question, the validity of sector diversification. If investors diversify based on industrial sector, intending to reduce the covariance between the stocks in their portfolio, a key issue to consider would be whether the volatility spillover between sectors is substantial enough to impact their initial estimates or assumptions about this covariance. The existence of significant volatility spillover between sectors would imply that there is some degree of integration between sectors. This would have implications on the diversification strategy employed.

Empirically, the volatility spillover between sectors can be represented as the interdependent conditional variance in a time series model such as the VARMA-GARCH model developed by Ling & McAleer (2003). The VARMA-GARCH model is a more recent and fairly more sophisticated multivariate model. It did, however, enable Hammoudeh, Yuan, & McAleer (2009) to examine the conditional volatility and conditional correlation cross effects with meaningful estimated parameters and less computational complications, as compared to the BEKK model of Engle & Kroner (1995).

2.4.3 Volatility Spillover between large and small cap stocks

Another way in which volatility spillover can be studied is by comparing spillovers between large and small capitalization stocks. This is the approach that was taken by Harris & Pisedtasalasai (2006), where they used the multivariate GARCH model of Bollerslev (1990) to investigate return and volatility spillovers

between large and small cap stocks in the UK. Bollerslev (1990) developed the model for use in modelling short-run nominal exchange rates. Harris & Pisedtasalasai (2006) found that there were assymetric return and volatility spillovers between the two groups of stocks: the return and volatility spillover effects from the large stocks to the small stocks was more significant than the spillover effects from small stock to large stocks. The implication here is that when trying to predict the future movements of small cap stocks, the current dynamics of large cap stocks should be considered, as part of the information used.

2.5 Research gap

Various studies on the topic of volatility on the NSE have been done including those done by Wagala, Nassiuma, Islam, & Mwangi (2012), Forgha (2012) and Tah (2013). However, none have touched on the issue of volatility spillover between sectors. Furthermore, based on the study by Hammoudeh, Yuan, & McAleer (2009) there has been evidence of inter-sector volatility spillover in other stock markets. This research attempts to contribute to literature on volatility on the NSE, particularly by providing information on volatility spillover between sectors.

2.6 Conceptual Framework

The major issues discussed in the literature review, related to the study are stock market volatility, diversification and stock market volatility spillover. One of the models previously used in a similar study is the VARMA-GARCH model which allows the identification of series (which in this case are sector indices) between which there is a significant volatility spillover. This volatility spillover could be used as an indicator of sector integration. Based on that, the conceptual framework for this study is represented by the figure 1 on the next page:

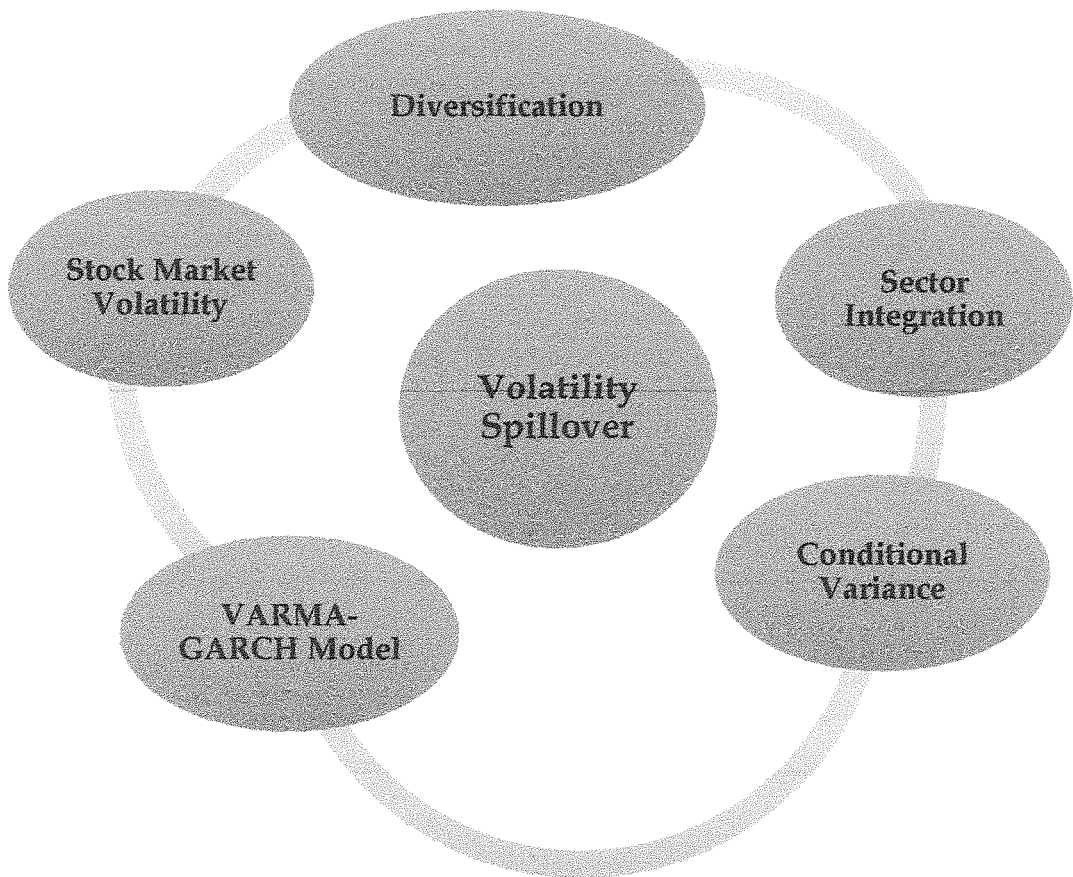


Figure 1: Conceptual Framework

3. Research Methodology

3.1 Research Design

This research attempts to determine the existence and magnitude of volatility spillover between sectors on the NSE. It is a quantitative, explanatory study, making use of the VARMA-GARCH model to determine the extent of volatility spillover between sectors.

Firstly, share price data from the various sectors of the NSE is collected and then sector-based indices of returns are calculated. Based on availability of data, the study uses share prices covering a seven year period. Thereafter, these indices are analyzed using the VARMA-GARCH model to produce estimates for the parameters of the mean and variance equations of the model. A hypothesis testing approach, employing p-values, is used to determine the significance of the model parameters that indicate volatility spillover.

3.2 Population and Sampling

The population in this study is the Nairobi Securities Exchange. Furthermore, the sample is the equity market, more specifically, the equities in the traditional sectors of the NSE. This excludes recently formed sectors such as the growth and enterprise market (GEMS) which only has one stock.

3.3 Data Collection

The type of data used for this study is numerical/quantitative. Furthermore, the data is obtained entirely from secondary sources. This study uses daily share price information as well as the shares in issue in the various sectors of the Nairobi Stock Exchange.

Based on the methodology of Hammoudeh, Yuan, & McAleer (2009), the stocks in the 11 individual sectors are grouped together to create broader sectors. The banking, insurance, investment and investment services stocks are all be grouped into one broad financial sector, the agricultural and commercial and services

sectors stand on their own as broad sectors and finally the broad industrial sector is made up of the construction and allied, automobiles and accessories, energy and petroleum, manufacturing and allied and telecommunications sectors.

3.4 Data Analysis

3.4.1 Market Cap Weighted Index

Since no developed and published sector indices exist for the Kenyan market, the share price and shares in issue are used to calculate a market capitalization weighted index for each sector. A market capitalization index is chosen because data for the shares in issue is readily available. To calculate the daily level of the market capitalization weighted index, the product of the share price and shares in issue is summed up for each share for each day in the seven year period.

Thereafter, the log of daily returns is calculated for the various indices. The general formula of the log returns is:

$$R_{i,t} = \ln \left(\frac{P_{i,t}}{P_{i,t-1}} \right) \quad (1)$$

Where $R_{i,t}$ is the return of index i at time t , $P_{i,t}$ is the level of index i at time t and $P_{i,t-1}$ is the level of index i at time $t-1$.

The indices of sector returns are then used in the VARMA-GARCH model to analyze the inter-sector volatility.

3.4.2 Empirical Time-Series Model

The multivariate technique that is employed is the vector autoregressive moving average GARCH (VARMA-GARCH) model developed by Ling & McAleer (2003). According to Hammoudeh, Yuan, & McAleer (2009), this method enables the examination of the conditional volatility and correlation cross effects with meaningful estimated parameters and less computational complications as compared with other methods such as the BEKK model of Engle & Kroner (1995).

3.4.3 Model Specifics

The model used in the study is specified below as equations (2) and (3), with a table below each equation to explain the key variables.

From the VARMA-GARCH model developed by Ling & McAleer (2003), and the work of Hammoudeh, Yuan, & McAleer (2009) on the Gulf Arab Stock Markets:

The equity sectors in the VARMA-GARCH system are indexed by i , and n is the total number of sectors.

The mean equation for the i^{th} sector in this system is AR(1), and is given by:

$$R_{i,t} = a_i + b_i R_{i,t-1} + \varepsilon_{i,t}, \quad (2)$$

$$\varepsilon_{i,t} = h_{i,t}^{1/2} \eta_{i,t}$$

Table 1: Mean Equation

Variable	Explanation
$R_{i,t}$	The return of the i^{th} sector of the $n \times 1$ vector R_t , defined as the log differences
$\eta_{i,t}$	An innovation: an independent and identically distributed random shock
$h_{i,t}$	the conditional variance of the i^{th} sector at time t

➤ a_i and b_i are constants

The interdependent conditional variance is specified as:

$$h_{i,t} = c_i + \sum_{j=1}^n \alpha_{ij} \varepsilon_{j,t-1}^2 + \sum_j \beta_{ij} h_{j,t-1} \quad (3)$$

Which is a generalization of the Bollerslev (1990) univariate GARCH process, where $h_{i,t}$ is the conditional variance at time t , $h_{j,t-1}$ refers to own past variance for $i = j$, and past conditional variances of the sectors in the market or system for $i \neq j$.

Table 2: Variance Equation

Variable	Explanation
$\sum_{j=1}^n \alpha_{ij} \varepsilon_{j,t-1}^2$	the short run persistence (or the ARCH effects of past shocks)
$\sum_j^n \beta_{ij} h_{j,t-1}$	the contribution to the long run persistence (or the GARCH effects of past volatilities).

➤ c_i is a constant.

From Equation (3), the conditional variance for the i^{th} sector is impacted by past shocks and past conditional variances of all the sectors in the market, thereby capturing interdependencies or spillovers. Therefore, this specification allows for the cross-sectional dependency of conditional volatilities among all the sectors. The past shock and volatility of one sector are allowed to impact the future volatilities not only of itself but also of all the other sectors in the system.

The VARMA-GARCH model is capable of providing numerical estimates for the mean equation, the variance equation and constant conditional correlations for each of the chosen sectors. The variance equations, for each of the sectors, can be represented as a function of the past volatilities of the sector itself as well as that of other sectors in the market.

The null hypothesis is that there is no volatility spillover between sectors. Therefore if the parameters indicating spillover from the VARMA-GARCH are statistically significant, it means that there exists a volatility spillover. The hypothesis test will be done at the 5% level using p-values for the parameters. The difference/ distance between the p-value and 5% can be used to check the strength of the significance or non-significance. This is used to check the magnitude of the spillover effect. The β coefficient will be of most interest since it represents the GARCH effects of past volatilities.

4. Results and Analysis

The descriptive statistics of the index series used in the model are given table 3 below:

Table 3: Descriptive Statistics

	AGRICULTURE	FINANCE	COMMERCIAL AND SERVICES	INDUSTRIAL
Sample Mean	0.0357	0.0438	0.0002	0.0174
Standard Error	1.4751	0.9891	1.4365	0.9502
SE of Sample Mean	0.0331	0.0222	0.0322	0.0213
t-Statistic (Mean=0)	1.0803	1.9731	0.0069	0.8176
t-statistic Signif Level (Mean=0)	0.2801	0.0486	0.9945	0.4137
Variance	2.1756	0.9783	2.0635	0.9029
Skewness	0.6811	0.9251	2.5098	0.1830
Kurtosis (excess)	5.8866	17.4435	36.9207	7.2725
Jarque-Bera	3025.5693	25500.6377	115058.0657	4394.2678

From the descriptive statistics in table 3, it is noted that the broad financial services sector has the highest mean return as whereas the commercial and services sector has the lowest. This indicates that the financial stocks had strong performance over the period considered compared to the agriculture, commercial and services and industrial sectors.

In terms of variance, the agricultural sector has the highest value whereas the broad industrial sector has the lowest. This is an indicator that stocks in the industrial sector had relatively stable returns over the period, whereas those in the agricultural sector were less stable. Figures 2 and 3 provide a graphical representation of the agricultural and industrial sector returns. Graphs for the commercial and services and finance sectors are also given in Appendix III.

Figure 2: Industrial Sector Returns



Figure 3: Agriculture Sector Returns



Recall that the formulae for the mean and variance equations of the VARMA-GARCH are:

$$R_{i,t} = a_i + b_i R_{i,t-1} + \varepsilon_{i,t}, \quad (2)$$

and

$$h_{i,t} = c_i + \sum_{j=1}^n \alpha_{ij} \varepsilon_{j,t-1}^2 + \sum_j \beta_{ij} h_{j,t-1} \quad (3)$$

Estimates for the mean equation and the α parameters of the variance equation are given in tables 5 and 6 (Appendix II).

The β parameters in the third part of the variance equation are of most interest because they relate to the lagged conditional variance, $h_{j,t-1}$ in other sectors when $i \neq j$ and own lagged conditional variance when $i=j$. This conditional variance is an indicator of spillover effects. The constant, c_i and β parameter estimates for the VARMA-GARCH are presented in table 4 below:

Table 4: VARMA-GARCH Estimates for c_i and β parameters³

	C (constant)	β_1 [AGR]	β_2 [FIN]	β_3 [CS]	β_4 [IND]
AGR [1]	0.09496677	0.695957199	0.049773698	0.744833932	1.103229584
T-Stat	1.8312	9.522	0.10374	1.33725	1.37938
P-value	0.067220358	0.000000000	0.917386152	0.181294104	0.167932843
FIN [2]	0.033122342	2.703274014	0.343786905	0.237779297	-0.529691232
T-Stat	1.18383	3.48008	3.48773	1.61451	-2.33314
P-value	0.236621965	0.000512078	0.000497736	0.106575622	0.019740121
CS [3]	0.310802676	4.038367476	-0.18201298	-0.123113405	2.431923485
T-Stat	2.30355	3.03645	-0.45683	-7.38861	2.63447
P-value	0.021350700	0.002424929	0.647843176	0.000000000	0.008492315
IND [4]	0.203081338	0.7185186	-0.223567375	-0.286628239	0.613577166
T-Stat	4.6424	1.93544	-2.0406	-6.18151	7.71602
P-value	0.000003669	0.053078047	0.041422532	0.000000001	0.000000000

³T-Stat = T - Statistic

AGR = Agricultural Sector, FIN = Financial Sector, CS = Commercial and Services Sector, IND = Industrial Sector

From table 4, the significance of parameters at the 5% level can be analysed to check for spillover effects. Recall that the null hypothesis is as follows:

H₀: There is no volatility spillover between sectors

The intercept/C parameters are not significant in all sectors except for the industrial sector. However, the p-value for the intercept for the agricultural sector is close to 5%, indicating that it is almost significant.

Looking at the agricultural sector, none of the β parameters is significant except for the parameter indicating own volatility spillover, which is to be expected, and is disregarded when assessing inter-sector volatility spillover. Therefore we have insufficient evidence to reject the null hypothesis at the 5% level and it is reasonable to conclude that there are no significant spillovers from the broad financial, industrial and commercial and services sectors to the agricultural sector.

Looking at the broad financial sector, all β parameters are significant except for the one relating to the commercial and services sector. Therefore, in the case of the commercial and services sector we have insufficient evidence to reject the null hypothesis and it is reasonable to conclude that there is no significant spillover effect from the commercial and services to the financial sector at the 5% level. On the other hand, we have sufficient evidence to reject the null hypothesis in the case of the agricultural and industrial sectors and it is reasonable to conclude that there are significant spillovers from the agricultural and industrial sectors to the financial sector. It is also notable that the p-value for the β of the agricultural sector (0.000512078) is lower/farther away from the 5% level than the value for the industrial sector (0.106575622). This indicates the stronger significance for the agricultural sector than the industrial sector showing a bigger spillover effect from the agricultural sector e.g. If the test was carried out at the 0.5% level, the

agricultural parameter would be significant and the industrial parameter would not.

Looking at the commercial and services sector, only the β parameters of the agricultural and broad industrial sectors are significant. Therefore in the case of the agricultural and industrial sectors, we have sufficient evidence to reject the null hypothesis and it is reasonable to conclude that there is volatility spillover from the agricultural and industrial sectors to the commercial and services sector. Furthermore, the p-value for the β parameter for the agricultural sector (0.002424929) is lower than that of the industrial sector (0.008492315) indicating a bigger spillover effect from the agricultural sector. In the case of the financial sector, we have insufficient evidence to reject the null hypothesis and it is reasonable to conclude that there is no significant volatility spillover from the financial to commercial and services sector at the 5% level.

Looking at the broad industrial sector, all the β parameters except for the agricultural sector parameter are significant. Therefore in the case of the financial and commercial and services sectors we have sufficient evidence to reject the null hypothesis and it is reasonable to conclude that there are volatility spillovers from the financial and commercial and services sectors to the industrial sector. The lowest p-value for the parameters is 0.000000001 for the commercial and services sector followed by 0.041422532 for the broad financial sector. Therefore there is a bigger spillover effect from the commercial and services sector. In the case of the agricultural sector, we have insufficient evidence to reject the null hypothesis at the 5% level and it is reasonable to conclude that there is no volatility spillover from the agricultural to the industrial sector at the 5% level.

Table 5 below summarises the ranking of the significant inter-sector volatility spillovers from the highest to the lowest.

Table 5: Ranking of significant volatility spillovers

Rank	Spillover A → B : From A to B	P-Value of β parameter
1	CS → IND	0.000000001
2	AGR → FIN	0.000512078
3	AGR → CS	0.002424929
4	IND → CS	0.008492315
5	IND → FIN	0.019740121
6	FIN → IND	0.041422532

5. Implications for Policy and Practice

The results of the study could have implications on portfolio diversification strategies. Based on the analysis, when there is high volatility in the sectors from which there is a high volatility spillover, portfolio managers could adjust their diversified portfolios to take into account the potential increase in volatility due to a spillover. An example of an adjustment could be to reduce portfolio weights in sectors that are exposed to volatility spillovers from sectors experiencing or expected to experience high volatility at a particular time. This, of course, assumes that the transaction costs associated with the rebalancing are small enough relative to the benefit gained to justify the rebalancing.

6. Summary and Conclusion

From the analysis, it can be concluded that there exists some volatility spillover between sectors on the Nairobi Securities Exchange. There are significant spillovers from the industrial and agricultural sectors to the financial sector, from the agricultural and industrial sector to the commercial and services sector, and from the financial and commercial and services sectors to the industrial sector.

Overall, the biggest volatility spillover is from the commercial and services sector to the broad industrial sector. This is because it has the lowest p-value of all the β parameters (0.000000001), excluding those indicating own volatility spillover.

It is also worth noting that as much as the agricultural sector appears not to be impacted by volatility in other sectors, it shows the biggest spillovers to the financial and commercial and services sectors. The agricultural sector is predominantly made up of beverage (tea and coffee) and horticulture companies which means that a significant amount of output from this sector is exported to the rest of the world. Perhaps this could explain why it has little spillover from other sectors but big spillovers to the financial and commercial and services sectors.

Finally, it is important to note that the sectors are made up of various different stocks whose individual performances impact overall sector performance differently. So it could be interesting (if there were enough computational power available) to look at volatility spillovers among the various individual stocks and how they might impact diversification.

7. References

- Adjouate, K., & Danthine, J.-P. (2004). Equity Returns and Integration: Is Europe Changing? *Oxford Review of Economic Policy*, 20(4), 555-570.
- Bartram, S. M., & Dufey, G. (2001). *International Portfolio Investment: Theory, Evidence, and Institutional Framework*.
- Bollerslev, T. (1990). Modelling the coherence in the short -run nominal exchange rates: A multivariate generalized ARCH approach. *Review of Economics and Statistics*, 72, 498-505.
- Chance, D. M., Shynkevich, A., & Yang, T.-H. (2011). Experimental Evidence on Portfolio Size and Diversification: Human Biases in Naïve Security Selection and Portfolio Construction. *The Financial Review*, 46, 427-457.
- Cummins, J. D., Wei, R., & Xie, X. (2011). *Financial Sector Integration and Information Spillovers: Effects of Operational Risk Events on U.S. Bank and Insurers*.
- De Moor, L., & Sercu, P. (2010). Country v sector effects in equity returns and the roles of geographical and firm-size coverage. *Small Business Economics*, 35(4), 433-448.
- Dou, P. Y., Gallagher, D. R., Schneider, D., & Walter, T. S. (2014). Cross-region and cross-sector asset allocation with regimes. *Accounting and Finance*, 54, 809-846.
- Ehling, P., & Ramos, S. B. (2003). *Geographical Versus Industrial Diversification: A Mean Variance Spanning Approach*. FAME- International Center for Financial Asset Management and Engineering.
- Engle, R. F., & Kroner, K. F. (1995). Multivariate Simultaneous Generalized ARCH. *Econometric Theory*, 11, 122-150.

- Flannery, M. J., & James, C. M. (1984). The Effect of Interest Rate Changes on the Common Stock Returns of Financial Institutions. *The Journal of Finance*, 39(4), 1141-1153.
- Forgha, N. G. (2012). An Investigation into the Volatility and Stock Returns Efficiency in African Stock Exchange Markets. *International Review of Business Research Papers*, 8(5), 176-190.
- Griffin, J. M., & Karolyi, G. A. (1998). Another Look at the Role of the Industrial Structure of Markets for International Diversification Strategies. *Journal of Financial Economics*(50), 351-373.
- Hammoudeh, S. M., Yuan, Y., & McAleer, M. (2009, August). Shock and Volatility Spillovers Among Equity Sectors of the Gulf Arab Stock Markets. *The Quarterly Review of Economics and Finance*, 49(3), 829-842.
- Harris, R. D., & Pisedtasalasai, A. (2006). Return and Volatility Spillovers Between Large and Small Stocks in the UK. *Journal of Business Finance & Accounting*, 33(9 & 10), 1556-1571.
- Haugen, R. A., Talmor, E., & Torous, W. N. (1991). The Effect of Volatility Changes on the Level of Stock Prices and Subsequent Expected Returns. *The Journal of Finance*, 46(3), 985-1007.
- Heston, S. L., & Rouwenhorst, G. K. (1994). Does Industrial Structure Explain the Benefits of International Diversification? *Journal of Financial Economics*(36), 3-27.
- Heston, S. L., & Rouwenhorst, K. G. (1995). Industry and country effects in international stock returns: Implications for Asset Allocation. *Journal of Portfolio Management*, 21(3), 53-58.

- Hwang, P., & Sitorus, R. E. (2014, September). A Study of Financial Integration and Optimal Diversification Strategy in ASEAN Equity Markets. *Journal of Economic Integration*, 29(3).
- King, B. (1966). Market and Industry Factors in Stock Price Behavior. *Journal of Business*(39), 130-190.
- Kouki, I., Harrathi, N., & Haque, M. (2011). A Volatility Spillover among Sector Index of International Stock Markets. *Journal of Money, Investment and Banking*(22), 32-45.
- Lessard, D. (1974). World, National, and Industry Factors in Equity Returns. *Journal of Finance*(29), 379-391.
- Lessard, D. (1976). World, Country, and Industry Relationship in Equity Returns: Implications for Risk Reduction through International Diversification. *Financial Analysts Journal*(32), 32-38.
- Ling, S., & McAleer, M. (2003). Asymptotic Theory for a Vector ARMA-GARCH Model. *Econometric Theory*, 19, 280-310.
- Natarajan, V. K., Singh, A. R., & Priyac, N. C. (2014). Examining mean-volatility spillovers across national stock markets. *Journal of Economics, Finance and Administrative Science*, 55-62.
- Schwert, W. G. (1990). Stock Market Volatility. *Financial Analysts Journal*, 46(3), 23-34.
- Singh, P., Kumar, B., & Pandey, A. (2010). Price and volatility spillovers across North American, European and Asian stock markets. *International Review of Financial Analysis*, 19(1), 55-64.
- Tah, K. A. (2013). Relationship between Volatility and Expected Returns in Two Emerging Markets. *Business and Economics Journal*, 84.

Wagala, A., Nassiuma, D. K., Islam, A. M., & Mwangi, J. W. (2012). Volatility Modelling of the Nairobi Securities Exchange Weekly Returns Using the Arch-Type Models. *International Journal of Applied Science and Technology*, 2(3), 165-174.

8. Appendices

Appendix I: List of NSE companies by sector

AGRICULTURAL	
1	Eaagads
2	Kakuzi
3	Kapchorua
4	Limuru Tea
5	Rea Vipingo
6	Sasini
7	WTK
AUTOMOBILES & ACCESSORIES	
8	C & G
9	CMC
10	Marshalls
BANKING	
11	Sameer
12	Barclays
13	CFC
14	DTK
15	Equity
16	HFCK
17	I&M
18	KCB
19	NBK
20	NIC
21	StanChart
22	Co-op
COMMERCIAL & SERVICES	
23	Express
24	Hutchings
25	KQ
26	Longhorn
27	NMG
28	Scan
29	Standard
30	TPS EA
31	Uchumi
CONSTRUCTION & ALLIED	
32	ARM
33	Bamburi

34	Crown
35	E.A.Cables
36	EAPCC
ENERGY & PETROLEUM	
37	KenGen
38	Kenol
39	KPLC
40	Total
41	Umeme
INSURANCE	
42	BAICL
43	CIC
44	Jubilee
45	Kenya Re
46	Liberty
47	Pan Africa
INVESTMENT	
48	Centum
49	City Trust
50	Olympia
51	TCL
INVESTMENT SERVICES	
52	NSE
MANUFACTURING & ALLIED	
53	A.Baumann
54	B.O.C
55	BAT
56	Carbacid
57	EABL
58	Eveready
59	Orchards
60	Mumias
61	Unga
TELECOMMUNICATIONS	
62	Access Kenya
63	Safaricom
GEMS	
64	Home Africa

Appendix II: VARMA-GARCH Estimates

Table 6: VARMA-GARCH Estimates for the Mean Equation

	AGRICULTURE	FINANCE	COMMERCIAL AND SERVICES	INDUSTRIAL
C	0.010999863	0.025125891	-0.084449811	-0.010989174
AR (1)	0.006291307	0.29565923	0.234544586	0.204039244

Table 7: VARMA-GARCH Estimates for Alpha Parameters

	α_1 [AGR]	α_2 [FIN]	α_3 [CS]	α_4 [IND]
AGR [1]	0.125785706	0.051944024	-0.035943977	-0.043003396
T-Stat	4.71898	1.75605	-1.87998	-1.07779
P-value	0.000002536	0.079233921	0.060256997	0.281258310
FIN [2]	2.703274014	0.343786905	0.237779297	-0.529691232
T-Stat	3.48008	3.48773	1.61451	-2.33314
P-value	0.000512078	0.000497736	0.106575622	0.019740121
CS [3]	4.038367476	-0.18201298	-0.123113405	2.431923485
T-Stat	3.03645	-0.45683	-7.38861	2.63447
P-value	0.002424929	0.647843176	2.17326E-13	0.008492315
IND [4]	0.7185186	-0.223567375	-0.286628239	0.613577166
T-Stat	1.93544	-2.0406	-6.18151	7.71602
P-value	0.053078047	0.041422532	0.000000001	0.000000000

Appendix III: Sector Index Returns Graphs

Figure 4: Financial Sector Returns

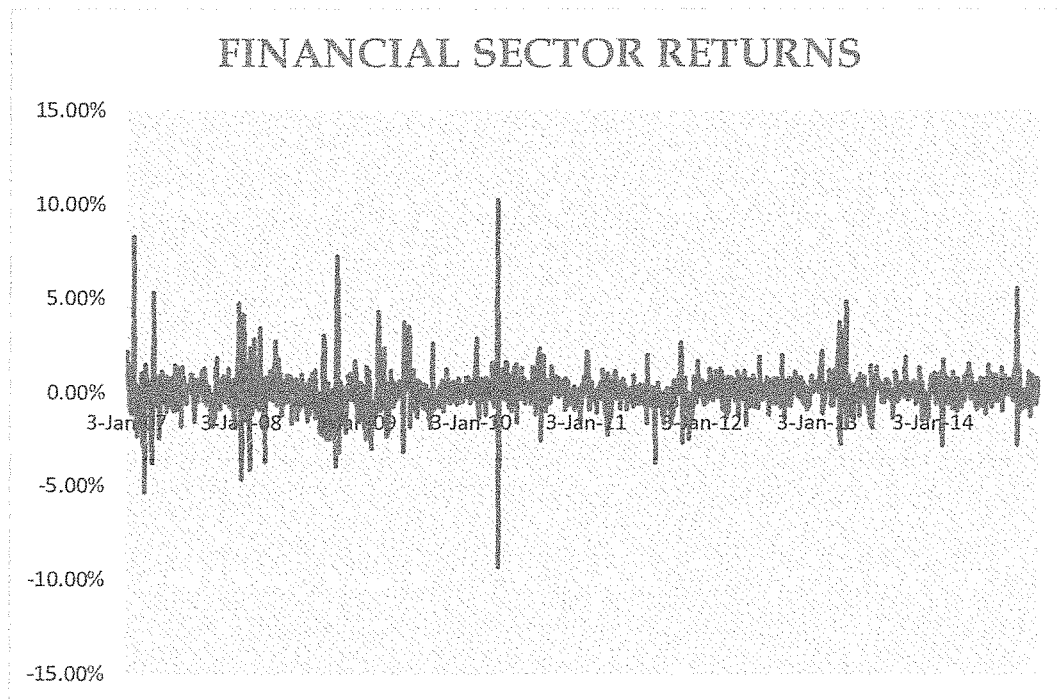


Figure 5: Commercial and Services Sector Returns

