

**ANALYSIS OF VOLATILITY SPILLOVER EFFECTS BETWEEN THE  
SOUTH AFRICAN, REGIONAL AND WORLD EQUITY MARKETS**

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## DECLARATION

Except for references specifically indicated in the text, and such help as has been acknowledged, this thesis is wholly my own work and has not been submitted to any other University, Technikon or College for degree purposes.

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## ABSTRACT

The current study examines the extent and magnitude by which global and regional shocks are transmitted to the volatility of returns in the stock markets of South Africa, Egypt, Nigeria, Botswana, Mauritius and Egypt. This is done so as to make inferences on the level of the domestic market's integration into the regional and world capital markets. By applying multivariate and univariate GARCH models, using weekly data from June 1995 to May 2010, the main empirical findings are threefold.

Firstly, the volatility analytical framework finds statistically significant and time-varying volatility spillover effects from the regional and global markets to the South African market. Global shocks are generally stronger and account for up to 23.9 percent of the volatility of South Africa's equity market compared to weaker regional factors which account for less than 1 percent of domestic variance. Only in countries with strong bilateral trade and economic links with South Africa, such as Botswana and Namibia, is it found that regional factors are more dominant than global factors for domestic volatility. Compared to the other African markets, the joint influence of foreign shocks on domestic volatility is highest in South Africa and Egypt, two of Africa's largest and most developed markets. The results further demonstrate that for all the African markets the explanatory power of both regional and global factors for domestic volatility is not constant over time and tends to increase during turbulent market periods.

Secondly, the analysis of the determinants of South Africa's second moment linkages with the global market suggests that the volatility of the exchange rate plays a cardinal role in influencing the magnitude by which global shocks affect domestic volatility. The increased global integration in the second moments cannot be attributed to either increased trade integration, convergence in inflation rates or to convergence in interest rates between South Africa and the global markets.

Lastly, tests were conducted to examine whether there have been contagion effects from the regional and global markets to South Africa from the 1997 Asian crisis and the 2007/8 global financial crisis. The results show no evidence of contagion during either the East Asian currency crisis or the recent global financial crisis to South Africa, while some African markets, such as Egypt, Mauritius and Botswana, exhibit contagion effects from either crisis.

Overall, the empirical findings generally support the view that African markets are segmented both at the regional and global levels as domestic volatility is more influenced by local

idiosyncratic shocks (the proportion not attributable to either global and regional factors). However, the volatility of South Africa, and to a lesser extent Egypt, remains relatively more open to global influence. This implies that the potential for gains from international portfolio diversification and the scope for success of policies aimed at the stabilisation of equity markets in these markets exist.

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## DEDICATION

I dedicate this work to the memory of my late father.

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## LIST OF ACRONYMS

ADL	Autoregressive Distributed Lag
ADR	American Depositary Receipt
AIC	Akaike Information Criteria
APT	Arbitrage Pricing Theory
ARCH	Autoregressive Conditional Heteroskedasticity
ARMA	Autoregressive Moving Average
AS-BEKK	Asymmetric BEKK Model
AS-DBEKK	Asymmetric Diagonal BEKK
AS-DVEC	Asymmetric Diagonal VEC
AS-VEC	Asymmetric VEC
BEKK	Baba Engle Kraft and Kroner
BHHH	Berndt, Hall, Hall and Hausman
BON	Bank of Namibia
CAPM	Capital Asset Pricing Model
CCC	Conditional Constant Correlation
DCC	Dynamic Conditional Correlation
DBEKK	Symmetric Diagonal BEKK
DVEC	Symmetric Diagonal VEC
DVECH	Symmetric Diagonal VECH
EGADC	Extended General Asymmetric Dynamic Covariance
EGARCH	Exponential GARCH
EM	Emerging Market
EME	Emerging Market Economy
EMS	European Monetary System
EMU	European Monetary Union
EU	European Union
F-ARCH	Factor ARCH
FA	Foreign Assets
FL	Foreign Liabilities
FDI	Foreign Direct Investment
FDIA	Foreign Direct Investment Assets
FDIL	Foreign Direct Investment liabilities

GARCH	Generalised Autoregressive Conditional Heteroskedasticity
GARCH-M	Generalised Autoregressive Conditional Heteroskedasticity in Mean
GBM	Geometric Brownian Motion
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GJR-GARCH	Glosten, Jagannathan and Runkle GARCH
HAC	Heteroskedasticity and Autocorrelation Consistent
HQIC	Hannan-Quinn Information Criteria
HSF	Hang Seng Futures
HSI	Hang Seng Index
HV	High Volatility State
ICAPM	Intertemporal Capital Asset Pricing Model
i.i.d.	Independently and identically distributed
ISE	Istanbul Stock Exchange
JSE	Johannesburg Stock Exchange
LM	Lagrange Multiplier
LRM	Linear Regression Model
LRMH	Linear Regression Model with Heteroskedasticity
LSE	London Stock exchange
LV	Low Volatility State
MA-GARCH	Moving average GARCH
MA-GARCH-M	Moving average GARCH in Mean
MENA	Middle East and North Africa
MGARCH	Multivariate GARCH
MVSWARCH	Multivariate Markov Switching ARCH
QML	Quasi-Maximum Likelihood
SACU	South African Customs Union
SACU-EX	SACU member states excluding South Africa
SADC	Southern African Development Community
SE	Spillover Effect
SIC	Schwarz Information Criteria
SL	Sharp-Lintner
UAP	Uncovered Asset Return Parity
UIP	Uncovered Interest Parity

UK	United Kingdom
US	United States
VAR	Vector Autoregressive



# CHAPTER ONE

## INTRODUCTION

### 1.1 CONTEXT OF THE RESEARCH

The deepening globalisation in international finance and trade, fostered by advances in information and communication technologies, financial innovation and the deregulation of capital markets, have intensified interdependencies and linkages between national and international financial markets. This has culminated in increased cross-border capital transactions. The continuous financial opening has meant that stock market traders in a given market incorporate into their decisions (whether to take long or short positions in financial assets) not only relevant information generated domestically within the economies of their domicile, but also that generated in other foreign markets. This has resulted in rapid inter-market information transmission and greater financial integration among the world's capital markets.

These developments have long sparked an interest among academics and practitioners to understand the nature of these linkages among the world's financial markets. The seminal work by Grubel (1968) and later in the 1970s by Levy and Sarnat (1970), Ripley (1973), Solnik (1974), Errunza (1977) and Hilliard (1979) paved the way for studies on the interdependence of the world's stock markets and the resultant implications this had for international portfolio diversification. The major finding of these studies was that the world's major equity markets were largely segmented, exhibiting insignificant evidence of co-movement. To that effect, these studies empirically authenticated the argument for international portfolio diversification. On the contrary, following the worldwide adoption of policies aimed at the relaxation of exchange rate controls and barriers on international capital movements coupled with advances in technology and communication systems, many authors since the 1980s have documented a gradual shift away from international equity market segmentation towards interdependence, and a corresponding gradual decline in opportunities for international diversification. This finding was valid among the major mature markets of the United States (US), United Kingdom (UK), Japan, France and Germany. These early works mainly studied market linkages by considering the returns co-movements among equity markets and the effect this had for policy and portfolio diversification. A few notable studies in this regard include those by Schollhammer and Sand (1987), Eun and Shim (1989), Joen and von Furstenberg (1989) and Koch and Koch (1991) among many others.

However, since the seminal works of Engle (1982) and Bollerslev (1986) on the modelling of conditional volatility, the extent to which such volatility is transmitted internationally has received considerable interest, especially among academics, practitioners and regulators. This research, fuelled by the need of policymakers, regulators, traders and speculators to understand the effect of overnight news transmission from one market to another, has not been confined just to equity markets, but also to other financial markets. For instance, Clare and Lekkos (2000) and Christiansen (2007) examine the inter-market linkages in the international bond markets, while Fehle (2000) and, most recently, In (2007) study the international linkages between swap markets.

A thorough understanding of the structure, drivers, and transmission mechanisms of the stock market prices and the volatility arising within these inter-market linkages has critical implications not only for the investors, but also for the policymakers.

First and foremost, from the investors' perspective, knowledge of the manner and the extent to which different financial markets are interrelated is crucial for the determination of efficient international hedging decisions so as to minimise the adverse effect of uncertainty on the expected returns on investments. Furthermore, an understanding of the manner in which international markets are interrelated facilitates the identification of diversification opportunities for investors' international portfolios. In an international context, modern portfolio theory suggests that when there is a change in the linkages among capital markets, investors have to spread away their non-systematic asset portfolio risk by investing in more isolated markets so as to minimise the likelihood of suffering unanimous losses in their entire financial asset portfolios.

Secondly, from the policymakers' perspective, financial instability is an important issue for the reason that financial crises such as bank collapses or stock market crashes may directly influence a country's economic well-being. The implication of this is that, if a stock market is integrated with another country's stock market, domestic financial stability would greatly depend on the financial stability of another country.<sup>1</sup> Such interdependence would highlight the vulnerability of a domestic economy to negative external shocks (by implication, the converse would be true for positive external shocks). Ng (2000) highlights another crucial point why understanding market

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<sup>1</sup> The recent subprime crisis in the United States (US) is a very clear example and underscores the extent to which an idiosyncratic shock to one economy can be transmitted through to the rest of the world.

interdependencies through volatility spill-over effects is critical for the evaluation of regulatory proposals to restrict international capital flows. Such a restrictive policy would perhaps be a mitigating factor to the vulnerability and instability that may arise due to deepened financial integration. Consequently, turbulence in financial markets has led to numerous calls for reforming the whole global financial system with the aim of improving its stability (c.f. Rogoff, 1999 and Eichengreen, 1999).

Lastly, financial interdependence may also offer potential economic benefits. On one hand increased financial integration implies an extension of avenues for sources of capital, thereby facilitating greater capital accumulation. On the other hand it also implies greater easing and pooling of risks to facilitate intertemporal smoothing of risk and consumption, and the enhancement of the efficiency with which savings are allocated internationally. Therefore, an understanding of the manner and extent to which financial markets are linked would give invaluable insights to policymakers for the evaluation of policy proposals aimed at not only maximising economic gains from stock market linkages but also cushioning the adverse shocks to the economy that would emanate from increased financial globalisation.

## **1.2 GOALS OF THE RESEARCH**

The main goal of research is to assess and quantify the extent to which the stock market volatility of South Africa is affected by idiosyncratic shocks originating locally, regionally and globally so as to make inferences about the magnitude of the interdependence of the South African equity market with its regional and global counterparts.

Specifically, this research aims to:

Examine the structure of the South African equity market volatility vis-à-vis the volatility of selected African and mature markets by extending the methodology of Ng (2000) to account for local, regional and global influences on domestic volatility;

Examine the relative importance of global, regional and local factors to the volatility of the South African equity market by assessing the proportion of the volatility that is driven by these factors;

Examine whether the relative importance of global and regional factors in driving the volatility of the South African Stock market has been time varying; and

Assess whether this time-varying level of integration can be linked to certain economic variables known to drive stock market linkages, such as those relating to bilateral trade linkages, exchange rate uncertainty, differences in interest rates, etc.

While the primary focus is on South Africa, the analysis is also extended to a select few other African markets for comparison purposes.

### **1.3 MOTIVATION FOR THE STUDY**

Apart from adding to the scant literature on the determinants of the interdependence of the South African stock market with its regional and global counterparts, this study contributes to the previous body of research in terms of both the main issues and the manner in which they are addressed.

Firstly, as will become apparent in the empirical section of the next chapter, most studies that have examined linkages among South African and world markets have mainly emphasised the linkages in terms of returns co-movement. This study goes further by also analysing not only the trends in the return generating process, but also the volatility transmission process of the South African equity market in relation to its regional and global counterparts.

Secondly, of the studies that examine regional and global interdependence of the South African equity market, none to our knowledge examine them jointly and as explicitly as done in this study. Methodologically, most of the past research fails to jointly examine the relative importance of regional and global factors in volatility transmission of the South African equity market by quantifying the magnitude and proportion of the volatility driven by regional and global factors, and whether these proportions have remained stable over time. In this respect, a notable novelty of this research is that in contrast to previous literature, the study attempts to link the time-variation in the global and regional integration to economic fundamentals so as to establish, beyond speculation, the factors that have driven South Africa's volatility transmission processes both at the regional and global level. This is of fundamental importance for policy formulation.

In addition to reasons of brevity in this study, our focus on the equity market is not arbitrary. It is motivated by our view that the stock market is the financial market that is most likely to be most affected by external shocks originating out of South Africa, in comparison to the money

and bond markets, which are expected to be much more responsive to domestic monetary policy conditions.

#### **1.4 METHOD OF THE STUDY**

In order to analyse the volatility linkages between South African and major emerging and developed world equity markets, one has to exercise diligence in the choice of countries to include in the study. The mature markets included in the study include the United States, Germany, United Kingdom and Japan. These markets are not arbitrarily selected: in addition to the magnitude of South Africa's trade linkages with these markets, they are among the world's largest stock markets and previous literature has underscored their predominance in the global price and volatility transmission to other markets. The southern African markets considered include two South African Customs Union (SACU) member states (Namibia and Botswana), and Mauritius, all members of Southern African Development Community (SADC) (regional markets). We also include in our sample the Egyptian and Nigerian markets. Our selection of these markets is not arbitrary, but governed by several factors. In view of the recent efforts that have been put forward by numerous African regional economic blocs to try to foster greater economic cooperation and integration at the regional level, we believe the existence of economic and bilateral trade linkages may induce stock markets in these regional areas to respond to information unique to these regions, especially among the SACU and SADC states. We also include two markets in the northern part of Africa: Egypt and Nigeria which are among Africa's largest markets.

The empirical study applies a methodology similar to that of Ng (2000), which enables us to model the volatility transmission process using both multivariate and univariate variants of the generalised autoregressive conditional heteroskedasticity (GARCH). This is in contrast to the numerous studies on volatility transmission in Africa that have mainly focused on using univariate GARCH models.

#### **1.5 ORGANISATION OF THE STUDY**

The rest of the study is organised as follows: Chapter Two reviews several theoretical and empirical literature on the interdependence of stock markets. This chapter is divided into two

sections, with the first devoted to analysing the main conceptual issues and discussing the theoretical background of this study, while the second section analyses the empirical literature that has been conducted in this field in the mature, emerging and African markets. Chapter Three provides an overview of the markets included in this study in terms of their trade linkages, the degree of capital mobility among them and the trends and characteristics of their respective stock markets. In Chapter Four, a formal description of the data and the methodology that will be adopted to address the goals of this research is given. Chapter Five presents and discusses the findings of the study, while Chapter Six summarises the main findings, concludes and discusses the implications of the study as well as identifying other areas for further research.

# CHAPTER TWO

## THEORETICAL FOUNDATIONS AND EMPIRICAL LITERATURE SURVEY

### 2.1 INTRODUCTION

This chapter reviews the existing theoretical and empirical literature on the interdependence of financial markets, primarily focusing on the transmission mechanism of shocks among equity markets. The chapter is divided into two sections. The first section broadly discusses several issues from a theoretical disposition relating to the significance of understanding these inter-market linkages in finance, highlighting the factors that drive markets to integrate and become interdependent. Some of the common approaches to studying equity markets are also briefly discussed and finally a review of some other issues on stock market interdependence in the literature is given. The second section of this chapter presents a comprehensive overview of the empirical literature documenting interdependence and volatility transmission in mature, emerging and developing markets and conclusions are drawn therefrom.

The significance of this chapter is to lay the theoretical background on volatility spillover effects and interdependence of stock markets.

### 2.2 NATURE OF EQUITY MARKET LINKAGES: CONCEPTUAL ISSUES

This section discusses some conceptual issues in the financial literature relating to international stock market linkages and the transmission of shocks amongst these markets.

#### ***2.2.1 Financial Contagion versus Financial Interdependence***

Contagion has been one of the most widely debated concepts in the international finance literature since the 1987 Asian financial crisis. However, there is little consensus in the literature as to the exact meaning of this concept. Calvo and Reinhart (1996) define financial contagion as the transmission of a financial crisis to a particular country due to its real and financial linkages with countries that are already experiencing a financial crisis. Park and Song (2000: 243) define contagion as the spread of market disturbances from one market to another. Taking an asset pricing perspective to studying contagion, Bekaert *et al.* (2005a: 40) define this notion as

correlation in excess of that which is expected from economic fundamentals. Financial contagion is observed through the intensification of the correlations among financial markets during turbulent periods, such as during a financial crisis. Most studies therefore rely on the analysis of changes in correlation patterns of financial markets before, during and or after a known financial crisis event to determine whether contagion occurred. Specifically, these studies find evidence of contagion when the hypothesis of an increase in a measure of correlation during (and or immediately after) turbulent market periods compared to non-crisis periods cannot be rejected<sup>2</sup>.

However, some studies, among them Forbes and Rigobon (2002), have formally shown that pure correlation-based tests of contagion tend to suffer from a conditioning bias due to the changing nature of volatility (i.e. heteroskedasticity) by overstating correlations in turbulent market periods, and therefore, make a distinction between contagion and interdependence. In harmony with the authors' argument, if two markets show a high degree of co-movement during tranquil periods even if the markets continue to be highly correlated after a shock to one of them, this may not necessarily constitute contagion, but rather interdependence. Contagion would only occur when there is a significant increase in the cross-market co-movement after the shock.

Indeed it is conceivable that the economic ramifications of interdependence and contagion during a financial crisis may have indistinguishable and perhaps equally devastating effects on a country's financial system. However, as noted by Collins and Biekpe (2003a: 184-185), the causes and policy interventions may be different and as such, it becomes imperative to make a distinction between contagion and interdependence.

It should therefore be emphasised that the purpose of this research is to analyse the volatility linkages between South Africa and the major regional and global equity markets so as to make inferences about its interdependence with the other equity markets. In addition, contagion is also analysed as a conceptually distinct phenomenon from interdependence.

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<sup>2</sup> See for instance King and Wadhvani (1990), Calvo and Reinhart (1996) and Collins and Biekpe (2003a) among many others.

### ***2.2.2 Global versus Regional Financial Interdependence***

The literature on financial market interdependence has mainly focused on addressing whether and to what extent particular markets are integrated into the global market, without explicitly addressing the question of *how* they are integrated<sup>3</sup>.

On one hand, it is undisputable that advances in global communication facilities and the liberalisation of financial markets have given rise to increased financial and real globalisation. On the other, the existence of regional trading blocs, Common Monetary Unions and Customs Unions, all of which aim at promoting regional economic integration through policy coordination, trade and investment, gives credence to the argument that economies are more likely to be integrated at a regional level owing to the presence of these economic ties. In fact, it is well documented in the literature that regional integration is strengthened through the formation of regional Free Trade Areas or Currency Unions (see Feng and Genna, 2003 and Baele, 2005).

This is particularly relevant for South Africa since studies that have examined regional financial integration have centred mainly on European and Asia-Pacific markets. At issue therefore is whether the advances in communication technology and the liberalisation of financial markets have meant that the South African equity market has become more integrated at the global level than at the regional level in spite of the regional economic arrangements that South Africa remains party to. Indeed the distinction between regional and global financial integration has important implications for policy as well as for international (regional or global) portfolio diversification as discussed in the next section (Section 2.3).

In view of the foregoing, this study endeavours to distinguish between regional and global sources of equity market integration in order to explicitly address the question of *how* the South African equity market is related to its foreign counterparts.

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<sup>3</sup> A few notable exceptions include Bekaert and Harvey (1997), Ng (2000), Baele (2005), Bekaert *et al.* (2005a) and Christiansen (2007) among others.

## **2.3 IMPORTANCE OF UNDERSTANDING EQUITY MARKET LINKAGES**

This section reviews some of the reasons why a country such as South Africa should seek to understand the relationships between the South African stock market and those of other countries and the implications for the transmission of stock market volatility among these markets.

It is a very well established fact in the vast finance literature that stock market traders in a given market incorporate into their decisions (whether to take long or short positions in financial securities) not only relevant information generated domestically, but also that generated in other foreign markets. This is the result of increased financial linkages brought about among other things by the lifting of barriers to the free cross-border flow of capital and goods (we turn to these drivers of stock market linkages in the subsequent section). Knowledge of the manner in which markets are related not only enables policymakers to identify and evaluate appropriate policies to enhance gains (and minimise the effect of adverse shocks) from financial interdependence, but also allows investors to diversify their portfolios and hedge their positions more effectively. These issues are briefly discussed below primarily in the context of equity markets.

### ***2.3.1 International Portfolio Selection and Diversification***

Consistent with the basic intuition of Markowitz (1959), the fundamental goal of portfolio diversification is to minimise or eliminate systematic risk inherent to individual assets by selecting a portfolio whose constituent assets have negatively or marginally correlated returns. In so doing, investors are able to achieve portfolios that are mean-variance efficient (i.e. portfolios that maximise returns for a given level of risk, or minimise risk for a given level of returns). Portfolio diversification may take at least two forms: investors may diversify their portfolios across the different asset classes or sectors domestically, or they may spread their portfolio risk across other asset classes or sectors in other foreign countries, a process referred to as international portfolio diversification. For purposes of this study, we focus on international portfolio diversification.

International portfolio diversification is justifiable only in as far as the gains from it exceed those from domestic (sector) diversification. Pioneering works such as those of Solnik (1974) and Errunza (1977) attested to the existence of gains from international portfolio diversification. Recently, with the increasing globalisation and interdependence of financial markets, there have

been concerns in the finance literature about the potential benefits of international portfolio diversification. Bekaert and Harvey (2003: 22) argue that the removal of price segmentation by the relaxation of policies to restrict the free flow of capital across national borders may increase correlations among financial markets and thereby lower portfolio diversification benefits. This has seen a recent shift in emphasis from country to domestic or industry (sector) diversification, especially in developed and integrated financial centres such as those of the European Monetary Union. In support of this view, Isakov and Sonney (2004: 375) emphasise that the shift in the relative importance of country and industry factors has led financial institutions in the Euro-zone to reorganise their research departments in terms of industries rather than countries.

It is a commonly held view in the literature that as international equity markets become increasingly integrated, the gains from international diversification tend to reduce due to the positive and increasing correlation among them.

### ***2.3.2 Potential Macroeconomic Benefits***

The economic importance of financial integration has received considerable attention in the literature. However, while there is consensus regarding the exact nature of the potential economic benefits of closer financial integration, there is little agreement as to whether financial integration leads to economic growth or vice versa, or whether the causality is bi-directional.

Generally, there have been two main approaches in the literature attempting to highlight the economic benefits of financial integration. The first approach emphasises the growth effects of financial integration through the manner in which it enables the easing and pooling of risks to facilitate intertemporal smoothing of risk and consumption, and the enhancement of the efficiency with which savings are allocated (c.f. Cole and Obstfeld, 1991; Lee and Shin, 2008). Under this approach, Levine (2001: 689) argues that closer financial ties have the potential to strengthen domestic financial systems leading to more investment, more efficient allocation of capital and higher economic growth. In conformity with this approach, and at a global level, Obstfeld (1994: 1318) develops a continuous-time stochastic model in which closer financial integration is argued to enhance efficient allocation of capital to facilitate international risk sharing, thereby impacting positively on economic growth.

The second approach emphasizes the growth effects of financial integration through the manner in which it enables capital accumulation, skill and technology transfer primarily through foreign

direct investment (FDI). In fact, this approach is consistent with some of the recent growth models, such as those of Grossman and Helpman (1991) and Barro and Sala-i-Martin (2004), which take into account the role that technology transfer plays in economic growth. Levine (1996; 1997; and 2001) argues that easing restrictions on foreign bank entry may improve the quality, price and availability of banking services since foreign banks may bring with them new and better skills, management techniques, products and training procedures which stimulate competition and thereby enhance efficiency in the domestic financial system.

It is an acceptable view in the literature that the growth response to financial integration depends on the existence of efficient and effective legal, investment and political institutions (c.f. Bekaert *et al.*, 2005b). Therefore, an understanding of the manner and extent to which financial markets are linked would give invaluable insights to policymakers for the evaluation of policy proposals aimed at maximising macroeconomic gains from stock market linkages.

### ***2.3.3 Financial System Regulation and Monetary Policy***

The fundamental role of monetary policy is to formulate and execute policies to regulate the financial system in such a manner that ensures high employment, economic growth, low inflation and the stability of interest rates, financial markets and foreign exchange markets. While the ultimate goals are clear, the process through which monetary policy is transmitted to the real and financial economy to realise the intended ultimate goals is less clear.

In highlighting the importance of the stock market in the transmission of monetary policy, Mishkin (2004) identifies at least three channels through which monetary policy may be transmitted through to financial asset and relative prices. The first channel, an offshoot of Tobin's  $q$  theory,<sup>4</sup> emphasises how monetary policy affects the economy through its effects on the valuation of equities and investment spending. According to this theory,  $q$  is defined as the market value of firms divided by the replacement cost of capital. Mishkin argues that an expansionary monetary policy increases expenditure on stocks thereby bidding their prices upwards (market value of firms relative to the replacement cost of capital increases) and therefore the value of  $q$ . This implies that the firms can issue shares and acquire capital to finance investment projects less expensively, thereby increasing investment spending, employment and output in the economy.

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<sup>4</sup> See Tobin (1969).

The second channel relates to the effect of monetary policy on consumer spending through its effect on the financial wealth of households, a major component of which is equity. The basic intuition of this channel is that an expansionary monetary policy which increases the price of stocks raises the financial wealth of households, thereby increasing the lifetime resources of individuals, resulting in an increase in consumption spending and output.

With the growing internationalisation of economies around the world, the third channel emphasises the transmission of monetary policy on the exchange rates and the effect this has on capital flows and on the net exports position of an open liberalised economy with a floating exchange rate regime. The basic intuition of this channel is that through a reduction in interest rates an expansionary monetary policy will lower the value of domestic currency deposits relative to other foreign currencies. This causes capital to flow from the domestic economy (with lower interest rates) to other foreign markets, resulting in the depreciation of the domestic currency. This will have the effect of raising the competitiveness of domestic goods and services (relative to other foreign goods and services) in international trade, thereby raising the net export position of the domestic economy and hence its aggregate output.

As the world's financial economies become more interconnected, a thorough appreciation of the effect of foreign policies on domestic economic activity becomes crucial. Resulting from increased financial integration, there has been mounting evidence in the literature that interest rate fluctuations in major countries tend to induce important effects on other countries<sup>5</sup>. This may cause stock market instability and irrational pricing of stocks. The implication of this is that stock prices cease to be aligned with economic fundamentals in the domestic markets.

In light of the destabilising effects of financial integration, there has been debate in the literature about what the appropriate policy responses by monetary authorities should be to these asset price misalignments. On one extreme end of the debate, some authors, among them, Cecchetti *et al.* (2000: 68), have argued that policymakers should react to misalignments in stock prices to reduce the probability of asset price bubbles occurring. According to this school of thought, monetary policy is better able to successfully achieve the stabilisation of prices and output (the ultimate objectives of monetary policy) by avoiding the distortions to the economy that would

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<sup>5</sup> See for instance Hall *et al.* (1992) and Frankel *et al.* (2004).

otherwise occur when such price misalignments occur. On the other end of the debate, Bernanke and Gertler (1999: 42-43 and 2001: 256) argue that monetary policy should continue to focus on achieving price and maximum sustainable growth such that responses of monetary policy to stock market volatility should be confined to the extent to which such asset price volatility is perceived to exert expected inflationary pressure on the economy.

It therefore follows that an understanding of the nature and extent of international financial market linkages will enable policymakers to informatively evaluate policy proposals aimed at cushioning the adverse shocks to the economy and the destabilising effects that may emanate from increased financial globalisation.

#### ***2.3.4 Policy Signalling and Financial Stability***

Related to the above discussion on financial system regulation and monetary policy, it has also been argued by Agénor (2003: 1095) and Agénor and Montiel (2008: 488) that by increasing the rewards for good policies and the penalties for bad ones, the enhancement of financial integration through the relaxation of barriers to the free flow of capital across borders, may induce countries to adopt more disciplined macroeconomic policies and thus reduce the frequency of policy mistakes. The scale to which such macroeconomic discipline translates into the implementation of sound policies would result in macroeconomic and financial stability.

A related argument by Bartolini and Drazen (1997: 151) is that external financial liberalisation plays a 'signalling' role that a country is ready and willing to adopt sound economic policies to the effect that it encourages the accumulation and efficient allocation of capital and thereby encourages higher economic growth rates.

It therefore follows that understanding the extent to which financial markets are linked gives insights to policymakers on how best to amplify the potential benefits of financial integration, while simultaneously finding appropriate policy responses aimed at minimising the resultant economic vulnerability that market interdependence brings.

## 2.4 UNDERLYING FORCES DRIVING EQUITY MARKET LINKAGES

This section reviews the literature on factors that are commonly held as fundamental drivers of the intensification of international equity market linkages with an emphasis on economic factors. There are numerous factors identified in the literature that cause financial markets to become more integrated. Some of these factors relate to the exchange rate regime which an economy adopts, the significance of macroeconomic and trade linkages, and finally, but not least, the adoption of financial liberalisation policies.

### 2.4.1 *Exchange Rate Regime*

It is imperative to note that international equity market linkages do not exist in complete isolation from exchange rates. The choice of the exchange rate regime not only has a bearing on the competitiveness of an open economy in international trade, but also plays a significant role in determining the extent and pace with which the domestic economy accommodates and adjusts to external shocks.

At least three channels through which exchange rates are linked to the stock market can be identified in the literature. The first channel is through the goods market suggested by Dornbusch and Fischer (1980). Under this channel, changes in the exchange rate are argued to affect the competitiveness of multinational firms and hence their earnings and stock prices, because a depreciation of the local currency would make exports cheaper, which boosts the demand and sales in foreign markets. Secondly, as Adler and Dumas (1984) observe, such a link is not confined to multinational firms. Even firms that do not have a large market in international trade, but whose input prices, output prices or demand for products are exposed to exchange rate movements, may display a tendency for exchange rate fluctuations to affect their stock prices. Thirdly, from an asset pricing perspective, the arbitrage pricing theory pioneered by Ross (1976) suggests that if the economy is described by a number of pervasive risk factors (which may include exchange rate risk), then these factors may well be priced to the effect that investors are willing to pay a premium in order to avoid or minimise such risk.

Having established the link between exchange rates and stock prices, the question that remains unresolved in the literature relates to whether a particular exchange rate regime matters for financial integration. On one side of the debate, proponents of a fixed exchange regime argue that floating exchange rates impede the strengthening of linkages among markets owing to the

uncertainty with respect to currency values. According to Frankel *et al.* (2004: 702) a fixed exchange rate has two major benefits: (1) that it reduces transactions costs and exchange rate risk, which discourage investment and trade, and (2) that it provides monetary authorities a credible nominal anchor for the conduct of monetary policy. The nominal anchor argument for fixing the exchange rate is that it reflects the monetary authority's commitment to propitiously affect the expectations of those sectors of the economy that determine wages, prices and capital flows by eliminating any concerns about inflation and any unfavourable exchange rate fluctuations.

On the other side of the debate, proponents of a floating exchange regime argue that the fixed exchange rate regime under the Bretton Woods system allowed for exchange rate changes, which, as White and Woodbury (1980: 175) earlier noted, would at times be large enough that the uncertainty that the fixed exchange rate was meant to eliminate was in fact not eliminated. Frankel (2003: 65-66) argues that under a floating regime (1) a country maintains its monetary independence, whereby in the event of a recession when unemployment is temporarily high and real growth temporarily low, the central bank reserves the discretion to respond by increasing money growth, lowering interest rates, depreciating the currency, and raising asset prices, all of which work to ease the economic downturn, (2) the floating exchange rate acts as an automatic self-adjustment mechanism to realign the economy after asymmetric external shocks to its trade flows. Contrastingly, and as suggested by Agénor (2001: 1098), under a fixed exchange rate regime, losses in competitiveness and growing external imbalances can erode confidence in the viability and sustainability of the peg and thus precipitate a currency crisis and increase financial instability.

For purposes of financial integration, a common position in the literature is that open economies with a pegged currency and unrestricted capital flows may not independently set domestic interest rates. Rather, changes in domestic interest rates should track the interest rate changes of those countries to which the currency is pegged to the effect that financial integration under this exchange rate regime would result from a convergence of interest rates and synchronisation of business cycles – a process briefly discussed below.

### ***2.4.2 Macroeconomic and Trade Linkages***

The extent to which two economies depend on each other has a great influence on the degree to which their equity markets are interdependent. From a macroeconomic perspective the existence of bilateral trade arrangements between countries has an important influence on the scale with which capital markets are interdependent. In other words, the stronger the bilateral trade ties between economies, the higher the magnitude of co-movement of their respective stock markets.

An examination of the literature shows that there are numerous ways in which cross-border trade in goods may have a bearing on cross-border financial and asset trade (and therefore capital mobility and integration). Firstly, Pretorius (2002: 92) demonstrates that if a substantial proportion of a particular country A's exports constitute a significant proportion of country B's imports, an economic downturn in country B will see a downswing in country B's stock market associated with the domestic economic downturn, and at the same time a downswing in country A's stock market due to reduction in exports to country B. The co-movement that would result in both countries would be due to convergence in the business cycles brought about through goods trade openness. Secondly, following Lane and Milesi-Ferretti (2003: 93), much goods trade directly entails corresponding financial transactions such as trade credit and export insurance. Thirdly, but not least, Lane and Milesi-Ferretti (2003: 93) further suggest that openness in goods markets may increase willingness to conduct cross-border financial transactions, reducing the financial home-bias<sup>6</sup> by creating a 'familiarity' effect.

In spite of the intuitive appeal of the view that countries that trade more with each other may have more closely synchronised business cycles, the matter has not until recently received much attention in the literature to validate it. Many authors, among them Frankel and Rose (1998), Clark and van Wincoop (2001), Otto *et al.* (2001), Calderon *et al.* (2002), Kose and Yi (2002), and not least Lane and Milesi-Ferretti (2003), have all found that pairs of countries that trade more with each other exhibit a higher degree of business cycle co-movement. Given the relationship earlier alluded to between cross-border trade in goods and services on one hand, and trade in financial assets on the other, one would reasonably anticipate that countries that have strong bilateral trade linkages would not only exhibit synchronicity in terms of real business cycles, but

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<sup>6</sup> The "home-bias" puzzle is a phenomenon in the finance literature that investors exhibit a tendency to hold a disproportionately large share of their equity portfolio in home country stocks as compared with predictions of the Capital Asset Pricing Model (c.f. Ben-Haim and Jeske, 2003: 2).

also in terms of financial asset price fluctuations. In other words, trade and macroeconomic linkages would act as a crucial driving force of stock market linkages.

### ***2.4.3 Financial Liberalisation Policies***

For purposes of this study, it is imperative to clarify exactly what is meant by financial liberalisation. As noted by Bekaert and Harvey (2003: 5), financial liberalisation may broadly take at least two forms. In one form, it may refer to those policies aimed at deregulating the domestic economy, such as privatisation and banking sector reforms. A thorough discussion of these policies is given in Gelos and Werner (2001) and Beim and Calomiris (2001). On the other hand, financial liberalisation may also refer to those deliberate policies aimed at facilitating the inward and outward flow of foreign equity investment such as the relaxation and lifting of capital controls to facilitate free capital mobility. The study places greater emphasis on the latter definition of financial liberalisation.

In theory, financial liberalisation, by facilitating unrestricted cross-border flow of capital, aiding greater international participation in domestic financial markets, should bring about full capital market integration through the equalisation of domestic and foreign expected equity market returns. Logically, and as noted by Bekaert and Harvey (2003: 4), it is unlikely that liberalisation would in reality result in full equity market integration owing to, among other factors, the 'home-bias' puzzle in financial asset holdings.

Nevertheless, it is a well established fact in the vast financial literature that governments' official policy on cross-border capital movements plays a critical role as a propagating mechanism for the intensification of equity market linkages (c.f. Bekaert and Harvey (1997, 2003); Ng (2000); Darrat and Benkato (2003); Kearney and Lucey (2004)). A high degree of international financial integration must be associated with unimpeded capital mobility. If policies on the removal of controls on capital flows are binding, the level of international cross-border asset holdings should increase if the capital account is liberalised (Lane and Milesi-Ferretti, 2003: 93).

The relaxation of these capital restrictions is what has created an enabling environment for the interaction of all the above-mentioned underlying forces to strengthen ties among domestic and foreign equity markets. As acknowledged by Ahmad and Sarver (1994: 319), the progressive removal of interest rate and exchange rate controls combined with lower restrictions on

international capital movements are the major reasons why the world's financial markets have become more closely integrated.

It is a widely accepted view in the vast finance literature that financial liberalisation creates an atmosphere conducive for the interplay of factors such as the exchange rate regime, macroeconomic and trade linkages, and synchronisation of business cycles (as discussed above) to drive the equity market linkages.

## 2.5 COMMON APPROACHES TO ANALYSING EQUITY MARKET LINKAGES

Two competing and related methodologies have developed in the finance literature to test for financial integration. On one hand, much work has utilised the Uncovered Asset Return Parity (UAP) relation derived from the Uncovered Interest Parity (UIP)<sup>7</sup> condition. On the other hand, another group of finance literature has adopted a Capital Asset Pricing Model (CAPM) framework to test for financial integration among nations. These two approaches are briefly discussed below.

### 2.5.1 Uncovered Asset Return Parity (UAP) Condition

The UAP condition relates the expected changes in exchange rates to the expected changes in the returns on equity securities. From the UIP condition, one may derive a UAP relation to test for the integration of a domestic equity market  $i$  with the foreign equity market  $g$ :

$$E_{t-1}[R_{i,t}] = E_{t-1}[R_{g,t}] + E_{t-1}[\Delta S_{i,t}] \quad (2.1a)$$

or in *ex post* form as

$$R_{i,t} = R_{g,t} + \Delta S_{i,t} \quad (2.1b)$$

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<sup>7</sup> The UIP condition shows that when the domestic interest rate is less than that of the foreign country, the domestic currency is expected to appreciate by an amount that is equivalent to the interest rate differential between the two countries. If the domestic and foreign markets are integrated, one implication of this condition is that the return on an uncovered foreign currency deposit should be equal to the return on an equivalent domestic deposit regardless of the national market within which the foreign deposit is placed. Deviations from this relationship signal that the capital markets of the two markets are not integrated (c.f. Frankel, 1992; Francis *et al.*, 2002).

where  $R_{i,t}$  and  $R_{g,t}$  are the excess return on domestic portfolio in country,  $i$  and the foreign market portfolio  $g$  respectively (in domestic currency) and  $S_{i,t}$  is the spot exchange rate of the domestic country  $i$ . The *ex post* formulation of the UAP relation simply shows that if the domestic and foreign market are fully integrated, then the asset returns of the domestic market are equal to those of the foreign market after taking into account the exchange rate changes. The basic intuition of Equations 2.1a and 2.1b is that if equity markets are fully integrated, any discrepancies between the returns of the domestic market and those of the foreign market are re-equilibrated through contemporaneous adjustments in expected exchange rates. Specifically, and in light of the above, if the domestic equity returns exceed those of the foreign equity market, then the exchange rate of the domestic currency is expected to appreciate by an amount proportional to the equity return differential. Deviations from this relation would imply the two equity markets are not fully integrated.

In spite of the intuitive appeal of models based on this simple version of the UAP condition to test for equity market linkages, other authors, among them Fratzscher (2002), have argued and questioned the feasibility of (2.1b) holding empirically. Two types of reason are given. Firstly, this version of the UAP relation does not take into consideration other risk premia that are priced in the market, such as those related to differences in volatility of market returns and exchange rates. Secondly, there may be other barriers to cross-country investment that may prevent markets from being fully integrated (Fratzscher, 2002: 168).

A more general approach for testing for integration between the two equity markets would have to do away with the assumption of investors' risk-neutrality and take into account other risk premia, such as differences in the volatility of equity returns, foreign exchange premia, etc., which may be associated with international equity investment (c.f. Cappiello and De Santis, 2007; Fratzscher, 2002).

### ***2.5.2 International Capital Asset Pricing Model***

In another segment of the vast finance literature, international linkages of equity markets across the globe have been tested by adopting an international version of the CAPM framework, whose theoretical underpinnings can be traced from the seminal works of Sharp (1964) and Lintner (1965) who showed the expected return on asset  $i$ :

$$E[R_i] = R_f + \beta_{im}(E[R_m] - R_f) \quad (2.2a)$$

$$\beta_{im} = \frac{\text{cov}[R_i, R_m]}{\text{var}[R_m]} \quad (2.2b)$$

where  $R_i$  is the return on the market portfolio and  $R_f$  is the return on the risk free asset. The Sharp-Lintner (SL) CAPM showed that the return on any risky asset is positively related to the excess return on the market portfolio. Within this framework, the market portfolio, which contains *all* the risky assets, is assumed to be mean-variance efficient in the sense of Markowitz (1959), and the correlation of the return on the asset  $i$  to the excess return on the market portfolio is captured by the coefficient  $\beta_{im}$  as shown in Equations 2.2a and 2.2b. The fundamental implication of the SL-CAPM is that in an efficient market, all unsystematic risk can be diversified away such that the only risk that would be priced by market agents on a portfolio is systematic risk (c.f. Bollerslev, Engle and Wooldridge, 1988; Fama and French, 2004; Belke and Polleit, 2009).

In spite of its simplicity and intuitive appeal, the SL-CAPM has several criticisms levelled against it. Perhaps two of the most significant weaknesses emanate firstly from its failure to capture factors other than market risk, which may be priced on a portfolio of risky assets. Secondly, the SL-CAPM as illustrated by Equation 2.2a is a single-state model (without a time dimension) in which investor's portfolio choices are made with preferences defined over wealth one period in the future.

In trying to circumvent this, numerous extensions to SL-CAPM have been proposed in the literature. Two renowned contributions in the literature are the Arbitrage Pricing Theory (APT) of Ross (1976) and the Intertemporal Capital Asset Pricing Model (ICAPM) of Merton (1973). Merton extended the static SL-CAPM to a multi-period, multi-factor model by assuming that investors maximise their utility over an extended time horizon. In other words, when choosing a portfolio at time  $t-1$  investors are concerned with the opportunities they will have to consume or invest the payoff at time  $t$ . In so doing, investors consider how their wealth at time  $t$  will vary with any set of *state variables* or *risk factors* expected to have an effect on their wealth. Merton showed that for a representative investor with  $N$  different risk factors, the excess return  $r$  on any risky asset  $i$  is:

$$E[r_{i,t}|I_{t-1}] = \beta_{1,t}E[\text{cov}(r_{i,t}, r_{1,t})|I_{t-1}] + \beta_{2,t}E[\text{cov}(r_{i,t}, r_{2,t})|I_{t-1}] + \dots + \beta_{N,t}E[\text{cov}(r_{i,t}, r_{N,t})|I_{t-1}] \quad (2.3)$$

where  $r_{1,t}$ ,  $r_{2,t}$  and  $r_{N,t}$  are the excess return on the respective risk factors ( $1, 2, \dots, N$ ), one of which may include, among other factors, the market portfolio (as implied by the SL-CAPM)<sup>8</sup>, and  $E[\cdot|I_{t-1}]$  is the expectation operator, conditional on the representative investor's information set known at period  $t-1$ . If Equation 2.3 holds for a single asset, then it should also hold for a given portfolio of risky assets,  $p$ , such that the expected return on portfolio  $p$  conditional on information at  $t-1$  can consistently be expressed as,

$$E(r_{p,t}|I_{t-1}) = \beta_{1,t}E[\text{cov}(r_{p,t}, r_{1,t})|I_{t-1}] + \beta_{2,t}E[\text{cov}(r_{p,t}, r_{2,t})|I_{t-1}] + \dots + \beta_{N,t}E[\text{cov}(r_{p,t}, r_{N,t})|I_{t-1}] \quad (2.4)$$

The basic intuition behind the ICAPM from Equation 2.4 is that an investor in a dynamic world would react to all news and events perceived to represent possible changes to future consumption and investment opportunities (c.f. Dean and Faff, 2001: 171). The reaction to these news and events are thereby reflected in the stock prices.

It has been shown by Fama and French (1998 and 2004) that if international capital markets are open, and representative investors are unconcerned with purchasing power parity, it follows that the market portfolio should also include international assets such that:

$$E(r_{p,t}|I_{t-1}) = \dots + \beta_{g,t}E[\text{cov}(r_{p,t}, r_{g,t})|I_{t-1}] + \dots + \beta_{N,t}E[\text{cov}(r_{p,t}, r_{N,t})|I_{t-1}] \quad (2.5a)$$

$$\beta_{g,t} = \frac{\text{cov}[r_{p,t}, r_{g,t}]}{\text{Var}[r_{g,t}]} \quad (2.5b)$$

where  $r_{g,t}$  and  $r_{p,t}$  are the expected return on the global portfolio  $g$  and domestic portfolio  $p$  of risky assets at time  $t$ . In such a setting, an investor with a portfolio of risky assets would not only consider state variables relating to the domestic economy, but also to other global risk factors.

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<sup>8</sup> By implication of the ICAPM, the Sharp-Lintner CAPM is a special case, where the only risk factor that investors price is covariance risk of an asset with the market portfolio.

Consistent with the intuition of Equation 2.1b, the global market beta coefficient  $\beta_{g,t}$  measures the sensitivity of the return on the domestic portfolio  $p$  to innovations in the global market return. The extent to which innovations in the global market are able to explain variations in the returns to the domestic portfolio would highlight the degree of international market interdependence between the domestic and the foreign (global) market.

Arguing within the theoretical framework of the ICAPM (with global state variables), interdependence of the domestic market with the global market, as shown by Jorion and Schwartz (1986), imposes restrictions on the asset pricing mechanism, such that purely domestic factors are less important in the pricing of assets. In other words, if markets are integrated and the global market portfolio is mean-variance efficient, then the only priced risk should be the systematic risk relative to the world market. Correspondingly, if markets are integrated at a regional level (with regional state variables), and the regional market portfolio is mean-variance efficient, then a similar argument should hold for the region as well.

Naturally, the questions that arise relate to which factors, global or regional, are more important for market interdependence. Are innovations occurring regionally less important than those occurring globally for pricing assets domestically? What proportion of innovations in the domestic stock market can be attributed to global and regional factors? Is the degree of stock market interrelation stable over time? These are all open issues that may only be addressed empirically and constitute the main focus of this research.

## **2.6 VOLATILITY TRANSMISSION: EMPIRICAL ISSUES AND EVIDENCE<sup>9</sup>**

With the existence of liberalised financial markets, the current financial globalisation debate typically emphasises the spillover effects among the world's capital markets, whereby innovations in one market are transmitted to other markets. This has implications for international portfolio diversification and for the stability of the global financial system.

Largely stemming from Markowitz's theory of portfolio selection, the pioneering works of Grubel (1968) and later in the 1970s research by Levy and Sarnat (1970), Ripley (1973), Solnik

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<sup>9</sup> For a comprehensive summary of the empirical literature on volatility transmission in the mature, emerging and African markets, see Table A1 in the appendix of this study.

(1974), Errunza (1977) and Hilliard (1979) paved the way for studies on the interdependence of the world's stock markets and the resultant implications for international diversification. The major findings of these works can be summarised in three broad categories. Firstly, the major result of these works was that international correlations of stock returns from the world's major equity markets were very low. Secondly, by implication of their findings, domestic (country-specific) rather than international factors were much more important for the pricing of domestic stocks. For the above two reasons, these studies empirically validated the argument for international portfolio diversification. Thirdly, from a methodological perspective, these studies mainly considered first moment linkages in returns based on simple correlation and Granger causality tests and mainly focused on the stock markets of mature economies such as those of the United States (US), Germany, Japan, United Kingdom (UK) and France.

Owing to the relaxation of exchange rate controls, removal of barriers to international portfolio flows, and advances in technology and communication systems, many authors since the 1980s have documented a gradual shift away from international equity market segmentation towards interdependence. A few notable examples include the studies by Schollhammer and Sand (1987), Eun and Shim (1989), von Furstenberg and Joen (1989) and Koch and Koch (1991) among many others.

In spite of using a wide variety of methodologies, all the above studies principally assessed the interdependence of stock markets in terms of the conditional first moment of the distribution of returns. However, since the seminal works of Engle (1982) and Bollerslev (1986) on Autoregressive Conditional Heteroskedasticity (ARCH) modelling, there has been increasing interest in the analysis of stock market interactions in both the first and second moments of returns.<sup>10</sup> The current study contributes to the literature in this regard.

This section reviews the empirical literature on the transmission of volatility and stock market interdependence, placing particular emphasis on the main issues raised and addressed in the empirical literature with respect to the interdependence in the developed, emerging and African stock markets.

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<sup>10</sup> See for instance Hamao *et al.* (1990); Theodossiou and Lee (1993); Susmel and Engle (1994); Koutmos and Booth (1995); Pan *et al et al.* (1999); Isakov and Pérignon (2000) and, recently, Cifarelli and Paladino (2005); Aragón-Manzana and Fernández-Izquierdo (2007) among many others.

### **2.6.1 Mature and Emerging Market Economies**

#### *Volatility Spillover Effects and Interdependence of Stock Markets*

Since the 1987 Asian crisis, there has been an extensive body of empirical literature on the ‘second moment’ interdependence of capital markets in mature and emerging markets. This literature has mainly focused on assessing the manner in which the volatility of one stock market is transmitted to another, predominantly referred to as volatility ‘spillover’ effects. For instance, Hamao *et al.* (1990), using daily and intra-day stock prices for the US, Japanese and UK markets for the period 1985 to 1988, adopt a univariate generalised autoregressive conditional heteroskedasticity in mean (GARCH-M) Model. They find unidirectional spillover effects from the US to UK and Japan, and UK to Japan. Considering a slightly different period (1988 to 1992) and adopting a GARCH and Exponential GARCH (or EGARCH) framework, Bae and Karolyi (1994) find evidence of price volatility spillover effects between the US and Japan, and in fact demonstrate that ignoring the asymmetry effect in the transmission mechanism of volatility significantly understates the magnitude and persistence of volatility shocks originating from the US or Japan to either market. Similar results are arrived at by Koutmos and Booth (1995) when they consider daily stock returns for the same markets as Hamao *et al.* (1990) for the period 1986 to 1993 using an extended multivariate EGARCH model.

Indeed, these findings are not only confined to this old empirical literature and the three largest mature markets: a cross review of the recent volatility transmission literature (for instance Isakov and Pérignon, 2000; Cifarelli and Paladino, 2005; Aragó-Manzana and Fernández-Izquierdo, 2007)<sup>11</sup> all point to the intensification of the interdependence of stock markets in mature markets.

The interest in understanding the transmission mechanism of shocks has not been restricted to mature markets only, but also to emerging market economies. Volatility spillover effects originating from mature markets, and the role these effects play in the stochastic return generating process of equity markets in emerging economies, have gained prominence in the empirical literature. For instance, Wei *et al.* (1999) examine the price and volatility spillover effects across developed (US, UK and Japan) and emerging markets (Hong Kong and Taiwan) using intra-day data from 1991 to 1992. The univariate GARCH spillover framework used reveals the existence of volatility spillover effects from the US to the emerging markets, over and

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<sup>11</sup> Reference may be made to the summary of the empirical literature on second moment linkages in the appendix of this research (Table A1).

above that exerted by Japan. On a similar subject, Li (2009) using weekly composite indices for the emerging markets of Asia, Latin America, Far East, Europe and Middle East, and Europe, adopts a Multivariate Markov Switching ARCH (MVSARCH)<sup>12</sup> and multivariate GARCH framework for the period 1988 to 2007. The author finds that the strongest US-emerging market correlations occur when both sets of markets are characterised by high volatility.

A cross review of the empirical literature in both mature and emerging markets on the manner in which the volatility of one stock market is transmitted to another points to two main broad conclusions. All these studies typically emphasise (1) the predominance of the US equity market in the global transmission of shocks and (2) the increasing interdependence of world markets across mature and emerging markets.

#### *Liberalisation and Interdependence of Stock Markets*

While there is a wide body of literature that examines the volatility spillover effects among emerging and mature markets, another body of the empirical literature has attempted to empirically examine *why* international capital markets have become increasingly interdependent over the years. One class of this empirical literature has examined the impact that financial liberalisation has had on the integration of financial markets. The basic argument is that the removal of impediments to the free cross-border flow of capital would aid foreign entry into domestic markets (and domestic participation in foreign markets), thereby facilitating greater stock market integration. This is particularly important for emerging countries, which have and continue to undergo numerous financial liberalisation processes, such as relaxing restrictions on foreign ownership of assets, launching country funds and, not least, issuing American Depositary Receipts (ADRs), all with the view to developing their financial markets further.<sup>13</sup> In fact, as pointed out by Bekaert and Harvey (2003: 4), such financial liberalisation processes in most emerging markets were adopted in tandem with macroeconomic and trade reforms.

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<sup>12</sup> The key feature of the MVSARCH model is that not only is the specification of the variance-covariance matrix time-varying, but also state-dependent- varying, depending upon the volatility regime (i.e. whether volatility is high or low). This enables inferences to be made regarding any volatility state-dependent structural changes in the correlation mechanism among variables.

<sup>13</sup> Country Funds and ADRs constitute vehicles through which foreign investors participate in domestic markets sometimes well before the official liberalisation date. The launch of such vehicles therefore gives information about the degree of openness of the local market to foreign investors and is therefore treated as a liberalisation event in numerous studies, for example, Bekaert and Harvey (2000); Ng (2000) and Bekaert and Harvey (2003).

In this respect, Bekaert and Harvey (1997) examine the effect that liberalisation has had on the volatility and correlations of 19 emerging market economies by adopting univariate GARCH frameworks that take into account local and world factors in modelling the dynamics of the volatility of the 19 emerging equity markets. By computing variance ratios which show the proportion of domestic volatility that is driven by world factors before and after liberalisation, the authors document an increasing influence of world factors after liberalisation in 12 of the 17 emerging markets that underwent official liberalisation events in the sample.

In order to examine the effect of the liberalisation policy of the Turkish financial market on its interdependence with the mature markets of US, Japan, Germany and UK, Darrat and Benkato (2003) propose a univariate GARCH volatility spillover framework, which specifies the conditional volatility of the Istanbul Stock Exchange (ISE) as a function of not only its own lagged conditional variance, but also the lagged conditional variance of the other four mature markets. Estimating the model for the full sample period (1986-2000), the pre- and post-liberalisation sub-periods, they find significant spill-over effects from the US and UK after deregulation of the Turkish financial market. A major weakness of this paper is associated with the use of low frequency monthly aggregate stock price data. While monthly data may eliminate problems of non-synchronous (non-overlapping) trading and the 'noise' associated with higher frequency data, it undoubtedly minimises the number of observations, and to a very large extent 'averages' out the daily information flows among the equity markets. Previous studies (c.f. Eun and Shim, 1989; Karolyi and Stulz, 1996) suggest that the use of high frequency data may be more appropriate for studying international correlations or volatility spillovers. In addition, the analysis of sub-periods prior to and after liberalisation further compounds this problem, putting into question the robustness of their results.

Adopting a methodology similar to that of Bekaert and Harvey (1997) but focusing on the volatility spillover effects from the US and Japan, Ng (2000) investigates the importance of capital market liberalisation on the interdependence of the Asian-Pacific Basin markets with their Japanese and US counterparts. By specifying a parametric univariate GARCH framework for the period 1980 to 2000, the author finds that liberalisation events such as capital market reform and country fund launching do have an impact on the return and volatility spillover effects. However, an investigation into whether liberalisation has encouraged cross-country investment (and therefore interdependence) yields contrasting results for each liberalisation event and for each of

the Asia-Pacific Basin states considered. This result is in part consistent with the earlier work of Kim and Rogers (1994) who examine the impact of liberalisation on the transmission of volatility among Japan, US and Korea. Using intra-day data for the period 1985 to 1992, Kim and Rogers adopt a univariate GARCH spillover model for the full sample period and the post-liberalisation sub-period. They find an increase in volatility spill-over effects, particularly from Japan in the post-liberalisation period. In terms of the interdependence of the Korean market with its mature counterparts, this result implies that the liberalisation policy in Korea may have enhanced the linkages of the Korean market, particularly by strengthening the relative importance of regional (Japanese) factors rather than global (US) factors on the Korean market.

In general, therefore, the broad findings of the empirical literature which examine the effect of financial liberalisation on stock market interdependence seem to support the suggestion of the theory that financial liberalisation is associated with intensified linkages among financial markets.

#### *Regional versus Global Interdependence of Stock Markets*

In view of the above, a major question that springs to mind is whether the interplay of liberalisation policies and the numerous other underlying factors that drive the interdependence of markets, have simultaneously strengthened the relative importance of regional and global factors in the stochastic return generating processes and volatility of emerging equity markets. One strand of literature, closely related to one of the objectives of this thesis, has attempted to examine whether regional monetary and economic ties through bilateral trade linkages and regional economic blocs have meant that capital markets have become integrated more at a regional level than a global level. This is extremely pertinent to those regions that have implemented deliberate policies to foster deepened economic, monetary and financial integration, such as those in Western European and the Asia Pacific regions.

In Western Europe, numerous empirical works have attested to the fact that economic integration has also resulted in capital market integration, thereby strengthening the relative importance of the Euro market alongside the US as the dominant market in Europe. For instance, Fratzscher (2002) builds on the Uncovered Interest Parity condition to investigate the role that the European Monetary Union (EMU) has played in the integration of 16 European equity markets, particularly through exchange rate stability. Using a trivariate GARCH framework with time-varying coefficients distinguishing between shocks originating regionally (within the Euro area) and globally (represented by the US market) for the period 1986 to 2000,

the author finds that the drive towards the EMU has seen the Euro regional market gain prominence in world financial markets. At a regional level, the increasing regional equity market integration is attributed to reduced exchange rate uncertainty and monetary policy convergence of interest rates and inflation. Similarly, Baele (2005), using a regime-dependent spillover framework to examine the extent to which globalisation and regional integration has led to equity market integration in 13 European markets between 1980 and 2001, finds an increasing influence of the European Union (EU) in regional and global financial markets. The increase in the interdependence of EU equity markets is attributed to increased trade integration, development of the European equity markets and low inflation rates. Kim *et al.* (2005) also examines the effect of the EMU on the integration of 15 European (12 EMU members and 3 non-members) states using a bivariate EGARCH framework. Similar results to those of Fratzscher (2002) and Baele (2005) are reached by Kim *et al.* (2005) with regard to the strengthening of intra-regional and inter-regional volatility spillover effects associated with the introduction of the Euro.

However, with benefit from a longer post-Euro sample period, a major contrasting result from the arguments made by Fratzscher (2002) and Baele (2005) relates to the role of exchange rate uncertainty in the integration process. Unlike the other authors, Kim *et al.* (2005) find that exchange rate stability has only played a vital role in the integration of three of the twelve smaller markets that adopted the Euro.<sup>14</sup>

Nevertheless, a consistent finding amongst all the empirical literature reviewed relates to the fact that economic and monetary integration in Western Europe has indeed translated into strengthened financial ties amongst European markets. This finding has not been confined to equity markets (c.f. Bodart and Redding, 1999; Christiansen, 2007). Furthermore, the increased financial integration of the EU markets has seen an emergence and strengthening role of the EU as a dominant player in the global financial market, a role that previously belonged exclusively to the US market.

With regard to the Asia Pacific Basin region, the findings of the influential work of Chen and Zhang (1997) give credence to the argument that economic integration primarily through

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<sup>14</sup> Consistent with the findings of Bodart and Redding (1999) (refer to Table A1 in the appendix), this conflicting result on the role of the exchange rate stability in propagating the interdependence of stock markets, lends more support to the theoretical arguments that changes in stock market co-movements are not primarily due to exchange rate risk premia (Kim *et al.*, 2005: 2499).

regional trade ties has resulted in increased regional and international (global) stock market correlations in this area.

The study of Chuang *et al.* (2007) examines the interdependence of equity variances in six East Asian markets after controlling for the exogenous influence of the mature markets outside the region i.e. the US and UK markets. They model the returns in a Vector Autoregressive (VAR)-BEKK<sup>15</sup> framework to obtain the conditional variances for the six markets and then apply a VAR model to examine the dynamic interdependence of the conditional variances. Forecast error variance decompositions and impulse response analyses reveal high levels of volatility interdependence among the Asian markets, with the Japanese market being the most exogenous, as the least susceptible to volatility shocks from the other Asian markets and playing an influential role in transmitting volatility to the other markets. The predominant influence of the Japanese market in East Asia is not new to the empirical literature (see Bekaert and Harvey, 1997; Liu and Pan, 1997; Ng 2000 and Caporale *et al.*, 2006).

However, the question of whether regional factors (due to regional economic integration) in relation to global factors (due to financial globalisation) are relatively more important in the interdependence of equity market variances in the East Asian/Asia-Pacific regions has not received considerable empirical attention. However, a few methodologically related empirical studies have examined this hypothesis.

Examining the magnitude and time-varying nature of global and regional volatility spillovers to six Asia Pacific markets, Ng (2000) proposes a volatility spillover model that allows the unexpected return of any Asia Pacific market to be driven by a local idiosyncratic shock and two exogenous shocks, one related to the region (proxied by the Japanese market) and the other related to the global market (proxied by the US market). By computing variance ratios with respect to the regional and global factor, the author finds considerable time-variation in the relative importance of global and regional factors for individual Asian-Pacific market volatility. On average, both regional and global factors are important for volatility in the Asia-Pacific region, although the global factors tend to dominate the regional factors. However, in spite of their relative importance, regional and global factors are found to account jointly for less than 10

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<sup>15</sup> Vector Autoregressive-Baba Engle Kraft and Kroner Model, named after the first authors to study this type of multivariate ARCH modelling.

percent of the conditional volatility in four of the six Pacific basin markets considered (Ng, 2000: 230).

This result compares favourably with that of Bekaert *et al.* (2005a)<sup>16</sup> with respect to the relative importance of both factors (regional and global) for volatility in the Asian markets, and in the sense that the global factor tends to dominate the regional factor in accounting for total return variation in the Asian markets considered. However, it differs in the sense that the global and regional shocks on average jointly account for 30 percent (compared to 10 percent in Ng, 2000) of the conditional volatility of each Asian market, with the exception of Korea and Taiwan. This conflicting result may be due to the 1997 Asian financial crisis which saw many markets display abnormal behaviour primarily through contagion effects. In support of this contention, Miyakoshi (2003), using a methodology related to that of Ng (2000) and Bekaert *et al.* (2005a), omits the period during the Asian crisis and only considers the period from 1998 to 2000. Miyakoshi (2003: 388) argues that in view of the relative magnitude of Asian assets held by Japanese investors, there exists a possibility that Asian markets can drive the return generating process of the Japanese market and therefore, in contrast to Ng (2000) and Bekaert *et al.* (2005a), insists on the endogeneity of the regional market (proxied by the Japanese market). The author finds that while regional factors do not affect the Asian market returns, they tend to be more dominant than global factors in influencing the volatility of those markets in the study.

In conclusion, despite the intricate inconsistencies outlined with respect to the findings of the studies that attempt to examine the relative importance of regional and global factors for Asian volatility, a few broad lines of agreement are worth noting. Firstly, in harmony with the results in Western Europe, regional and global factors both play an important role for volatility in Asian markets. Secondly, the relative importance of regional and global factors has been time-varying and increasing overtime, and thirdly, while there is no consensus, the majority of the findings lend support to the argument that global factors dominate regional factors in accounting for return volatility of markets in the Asian region.

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<sup>16</sup> Bekaert *et al.* (2005a) utilise a methodology similar to that of Ng (2000) and apply it to three different regions: Europe, South East Asia and Latin America. Here we only review the results with respect to the Asian region. The major contrasting feature between these sets of studies relates to the sample period analysed and the specification of the regional market. Bekaert *et al.* (2005a) study the period from 1980 to 1998, while Ng (2000) concentrates on the same period up to 1996. Furthermore, Bekaert *et al.* (2005a) specify the regional market as a market capitalisation weighted average of all the countries within the region excluding the country under review, while Ng (2000) proxies the regional market by the Japanese market, the largest market in the East Asia and Pacific region.

### ***2.6.2 African and South African Markets***

While a significant proportion of research has been conducted elsewhere around the globe, the poor level of development of African stock markets has resulted in little emphasis on understanding the dynamic interrelations among these markets with the rest of the world's capital markets. The empirical literature on the second moment linkages of African stock markets with their global and African counterparts is somewhat inadequate. The vast majority of the studies that have examined the interdependence of African markets have mainly emphasised linkages in the first moment of returns.

The few studies that have examined first moment linkages among African stock markets with their regional and/or global counterparts include those by Lamba and Otchere (2001), Piesse and Hearn (2002), Collins and Biekpe (2003a), Alhassan (2006) and Chinzara and Aziakpono (2009a). Lamba and Otchere (2001) provide the first comprehensive analysis of dynamic interactions of seven African equity markets with their regional (African) and global counterparts using a multivariate VAR model between 1988 and 2000. The results indicate integration along regional lines, especially among South Africa, Namibia and Zimbabwe. Furthermore, with the exception of Namibia and South Africa, there is little evidence of interdependence of African markets with their global counterparts. Similar results for Namibia and South Africa are obtained by Piesse and Hearn (2002) who conduct cointegration tests on the three dominant Southern African Customs Union (SACU) member states, namely South Africa, Botswana and Namibia for the period 1990 to 2000. Collins and Biekpe (2003a) use Granger causality tests to analyse the interdependence among returns of eight African markets and an adjusted correlation coefficient (as in Forbes and Rigobon, 2002) to analyse the extent to which these countries were affected by the 1997 Asian crisis. The Granger causality tests reveal linkages among regional lines, specifically for South Africa and Zimbabwe. With the exception of the two largest African markets, Egypt and South Africa, the Forbes and Rigobon (2002) adjusted correlation coefficients suggest no evidence of contagion from the Asian crisis.

A few studies have also examined second moment linkages among African markets (c.f. Pretorius and De Beer, 2004; Piesse and Hearn, 2005; Hamavindu and Floros, 2006). Even fewer studies have examined the second moment linkages among African markets and their global counterparts (e.g. Samouilhan, 2006 and 2007 and Chinzara and Aziakpono, 2009b).

In analysing the second moment linkages among seven African markets, Piesse and Hearn (2005) estimate a group of pair-wise asymmetric univariate volatility spillover models by augmenting one country's conditional volatility process with the lagged conditional volatilities of another African country to examine volatility spillover effects between pairs of ten major sub-Saharan African stock markets<sup>17</sup>. The authors find the largest markets of South Africa and Nigeria to be most influential in transmitting volatility to the other African markets, particularly among countries with shared trading mechanisms and shared trade links. Pretorius and De Beer (2004) earlier drew similar conclusions in the foreign exchange market between South Africa and Zimbabwe.

Hamavindu and Floros (2006), using daily data on Namibia and South Africa from the period 1999 to 2003, adopt a GARCH and cointegration framework in order to assess the extent of Namibia's financial integration with South Africa. They argue that, given the strong economic ties between Namibia and South Africa, there is a strong possibility of there being some volatility spillover effects, which may have consequences for portfolio diversification opportunities between the two markets. While all the above studies that have examined returns and volatility linkages between South Africa and Namibia have documented strong interdependence between the two countries, Hamavindu and Floros (2006) find contrasting results when they use the local Namibian index which omits stocks with primary listings on the Johannesburg Stock Exchange (JSE), suggesting that the Namibian Stock exchange is an attractive regional portfolio diversification tool in South African. Their findings further suggest that the co-movement found by other authors (for example, Lamba and Otchere, 2001; Piesse and Hearn, 2002) may be induced by those stocks on the Namibian stock exchange that have primary listings on the Johannesburg stock exchange.

While the above studies have considered linkages among African markets, another set of empirical literature has examined the extent to which African markets are linked to other world markets in the second moments of returns. Samouilhan (2006) examines the returns and volatility interaction between the South African equity market and its mature counterpart (UK market) using daily data for the period 1996 to 2004, adopting an autoregressive univariate asymmetric volatility spillover (EGARCH) framework whereby the domestic conditional volatility process is augmented by the lagged conditional volatility of the UK market. Significant

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<sup>17</sup> The sub-Saharan markets considered are Botswana, Ghana, Kenya, Malawi, Mauritius, Namibia, Nigeria, South Africa, Zambia and Zimbabwe.

volatility spillovers are found between the two markets, with high (low) volatility on the London Stock exchange (LSE) associated with high (low) volatility on the JSE. In a related study, Samouilhan (2007) investigates the link between South African and international markets by examining the extent to which the JSE prices in domestic variance risk and covariance risk with respect to the LSE using a factor-ARCH-in-mean model for the same period. Similar results are found concerning the second moment linkages and, furthermore, local variance risk is priced in more than foreign covariance risk on the JSE. In other words, local factors are significantly more important relative to global factors in explaining the volatility of the JSE.

In a recent study, Chinzara and Aziakpono (2009b) analyse dynamic returns linkages among South African stock markets with six other world markets within a multivariate VAR framework for the period 1995 to 2007. They also examine the trends and transmission of volatility among these markets by modelling the conditional volatilities of each market using a univariate ARCH set of models, then analysing the volatility propagation mechanism through a VAR framework. With respect to the returns linkages, they find that Australia followed by the US then China exert the greatest influence on the South African returns. With respect to the second moment linkages, they find that Australia, followed by the US and China, has the greatest importance for the volatility of the South African market.

Of particular interest is that in spite of the dual listing arrangements between South Africa and the UK market, despite the UK market being the most correlated with the South African market<sup>18</sup> in their sample (pp. 80) and contrary to the findings of previous earlier empirical studies (c.f. Lamba and Otchere, 2001; Samouilhan 2006 and Samouilhan 2007), Chinzara and Aziakpono (2009b: 81-82) document an insignificant influence of the UK market on both the returns and volatility linkages with South Africa.

In general, while acknowledging some of the conflicting findings among the empirical literature on the interdependence of African markets with their global counterparts, a few broad lines of agreement can be drawn. Firstly, a cross-reading of the previous literature lends support to the argument that African markets remain largely segmented, except for those regions that have

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<sup>18</sup> Indeed, one should acknowledge that high correlation between markets does not necessarily imply integration between those markets, especially at broad index level. In fact Bekaert and Harvey (1995: 436) point out that even though a country may be perfectly integrated with the world market, it may nonetheless generate low or negative correlations with respect to the world market due to differences in average industry mixes between the two markets. Reference may also be made to Collins and Abrahamson (2004: 661-662) for an illustration of this issue.

common trading mechanisms and strong trade links, especially in Southern Africa, and particularly between South Africa and Namibia. Secondly, with respect to the interdependence of African equity markets with their overseas counterparts, the general consensus is that most African states are largely segmented from the rest of the global markets, with the exception of South Africa.

A review of the African empirical literature, in relation with that in other regions earlier discussed, one notices certain weaknesses and deficiencies. Amongst all the empirical literature that were reviewed on the propagation of volatility among African and the world's stock markets, none of the studies (at least to the author's knowledge) examines these linkages through multivariate GARCH models. They mostly use univariate GARCH models (and/or their numerous symmetric and asymmetric variants). Owing to the fact that the volatilities of stock returns are time-varying and the generally accepted finding in the vast financial literature that the volatilities of stock returns tend to move together in opposition to, or in response to other markets' volatilities, should in itself warrant the use of multivariate GARCH models. The advantage of using multivariate GARCH models is that, in addition to specifying how the conditional volatilities vary over time, they also specify the dynamics of the conditional covariances of the variables within the system.

Another weakness of most studies focusing on the interdependence of the South African market with its global counterparts is that methodologically they fail to jointly examine the relative importance of regional and global factors in explaining the volatility of the South African equity market by quantifying the proportion of the volatility driven by regional and global factors, and whether these proportions have remained stable over time (in the sense of Bekaert and Harvey 1997; Bekaert *et al.*, 2005a; Ng, 2000 and Christiansen, 2007). Furthermore, while many studies have attested to the increasing predominance of global factors in the South African equity market, none of the studies have attempted to empirically link this time-varying interdependence to certain economic fundamentals so as to analyse beyond conjecture the actual drivers of the second moment linkages of the South African market as guided by the theoretical literature on the fundamental driving forces of stock market volatility linkages. It is the author's fervent view that an analysis of stock market linkages is inadequate without an attempt at understanding the driving forces behind those linkages. This is of particular importance for policy, and if one desires to assess whether there has been progress towards integration among African markets,

especially in view of the recent efforts that have been put forward by the numerous African governments in trying to foster economic cooperation and integration at the regional level.

In addition to complementing the few existing African literature on volatility transmission (spillover) analysis, and in view of the inconsistent and often conflicting results of the previous empirical literature, this study seeks to mitigate the above highlighted weaknesses and deficiencies of the current literature to offer a better understanding of the South African equity market in relation to its regional and global counterparts.

## **2.7 CONCLUSION**

This chapter reviewed the existing theoretical and empirical literature on the interdependence of financial markets, primarily focusing on the transmission mechanism of volatility shocks among equity markets. The first section broadly discussed several issues from a theoretical disposition. At first, the motivation for why it is of importance to understand inter-market linkages in finance was addressed. It was concluded that such an understanding would help investors to identify international diversification opportunities, and help regulators to implement policies aimed at amplifying potential gains from integration, while assisting them to evaluate policy proposals aimed at mitigating the potential financial vulnerability that international financial interdependence may bring. Factors driving equity market linkages were discussed and identified to broadly include exchange rate regime, macroeconomic linkages, bilateral trade ties, and policies aimed at liberalising the financial system. In addition, some of the common approaches to studying equity market linkages were also briefly discussed.

In the second section, a comprehensive overview of the empirical literature documenting interdependence and volatility transmission in mature, emerging and developing markets was given. With regard to the literature in emerging and mature markets, the broad issues related firstly to the predominance of the US market in the global transmission of volatility. Secondly, in both Western and East Asia and the Pacific, the interplay of both regional and global factors was found to be critical for the volatility of those markets. Thirdly, while there is no consensus in both Western European and East Asia and Pacific markets regarding which factors between global and regional are more important for the volatility in those markets, the empirical findings generally point to increasing interdependence both at the regional and global level in those markets.

With respect to the literature in the African markets, the majority of the findings on the linkages in both the first and second moments of returns support the view that African markets are largely segmented both at the regional level (except where strong trade ties and common trading mechanisms are existent) and at the global level, with the exception of the South African and Namibian markets which have remained largely open to foreign influence.

The next chapter presents an overview of the stock markets in order to establish the plausibility of there being some indication of linkages. Together with this chapter, the next chapter forms the basis for the more formal subsequent analytical framework that follows in Chapter Four.

## **CHAPTER THREE**

### **SOUTH AFRICAN TRADE AND CAPITAL MARKET LINKAGES: AN OVERVIEW**

#### **3.1 INTRODUCTION**

This section presents an overview of issues critical for stock market linkages. Section 3.2 presents a brief overview and discussion of the characteristics of the South African and regional stock markets in comparison with their mature counterparts in terms of size, liquidity and level of development. Section 3.3 examines trends in South Africa's external trade in goods and services with the rest of the world with a view to making preliminary inferences about the extent to which the South African market is linked to its regional and global counterparts through these trade relations. Section 3.4 analyses broad trends in the degree of financial integration in the past two decades by examining broad trends in capital mobility over time. Section 3.5 gives a preliminary analysis of trends in the South African stock market vis-à-vis the regional and mature counterparts in order to illustrate the extent to which all the markets respond to common shocks. Section 3.6 briefly concludes the chapter.

#### **3.2 MARKET CHARACTERISTICS: SIZE, LIQUIDITY AND DEVELOPMENT**

This section examines the characteristics of African regional markets in comparison to their emerging (China) and mature (United States, United Kingdom, Japan and Germany) counterparts. This is particularly relevant to the study at hand because stock market characteristics with respect to similarity in size, liquidity and development have been argued to influence co-movement among equity markets.<sup>19</sup> Size and liquidity are associated with stock market informational efficiency, such that the more efficient a market is (in relation to one that is less efficient), the greater the extent to which that efficient market is able to price relevant domestic and foreign information.

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<sup>19</sup> See for instance Banz (1981), Keppeler and Traub (1993) and Pretorius (2002).

**Table 3.1a**  
**African and World Stock Market Characteristics, 2000-2007**

Country	Year	Market Cap, Million \$	Value Traded, Million \$	Market Cap/GDP, %	Value Traded/GDP, %	Turnover Ratio, %	Domestic Listings
Botswana	2000	977.61	47.32	15.8	0.8	4.8	16
	2007	5,887.21	110.08	47.7	0.9	2.2	18
Egypt	2000	28,741.38	11,120.01	28.8	11.1	34.7	1076
	2007	139,289.00	53,080.88	106.8	40.7	45.6	435
Mauritius	2000	1,331.23	75.44	29.0	1.6	5.0	40
	2007	5,665.51	369.00	75.3	4.9	8.0	90
Namibia	2000	311.21	22.05	8.0	0.6	4.5	13
	2007	702.00	22.84	7.9	0.3	3.7	9
Nigeria	2000	4,236.90	262.80	9.2	0.6	7.3	195
	2007	86,346.84	16,774.19	52.0	10.1	28.2	212
Rep. SA	2000	204,952.31	77,494.02	154.2	58.3	33.9	616
	2007	833,547.93	425,747.17	293.8	150.0	55.0	422
UK	2000	2,576,991.90	1,835,278.00	174.4	124.2	66.6	1904
	2007	3,858,505.43	10,324,476.56	137.6	368.3	270.1	2588
Japan	2000	3,157,221.80	2,693,856.28	67.6	57.7	69.9	2561
	2007	4,453,474.91	6,497,192.63	101.7	148.3	141.6	3844
USA	2000	15,104,037.00	31,862,485.22	154.7	326.3	200.8	7524
	2007	19,947,283.82	42,613,206.25	145.2	310.1	216.5	5130
China	2000	580,990.89	721,537.72	48.5	60.2	158.3	1086
	2007	6,226,305.29	7,791,702.08	177.6	222.3	180.1	1530
Germany	2000	1,270,243.20	1,069,120.46	66.8	56.3	79.1	1022
	2007	2,105,505.64	3,363,092.53	63.4	101.2	179.7	658

**Source:** Author's compilation based on data from the World Bank's World Development Indicators.

**Note:** Market capitalisation, GDP and Value Traded are measured in millions of US Dollars.

As evident from Table 3.1a, African markets have recorded remarkable growth over the past decade. With the exception of South Africa, African markets are generally small in both absolute size and size in relation to their respective gross domestic product (GDP). However, between 2000 and 2007 all the markets, with the exception of Namibia, recorded outstanding growth in terms of market capitalisation to GDP with the largest growth recorded in Nigeria (465 percent), Egypt (271 percent), Botswana (201 percent), Mauritius (159 percent) and South Africa (90 percent). In comparison to their mature counterparts, only Japan has recorded growth in market capitalisation to GDP (of 50 percent), with the US, UK and Germany recording negative growth of -6 percent -5 percent and -21 percent respectively. Of all the non-African markets, the most remarkable increase in market capitalisation to GDP can be found in China with an increase of about 266 percent.

There is wide variability in terms of liquidity among African markets. The South African market dominates with a stocks traded annual turnover of 55 percent, followed by Egypt (46 percent) and Nigeria (28 percent). Botswana is the most illiquid market with a stocks traded annual turnover of only 2 percent, followed by Namibia (4 percent) and Mauritius (8 percent). However, in comparison to the 2000 liquidity levels, most African markets in 2007, with the exception of Botswana and Namibia, recorded significant increases in liquidity, with the largest increases being noted for Nigeria (with a growth of 287 percent), followed by South Africa (62 percent), Mauritius (60 percent) and Egypt (31 percent). In comparison to their mature counterparts of UK, Germany, Japan and US, African markets are by far relatively less liquid as evidenced by their respective turnover ratios (and value traded per GDP) that are significantly lower than those recorded in the mature markets. China is also highly liquid with a stocks traded turnover of 180 percent, which is remarkably greater than any of the African markets.

With regard to the changes in domestic company listings between 2000 and 2007, only Mauritius (from 40 to 90) recorded significant growth, followed by Nigeria (from 195 to 212) and Botswana (from 16 to 18), while Egypt (from 1,076 to 435), South Africa (from 616 to 422) and Namibia (from 13 to 9) recorded negative growth. As with stock market size and liquidity, the mature markets and China by far exceed their African counterparts in numbers of domestic listings. In spite of a 32 percent decrease between 2000 and 2007, the US market dominates in number of domestic listings (from 7,524 to 5,130) followed by Japan (from 2,561 to 3,844) and UK (from 1,904 to 2,588), China (from 1,085 to 1,530) and Germany (from 1,022 to 658).

When one compares the statistics of the stock market characteristics prior to the recent global financial crisis, with those after it, it is clear that all the markets responded in a similar fashion. As illustrated in Table 3.1b, all the markets witnessed a significant reduction in their market capitalisation and domestic listings between 2007 and 2008. In response to the crisis, world governments embarked on policies aimed at curbing the adverse effects of the global financial meltdown such that by 2009 most economies were already witnessing the easing of the crisis. In fact, as shown in Table 3.1b, all the mature markets as well as China recorded rebounds in their market capitalisation figures. The figures for domestic company listings are somewhat mixed. For the non-African markets, rebounds were only recorded in the US and China, while Germany, UK and Japan recorded further declines in domestic company listings over the same period. A similar trend was also observed in the overwhelming majority of the African markets.

In relation to this study, the significance of these trends is that the markets appear to respond to common news. The global financial crisis which had its roots in the US not only had ramifications within the borders of its source, but also had similar effects in other markets. This is a simple, albeit inconclusive demonstration of the inter-linkages that (potentially) exist among the world's stock markets with those in Africa.

**Table 3.1b**  
**Effect of Global Financial Crisis on Stock Market Characteristics 2008-2009**

Country	Year	Market Million \$	Cap, Value Million \$	Traded, Market Cap/ GDP, %	Value Traded/ GDP, %	Turnover Ratio, %	Domestic Listings
Botswana	2008	3,555.77	144.17	26.5	1.1	3.1	19
	2009	4,283.28	103.23	34.3	0.88	2.6	20
Egypt	2008	85,885.39	69,639.22	52.9	42.9	61.9	373
	2009	91,091.44	52,812.98	47.8	28.1	59.7	306
Mauritius	2008	3,442.53	403.24	36.9	4.3	8.9	41
	2009	4,982.28	329.75	55.1	3.8	0.3	40
Namibia	2008	618.69	18.76	7.0	0.2	2.8	7
	2009	967.71	22.20	8.9	0.2	0.1	7
Nigeria	2008	49,802.82	19,948.97	24.0	9.6	29.3	213
	2009	33,373.81	4,574.72	19.7	2.7	26.9	216
Rep. SA	2008	491,281.77	401,493.25	177.7	145.2	60.6	425
	2009	805,168.89	342,502.17	-	-	83.8	411
UK	2008	1,851,953.51	6,484,292.41	69.3	242.5	226.9	2415
	2009	2,796,444.3	3,391,103.00	128.6	156.5	146.4	2179
Japan	2008	3,220,485.16	5,866,404.20	65.6	119.5	153.2	3299
	2009	3,533,979.03	4,161,946.22	66.7	82.7	128.8	3208
USA	2008	11,737,645.61	70,085,485.47	83.3	258.8	232.3	5603
	2009	15,077,285.70	46,735,934.70	105.8	327.8	348.6	5,665
China	2008	2,793,612.60	5,470,529.16	61.6	120.7	121.3	1604
	2009	5,007,646.10	8,956,187.66	100.5	179.7	229.6	1700
Germany	2008	1,107,957.42	3,105,287.79	30.3	84.9	191.5	638
	2009	1,297,567.92	1,288,867.41	38.8	38.5	107.2	601

**Source:** Author's compilation based on data from the World Bank's World Development Indicators

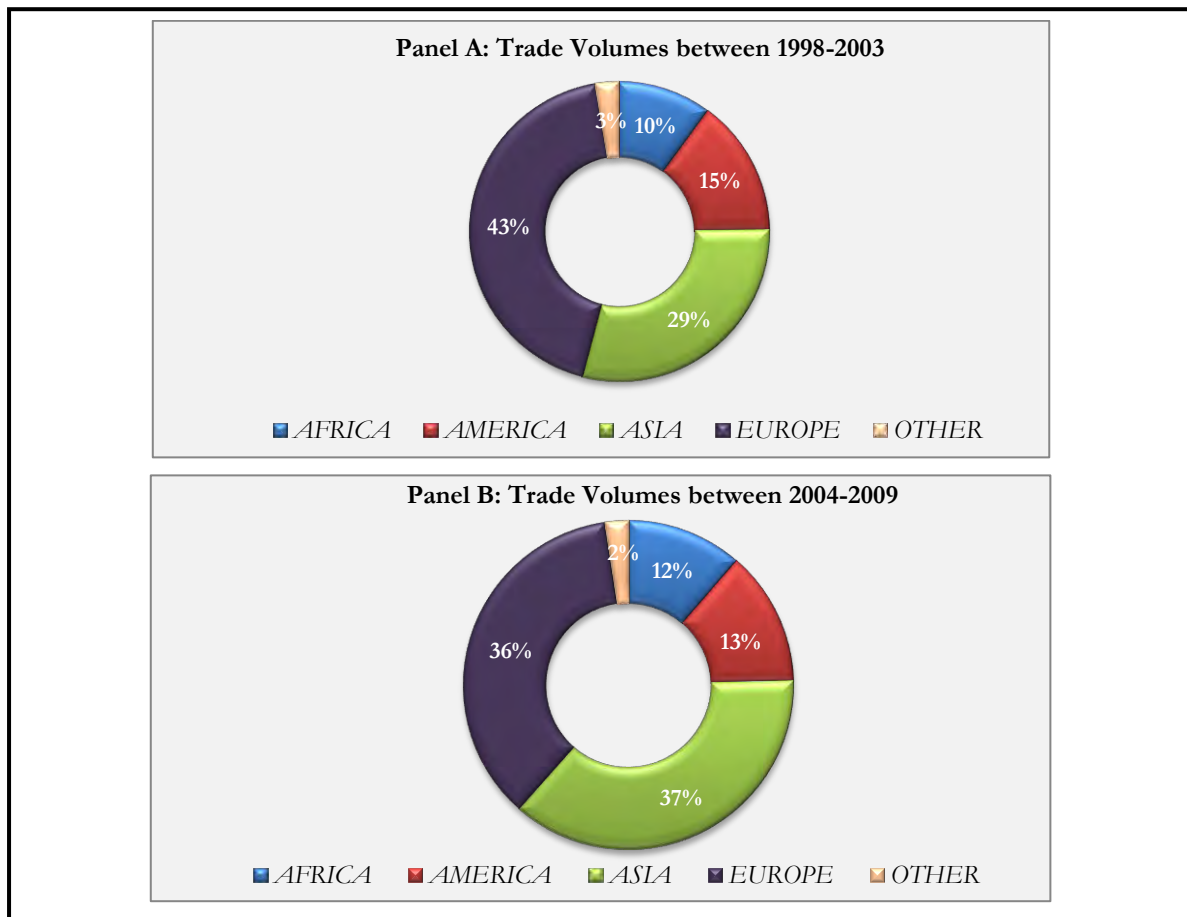
**Note:** Market capitalisation, GDP and Value Traded are measured in millions of US Dollars

### 3.3 GLOBAL AND REGIONAL TRADE LINKS: TRENDS AND SIZE

In this section, we examine some broad trends in South Africa's external trade in goods and services with the rest of the world. It was established in the preceding chapter that the degree to which two economies depend on each other through trade linkages would potentially result in the synchronisation of business cycles and influence the degree of stock market co-movement among trading partners. Given the fact that transactions from cross-border trade in goods and services would also entail corresponding financial transactions (c.f. Lane and Milesi-Ferretti,

2003), one would reasonably anticipate that countries that have strong bilateral trade linkages would not only exhibit synchronicity in terms of real business cycles, but also in terms of financial asset price fluctuations.

**Figure 3.1**  
**Proportion of South Africa's Total Global External Trade by Market, %**

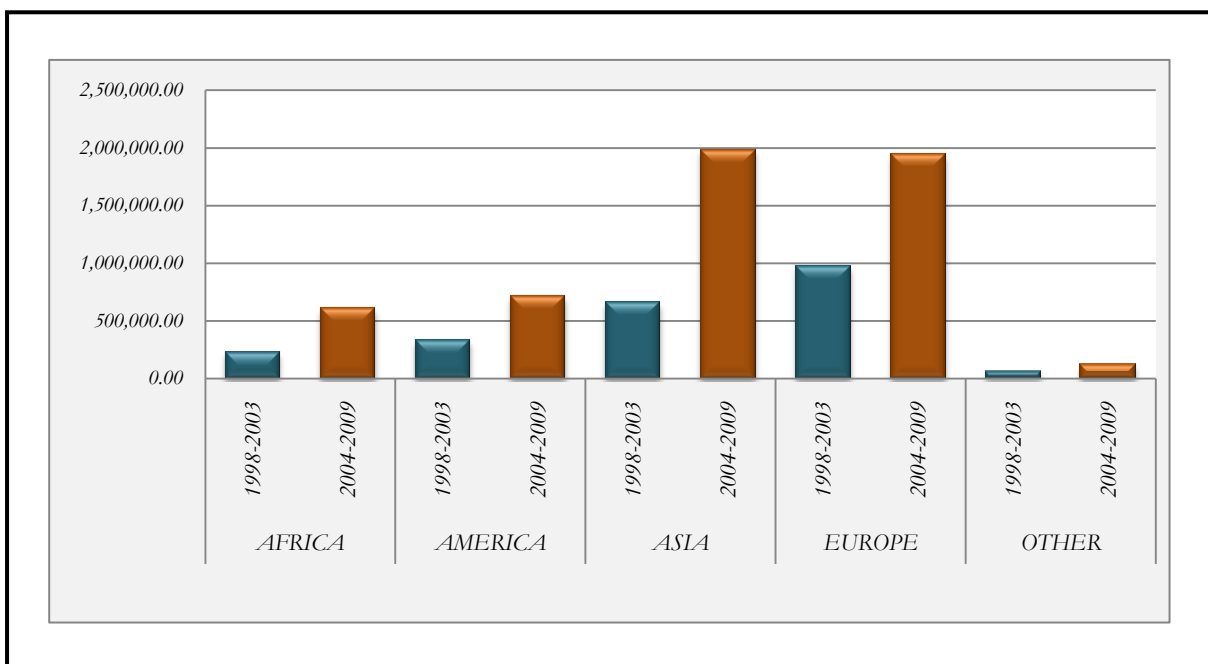


**Source:** Author's computations based on data obtained from Thompson DataStream.

Figure 3.1 shows the relative importance of South Africa's import and export markets in Africa, America, Asia and Europe. The trade volume measures used are the aggregation of the sum of imports and exports over the period 1998 to 2009, divided into two sub-periods. Panel (A) of Figure 3.1 shows the composition (by region) of South Africa's aggregate trade volumes for the period 1998 to 2003. During the sub-period 1998 to 2003, the European market constituted South Africa's largest trading partner, accounting for about 43 percent of South Africa's global trade, followed by Asia and America, accounting for 29 percent and 15 percent respectively. Of the total South African trade in goods and services during the period from 1998 to 2003, the rest of Africa constituted only about 10 percent. Panel (B) of Figure 3.1 shows the composition (by

region) of aggregate trade volumes of South Africa between 2004 and 2009. The previous role of the European market as South Africa’s most important trading partner has been overtaken by robust trade growth from Asia. This can be explained by the recent increase in importance of China as South Africa’s trading partner, brought about in part due to robust economic growth in the world’s largest emerging market. Between 2004 and 2009, the Asian market grew to be the most dominant market, accounting for about 37 percent of South Africa’s total external trade volumes.

**Figure 3.2**  
**Trends in South Africa’s Global Trade by Region (1998-2009)**



**Source:** Author’s computations based on data obtained from Thompson DataStream.

**Note:** The trade volume measurement is an aggregation of the sum of South Africa’s imports from and exports to the respective regions in the sub-periods 1998-2003 and 2004-2009 measured in millions of US Dollars.

The European market declined in relative importance from about 43 percent between 1998 and 2003 to 36 percent in the second sub-period, while the American market has declined in importance, from 15 percent from 1998 to 2003 to 13 percent in the second sub-period. The African market has exhibited a marginal increase in relative importance from 10 percent of South Africa’s total global trade in the first sub-period to 12 percent in the second sub-period.

The decline in relative importance of the European and US markets may not be attributed to a decline in total trade volumes between the two sub-periods. Figure 3.2 compares the trends in total external trade volumes by market between the two sub-periods.

Generally, there has been an increase in trade links in all the markets between the two sub-periods which has almost doubled in the US and European markets.

Of particular interest is the growth in trade volumes with the Asian and African markets. Over the two sub-periods, trade volumes with the Asian market grew by a remarkable 201 percent and with the African market by 170 percent, compared to that with the US and European market which grew by 115 percent and 99.7 percent respectively. The relatively higher growth in trade volumes with these two markets (compared to that in the US and European) explain the decline in the relative importance of the US and European markets over the two six-year sub-periods illustrated in panel B of Figure 3.1.

In conformity with the predictions of the theoretical literature with regard to the relationship between product trade and financial asset trade, the general picture created by the patterns in trade would support two lines of thought. On one hand, one would reasonably anticipate an intensification of linkages between South Africa and the world's financial markets. Secondly, and at the regional level and in view of the growth in the relative importance of the African market as South Africa's trading partner (due to the robust growth in trade volumes), one would also anticipate an increase in the linkages of the South African financial market with its regional trading counterparts.

While these patterns in trade linkages may give a preliminary indication of financial market linkages, an intuitive and slightly more robust approach would be to analyse trends in the cross-border flow of capital between South Africa and the rest of the world to obtain further insights into the dynamics of financial linkages and integration around the globe. This aspect is explored in the next section.

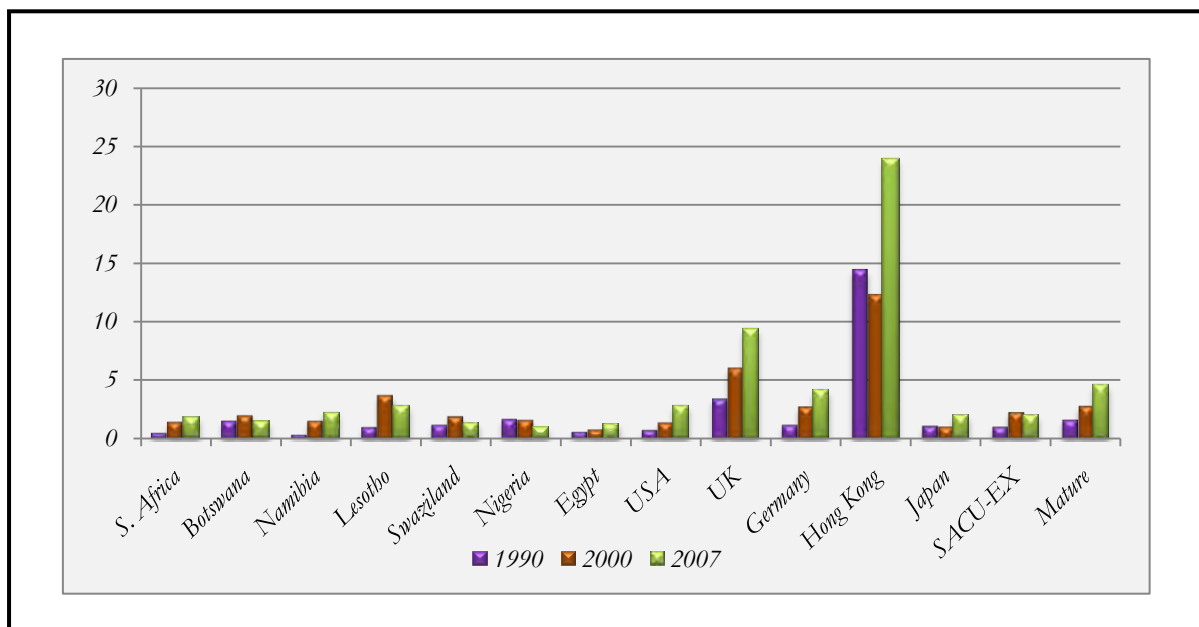
### **3.4 TRENDS IN GLOBAL FINANCIAL INTEGRATION**

It has been well established in the vast empirical literature that advances in information and communication technologies, the lifting of barriers to cross-border flow of capital and increasing

financial globalisation, characterised by increases in the accumulation of greater stocks of foreign assets and liabilities, has meant not only greater synchronicity in fluctuations of cross-border holdings, but also accelerated capital mobility culminating in intensified financial market linkages.

This section seeks to analyse broad trends in the degree of financial integration over the past two decades. Of primary importance in this regard is the choice of the measure of integration that would adequately capture the scale and dynamics of financial linkages in a manner that would enable comparison of the trends in global financial integration.

**Figure 3.3**  
**Changes in Degree of Financial Integration: 1990, 2000 and 2007**



**Source:** Author's computations based on data from the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

**Notes:** The measure of financial integration is the ratio of the sum of Foreign Assets and Foreign Liabilities to GDP, measured in US Dollars. SACU-EX is the average for the SACU region excluding South Africa, while Mature is the average of the four mature markets USA, UK, Germany and Japan. China is represented by Hong Kong.

Lane and Milesi-Ferretti (2003: 86) and (2007: 234) construct a volume-based measure of financial integration (*IFIGDP*) defined as:

$$IFIGDP_t = \frac{FA_t + FL_t}{GDP_t} \quad (3.1)$$

where FA (FL)<sup>20</sup> denotes the aggregate stock of external assets (liabilities) and GDP denotes the gross domestic product.

Figure 3.3<sup>21</sup> compares the changes in the scale of financial integration in South Africa, Botswana, Namibia, Lesotho, Swaziland, Nigeria, Egypt, USA, UK, Japan and China (Hong Kong) as at 1990, 2000 and 2007. Respectively, SACU-EX (the average of the SACU member states excluding South Africa) and Mature are the average levels of integration in the Southern African Customs Union (excluding South Africa) and the mature markets of US, UK and Japan. At issue here is the question of whether capital flows have intensified among these countries and regions over the past two decades.

While all the countries seem to display marked increases in the level of financial integration, a few exceptions are worth noting. Financial integration in three of the SACU countries (Lesotho, Botswana and Swaziland) increased marginally in 2000 then decreased in 2007. This measure of financial integration has been decreasing in Nigeria over the three periods. Only in South Africa, Namibia and Egypt does one find a progressive upward trend in the scale of financial openness.

In comparing the change in the degree of financial integration between African markets and their mature counterparts it can be seen that, consistent with the literature as reviewed in the preceding chapter, mature markets have become more financially integrated than their African counterparts over the past two decades. China, as represented by Hong Kong, shows the greatest scale of financial openness.

It is valuable also to analyse the trends in the flows of portfolio debt assets and debt liabilities for the respective countries and regions as at 1990, 2000 and 2007 to obtain further insights into the trends and magnitude of cross-border portfolio debt flows in those countries. Specifically, one constructs the portfolio debt measure of integration (GPDGDP) as:

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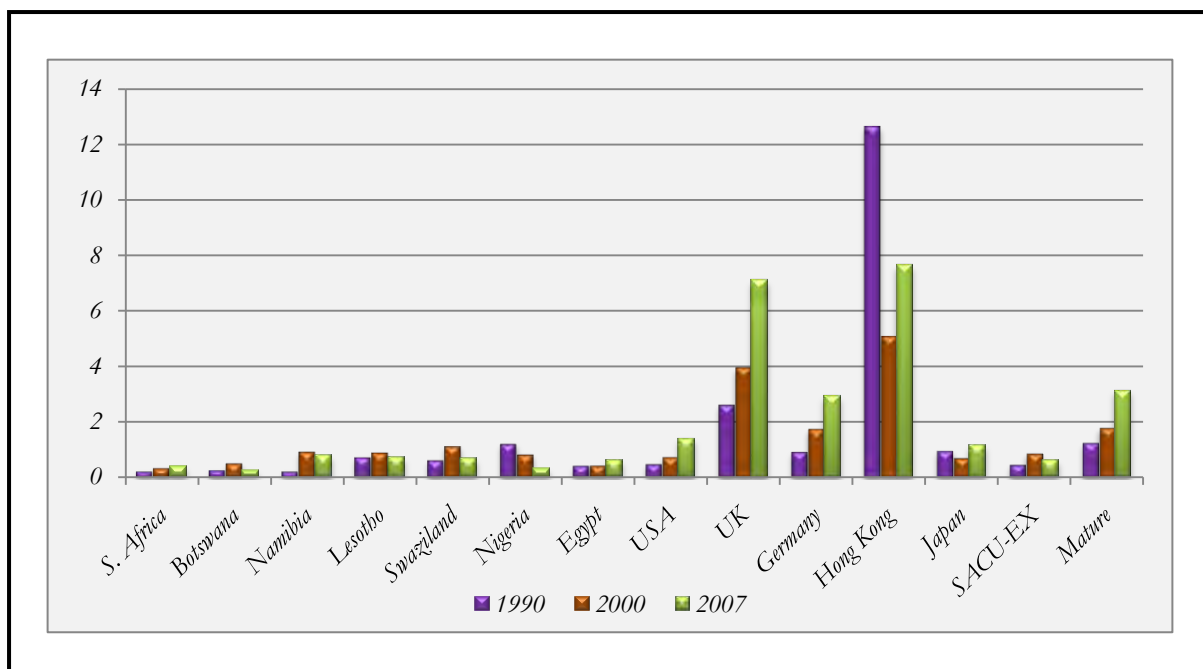
<sup>20</sup> Foreign Assets constitute an aggregation of Foreign Direct Investments (FDI) assets, portfolio equity assets, debt assets, derivatives assets and Foreign Exchange reserves, while Foreign Liabilities constitute an aggregation of FDI liabilities, portfolio equity liabilities, debt liabilities and derivatives liabilities. Refer to Lane and Milesi-Ferretti (2003) for a thorough overview.

<sup>21</sup> While Swaziland and Lesotho do not constitute part of our sample of interest for this study, we include them here for comparison purposes and to illustrate which countries have influenced the financial integration average trends in the SACU region excluding South Africa (SACU-EX).

$$GPDGDP_{it} = \frac{PDA_{it} + PDL_{it}}{GDP_{it}} \quad (3.2)$$

where PDA (PDL)<sup>22</sup> denotes the portfolio assets (liabilities) and GDP is as defined earlier.

**Figure 3.4**  
**Changes in Degree of Financial Integration (Portfolio Debt): 1990, 2000 and 2007**



**Source:** Author's computations based on data from the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

**Notes:** The measure of financial integration is the ratio of the sum of Portfolio Debt Assets and Portfolio Debt Liabilities to GDP, measured in US Dollars. SACU-EX is the average for the SACU region excluding South Africa, while Mature is the average of the four mature markets USA, UK, Germany and Japan. China is represented by Hong Kong.

Figure 3.4 compares the changes in the scale of financial integration (as measured by the sum of portfolio debt assets and liabilities as a proportion of GDP) in South Africa, Botswana, Namibia, Lesotho, Swaziland, Nigeria, Egypt, USA, UK, Japan and China (Hong Kong) as at 1990, 2000 and 2007.

<sup>22</sup> The "portfolio debt assets" and "portfolio debt liabilities" include the sum of portfolio debt securities and other investment (but not FDI intercompany debt, which is in the FDI statistics subsumed under FA and FL statistics). Refer to Lane and Milesi-Ferretti (2003) and (2007) for a detailed description of the data.

The trends in the scale of financial integration in Figure 3.4 are remarkably similar to those reported in Figure 3.3. The non-African markets, led by China (Hong Kong), UK and Germany followed by US and Japan are the most open to portfolio debt flows (relative to their respective gross domestic products). On average they appear to be relatively more open to portfolio debt flows than their African counterparts. All the SACU member states excluding South Africa experienced an increase in the level of financial integration in 2000 before witnessing a decline in 2007. Only in South Africa and Egypt, two of Africa's largest economies, has the scale of financial integration been on an upward trend since 1990. Finally, as with the volume based measure of financial integration (Equation 3.1), Nigeria has recorded a decreasing level of financial integration since 1990.

As noted in Milesi-Ferretti (2003: 86), the international trade in debt instruments may be driven by numerous special factors. Because our interest is in the interdependence of global equity markets, it is worthwhile to measure the degree of financial integration that emphasises the role of stock market integration in driving financial market linkages.

One such measure ( $GEQGDP$ ), as suggested by Lane and Milesi-Ferretti (2003) based on the aggregate stocks of FDI and Portfolio equity is constructed as:

$$GEQGDP_i = \frac{(PEQA_{it} + FDQL_{it} + PEQL_{it} + FDIL_{it})}{GDP_{it}} \quad (3.3)$$

where PEQA (PEQL) denotes the stock of portfolio equity assets (liabilities) and FDIA (FDIL) denotes the stock of foreign direct investment assets (liabilities). Figure 3.5 plots the trends in the global financial integration based on this equity-based measure of financial integration for South Africa in comparison with its mature market, emerging market (China) and regional market (SACU-EX) counterparts.

The period from 1990 to about 2007 was characterised by a fairly steady increase in financial integration, with China (Hong Kong)<sup>23</sup> followed by the mature markets being more integrated into global financial market trailed by the SACU-EX region and South Africa. However, the period surrounding the 1997 Asian financial crisis, the Dot-com (IT) bubble around the late

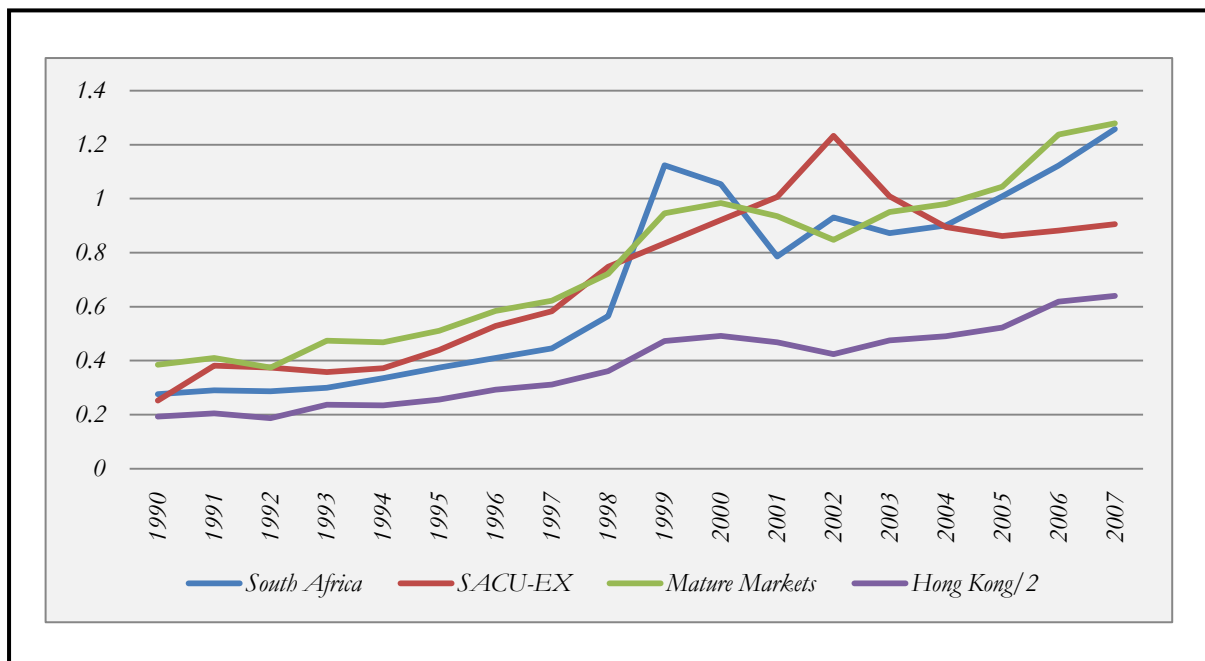
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<sup>23</sup> Note that the measure of financial integration for Hong Kong shown in Figure 3.4 is scaled downwards by half to allow for comparable illustration of the trend over time.

1990s to 2000 and the September 11, 2001 attacks through to the 2002 market downturn witnessed a marked shift in the degree of integration of Southern Africa in comparison to its mature counterparts. During this period, particularly from 1997/8 to around 2003, while all the markets displayed an increase in integration, South Africa dominated the increase followed by the SACU-EX region (which witnessed a declining trend since around 2002) and the mature markets in that order.

This shift in the level of financial integration could be indicative of investors' adjustments of their cross-border holdings in response to the turbulence that characterised the markets during this period. From about 2003 to 2007, the markets reverted to their original steady upward trend whereby the mature markets, trailed closely by South Africa, exhibited increasing financial integration. A notable exception was the SACU-EX region which has since seen a steady increase in financial segmentation.

**Figure 3.5**  
**Regional and Global Financial Integration Trends, 1990-2007**



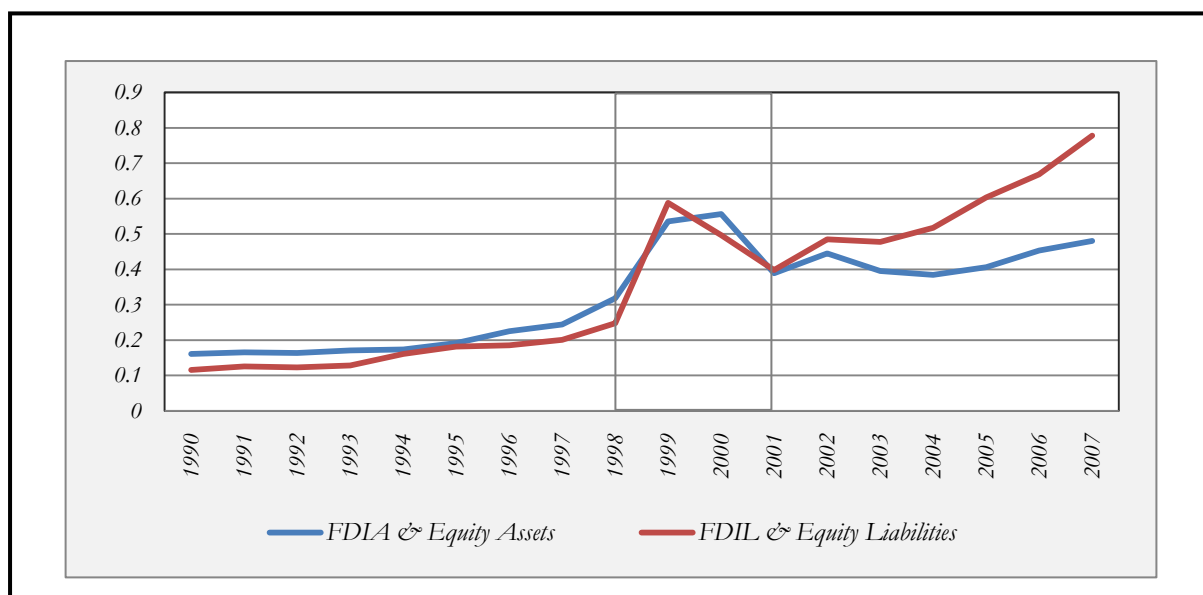
**Source:** Author's computations based on data from the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

**Notes:** The measure of financial integration is the ratio of the sum of foreign portfolio equity and foreign direct Investments (assets and liabilities) to GDP. China (Hong Kong) is scaled downwards by half to allow for comparable illustration of the trend over time.

Since our primary interest is in South Africa, it is also worthwhile to gain further insights into what factors have driven the financial integration process of South Africa. Could the trends in the integration process have been driven by proportionate growth in FDI assets (liabilities) and foreign portfolio equity asset (liability) flows?

In order to gain some insights into this issue, Figure 3.6 shows the decomposition of the financial integration measure into its asset and liability components as a ratio of GDP. This enables one to clearly observe how the two components have interacted over time from 1990 to 2007 to result in the increased integration earlier observed. The period from 1990 to 1998 saw the stocks of portfolio equity and assets and portfolio equity liabilities record steady growth, with the latter trailing the former. However, the crisis-prone period between 1998 and 2001 saw a shift in this trend. In fact, the period from 2001 to 2007 was characterised by a marked increase in the stocks of portfolio equity liabilities over that of the portfolio equity asset flows.

**Figure 3.6**  
**South Africa's Portfolio Assets and Liabilities, 1990-2007**



**Source:** Author's computations based on data from the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

**Notes:** FDIA and Equity Assets (liabilities) is the ratio of the sum of foreign portfolio equity and foreign direct Investments assets (liabilities) to GDP.

On average, the trends in financial integration based on these volume measures lend support to the general findings in the empirical literature, as discussed in Chapter Two, that financial

markets have become increasingly interdependent, not only at the global level, but also at the regional level, especially if one compares the full dynamics of the integration process.

Specifically, for South Africa, the trend towards increased financial integration has been driven primarily by robust growth in the stocks of portfolio equity liabilities, especially since 2001.

### **3.5 SOUTH AFRICAN, REGIONAL AND GLOBAL STOCK MARKET TRENDS**

This section compares the trends in the stock market price indices in order to establish whether there is a reasonable indication of co-movement among the different markets. Having analysed the trends and dynamics of South Africa's global trade and capital flows and having established that trends in both trade and capital flows lend support to the general finding of the literature—that the world's product and financial markets have indeed become increasingly interdependent over time, it would also be worthwhile to analyse the actual trends in the stock markets in order to gain further insights into these linkages. This is important because if markets have indeed become more integrated as the evidence seems to suggest thus far, then it means they respond to similar information. Therefore, this suggested response to common stimuli should be reflected in the pricing mechanisms of the stock markets in question, and the best way to validate this (at least in a general manner), is to examine the trends in the stock prices of the respective markets over time. Figure 3.7 shows the graphical plots of the stock market price indices from 2000 to 2010.

As can be clearly seen, there is an indication of stock market co-movement along regional lines (South Africa, Namibia, Botswana and Mauritius) as well as among those resource-based markets such as South Africa, Namibia, Botswana, Mauritius, Nigeria and Egypt. The mature markets of UK and USA display a pattern quite different from that displayed by African markets. This could be due to the fact that African markets respond to common information similarly amongst themselves, but differently from the manner in which the mature markets respond. However, given the evidence suggesting that international financial markets have become increasingly integrated not only regionally but also globally as shown thus far, then the stock prices should exhibit some indication of similar responses to common stimuli both regionally and globally.

In order to show this, we focus on the markets' response to two very well known global shocks that may have had the potential to affect all the markets similarly in our sample. We consider the

events originating from the US: the September 11, 2001 terror attacks and the 2007 to 2008 global financial crisis that had its roots in the US subprime mortgage market.

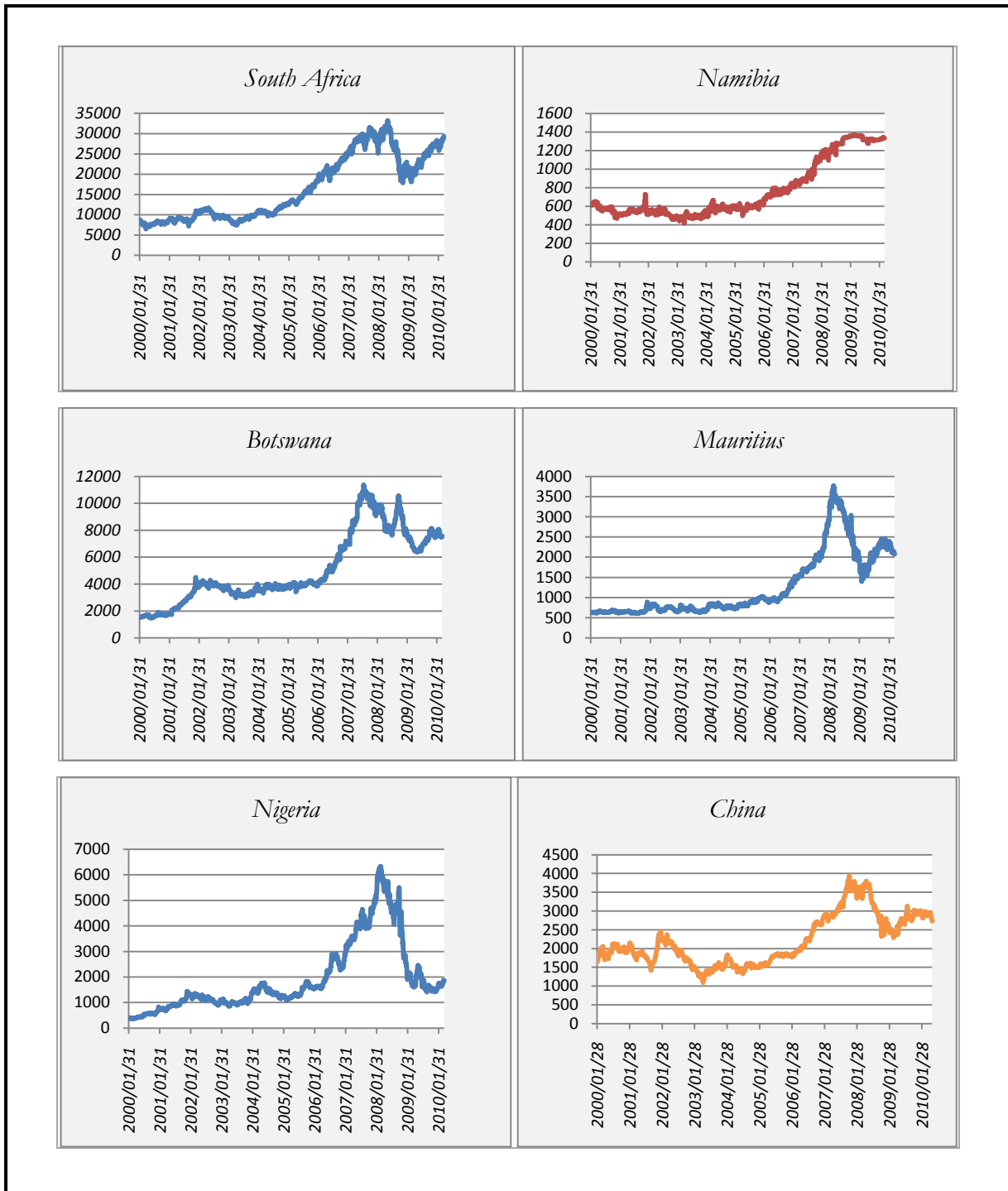
With regard to the September 11, 2001 terror attacks, all the African markets with the exception of South Africa and to a lesser extent Namibia, seem not to display any marked drop in their stock prices in the short period surrounding the third quarter of 2001. By contrast, the mature markets (US, UK, Japan and Germany) as well as China display a much more persistent indication of pessimism as can be deduced from the sharp decline in their respective stock market prices.

With regard to the global financial crisis, all the markets in the sample seem to display striking downturns in their respective stock markets during the period surrounding the crisis. With the exception of Namibia, the downturn appears to have resulted in a greater loss of value in African markets than in the mature markets. This could perhaps be a consequence of the swift and coordinated pre-emptive action that was taken in the mature markets to minimise the adverse effects of the financial crisis in those economies.

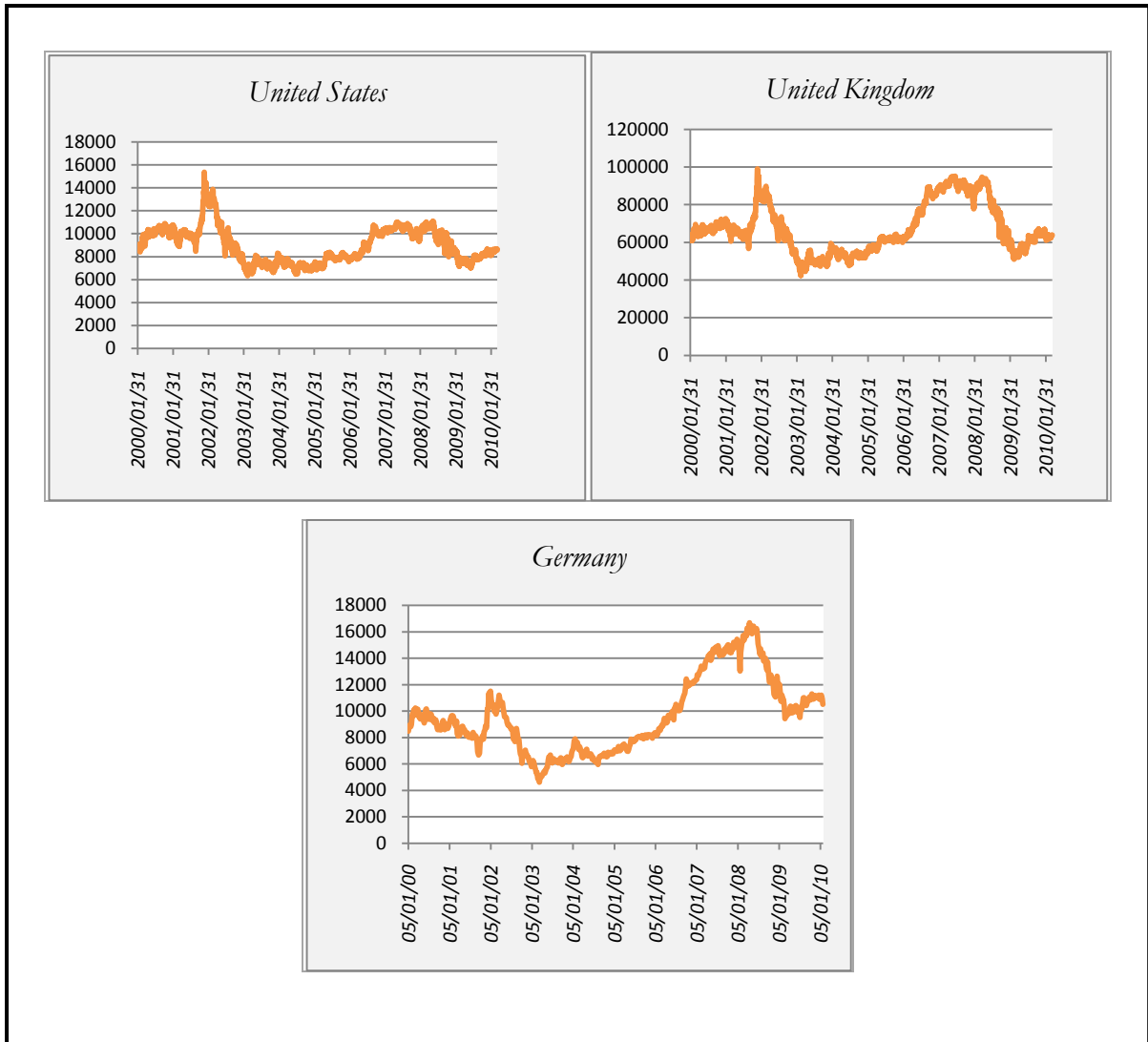
### **3.6 CONCLUSION**

This chapter has examined the eleven markets that constitute the focus of this study in four broad areas: in terms of the trends and indicators of stock market development, the importance and size of trade links of South Africa with the rest of the globe, trends and dynamics of capital flows among these markets and finally trends in the respective markets' stock price indices. The general indication gleaned from this broad analysis is that there has been an intensification of linkages among international markets both at regional and global levels associated with economic factors related to cross-border trade, as well as factors related to the cross-border flow of capital.

**Figure 3.7**  
**Stock Market Trends, 2000-2010**



(Continued on next page)



**Source:** Author's compilation based on data obtained from Thompson DataStream.

**Note:** The graphical plots are colour-coded by trend.

With regard to the time-variation that was observed in terms of trade flows and capital flows, could similar dynamics over time be observed with regard to the cross-border price and volatility spillovers? Indeed, these are all questions that may only be addressed empirically and constitute the main focus of this study.

The next chapter develops the formal analytical framework and a discussion of the data to be used so as to properly analyse and address these unresolved issues.

## **CHAPTER FOUR**

### **METHODOLOGICAL FRAMEWORK AND DATA ISSUES**

#### **4.1 INTRODUCTION**

This chapter describes the formal analytical framework that is used to achieve the objectives outlined in Chapter One of this study. Issues pertaining to data and proxies used are also discussed herein. As earlier noted, the main objective of this research is to assess and quantify the extent to which the stock market volatility of South Africa is affected by stock market shocks originating locally, regionally and globally so as to make inferences about the magnitude and determinants of the interdependence of the South African equity market with its regional and global counterparts. In doing so, we follow several authors (c.f. Bekaert and Harvey, 1997; Ng, 2000; Baele, 2005; Cifarelli and Paladino, 2005; Aragó-Manzana and Fernández-Izquierdo, 2007) by modelling the volatility processes using the ARCH modelling techniques introduced by Engle (1982) and Bollerslev (1986). Specifically, the model developed here resembles that used by Bekaert and Harvey (1997), Ng (2000), Baele (2005) and Christiansen (2007).

The rest of this chapter is organised as follows. Section 4.2 describes the model adopted in this study and the empirical framework proposed. Section 4.3 outlines the model selection criteria and specification tests. Section 4.4 discusses the empirical estimation procedure, while Section 4.5 discusses the data used and Section 4.6 concludes the chapter.

#### **4.2 THE VOLATILITY TRANSMISSION MODEL**

This study attempts to shed more light on the determinants and changing nature of South Africa's second moment equity market correlations with its African and global counterparts. Therefore, we propose a model which allows for three sources of unexpected returns, namely (1) a purely domestic shock, (2) a regional African shock, and (3) a global shock from the mature equity markets. In this respect, the model adopted may be viewed as an extension of Bekaert and Harvey (1997) in the sense that one assumes two regional (foreign) sources of domestic market volatility instead of just one world source, and closely related to that of Ng (2000) and Baele (2005).

The empirical tests conducted in this study are based on the univariate ARCH models of Engle (1982) and Bollerslev (1986) and multivariate ARCH models of Bollerslev *et al.* (1988), Bollerslev (1990) and Engle and Kroner (1995). The approach proposed in this study is a two-factor model in which the unexpected return of the South African market is influenced not only by news originating within the local market, but also by two foreign sources: a regional shock from within the African region and a global shock from other mature (world) markets. Firstly, in Section 4.2.1 we describe the joint process governing the global and regional returns and volatility processes in a bivariate GARCH framework. We explore several specifications for the conditional variance-covariance processes governing the two sources of unexpected returns, and select the best performing bivariate specification. Section 4.2.2 describes the univariate volatility transmission model which takes into account the domestic, regional and global shocks.

#### 4.2.1 A Bivariate Model for the Regional and Global Market

The joint process governing the returns of the African (regional) and mature (global) equity returns may be expressed as follows:

$$\begin{bmatrix} R_{reg,t} \\ R_{g,t} \end{bmatrix} = \begin{bmatrix} \alpha_{reg,0} \\ \alpha_{g,0} \end{bmatrix} + \begin{bmatrix} \alpha_{reg,1} & \alpha_{reg,2} \\ \alpha_{g,1} & \alpha_{g,2} \end{bmatrix} \begin{bmatrix} R_{reg,t-1} \\ R_{g,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{reg,t} \\ \varepsilon_{g,t} \end{bmatrix}, \quad (4.1)$$

$$\varepsilon_t | I_{t-1} \sim N(0, H_t) \quad (4.2)$$

where  $R_t = [R_{reg,t}, R_{g,t}]'$  denotes the returns on respectively the aggregate African region and global equity market at a given time  $t$ .  $\varepsilon_t = [\varepsilon_{reg,t}, \varepsilon_{g,t}]'$  is a vector of innovations (disturbance terms). Equation 4.1, known as the conditional bivariate mean equation, basically links the joint process governing the regional and global market returns at a given time,  $t$ , to their respective past returns. Under the assumption of conditional bivariate normality,  $H_t$  is a  $(2 \times 2)$  positive definite conditional variance-covariance matrix which is 'conditioned' on past information  $I_{t-1}$ .

The theoretical literature proposes several specifications for the conditional variance-covariance matrix  $H_t$ .<sup>24</sup> For the purpose of this study we explore three main specifications for the conditional variance-covariance matrix, namely, the VECM model, the Conditional Constant Correlation Model (CCC) and the BEKK model. The characteristics of each of these different specifications as well as the motivation behind their selection are briefly discussed below.

#### VECM ( $p, q$ ) MODEL

The general VECM specification of the variance-covariance matrix  $H_t$  proposed by Bollerslev *et al.* (1988) expressed each element of  $H_t$  as a linear function of the lagged squared errors and cross-products of errors and lagged values of the elements of  $H_t$ . A VECM ( $p, q$ ) may be expressed as:

$$h_t = C + \sum_{i=1}^p A_i \text{vech}(\varepsilon_{t-i} \varepsilon_{t-i}') + \sum_{j=1}^q G_j \text{vech}(H_{t-j}) \quad (4.3)$$

$$h_t = \text{vech}(H_t) \quad (4.4)$$

where the  $\text{vech}(\cdot)$  operator stacks the lower triangular elements of a  $N \times N$  symmetric matrix as a vector of order  $N(N+1)/2 \times 1$ . In Equation 4.3, the matrices represented by  $A$  and  $G$  are symmetric coefficient matrices of order  $N(N+1)/2 \times 1$  while  $C$  is a  $(N+1)N/2 \times 1$  parameter Vector. Equation 4.3 shows the unrestricted VECM model. While being flexible in the sense that it allows the interaction of all the elements of the variance-covariance matrix,  $H_t$ , Brooks (2008: 434-435) among others, observe that in its general form, the VECM model suffers from several major drawbacks.

Firstly, the estimation of the model poses a particular challenge in the sense that it requires the estimation of  $N(N+1)(N(N+1)+1)/2$  parameters which makes estimation cumbersome as the number of series within the system grows.

Secondly, and perhaps more importantly, without imposing any strong parameter restrictions, it fails to guarantee a positive definite  $H_t$ . The property of positive definiteness is of fundamental importance from a mathematical standpoint since variances can never be negative, and the

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<sup>24</sup> Refer to Bauwens *et al.* (2006) for a comprehensive survey of these alternative conditional variance-covariance specifications.

covariance between two series is the same irrespective of which of the two series is taken first (Brooks, 2008: 434). To that end, various approaches have been suggested in the theoretical literature to guarantee a positive-definite  $H_t$  as well as minimisation of the dimensionality problem. One such approach, also adopted in this study, is that by Bollerslev *et al.* (1988) who suggest necessary conditions to circumvent these drawbacks. By constraining  $\mathbf{A}$  and  $\mathbf{G}$  to be diagonal, the rate at which the parameters grow with the dimensionality of the model is considerably reduced to  $N(N+5)/2$ . Furthermore, to ensure the positive definiteness of  $H_t$ , the model is expressed in terms of Hadamard products<sup>25</sup>. The resultant model, called Diagonal VECH (DVECH) can be expressed as:

$$H_t = C^\circ + A^\circ \odot (\varepsilon_t \varepsilon_{t-1}') + G^\circ \odot H_{t-1} \quad (4.5a)$$

where the symbol  $\odot$  is the Hadamard product with  $A^\circ$  and  $G^\circ$  restricted to be diagonal such that:

$$C^\circ = \begin{bmatrix} c_{11} \\ c_{12} \\ c_{22} \end{bmatrix}; \quad A^\circ = \begin{bmatrix} a_{11} & 0 & 0 \\ 0 & a_{22} & 0 \\ 0 & 0 & a_{33} \end{bmatrix} \text{ and } \quad G^\circ = \begin{bmatrix} g_{11} & 0 & 0 \\ 0 & g_{22} & 0 \\ 0 & 0 & g_{33} \end{bmatrix}$$

Attanasio (1991: 493) shows that the specification of  $H_t$  as in Equation 4.5a is positive semi-definite for all  $t$  provided that  $A^\circ$ ,  $G^\circ$ ,  $C^\circ$  and the initial variance-covariance matrix ( $H_0$ ) are constrained to be semi-definite (see also Bauwens *et al.*, 2006). Furthermore, because (4.5a) is a diagonal model, covariance stationarity conditions are determined solely by the diagonal elements of  $A^\circ$  and  $G^\circ$  matrices. Specifically, the DVECH model is only covariance stationary if and only if  $a_{ii} + g_{ii} < 1$  for all  $i$  (Engle and Kroner (1995: 133).

The third weakness of the general form VECH model (including the restricted version represented in Equation 4.5a) relates to the fact that, by virtue of its construction, it imposes a symmetric response of the conditional variance-covariance matrix to positive and negative news. However, previous research has shown that equity return time-series exhibit asymmetric effects

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<sup>25</sup> The Hadamard product, denoted by  $\odot$ , represents an element-by-element multiplication of matrices. For instance if  $K = (k_{ij})$  and  $L = (l_{ij})$  are both  $m \times n$  matrices, then  $K \odot L$  is the  $m \times n$  matrix containing element-wise products  $(k_{ij} l_{ij})$  (c.f. Bauwens *et al.*, 2006: 82; Baele, 2005: 378).

whereby stock return volatility responds differently to return shocks depending on whether the shocks reflect positive or negative news (c.f. Engle and Ng, 1993; Glosten *et al.*, 1993; Kroner and Ng, 1998). Two competing theories have emerged in the finance literature to explain this phenomenon: the leverage hypothesis and the volatility feedback effect.

The leverage effect phenomenon draws its theoretical foundations from the early works of Black (1976), Christie (1982) and French *et al.* (1987) who suggested that a fall in a firm's stock value increases the firm's debt-to-equity ratio. This would cause shareholders, who bear the residual risk of the firm, to perceive the future stream of cash flows from their equity investment in that firm as being more risky and therefore increase the stock's volatility. The volatility feedback effect, proposed by Campbell and Hentschel (1992) and Koutmos (1997), suggested that under the assumption of constant dividends, if expected returns increase as stock price volatility increases, then it should follow that stock prices should fall when volatility increases. In other words, given that equity return volatility is priced in the market, stock prices will decline depending on the extent to which anticipated increases in volatility raise the required return on equity.<sup>26</sup>

It follows therefore that imposing a symmetric response to shocks as in Equations 4.3 and 4.5a, would result in the misspecification of the model if the data manifests asymmetric effects. To that end, we also explore the estimation of an asymmetric VECH model suggested by Kroner and Ng (1998). Specifically, by defining  $\xi_{j,t} = \min(0, \varepsilon_t)$ , for  $j =$  regional and global equity market, the symmetric VECH model represented by Equation 4.5a can be extended to an asymmetric VECH model of the form:

$$H_t = C^\circ + A^\circ \odot (\varepsilon_t \varepsilon_{t-1}') + G^\circ \odot H_{t-1} + L \odot (\xi_{t-1} \xi_{t-1}') \quad (4.5b)$$

where  $A^\circ$ ,  $G^\circ$  and  $C^\circ$  are as defined earlier in Equation 4.5a, and:

$$\xi_t = \begin{bmatrix} \xi_{reg,t} \\ \xi_{g,t} \end{bmatrix}.$$

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<sup>26</sup> Refer also to Bekaert and Wu (2000) for an empirical evaluation of these two competing theories.

The asymmetric VECH model allows the cross product term of the negative shocks to determine the variance-covariance to the effect that covariance will be higher when there is negative news than when there is positive news (Kroner and Ng, 1998: 836). Essentially, the diagonal elements (coefficients) of the parameter matrix  $L$  will be positive and statistically significant if the variance-covariance matrix displays an asymmetric response to positive and negative news.

To that effect, we estimate the model represented in Equation (4.5b) in the empirical section.

#### BEKK ( $p, q, K$ ) MODEL

The difficulties associated with the VECH model's ability to guarantee that the parameterisation of the variance-covariance matrix  $H_t$  is positive-definite led Engle and Kroner (1995) to suggest an alternative specification of  $H_t$ . In its general form, BEKK ( $p, q, K$ ) can be expressed as:

$$H_t = C^* C^{*'} + \sum_{k=1}^K \sum_{i=1}^q A_{ki}^* \varepsilon_{t-i} \varepsilon_{t-i}' A_{ki}^{*'} + \sum_{k=1}^K \sum_{i=1}^p G_{ki}^* H_{t-i} G_{ki}^{*'} \quad (4.6)$$

where  $C^*$ ,  $A_k^*$  and  $G_k^*$  are symmetric  $N \times N$  parameter matrices. The summation limit  $K$  determines the generality of the process. Like the VECH model, the BEKK model allows every element of the conditional variance-covariance matrix to be a function of  $H_{t-i}$  and  $\varepsilon_{t-j} \varepsilon_{t-j}'$ . The intercept matrix  $C^*$  is decomposed into  $C^* C^{*'}$  where  $C^*$  is the upper triangular matrix and without any further restrictions  $C^* C^{*'}$  is positive definite. The representation in Equation 4.6 is general in the sense that it includes all positive definite diagonal representations and nearly all positive definite VECH representations (Engle and Kroner, 1995: 127).

In the general form implied by Equation 4.6, the interpretation of the parameters in the BEKK ( $p, q, K$ ) model is cumbersome. In the first-order BEKK model, where  $p=q=K=1$ , Equation 4.6 simplifies to:

$$H_t = C^* C^{*' } + A_1^* (\varepsilon_{t-1} \varepsilon_{t-1}' ) A_1^{*'} + G_1^* H_{t-1} G_1^{*'} \quad (4.7a)$$

where

$$C^* = \begin{bmatrix} c_{11}^* & c_{12}^* \\ 0 & c_{22}^* \end{bmatrix}; \quad A_1^* = \begin{bmatrix} a_{11}^* & 0 \\ 0 & a_{22}^* \end{bmatrix} \quad \text{and} \quad G_1^* = \begin{bmatrix} g_{11}^* & 0 \\ 0 & g_{22}^* \end{bmatrix}$$

In practice, without any restrictions, Equation 4.7a would require the estimation of 12 parameters for the bivariate case, which increases exponentially with a higher number of series. In order to reduce this number and thereby reduce the generality of the model, Engle and Kroner (1995) suggest imposing a ‘diagonal BEKK’ model whereby  $A_1^*$  and  $G_1^*$  as shown in Equation 4.7a are diagonal matrices. The implication of this is that for the bivariate model of the regional and global markets it would only be necessary to estimate 7 parameters. The resultant diagonal BEKK model may be viewed as a DVECH equivalent. However, the diagonal BEKK model is guaranteed to be positive-definite while the DVECH is not (Bauwens *et al.*, 2006: 83). As in the case of the DVECH model, the choice of the ‘diagonal’ restriction is justified by the fact that in the diagonal BEKK model, the covariance stationarity conditions are easy to check because they are solely determined by the diagonal elements of the diagonal matrices  $A_1^*$  and  $G_1^*$ . Specifically, Engle and Kroner (1995: 133) show that the diagonal BEKK model is covariance stationary if and only if  $(a_{ii}^*)^2 + (g_{ii}^*)^2 < 1$  for all  $i$ .

In order to account for possible leverage effects, we also explore the estimation of an asymmetric version of the diagonal BEKK model represented by Equation 4.7a, specified as:

$$H_t = C^*C^{*'} + A_1^*(\varepsilon_{t-1}\varepsilon_{t-1}')A_1^{*'} + G_1^*H_{t-1}G_1^{*'} + L_1^*(\xi_{t-1}\xi_{t-1}')L_1^{*'} \quad (4.7b)$$

where

$$\xi_t = \begin{bmatrix} \xi_{reg,t} \\ \xi_{g,t} \end{bmatrix} \text{ and } L_1^* = \begin{bmatrix} l_{11}^* & 0 \\ 0 & l_{22}^* \end{bmatrix}$$

with  $\xi_{j,t} = \min(0, \varepsilon_{j,t})$  for  $j =$  (regional and global equity market),  $L_1^*$  is a  $(2 \times 2)$  matrix whose constituent diagonal elements (the parameters given by  $l_{11}^*$  and  $l_{22}^*$ ) capture the asymmetric response of the conditional variance and covariance to negative and positive innovations in the sense of Brooks *et al.* (2002).

For the purposes of this study one estimates both the symmetric diagonal BEKK model (Equation 4.7a) and the asymmetric diagonal BEKK model (Equation 4.7b) in the empirical section to model the variance-covariance dynamics of the regional and global equity market.

## CONDITIONAL CONSTANT CORRELATION MODEL

The Conditional Constant Correlation (CCC) model can be ascribed to a set of multivariate correlation models which are based on the decomposition of the conditional covariance matrix into conditional standard deviations and correlations. The CCC model introduced by Bollerslev (1990) is conceptually different from the other VEC and BEKK models (and their respective variants) described above in the sense that while VEC and BEKK provide dynamics for variances and covariances, conditional correlation models provide the dynamics for the variances and correlations. Specifically, Bollerslev (1990) proposed a class of MGARCH models in which the conditional correlations are constant and therefore the conditional covariances are proportional to the product of the corresponding conditional standard deviations, taking the form:

$$H_t = D_t \Gamma D_t = \left( \rho_{ij} \sqrt{h_{iit} h_{jtt}} \right) \quad (4.8)$$

where  $D_t = \text{diag}(h_{11t}^{1/2} \dots h_{NNt}^{1/2})$ , each of the conditional variances  $h_{iit}$  in  $D_t$  can be defined as any univariate GARCH ( $p, q$ ) model, and  $\Gamma = (\rho_{ij})$  is an  $N \times N$  symmetric positive definite matrix containing all the ‘time-invariant’ constant correlations  $\rho_{ij}$  with  $\rho_{ii} = 1$  for all  $i \neq j$ . By intuition of the model given in Equation 4.8, the time-varying conditional covariances are parameterised to be proportional to the product of the corresponding conditional standard deviations. Bollerslev (1990: 499) shows that  $H_t$  will almost surely be positive definite for all values of  $t$  if and only if each of the  $N$  conditional variances are well defined and the matrix  $\Gamma$  is positive-definite.

In comparison to the other models described thus far, namely VEC and BEKK, the CCC model is argued to be much more parsimonious in characterising the conditional variances in the sense that it only requires the estimation of  $N(N+5)/2$  parameters (Bauwens *et al.*, 2006: 86). However, the major weakness of this model lies in its assumption of time-invariant correlations which may be viewed as being too restrictive for practical purposes, especially in view of the vast empirical evidence which generally suggests that correlations among financial series are dynamic and vary over time (e.g. Capiello *et al.*, 2006). However, owing to the difficulty in justifying time-invariant correlations, we do not estimate Equation 4.8 for the bivariate model of the global and regional markets.

The estimation of the joint process governing the returns of the regional and global market using the bivariate GARCH models described above enables one to derive the regional and global shocks that are used as explanatory variables in the univariate volatility spillover model for South Africa and the other African markets considered in this study.

#### 4.2.2 Univariate Volatility Spillover Model

This section describes the univariate extended AR-GARCH framework characterising the domestic market's return generating processes. Following several studies (c.f. Bekaert and Harvey, 1997; Ng, 2000; Baele, 2005 and Christiansen, 2007), local unexpected returns, apart from being driven by a purely domestic shock, are also allowed to be driven by innovations from the global and regional market returns. Firstly, owing to the fact that common news could drive the regional and global returns, and secondly, to avoid spurious spillovers between the global and regional equity markets, the returns from the regional and global markets are orthogonalised using a Cholesky decomposition assuming that the regional return shock is driven by a purely idiosyncratic shock and by the global return shock.

Specifically, it is assumed that:

$$\begin{bmatrix} \hat{\varepsilon}_{reg,t} \\ \hat{\varepsilon}_{g,t} \end{bmatrix} = \begin{bmatrix} 1 & -k_{t-1} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{\varepsilon}_{reg,t} \\ \hat{\varepsilon}_{g,t} \end{bmatrix},$$

with (4.9)

$$k_t = \frac{\text{cov}_{t-1}(\varepsilon_{reg,t}, \varepsilon_{g,t})}{\text{var}_{t-1}(\varepsilon_{g,t})}$$

where  $\hat{\varepsilon}_{reg,t}$  and  $\hat{\varepsilon}_{g,t}$  denote the orthogonalised regional and global shock respectively. Their respective conditional variances are denoted by  $\sigma_{reg,t}^2$  and  $\sigma_{g,t}^2$ . Following Bekaert and Harvey (1997) and Ng (2000), foreign innovations from the regional and global markets are allowed to influence the domestic equity return through the error term representing the unexpected return. To that end, the proposed univariate volatility spillover model for country  $i$ , can be specified as:

$$R_{i,t} = \beta_{i,o} + \beta_i R_{i,t-1} + \gamma_{i,t-1} R_{reg,t-1} + \delta_{i,t-1} R_{g,t-1} + \varepsilon_{i,t} \quad (4.10)$$

$$\varepsilon_{i,t} = e_{i,t} + \phi_{i,t-1} \hat{e}_{reg,t} + \psi_{i,t-1} \hat{e}_{g,t} \quad (4.11)$$

$$e_{i,t} | I_{t-1} \sim N(0, \sigma_{i,t}^2) \quad (4.12)$$

$$\sigma_{i,t}^2 = E[e_{i,t}^2 | I_{t-1}] = \varphi_{i,0} + \varphi_{i,1} \sigma_{i,t-1}^2 + \varphi_{i,2} e_{i,t-1}^2 + \varphi_{i,3} e_{i,t-1}^2 \zeta_{i,t-1} \quad (4.13a)$$

For Equations 4.10 and 4.11 the conditional country  $i$  mean return depends on the lagged regional ( $R_{reg,t}$ ), global ( $R_{g,t}$ ) and own ( $R_{i,t}$ ) return while  $\varepsilon_{i,t}$  is the unexpected return of country  $i$ . As indicated by Equation 4.12,  $e_{i,t}$  is a purely idiosyncratic shock which is assumed to follow a conditional normal distribution with a zero mean and a time-varying variance  $\sigma_{i,t}^2$ . The conditional variance defined over the purely idiosyncratic shock ( $e_{i,t}$ ) follows an asymmetric GARCH (1, 1) process whereby  $\zeta_{i,t-1} = 1$  if  $e_{i,t-1} < 0$  and  $\zeta_{i,t-1} = 0$  otherwise. The conditional variance stationarity condition for the variance equation represented in Equation 4.13a would require that the sum of the coefficient of the lagged conditional variance and the coefficient of the lagged idiosyncratic shock be less than unity. In other words, Equation 4.13a would be conditional variance stationary if the condition:  $\varphi_{i,1} + \varphi_{i,2} < 1$  is not violated.

The choice of the specification as in Equation 4.13a is motivated by the vast evidence in the financial literature which suggests that volatility responds differently to positive and negative shocks of the same magnitude as discussed earlier in Section 4.2.1. The intuition behind the specification of the variance equation as in (4.13a) is to allow for negative news (i.e.  $e_{i,t-1} < 0$ ) and positive news (i.e.  $e_{i,t-1} > 0$ ) to affect the conditional variance differently, whereby the lagged idiosyncratic shock  $e_{i,t}$  will have a larger effect on the conditional variance when there is negative news than when there is positive news. Specifically, the asymmetry coefficient given by  $\varphi_{i,3}$  will be positive and statistically significant if the data displays these asymmetric effects. The model represented by Equation 4.13a is in fact the asymmetric extension of the GARCH model proposed by Glosten *et al.* (1993), often referred to simply as the GJR-GARCH model.

In addition to the finding that equity return-series exhibit asymmetric effects, as alluded to above (Section 4.2.1), the choice of an asymmetric version of the GARCH model is motivated by a further factor. Previous studies that have modelled the volatility of the South African equity market have shown that the South African equity market displays the abovementioned leverage

effect, whereby an asymmetric GARCH model is ideal in characterising the market's volatility (c.f. Piesse and Hearn, 2005; Chinzara and Aziakpono, 2009b) who all find highly statistically significant asymmetry coefficients.

Nevertheless, while one expresses Equation 4.13a as an asymmetric GJR-GARCH (1, 1) process, it is plausible that a symmetric GARCH (1, 1) process may provide a better fit for the conditional variance of South Africa, especially in view of the fact that the abovementioned authors adopt a mean and variance specification fundamentally different from that adopted in the study at hand. Whether the South African equity market manifests leverage effects or not even under a different mean and variance specification remains an empirical question. To that end, if the conditional variance of country  $i$  is assumed to be symmetric, it would be adequate to express Equation 4.13a as a simple GARCH (1, 1) process (i.e. without the asymmetry term given by  $\varphi_{i,3}e_{i,t-1}^2\zeta_{i,t-1}$  in 4.13b) as suggested by Engle (1982) and generalised by Bollerslev (1986) whereby:

$$\sigma_{i,t}^2 = E[e_{i,t}^2 | I_{t-1}] = \varphi_{i,0} + \varphi_{i,1}\sigma_{i,t-1}^2 + \varphi_{i,2}e_{i,t-1}^2 \quad (4.13b)$$

with all the coefficients as defined earlier. Similar conditional variance stationarity conditions of the GJR-GARCH model as described above apply to (4.13b) as well. We explore the estimation of both the asymmetric GJR-GARCH (4.13a) and the symmetric GARCH (4.13b) and the superior model will be selected based on the univariate GARCH model specification tests and selection criteria as described in Section 4.3 below.

Importantly, the specification of the return of equity market  $i$  shown in Equation 4.10 to 4.13 implies that mean/return spillovers occur when past information about the regional and the global market exert persistent effects on the returns of country  $i$ , while volatility spillovers are associated with the impact of present information flows from the foreign (regional and global) markets (Ng, 2000: 215-215). Empirically, such mean spillovers would only occur when the mean spillover parameters,  $\gamma_{i,t-1}$  and  $\delta_{i,t-1}$  in Equation 4.10, are statistically significant. Furthermore, as shown in Equation 4.11, volatility spillovers from the regional and global market to market  $i$  are introduced by the foreign idiosyncratic shocks from the regional and global market defined earlier as  $\hat{e}_{reg,t}$  and  $\hat{e}_{g,t}$  respectively, provided that the parameters  $\phi_{i,t-1}$  and  $\psi_{i,t-1}$  are statistically significant. Precisely how this translates into volatility spillovers is elucidated below.

## VOLATILITY SPILLOVERS

It is worthwhile to recall that in Equation 4.11, the unexpected return  $\varepsilon_{i,t}$  of the local country  $i$  was decomposed into three components: (1) a component related to the regional shock, (2) a component related to the global shock, and (3) a purely domestic shock. Specifically, in Equation 4.11 it was shown that:  $\varepsilon_{i,t} = e_{i,t} + \phi_{i,t-1} \hat{e}_{reg,t} + \psi_{i,t-1} \hat{e}_{g,t}$

From the foregoing, it is assumed that the purely idiosyncratic shocks  $e_{i,t}$  are uncorrelated among all the markets as well as with the regional and global markets:

$$E[e_{i,t}, e_{j,t}] = 0, \quad \forall_{i \neq j} \quad (4.14)$$

$$E[e_{i,t}, \hat{e}_{reg,t}] = 0, \quad \forall_i \quad (4.15)$$

$$E[e_{i,t}, \hat{e}_{g,t}] = 0, \quad \forall_i \quad (4.16)$$

Furthermore, recall that the regional and global markets were orthogonalised under the assumption that the regional return shock ( $\hat{e}_{reg,t}$ ) is driven by a purely idiosyncratic shock and by the global return shock ( $\hat{e}_{g,t}$ ), with the global shock being purely idiosyncratic as alluded to earlier. Taking into consideration the orthogonalisation of  $\hat{e}_{reg,t}$  and  $\hat{e}_{g,t}$  under the above-mentioned assumption<sup>27</sup> and also the expression for  $\varepsilon_{i,t}$  in Equation 4.11, Ng (2000: 215) shows that:

$$E[\varepsilon_{i,t}^2 | I_{t-1}] = h_{i,t} = \sigma_{i,t}^2 + \phi_{i,t-1}^2 \sigma_{reg,t}^2 + \psi_{i,t-1}^2 \sigma_{g,t}^2 \quad (4.17)$$

Equation 4.17 shows that that the conditional variance,  $h_{i,t}$  of the unexpected return of country  $i$  depends on the variance of the contemporaneous regional, global and own local shocks. When for instance the global idiosyncratic volatility is large, provided the parameter  $\psi_{i,t-1}$  is statistically significant, the conditional variance of the domestic unexpected return would *ceteris paribus* be expected to increase. In this study, this is what is regarded as volatility spillover effects.

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<sup>27</sup> Under this modification, the African shock represents a regional shock that is unrelated to the global or world factors.

Therefore the statistical significance of the parameters,  $\phi_{i,t-1}$  and  $\psi_{i,t-1}$  would determine the existence of volatility spillover effects originating from the regional and global equity markets respectively.

#### VARIANCE RATIOS

As stated in Chapter One of this study, one of the objectives of this research is to examine the relative importance of global, regional and local factors in the volatility of the South African equity market by assessing the proportion of domestic volatility that is driven by these factors. From the assumptions given in Equations 4.14 to 4.16, as well as from the expression in (4.17), one may follow several other authors (e.g. Ng, 2000; Baele, 2005 and Christiansen, 2007) by computing variance ratios to quantify the proportion of the variance of the unexpected return of country  $i$  that is explained by, respectively, regional and global shocks as:

$$VR_{i,t}^{reg} = \frac{\phi_{i,t-1}^2 \sigma_{reg,t}^2}{h_{i,t}} \in [0,1] \quad (4.18)$$

$$VR_{i,t}^g = \frac{\psi_{i,t-1}^2 \sigma_{g,t}^2}{h_{i,t}} \in [0,1] \quad (4.19)$$

where  $VR_{i,t}^{reg}$  and  $VR_{i,t}^g$  quantify the relative importance of regional and global factors for the conditional volatility of domestic country  $i$ . The variance ratios assume values between zero and one. It therefore follows that the proportion of the total conditional variance of the unexpected return for the domestic country  $i$  that is caused by purely local factors,  $VR_{i,t}^i$  is given by  $VR_{i,t}^i = 1 - VR_{i,t}^{reg} - VR_{i,t}^g$ . These ratios are computed to gain insights into the extent and magnitude of the regional and global integration of South African equity market.

Whether this level of integration has been time-varying, as the preliminary analysis of trade and cross-border flow of capital in Chapter Three seemed to suggest, can only be thoroughly ascertained by analysing the dynamics of the mean and volatility spillover parameters over time. How this issue is implemented within the proposed analytical framework described thus far is briefly outlined below.

## ANALYSIS OF TIME-VARYING INTEGRATION

In order to determine whether there have been any mean and volatility spillover effects and whether the magnitude of these effects has been time-varying within this model, it is necessary to make certain assumptions about the parameterisations of the mean and volatility spillover parameters given by  $\gamma_{i,t-1}$ ,  $\delta_{i,t-1}$ ,  $\phi_{i,t-1}$  and  $\psi_{i,t-1}$  in Equations 4.10 and 4.11. In this study, two different parameterisations for the mean and volatility spillover parameters are explored.

In the first instance, the spillover parameters are assumed to be time invariant so as to assess whether there are any significant mean and volatility spillover effects from the regional and global markets to the domestic equity market. Particularly, in the *Constant Spillover* model, it is assumed that:

$$\begin{aligned}
 \gamma_{i,t-1} &= \gamma_i & \forall_i \\
 \delta_{i,t-1} &= \delta_i & \forall_i \\
 \phi_{i,t-1} &= \phi_i & \forall_i \\
 \psi_{i,t-1} &= \psi_i & \forall_i
 \end{aligned} \tag{4.20}$$

In the second parameterisation, referred to as the *Trend Spillover* model, the assumption of time-invariant (constant) mean and volatility spillover parameters is relaxed. In harmony with Christiansen (2007), the parameters are allowed to gradually assume different values each year that elapses. Specifically, in the *Trend Spillover* model, it is presupposed that:

$$\begin{aligned}
 \gamma_{i,t-1} &= \gamma_{0,i} + \gamma_{1,i}DT_t \\
 \delta_{i,t-1} &= \delta_{0,i} + \delta_{1,i}DT_t \\
 \phi_{i,t-1} &= \phi_{0,i} + \phi_{1,i}DT_t \\
 \psi_{i,t-1} &= \psi_{0,i} + \psi_{1,i}DT_t
 \end{aligned} \tag{4.21}$$

In a sample with observations running from the year 1995, the function  $DT_t$  equals 1 for 1995 observations, 2 for 1996 observations, and so forth. As argued by Christiansen (2007: 929), the use of an annual step function, as opposed to the trend (where  $DT_t$  would equal to 1 for the first

observation, 2 for the second observation, etc.) is to facilitate a much more intuitive interpretation of the results of the Trend Spillover model.

Having established the framework for analysing the dynamics of volatility spillovers, one may seek to understand the economic forces that have driven these second moment equity market linkages. As this issue constitutes part of the objectives of this research, we next discuss briefly how the adopted volatility spillover model may be parameterised to shed some light on this issue.

### *ECONOMIC DETERMINANTS OF VOLATILITY LINKAGES*

An examination of related empirical work that attempts to model the economic determinants of time-varying international stock market correlations tends to broadly reveal two related analytical approaches. On one hand, one strand of literature addresses this issue by modelling a measure of stock market correlations on a set of underlying information variables that may capture the time variation in the correlations (e.g. Pretorius, 2002; Kim *et al.*, 2005). On the other hand, another set of related studies have addressed this issue by allowing the volatility spillover parameters (such as  $\gamma_{i,t-1}$ ,  $\delta_{i,t-1}$ ,  $\phi_{i,t-1}$  and  $\psi_{i,t-1}$  in our proposed model) to be driven by some information variables predicted by economic theory to influence stock market linkages (e.g. Bekaert and Harvey, 1997; Ng, 2000; Fratzscher, 2002; Baele, 2005; Bekaert *et al.*, 2005a). In the study at hand, we adopt an approach related more to the former, with a major difference being in the measure of the stock market correlation/integration variable as elucidated below.

It is worthwhile to recall the variance ratios for the regional and global markets that were derived earlier (Equations 4.18 and 4.19). These ratios quantify the magnitude of the local conditional volatility that can be explained by regional factors and by global factors over time. Changes in these variance ratios over time would reflect the time-varying importance of foreign factors (regional and global) on domestic stock market volatility, and therefore highlight the time-varying international equity market linkages. Within our proposed analytical framework, to investigate the sources of the time-varying degree of international integration at a global and regional level, one may model this time-varying measure of equity market integration as a function of underlying economic and financial variables. Specifically, following the approach adopted by Christiansen (2007), we estimate the following model:

$$VR_{i,t}^j = \beta_{i,0} + \beta_{i,t} Z_{i,t-1} + \mu_{i,t} \quad (4.22)$$

where  $\beta_{i,0}$  and  $\mu_t$  are a constant term and residual term respectively, and  $Z_t$  is a vector of underlying economic and financial information variables known to have explanatory power with respect to stock market correlations over time. As may be recalled, Chapter Two of this study reviewed the theoretical literature on factors that are held as fundamental drivers of the intensification of equity market linkages. To that end, the framework represented by Equation 4.22 seeks to empirically test the extent to which those factors can explain the time-varying degree of equity linkages of the South African equity market with its regional and global counterparts. The exact information variables that constitute the Vector  $Z_t$  remain a controversial subject in the literature.

From the foregoing and in harmony with the objectives as earlier set out, the study attempts to assess the extent to which a set of economic variables can explain the second moment linkages between South Africa and its global counterparts. The variables described here are those that can proxy for the drivers of equity market linkages as described in the theoretical literature review in Chapter Two and they relate to the volatility of the exchange rate, the magnitude of trade linkages, the similarity of business cycles and differences in monetary policies between the domestic and foreign economies.

We turn to this issue and discuss the variables used in Equation 4.22 in greater detail along with our *a priori* expectations below.

#### *Exchange Rate Volatility*

Since equity market linkages do not occur in complete isolation of the exchange rates as earlier discussed in Chapter Two, and in view of the instability of South African Rand exchange rate, it is profitable to assess the impact this has on South Africa's second moment linkages with its global counterparts. As a measure of foreign exchange volatility, we model weekly Rand/Dollar exchange rate log returns as a symmetric/asymmetric univariate GARCH ( $p, q$ ) process and use the conditional variance series as an explanatory variable in the model represented by Equation 4.22. The choice of the appropriate ARCH ( $p, q$ ) order and the appropriate model (symmetric or asymmetric) are based on the univariate model selection criteria described earlier (see Section 4.3).

It has been argued that even in the absence of restrictions on cross-border capital flows (as is the case for South Africa) a highly unstable exchange rate may act as a device against equity market integration. This is so because the more exchange rates are volatile and unpredictable, the more costly hedging against foreign exchange risk becomes (c.f. Fratzscher, 2002: 181). This would hamper foreign participation in domestic markets (and vice versa), thereby limiting the extent of financial linkages. Such a situation would imply a negative relationship between exchange rate volatility and financial integration (given in this study by the proportion of volatility explained by global factors).

Contrastingly, to the extent that increases in exchange rate volatility may be associated with currency crises, and in view of the empirical regularity that suggests markets tend to move together in periods of market turbulence, one would reasonably anticipate a positive relationship between exchange rate volatility and integration.

To that end, it is unclear *a priori* the exact nature of the relationship between exchange rate volatility and the proportion of volatility explained by global factors and therefore remains an empirical issue.

**Table 4.1**  
**Sources of Integration: Variable Description**

Variable	Description	Frequency
$VR_{i,t}^g$	Proportion of RSA volatility driven by global factors (dependant variable)	Weekly
$VolFX_{i,t}^g$	Conditional variance series obtained from the estimation of a GARCH ( $p, q$ ) process on the natural log return on the Rand/US Dollar exchange rate series.	Weekly
$TRADE_{i,g}$	$\frac{x_{ig}}{X_{ig} + Z_{ig}}$ where $x_{ig}$ exports of RSA to the global market, $X_i$ and $Z_i$ are the markets' total exports to and imports from the global market.	Monthly
$INFL_{i,g}$	The absolute difference between the consumer price inflation rate of the global market and that of RSA.	Monthly
$IBR_{i,g}$	The absolute difference between the interbank call money rates of the global market and that of RSA	Weekly

**Source:** All the data are available from DataStream for the full length of the study, with the exception of the TRADE data for RSA which misses a few observations for the period 1995-1997. These missing observations were obtained from the Department of Trade and Industry in South Africa.

### *Bilateral Trade Linkages*

Because international trade in goods entails corresponding international financial transactions, exposes countries to common shocks, and results in a reduction in the home-bias effect, as described earlier in Chapter Two, one would reasonably anticipate a positive link between trade and the second moment equity market linkages of South Africa with its global trading counterparts.

To measure the importance of the trade linkages between South Africa and its global counterpart, authors such as Pretorius (2002) compute the sum of the ratio of South Africa's imports from, plus exports to, the global market and the ratio of the global market's exports to, and imports from South Africa. However, given that South African trade with the US only constitutes a small proportion of total US external trade, a shock to either economy would more likely be felt in South Africa and not the US. Furthermore, an adverse shock to the US economy would more likely be felt by South Africa, through its exports to the US. Therefore, the trade variable we propose is the magnitude of South Africa's exports to the global (US) market as a proportion of total trade with the US (see Table 4.1).

Therefore, to control for this, the trade variable is lagged in the model.

### *Synchronisation of Business Cycles*

A central argument of the theoretical literature as presented in Chapter Two is that in addition to having strong trade linkages, countries that exhibit synchronicity in real business cycles tend to also exhibit synchronicity in asset price fluctuations. Within this context, it is conceivable to anticipate a link between a measure of real (macroeconomic) convergence and the magnitude by which global factors explain the volatility of South African equity market. To examine whether macroeconomic linkages are important in explaining the second moment linkages between the South African and global market, we follow Fratzscher (2002) and Christiansen (2007) by using consumer price inflation. One computes the rate of inflation as a log of changes in the Consumer Price Index (CPI), computed as  $\ln(CPI_{i,t} / CPI_{i,t-1}) \times 100$  where  $i =$  (global market, South African market).

In this study, we use the absolute difference in inflation rates between the regional and South African market. If the two markets exhibit evidence of synchronised business cycles, the inflation differential should not be very wide. A smaller inflation differential should be associated with an

increased influence of the global market on South Africa's volatility. In other words, if the theoretical argument presented thus far holds (relating to synchronisation of business cycles and co-movement of asset prices), one would expect a negative relationship to exist between the inflation differential and the magnitude by which global factors explain local volatility.

#### *Monetary Policy Convergence*

It has been argued in the theoretical literature that in an open economy the interplay of domestic and foreign policies tend to have implications for the stock market. Furthermore, as argued by Pretorius (2002: 92), similarity in monetary policies can induce correlations among financial markets. We examine the validity of this proposition by including two measures of monetary convergence. In this regard, we compute the absolute difference between the South African overnight interbank call money rate and that of the global (US) market. If the two markets exhibit co-movement in the conduct of monetary policy, their interest rates should display this co-movement, and the difference between them should not be very divergent over time. The smaller the interest rate differential between the two markets, the greater the degree to which global (US) factors are able to explain domestic volatility. One would therefore expect a negative relation between the interest rate differential and the proposed measure of integration.

While all the above variables may not fully constitute the full set of factors that determine the extent to which global shocks account for domestic market volatility, they are certainly posited to shed light on the some of the fundamental drivers of South Africa's stock market volatility, a central contribution of this study.

#### **4.2.3 *Analysis of Regional and Global Contagion Effects***

Any study of second moment interdependence of international stock markets would be incomplete without addressing the issue of contagion. As discussed in Chapter Two, there appears to be no agreement as to the exact definition of contagion. However, from the influential work of Forbes and Rigobon (2002), what came out clearly was that contagion is not manifested simply when equity market returns exhibit increased correlation during turbulent periods. To that end we follow Bekaert *et al.* (2005a) who define contagion as excess correlation, that is, correlation over and above that which one would expect from economic fundamentals.

The contagion analytical framework first proposed by Bekaert *et al.* (2005a), extended by Baele (2005) and applied to European bond markets by Christiansen (2007), defines contagion as the excess correlation between the idiosyncratic shocks. In the current study, this methodology is used for the first time to test for contagion in South African equity markets from the 1997 East Asian crisis as well as from the more recent global financial crisis which had its roots in the US subprime mortgage market debacle. The fundamental argument with this contagion methodology is that in turbulent market periods, if there is no contagion, the idiosyncratic shocks should not exhibit correlation. We therefore run the following regression to test for contagion:

$$e_{i,t} = b_1 + (b_2 + b_3 D_t) \hat{e}_{reg,t} + (b_4 + b_5 D_t) \hat{e}_{g,t} + \mu_{i,t} \quad (4.23)$$

where  $e_{i,t}$ ,  $\hat{e}_{reg,t}$  and  $\hat{e}_{g,t}$  are the estimated idiosyncratic shocks from the local, regional and global equity markets respectively (as defined earlier),  $\mu_{i,t}$  is the residual term from the estimation of the model represented in Equation 4.23 and  $D_t$  is a crisis indicator dummy variable which assumes the value of one during the crisis period and zero otherwise. Most importantly, from the regression of the contagion model given by Equation 4.23, if  $b_2 = b_3 = 0$  then there is no contagion from the aggregate regional market to the South African equity market. Similarly, if  $b_4 = b_5 = 0$  then the hypothesis of contagion from the global equity markets is rejected. In the empirical section, we conduct Wald tests for the joint tests of ‘no contagion’ as described above.

From the foregoing, the study at hand contributes to the literature on contagion. In the next section, a brief overview of the model selection criteria and specification tests is given.

### 4.3 MODEL SELECTION CRITERIA AND SPECIFICATION TESTS

When empirically implementing the univariate or multivariate GARCH modelling techniques used in this study, it is desirable check to *ex ante* whether the data manifests evidence of univariate or multivariate ARCH effects to warrant the use of these ARCH modelling techniques. Section 4.2 of this study explored the competing specifications for the conditional variance-covariance matrix (in the bivariate model for the regional and global equity market) as well as for the conditional variance (in the proposed univariate volatility spillover model). Given these different specifications, it also becomes fundamentally important to check *ex post* the

adequacy of the univariate and multivariate specifications in modelling ARCH effects inherent in the financial data employed herein.

To that end, this section briefly discusses the specification tests and criteria used to assess the appropriateness of the bivariate and univariate GARCH models explored in this study. This is fundamentally important not only to enable the selection of the best performing models, but also to ensure robustness of results and thereby facilitate reliable inferences. The specification tests for the bivariate GARCH models are discussed in the first subsection and thereafter those for the univariate GARCH models.

#### **4.3.1 *Diagnostic Tests for the Univariate GARCH Models***

In order to check whether the univariate GARCH models employed in this study are correctly specified, as well as to assess the best performing model, an analysis of the properties of the residuals implied by the models is explored in this study. To that end we analyse the standardised residuals of the regional, global and country  $i$  equity market.

As suggested by Baele (2005: 382) and Christiansen (2007: 944) in a well specified model, the standardised residuals ( $\hat{z}_{i,t}$ ) of the models should not violate certain moment conditions. They should: (i) have zero mean ( $E[\hat{z}_{i,t}] = 0$ ), (ii) have unit variance ( $E[\hat{z}_{i,t}^2 - 1] = 0$ ), (iii) be serially uncorrelated at order  $j$ , ( $E[\hat{z}_{i,t}, \hat{z}_{i,t-j}] = 0$ ). Furthermore (iv) no ARCH effects should remain in the residuals after estimation of the models, and (v) the squared standardised residuals should be serially uncorrelated at order  $j$ , ( $E[\hat{z}_{i,t}^2, \hat{z}_{i,t-j}^2] = 0$ ).

In this study, following several other studies, we propose the Engle (1982) ARCH Lagrange Multiplier (LM) test to test for the presence of ARCH effects. To test for autocorrelation, we propose the Ljung and Box (1978)  $Q$ -test. The properties of these diagnostic tests are briefly discussed below.

#### *ENGLE'S ARCH LM TEST*

The ARCH LM test for autoregressive conditional heteroskedasticity in the residuals proposed by Engle (1982) was motivated by the observation that in many financial time-series, the magnitude of the residuals appeared to be related to the magnitude of recent residuals (Eviews 6, 90

2007: 158). As suggested in Engle (1982: 1000), the ARCH LM test is fundamentally an auxiliary test regression of the squared residuals on their  $q$  squared lags (and a constant)<sup>28</sup> to test the joint null hypothesis that all the  $q$  lags have coefficient values that are not significantly different from zero (i.e. no ARCH effect). Engle's LM statistic, defined as  $TR^2$  (i.e. the total number of observations,  $T$  multiplied by the  $R^2$  from the auxiliary test regression), assumes a  $\chi^2(q)$  distribution.

Empirically, the ARCH LM test would therefore involve the rejection of the null hypothesis of 'no ARCH effects' when the test statistic  $TR^2$  exceeds the critical value from the chi-squared distribution at the conventional statistical significance level.

### UNIVARIATE LJUNG-BOX $Q$ -TEST

The Ljung-Box  $Q$ -test proposed by Ljung and Box (1978) is a test of linear dependence (autocorrelation) in the standardised residuals. The  $Q$ -statistic at lag  $q$  is a test statistic for the null hypothesis that there is no autocorrelation up to order  $q$  and, as Brooks (2008: 210) demonstrates, is calculated as:

$$Q_{Ljung-Box} = T(T+2) \sum_{k=1}^q \frac{\hat{\tau}_k^2}{T-k} \sim \chi_q^2 \quad (4.24)$$

where  $T$  is the sample size,  $q$  is the maximum lag length and,  $\hat{\tau}_k$  is the  $k^{th}$  sample residual autocorrelation (or normalised sample residual autocovariances). As shown in Equation 4.24, the Ljung-Box  $Q$ -test statistic is asymptotically distributed as a  $\chi^2(q)$  distribution under the null hypothesis of no autocorrelation (i.e. all the  $q$  autocorrelation coefficients are statistically significantly not different from zero).

While there are other approaches to testing for autocorrelation, such as for instance the Box and Pierce (1970) approach, our choice of the Ljung-Box  $Q$ -test is motivated by two factors. Firstly, as Brooks (2008: 210) observes, compared to the Ljung-Box  $Q$ -test, the Box-Pierce approach tends to have poor small sample properties such that it leads to the wrong decision too

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<sup>28</sup> The auxiliary test regression run is specified as:

$$e_t^2 = \beta_0 + \left[ \sum_{s=1}^q \beta_s e_{t-s}^2 \right] + v_t$$

where  $v_t$  is the residual term from the auxiliary regression.

frequently. Secondly, the Ljung-Box test enjoys applicability in related financial literature (e.g. Baele, 2005; Christiansen, 2007). Therefore, for the above two reasons, our choice of the Ljung-Box  $Q$ -test is justified.

### **4.3.2 Diagnostic Tests for Bivariate GARCH Models**

As acknowledged by many authors (c.f. Ding and Engle, 2001; Bauwens *et al.*, 2006), in contrast to the huge body of diagnostic tests devoted to univariate GARCH models, there are relatively few tests available for multivariate GARCH models. For the purposes of this study, we propose three criteria to evaluate the bivariate specifications of the conditional variance-covariance matrix of the regional and global equity market to ensure the best performing model is selected and is correctly specified: (1) preliminarily, models are ranked based on statistical information criteria, (2) checking for ARCH effects, and (3) checking the distributional properties of the estimated residuals.

#### *INFORMATION CRITERIA*

As a preliminary guide to ranking the performance of the various bivariate models, the information criteria are used, specifically the Akaike Information Criteria (AIC) and Schwarz Information Criteria (SIC). These model selection guides are not exclusive to the study at hand: similar approaches have been adopted in other studies (c.f. Bera *et al.*, 1997; Cifarelli and Paladino, 2005; Boudreault and Panneton, 2007). On that basis, their application to the current study is justifiable. In this regard, the most parsimonious model is that which produces the minimum information criteria, as measured by AIC and SIC. To compute the three information criteria, we adopt the approach used in Eviews (c.f. Eviews 6, 2007).

While the information criteria provide a reasonable preliminary step in evaluating the performance of the bivariate models, they do not give any indication with regard to the models' ability to adequately account for the ARCH effects. Furthermore, as argued by Fernández-Izquierdo and Lafuente (2004: 134), although the information criteria have been widely used in the ARCH literature, their statistical properties in this context are unknown. For the bivariate GARCH models, what is fundamentally important is the extent to which the different bivariate specifications model the bivariate ARCH effects in the regional and global equity markets. For that reason, the subsequent test focuses on this issue.

## BIVARIATE LJUNG-BOX $Q$ -TEST

Several authors have recognised that portmanteau tests of the Ljung-Box type are perhaps the most widely used diagnostics to test for ARCH effects (c.f. Tse, 2002; Bauwens *et al.*, 2006). The most appropriate test to use in this setting is the multivariate Ljung-Box portmanteau test proposed by Hosking (1980). In spite of having limited theoretical justifications, multivariate Ljung-Box portmanteau tests enjoy widespread applicability in the empirical ARCH literature.<sup>29</sup> Owing to software constraints, this test cannot be implemented in this study.<sup>30</sup>

To circumvent this constraint, we adopt the approach used in Bera *et al.* (1997) and Brooks, *et al.* (2002) to check for misspecification. We generate the standardised residuals corresponding to the global and regional market ( $\hat{z}_g$  and  $\hat{z}_{reg}$ ) from each estimated bivariate model. Serial correlation is checked by simply conducting a univariate Ljung-Box  $Q$ -test (of the form proposed in Section 4.3.1 (B) above) on each standardised residual series. Furthermore, to check for “remaining ARCH effects” we conduct the same test, but on each squared standardised residual ( $\hat{z}_g^2$  and  $\hat{z}_{reg}^2$ ). If the models are well specified, no serial correlation (linear dependence) and ARCH effects (non-linear dependence) should remain in the standardised residuals.

## NORMALITY TESTS

As recommended by Lütkepohl (2005: 578), normality tests can be performed in order to check the validity of the fitted multivariate GARCH model because, as statistical theory suggests, the standardised residuals of a well fitted model should be independently and identically distributed (*i.i.d.*) normally distributed random variables for Gaussian innovations (Boudreault and Panneton, 2007: 46). In this regard, it is thus desirable to check the distributional properties of the standardised residuals of the bivariate specifications of the variance-covariance matrices described earlier for the regional and global market. Specifically, in a well-specified model, as shown in Baele (2005), the following moment conditions should hold: (1)  $E[\hat{z}_{i,t}^3] = 0$  and (2)  $E[\hat{z}_{i,t}^4 - 3] = 0$ .

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<sup>29</sup> For further details on the multivariate Ljung-Box portmanteau test statistic as well as its modified equivalent (with a correction for small sample biases), refer to Lütkepohl (2001, 2005) and EvIEWS 6 (2007).

<sup>30</sup> To the best of our knowledge, EvIEWS 6 does not allow the implementation of this test in MGARCH estimation.

To that end, we adopt the multivariate Jarque-Bera residual normality test which compares the third and fourth moments of the estimated standardised residuals of the bivariate models described earlier to those from the normal distribution. Under the null hypothesis of a normal distribution, the test statistic assumes a  $\chi^2$  distribution.

Having described the diagnostic tests and model selection criteria for multivariate and univariate GARCH models, our focus now turns to the actual estimation procedure that will be adopted in the empirical section of the study to realise the objectives outlined in Chapter One.

#### 4.4 MODEL ESTIMATION: PROCEDURE AND ISSUES

For purposes of this study, the estimation method adopted is the two-step procedure proposed initially by Bekaert and Harvey (1997) and subsequently by Ng (2000) and Baele (2005).

In the first step, a bivariate GARCH model is estimated to jointly model the returns of the regional and global equity market. The four alternative specifications (DVECH, Asymmetric-DVECH, diagonal BEKK, and asymmetric diagonal BEKK models) for the variance-covariance matrix described earlier are estimated. The best performing model is chosen based on the criteria described in Section 4.3.2. In recognition of the fact that common factors could be at play, potentially driving the regional and global returns and thereby leading to a problem of finding spurious mean and volatility spillovers between the two markets, we avoid this problem by orthogonalising the residuals from the regional and global markets under the assumption outlined in Section 4.2.2 to obtain regional idiosyncratic shocks ( $\hat{e}_{reg,t}$ ) that are unrelated to the global idiosyncratic shocks ( $\hat{e}_{g,t}$ ).

In the second step, a univariate extended AR-GARCH framework is estimated for the equity market of interest (1) conditional on the estimates of the regional and global market returns in step one and (2) under the assumption that the purely idiosyncratic shocks from the regional and global equity market are normally distributed with mean zero and a time-varying variance. Specifically, the lagged regional and global returns (in addition to own country  $i$  lagged returns) are introduced in the mean equation and the orthogonalised contemporaneous idiosyncratic shocks from the regional and global markets are introduced in the unexpected return of country  $i$

(refer to Equations 4.10 to 4.13). This approach is posited to yield consistent estimates and misspecification is checked using the univariate diagnostic tests described in Section 4.3.1 above.

The empirical estimation of the four bivariate GARCH systems and the two univariate GARCH processes is done by maximising a corresponding conditional log-likelihood function of the form represented in Ng (2000: 213) for the bivariate GARCH models in the first step, and of the form in Brooks (2008: 395) for the univariate GARCH models in the second step. Most importantly, it is worthwhile noting that in both steps, maximum likelihood estimation techniques are employed under the assumption of bivariate normality (in the first step) and univariate normality (in the second step). In consideration of the type of the financial data used in the study at hand, one may reasonably argue that such an assumption may not be valid. In fact, as observed by Bauwens *et al.* (2006: 96-97), it is very well established in many studies that high frequency financial data tends to deviate from normality mainly due to excess kurtosis (kurtosis in excess of three), which leaves too many outliers for the Gaussian assumption to hold. Therefore care should be exercised in the choice of the estimation method.

Bollerslev and Wooldridge (1992) provide a Quasi-Maximum Likelihood (QML) approach which is consistent even if the data generating process is not conditionally Gaussian. Therefore, following many other authors<sup>31</sup>, we provide QML estimates as proposed by Bollerslev and Wooldridge (1992) that are robust to misspecification of the distribution of the error terms. Furthermore, in light of the arguments put forward by Engle and Kroner (1995: 139-140) and following several other authors<sup>32</sup>, when conducting the estimation of parameters for the bivariate GARCH and univariate GARCH models, we utilise an iterative, numerical and non-linear (BHHH) optimisation algorithm due to Berndt *et al.* (1974).

The next section describes the data that will be used to implement the analytical framework described thus far, highlighting the main issues relating to our choice of the data and the explanation of the proxies used.

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<sup>31</sup> See for instance Baele (2005) and Caporale *et al.* (2005).

<sup>32</sup> See for instance Fratzscher (2002), Christiansen (2007) and Gannon and Au-Yeung (2004), among many others.

#### 4.5 DATA: DESCRIPTION, PROXIES AND ISSUES

The data applied in this study are the weekly price indices obtained from Thompson DataStream for eleven markets, namely, South Africa (RSA), Namibia (NAM), Botswana (BOT), Mauritius (MAU), Egypt (EGY), Nigeria (NIG), United States of America (USA), United Kingdom (UK), Japan (JAP), Germany (GER) and China (CHI) from June 1995 to May 2010. Our choice of the countries to be included in the current study is not arbitrary, but motivated by the considerations already given in Chapter One. DataStream indices are preferred for two main reasons: firstly because they are much more homogeneous, which enables comparison across different markets, and secondly because they tend to be more representative of the market since they capture at least 80 percent of a country's market capitalisation. Unfortunately, these indices were only available for the non-African countries in the sample. Therefore, for the African countries the stock price indices used are the broad market indices compiled by FTSE/JSE for RSA, Standard and Poor's for BOTS, NAM and NIG, Mauritius Stock Exchange for MAU and FTSE for EGY. In line with convention in the vast financial literature, the returns used in this study are continuously compounded log returns computed as  $R_{i,t} = \ln(P_{i,t} / P_{i,t-1}) \times 100$  where  $P_{i,t}$  is the price index of a particular market at time  $t$ .

**Figure 4.1**

**Regional and Global Market Trading Times in South African Time**

JAP Opens	02 00
	03 30
CHI Opens	04 00
JAP Closes	08 00
MAU and GER Opens	08 30
	09 00
RSA and BOT Open	09 30
EGY and NAM Opens	10 00
CHI Closes	11 30
UK Opens	12 00
MAU Closes	14 30
NIG Opens	15 30
NIG Closes	16 00
EGY Closes	16 30
BOT Closes	17 00
USA Opens	18 30
RSA Closes	19 00
UK Closes	22 30
GER Closes	23 00
USA Closes	

**Source:** Author's compilation based on actual trading times as obtained from respective markets' stock exchanges and [www.marketclocks.com](http://www.marketclocks.com).

One important point that warrants attention relates to the frequency of the data used in the study. Weekly data is preferred to daily data for several reasons. First and foremost, any study of information transmission among financial markets can only be valid if it takes into account the

non-synchronous trading among those markets. The different trading times (South African time) for the markets considered in this study are illustrated in Figure 4.1.

Immediately apparent is the fact that there exist perfectly and partially non-overlapping trading periods amongst all the markets, especially with the non-African markets. African markets such as NIG, MAU and EGY tend to close much earlier than RSA, with the effect that any important developments (regionally or globally) that occur after these markets close are likely to be incorporated into the RSA returns on that day, while only being incorporated on the subsequent day in the other three markets. This failure to share the same information at the same time has critical implications for the study at hand. Within the adopted analytical framework, the effect of using daily (non-synchronous close-to-close) data is that it would potentially distort our inferences by inducing spurious dependencies amongst the different equity market returns and volatility shocks that cannot be distinguished from information/volatility spillovers.

Therefore to partially offset this problem, we follow other related studies (e.g. Ng, 2000; Baele, 2005; Christiansen, 2007) by using weekly return series.<sup>33</sup> The advantage of weekly data is that distortions related to homogeneous non-trading (e.g. due to country-specific holidays) and the day-of-the-week calendar anomaly are avoided. Therefore, in view of the above issues and the objectives of the current study, our choice of weekly data is justifiable.

As may be recalled, the main goal of this research is to assess and quantify the extent to which RSA volatility is driven by idiosyncratic shocks originating locally, regionally and globally. As a proxy for the regional market, in the absence of a comprehensive regional African index, we adopt an approach followed by Fratzscher (2002) and Bekaert *et al.* (2005a) by constructing a regional market as a market capitalisation weighted average of the region's constituent countries (i.e. the African countries in the current sample). With regard to the proxy for the global market, we use three measures: (1) The USA market, (2) the Chinese market, and (3) a weighted average of three other mature world markets (JAP, GER and UK). The use of the US market as a global

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<sup>33</sup> It is imperative to acknowledge that this is not the only way to deal with the problem of non-synchronous trading. As observed by Ng (2000), previous studies (e.g. Eun and Shim, 1989; Karolyi and Stulz, 1996) suggest that high frequency daily data (intraday open-to-close and close-to-open data) may be more desirable for studying international correlations and spillovers. However, intraday daily data are not available for most of the African countries considered in the study at hand. Moreover, we doubt that such high frequency data would be practical in view of the relative illiquidity of most African markets such as NAM, BOT and MAU over the full length of the study, especially in the period prior to 2000. Other approaches involve the use of two-day rolling average returns based on each market's aggregate stock market index (c.f. Forbes and Rigobon, 2002).

market is not unique to the current study (see for instance Ng, 2000; Christiansen, 2007) and the basic argument given for the use of this market is that it is the largest market in the world. Furthermore, as was concluded in the empirical section of Chapter Two, the US market is dominant in the global transmission of volatility. The inclusion of JAP, GER and UK is motivated by the relative dominance of these three markets in the global transmission of volatility as the empirical literature review seemed to suggest. We also include CHI not only for its dominance as the fastest growing economy, but also in view of the size and importance of its bilateral trade links with RSA. We are of the view that the growth in trade with the Asian market may not adequately be captured if the Chinese market was omitted from the sample. To that end, the regional and global markets are constructed as follows:

$$R_{reg/g,t} = \frac{\sum_{k \neq i} w_k R_{k,t}}{\sum_{k \neq i} w_{k,t}} \quad (4.26)$$

with  $k$  indexing the African markets (excluding the RSA market) or the 3 non-African developed markets (UK, JAP and GER but not USA or CHI) and  $w_k$ , denoting the market capitalisation of market  $k$ . The exclusion of the RSA market from the regional markets is purely to prevent spurious correlations of the RSA market with the regional market that may not be as a result of information spillovers.

## 4.6 CONCLUSION

This chapter presents a thorough description of the analytical framework that is used to assess and quantify the extent to which the stock market volatility of South Africa is affected by idiosyncratic shocks originating locally, regionally and globally so as to make inferences about the magnitude of the interdependence of the South African equity market with its regional and global counterparts. In Section 4.2 the proposed volatility spillover model was described. Firstly, we described several bivariate GARCH models that are used to model the returns for the regional and global market and to derive regional and global shocks. In the second instance, the univariate extended AR-GARCH models that introduce regional and global shocks into domestic volatility were described. In Section 4.3 the criteria used to select the best performing univariate and multivariate GARCH models were outlined. Specification tests used to check the models' adequacy were also given. The actual estimation procedure followed as well as estimation issues were discussed in Section 4.4. Finally, Section 4.5 discussed the data with

regard to its sources, scope and the description of the proxies used. Critical issues relating to the choice of the data frequency as well as the derivation of the variables used were also covered.

Having set out the analytical framework, the next chapter proceeds to apply this framework to the data so as to realise the objectives of this study as set out in Chapter One.

## **CHAPTER FIVE**

### **EMPIRICAL RESULTS**

#### **5.1 INTRODUCTION**

This study set out not only to examine the presence of volatility spillover effects in the South African equity market, but also to assess and quantify the extent to which volatility is driven by shocks originating regionally and globally. By examining the nature, determinants and relative importance of these sources of South African stock market volatility, this study sheds light on the state and magnitude of South Africa's interdependence with its global and regional equity market counterparts.

Findings from the review of the empirical literature in Chapter Two, as well as the broad preliminary analysis in Chapter Three, suggested, albeit inconclusively, that it is conceivable that linkages among equity markets have intensified both at the regional and global level. The general consensus is that African markets are largely segmented, not only from the rest of the world, but from each other. Exceptions to this are countries with strong financial, trade and economic links such as Namibia and South Africa, which have shown that they remain linked globally and with each other. However, several gaps still remain in the literature, especially with regard to examining second moment linkages among African markets.

To that end, this chapter implements the analytical framework described in Chapter Four to formally achieve the objectives set out earlier. The rest of the chapter is organised as follows: Section 5.2 presents a preliminary analysis of the data and discusses its characteristics. Section 5.3 discusses the results of the volatility spillover framework. Section 5.4 analyses the variance ratios. Section 5.5 examines the determinants of volatility linkages in South Africa. The results of the tests of contagion from the 1997 Asian currency crisis and the 2007/8 global financial crisis are presented in Section 5.6 and Section 5.7 briefly concludes.

#### **5.2 PRELIMINARY DATA ANALYSIS**

Table 5.1 gives a summary of descriptive statistics for the unconditional weekly returns (in %) of the equity markets of South Africa, Egypt, Nigeria, Botswana, Mauritius and Namibia. Descriptive statistics for the aggregate regional market proxy (REG) as well as the three global

market proxies, the US and MATURE and China are also reported.<sup>34</sup> Specifically, the reported statistics include the mean logarithmic returns with their corresponding maximum, minimum and standard deviation. The distributional properties are also examined through their skewness and kurtosis. The Jarque-Bera test statistic for normality in the distribution of returns and the Ljung-Box  $Q$ -test for autocorrelation in the returns ( $Q$ ) and squared returns ( $Q^2$ ) are also reported.

**Table 5.1**  
**Summary Descriptive Statistics**

	MAT	USA	CHI	REG	RSA	EGY	NIG	BOTS	MAU	NAM
Mean	0.104	0.189	0.185	0.340	0.205	0.364	0.304	0.400	0.226	0.145
Max.	13.511	12.211	17.144	14.176	16.040	16.331	14.367	36.132	11.379	14.447
Min	-12.16	-14.25	-24.23	-18.46	-18.60	-17.89	-27.95	-12.49	-17.25	-17.86
Std. Dev.	2.645	2.955	4.048	3.578	3.034	4.399	4.134	2.874	2.941	3.268
Skewness	0.226	0.039	-0.489	-0.094	-0.365	-0.102	-0.608	3.640	-0.334	0.048
Kurtosis	5.383	4.914	6.705	4.818	7.037	4.568	7.141	40.402	6.360	8.142
J-B	184.3*	115.0*	460.2*	104.7*	527.4*	78.3*	583.6*	45493.7*	367.6*	592.9*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	7.190	18.27	18.84§	18.75§	18.16	19.21§	23.28#	59.97*	13.68	28.24#
	[0.845]	[0.108]	[0.092]	[0.095]	[0.111]	[0.084]	[0.025]	[0.000]	[0.322]	[0.005]
$Q^2(12)$	56.530	84.62*	174.93	81.04*	184.18*	144.31*	143.45*	17.64	140.75*	28.72#
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.127]	[0.000]	[0.004]
Obs.	752	752	752	752	752	752	752	752	752	538

The table reports descriptive statistics for the weekly returns of several equity markets in (%): South Africa (RSA), Egypt (EGY), NIG (NIG), Botswana (BOTS), Mauritius (MAU) and Namibia (NAM). The United States (US) and China (CHI) are used as global market proxies along with MAT. MAT and REG are the aggregate global and regional market proxies respectively. All the observations start from 29/12/1995 with the exception of Namibia (NAM) which only starts from 04/02/2000. The  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box test statistics of no autocorrelation up to the 12<sup>th</sup> lag in the returns and squared returns respectively. J-B is the Jarque-Bera test statistic of normality with corresponding p-values in parentheses [·], while (\*), (#) and (§) indicate statistical significance at 1%, 5% and 10% respectively.

The unconditional mean weekly returns for all the markets are positive and for the African markets range from around 0.40 percent in Botswana to about 0.15 percent in Namibia. South Africa records mean weekly returns of about 0.21 percent compared to 0.36 percent, 0.30 percent and 0.23 percent in Egypt, Nigeria and Mauritius respectively.

<sup>34</sup> The aggregate African regional market (REG) and Mature (MAT) are both aggregate market capitalisation weighted averages computed as described in Chapter Four. The reported aggregate African regional market excludes South Africa.

With the exception of Namibia, all these weekly returns are still considerably higher than those recorded in the global markets as captured by the US (0.19 percent), aggregate Mature (0.10 percent) and China (0.19 percent). The high returns tend to be accompanied by high risk as four out of the six African markets have standard deviations higher than those recorded in the global markets<sup>35</sup>. China, an emerging market, stands out from the US and the aggregate mature market by recording the highest variability in unconditional returns of all the global market proxies used in this study. It is evident from these statistics that African markets and China generally offer higher returns than developed markets, however these high returns are characterised by higher volatility, a feature typical of emerging markets and consistent with the literature (e.g. Bekaert and Harvey, 1995 and 1997; Ng, 2000).

Negative shocks tend to be more frequent than positive shocks as indicated by the negative skewedness observed in four out of the six African markets including South Africa. The converse seems true for the developed global markets, which in the case of the US market tends to zero. Furthermore, the measure of kurtosis also shows all the weekly return series exhibit excess kurtosis (kurtosis in excess of three). This statistic is especially high in China and the African markets. This implies that large shocks to the returns of Chinese and African markets tend to be more common than one would expect statistically from a normal distribution. It is therefore not surprising that the Jarque-Bera test statistic rejects the null hypothesis of normality at all conventional significance levels. As a whole, the data manifest the typical attributes of financial data, namely leptokurtosis and non-normality. As a result, the empirical framework has to take this into consideration.

Lastly, the Ljung-Box  $Q$ -test statistic rejects the null of 'no 12<sup>th</sup> order autocorrelation' in the weekly returns of all markets except South Africa, Mauritius and the developed global markets, clearly suggesting high persistence of linear dependence in the returns of some African markets. However, with the exception of only Botswana with a p-value of only 12.7 percent, the squared weekly returns of all the markets exhibit highly significant evidence on non-linear dependence. Linear dependence in returns has been attributed to several factors such as non-synchronous trading (c.f. French *et al.*, 1987), market imperfections such as infrequent trading of the component securities in the respective markets, or due to some fundamental forces, such as

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<sup>35</sup> Botswana appears to be a special case, with high returns but lower risk than the other African markets, including the aggregate regional market. However, Botswana tends to be subject to frequent extreme positive shocks to returns as seen by the high positive skewedness and high kurtosis figures.

predictable changes in responsiveness to world risk factors (c.f. Lo and Mackinley, 1988; Harvey, 1995; Koutmos and Booth, 1995; Bekaert and Harvey, 1997).

However, in view of the fact that weekly data is used, such persistent autocorrelation as found in these data is less likely to be due to non-synchronous trading but may more likely be a consequence of some informational market inefficiencies associated with infrequent trading in the constituent securities. This is conceivable given the fact that only the least liquid markets in the sample register persistent linear dependence in weekly returns.<sup>36</sup> The strong evidence of persistent non-linear dependence observed not only in the African markets, but also in the global markets, may indicate the presence of autoregressive conditional heteroskedasticity.

While the descriptive statistics give the characteristics of each market in isolation, it is worthwhile taking a general view of the degree to which markets respond to similar news. Table 5.2 reports pair-wise correlation coefficients to give a rough measure of interdependence between the markets.

A remarkable feature of the South African market is that it is more correlated with the developed markets (US and aggregate mature markets) than with China, the aggregate region and the other African markets where correlations are low (in the case of China), close to zero (in the case of Mauritius), and negative (in the case of Nigeria, Botswana and Namibia). The relationship with Namibia is in fact quite peculiar given the monetary and financial links that bind the two countries. By virtue of its membership of the Common Monetary Area, Namibia does not pursue an independent monetary policy to that of South Africa, with its local currency, the Namibian Dollar, pegged at par with the South African Rand (c.f. BON, 2008)<sup>37</sup>. For that reason, one would expect a high and positive correlation between the two markets.

Furthermore, the three countries, Botswana, Namibia and South Africa belong to the same customs union, SACU. Given these financial and economic links, one would expect a higher degree of interdependence in weekly returns than the correlations show, and this therefore warrants further investigation. In fact South Africa appears to be more correlated with the two

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<sup>36</sup> Refer to Chapter Three for information on stock market characteristics.

<sup>37</sup> Namibia's discretionary powers over its monetary policy are confined to the use of capital controls, and prudential requirements imposed on banking and other financial institutions, for instance, the maintenance of a Repo rate that is different from that of the South African Reserve Bank when the need arises, and the control of the domestic level of money supply, so as to control domestically induced inflation (BON, 2008: 4).

other largest African markets, which are outside the main southern African regional economic blocs.

**Table 5.2**  
**Ordinary Pair-wise Contemporaneous Correlations**

	MAT	USA	CHI	REG	RSA	EGY	NIG	BOTS	MAU	NAM
MAT	1.000									
USA	0.733	1.000								
CHI	0.191	0.086	1.000							
REG	0.429	0.351	0.211	1.000						
RSA	0.560	0.457	0.067	0.087	1.000					
EGY	0.413	0.317	0.187	0.949	0.144	1.000				
NIG	0.248	0.262	0.166	0.527	-0.076	0.254	1.000			
BOTS	0.163	0.187	0.075	0.211	-0.059	0.120	0.260	1.000		
MAU	0.481	0.470	0.186	0.521	0.009	0.451	0.389	0.281	1.000	
NAM	0.222	0.228	0.021	0.204	-0.028	0.160	0.201	0.149	0.303	1.000

The table shows the contemporaneous ordinary pair-wise correlation coefficients of weekly returns of several equity markets over the common sample period starting from 04/02/2000. REG is the aggregate regional market comprising all the African markets. As such, with the exception of REG correlation with South Africa, correlations with the other African markets may be spurious and a mere reflection of the dominance of the respective country in the index.

Mauritius has the highest correlation with the African markets, with coefficients of 45.1 percent, 38.9 percent, 30.3 percent and 28.1 percent with Egypt, Nigeria, Namibia and Botswana respectively. The correlations of individual African markets with the world markets appear to be quite low (below 50 percent), with the highest recorded between Mauritius and aggregate Mature and the US at 51.5 percent and 47 percent respectively, followed by South Africa (at 42.2 percent and 45.7 percent), Egypt (42.5 percent and 31.7 percent), Nigeria (31.3 percent and 26.2 percent), Namibia (23.7 percent and 22.8 percent) and lastly Botswana (21.7 percent and 18.7 percent). The correlation of China with either the developed or African markets are generally low. The low correlations between China and the developed markets are consistent with the empirical regularity that emerging markets exhibit low correlations with developed markets (see Bekaert and Harvey, 1995; 1997; Ng, 2000).

In summary therefore, some issues can be highlighted with respect to the analytical framework adopted in this study from the descriptive statistics and the correlation analysis. Firstly, the high persistence of linear dependencies in the series justifies our use of autoregressive models, while

the leptokurtic nature of the return series coupled with the strong presence of non-linear dependencies in the weekly returns of all the markets validates the author's choice of autoregressive conditional heteroskedasticity (ARCH) models to analyse the linkages among these markets. ARCH models have generally been found to be effective at capturing these aspects of financial data. Secondly, as the data manifests strong evidence against normality, care should be exercised in the assumptions made about the distributional properties of the residual terms from the models to avoid misspecification of the models. Lastly, while the analysis of correlations between South African and other markets generally paints a picture of weak correlations, interdependencies among the markets could exist. Indeed there is some evidence of common factors driving the markets in the same direction (especially with the world markets).

This therefore warrants further investigation into the nature of this interdependence, a matter pursued in subsequent sections.

### **5.3 RESULTS FROM THE VOLATILITY SPILLOVER MODEL**

The two-step estimation procedure similar to the one proposed initially by Bekaert and Harvey (1997) and subsequently employed by Ng (2000) and Baele (2005) is implemented in the current study to analyse the second moment interdependence of the South African stock market with its regional and world counterparts.

In the first step (Section 5.3.1), a bivariate GARCH model is estimated to jointly model the returns of the regional and global equity market. The regional and global markets are orthogonalised, assuming that the regional shock is driven in part by the global shock and a purely idiosyncratic regional shock, while the global shock is purely idiosyncratic. In the second step (Section 5.3.2), the orthogonalised idiosyncratic shocks from the regional and global markets are used as inputs into the univariate (extended AR-GARCH) volatility spillover model for the South African market and the other African markets.

#### **5.3.1 *Bivariate model for the global and the regional market***

The main objective of this research is to examine the relative importance of global and regional shocks to the South African market. Therefore, it is of paramount importance to ensure that the joint process governing the regional and global market returns is correctly specified. To that end,

four different specifications of the variance-covariance dynamics from the two aggregate markets are explored, namely diagonal VEC (DVEC), diagonal BEKK (DBEKK), diagonal VEC with asymmetry (AS-DVEC) and diagonal BEKK with asymmetry (AS-DBEKK). The best performing model is selected based on criteria described in Chapter Four.

### 5.3.1.1 ROBUSTNESS TESTS FOR THE BIVARIATE MEAN EQUATION

As highlighted in Chapter Four, the joint process governing the returns of the African (regional) and mature (global) equity returns, known as the bivariate conditional mean equation, may be expressed as follows:

$$\begin{bmatrix} R_{reg,t} \\ R_{g,t} \end{bmatrix} = \begin{bmatrix} \alpha_{reg,0} \\ \alpha_{g,0} \end{bmatrix} + \begin{bmatrix} \alpha_{reg,1} & \alpha_{reg,2} \\ \alpha_{g,1} & \alpha_{g,2} \end{bmatrix} \begin{bmatrix} R_{reg,t-1} \\ R_{g,t-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{reg,t} \\ \varepsilon_{g,t} \end{bmatrix},$$

$$\varepsilon_t | I_{t-1} \sim N(0, H_t) \quad (5.1)$$

The vector of residual terms  $\varepsilon_t = [\varepsilon_{reg,t}, \varepsilon_{g,t}]'$  is a white noise process which, under the assumption of bivariate conditional normality, has zero mean and a time-varying conditional variance and covariance,  $H_t$ .

We empirically estimate the model in Equation 5.1 as shown and check whether it is correctly specified. Specifically we perform a number of diagnostic checks, such as conditional bivariate normality, autocorrelation and conditional heteroskedasticity tests using the standardised residuals obtained from the estimated bivariate conditional mean equations in much the same manner as other authors do (e.g. Bera *et al.*, 1997; Brooks *et al.*, 2002).

Tables 5.3 to 5.5 report the standardised residual diagnostics from the estimation of the bivariate conditional mean equation with regard to the US, aggregate mature and China as the 'global market' proxies respectively for the equity markets of South Africa, Egypt, Nigeria, Botswana, Mauritius and Namibia.

In Table 5.3, the mean of zero and variance of one are as one would expect from the standardised residuals of a well-specified model across all the markets. The skewness statistics produce skewness values that are smaller and cannot statistically be distinguished from zero at

any conventional significance level (i.e. 1 percent, 5 percent or 10 percent) for the standardised residuals pertaining to the global standard shock,  $\hat{z}_g$ . However, the skewness statistics pertaining to the regional markets ( $\hat{z}_{reg}$ ) tend to be larger, negative and statistically significance at the 5 percent significance level for South Africa, and at 1 percent for the rest of the African equity markets. The model fails to adequately capture the leptokurtosis inherent in the returns, as all the markets exhibit significant excess kurtosis, and the null hypothesis of bivariate conditional normality is strongly rejected at the 1 percent significance level.

**Table 5.3**  
**Bivariate Conditional Mean Diagnostics: US Global Market Proxy**

	S. Africa		Egypt		Nigeria		Botswana		Mauritius		Namibia	
	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000
Var.	1.001	1.001	1.001	1.001	1.001	1.001	1.001	0.993	1.001	1.001	1.002	1.002
Skew.	0.043	-0.200	0.072	-0.647	0.054	-0.552	0.058	-0.673	0.058	-0.683	0.133	-0.742
	[0.630]	[0.025]	[0.421]	[0.000]	[0.547]	[0.000]	[0.519]	[0.000]	[0.517]	[0.000]	[0.210]	[0.000]
Kurt.	4.861	4.807	4.888	6.814	4.901	6.674	4.898	6.425	4.898	6.473	4.830	5.190
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	18.159	11.179	14.719	18.228	18.220	16.514	18.215	17.978	18.216	17.740	17.105	11.705
	[0.111]	[0.514]	[0.257]	[0.109]	[0.109]	[0.169]	[0.109]	[0.116]	[0.109]	[0.124]	[0.146]	[0.470]
$Q^2(12)$	85.83	83.43	86.68	176.42	86.59	194.03	86.66	150.12	86.65	147.72	55.47	210.24
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports standardised residual diagnostics from the estimation of the bivariate conditional mean equation models for the respective markets using the US as a proxy for the global market. Var., Skew. and Kurt. are the variance, skewness and kurtosis statistics respectively.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual,  $Z_{it}$  and standardised squared residual,  $Z_{it}^2$  respectively (for  $i=g, reg$ , where  $g$  denotes global market and  $reg$  the aggregate regional market). Skew. and Kurt. are the skewness and kurtosis test statistics computed from the Jarque-Bera test of normality. Associated marginal significance levels are represented as p-values and reported in parentheses, [.]

Perhaps more important is the fact that the bivariate conditional mean model was able to adequately capture all linear dependence in the standardised residuals. The Ljung-Box tests for ‘no 12<sup>th</sup> order serial correlation’ in the standardised residuals cannot be rejected in all the markets at any conventional significance levels. Autocorrelation in the squared standardised residuals provide an indirect test for autoregressive conditional heteroskedasticity (ARCH). As the results of the Ljung-Box test for ‘no 12<sup>th</sup> order serial correlation’ in the squared standard residuals display, there is highly significant evidence of non-linear dependence of conditional variance on

past values in both the regional and global markets, an indication of the presence of conditional heteroskedasticity.

**Table 5.4**

**Bivariate Conditional Mean Diagnostics: Mature Market Proxy**

	S. Africa		Egypt		Nigeria		Botswana		Mauritius		Namibia	
	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000
Var.	1.001	1.001	1.001	1.001	1.001	1.001	1.001	0.993	1.001	1.001	1.002	1.002
Skew.	0.169	-0.035	0.222	-0.380	0.221	-0.281	0.213	-0.435	0.214	-0.437	0.140	-0.340
	[0.059]	[0.692]	[0.014]	[0.000]	[0.014]	[0.002]	[0.017]	[0.000]	[0.017]	[0.000]	[0.184]	[0.013]
Kurt.	4.953	4.075	5.165	7.744	5.136	7.829	5.120	7.212	5.129	7.331	4.476	6.181
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	10.848	14.451	13.522	18.583	13.121	20.572	12.992	22.105	13.010	21.994	10.248	10.961
	[0.542]	[0.273]	[0.332]	[0.199]	[0.360]	[0.169]	[0.370]	[0.124]	[0.368]	[0.118]	[0.594]	[0.532]
$Q^2(12)$	65.68	82.84	61.620	216.46	62.14	243.15	62.16	196.70	62.13	193.67	54.440	342.06
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports standardised residual diagnostics from the estimation of the bivariate conditional mean equation models for the respective markets using the aggregate Mature as a proxy for the global market. Var., Skew. and Kurt. are the variance, skewness and kurtosis statistics respectively.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual,  $Z_{i,t}$  and standardised squared residual,  $Z_{i,t}^2$  respectively, (for  $i=g, reg$ , where  $g$  denotes global market and  $reg$  the aggregate regional market). Skew. and Kurt. are the skewness and kurtosis test statistics computed from the Jarque-Bera test of normality. Associated marginal significance levels are represented as p-values and reported in parentheses, [.]

Similar results are observed for the bivariate conditional mean using either the aggregate mature market or China as a proxy for the global (world) market (see Tables 5.4 and 5.5), as when one uses the US market to proxy for the global market. Persistent dependence in the standardised residuals can only be found in the standardised squared residuals. In essence, therefore, across all the markets and for all the three global market proxies, there is compelling statistical evidence that while the bivariate mean equation accounts for the linear dependence in the standardised residuals, it fails remarkably to capture the ‘ARCH effects’ inherent in both the regional and global market returns. It is this aspect of the joint process governing the returns of the regional and global market that the next section seeks to address.

From the diagnostic checks of the mean equations for both global market proxies, two main issues require further consideration. Firstly, the failure of the mean equation to fully capture the non-linear dependence on past values in the squared standardised residuals, a direct indication of the presence ARCH effects, necessitates the estimation of a variance-covariance equation to

capture these ARCH effects. Secondly, as one would expect from financial time-series, bivariate normality, a primary assumption of Equation 5.1, is strongly rejected mainly due to the fact that the residual terms are highly leptokurtic as observed in Tables 5.3 to 5.5.

**Table 5.5**  
**Bivariate Conditional Mean Diagnostics: China as Global Market Proxy**

	S. Africa		Egypt		Nigeria		Botswana		Mauritius		Namibia	
	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$	$\hat{z}_g$	$\hat{z}_{reg}$
Mean	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000
Var.	1.001	1.001	1.001	1.001	1.001	1.001	1.001	0.993	1.001	1.001	1.002	1.002
Skew.	-0.533	0.004	-0.497	-0.452	-0.496	-0.413	0.058	-0.678	0.058	-0.683	-0.047	-0.356
	[0.000]	[0.962]	[0.000]	[0.000]	[0.000]	[0.000]	[0.519]	[0.000]	[0.517]	[0.000]	[0.657]	[0.001]
Kurt.	6.927	4.270	6.515	6.981	6.592	6.822	[4.892]	[6.367]	4.898	6.473	4.023	4.524
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	6.481	16.561	4.599	18.488	4.120	20.187	18.215	17.821	18.216	17.740	9.483	14.634
	[0.890]	[0.167]	[0.970]	[0.102]	[0.981]	[0.114]	[0.109]	[0.121]	[0.109]	[0.124]	[0.661]	[0.262]
$Q^2(12)$	145.77	86.93	253.64	131.24	264.58	156.20	86.66	79.15	86.65	147.72	64.61	194.97
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports standardised residual diagnostics from the estimation of the bivariate conditional mean equation models for the respective markets using China as a proxy for the global market. Var., Skew. and Kurt. are the variance skewness and kurtosis statistics respectively.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual,  $Z_{i,t}$  and standardised squared residual,  $Z_{i,t}^2$  respectively, (for  $i=g, reg$ , where  $g$  denotes global market and  $reg$  the aggregate regional market). Skew. and Kurt. are the skewness and kurtosis test statistics computed from the Jarque-Bera test of normality. Associated marginal significance levels are represented as p-values and reported in parentheses, [.]

This finding should not necessarily invalidate our findings. As noted by Brooks (2008: 399), under the maximum likelihood estimation method typically used to estimate GARCH models, the parameter estimates will still be consistent even if the residual terms are non-normal. However, in the context of non-normality, the associated standard errors will be inappropriate. One approach to avoid such problems of non-normality would be to explore alternative statistical distributions of the error terms, for instance the student's t-distribution. Another approach would be to use an alternative estimator of the variance-covariance matrix. Bollerslev and Wooldridge (1992) suggest a Quasi-Maximum Likelihood (QML) estimator of the variance-covariance which is consistent and robust to non-normality, provided that the conditional mean and variance are well specified. Following several other authors, we adopt the latter approach in this study.<sup>38</sup>

<sup>38</sup> See for instance Baele (2005), Christiansen (2007) and Beirne *et al.* (2008) among many others.

The next subsection discusses the results from the alternative specifications of the variance-covariance matrix as well as selecting the appropriate models that ensure that the ARCH effects found in the bivariate conditional mean models are adequately captured.

### **5.3.1.2 ROBUSTNESS TESTS FOR THE BIVARIATE GARCH MODELS**

Since the literature is vague concerning the precise specification of the variance-covariance matrix  $H_p$ , we empirically explore four different specifications of the variance-covariance dynamics from the three global market proxies, namely DVEC, DBEKK, AS-DVEC and AS-DBEKK. As earlier noted, all the models are estimated by QML estimation and the best performing model is selected based on criteria described in Chapter Four.

First and foremost, to compare the models, an approach used by Ng (2000) was to analyse the correlations of the second moments associated with the variance-covariance specifications. To that end we computed the correlations of the second moments implied by the four alternative variance-covariance specifications. The conditional variances of the aggregate regional and global markets range from 99.96 percent to 99.99 percent respectively. The conditional covariances of the regional and global markets implied by the four models are also very highly correlated and range from 99.13 percent to 99.99 percent. The correlations of the residuals implied by all the four specifications were also computed. For the regional and global markets, these correlations are all in excess of 99.99 percent. This indicates that the estimation results from the four variance-covariance specifications yield very similar results. This may further be confirmed by inspection of graphical plots of the conditional second moments. Figures B-1 and B-2 compare the conditional covariances and conditional variances respectively, for the regional and global market as estimated by each of the four bivariate models. It is immediately clear that the estimates of the second moments estimated by the different bivariate specifications are very similar, as they are highly indistinguishable by visual inspection of the graphical plots.

Table B-1 reports the parameter estimates from the QML estimation of the four bivariate GARCH models for the regional and global markets (with the US market as the global market proxy), while Table B-2 displays the same for the aggregate mature market proxy and Table B-3 for China as a global market proxy. The statistical significance levels are based on the robust

Bollerslev and Wooldridge (1992) standard errors (given the number of parameters, these are not shown in Tables B-1, B-2 or B-3 for brevity reasons).<sup>39</sup>

As one may observe from Tables B-1 to B-3, most of the variance parameters of the symmetric models (DVEC, DBEKK) and asymmetric models (AS-DVEC and AS-DBEKK) are statistically significant and seem quite reasonable across all the markets. There is no evidence against covariance stationarity. As described in Chapter Four, the covariance stationarity conditions are determined by  $a_{ii} + g_{ii} < 1$  for all  $i$  (for DVEC and AS-DVEC models) and by  $(a_{ii}^*)^2 + (g_{ii}^*)^2 < 1$  for all  $i$  (for the BEKK and AS-BEKK models). In no instance across any of the markets do we find that the covariance stationarity condition is violated. It is observed that for South Africa these values range from 0.9111 to 0.9795 for all the models and for all three global market proxies. Across all the markets considered in the sample, and for both global market proxies, these values range from around 0.8721 to 0.9876. Although less than one, the close proximity to one is a firm indication of high persistence in variance for the aggregate and global markets. The finding of high persistence in variance is not unique to this study (see for instance Koutmos and Booth, 1995; Fernández-Izquierdo and Lafuente, 2004; Kim *et al.*, 2005).

Furthermore, for the two asymmetric models, the statistical significance of the elements of the matrix  $\mathbf{L}$  (see Equations 4.5b and 4.7b in Chapter Four) indicates the presence of asymmetry in the variance-covariance matrix. In Table B-1, these asymmetry parameters are given by  $(l_{11}, l_{12}$  and  $l_{12})$ . As evident from Table B-1, we find no statistical evidence in support of asymmetry in the variance-covariance matrix in either South Africa or any other African market except Nigeria, where there appears to be some weak evidence of asymmetry, which is captured at the 10 percent significance level (see Table B-1). Of course it is inappropriate to select the most robust and parsimonious model based solely on the statistical significance of the parameters and the covariance stationarity conditions.

Therefore for purposes of model selection, we subject the bivariate GARCH models to more rigorous model testing. Specifically, and in accord with many other authors (e.g. Bera *et al.*, 1997, Brooks *et al.*, 2002; Christiansen, 2007), we base our robustness tests around bivariate normality, autocorrelation and heteroskedasticity tests, using the standardised residuals obtained from the

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<sup>39</sup> These are available from the author on request.

estimation of the four bivariate GARCH models. Akaike information criterion (AIC) and Schwarz information criterion (SIC) are also computed to aid the model selection process.

Table B-4 reports the results of the bivariate GARCH diagnostic checks for the US market as a proxy for the global market. As in the bivariate conditional mean equation (see Tables 5.3, 5.4 and 5.5), the Ljung-Box  $Q$ -statistics are all not statistically significant at any conventional level, which implies that the models generally perform well in capturing 12<sup>th</sup> order linear dependence on past values in the residuals. Furthermore, as in the bivariate mean equation, one still finds strong evidence against bivariate normality as in all the models and across all the markets, the null hypothesis of bivariate normality is strongly rejected (with p-values of less than 0.0001). In all the models and across all the markets, the residuals still exhibit excess kurtosis. However, compared to the figures earlier found in the mean equation (see Tables 5.3, 5.4 and 5.5), the kurtosis values from the bivariate GARCH models tend to be considerably smaller than in the mean equation for all the bivariate GARCH models and across all the markets. This indicates the models' ability to capture at least some of the leptokurtosis inherent to return series, a feature consistent with what one would expect from GARCH models (see Brooks, *et al.*, 2002; Brooks, 2008). Nevertheless, the strong rejection of the null hypothesis of bivariate normality is a firm indication of the model's inability to account for all the non-normality. As in the bivariate conditional mean equation, the conditional distributions are still, to a very large extent, fat-tailed non-normal, justifying our use of the QML estimation method.

More importantly, and perhaps the major achievement of the bivariate GARCH model, is the information given by the  $Q^2$  statistics. In contrast to our earlier findings in the bivariate conditional mean equation reported in Tables 5.3 to 5.5), none of the Ljung-Box  $Q^2$  statistics are statistically significant after the estimation of the bivariate GARCH models for all the models as reported in Tables B-4, B-5 and B-6. The residual terms for the regional and global markets no longer exhibit 12<sup>th</sup> order dependence on past values in the conditional variances. This indicates that bivariate GARCH models effectively captured the ARCH effects inherent in the regional and global market returns (which the bivariate conditional mean equation could not capture).

To aid the model selection process, one may be tempted to utilise the information criteria. However, this proves to be a futile effort if one does not fully consider the other features of the models. Moreover, as reported in Tables B-4 to B-6, the information criteria tend to offer inconsistent results, making selection based solely on this criteria a difficult effort. In addition, as

observed by Fernández-Izquierdo and Lafuente (2004: 134), although information criteria have been widely used in the ARCH literature, their statistical properties in this context remain unknown. This coupled with the closeness and mixed findings of the AIC and SIC, implies more consideration should be given to balance the results.

Since asymmetry in the variance-covariance matrix is rejected in all the markets except Nigeria, the pursuit of the symmetric models (DVEC and BEKK) may yield more parsimonious and superior results for all the markets except Nigeria. This therefore rules out the AS-VEC and AS-BEKK models for all the markets apart from Nigeria where the asymmetric models tend to be superior. For South Africa, Egypt, Botswana, Mauritius and Namibia we select the DVEC model, as it better captures the autoregressive conditional heteroskedasticity in the residuals, as can be noted from the consistently higher overall p-values associated with the  $Q^2$  statistics. Only for Nigeria (and only for the US global market proxy) do we select the AS-BEKK model.

Consistent with our methodology as outlined in Chapter Four, the residuals from the selected well-performing models are generated. We orthogonalise these residuals as outlined in Chapter Four to create global shocks that are unrelated to regional shocks. These regional and global shocks are used in the subsequent univariate volatility spillover model.

### **5.3.2 *Results of the univariate volatility spillover model***

In this section we report the results from the empirical estimation of the univariate spillover model as outlined in Chapter Four. Specifically, we estimate Equations 4.10 to 4.13. This section is divided into two subsections. In the first, we test the presence of mean and volatility spillover effects by assuming the spillover weight parameters are time-invariant, in what is known as the ‘Constant Spillover’ model. In the subsequent section, this assumption is dropped and the spillover weight parameters are allowed to vary over time, in what is known as the ‘Trend Spillover’ model.

#### **5.3.2.1 *THE CONSTANT SPILLOVER MODEL***

##### *The Univariate Mean Equation*

As a preliminary step, we check the specification of the mean equation associated with the Constant Spillover model for the US and aggregate Mature market proxy. The mean equation is

estimated and we test for autocorrelation and the presence of ARCH effects. The results of these tests are reported in Table 5.6.

As evident from Table 5.6, the mean equation is able to capture the linear dependence on past values in returns. The Durbin-Watson statistic shows that there is no significant evidence of autocorrelation in the South African, or any other market for both global market proxies.<sup>40</sup>

**Table 5.6**  
**Mean Equation Diagnostics: Constant Spillover Model**

Market	US Market Proxy			Aggregate Mature Market			China Global Market proxy		
	DW	ARCH-LM	[p-value]	DW	ARCH-LM	[p-value]	DW	ARCH-LM	[p-value]
S. Africa	1.997	14.808	[0.000]	1.995	8.515	[0.000]	1.992	8.540	[0.000]
Egypt	2.017	8.574	[0.000]	2.017	4.583	[0.000]	2.012	5.578	[0.000]
Nigeria	2.021	17.020	[0.000]	2.009	8.668	[0.000]	2.001	7.142	[0.000]
Botswana	1.998	2.558	[0.026]	1.997	1.272	[0.230]	1.998	1.267	[0.233]
Mauritius	2.024	11.980	[0.000]	2.019	5.777	[0.000]	2.005	8.765	[0.000]
Namibia	2.069	5.130	[0.000]	2.057	3.243	[0.000]	2.052	2.279	[0.008]

The table reports some diagnostics on the mean equation for the US and aggregate mature and China as global market proxies associated with the Constant Spillover model. DW is the Durbin-Watson Statistic and ARCH-LM is the Engle (1982) Lagrange Multiplier test of 5<sup>th</sup> order autoregressive conditional heteroskedasticity in the residuals. Associated p-values are in parentheses, [.]

However, the Lagrange Multiplier tests for 5<sup>th</sup> order autoregressive conditional heteroskedasticity strongly rejects the null hypothesis of ‘no ARCH effects’ in the mean equation at the 1 percent significance level for all the African markets with the exception of Botswana which is at the 5 percent significance level. This constitutes overwhelming evidence that the mean equation is unable to capture the ARCH effects inherent in the return generating process.

#### *Selecting Appropriate GARCH Model*

Having established that the mean equation fails to capture the conditional heteroskedasticity, one therefore proceeds to estimate univariate GARCH models. As stipulated in Chapter Two, we

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<sup>40</sup> The critical value for the Durbin-Watson Statistic is 2. If the test statistic exceeds 2, then there is evidence of negative autocorrelation, while if it is less than two, it is an indication of positive autocorrelation. Since the statistic is approximately equal to 2 in all cases (see Table 5.6), one may safely conclude there is no autocorrelation.

explorer two specifications for the conditional variance process, namely an asymmetric GJR-GARCH (1, 1, 1) and a symmetric GARCH (1, 1) specified respectively as:

$$\sigma_{i,t}^2 = E[e_{i,t}^2 | I_{t-1}] = \varphi_{i,0} + \varphi_{i,1}\sigma_{i,t-1}^2 + \varphi_{i,2}e_{i,t-1}^2 + \varphi_{i,3}e_{i,t-1}^2\zeta_{i,t-1} \quad (5.2a)$$

$$\sigma_{i,t}^2 = E[e_{i,t}^2 | I_{t-1}] = \varphi_{i,0} + \varphi_{i,1}\sigma_{i,t-1}^2 + \varphi_{i,2}e_{i,t-1}^2 \quad (5.2b)$$

where all the parameters are as defined earlier (see Equations 4.13a and 4.13b in Chapter Four).

The two variance specifications were estimated for each of the instances where the US market, aggregate mature market and Chinese market are used to proxy the global market. The results from these estimations are reported in Table B-7 for the US global market proxy, Table B-8 for the aggregate mature global market proxy and Table B-9 for China as a proxy for the global market.

For the symmetric and the asymmetric models, the coefficients given by  $\varphi_{i,0}$ ,  $\varphi_{i,1}$  and  $\varphi_{i,2}$  are respectively the intercept, coefficient of past variance and coefficient of past squared residual (see Equations 5.2a and 5.2b). As evident in Tables B-7 to B-9, these coefficients are reasonable and highly statistically significant in nearly all cases. The summation of the coefficient of past variance and the coefficient of the past squared residual ( $\varphi_{i,1} + \varphi_{i,2}$ ) is close to one in at least five of the six African markets. The proximity to one indicates high persistence in variance. Our finding of high persistence in the variances of the African markets is not unique to this study and compares favourably in part with the findings of some recent studies (e.g. Piesse and Hearn, 2005; Mangani, 2008; Chinzara and Aziakpono, 2009b).

Instances where the condition  $\varphi_{i,1} + \varphi_{i,2} < 1$  is not breached imply conditional variance stationarity. However, we do find cases where the conditional variance stationarity condition is breached, implying volatility persists explosively through time.<sup>41</sup> However, non-stationarity in variance has very little theoretical foundation. As Brooks (2008: 394) notes, GARCH models whose coefficients imply non-stationarity in variance may have some highly undesirable

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<sup>41</sup> For Namibia (associated with the GARCH model only), Nigeria, Botswana and Mauritius (associated with the GJR-GARCH model only) the sum of  $\varphi_{i,1}$  and  $\varphi_{i,2}$  partially exceeds one.

properties. We therefore disregard models that imply non-stationarity in the model selection process.

Another important parameter peculiar to the asymmetric GARCH model is  $\varphi_{i,3}$ , which as outlined in Chapter Four, is the asymmetry coefficient. *A priori*, if the leverage hypothesis holds in the African markets, the asymmetry coefficients are expected to be positive and statistically significant. Indeed, this is the case for South Africa and Namibia, implying negative shocks tend to have a larger impact on volatility than positive shocks of the same magnitude.

Having discussed the results from the estimated models, we proceed to select the best performing model on which to base the interpretation of the results for the Constant Spillover model. As outlined in Chapter Four our model selection criteria incorporates the summation of the coefficient of past variance and the coefficient of the past squared return, along with the models' ability to capture 5<sup>th</sup> order autoregressive conditional heteroskedasticity. Given that the GJR-GARCH (1,1,1) model yields lower  $(\varphi_{i,1} + \varphi_{i,2})$  figures than the GARCH (1,1) model, and the statistical significant evidence of leverage effects in South Africa and Namibia<sup>42</sup>, the GJR-GARCH (1,1,1) model is preferred over the GARCH (1,1) for these two markets. For the other markets, the converse is true and the GARCH (1, 1) specification is selected. For all the selected models, the null hypothesis of no 5<sup>th</sup> order autoregressive conditional heteroskedasticity cannot be rejected at any conventional statistical significance levels. In this regard, the selected models are well specified and inference may ensue.

#### *The Constant Spillover Model Results*

The results of the selected best performing Constant Spillover model are given in Table 5.7 for the US market proxy, Table 5.8 for the aggregate mature global market proxy and Table 5.9 for China as a proxy for the global market.

As alluded to earlier, in order to test for the presence of mean and volatility spillover effects, the Constant Spillover model constrains all mean and volatility spillovers to be constant over time. Furthermore, the parameters  $\gamma_i$  and  $\delta_i$  measure the mean spillover effects from the aggregate

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<sup>42</sup> For Namibia, and specifically for the aggregate Mature market proxy, 5<sup>th</sup> order ARCH effects can only be captured by the inclusion of an additional second order past variance. The resultant model coefficients imply variance stationarity, and therefore for this market, we select the GJR-GARCH (2,1,1).

region and global market respectively, while the parameters  $\phi_i$  and  $\psi_i$  measure the volatility spillover effects from the aggregate region and global market respectively.

**Table 5.7**  
**Constant Spillover Model-US Market (Global Market) Proxy**

Market	$\beta_{i,0}$	$\beta_{i,1}$	$\gamma_i$	$\delta_i$	$\phi_i$	$\psi_i$	SPILL (REG)	SPILL (USA)
S. Africa	0.243* (0.097)	0.004 (0.043)	-0.019 (0.026)	0.055 (0.035)	-0.017 (0.027)	0.382* (0.030)	0.480 [0.619]	85.812* [0.000]
Egypt	0.272# (0.137)	0.061 (0.042)	0.214* (0.079)	-0.022 (0.056)	0.122 (0.144)	0.904* (0.152)	3.774# [0.023]	17.919* [0.000]
Nigeria	0.404* (0.106)	0.089# (0.040)	0.160* (0.056)	-0.090§ (0.050)	-0.199* (0.057)	0.375* (0.050)	8.983* [0.000]	29.110* [0.000]
Botswana	0.265* (0.080)	0.053 (0.045)	0.030 (0.046)	0.006 (0.060)	-0.115* (0.043)	0.133* (0.030)	5.411* [0.005]	10.620* [0.000]
Mauritius	0.183# (0.082)	0.054 (0.040)	0.141* (0.043)	-0.039 (0.039)	-0.192* (0.035)	0.364* (0.030)	19.035* [0.000]	74.442* [0.0000]
Namibia	0.076 (0.092)	-0.234* (0.059)	0.002 (0.034)	0.022 (0.034)	-0.094# (0.038)	0.049§ (0.027)	3.274# [0.039]	1.627 [0.198]

(\*), (#) and (§) imply the coefficients are statistically significant at the 1%, 5% and 10% levels respectively. Consistent Bollerslev & Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets (.) and p-values in parentheses []. SPILL (REG) and SPILL (USA) are Wald test statistics that measure the joint null hypothesis of no mean and volatility spillovers from the aggregate regional and global market respectively, i.e.  $H_0 : \gamma_i = \phi_i = 0$  (from the aggregate region) and  $H_0 : \delta_i = \psi_i = 0$  (from the global market). The Wald test statistics are distributed as chi-squared with 2 degrees of freedom.

As reported in Table 5.7, own past returns are of minor importance for the conditional mean:  $\beta_{i,1}$  tends to be small and not statistically significant for South Africa and the majority of the other African markets. Exceptions to this are Nigeria and Namibia which display positive and negative first order autocorrelation respectively. This dependence of returns on past values may be associated with market imperfections and inefficiencies promoted by low levels of liquidity in the two markets (see Lo and Mackinley, 1988; Harvey, 1995; Koutmos and Booth 1995; Bekaert and Harvey 1997).

The aggregate regional mean spillover parameter  $\gamma_i$  is not statistically significant in South Africa. Similarly, the mean spillover parameter from the global market is not significant. There appear to be no significant mean spillovers from the aggregate region and the global markets for South Africa. The picture from the rest of the African markets is somewhat mixed. Mean

spillover effects from the aggregate region can be found in Egypt, Nigeria and Mauritius only while mean spillovers from the global markets can only be found in Nigeria (at the 10 percent significance level).

There are no statistically significant volatility spillover effects from the aggregate region to South Africa. The volatility spillover parameter from the region ( $\phi_i$ ) is not significant for South Africa but tends to be highly significant for all the other African markets except Egypt. In contrast, we find evidence of volatility spillovers from the global market. The global market volatility spillover parameter ( $\psi_i$ ) is significant in South Africa and the other African markets. The parameter estimates for volatility spillover effects show that in South Africa and the rest of the African markets,  $|\phi_i| < |\psi_i|$ , suggesting that the volatility of these markets is more sensitive to world factors than to regional factors. An exception to this is Namibia, where the converse holds true. This finding for Namibia is not particularly surprising owing to the monetary and economic links of Namibia with South Africa, which constitutes the greatest proportion of the regional market proxy used for Namibia.

The joint Wald test of *no spillovers* from the aggregate region at all, i.e.  $H_0 : \gamma_i = \phi_i = 0$ , cannot be rejected for South Africa, but is strongly rejected for the other African markets. However, the robust joint Wald tests of *no spillovers* from the global (US) market, i.e.  $H_0 : \delta_i = \psi_i = 0$ , is strongly rejected for South Africa and the other African markets, with the exception of Namibia. This is an indication that the South African returns and volatility are less susceptible to shocks originating regionally but more responsive to world (US) shocks.

With reference to the second global market proxy, the aggregate mature market, the results as reported in Table 5.8 are in some respects similar to those of the US market proxy. We find no evidence of mean spillovers from the aggregate region to South Africa, while for the other African markets the mean spillover effects are confined to Egypt, Nigeria and Mauritius. Again no mean spillover effects from the world markets to South Africa and the rest of the African markets are found, with the exception of Mauritius and Namibia where we find past returns from the aggregate mature markets exert some persistent influence on the countries' returns. With the exception of Egypt, there is strong evidence of volatility spillovers from the aggregate region to the rest of the African markets including South Africa. The volatility of the majority of the markets is strongly influenced by world factors, with the exception of Namibia and

Botswana. The dominance of regional factors over global factors for the volatility of the Namibian and Botswana equity markets may be attributed to their economic and trade links with South Africa (constituting the largest share in their respective regional market proxies).

**Table 5.8**  
**Constant Spillover Model-Aggregate Mature Global Market Proxy**

Market	$\beta_{i,0}$	$\beta_{i,1}$	$\gamma_i$	$\delta_i$	$\phi_i$	$\psi_i$	SPILL (REG)	SPILL (MAT)
S. Africa	0.252* (0.083)	-0.016 (0.038)	-0.005 (0.028)	0.005 (0.041)	-0.067# (0.026)	0.517* (0.035)	3.238# [0.040]	110.331* [0.000]
Egypt	0.265# (0.134)	0.068 (0.043)	0.248* (0.072)	-0.048 (0.060)	-0.079 (0.061)	0.454* (0.051)	7.452* [0.001]	40.333* [0.000]
Nigeria	0.435* (0.108)	0.113* (0.041)	0.184* (0.062)	-0.093 (0.060)	-0.249* (0.052)	0.435* (0.056)	14.287* [0.000]	30.095* [0.000]
Botswana	0.376 (0.096)	-0.043 (0.016)	0.019 (0.035)	0.009 (0.032)	-0.117* (0.040)	0.095* (0.037)	4.447# [0.012]	3.349# [0.036]
Mauritius	0.182# (0.086)	0.081# (0.039)	0.162* (0.044)	-0.094# (0.047)	-0.179* (0.037)	0.375* (0.036)	17.997* [0.000]	57.990* [0.000]
Namibia	0.128§ (0.075)	-0.227* (0.060)	-0.050 (0.036)	0.103# (0.050)	-0.120# (0.052)	0.037 (0.037)	2.709§ [0.066]	2.274 [0.104]

(\*), (#) and (§) imply the coefficients are statistically significant at the 1%, 5% and 10% levels respectively. Consistent Bollerslev & Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets (.) and p-values in parentheses [.]. SPILL (REG) and SPILL (MAT) are Wald test statistics that measure the joint null hypothesis of 'no mean and volatility spillovers' from the aggregate regional and global market respectively: i.e.  $H_0 : \gamma_i = \phi_i = 0$  (from the region) and  $H_0 : \delta_i = \psi_i = 0$  (from the global market).

The joint Wald test of *no mean and volatility spillovers* at all from the aggregate region can be rejected in all the markets. The Wald joint test of *no mean and volatility spillovers* from the regional mature markets is strongly rejected in all the markets except Namibia. A further important observation is that in South Africa and the majority of the African markets, the Wald statistic pertaining to global factors tend to be larger than those pertaining to the regional factors. This is a further indication of the dominance of global factors over regional factors for the volatility and returns of most of the African markets. This finding suggests African markets are less integrated regionally than they are globally. The predominance of global factors over regional factors is not unique to South African markets and the majority of the African markets considered in this study. These results compare favourably with those in Ng (2000), Baele (2005) and Bekaert *et al.* (2005a) who all record a general predominance of global factors over regional factors.

Lastly, with reference to the third global market proxy (China), the results as reported in Table 5.9 offer few similarities to our earlier findings for the US and aggregate mature market proxies. We find less evidence in support of mean spillovers from the global market, while mean spillovers from the aggregate regional market are confined to Egypt, Nigeria and Mauritius.

**Table 5.9**  
**Constant Spillover Model-China as Global Market Proxy**

Market	$\beta_{i,0}$	$\beta_{i,1}$	$\gamma_i$	$\delta_i$	$\phi_i$	$\psi_i$	SPILL (REG)	SPILL (CHI)
S. Africa	0.201# (0.097)	-0.061 (0.044)	0.006 (0.027)	0.022 (0.030)	0.069# (0.027)	0.119* (0.036)	3.233# [0.040]	5.503* [0.004]
Egypt	0.256§ (0.139)	0.054 (0.042)	0.207* (0.065)	0.000 (0.037)	0.103§ (0.056)	0.063§ (0.036)	6.301* [0.002]	1.496 [0.225]
Nigeria	0.446* (0.117)	0.076§ (0.042)	0.123§ (0.063)	0.033 (0.043)	-0.026 (0.058)	0.043 (0.033)	1.919 [0.148]	1.436 [0.238]
Botswana	0.363* (0.094)	-0.033§ (0.017)	0.009 (0.035)	-0.007 (0.023)	-0.053 (0.036)	0.026 (0.026)	1.163 [0.313]	0.740 [0.478]
Mauritius	0.177# (0.090)	0.074§ (0.040)	0.102# (0.040)	-0.026 (0.021)	0.004 (0.035)	0.010 (0.026)	3.258# [0.039]	0.898 [0.408]
Namibia	0.103 (0.069)	-0.221* (0.059)	0.031 (0.030)	0.028 (0.029)	-0.055§ (0.029)	0.004 (0.023)	2.035 [0.132]	0.467 [0.627]

(\*), (#) and (§) imply the coefficients are statistically significant at the 1%, 5% and 10% levels respectively. Consistent Bollerslev & Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets ( ) and p-values in parentheses [ ]. SPILL (REG) and SPILL (CHI) are Wald test statistics that measure the joint null hypothesis of ‘no mean and volatility spillovers’ from the aggregate regional and global market respectively: i.e.  $H_0 : \gamma_i = \phi_i = 0$  (from the region) and  $H_0 : \delta_i = \psi_i = 0$  (from the global market).

In contrast to our earlier findings for the other two global market proxies (which supported the predominance of global shocks over regional shocks for the volatility of the African markets) only in South Africa and Egypt do we find volatility spillovers from China. For the volatility of the two markets, global (Chinese) factors only dominate regional factors in South Africa. The result suggests that the recent increase in importance of China as South Africa’s trading partner has seen a corresponding increase in importance of Chinese factors on domestic volatility. However, the same may not be said of the other African markets in the study.

In essence, across all the three global market proxies, the results of the Constant Spillover model suggest strong evidence of volatility spillover effects from both the aggregate regional and the

global markets to the African markets. There is less strong evidence of mean spillovers from the aggregate region, and extremely weak evidence of mean spillovers from the world markets. For South Africa, in particular, we find no evidence of mean spillovers from either the regional or world markets. The volatility of South Africa tends to be driven primarily by world factors and less by regional shocks.

### 5.3.2.2 *TREND SPILLOVER MODEL*

In the Trend Spillover model, the assumption of constant, time-invariant spillover weight parameters is relaxed by allowing the spillover parameters to assume different values for every subsequent year (see Equation 4.21). Before discussing the actual results from the Trend Spillover model, specification tests were conducted on the mean equation. Subsequently, the best performing variance model was selected.

**Table 5.10**  
**Mean Equation Diagnostics: Trend Spillover Model**

Market	US Market Proxy			Aggregate Mature Market			China Global Market proxy		
	DW	ARCH-LM	[p-value]	DW	ARCH-LM	[p-value]	DW	ARCH-LM	[p-value]
S. Africa	2.001	14.906	[0.000]	1.998	8.823	[0.000]	1.99	8.955	[0.000]
Egypt	2.039	7.407	[0.000]	2.024	4.224	[0.000]	2.021	4.509	[0.000]
Nigeria	2.033	19.494	[0.000]	2.007	9.793	[0.000]	2.006	8.526	[0.000]
Botswana	1.995	2.689	[0.020]	1.993	0.218	[0.013]	1.997	1.697	[0.086]
Mauritius	2.041	13.23	[0.011]	2.033	6.657	[0.000]	2.004	8.032	[0.011]
Namibia	2.068	5.529	[0.000]	2.058	3.51	[0.000]	2.053	2.37	[0.006]

The table reports some diagnostics on the mean equation for the US, aggregate mature and China as global market proxies associated with the Trend Spillover model. DW Statistic is the Durbin-Watson Statistic and ARCH-LM is the Engle (1982) Lagrange Multiplier test of 5<sup>th</sup> order autoregressive conditional heteroskedasticity in the residuals. Associated p-values are given in parentheses [-].

#### *The Mean Equation*

As in the Constant Spillover model, the specification tests on the mean equation for the Trend Spillover model are generally centred on checking whether the model captures serial correlation, as well as conditional heteroskedasticity. These results are reported in Table 5.10.

Across the three global market proxies, the general finding is that while the mean equation satisfactorily captures serial correlation, it fails to capture the ARCH effects inherent in all the returns of the respective markets. To that end, univariate symmetric and asymmetric GARCH models are estimated and the best performing models are selected.

#### *Selecting the Appropriate GARCH Model*

The estimation results for the univariate GARCH models associated with the Trend Spillover model are reported in Tables B-10, B-11 and B-12 for the US, aggregate mature and China as proxies for the global market respectively.

Consistent with our earlier findings for the Constant Spillover model, asymmetric GARCH models tend to fit South Africa and Namibia better since these markets exhibit asymmetry, while symmetric GARCH models tend to fit the other African markets well in the sense that no ARCH effects remain, there is no breach of the variance stationarity condition and leverage effects are captured (for South Africa and Namibia).

#### *The Trend Spillover Model Results*

As described earlier, the Trend Spillover model allows the spillover weight parameters to increase or decrease by a constant amount each year that elapses, by so doing, capturing the time-varying effect of regional and global factors on the mean and volatility of the returns of each of the African markets considered in the study. The results of the Trend Spillover model are reported in Tables 5.11, 5.12 and 5.13 for the US, aggregate mature and Chinese global market proxies respectively.

With regard to the results for the global market proxied by the US market (Table 5.11), we find that compared to our earlier findings (with the Constant Spillover model) there is marginally strong evidence of mean spillover effects either from the aggregate region or from the global market. In order to have mean spillover effects, from the aggregate region either  $\gamma_{i,0}$  or  $\gamma_{i,1}$  and from the global markets either  $\delta_{i,0}$  or  $\delta_{i,1}$  must be statistically significant. This is the case for South Africa, Egypt, Nigeria, Mauritius and Namibia. In all these markets, the hypothesis that the mean spillovers are constant, such that  $\gamma_{i,1} = 0$  (aggregate region) and  $\delta_{i,1} = 0$  (global

market) can be rejected.<sup>43</sup> For the market of primary interest, South Africa, the mean spillovers from the aggregate region have been decreasing (i.e.  $\gamma_{i,1} < 0$ ) throughout the sample period, while the mean spillover effect from the global market (US) has been increasing (i.e.  $\delta_{i,1} > 0$ ).

**Table 5.11**  
**Trend Spillover Model- US Global Market Proxy**

Market	Mean Spillovers				Volatility spillovers				V. Spill (REG)	V. Spill (MAT)
	$\gamma_{i,0}$	$\gamma_{i,1}$	$\delta_{i,0}$	$\delta_{i,1}$	$\phi_{i,0}$	$\phi_{i,1}$	$\psi_{i,0}$	$\psi_{i,1}$		
S. Africa	0.098 (0.074)	-0.014§ (0.008)	-0.114 (0.089)	0.020# (0.009)	0.096 (0.071)	-0.013§ (0.007)	0.247* (0.078)	0.017# (0.008)	1.958 [0.142]	91.437* [0.000]
Egypt	-0.067 (0.128)	0.043* (0.014)	0.228# (0.117)	-0.040# (0.016)	0.005 (0.270)	0.022 (0.031)	-0.040 (0.306)	0.132* (0.038)	0.975 [0.378]	23.985* [0.000]
Nigeria	0.058 (0.091)	0.018 (0.013)	0.110 (0.102)	-0.034# (0.014)	-0.087 (0.105)	-0.019 (0.014)	0.080 (0.116)	0.041# (0.017)	7.994* [0.000]	25.692* [0.000]
Botswana	-0.046 (0.076)	0.009 (0.009)	0.049 (0.144)	-0.005 (0.012)	-0.029 (0.069)	-0.011 (0.007)	0.034 (0.080)	0.012 (0.009)	5.866* [0.003]	10.879* [0.000]
Mauritius	-0.031 (0.099)	0.026§ (0.013)	0.153§ (0.081)	-0.030* (0.010)	-0.170# (0.073)	-0.004 (0.010)	-0.132§ (0.082)	0.066* (0.010)	17.052* [0.000]	111.212* [0.000]
Namibia	0.368 (0.240)	-0.027§ (0.016)	-0.412# (0.208)	0.031# (0.014)	-0.558* (0.194)	0.033# (0.014)	0.504* (0.135)	-0.034* (0.009)	8.109* [0.000]	7.053* [0.000]

(\*), (#) and (§) indicate that the coefficients are statistically significant at the (1%), (5%) and (10%) levels respectively. The consistent Bollerslev and Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets (.) while p-values are given in parentheses [.]. V. Spill (REG) and V. Spill (MAT) are Wald test statistics of a joint null hypothesis of no volatility spillovers from the aggregate region (i.e.  $H_0 : \phi_0 = \phi_1 = 0$ ) and global market (i.e.  $H_0 : \psi_{i,0} = \psi_{i,1} = 0$ ) respectively: The Wald test statistics are distributed as chi-squared with 2 degrees of freedom.

A similar trend is observed for Namibia, but the converse holds for the other three markets with mean spillover effects. In contrast to South Africa and Namibia, the mean spillovers from the aggregate region and global markets have been increasing and decreasing respectively throughout the sample period.

Concerning the presence of volatility spillover effects, the Trend Spillover model suggests less strong evidence of volatility spillovers from the aggregate region but stronger volatility spillover effects from the global (US) market consistent with our earlier findings with the Constant Spillover model. In order to have volatility spillover effects from the aggregate region at least

<sup>43</sup> Nigeria is an exception to this because the only statistically significant mean spillover effects come from the global market, i.e. neither  $\gamma_{i,0}$  nor  $\gamma_{i,1}$  are significant.

$\phi_{i,0}$  or  $\phi_{i,1}$  should be statistically significant. Volatility spillover effects from the aggregate region are confined to South Africa (weakly significant), Mauritius and Namibia. The hypothesis of constant regional volatility spillovers, that is,  $\phi_{i,1} = 0$  can be rejected only for South Africa and Namibia. The effect of regional shocks on the volatility of the South African equity market has been decreasing, while the converse holds for Namibia.

**Table 5.12**  
**Trend Spillover Model-Aggregate Mature Global Market Proxy**

Market	Mean Spillovers				Volatility spillovers				V. Spill (REG)	V. Spill (MAT)
	$\gamma_{i,0}$	$\gamma_{i,1}$	$\delta_{i,0}$	$\delta_{i,1}$	$\phi_{i,0}$	$\phi_{i,1}$	$\psi_{i,0}$	$\psi_{i,1}$		
S. Africa	0.092 (0.069)	-0.012§ (0.007)	-0.048 (0.092)	0.009 (0.009)	0.134§ (0.069)	-0.024* (0.007)	0.203# (0.083)	0.037* (0.008)	11.540* [0.000]	180.133* [0.000]
Egypt	0.029 (0.123)	0.029§ (0.016)	0.182 (0.121)	-0.030§ (0.016)	0.046 (0.122)	-0.022 (0.017)	-0.193§ (0.120)	0.085* (0.014)	1.880 [0.153]	58.485* [0.000]
Nigeria	0.121 (0.107)	0.005 (0.014)	-0.006 (0.113)	-0.010 (0.014)	0.028 (0.105)	-0.049* (0.015)	0.204§ (0.118)	0.032§ (0.019)	17.360* [0.000]	34.132* [0.000]
Botswana	-0.058 (0.074)	0.002 (0.009)	0.051 (0.097)	0.002 (0.010)	-0.002 (0.067)	-0.016§ (0.008)	-0.061 (0.125)	0.019§ (0.011)	6.426* [0.002]	7.745* [0.001]
Mauritius	-0.071 (0.102)	0.035# (0.015)	0.110 (0.097)	-0.031# (0.012)	0.020 (0.076)	-0.034* (0.010)	-0.117 (0.085)	0.064* (0.010)	24.023* [0.000]	91.694* [0.000]
Namibia	0.828* (0.304)	-0.058* (0.021)	-0.620§ (0.288)	0.044§ (0.020)	-0.643* (0.188)	0.037* (0.013)	0.251§ (0.100)	-0.017§ (0.008)	10.118* [0.000]	3.664 [0.026]

(\*), (#) and (§) indicate that the coefficients are statistically significant at the (1%), (5%) and (10%) levels respectively. The consistent Bollerslev and Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets (.) while p-values are given in parentheses [.]. V. Spill (REG) and V. Spill (MAT) are Wald test statistics of a joint null hypothesis of no volatility spillovers from the aggregate region (i.e.  $H_0 : \phi_0 = \phi_1 = 0$ ) and global market (i.e.  $H_0 : \psi_{i,0} = \psi_{i,1} = 0$ ) respectively: The Wald test statistics are distributed as chi-squared with 2 degrees of freedom.

The Trend Spillover model also suggests there are strong volatility spillover effects from the global markets at play. We have volatility spillover effects from the global markets when either  $\psi_{i,0}$  or  $\psi_{i,1}$  or both are statistically significant. This is the case for all the markets with the exception of Botswana. The hypothesis that the effect of global factors on local volatility is constant can be rejected for all these markets without exception. For South Africa, Egypt, Nigeria and Mauritius, the effect of global (US) factors on local volatility has been increasing (i.e.  $\psi_{i,1} > 0$ ) over time. Only for Namibia has the effect of global factors on volatility been declining (i.e.  $\psi_{i,1} < 0$ ) over time.

The results for the Trend Spillover model with the aggregate mature market as the global market proxy are reported in Table 5.12. The results tend to be largely similar to those of the US world market proxy described above. There is weak evidence of the effect of regional factors on local returns, which has been decreasing for South Africa and Namibia but increasing for Egypt and Mauritius. Compared to the US global market proxy, the global market given as the aggregate mature market exerts weaker influence on the returns, which are confined to the same markets, namely South Africa (decreasing over time), Egypt (increasing over time) Mauritius (increasing over time) and Namibia (decreasing over time).

Concerning the presence of volatility spillover effects, we find evidence in support of regional factors exerting influence on local volatility in South Africa and rest of the African markets, with the exception of Egypt. In addition, the joint Wald test of no volatility spillovers from the aggregate region ( $H_0 : \phi_0 = \phi_1 = 0$ ) is strongly rejected in all markets except Egypt.

Volatility spillover effects from the aggregate mature markets are also found in South Africa and the rest of the African markets without exception. In support of this, the joint Wald test of no volatility spillovers from the aggregate region (i.e.  $H_0 : \psi_{i,0} = \psi_{i,1} = 0$ ) is strongly rejected in all the markets. An intriguing finding is that the regional influence on local volatility has been declining over time in South Africa and nearly all the African markets (i.e.  $\phi_{i,1} < 0$ ), while the influence of world factors on local volatility has been increasing in all the markets (i.e.  $\psi_{i,1} > 0$ ). The only exception is Namibia, where regional (global) influence on local volatility has been increasing (decreasing). These results seem to suggest that the second moment linkages among the African markets have been weakening over time, while those with the rest of the global market have been strengthening over time for the overwhelming majority of the African markets. The exception (Namibia) may be attributed to the fundamental trade and economic links that exist between Namibia and South Africa (constituting the largest weight in the measure of the regional market).

Finally, with regard to the third proxy for the global market, China, the results of the Trend Spillover model are reported in Table 5.13. Mean spillovers from the global market (China) can only be found in Namibia, and have been increasing over time, while volatility spillovers from China are confined to South Africa and Mauritius. In both cases, the influence of global

(Chinese) shocks on the volatility of the two markets has been increasing over time. For South Africa, this result is not particularly surprising owing to the increase in the relative importance of China as South Africa's trading partner in recent years.

In essence, therefore, our analysis thus far has established that there are mean and volatility effects from the aggregate regional and world markets on local markets, and these effects have in most instances been time-varying.

**Table 5.13**  
**Trend Spillover Model-Aggregate China as Global Market Proxy**

Market	Mean Spillovers				Volatility spillovers				V. Spill (REG)	V. Spill (CHI)
	$\gamma_{i,0}$	$\gamma_{i,1}$	$\delta_{i,0}$	$\delta_{i,1}$	$\phi_{i,0}$	$\phi_{i,1}$	$\psi_{i,0}$	$\psi_{i,1}$		
S. Africa	0.084 (0.074)	-0.008 (0.007)	0.078 (0.068)	-0.007 (0.007)	0.122§ (0.071)	-0.006 (0.007)	0.058 (0.078)	0.010§ (0.008)	3.121# [0.044]	8.507* [0.000]
Egypt	0.020 (0.114)	0.026§ (0.014)	0.035 (0.069)	-0.005 (0.010)	-0.057 (0.122)	0.021 (0.015)	-0.043 (0.075)	0.018 (0.015)	2.542§ [0.079]	1.591 [0.204]
Nigeria	0.030 (0.130)	0.011 (0.018)	0.079 (0.079)	-0.009 (0.010)	-0.002 (0.115)	-0.005 (0.015)	-0.074 (0.068)	0.023 (0.013)	0.539 [0.583]	5.837* [0.003]
Botswana	-0.089 (0.069)	0.012 (0.008)	0.060 (0.063)	-0.008 (0.006)	-0.044 (0.074)	0.002 (0.007)	0.011 (0.074)	0.004 (0.007)	0.255 [0.775]	0.870 [0.419]
Mauritius	0.004 (0.097)	0.016 (0.013)	-0.014 (0.042)	-0.001 (0.007)	-0.196# (0.075)	0.029* (0.010)	-0.068 (0.050)	0.015# (0.008)	4.102# [0.017]	1.989 [0.138]
Namibia	0.424# (0.174)	-0.028# (0.012)	-0.223# (0.098)	0.013# (0.007)	-0.394* (0.116)	0.022* (0.008)	0.002 (0.117)	-0.002 (0.008)	11.183* [0.000]	0.663 [0.516]

(\*), (#) and (§) indicate that the coefficients are statistically significant at the (1%), (5%) and (10%) levels respectively. The consistent Bollerslev and Wooldridge (1992) standard errors that are robust to the distribution of the error term are given in brackets (.) while p-values are given in parentheses [.]. V. Spill (REG) and V. Spill (CHI) are Wald test statistics of a joint null hypothesis of no volatility spillovers from the aggregate region (i.e.  $H_0 : \phi_0 = \phi_1 = 0$ ) and global market (i.e.  $H_0 : \psi_{i,0} = \psi_{i,1} = 0$ ) respectively: The Wald test statistics are distributed as chi-squared with 2 degrees of freedom.

The influence of world factors on local volatility has been more dominant and increasing in most African markets, while that of regional factors has mostly been decreasing. The influence of world and regional factors on local mean returns has been mixed: increasing, decreasing and in some cases time invariant. Lastly, on the balance of the results from the three global market proxies, the US and the aggregate mature market proxy tend to exert the most mean and volatility spillover effects on the African markets compared to the Chinese market as a global market proxy.

## 5.4 VARIANCE RATIO ANALYSIS

Our analysis of spillover effects thus far has been based on the statistical significance of the spillover parameters. However, these are not particularly relevant in quantifying the relative importance of regional and global markets on the local markets. While the sizes of the spillover parameters give an indication of the strength of the volatility spillovers, they cannot be used on their own to assess the proportion of volatility driven by regional and global factors. Therefore, in order to assess the magnitude and evolution through time of the regional and global volatility spillover effects on the volatility of each of the markets in this study, variance ratios are computed using Equations 4.18 to 4.19.

**Table 5.14**  
**Proportion of Variance Driven By Global and Regional Shocks**

Market	US Market		Aggregate Mature Market		Chinese Market	
	$VR_{i,t}^g$	$VR_{i,t}^{reg}$	$VR_{i,t}^g$	$VR_{i,t}^{reg}$	$VR_{i,t}^g$	$VR_{i,t}^{reg}$
S. Africa	16.29%	0.05%	23.69%	0.78%	2.76%	0.85%
Egypt	30.17%	0.50%	8.88%	0.29%	0.36%	0.53%
Nigeria	9.09%	2.15%	10.59%	2.08%	0.22%	0.04%
Botswana	2.11%	1.19%	1.26%	0.83%	0.11%	0.26%
Mauritius	16.32%	3.49%	14.01%	2.99%	0.02%	0.00%
Namibia	0.51%	1.47%	0.16%	1.63%	0.00%	0.61%

The table reports the full sample average proportion of domestic volatility of the African markets driven by global shocks ( $VR_{i,t}^g$ ) and regional shocks ( $VR_{i,t}^{reg}$ ) where the global shocks are proxied by three markets: the US market, the aggregate mature market and the Chinese market.

The variance ratios,  $VR_{i,t}^{reg}$  and  $VR_{i,t}^g$ , give the proportion of the local variance that is explained by regional and global shocks respectively over time.<sup>44</sup> The analysis of these ratios gives insights into the magnitude of the second moment linkages of the African markets with their regional and global counterparts over time. The mean proportion of the variance that may be attributed

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<sup>44</sup> By implication, the variance ratio increases when the volatility factor (regional or global) increases. This is largely consistent with the literature which suggests that correlations among markets increase if volatility of the factor increases (c.f. Bekaert *et al.*, 2005a: 40; Ng, 2000: 216).

to regional and global for the three global market proxies is reported in Table 5.14 for the full sample period.

The results for the US global market proxy indicate that on average, and across all the markets, the proportion of total return variance that can be attributed to global (US) shock spillovers is in the region of 12.4 percent, ranging from 0.5 percent in Namibia to about 30.2 percent in Egypt. For South Africa and Mauritius, global shocks account for about 16.3 percent of total variance, while for Nigeria and Botswana, global shocks only account for about 9.1 percent and 2.1 percent of total volatility respectively. With regard to regional shocks, they appear less pronounced than global shocks. On average across all the African markets, regional shocks only account for about 1.5 percent of local variance across all the African markets and range from about 0.05 percent in South Africa to about 3.5 percent in Mauritius. In all, regional shocks are largely negligible, accounting for less than 3.5 percent of total variance in most of the markets.

The results for the aggregate mature global market proxy are very similar to those of the US global market proxy. Across all the African markets, global shocks are on average found to be more dominant than regional shocks, accounting for about 9.8 percent of the total local volatility of the African markets, compared to around 1.4 percent attributable to regional shocks. As with the US market proxy, the largest variance that can be attributed to global (aggregate mature) shocks may be found in South Africa (23.7 percent), followed by Mauritius (14 percent), Nigeria (10.6 percent), Egypt (8.9 percent), Botswana (1.3 percent) and Namibia (0.2 percent). Compared with our findings for the US global market proxy), the biggest difference with the aggregate mature market proxy is with Egypt, where initially global factors accounted for over 30 percent of local volatility, but with the aggregate mature proxy, account for only 8.9 percent. This is an indication that the Egyptian market is influenced more by shocks originating or associated with the US than with those associated with the constituent markets of the aggregate mature global market proxy. The proportions of local volatility that can be explained by regional factors remain largely negligible, accounting for less than 3 percent of total volatility in all the African markets.

Concerning the third global market proxy, China, the results are somewhat different from those reported for the US and aggregate mature global market proxies. On average across all the African markets, global (China) factors only account for about 0.6 percent of domestic volatility, ranging from less than 0.01 percent in Namibia to about 2.8 percent in South Africa. This result is an indication that the local stock market volatility in African markets is influenced more by

shocks originating from the US and aggregate mature markets than from China. As earlier found with the US and aggregate mature global market proxies, regional factors exert a negligible influence on the volatility of the African markets.

It is imperative to observe that the proportion of the volatility of African markets driven by global or regional shocks is not constant over time. This is particularly clear when one examines the trends of these variance ratios over time as plotted in Figures B-3 to B-5. Most notable is the fact that these variance ratios tend to increase during known crisis periods, for instance the periods surrounding the 1997 Asian crisis or the more recent global financial crisis of 1997, suggesting that African markets are more susceptible to external (regional or global) shocks during crisis periods. This finding supports the empirical regularity in the finance literature that stock markets tend to experience increased correlations during crisis periods.

In summary, the analysis of variance ratios establishes two main issues. Firstly, they reinforce our earlier finding that global and regional spillovers do exist in African markets. However, the variance ratios demonstrate that global shocks tend to be relatively more dominant in explaining local volatility than regional shocks. For South Africa, our market of primary interest in this study, regional shocks are to a very large extent negligible, accounting for less than 1 percent of local volatility. This suggests that there is great scope for policies that may be aimed at stabilising excess volatility in equity markets in South Africa as well as in other African markets.

The part of volatility that policymakers would hope to exert an influence on is the part of volatility that is not explained by external (regional or global) factors. As the results suggest, this part is well in excess of that attributable to external shocks and hence there is a possibility of success for domestic policies aimed at stabilising the stock market. Secondly, the effect of foreign shocks (i.e. regional and global) on the volatility of local equity markets has been time-varying, increasing during turbulent periods. Whether this increased influence of external shocks on domestic volatility during crisis periods is an indication of contagion may not be thoroughly gleaned from this simple analysis and constitutes the subject of interest in Section 5.6.

A further question that arises, especially with global shocks, relates to identifying which factors have been behind the time-varying volatility linkages. This issue is addressed in the next section.

## 5.5 ECONOMIC DETERMINANTS OF VOLATILITY LINKAGES<sup>45</sup>

As alluded to in Chapter Four, changes in the variance proportions over time reflect the time-varying importance of foreign shocks on domestic stock market volatility, and therefore highlight the time-varying international equity market linkages. In order to investigate the determinants of volatility linkages, one allows the variance proportion to be driven by a set of information variables that may influence volatility linkages. The variables considered relate to the size of trade between South Africa and the US (as the global market), convergence in interest rates, convergence in inflation rates and exchange rate volatility<sup>46</sup>.

**Table: 5.15**

**Economic Determinants of Global (US) Variance Proportion**

	Constant	Trade Integration	Interest rate Differential	Inflation Differential	Exchange Rate Volatility	B-G Test	R <sup>2</sup>
S. Africa	0.030*	-0.102§	-0.022	-0.007	0.001#	1.080	0.843
	(0.008)	(0.060)	(0.042)	(0.005)	(0.001)	[0.374]	

The table reports the results from the regression of the proportion of South Africa's conditional volatility attributable to US shocks on a constant, and measures of Trade Integration, monetary policy convergence, inflation convergence and volatility of the Rand-US Dollar exchange rate. Corresponding standard errors are in brackets (.). B-G Test is the 10<sup>th</sup> order Breusch-Godfrey Serial correlation LM test with the associated P-value in parenthesis [·]. (\*), (#) and (§) indicate statistical significant at the (1%), (5%) and (10%) levels respectively

The results from the regression are reported in Table 5.15. Initially, the estimation of the model as in Equation 4.22 yielded an R<sup>2</sup> of 21.4 percent, suggesting the variables do present a fairly good fit of the data. However, we found highly significant serial correlation in the residuals, which we accounted for by introducing a lagged value of the dependent variable ( $VR_{i,t}^g$ ). Only then do we reject the hypothesis of tenth order serial correlation and the R<sup>2</sup> increases to 84.3 percent as reported in Table 5.15. The action appears not to have any discernible effect on the magnitude, sign or statistical significance of the other coefficients.

<sup>45</sup> Owing to data limitations at the weekly frequency used throughout the study, this analysis is confined to South Africa, considering only the US as a global market proxy. Furthermore, since the regional factors on volatility of the South African equity markets are negligible, we only consider the effect of global factors on local volatility.

<sup>46</sup> Refer to Chapter Four for a comprehensive description of the variables.

As shown in Table 5.15, only trade (negative sign) and exchange rate volatility (positive sign) appear to have a significant influence on the extent to which US shocks can explain South African equity market volatility. Despite entering with the expected sign, inflation and interest rate differentials between South Africa and the US are not statistically significant in explaining the volatility linkages between South Africa and the global market. The positive sign on the coefficient of exchange rate volatility implies that higher exchange rate volatility is associated with a higher level of second moment linkages between South Africa and the US. Put in the context of other studies, this is in line with literature that supports the empirical regularity that correlations among equity markets increase in times of turmoil, especially during a currency crisis (e.g. Baele, 2005: 395).

The negative sign associated with the trade variable is a somewhat perplexing result, especially when viewed in light of the theoretical literature which suggests that economies that have strong bilateral trade linkages would not only exhibit synchronicity in real business cycles, but also in terms of financial asset price fluctuations.<sup>47</sup> For South Africa, increased size of trade (between the US and South Africa) appears to be associated with a lesser proportion by which South Africa's volatility can be attributed to the global shocks. One plausible explanation could be that the size of South African exports may not be large enough (relative to total US imports) to cause increased volatility in the US market when there is a shock to South Africa's trade with the US. Such a shock is likely to be felt more in South Africa than in the US. By virtue of the construction of the variance proportions (see Equation 4.19); increased factor (US) volatility results in higher second moment linkages of the domestic market with that external factor. Whether trade linkages may have a similar effect on South African returns linkages with the US as the results show with volatility linkages is a matter beyond the scope of this study.

However, the variables considered, although insightful, are clearly limited in explaining the second moment linkages of the South African market with its global counterpart. Other factors such as stock/financial market development, political risk and country credit rating may all help explain these linkages.

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<sup>47</sup> See Chapter Two for a comprehensive discussion of this issue.

## 5.6 TESTS OF CONTAGION

The volatility spillover model presented thus far enables one to test for contagion effects within the South African and other African markets. The contagion framework first introduced by Bekaert *et al.* (2005a: 46) measures contagion as the correlation of the idiosyncratic shock (unexpected) returns. This contagion methodology is extended by Baele (2005) and applied to bond markets by Christiansen (2007). Subsequently, we apply it to the African markets to test for contagion effects in African equity markets. The contagion model is premised on the fundamental argument put forward by Bekaert *et al.* (2005a) that, in the case of no contagion effects from the regional and global markets to the local market, the respective foreign idiosyncratic shocks should not display any remaining correlations. Furthermore, the hypothesis that such correlations may arise during turbulent market periods is tested using the following model:

$$e_{i,t} = b_1 + (b_2 + b_3 D_t) \hat{e}_{reg,t} + (b_4 + b_5 D_t) \hat{e}_{g,t} + \mu_{i,t} \quad (5.3)$$

where  $\hat{e}_{reg,t}$  and  $\hat{e}_{g,t}$  are the estimated orthogonalised idiosyncratic shocks from the bivariate model of the regional and global markets respectively and  $D_t$  is a crisis dummy. In this work, our interest is confined to the 1997 Asian crisis and the more recent global financial crisis:  $D_t$  equals one during the period surrounding the crisis and zero otherwise.<sup>48</sup> The null hypothesis of no contagion from the aggregate regional market is not rejected if  $b_2$  and  $b_3$  are jointly equal to zero. Similarly, the null hypothesis of no contagion from the aggregate global market is not rejected if  $b_4$  and  $b_5$  are jointly equal to zero. The parameters  $b_3$  and  $b_5$  are the additional contribution of the crisis periods to contagion effects.

The results of the contagion tests with respect to the Asian crisis for the US, aggregate mature and China global market proxies are reported in Tables 5.16, 5.17 and 5.18 respectively, while those relating to the global financial market are reported in Tables 5.19, 5.20 and 5.21 for the three respective global market proxies.

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<sup>48</sup> For the Asian crisis, we use the dates used by Bekaert *et al.* (2005a) where  $D_t$  is equal to 1 for the period April 1997 to October 1998 and 0 otherwise. With respect to the global financial crisis,  $D_t$  equals 1 for the period October 2007 to December 2009 and 0 otherwise. This period corresponds with the peaks observed in the graphical plots of the conditional volatility series of virtually all the markets. Furthermore, the Turner Review (2009) commissioned by the UK's Financial Services Authority sets the beginning of the global financial crisis round about the dates considered in this study.

### 5.6.1 Tests of Contagion: Evidence from the 1997 East Asian Crisis

The results from the US global market proxy (Table 5.16) suggest there are no contagion effects either from the aggregate region or the global market to the South African market. In no case do we find any of the contagion parameters statistically significant. Elsewhere the picture is somewhat similar. Although Egypt displays weakly significant contagion parameters ( $b_2$ ,  $b_4$  and  $b_5$ ), the robust joint tests of  $b_2=b_3=0$  and  $b_4=b_5=0$  cannot be rejected. In fact the joint null hypothesis tests of no contagion effects from the aggregate region or the global market cannot be rejected for the South African or any other African market.

**Table: 5.16**  
**Contagion from Asian Crisis-US Global Market proxy**

	$b_1$	$b_2$	$b_3$	$b_4$	$b_5$	$b_2=b_3=0$	$b_4=b_5=0$
S. Africa	-0.036 (0.105)	-0.042 (0.040)	-0.170 (0.285)	0.028 (0.043)	-0.105 (0.141)	0.816 [0.442]	0.382 [0.683]
Egypt	0.102 (0.153)	0.251§ (0.150)	-0.457 (0.319)	0.340§ (0.193)	-0.862§ (0.522)	1.704 [0.183]	2.120 [0.121]
Nigeria	-0.131 (0.157)	-0.095 (0.101)	0.133 (0.131)	-0.023 (0.063)	-0.013 (0.162)	0.556 [0.574]	0.096 [0.909]
Botswana	0.152 (0.115)	-0.045 (0.056)	0.124 (0.090)	-0.002 (0.030)	0.040 (0.106)	0.956 [0.385]	0.072 [0.931]
Mauritius	0.030 (0.098)	0.026 (0.053)	-0.067 (0.080)	0.076 (0.051)	0.006 (0.149)	0.351 [0.704]	1.283 [0.278]

The table reports the results of running the contagion regression from the 1997 Asian crisis with the US market as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the aggregate mature market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses [.]. Based on Heteroskedasticity and Autocorrelation Consistent (HAC) Newey & West (1987) standard errors in brackets (.),\*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from April 1997 to October 1998.

Even with the aggregate mature as global market proxy (Table 5.17), we do not find statistically significant evidence of contagion effects from the aggregate regional or global markets to the South African market associated with the 1997 East Asian crisis. Elsewhere the picture changes with the introduction of the second global market proxy. The null hypothesis of no overall contagion effects from the aggregate region is strongly rejected for Botswana, while the

hypothesis of no contagion effects from the aggregate global market proxy is strongly rejected for Egypt, Botswana and Mauritius. In nearly all these cases, correlations tend to increase during the Asian crisis. This is gleaned from the fact that  $b_3$  for Nigeria and Botswana, and  $b_5$  for Egypt, and Botswana are statistically significant.

In essence, we do not find evidence of contagion effects from the US market into the South African equity market or any other African market. However, we do find evidence of contagion effects from the aggregate region into the Botswana market. Contagion effects from the aggregate global market are found in Egypt, Botswana and Mauritius. Where contagion effects are found, such effects are characterised by increased correlations of idiosyncratic shock returns during the 1997 Asian crisis period.

**Table: 5.17**

**Contagion from Asian Crisis-Aggregate Mature Global Market proxy**

	$b_1$	$b_2$	$b_3$	$b_4$	$b_5$	$b_2=b_3=0$	$b_4=b_5=0$
S. Africa	-0.020 (0.100)	-0.044 (0.043)	-0.083 (0.238)	0.047 (0.051)	-0.294 (0.206)	0.646 [0.525]	1.188 [0.306]
Egypt	0.066 (0.147)	-0.001 (0.076)	-0.021 (0.133)	0.172# (0.073)	-0.524* (0.150)	0.020 [0.980]	6.387* [0.002]
Nigeria	-0.154 (0.150)	-0.156 (0.104)	0.282# (0.123)	-0.015 (0.067)	-0.168 (0.177)	2.902§ [0.056]	0.645 [0.525]
Botswana	0.065 (0.117)	-0.080 (0.054)	0.247# (0.097)	0.049 (0.042)	-0.229# (0.108)	3.245# [0.040]	2.319§ [0.099]
Mauritius	0.029 (0.095)	-0.090 (0.061)	0.078 (0.085)	0.138# (0.055)	-0.169 (0.145)	1.093 [0.336]	3.186# [0.042]

The table reports the results of running the contagion regression from the 1997 Asian crisis with the Aggregate Mature as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the aggregate mature market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses []. Based on Heteroskedasticity and Autocorrelation Consistent Newey & West (1987) standard errors in shown in brackets (.), \*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from April 1997 to October 1998.

With regard to the results from the third global market proxy (China) as reported in Table 5.18, there is no empirical evidence in support of overall contagion from the global markets during the Asian currency crisis. The null of  $b_4=b_5=0$  can not be rejected in all the African markets. However, there is some statistical evidence of contagion from the aggregate region into the

markets of Egypt and Mauritius. As with the other global market proxies discussed above, there is no evidence of contagion from either the aggregate region or the global markets from the use of China as a global market proxy. This result is somewhat perplexing. In view of the fact that the currency crisis had its roots in the East Asian markets, one would reasonably expect that China may exert some contagious effects on the rest of the African markets. Our empirical findings suggest otherwise.

**Table: 5.18**  
**Contagion from Asian Crisis-China as Global Market proxy**

	<b>b<sub>1</sub></b>	<b>b<sub>2</sub></b>	<b>b<sub>3</sub></b>	<b>b<sub>4</sub></b>	<b>b<sub>5</sub></b>	<b>b<sub>2</sub>=b<sub>3</sub>=0</b>	<b>b<sub>4</sub>=b<sub>5</sub>=0</b>
S. Africa	0.000 (0.117)	0.017 (0.037)	-0.112 (0.075)	0.000 (0.039)	-0.161 (0.168)	1.215 [0.297]	1.249 [0.288]
Egypt	0.025 (0.152)	0.147# (0.066)	-0.325# (0.131)	0.026 (0.065)	-0.044 (0.078)	3.786# [0.023]	0.166 [0.847]
Nigeria	-0.220 (0.160)	-0.026 (0.098)	-0.013 (0.126)	0.020 (0.082)	-0.017 (0.097)	0.144 [0.866]	0.030 [0.970]
Botswana	0.149 (0.115)	-0.037 (0.053)	0.096 (0.087)	-0.004 (0.034)	-0.021 (0.050)	0.612 [0.542]	0.257 [0.773]
Mauritius	-0.003 (0.104)	0.090 (0.061)	-0.176§ (0.092)	0.106§ (0.059)	-0.088 (0.083)	1.846 [0.159]	1.657 [0.191]

The table reports the results of running the contagion regression from the 1997 Asian crisis with the China as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the global (Chinese) market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses [.]. Based on Heteroskedasticity and Autocorrelation Consistent Newey & West (1987) standard errors in shown in brackets (.), \*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from April 1997 to October 1998.

When placed in the context of the findings of other studies, the results are comparatively mixed. Forbes and Rigobon (2002) found that no emerging market, including South Africa, experienced contagion during the 1997 East Asian crisis, consistent with our findings in this study. Furthermore, our findings for Egypt are in support of those found in Collins and Biekpe (2003a and 2003b) while the results for Botswana and Mauritius contradict them. It is imperative to point out that the disparities among the findings may be due to the fact that our contagion testing methodology is fundamentally different from that adopted by the above authors.

A further reason that could explain the contradicting results may be the fact that all these studies confine their turbulent periods to a shorter month-long period surrounding the Hong Kong crash between mid October 1997 and November 1997 and not the entire crisis period as done in this study. In fact, as conceded by Forbes and Rigobon (2002: 2238) it is obviously plausible that contagion occurred during other periods of time, or from the combined impact of turmoil in a group of (East Asian) markets instead of in a single country, further justifying our use of a longer Asian crisis period and the alternate global market proxies.

In the next section, we turn our attention to testing for contagion effects from the more recent global financial crisis.

**Table: 5.19**  
**Contagion from Global Financial Crisis: US Global Market proxy**

	$b_1$	$b_2$	$b_3$	$b_4$	$b_5$	$b_2=b_3=0$	$b_4=b_5=0$
S. Africa	-0.031 (0.110)	-0.015 (0.036)	-0.121 (0.104)	0.012 (0.043)	0.041 (0.118)	1.081 [0.340]	0.158 [0.854]
Egypt	0.090 (0.152)	0.141 (0.145)	0.200 (0.392)	0.179 (0.194)	0.299 (0.434)	0.896 [0.409]	1.187 [0.306]
Nigeria	-0.159 (0.159)	-0.015 (0.057)	-0.174 (0.235)	0.031 (0.055)	-0.306§ (0.157)	0.378 [0.685]	1.907 [0.149]
Botswana	0.143 (0.115)	0.024 (0.050)	-0.169§ (0.102)	0.014 (0.032)	-0.058 (0.075)	1.438 [0.238]	0.310 [0.734]
Mauritius	0.043 (0.096)	0.010 (0.041)	-0.001 (0.139)	0.048 (0.052)	0.164 (0.115)	0.031 [0.969]	2.553§ [0.079]
Namibia	0.126 (0.113)	-0.126 (0.077)	0.143 (0.087)	0.283* (0.068)	-0.341* (0.081)	1.417 [0.243]	9.545* [0.000]

The table displays the results of running the contagion regression from the global financial crisis with the US market as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the aggregate mature market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses [.]. Based on Heteroskedasticity and Autocorrelation Consistent Newey & West (1987) standard errors in brackets (.), \*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from October 2007 to December 2009.

### 5.6.2 Tests of Contagion: Evidence from the Global Financial Crisis

The results from the US global market proxy (Table 5.19) suggest there are no contagion effects from the aggregate region and the US market to the South African market. We do not find any

evidence to suggest correlations of the South African return shocks between either the regional or global idiosyncratic shocks during the global financial crisis period as none of the contagion parameters are statistically significant and the null hypothesis of  $b_2=b_3=0$  and  $b_4=b_5=0$  cannot be rejected. With respect to the other African markets, only in Mauritius and Namibia can the null hypothesis of no contagion effects from the US market be rejected. In Namibia, and to a lesser extent Mauritius, there is evidence that correlations increased during the global financial crisis.

**Table: 5.20**

**Contagion from Global Financial Crisis: Aggregate Mature Global Market proxy**

	<b>b<sub>1</sub></b>	<b>b<sub>2</sub></b>	<b>b<sub>3</sub></b>	<b>b<sub>4</sub></b>	<b>b<sub>5</sub></b>	<b>b<sub>2</sub>=b<sub>3</sub>=0</b>	<b>b<sub>4</sub>=b<sub>5</sub>=0</b>
S. Africa	-0.024 (0.105)	0.017 (0.036)	-0.247# (0.098)	-0.032 (0.052)	0.272§ (0.150)	3.312# [0.037]	1.646 [0.194]
Egypt	0.063 (0.147)	0.054 (0.064)	-0.265§ (0.160)	0.017 (0.075)	0.487* (0.128)	1.392 [0.249]	11.890* [0.000]
Nigeria	-0.190 (0.154)	0.012 (0.058)	-0.375 (0.236)	-0.007 (0.055)	-0.129 (0.186)	1.279 [0.279]	0.295 [0.745]
Botswana	0.033 (0.115)	0.044 (0.053)	-0.249* (0.089)	0.029 (0.043)	-0.057 (0.109)	4.446# [0.012]	0.274 [0.760]
Mauritius	0.028 (0.095)	-0.007 (0.040)	-0.368* (0.135)	0.042 (0.051)	0.450* (0.108)	4.306# [0.014]	13.601* [0.000]
Namibia	0.075 (0.110)	-0.178# (0.090)	0.180§ (0.104)	0.298* (0.072)	-0.305* (0.090)	1.971 [0.140]	8.639* [0.000]

The table displays the results of running the contagion regression from the global financial crisis with the Aggregate Mature market as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the aggregate mature market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses [.]. Based on Heteroskedasticity and Autocorrelation consistent Newey & West (1987) standard errors in brackets (.), \*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from October 2007 to December 2009.

With the aggregate mature as global market proxy (Table 5.20), we find some evidence of contagion from the aggregate region into the South African market as  $b_2=b_3=0$  is rejected at the 5 percent significance level. The observed contagion effect is characterised by increased correlations between the South African residual and that from the regional market during the global financial crisis.

With regard to the other African markets, contagion effects associated with increased correlations during the global financial crisis from the aggregate region to Botswana and Mauritius are found. The null hypothesis of no overall contagion effects from the aggregate mature global market ( $b_4=b_5=0$ ) to the Egyptian, Mauritian and Namibian markets are strongly rejected. In all the three markets, contagion effects, characterised by increased correlation of local idiosyncratic shock returns with those from the aggregate mature market, are found to increase during the global financial crisis period.

**Table: 5.21**  
**Contagion from Global Financial Crisis: China as Global Market proxy**

	b <sub>1</sub>	b <sub>2</sub>	b <sub>3</sub>	b <sub>4</sub>	b <sub>5</sub>	b <sub>2</sub> =b <sub>3</sub> =0	b <sub>4</sub> =b <sub>5</sub> =0
S. Africa	0.000 (0.109)	0.017 (0.035)	-0.112 (0.111)	0.000 (0.038)	-0.161 (0.135)	0.520 [0.595]	0.775 [0.461]
Egypt	0.053 (0.153)	0.088 (0.068)	0.029 (0.127)	-0.044 (0.044)	0.361* (0.116)	1.404 [0.246]	4.849* [0.008]
Nigeria	-0.225 (0.162)	0.064 (0.064)	-0.316§ (0.174)	-0.019 (0.038)	0.196 (0.237)	1.706 [0.182]	0.409 [0.665]
Botswana	0.135 (0.115)	0.034 (0.049)	-0.214# (0.089)	-0.007 (0.028)	-0.046 (0.070)	3.158# [0.043]	0.364 [0.695]
Mauritius	0.013 (0.104)	0.068 (0.059)	-0.016 (0.116)	0.040 (0.032)	0.239 (0.172)	0.793 [0.453]	2.131 [0.120]
Namibia	0.052 (0.111)	0.133 (0.090)	-0.135 (0.096)	0.038 (0.051)	-0.015 (0.072)	1.094 [0.336]	0.376 [0.687]

The table reports the results of running the contagion regression from the global financial crisis with China as proxy for the global market. The last two columns show the Wald test results of the null of no overall contagion from the aggregate region ( $H_0: b_2=b_3=0$ ) and from the Chinese market ( $H_0: b_4=b_5=0$ ). Corresponding P-values are in parentheses [·]. Based on Heteroskedasticity and Autocorrelation Consistent Newey & West (1987) standard errors in brackets (·), \*, # and § indicate statistical significance at the 1%, 5% and 10% levels respectively. The crisis period runs from October 2007 to December 2009.

The parameter  $b_5$  is statistically significant in all three markets (Egypt, Mauritius and Namibia), suggesting that the global financial crisis exerted some contagious influence on these markets through their linkages with the aggregate mature markets. Such contagion effects were characterised by increased correlations between the idiosyncratic shocks from the global market with those from the respective African markets during the crisis. For South Africa, while the

parameter parameter  $b_5$  is statistically significant at the 10% significance level, the joint null hypothesis of no contagion from the aggregate mature market (i.e.  $b_4=b_5=0$ ) cannot be rejected.

With regard to the third global market proxy, China, the results as reported in Table 5.21 suggest that China only exerted strong contagion effects on Egypt as the null of  $b_4=b_5=0$  can only be rejected in Egypt. We find no overall contagion from China to South Africa or any of the other African markets but Egypt. Furthermore, evidence of contagion from the aggregate region to the other African markets can only be found in Botswana as it is the only market where the null of  $b_2=b_3=0$  is strongly rejected.

In summary, we do not find strong evidence in support of contagion associated with the global financial crisis from the US market into South Africa or any other African market, with the exception of Namibia and to a lesser extent Mauritius. We do however find evidence in support of contagion effects related to the global financial crisis from the aggregate mature market into Egypt, Mauritius and Namibia and to some extent South Africa. At first glance, this is a particularly perplexing result. Given the fact that the global financial crisis had its roots in the US, one would reasonably expect the US market to be more dominant than the aggregate mature global market in spreading the contagion effects of the crisis to these markets. However, upon closer inspection, it can be noted that the constituent markets of the aggregate mature market proxy, specifically the UK and Germany, constitute important trading partners of these markets, which are highly correlated with the US market. The contagion effects observed from the aggregate mature markets to the three African markets may conceivably be viewed as an indirect effect of the US-born global financial crisis via its effect on the aggregate mature markets. Given the trade and economic links with the aggregate mature markets, the three African markets are indirectly exposed to the contagious spillover effect from the US. The subdued contagion effects observed from the Chinese market to the rest of the African markets are not entirely surprising, given the origin of the global financial crisis. Lastly, the contagion effects associated with the global financial crisis from the aggregate region are confined to Botswana and, to a lesser extent, South Africa.

## 5.7 CONCLUSION

This chapter discusses and presents the results from the empirical analysis based of the volatility spillover framework outlined in Chapter Four. Multivariate and univariate GARCH

econometric tools were used to investigate the presence of volatility spillovers from regional and global markets onto the South African market. We quantified the relative importance of these two sources of volatility to the South African equity market volatility. The determinants of volatility linkages were also examined, and tests of contagion were conducted. While our primary interest was South Africa, the analysis was also extended to other African markets (namely, Botswana, Mauritius, Namibia, Nigeria and Egypt) for purposes of comparison.

The descriptive statistics of the return series of the markets considered in the study conform to the well-documented properties of financial data, i.e. non-normality due to excess kurtosis and non-linear dependence on past squared returns mainly as a consequence of ARCH effects.

We find less evidence in support for mean spillovers from the regional and global markets to the South African equity market as in other African markets. However, we find stronger evidence in support of time-varying volatility spillovers from the regional and global markets to the South African markets, with global shocks dominating regional shocks. A similar trend obtains in the majority of the other African markets.

In quantifying the proportion of local volatility driven by regional and global shocks, we find that global shocks account for approximately 20 percent of South Africa's volatility, while regional shocks are largely negligible, accounting for less than 1 percent of domestic stock market volatility. The time-varying proportion of volatility driven by global shocks is associated with factors such as trade and volatility of the exchange rate. Interest rate and inflation rate differentials are found to have no significant effect on the extent to which the volatility of the South African market is linked to the rest of the global market.

Lastly, our tests of contagion reveal that the South African equity market was largely shielded from the contagious effects of the Asian crisis and to a lesser extent the recent global financial crisis, as we do not find excess correlation (above that which would be expected given the economic fundamentals) of the South African market with either the regional or global markets during the turbulent periods. The same however cannot be said of Egypt and Mauritius with the major source of contagion being the global markets.

## **CHAPTER SIX**

### **SUMMARY OF FINDINGS, POLICY IMPLICATIONS AND AREAS FOR FUTURE RESEARCH**

#### **6.1 INTRODUCTION**

There is growing interest worldwide in understanding the manner in which international stock markets are related through the extent to which information flows among these markets. This interest has been driven by the need to harness the potential growth effects of integration, the need to understand the implications of financial integration for the evaluation of policies aimed at achieving financial stability, and by the need to identify viable international portfolio diversification opportunities, which continues to pose a challenge to portfolio managers as the world becomes more financially integrated.

The study of the extent to which international equity markets are related has taken at least two forms. On one hand, much research has examined the extent to which information in one market affects the returns in another market, called first moment linkages. On the other hand, another group of studies have examined the manner in which information in one market affects the volatility of returns in another markets, known as second moment linkages. While considerable research has been done internationally on both first and second moment linkages, the research in African markets has mainly centred on first moment linkages. Of the few studies that have considered second moment linkages none to our knowledge has jointly examined how innovations in regional and global markets affect volatility in the African markets. Most of these studies have simply identified whether there are any volatility spillover effects either from the other individual African markets or from the world's major equity markets, without a view of establishing explicitly the magnitude by which those sources of volatility affect the variability of returns in the respective local markets. It is this author's view that a clear grasp of the magnitude by which external shocks affect domestic volatility is critical for drawing policy conclusions as it dictates the appropriate regulatory strategy (e.g. regional, global or country-specific) that regulators and governments may adopt to achieve and maintain financial stability.

Against this background, this research belongs to the group of studies on second moment linkages and examined the extent to which the volatility of the South African, Egyptian,

Nigerian, Botswana, Mauritian and Namibian equity markets are influenced by idiosyncratic shocks originating regionally and globally with a view to making inferences about the nature and magnitude of the market's interdependence with its regional and global counterparts. While our primary interest remained with South Africa, the analysis was also extended to other African markets for purposes of comparison. The fundamental objectives of the study were (1) to examine the structure of the volatility of the South African equity market vis-à-vis the volatility of selected African and mature markets by accounting for local, regional and global influences on volatility, (2) to examine the relative importance of global, regional and local factors to the volatility of the South African equity market by assessing the proportion of the volatility that is driven by these factors, and (3) to examine whether the relative importance of global and regional factors in driving the volatility of the South African stock market has been time-varying and, if so, whether such time-varying level of integration can be linked to certain economic factors known to drive stock market linkages. The ultimate aim was to assess the feasibility of policies aimed at stabilising the equity market as well as identifying whether there is scope for potential portfolio diversification regionally and globally for domestic equity portfolio holders.

This chapter has four objectives. Firstly, to give a brief summary of the whole study; secondly, to highlight the key empirical evidence as presented in Chapter Five; thirdly, to assess the implications of the study and draw policy conclusions, and finally, to identify areas for further research.

## **6.2 SUMMARY OF THE STUDY**

The first part of the study (Chapter Two) reviewed the relevant literature on the cross-border interdependence of equity markets. The reasons why it is important to understand stock market linkages were broadly classified as: identifying the prospects of international portfolio diversification, enabling the evaluation of appropriate financial regulatory policies, and evaluating policies aimed at maximising potential macroeconomic gains from integration, while simultaneously devising policies aimed at minimising the financial system vulnerability that increased integration brings. The fundamental drivers of international linkages of financial markets were broadly identified as relating to the exchange rate regime and stability, economic and trade linkages, coordinated economic and monetary policies, and financial liberalisation policies. The review of relevant empirical literature on the above issues yielded several outcomes. The mature markets of Western Europe and the emerging markets in East Asia and the Pacific

all attest to the increasing importance of regional and global factors on domestic volatility, with the global factors being more dominant. In Western Europe, EU member states record an increasing persistence of regional factors on local volatility, mainly associated with the adoption of a single currency and coordinated economic and financial policies. African markets, however, are relatively segmented both at the regional level (except where strong trade ties and common trading mechanisms are existent) and at the global level (with the exception of the South African and Namibian markets, which have remained partially open to foreign influence).

In Chapter Three, an overview of the markets in South Africa and other foreign markets was conducted with the aim of establishing the plausibility of there being some indication of international linkages. The broad analysis painted a general picture of intensification of linkages amongst South African, African and international markets both at the regional and global levels, albeit inconclusively. These linkages were mainly associated with economic factors related to cross-border trade as well as factors related to the cross-border flow of capital, largely consistent with assertions of the empirical literature.

The formal analytical framework as well as the data that was used to empirically achieve the fundamental objectives (as set out in Chapter One) was discussed in Chapter Four. The analysis mainly centred on using Bivariate GARCH and univariate GARCH econometric tools. The main results of the empirical implementation of this analytical framework were set out in Chapter Five, and the important empirical findings are summarised in the next section.

### **6.3 SUMMARY OF MAIN EMPIRICAL FINDINGS**

To analyse the manner in which the volatility of the South African stock market and the other African markets are affected by the volatility in the global and regional markets, a widely used analytical framework to analyse this subject in the financial markets of Europe and Asia was adopted.<sup>49</sup> The major advantage of the model is that it distinguishes between regional and global volatility effects. To our knowledge, the model has not been exclusively applied to South Africa or any African markets, thus we provide novel findings in this regard. The main findings of the study can be broadly categorised in three groups:

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<sup>49</sup> See for instance Bekaert and Harvey (1997); Bekaert *et al.* (2005a); Ng (2000); Baele (2005) and Christiansen (2007). All these studies (except Bekaert and Harvey (1997) which considers Nigeria and Zimbabwe) mainly consider mature and/or emerging countries other than Africa.

### ***Presence, Nature and Magnitude of Global and Regional Volatility Spillover Effects***

Initially, the volatility spillover analysis was done through the Constant Spillover model, which constrains all the volatility spillover weight parameters to be time invariant. The empirical results show that both regional and global factors are relevant for volatility spillovers in the African markets. Specifically, the results show that for South Africa local volatility is affected more by global idiosyncratic shocks than by regional shocks as in most other African markets. Exceptions to this are in those countries with strong bilateral trade and economic links with South Africa, such as Botswana and Namibia, where it is found that regional factors are more dominant than global factors for domestic volatility. The use of three global market proxies (the US, aggregate mature and China) enables one to get a clearer grasp of which particular market affects the volatility of African markets. On the balance of all the results, the aggregate mature market followed by the US as global market proxies are significant for the volatility of African markets. On the balance of all results from the Constant Spillover model, China is found to exert a more dominant influence over the regional market only in South Africa. The result suggests that the recent increase in the importance of China as South Africa's trading partner has seen a corresponding increase in the importance of Chinese factors on domestic volatility. The same may not be said of the other African markets. Furthermore, compared to the other two global market proxies, China is less dominant in the transmission of volatility to the African markets.

When we relax the assumption of constant volatility spillovers in the Trend Spillover model, the results show that in all the markets, regional and global effects on domestic volatility are found to be time-varying. For South Africa, as in most other African markets, the effect of world factors on local volatility has been increasing over time, with the largest increases observed in South Africa and Egypt, two of Africa's largest markets. This result suggests the two markets have been becoming integrated into the global market at a faster pace than other African markets. The effect of regional factors on domestic volatility has, however, been either constant or declining over time.

To examine the magnitude of local volatility that can be attributed to global and regional factors, we computed variance ratios. The results show that the proportion by which global factors account for volatility in the African markets varies with the proxy (for the global market) employed. Compared to the other African markets, South Africa appears to be relatively more

influenced by world factors. The results showed that global factors as represented by the US market accounted for 16.3 percent of South Africa's volatility, while those represented by the aggregate mature market accounted for 23.7 percent of the volatility. China as a global market proxy accounts for only about 2.8 percent of South Africa's volatility. Across all the three global market proxies it was found that the volatility in South Africa is the most influenced by global factors, followed by Egypt, Nigeria, Botswana, Mauritius and Namibia (in that order). With regard to the aggregate region, the results showed that regional factors were negligible in explaining volatility and accounted for less than 1 percent of South Africa's volatility. Similarly, the proportion of domestic volatility that may be attributed to regional factors in the other African markets is generally low, ranging from about 3.5 percent to less than 1 percent.

The empirical results also revealed that the magnitude of domestic volatility attributable to regional or global factors in the African markets was time-varying and tends to increase in turbulent periods i.e. when the volatility of the factor (regional or global) is high, such as during the Asian crisis of 1997 and to a lesser extent during the global financial crisis of 2008 to 2009.

In essence, our findings generally support the view that African markets are segmented both at the regional and global levels as domestic volatility is more influenced by local idiosyncratic shocks (the proportion not attributable to either global and regional factors). However, the volatility of South Africa, and to a lesser extent Egypt, remain relatively more open to global influence.

### ***Economic Determinants of Second South Africa's Second Moment Linkages***

In an attempt to establish what economic factors have been behind the relative importance of global shocks on South Africa's volatility, we found that the most important factor associated with the increased second moment linkages relates to the volatility of South Africa's currency with respect to the US dollar. Factors such as differences in interest rates and differences in inflation rates do not appear to influence the extent to which global factors influence South Africa's volatility. The inability of these variables to account for the second moment linkages of South Africa with the global market (US) could be explained by the fact that South Africa pursues a largely autonomous monetary policy, which is not directly influenced by interest rates globally, to the extent that there is no convergence in interest rates linked to integration. However, we interpret these results with caution as the explanatory power of the model (used to

investigate the economic determinants of integration) is limited. Other factors, such as stock/financial market development, political risk, and country risk/credit rating, may further help explain these second moment linkages which are not readily available at the weekly frequency to enable a more thorough analysis in this study.

### ***Regional and Global Contagion Effects from Financial Crises***

Our tests of contagion were based on the argument made by Bekaert *et al.* (2005a) that when there is no contagion, the idiosyncratic shocks of the respective markets should not exhibit correlations in turbulent times. The analysis was confined to the 1997 East Asia crisis and the recent global financial crisis of 2008 to 2009. We found that South Africa did not exhibit strong evidence of contagion effects in both turbulent periods from either the global or regional markets, although the results show some evidence of regional or global contagion effects from either the Asian or global financial crisis to a few African markets, especially Egypt, Mauritius and Botswana.

## **6.4 PORTFOLIO DIVERSIFICATION AND POLICY IMPLICATIONS**

The study analysed the extent to which shocks originating regionally and globally are able to explain the variability of stock market returns. The findings in this study have implications for policy as well as for equity portfolio managers.

### ***Implications for Policy***

The fundamental role of monetary policy is to formulate and execute policies to regulate the financial system in such a manner that ensures high employment, economic growth, low inflation and the overall stability of financial markets and foreign exchange markets. In this regard, understanding the sources of the volatility of equity markets becomes critical for policy. This is so because excess volatility in financial markets has a great impact on the overall stability of financial markets. The extent to which foreign idiosyncratic shocks exert an influence on domestic volatility gives insights into the degree of integration of the domestic market into the global or regional market. This implies that in the event of negative external shocks, domestic financial stability would greatly depend on the financial stability of the external markets, thereby highlighting the vulnerability of the domestic financial system to those adverse external shocks.

This should be of particular concern to policy makers especially when foreign shocks exert a substantial influence on domestic volatility. Against this background, the study examined the extent to which two external idiosyncratic shocks, a regional and a global shock, influence domestic volatility. The study also quantified the magnitude by which those external shocks affect domestic variance in South Africa and five other African markets.

Firstly, with respect to South Africa, our empirical findings show that while regional shocks are negligible, accounting for less than 1% of domestic volatility, global shocks are much more dominant accounting for an average of 16.3 percent (US global market proxy) and 23.7 percent (Aggregate mature proxy) of the domestic equity market volatility. For this reason, policymakers should take into consideration factors occurring within these external markets, as these have the potential of negatively affecting the financial stability of the South African financial system especially during times of crisis. Since equity markets do not operate in complete isolation from the other financial markets, (e.g. the foreign exchange markets, derivative markets, the long term and short term debt markets, etc.), extreme volatility in the equity markets has the potential to affect the other financial markets and thereby threatening the entire domestic financial system. We therefore advocate that policymakers in their bid to formulate and execute policies aimed at stabilising domestic financial markets, should also take into consideration global factors from external markets such as those in the US or those markets subsumed in the aggregate mature proxy. Indeed this recommendation still holds even for those other African markets such as Egypt, Nigeria and Mauritius, whose volatility is moderately influenced by global factors from the US and the aggregate mature markets (UK, Germany and Japan).

Secondly, our empirical finding that regional and global factors jointly account for a smaller proportion of domestic volatility than that attributable to local factors is an indication of the fact that South Africa is not fully integrated at either the regional or global level. This implies that the South African equity market, by its partial segmentation from the regional and global markets, is to a large extent shielded from the adverse shocks originating from these sources. The partial segmentation of the South African market implies that there is considerable scope for success for those policies that are aimed at achieving greater financial (stock market) stability. This is so because a significant proportion of the domestic volatility that policymakers would desire to exert an influence on, is not determined by global or regional factors. Therefore, for as long as South Africa is only partially integrated into the global/regional equity markets, an autonomous

domestic monetary policy remains a viable and effective tool for the stabilisation of the domestic financial system. Such an autonomous monetary policy would be ineffective if a greater proportion of domestic volatility was determined more by foreign factors than by local factors. Of greater concern to policymakers however should be the fact that, by its partial segmentation from the global and regional markets, South Africa foregoes some of the benefits associated with regional and global integration. Agénor and Montiel (2008: 484) identify several potential benefits to international financial integration which include among other things international risk sharing and increased financial system efficiency and stability. In this regard, we advocate for deeper capital market integration at the global level and especially at the regional level from where South Africa is found to be most segmented.

At the regional level, one approach to boosting regional financial integration would be to establish common/shared mechanisms with regional markets for the trading of stocks and the settlement of stock market transactions. The success of such a coordinated regional policy strategy would be greatly contingent upon the political will of authorities in South Africa and the regional markets, the development of legal and regulatory institutions, and the standardisation of listing requirements across the region. In addition, as argued by Piesse and Hearn (2005: 51), harmonisation of tax regimes, accounting systems and the commitment to enforce regulation are essential and constitute additional hurdles for most of the African markets.

### ***Implications for Portfolio Diversification***

The implications of our findings in this study for portfolio diversification are rather uncomplicated. A necessary but not sufficient condition, which has been identified by the seminal works of Markowitz (1952 and 1959), is that as long as the correlation amongst the returns of investment options is not perfect, there exists the potential for benefits from diversification. The partial segmentation of the South African market from the global and regional market implies that the addition of foreign stocks from the global market (to a lesser extent) and the regional markets (to a greater extent) would reduce the variability of the portfolio returns of the South African equity portfolio managers and investors. Our empirical findings revealed that only shocks from the US and the aggregate mature markets are important for the volatility in South Africa and the other African markets. Shocks originating from the aggregate region and from China are less important for domestic volatility. Therefore, investors may take advantage of the segmentation of the South African market from China and the aggregate region

by including Chinese and other regional market stocks in their domestic portfolio holdings. This would minimise unsystematic risk. While this recommendation is purely motivated by the findings in this study, the practical implementation of such an investment strategy would have to take into consideration far much more than just the degree of integration of South Africa with these markets, such as political risk, legal and institutional factors, etc all of which are beyond the scope of this study. For that reason, the long-term prospects of such diversification benefits cannot be thoroughly appreciated from the findings of this study alone.

## **6.5 AREAS FOR FURTHER RESEARCH**

A major challenge of our study relates to the unavailability of relevant data which hindered the extension of the analysis of the determinants of second moment linkages in countries other than South Africa. Future research may focus on the time-series and cross-sectional analysis of the primary determinants of global integration and regional segmentation of African markets with a wider dataset.

Another area that future research could focus on regards the use of volatility regime-dependent spillover models in the sense of Baele (2005). Our analysis of variance ratios revealed that correlations among markets tend to increase during turbulent times – a finding largely consistent with the theory on contagion. We then further assessed the issue of contagion from two crisis events by using dummy variables. However, we concede that there is a danger to this for two reasons. Firstly, it is conceivable that correlations may increase during times other than as defined by the dummies e.g. during the Mexican Peso crisis, the Dot.com bubble, the September 11<sup>th</sup> terror attacks, etc. Secondly, the effect of the crises (or events) on volatility may take a longer time to manifest than those defined by the dummies. In such a case, the use of dummy variables becomes less appropriate. A possible solution would be the use of a model that allows the parameters that measure volatility spillover effects to vary according to the volatility regime over time in the sense of Baele (2005). To that effect, future research could explore this aspect in the context of African markets.

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## APPENDIX A

### SUMMARY OF THE EMPIRICAL LITERATURE ON SECOND MOMENT STOCK MARKET LINKAGES

**Table A-1**  
**Summary of the Empirical Literature on Second Moment Stock Market Linkages**

**PANEL A: Summary of Studies with a Primary Focus on Mature Economies (Developed Markets)**

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Gannon and Au-Yeung (2005)	2 countries, US and Hong Kong Spot and Futures markets	1994-2001, Daily	Bivariate GARCH (BEKK) with multiple switching points in variance equation	Switch points capture changes in volatility structure due to regulatory events on HSI and HSIF.	US SE found in the HSI and HSIF. Evidence of structural changes in volatility found when US is excluded.
Bodart and Reding (1999)	6 European Countries: EMS and non EMS	1989-1994, Daily	Multivariate/Univariate GARCH models	Bivariate GARCH models that are used to analyse how exchange rate regime affects conditional correlations among countries.	Unlike on the bond market, there is little significant evidence that stock correlations among the countries reviewed are affected by the degree of exchange rate variability.
Cifarelli and Paladino (2005)	3 Countries: US, UK and Germany	1992-2000, Daily	Symmetric and asymmetric multivariate GARCH models	Model allows analysis of extent to which stock market volatility diffusion causes stock market exuberance transmission.	Volatility SE are largely accounted for by stock market exuberance Markets tend to be more interlinked during bouts of crises.
Fratzschler (2002)	16 OECD countries	1986-2000, Daily	Multivariate volatility model	Through a tri-variate GARCH specification regional and global shocks are distinguished and analysed.	European equity markets have become integrated with Euro area market experiencing an increasingly dominant role in Europe over that of the US.
In (2007)	3 countries, US, UK and Japan	1996-2001, Daily	Multivariate VAR-GARCH	Model enables testing asymmetry in the volatility SE.	Unidirectional SE from the US to UK and Japan Significant reciprocal SE between UK and Japan.
Isakov and Pérignon (2000)	5 countries, and Switzerland	1988-1998, Daily	Multivariate volatility model (GARCH-BEKK)	Inferences are made by modelling a series of bivariate GARCH-BEKK with the 5 markets.	Asymmetric volatility SE to Switzerland are mainly from European countries, and not significantly from the US.
Kim <i>et al.</i> (2005)	12 EMU countries, 3-non-EMU states, Japan and US	1989-2003, Daily	Multivariate volatility model (ARMA-EGARCH)	This model specification used eliminates the assumption of constant correlation between stock returns. <sup>50</sup>	Time varying conditional correlations found with persistent effects among countries with similar industrial structures. Volatility SE among EMU States indicates increased integration.
Koutmos and Booth (1995)	3 countries, US, UK and Japan	1986-1993, Daily	Multivariate volatility model (M-EGARCH) with constant correlations	Jointly examines the interdependencies, however fails to account for overlapping trading in UK and US.	SE found from US to UK and Japanese markets. SE found from Japan to UK. SE are pronounced during periods of negative news.
Savva (2009)	6 countries, US and European countries	1990-2005, Daily**	Multivariate volatility framework (EGADC) <sup>51</sup>	The framework nests several multivariate versions of GARCH models: VECH, CCC, BEKK and F-ARCH).	Bi-directional volatility SE between US and Europe. Correlation between markets increases after three occurrences of negative news, and since introduction of Euro.

<sup>50</sup> See for instance Bollerslev (1990).

<sup>51</sup> Extended General Asymmetric Dynamic Covariance.

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Savva <i>et al.</i> (2009)	4 countries, US, UK, France and Germany	1990-2004, Daily**	Asymmetric Dynamic Conditional Correlation (DCC) model, VAR, M-EGARCH	The study employs daily pseudo-closing prices for all the markets to avoid the problem of non-synchronous trading.	SE recorded among European markets which have intensified after introduction of the Euro. SE from foreign markets are transmitted asymmetrically.
Aragó-Manzana and Fernández-Izquierdo (2007)	5 countries: Europe	1995-2004, Daily	Multivariate GARCH-BEKK framework	SE are modelled using a series of bivariate GARCH-BEKK specifications of the local with the foreign stock market.	Indistinguishable asymmetric information SE are detected among all the countries EMU and non-EMU countries.
Bae and Karolyi (1994)	2 Countries: US and Japan	1988-1992, Daily	Univariate GARCH, EGARCH Models	Day time and overnight asymmetric news transmission between the two markets is analysed using intraday opening and closing stock prices.	Volatility SE are evident. SE originating from the US to Japan are significantly understated in magnitude and persistence if asymmetry in their transmission is not taken into consideration.
Bartram and Wang (2005)	US and UK (mimicking prices)	1978-1997, Daily (artificial)	Monte Carlo simulations, GARCH	Time series of returns are simulated according to alternative stochastic processes: LRM, LRMH, GBM & GARCH.	Simulation results show that market dependence is not generally conditional on volatility regimes, such that a bias in correlation measures only occurs for invariant conditionally heteroscedastic return generating processes. <sup>52</sup>
Baele (2005)	8 EMU, 3 EU, 2 Non-EU Countries and US.	1980-2001, Weekly	Multivariate/Univariate regime switching Volatility Spillover Model	Spillover model allows volatility to be driven by local, regional and global factors. Regime Switching model accounts for shock sensitivities to change over time.	SE intensity have increased since the 1980s. Regional and US shocks have increased (8%-23% and 15%-27% respectively) in explaining local volatility. Trade integration, equity market development & low inflation contribute to increasing EU regional integration.
Christiansen (2007)	US, Europe, 6 EMU States and 3 non-EMU member states	1988-2002, Weekly	Univariate AR-GARCH Implemented as in Ng (2000)	Spillover model allows volatility to be driven by local, regional and global factors.	Stronger regional than global SE on EMU states than on non-EMU. Weaker US SE than Aggregate European SE.
Fernández and Lafuente (2004)	12 countries: Europe, Asia and America	1997-2001, Daily	Multivariate EGARCH models, Principal Analysis	Factor Analysis is used to analyse stock price volatility dynamics into 3 latent factors: Europe, Asia and America.	Significant leverage effects are found. Volatility SE during this period (Asian crisis) was transmitted through contagion not by economic fundamentals
Hamao <i>et al.</i> (1990)	3 countries: Japan, US, UK	1985-1988, Daily	Univariate GARCH-M models	Conditional variance in close-to-open and open-to-close returns of local market is approximated by a MA-GARCH-M process.	Unidirectional volatility SE from the US to UK (weaker) and Japan (stronger), UK to Japan (weak) after the 1987 crash. There is no significant SE prior to the 1987 crash.
Koch and Koch (1991)	8 countries: US, UK, Germany, Japan, Hong Kong, Australia, Singapore & Switzerland	1972-1987, Daily	Dynamic Simultaneous Equations	Simultaneous equation model is estimated to describe contemporaneous and lead-lag first moment relationships among 8 markets.	Increased interdependence of markets over time especially among countries in similar geographical locations with overlapping trading hours.

NOTES: SE Spillover Effect  
 EMU European Monetary Union  
 SE Spillover Effect  
 EMU European Monetary Union

HSI Hang Seng Index  
 HSIF Hang Seng Futures  
 LRM Linear Regression Model  
 GBM Geometric Brownian Motion

\*\* Daily Closing Pseudo prices are used to avoid non-synchronous closing times  
 LRMH Linear Regression Model with Heteroskedasticity

<sup>52</sup> This finding contrasts that of Forbes and Rigobon (2002), who show that most correlation coefficients used in the vast literature to document inter-market linkages during turbulent times (usually referred to as contagion), are biased measures of dependence. When these biases are accounted for, there is no evidence of contagion in the 1987 US crisis, 1994 Mexican crisis or 1997 Asian crisis.

**PANEL B: Summary of Studies with a Primary Focus on Mature and/or Emerging Market Economies (Emerging Markets)**

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Alper and Yilmaz (2004)	3 developed markets and 4 emerging markets	1992-2001, Weekly	Univariate MA-GARCH models	Simple rolling regressions are employed to analyse volatility persistence before and after crises	Volatility contagion effects are found, mainly coming from the developed markets (US, Japan and UK) estimated on average to be four times that coming from the emerging countries reviewed.
Beirne <i>et al.</i> (2008)	41 EMEs , 6 Mature markets	1993,1996-2008, Weekly	Multivariate Volatility Models: Trivariate GARCH-BEKK models [Local, Regional and Global markets]	Changes in volatility transmission are examined during turbulent periods in mature markets.	Volatility SE from mature markets are found in most EMEs, and from regional to local markets, with the spillover parameters changing during turbulent times (in mature markets) – contagion.
Bekaert <i>et al.</i> (2005a)	22 countries: Asia, Europe and Latin America	1980-1998,	Asymmetric GARCH with the mean equation implemented is a two-factor asset pricing model	As in Ng (2000), Spillover model allows volatility to be driven by local, regional and global factors.	No additional contagion documented after Mexican crisis, but increased integration in Asia during Asian crisis.
Caporale <i>et al.</i> (2005)	8 East Asian Countries	1990-1995, Weekly	Conditional Correlation Analysis, Univariate GARCH	This framework is adopted to analyse “contagion” which the authors define as increased cross-market linkages in response to a shock on another country.	Contagion began in late 1997 at the time of the Hong Kong crash or onset of the Korean crisis, with the source of the crisis (Thailand) affecting the rest of the countries in the region.
Caporale <i>et al.</i> (2006)	US, Japan, Europe (4 ), South East Asia (8) countries	1986-2000, Daily	Multivariate Volatility models [GARCH-BEKK], Bootstrapping	A series of bivariate GARCH models are estimated to measure volatility SE before and after the 1997 Asian crisis.	Bi-directional volatility SE in the pre-crisis and whole sample. However, causality in variance links runs from country in turmoil to others following the onset of the crisis.
Chiang <i>et al.</i> (2007)	8 Asian Countries, US	1990-2003, Daily	Correlation Analysis, Multivariate GARCH [DCC-GARCH model]	Heteroscedasticity-adjusted correlation and dynamic correlation analyses are used to investigate contagion during the 1996 Asian crisis.	There was significant increase in cross-market co-movement during the crisis (contagion). However, the stability of the covariances is subject to structural changes (e.g. in response to news about foreign currency sovereign credit ratings).
Chuang <i>et al.</i> (2007)	6 East Asian (Emerging) Markets	1992-2006, Weekly	Multivariate VAR-GARCH (BEKK) and VAR	Volatility transmission is examined through a VAR system of 6 conditional variances.	SE are recorded, with a larger proportion coming from Japan to the rest of the East Asian states. Volatilities have increased post-Asian crisis period.
Darrat and Benkato (2003)	5 countries: Turkey, US, UK, Japan and Germany	1986-2000, Monthly	Johansen-Juselius Cointegration, Univariate GARCH model	Volatility SE are analysed by expressing the conditional volatility of ISE, as a function of the lagged conditional variances of the other four markets.	Volatility SE between the ISE and the other four matured markets are found to have strengthened after liberalisation, with the US and UK being the main drivers of ISE volatility.
Ng (2000)	6 Pacific Basin states (emerging markets) , US and Japan	1980-1996, Weekly	Univariate and Multivariate GARCH models	Spillover model allows volatility to be driven by local, regional and global factors.	Volatility SE effects from US and Japan found. Global and regional factors account for less than 10% of Pacific basin volatility.
Vrugt (2009)	4 countries: Japan, Hong Kong, S. Korea, Australia	1996-2007, Daily	Univariate GARCH models	Analysis of how macroeconomic news announcements from the US and Japan affect conditional volatility in the 4 countries.	US announcements are more important than Japanese (even in Japan) for all the markets reviewed.

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Wei <i>et al.</i> (1995)	3 Developed and 2 Emerging markets	1991-1992, Daily	Univariate GARCH models	Problems associated with non-synchronous trading are overcome by the use of Intra-day, open-to-close and close-to-open prices.	Volatility SE are found from the US to the emerging countries over that exerted by Japan.
Apergis <i>et al.</i> (1997)	Greece vis-à-vis USD, EC, ECU currencies	1992-1996, Daily	Univariate GARCH models	The GARCH variance equation for stock price conditional volatility includes lagged conditional volatilities of the 3 currencies.	Volatility SE between Greek stock volatility and the USD volatility are found, but not with the other European currencies.
Bekaert and Harvey (1997)	20 Emerging markets, US	1976-1992, Monthly	Univariate volatility models	EM volatility dynamics and what drives them are analysed by distinguishing world and local factors.	World factors drive less than 10% of volatility in 16 out of 20 EM surveyed, but increases after liberalisation and crises for 12 of the 17 countries that underwent liberalisation.
Li (2009)	US and 5 Emerging market groups	1988-2007, Weekly	Multivariate Markov Switching ARCH, Multivariate GARCH Models	US-EM co-movements when both markets are in HV/LV states/regimes and the US-EM portfolio diversification implications are investigated.	The author finds that US-EME correlations vary depending on the volatility states of the two market groups. Strongest US-EM correlations result when both US-EM markets are simultaneously characterised by high volatility.
Miyakoshi (2003)	7 Asian countries, US and Japan	1998-2000, Daily	Multivariate EGARCH model	Spillover model allows volatility to be driven by local (endogenous), regional and global (exogenous) factors.	Mean return SE from US (and not Japan) to the Asian markets. Volatility SE from Japan (more than from the US) affects Asian market volatility in contrast to Ng (2000).
Niarchos <i>et al.</i> (1999)	2 US and Greece	1993-1997, Daily	Multivariate Asymmetric volatility models, Cointegration tests	Study implements a bivariate EGARCH that allows for both mean and volatility SE between the two markets.	No mean and volatility SE detected between US and Greece. Cointegration tests do not show a long-run association between US and Greece
Pan <i>et al.</i> (1999)	5 Asia Pacific countries and the US	1988-1994, Daily	Cointegration, Univariate GARCH model	A modified cointegration test with ARCH effects is used to capture common time-varying volatility in these markets.	There is no evidence of long-run associations in mean returns. However, statistically significant long-run common time-varying volatility is detected among the six Asia-Pacific markets.
Tastan (2005)	6 countries: Turkey, EU and US	1990-2004, Daily	Multivariate Volatility models [VAR-DCC-MVGARCH]	Turkey's integration into the EU and global market is analysed through time-varying correlations and conditional covariances.	Turkey exhibited a weak association with rest of the markets prior to the European customs union. After the customs union, there was a shift in the covariance structure of Turkey with other markets.
Tse <i>et al.</i> (2003)	2 US and Poland	1994-2003, Daily	Multivariate Asymmetric Volatility models, Cointegration tests	Study implements a bivariate EGARCH <sup>53</sup> that allows for both mean and volatility SE between the two markets.	There is weak evidence of mean SE from the US, but no evidence of volatility SE. Cointegration tests reveal no evidence of a long-run relationship between US and Polish markets.
Kim and Rogers (1994)	3 Countries: US, Japan and Korea	1985-1992, Daily (intra-day)	Univariate GARCH models	The effect of liberalisation on volatility transmission is assessed by examining the full sample and a post liberalisation sub period.	Volatility SEs have intensified since liberalisation especially for close-to-open returns, showing that information from the major mature markets has become pertinent for the opening price in Korea.

NOTES: EME Emerging Market Economy  
SE Spillover Effect  
EMS European Monetary System

ISE Istanbul Stock Exchange  
HV High Volatility State  
LV Low Volatility State

EME Emerging Market Economies

<sup>53</sup> Non-synchronous trading between the two markets is accounted for by introducing a first order moving average term in the mean return equations.

**PANEL C: Summary of Studies with a Primary Focus on South African and/or African Markets**

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Alhassan (2006)	9 countries: Ghana and major world markets	1990-2003, Weekly	Cointegration and Error correction analysis	First moment return associations are modelled using cointegration and error correction analysis.	Preliminary results show Ghana is not co-integrated with any of the markets except Japan. However, an error correction model fails to validate this finding.
Hamavindu and Floros (2006)	2 countries: RSA and Namibia	1999-2003, Daily	Unit root tests, Johansen Cointegration tests and Univariate GARCH models	The returns are adjusted for thin trading to eliminate spurious serial correlation in index returns.	First moments of returns exhibit low correlations and with weak evidence of long run relationship. No evidence of volatility SE between Namibia and RSA.
Lamba and Otchere (2001)	9 developed countries, 7 African countries	1988-2000, Weekly	Vector Autoregressive (VAR) Model, Cointegration	The study analyses South Africa's return co-movements with several developed markets prior to and after the apartheid regime.	With the exception of RSA and Namibia, the authors record weak evidence of co-movement of African countries with overseas markets
Piesse and Hearn (2002)	3 Countries: RSA, Namibia and Botswana	1990-2000, Monthly	Cointegration and Autoregressive Distributed Lag (ADL) extension	First moment return co-movements are examined among the 3 markets to test the hypothesis of market integration.	There is significant evidence of a common stochastic trend driving the returns of Namibia and South Africa, which is stronger in Namibia, and 'spills over' into the more open RSA.
Piesse and Hearn (2005)	10 Sub-Saharan Countries	1993-2000, Daily	Univariate EGARCH spillover model	SE's are mapped by augmenting a single county's conditional volatility captured by an EGARCH model with another county's conditional volatility.	SE mainly between countries with strong trade links or sharing mechanisms for trade and settlement SE are mainly transmitted by RSA and Nigeria (largest markets) to other regional markets.
Pretorius and De Beer (2004)	2 Countries: RSA and Zimbabwe (currencies)	1996-1999, Daily	Univariate ARCH Models , Correlation Analysis	ARCH and correlation coefficients are used to examine contagion Rand and Zimbabwean Dollar volatility.	Significant volatility SE effects are detected in support of the contagion hypothesis through financial linkages, but not through bilateral trade linkages between the South African Rand and the Zimbabwean Dollar.
Samouilhan (2006)	2 Countries: RSA and UK	1996-2004, Daily	Univariate asymmetric volatility models (EGARCH)	First and second moment return associations are investigated between UK and RSA at broad and sector levels.	Significant volatility SE effects recorded with high/lower volatility in foreign markets associated with high/low domestic volatility. Causality in the SE was not addressed.
Samouilhan (2007)	2 countries: RSA and UK	1996-2004, Daily	Univariate volatility Models (GARCH)	An ICAPM that takes into account variance and covariance risk is used to determine the price of these two risks.	Significant volatility SE are detected such that increases in LSE volatility is associated with increased JSE volatility. Domestic (RSA) risk is priced more than foreign risk.

Study	Countries Covered	Period Covered and Frequency	Estimation Method	Methodological Issues	Summary of Findings
Yu and Hassan (2008)	13 countries: MENA and mature economies	1999-2005, Daily	Cointegration Tests, Univariate and Multivariate GARCH Models	First moment return interdependence is examined via cointegration while volatility SE by GARCH, Multivariate AR-EGARCH models	Evidence of stronger co-movement among Non-GCC <sup>54</sup> countries than with the mature markets, especially the US. While the US has significant volatility SE on most MENA countries, stronger volatility SE exist among the MENA countries.

**NOTES:** MENA Middle East and North Africa GCC Gulf Cooperation Council

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<sup>54</sup> These countries include Egypt, Jordan, Morocco, and Turkey.

## APPENDIX B

### EMPIRICAL RESULTS OF THE VOLATILITY SPILLOVER FRAMEWORK

Figure B-1

#### Estimated Conditional Regional and Global Market Covariances

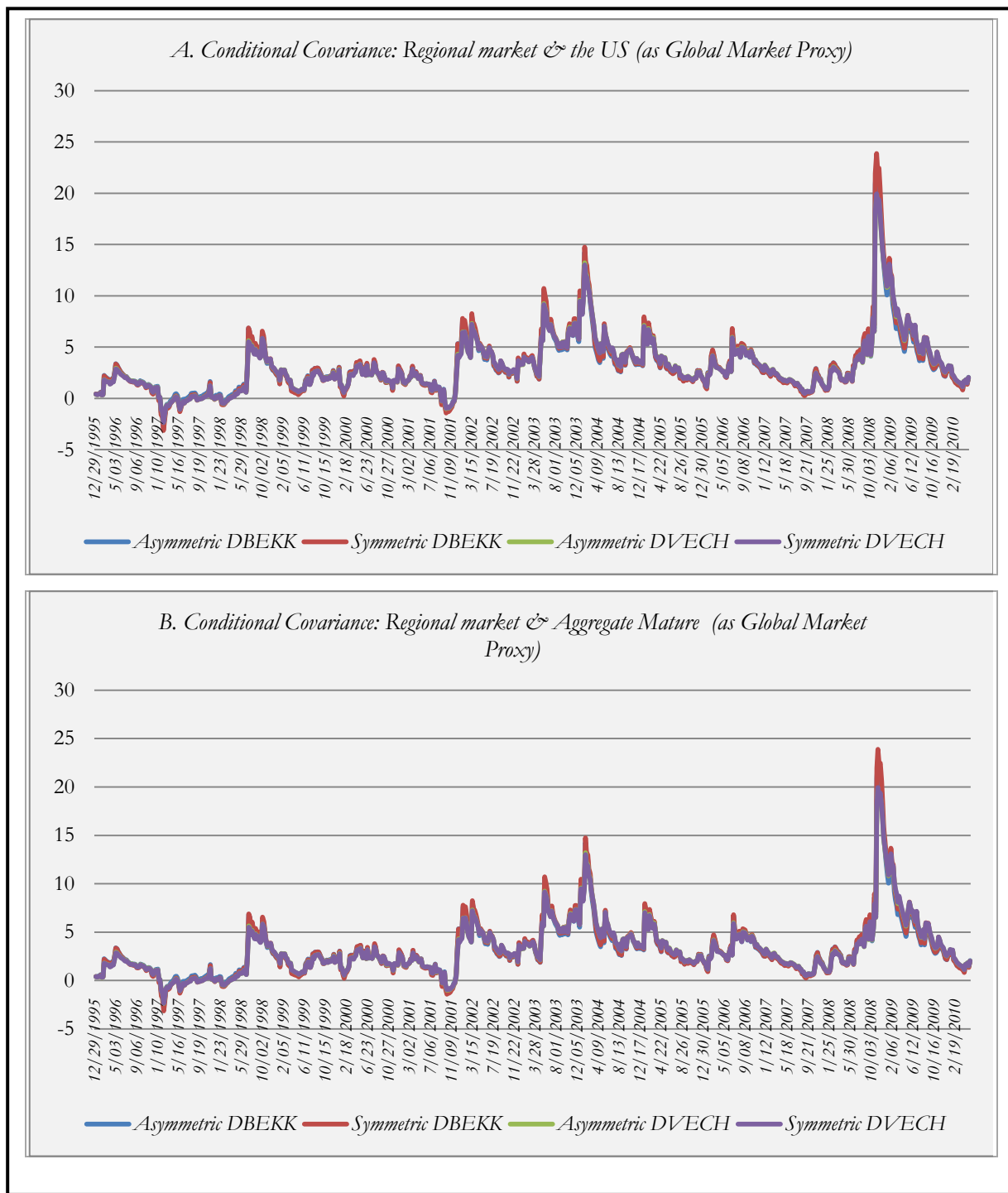


Figure B-1 (Continued)

**Estimated Conditional Regional and Global Market Covariances**

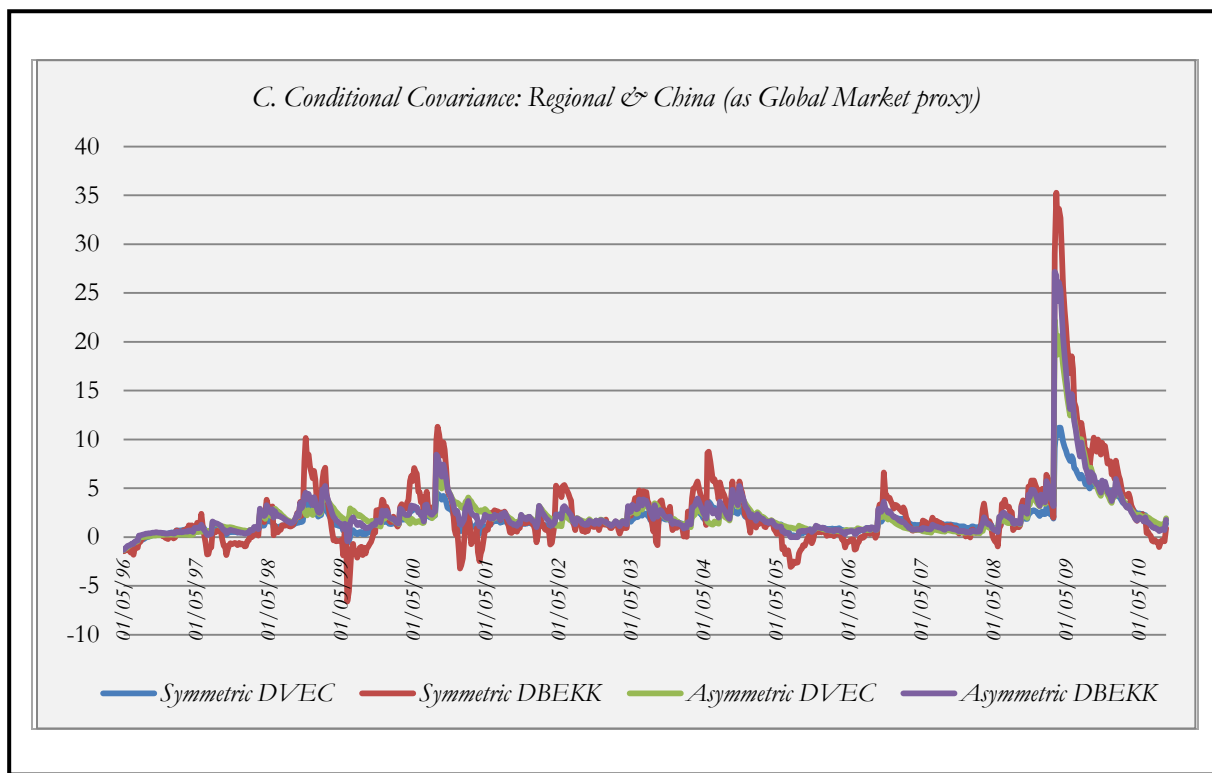


Figure B1 reports the conditional covariance of the regional and global markets as estimated by the different Bivariate GARCH specifications, for the Aggregate US global market proxy (A) and the Aggregate Mature global market proxy (B) and China (C).

Figure B-2

Estimated Regional and Global Market Conditional Variances

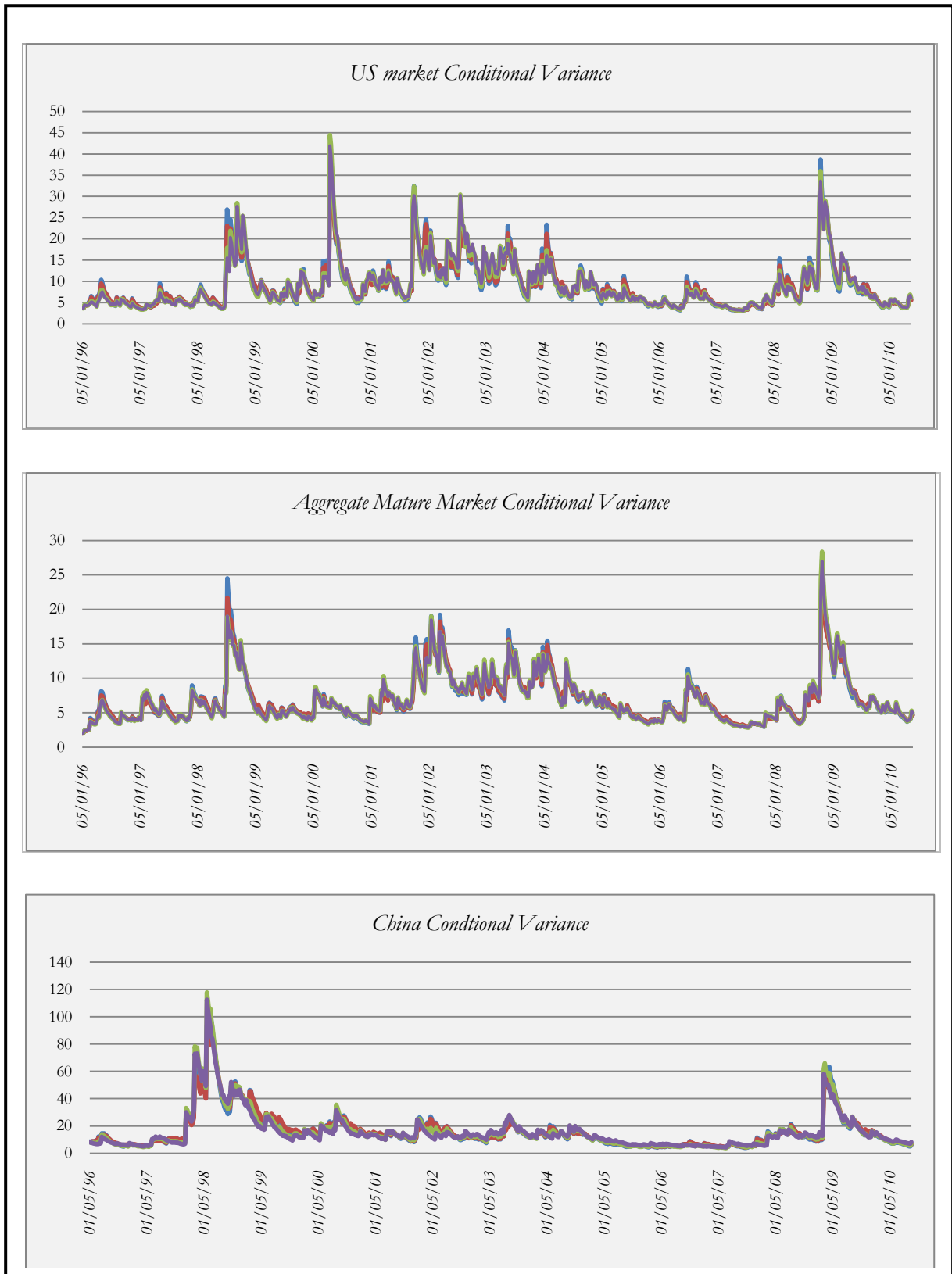


Figure B-2 (continued)

**Estimated Conditional Regional and Global Market Variances**

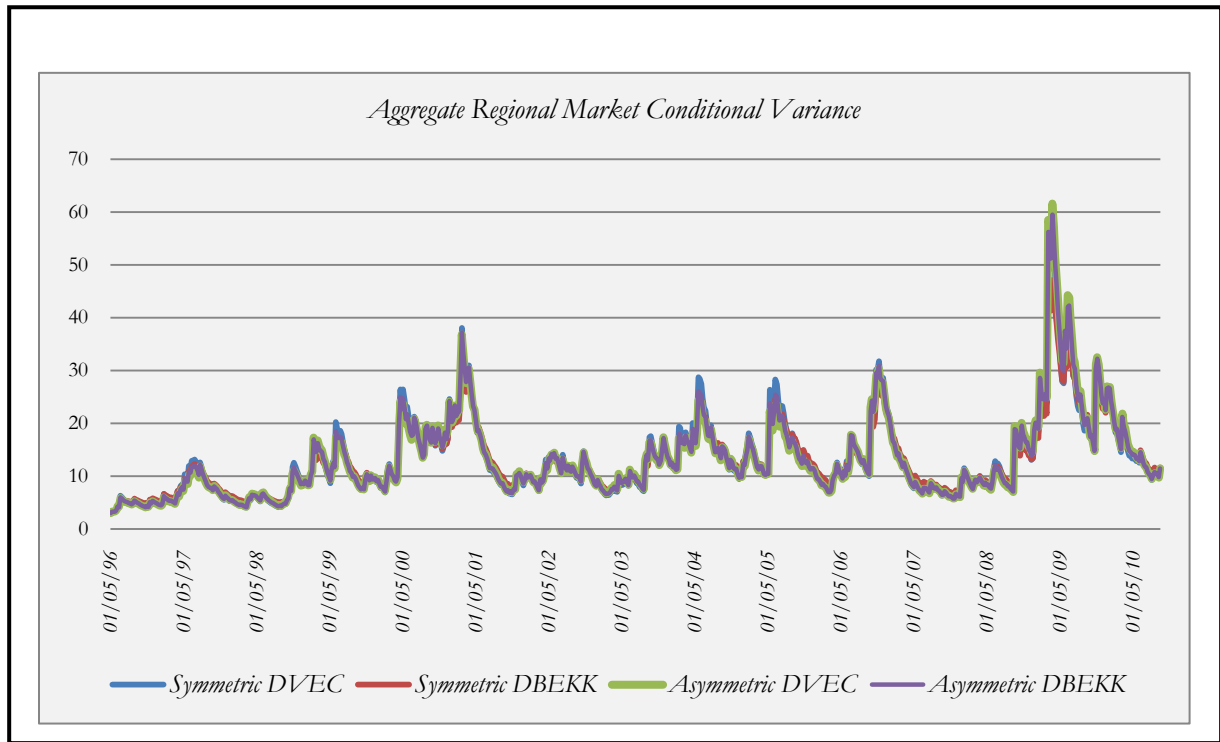


Figure B-2 plots the estimated conditional variances of the regional and global markets (US, aggregate mature and China) as estimated by the different bivariate GARCH specifications.

Table B-1

**Bivariate GARCH Model for the Regional and Global Market: US Global Market Proxy**

	RSA				EGYPT				NIGERIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.436*	0.343#	0.435	0.385	0.297#	0.312#	0.284#	0.322	0.297#	0.302#	0.287#	0.333
$c_{12}$	0.083	0.109#	0.063	0.106	0.047	0.101#	-0.011	0.090§	0.046	0.112#	-0.001	0.111§
$c_{22}$	0.389*	0.303*	0.359#	0.305*	0.339*	0.264#	0.302#	0.304§	0.424*	0.283*	0.277#	0.323§
$a_{11}$	0.134*	0.328*	0.083§	0.260*	0.094*	0.319*	0.059§	0.264*	0.090*	0.310*	0.062#	0.254*
$a_{12}$	0.047*	-	0.039	-	0.046*	-	-0.015	-	0.044*	-	-0.009	-
$a_{22}$	0.082*	0.248*	0.078	0.239*	0.079*	0.283*	0.007	0.145	0.080*	0.282*	-0.005*	0.128
$g_{11}$	0.822*	0.927*	0.829	0.921*	0.875*	0.932*	0.880*	0.928*	0.878*	0.935*	0.878*	0.929*
$g_{12}$	0.924*	-	0.924	-	0.935*	-	0.960*	-	0.939*	-	0.953*	-
$g_{22}$	0.890*	0.958*	0.893	0.955*	0.876*	0.942*	0.893*	0.938*	0.859*	0.940*	0.901*	0.935*
$l_{11}$	-	-	0.092	0.309	-	-	0.064	0.271	-	-	0.060	0.271
$l_{12}$	-	-	0.025	-	-	-	0.083	-	-	-	0.083	-
$l_{22}$	-	-	0.007	0.146	-	-	0.108	0.332	-	-	0.116	0.343§
AIC	10.092	10.101	10.088	10.092	9.513	9.517	9.464	9.491	9.419	9.429	9.368	9.398
SIC	10.184	10.181	10.192	10.184	9.605	9.597	9.569	9.584	9.511	9.509	9.473	9.491
J-B	67.553*	65.734*	78.137*	76.120*	97.019*	97.624*	93.047*	95.093*	96.981*	97.466*	87.752*	91.477*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Table B-1 (Continued)

**Bivariate GARCH Model for the Regional and Global Market: US Global Market Proxy**

	BOTSWANA				MAURITIUS				NAMIBIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.294#	0.298#	0.277#	0.327	0.294#	0.298#	0.277#	0.328	0.225#	0.292#	0.136#	0.244
$c_{12}$	0.051§	0.109#	0.000	0.106§	0.050§	0.109#	0.000	0.106§	0.055	0.173#	0.007	0.128
$c_{22}$	0.339*	0.249#	0.256#	0.285§	0.341*	0.250#	0.257#	0.286§	0.640#	0.373#	0.264*	0.332
$a_{11}$	0.089*	0.311*	0.057#	0.254*	0.089*	0.311*	0.057#	0.254	0.079*	0.308*	0.019	0.167
$a_{12}$	0.046*	-	-0.010	-	0.046*	-	-0.010	-	0.034*	-	-0.025	-
$a_{22}$	0.074*	0.276*	-0.007	0.138	0.074*	0.276*	-0.007	0.137	0.066*	0.252*	-0.027	0.057
$g_{11}$	0.879*	0.935*	0.884*	0.930*	0.879*	0.935*	0.884*	0.930*	0.895*	0.935*	0.915*	0.940*
$g_{12}$	0.936*	-	0.956*	-	0.936*	-	0.956*	-	0.947*	-	0.959*	-
$g_{22}$	0.874*	0.943*	0.906*	0.938*	0.874*	0.943*	0.906*	0.938*	0.829*	0.937*	0.923*	0.942*
$l_{11}$	-	-	0.058	0.271	-	-	0.058	0.271	-	-	0.103	0.361
$l_{12}$	-	-	0.080	-	-	-	0.080	-	-	-	0.108	-
$l_{22}$	-	-	0.111	0.328	-	-	0.111	0.328	-	-	0.112	0.315
AIC	9.347	9.354	9.299	9.328	9.350	9.357	9.302	9.331	9.340	9.351	9.271	9.310
SIC	9.440	9.434	9.404	9.420	9.443	9.437	9.407	9.423	9.460	9.455	9.406	9.430
J-B	95.502*	94.930*	88.566*	90.260*	96.025*	95.367*	88.941*	90.549*	72.281*	71.692*	57.829*	67.531*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports the QML estimates of the bivariate DVEC, DBEKK, AS-VEC and AS-BEKK models for the global and regional markets for the respective countries. (\*), (#) and (§) indicate statistical significance at 1%, 5% and 10% respectively. JB is the Jarque-Bera test of normality. AIC and SIC are the Akaike Information criterion and Schwarz information criteria, respectively. Associated P-values in parentheses.

Table B-2

**Bivariate GARCH Model for the Regional and Global Market: Aggregate Mature Market Proxy**

	RSA				EGYPT				NIGERIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.337#	0.290#	0.326	0.314	0.188§	0.286#	0.214#	0.275	0.194	0.267#	0.220#	0.273
$c_{12}$	0.041	0.094§	0.036	0.138#	0.047§	0.117*	0.038	0.113§	0.053	0.119*	0.042	0.122§
$c_{22}$	0.359#	0.334#	0.350#	0.366#	0.267*	0.244#	0.214*	0.263§	0.262*	0.237#	0.202#	0.263
$a_{11}$	0.087*	0.270*	0.063	0.251*	0.072*	0.302*	0.062§	0.256*	0.073*	0.301*	0.065§	0.257*
$a_{12}$	0.048*	-	0.043#	-	0.047*	-	0.027	-	0.053*	-	0.033	-
$a_{22}$	0.090*	0.294*	0.089*	0.301*	0.070*	0.284*	0.024	0.187	0.068*	0.280*	0.016	0.182§
$g_{11}$	0.865*	0.941*	0.867*	0.935*	0.905*	0.934*	0.896*	0.935*	0.903*	0.936*	0.893*	0.935*
$g_{12}$	0.936*	-	0.938*	-	0.939*	-	0.931*	-	0.931	-	0.926*	-
$g_{22}$	0.886*	0.945*	0.888*	0.940*	0.893*	0.942*	0.903*	0.939*	0.893*	0.943*	0.909*	0.939*
$l_{11}$	-	-	0.047	0.193	-	-	0.033	0.221	-	-	0.030	0.223
$l_{12}$	-	-	0.008	-	-	-	0.051	-	-	-	0.050	-
$l_{22}$	-	-	0.001	-0.037	-	-	0.080	0.298	-	-	0.083	0.300
AIC	9.841	9.845	9.842	9.844	9.184	9.189	9.166	9.175	9.071	9.082	9.053	9.065
SIC	9.934	9.925	9.947	9.936	9.276	9.269	9.271	9.267	9.164	9.162	9.158	9.158
J-B	121.11*	124.48*	134.70*	135.19*	288.90*	349.93*	244.70*	282.03*	272.18*	329.45*	227.52*	254.94*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Table B-2 (Continued)

**Bivariate GARCH Model for the Regional and Global Market: Aggregate Mature Market Proxy**

	BOTSWANA				MAURITIUS				NAMIBIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.179§	0.251#	0.257	0.257	0.178§	0.251	0.199	0.257	0.165§	0.231§	0.177	0.222
$c_{12}$	0.051§	0.113*	0.113	0.113§	0.050§	0.112*	0.037	0.113§	0.089§	0.159*	0.098	0.182§
$c_{22}$	0.228*	0.206#	0.226	0.226	0.229*	0.206	0.181	0.226	0.324*	0.258#	0.251#	0.328
$a_{11}$	0.071*	0.297*	0.066	0.257*	0.071*	0.297*	0.062§	0.257*	0.063#	0.277*	0.041	0.188
$a_{12}$	0.051*	-	0.050	-	0.051*	-	0.032	-	0.038*	-	0.013	-
$a_{22}$	0.064*	0.275*	0.037	0.193§	0.064*	0.275*	0.018	0.193	0.047#	0.221*	0.011	0.070
$g_{11}$	0.908*	0.939*	0.878*	0.937*	0.908*	0.939*	0.900*	0.937*	0.916*	0.945*	0.907*	0.945*
$g_{12}$	0.934*	-	0.882*	-	0.935*	-	0.931*	-	0.940*	-	0.928*	-
$g_{22}$	0.900*	0.945*	0.886*	0.941*	0.900*	0.945*	0.913*	0.941*	0.898*	0.953*	0.909*	0.944*
$l_{11}$	-	-	0.047	0.216	-	-	0.029	0.216	-	-	0.776	0.283
$l_{12}$	-	-	0.060	-	-	-	0.046	-	-	-	0.653	-
$l_{22}$	-	-	0.079	0.280	-	-	0.073	0.280	-	-	0.512	0.297
AIC	8.989	8.998	8.986	8.986	8.993	9.002	8.977	8.990	8.877	8.888	8.861	8.864
SIC	9.081	9.078	9.078	9.078	9.085	9.082	9.081	9.082	8.996	8.992	8.997	8.984
J-B	269.433*	319.906*	257.184*	257.184*	272.520*	323.297*	227.597*	259.215*	110.812*	149.278*	103.309*	125.241*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports the QML estimates of the bivariate DVEC, DBEKK, AS-VEC and AS-BEKK models for the global and regional markets for the respective countries. (\*), (#) and (§) indicate statistical significance at 1%, 5% and 10% respectively. JB is the Jarque-Bera test of normality. AIC and SIC are the Akaike Information criterion, and Schwarz information criteria, respectively. Associated P-values in parentheses.

Table B-3

**Bivariate GARCH Model for the Regional and Global Market: China as Proxy**

	RSA				EGYPT				NIGERIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.236#	0.216#	0.255	0.310	0.241#	0.189#	0.243#	0.225§	0.213	0.157#	0.192§	0.198§
$c_{12}$	0.049§	0.041	0.021	0.046	0.351	0.049	0.323	0.063	0.350	0.055	0.001	0.055
$c_{22}$	0.345#	0.326#	0.333	0.333§	0.410*	0.518*	0.525§	0.527	0.477*	0.608#	0.578§	0.539
$a_{11}$	0.097*	0.281*	0.045	0.060	0.096*	0.286*	0.094*	0.308*	0.094*	0.278*	0.094*	0.304*
$a_{12}$	0.019	-	-0.003	-	0.080	-	0.076	-	0.086	-	0.014	-
$a_{22}$	0.091*	0.255*	0.068	0.277*	0.106*	0.330*	0.013	0.107	0.107*	0.336*	-0.007	0.098
$g_{11}$	0.892*	0.954*	0.899*	0.959*	0.887*	0.952*	0.888*	0.942*	0.890*	0.956*	0.891*	0.944*
$g_{12}$	0.948*	-	0.926*	-	0.522	-	0.559#	-	0.505§	-	0.940*	-
$g_{22}$	0.886*	0.955*	0.892*	0.944*	0.844*	0.911*	0.839	0.913*	0.828*	0.899*	0.824*	0.908*
$l_{11}$	-	-	0.082	0.060	-	-	0.000	0.062	-	-	0.005	0.077
$l_{12}$	-	-	0.053	-	-	-	0.004	-	-	-	0.031	-
$l_{22}$	-	-	0.035	0.277	-	-	0.150	0.408§	-	-	0.194	0.414§
AIC	10.674	10.691	10.660	10.664	9.993	10.016	9.972	9.970	9.890	9.913	9.866	9.862
SIC	10.766	10.771	10.765	10.757	10.085	10.096	10.077	10.062	9.983	9.993	9.970	9.954
J-B	328.31*	225.32*	264.56*	258.69*	157.48*	189.02*	104.87*	106.67*	95.11*	194.04*	92.49*	93.27*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

Table B-3 (Continued)

**Bivariate GARCH Model for the Regional and Global Market: China as Proxy**

	BOTSWANA				MAURITIUS				NAMIBIA			
	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK	DVEC	DBEKK	AS_DVEC	AS_DBEKK
$c_{11}$	0.219#	0.162#	0.196§	0.199§	0.220	0.163	0.197§	0.200§	0.368#	0.289#	0.357#	0.392#
$c_{12}$	0.340	0.045	0.005	0.051	0.341	0.046	0.006	0.052	0.179	0.149#	0.091	0.169#
$c_{22}$	0.390*	0.483#	0.486	0.465	0.393*	0.485	0.486	0.466	0.722#	0.882#	0.756	0.738
$a_{11}$	0.097*	0.282*	0.096*	0.308*	0.097*	0.282*	0.096*	0.308*	0.089#	0.256*	0.089#	0.301*
$a_{12}$	0.081	-	0.016	-	0.081	-	0.017	-	0.050	-	0.046	-
$a_{22}$	0.104*	0.324*	0.000	0.099	0.103*	0.324*	0.000	0.099	0.106#	0.323*	-0.026	0.135
$g_{11}$	0.887*	0.954*	0.888*	0.943*	0.887*	0.954*	0.889*	0.943*	0.864*	0.947*	0.865*	0.926*
$g_{12}$	0.516	-	0.935*	-	0.514	-	0.933*	-	0.819*	-	0.880*	-
$g_{22}$	0.841*	0.910*	0.834*	0.914*	0.841*	0.910*	0.835*	0.914*	0.784*	0.873*	0.801*	0.884*
$l_{11}$	-	-	0.005	0.078	-	-	0.005	0.078	-	-	0.000	0.020
$l_{12}$	-	-	0.030	-	-	-	0.030	-	-	-	0.003	-
$l_{22}$	-	-	0.181	0.407§	-	-	0.179	0.406	-	-	0.203	0.400
AIC	9.830	9.853	9.806	9.802	9.833	9.855	9.810	9.805	9.584	9.588	9.552	9.552
SIC	9.922	9.933	9.911	9.894	9.925	9.935	9.914	9.897	9.736	9.723	9.720	9.703
J-B	139.300*	182.323*	87.846*	86.650*	142.039*	184.248*	89.856*	88.791*	44.024*	54.521*	17.082*	22.481*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]

The table reports the QML estimates of the bivariate DVEC, DBEKK, AS-VEC and AS-BEKK models for the global and regional markets for the respective countries. (\*), (#) and (§) indicate statistical significance at 1%, 5% and 10% respectively. JB is the Jarque-Bera test of normality. AIC and SIC are the Akaike Information criterion, and Schwarz information criteria, respectively. Associated P-values in parentheses.

Table B-4

## Bivariate GARCH Model Diagnostics: US Market as Global Market Proxy

## Panel: A

		S. Africa				Egypt				Nigeria			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	0.052	0.068	0.112	0.129	0.045	0.055	0.145	0.114	0.040	0.053	0.122	0.103
		[0.560]	[0.449]	[0.208]	[0.150]	[0.617]	[0.536]	[0.106]	[0.202]	[0.657]	[0.555]	[0.172]	[0.247]
Skewness	$\hat{z}_{reg}$	-0.061	-0.035	-0.061	-0.024	-0.820	-0.870	-0.696	-0.761	-0.791	-0.837	-0.652	-0.681
		[0.494]	[0.699]	[0.495]	[0.788]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	4.217	4.150	4.486	4.481	4.080	3.967	4.408	4.357	4.159	4.063	4.401	4.462
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	3.997	4.073	3.996	4.031	5.172	5.350	4.578	4.852	5.047	5.200	4.449	4.667
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	11.749	12.094	12.017	12.291	12.669	12.361	12.479	12.267	12.601	12.339	12.414	12.330
		[0.466]	[0.438]	[0.444]	[0.423]	[0.394]	[0.417]	[0.408]	[0.424]	[0.399]	[0.419]	[0.413]	[0.420]
$Q(12)$	$\hat{z}_{reg}$	12.905	12.359	12.280	12.151	10.406	11.192	8.009	8.932	11.823	13.246	8.819	9.923
		[0.376]	[0.417]	[0.423]	[0.434]	[0.580]	[0.513]	[0.784]	[0.709]	[0.460]	[0.351]	[0.718]	[0.623]
$Q^2(12)$	$\hat{z}_g$	9.031	11.225	9.894	11.605	13.932	13.033	16.087	13.361	13.969	12.286	15.037	13.328
		[0.700]	[0.510]	[0.625]	[0.478]	[0.305]	[0.367]	[0.187]	[0.343]	[0.303]	[0.423]	[0.239]	[0.346]
$Q^2(12)$	$\hat{z}_{reg}$	10.046	13.445	9.421	11.538	7.434	11.110	6.444	7.889	6.922	10.282	6.736	6.568
		[0.612]	[0.338]	[0.667]	[0.483]	[0.828]	[0.520]	[0.892]	[0.794]	[0.863]	[0.591]	[0.875]	[0.885]
AIC		10.092	10.101	<b>10.088</b>	10.092	9.513	9.517	<b>9.464</b>	9.491	9.419	9.428	<b>9.368</b>	9.398
BIC		10.184	<b>10.181</b>	10.192	10.184	9.605	9.597	<b>9.569</b>	9.584	9.511	9.508	<b>9.473</b>	9.491

## Panel: B

		Botswana				Mauritius				Namibia			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	0.041	0.056	0.121	0.105	0.041	0.056	0.122	0.106	-0.040	-0.021	0.067	0.030
		[0.649]	[0.532]	[0.174]	[0.240]	[0.649]	[0.531]	[0.174]	[0.2373]	[0.704]	[0.846]	[0.527]	[0.780]
Skewness	$\hat{z}_{reg}$	-0.780	-0.818	-0.641	-0.674	-0.783	-0.821	-0.645	-0.677	-0.829	-0.898	-0.731	-0.858
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	4.161	4.059	4.440	4.447	4.160	4.057	4.437	4.445	4.067	3.902	4.176	4.253
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	4.975	5.098	4.379	4.611	4.992	5.115	4.391	4.622	4.362	4.663	3.989	4.476
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	12.635	12.366	12.571	12.376	12.646	12.372	12.573	12.377	11.881	11.618	12.192	10.780
		[0.396]	[0.417]	[0.401]	[0.416]	[0.395]	[0.416]	[0.401]	[0.416]	[0.455]	[0.477]	[0.430]	[0.548]
$Q(12)$	$\hat{z}_{reg}$	13.016	13.343	9.747	10.827	12.971	13.286	9.712	13.555	7.546	8.212	6.868	6.434
		[0.368]	[0.345]	[0.638]	[0.544]	[0.371]	[0.349]	[0.641]	[0.330]	[0.819]	[0.768]	[0.866]	0.893
$Q^2(12)$	$\hat{z}_g$	14.180	13.315	16.175	13.577	14.171	13.290	16.163	10.793	9.257	8.428	7.551	6.048
		[0.289]	[0.347]	[0.183]	[0.329]	[0.290]	[0.348]	[0.184]	[0.547]	[0.681]	[0.751]	[0.819]	[0.914]
$Q^2(12)$	$\hat{z}_{reg}$	8.770	11.519	7.972	8.290	8.687	11.437	7.861	8.209	7.088	13.090	15.178	11.359
		[0.722]	[0.485]	[0.787]	[0.762]	[0.729]	[0.492]	[0.796]	[0.769]	[0.852]	[0.363]	[0.232]	[0.498]
AIC		9.347	9.354	9.299	<b>9.328</b>	9.350	9.357	<b>9.302</b>	9.331	9.340	9.351	<b>9.271</b>	9.310
SIC		9.440	9.434	<b>9.404</b>	9.420	9.443	9.437	<b>9.406</b>	9.423	9.460	9.455	<b>9.406</b>	9.430

The table reports standardised residual diagnostics from the Diagonal VEC (DVEC), Diagonal BEKK (BEKK), Asymmetric Diagonal VEC (ASVEC) and Asymmetric Diagonal BEKK (AS-BEKK) models for the respective markets with the USA as the global market proxy.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual  $Z_{i,t}$  and standardised squared residual  $Z_{i,t}^2$  respectively (for  $i=g, reg$ ). Associated p-values are displayed in parentheses [·]. AIC and SIC are the Akaike Information criteria, and Schwarz information criteria, respectively. The minimum AIC and SIC are in bold.

Table B-5

**Bivariate GARCH Model Diagnostics: Aggregate Mature as Global Market Proxy****Panel: A**

		S. Africa				Egypt				Nigeria			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	0.064	0.075	0.121	0.116	0.071	0.048	0.135	0.080	0.066	0.048	0.121	0.068
		[0.472]	[0.399]	[0.175]	0.195	[0.425]	[0.589]	[0.130]	[0.368]	[0.458]	[0.588]	[0.175]	0.446
Skewness	$\hat{z}_{reg}$	0.037	0.045	0.032	0.040	-0.671	-0.722	-0.563	-0.620	-0.626	-0.721	-0.514	-0.580
		[0.678]	[0.612]	[0.723]	0.655	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	4.384	4.379	4.492	4.482	4.429	4.231	4.416	4.417	4.463	4.279	4.429	4.470
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	3.909	3.895	3.946	3.915	4.926	5.299	4.576	4.824	4.786	5.222	4.439	4.653
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	6.867	6.985	7.130	7.131	9.609	9.225	9.831	9.574	9.404	9.131	9.597	9.414
		[0.866]	[0.859]	[0.849]	[0.849]	[0.650]	[0.684]	[0.631]	[0.653]	[0.668]	[0.692]	[0.651]	[0.667]
$Q(12)$	$\hat{z}_{reg}$	10.262	9.794	10.264	10.349	12.077	13.781	10.320	12.911	14.025	16.305	12.119	16.091
		[0.593]	[0.634]	[0.593]	[0.585]	[0.440]	[0.315]	[0.588]	[0.376]	[0.299]	[0.178]	[0.436]	[0.187]
$Q^2(12)$	$\hat{z}_g$	17.347	17.955	17.187	17.161	15.367	14.249	15.313	14.624	15.892	14.921	15.754	15.101
		[0.137]	[0.117]	[0.143]	[0.144]	[0.222]	[0.285]	[0.225]	[0.263]	[0.196]	[0.246]	[0.203]	[0.236]
$Q^2(12)$	$\hat{z}_{reg}$	6.474	6.296	6.086	6.067	11.046	11.189	8.637	8.166	11.908	13.826	10.065	9.629
		[0.890]	[0.900]	[0.912]	[0.913]	[0.525]	[0.513]	[0.734]	[0.772]	[0.453]	[0.312]	[0.610]	0.649
AIC		9.805	<b>9.802</b>	9.807	9.803	<b>9.174</b>	9.176	9.151	9.165	9.065	9.077	<b>9.040</b>	9.061
BIC		9.897	<b>9.882</b>	9.911	9.896	9.266	<b>9.256</b>	9.256	9.258	9.157	9.157	<b>9.145</b>	9.153

**Panel: B**

		Botswana				Mauritius				Namibia			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	0.021	-0.007	0.061	0.061	0.021	-0.007	0.082	0.062	-0.182	-0.171	-0.132	-0.126
		[0.817]	[0.936]	[0.494]	[0.494]	[0.818]	[0.938]	[0.359]	[0.489]	[0.085]	[0.106]	[0.213]	[0.233]
Skewness	$\hat{z}_{reg}$	-0.724	-0.786	-0.677	-0.677	-0.729	-0.790	-1.166	-0.680	-0.672	-0.746	-0.688	-0.719
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	4.584	4.451	4.632	4.632	4.582	4.450	4.883	4.631	4.254	4.124	4.148	4.198
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	5.000	5.376	4.925	4.925	5.020	5.394	9.319	4.939	4.200	4.751	4.156	4.425
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	6.191	5.967	6.402	6.402	6.201	5.977	8.121	6.415	6.601	6.633	6.778	7.044
		[0.906]	[0.918]	[0.894]	[0.894]	[0.906]	[0.917]	[0.776]	[0.894]	[0.883]	[0.881]	[0.872]	[0.855]
$Q(12)$	$\hat{z}_{reg}$	15.365	18.560	17.910	17.910	15.335	18.533	12.486	17.881	7.293	7.973	7.333	8.486
		[0.222]	[0.100]	[0.118]	[0.118]	[0.224]	[0.100]	[0.407]	[0.119]	[0.838]	[0.787]	[0.835]	[0.746]
$Q^2(12)$	$\hat{z}_g$	14.723	13.573	15.182	15.182	14.734	13.586	15.721	15.212	8.168	7.426	5.868	5.572
		[0.257]	[0.329]	[0.232]	[0.232]	[0.256]	[0.328]	[0.204]	[0.230]	[0.772]	[0.828]	[0.923]	[0.936]
$Q^2(12)$	$\hat{z}_{reg}$	13.757	11.559	10.383	10.383	13.645	11.449	9.307	10.256	8.746	11.363	8.073	8.019
		[0.317]	[0.482]	[0.582]	[0.582]	[0.324]	[0.491]	[0.677]	[0.594]	[0.724]	[0.498]	[0.779]	[0.784]
AIC		8.989	8.999	8.986	<b>8.986</b>	8.993	9.003	8.970	<b>8.990</b>	8.830	8.853	<b>8.812</b>	8.837
SIC		9.081	9.079	<b>9.079</b>	9.079	9.085	9.083	<b>9.074</b>	9.082	8.950	8.957	<b>8.948</b>	8.957

The table reports standardised residual diagnostics from the Diagonal VEC (DVEC), Diagonal BEKK (BEKK), Asymmetric Diagonal VEC (ASVEC) and Asymmetric Diagonal BEKK (AS-BEKK) Models for the respective markets with aggregate mature as the global market proxy.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual  $Z_{it}$  and standardised squared residual  $Z_{it}^2$  respectively, (for  $i=g, reg$ ). Associated p-values are displayed in parentheses [.]. AIC and SIC are the Akaike Information criteria, and Schwarz information criteria, respectively. The minimum AIC and SIC are in bold.

Table B-6

**Bivariate GARCH Model Diagnostics: Aggregate China as Global Market Proxy****Panel: A**

		S. Africa				Egypt				Nigeria			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	-0.691	-0.689	-0.595	-0.593	-0.251	-0.276	-0.245	-0.248	-0.256	-0.282	-0.277	-0.253
		[0.000]	[0.000]	[0.000]	[0.000]	[0.005]	[0.002]	[0.006]	[0.006]	[0.004]	[0.002]	[0.002]	[0.005]
Skewness	$\hat{z}_{reg}$	0.084	0.062	0.128	0.099	-0.649	-0.662	-0.507	-0.506	-0.622	-0.644	-0.446	-0.450
		[0.346]	[0.485]	[0.152]	[0.266]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	5.768	5.526	5.482	5.451	4.017	3.899	4.013	4.015	3.947	3.868	3.953	3.963
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	3.944	3.906	3.903	3.900	4.437	4.781	4.028	4.053	4.464	4.863	3.973	3.993
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	5.316	5.356	5.800	6.220	3.152	3.310	3.183	3.326	2.800	2.845	3.012	2.958
		[0.947]	[0.945]	[0.926]	[0.905]	[0.994]	[0.993]	[0.994]	[0.993]	[0.997]	[0.997]	[0.995]	[0.996]
$Q(12)$	$\hat{z}_{reg}$	14.290	14.205	14.446	14.202	9.457	9.003	8.738	8.590	11.542	11.793	11.712	11.012
		[0.283]	[0.288]	[0.273]	[0.288]	[0.663]	[0.703]	[0.725]	[0.737]	[0.483]	[0.462]	[0.469]	[0.528]
$Q^2(12)$	$\hat{z}_g$	7.143	7.880	6.466	9.265	15.069	16.481	15.185	14.554	16.695	18.712	15.895	15.940
		[0.909]	[0.794]	[0.891]	[0.680]	[0.238]	[0.170]	[0.231]	[0.267]	[0.161]	[0.096]	[0.196]	[0.194]
$Q^2(12)$	$\hat{z}_{reg}$	7.982	8.375	8.480	7.417	9.496	20.557	8.197	8.698	11.218	20.702	9.962	10.344
		[0.787]	[0.755]	[0.747]	[0.829]	[0.660]	[0.057]	[0.770]	[0.729]	[0.510]	[0.055]	[0.619]	[0.586]
AIC		10.674	10.691	<b>10.660</b>	10.664	9.993	<b>10.016</b>	9.972	9.970	9.890	9.913	9.866	<b>9.862</b>
BIC		10.766	10.771	10.765	<b>10.757</b>	10.085	10.096	10.077	<b>10.062</b>	9.983	9.993	9.970	<b>9.954</b>

**Panel: B**

		Botswana				Mauritius				Namibia			
		DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK	DVEC	BEKK	ASVEC	ASBEK
Skewness	$\hat{z}_g$	-0.262	-0.293	-0.286	-0.263	-0.264	-0.294	-0.286	-0.265	-0.099	-0.119	-0.108	-0.085
		0.003	[0.001]	[0.001]	[0.003]	[0.003]	[0.001]	[0.001]	[0.003]	[0.349]	[0.260]	[0.3054]	[0.424]
Skewness	$\hat{z}_{reg}$	-0.587	-0.619	-0.419	-0.418	-0.591	-0.622	-0.422	-0.422	-0.594	-0.627	-0.396	-0.457
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_g$	3.957	3.875	3.968	3.976	3.970	3.887	3.981	3.989	3.206	3.216	3.244	3.229
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
Kurtosis	$\hat{z}_{reg}$	4.372	4.784	3.919	3.917	4.386	4.790	3.932	3.930	3.764	4.006	3.311	3.428
		[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]
$Q(12)$	$\hat{z}_g$	2.628	2.700	2.837	2.802	2.624	2.694	2.833	2.799	10.821	11.126	11.094	10.881
		[0.998]	[0.997]	[0.997]	[0.997]	[0.998]	[0.997]	[0.997]	[0.997]	[0.544]	[0.518]	[0.521]	[0.539]
$Q(12)$	$\hat{z}_{reg}$	11.762	12.057	11.799	11.257	11.824	12.106	11.778	11.288	7.729	7.481	7.242	7.396
		[0.465]	0.441	[0.462]	[0.507]	[0.460]	[0.437]	[0.464]	[0.504]	[0.806]	[0.824]	[0.841]	[0.830]
$Q^2(12)$	$\hat{z}_g$	15.409	17.233	14.668	14.661	15.471	17.261	14.733	14.729	10.543	11.842	10.556	10.504
		[0.220]	[0.141]	[0.260]	[0.261]	[0.217]	[0.140]	[0.256]	[0.257]	[0.568]	[0.458]	[0.567]	[0.572]
$Q^2(12)$	$\hat{z}_{reg}$	12.263	20.452	11.444	11.807	12.050	20.204	11.290	11.633	13.606	14.920	13.941	14.383
		[0.425]	[0.059]	[0.491]	[0.461]	[0.442]	0.063	[0.504]	[0.476]	[0.327]	[0.246]	[0.304]	[0.277]
AIC		9.830	9.853	9.806	<b>9.802</b>	9.833	9.855	9.810	<b>9.805</b>	9.584	9.588	<b>9.552</b>	<b>9.552</b>
SIC		9.922	9.933	<b>9.911</b>	9.894	9.925	9.935	<b>9.914</b>	9.897	9.736	9.723	9.720	<b>9.703</b>

The table reports standardised residual diagnostics from the Diagonal VEC (DVEC), Diagonal BEKK (BEKK), Asymmetric Diagonal VEC (ASVEC) and Asymmetric Diagonal BEKK (AS\_BEKK) Models for the respective markets with China as the global market proxy.  $Q(12)$  and  $Q^2(12)$  are the Ljung-Box tests for 12<sup>th</sup> order serial correlation in the standardised residual  $Z_{i,t}$  and standardised squared residual  $Z_{i,t}^2$ , respectively, (for  $i=g, reg$ ). Associated p-values are displayed in parentheses [.]. AIC and SIC are the Akaike Information criteria, and Schwarz information criteria, respectively. The minimum AIC and SIC are in bold.

Table B-7

**Volatility Model Selection: US Market Proxy (Constant Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.402* [0.002]	0.711# [0.025]	0.282* [0.010]	0.586# [0.022]	0.148 [0.133]	-0.022* [0.000]	0.456* [0.000]	0.709# [0.022]	0.458# [0.025]	0.671* [0.002]	0.079 [0.192]	0.032# [0.013]
$\varphi_{i,1}$	0.842* [0.000]	0.872* [0.000]	0.912* [0.000]	0.864* [0.000]	0.904* [0.000]	0.943* [0.000]	0.847* [0.000]	0.872* [0.000]	0.872* [0.000]	0.843* [0.000]	0.931* [0.000]	0.873* [0.000]
$\varphi_{i,2}$	0.104* [0.000]	0.089* [0.000]	0.071* [0.001]	0.083 [0.296]	0.073# [0.018]	0.066# [0.012]	0.038 [0.129]	0.090* [0.006]	0.140* [0.000]	0.157 [0.203]	0.097* [0.007]	0.103* [0.000]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.094# [0.001]	-0.002 [0.974]	-0.075 [0.102]	-0.169 [0.185]	-0.078# [0.027]	0.119* [0.001]
$\varphi_{i,1} + \varphi_{i,2}$	<i>0.946</i>	<i>0.961</i>	<i>0.983</i>	<i>0.947</i>	<i>0.978</i>	<i>1.010</i>	<i>0.885</i>	<i>0.962</i>	<i>1.011</i>	<i>1.000</i>	<i>1.028</i>	<i>0.976</i>
ARCH (5)	0.157 [0.978]	0.827 [0.530]	0.272 [0.929]	1.343 [0.244]	0.591 [0.709]	2.277# [0.047]	0.263 [0.934]	0.822 [0.534]	0.214 [0.957]	1.410 [0.218]	0.615 [0.688]	1.498 [0.189]
AIC	4.736	5.614	5.380	4.906	4.609	4.990	4.729	5.617	5.381	4.909	4.598	4.992
SIC	4.792	5.669	5.440	4.962	4.664	5.062	4.791	5.678	5.442	4.871	4.659	5.072
Selection		***	***	***	***		***					***

(\*), (#) and (§) significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses [.]. (\*\*\*) indicates the model selected for each country. ARCH ( $q$ ) is the  $q$ th order Engle's LM test for conditional heteroskedasticity.

Table B-8

**Volatility Model Selection: Aggregate Mature Global Market Proxy (Constant Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.200§ [0.090]	0.868# [0.025]	0.521* [0.007]	0.208§ [0.060]	0.209§ [0.086]	0.013 [0.681]	0.223* [0.006]	0.864# [0.020]	0.511# [0.016]	0.615* [0.002]	0.110 [0.167]	0.015 [0.703]
$\varphi_{i,1}$	0.885* [0.000]	0.865* [0.000]	0.840* [0.000]	0.974* [0.000]	0.893* [0.000]	0.897* [0.000]	0.890* [0.000]	0.865* [0.000]	0.841* [0.000]	0.854* [0.000]	0.926* [0.000]	0.878* [0.000]
$\varphi_{i,2}$	0.087* [0.002]	0.084* [0.004]	0.133* [0.000]	0.001 [0.806]	0.075 [0.026]	0.124* [0.006]	0.024 [0.595]	0.085# [0.024]	0.203* [0.000]	0.152 [0.209]	0.091# [0.014]	0.095 [0.175]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.100§ [0.088]	-0.002 [0.973]	-0.131# [0.025]	-0.163 0.196	-0.067§ [0.053]	0.127§ 0.066
$\varphi_{i,1} + \varphi_{i,2}$	0.972	0.949	0.973	0.975	0.968	1.021	0.914	0.950	1.043	1.006	1.017	0.973
ARCH (5)	0.598 [0.845]	0.572 [0.866]	0.429 [0.952]	1.255 [0.241]	1.283 [0.223]	1.238 [0.253]	0.656 [0.794]	0.571 [0.866]	0.385 [0.969]	0.665 [0.786]	1.155 [0.312]	1.073 0.381
AIC	4.640	5.581	5.369	4.911	4.633	4.991	4.626	5.584	5.358	4.865	4.626	4.983
SIC	4.696	5.637	5.425	4.967	4.689	5.062	4.688	5.645	5.419	4.926	4.687	5.063
Selection		***	***	***	***		***					***

(\*), (#) and (§) significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses [.]. (\*\*\*) indicates the model selected for each country. ARCH ( $q$ ) is the  $q$ th order Engle's LM test for conditional heteroskedasticity.

Table B-9

**Volatility Model Selection: China as Global Market Proxy (Constant Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.200§ [0.090]	0.868# [0.025]	0.521* [0.007]	0.208§ [0.060]	0.209§ [0.086]	0.013 [0.681]	0.223* [0.006]	0.864# [0.020]	0.511# [0.016]	0.615* [0.002]	0.110 [0.167]	0.015 [0.703]
$\varphi_{i,1}$	0.885* [0.000]	0.865* [0.000]	0.840* [0.000]	0.974* [0.000]	0.893* [0.000]	0.897* [0.000]	0.890* [0.000]	0.865* [0.000]	0.841* [0.000]	0.854* [0.000]	0.926* [0.000]	0.878* [0.000]
$\varphi_{i,2}$	0.087* [0.002]	0.084* [0.004]	0.133* [0.000]	0.001 [0.806]	0.075 [0.026]	0.124* [0.006]	0.024 [0.595]	0.085# [0.024]	0.203* [0.000]	0.152 [0.209]	0.091# [0.014]	0.095 [0.175]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.100§ [0.088]	-0.002 [0.973]	-1.131# [0.025]	-0.163 0.196	-0.067§ [0.053]	0.127§ 0.066
$\varphi_{i,1} + \varphi_{i,2}$	0.972	0.949	0.973	0.975	0.968	1.021	0.914	0.950	1.043	1.006	1.017	0.973
ARCH (5)	0.598 [0.845]	0.572 [0.866]	0.429 [0.952]	1.255 [0.241]	1.283 [0.223]	1.238 [0.253]	0.656 [0.794]	0.571 [0.866]	0.385 [0.969]	0.665 [0.786]	1.155 [0.312]	1.073 0.381
AIC	4.640	5.581	5.369	4.911	4.633	4.991	4.626	5.584	5.358	4.865	4.626	4.983
SIC	4.696	5.637	5.425	4.967	4.689	5.062	4.688	5.645	5.419	4.926	4.687	5.063
Selection		***	***	***	***		***					***

(\*), (#) and (§) Significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses [.]. (\*\*\*) indicates the model selected for each country. ARCH ( $q$ ) is the  $q$ th order Engle's LM test for conditional heteroskedasticity.

**Table B-10**

**Volatility Model Selection: US Market Proxy (Trend Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.400* [0.002]	0.496# [0.016]	0.720# [0.013]	0.501# [0.018]	0.136 [0.103]	0.083 [0.152]	0.431* [0.001]	0.488# [0.014]	0.617# [0.016]	0.664* [0.001]	0.069§ [0.098]	0.044 [0.327]
$\varphi_{i,1}$	0.832* [0.000]	0.875* [0.000]	0.808* [0.000]	0.871* [0.000]	0.880* [0.000]	0.738* [0.000]	0.841* [0.000]	0.875* [0.000]	0.827* [0.000]	0.843* [0.000]	0.930* [0.000]	0.794* [0.000]
$\varphi_{i,2}$	0.115* [0.000]	0.101* [0.000]	0.148* [0.000]	0.088 [0.287]	0.102* [0.002]	0.369* [0.000]	0.059§ [0.062]	0.107* [0.001]	0.182* [0.000]	0.158 [0.202]	0.124* [0.000]	0.164# [0.027]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.074 [0.016]	-0.013 [0.791]	-0.090§ [0.090]	-0.168 [0.189]	-0.128* [0.000]	0.268§ [0.055]
$\varphi_{i,1} + \varphi_{i,2}$	<i>0.947</i>	<i>0.976</i>	<i>0.957</i>	<i>0.960</i>	<i>0.982</i>	<i>1.107</i>	<i>0.900</i>	<i>0.982</i>	<i>1.009</i>	<i>1.001</i>	<i>1.054</i>	<i>0.958</i>
ARCH LM	0.311 [0.906]	0.704 [0.620]	0.203 [0.961]	1.454 [0.203]	0.231 [0.949]	0.996 [0.419]	0.352 [0.881]	0.661 [0.653]	0.257 [0.937]	1.370 [0.234]	0.443 [0.818]	0.718 [0.610]
AIC	4.724	5.587	5.367	4.911	4.550	4.958	4.722	5.590	5.364	4.855	4.526	4.941
SIC	4.804	5.667	5.447	4.991	4.630	5.062	4.808	5.676	5.451	4.941	4.612	5.053
Selection		***	***	***	***		***					***

(\*), (#) and (§) significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses [.]. (\*\*\*) indicates the model selected for each country. ARCH ( $q$ ) is the  $q$ th order Engle's LM test for conditional heteroskedasticity.

Table B-11

**Volatility Model Selection: Aggregate Mature Global Market Proxy (Trend Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.192# [0.052]	0.750# [0.012]	0.602* [0.006]	0.203# [0.058]	0.209§ [0.074]	0.071 [0.130]	0.220* [0.008]	0.762* [0.009]	0.538# [0.016]	0.641* [0.002]	0.160§ 0.090	0.058 [0.094]
$\varphi_{i,1}$	0.881* [0.000]	0.869* [0.000]	0.819* [0.000]	0.975 [0.000]	0.866* [0.000]	0.709* [0.000]	0.883* [0.000]	0.868* [0.000]	0.831* [0.000]	0.849* [0.000]	0.884* [0.000]	0.685* [0.000]
$\varphi_{i,2}$	0.092* [0.003]	0.085* [0.002]	0.147* [0.000]	0.001 [0.807]	0.102* [0.006]	0.421* [0.000]	0.038 [0.354]	0.081# [0.024]	0.200* [0.000]	0.155 [0.204]	0.125* [0.003]	0.304§ [0.010]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.085§ [0.098]	0.008 [0.872]	-0.115# [0.038]	-0.166 [0.186]	-0.068 [0.108]	0.391# [0.042]
$\varphi_{i,1} + \varphi_{i,2}$	<i>0.973</i>	<i>0.954</i>	<i>0.966</i>	<i>0.976</i>	<i>0.968</i>	<i>1.130</i>	<i>0.921</i>	<i>0.949</i>	<i>1.031</i>	<i>1.003</i>	<i>1.009</i>	<i>0.989</i>
ARCH LM	1.069 [0.384]	0.671 [0.781]	0.474 [0.931]	1.258 [0.239]	0.625 [0.822]	1.466 [0.133]	0.993 [0.453]	0.680 [0.771]	0.413 [0.959]	0.736 [0.717]	0.589 [0.852]	1.433 [0.147]
AIC	4.601	5.535	5.349	4.911	4.557	4.959	4.592	5.538	5.342	4.865	4.553	4.942
SIC	4.681	5.615	5.429	4.991	4.637	5.063	4.678	5.624	5.429	4.951	4.640	5.054
Selection		***	***	***	***		***					***

(\*), (#) and (§) significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses []. (\*\*\*) indicates the model selected for each country. ARCH ( $g$ ) is the  $g$ th order Engle's LM test for conditional heteroskedasticity.

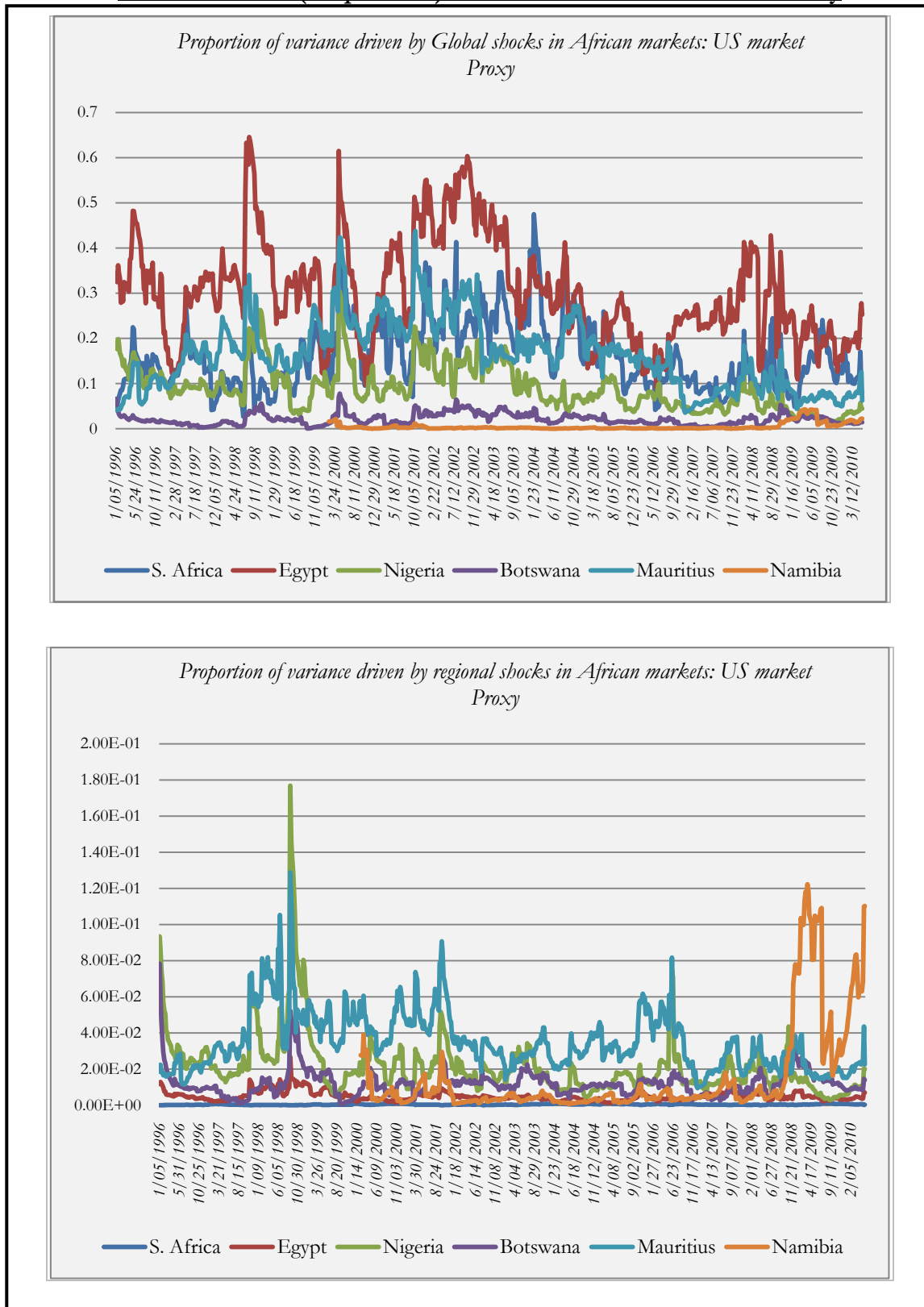
Table B-12

**Volatility Model Selection: Aggregate Mature Global Market Proxy (Trend Spillover model)**

	GARCH (1,1)						GJR_GARCH (1,1)					
	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia	S. Africa	Egypt	Nigeria	Botswana	Mauritius	Namibia
$\varphi_{i,0}$	0.513* [0.003]	0.623# [0.045]	0.162# [0.012]	0.411# [0.021]	0.193§ [0.079]	0.052§ [0.075]	0.663* [0.002]	0.624# [0.040]	0.367# [0.024]	0.571* [0.002]	0.105 [0.106]	0.033 [0.157]
$\varphi_{i,1}$	0.814* [0.000]	0.873* [0.000]	0.943* [0.000]	0.885* [0.000]	0.857* [0.000]	0.565* [0.000]	0.808* [0.000]	0.873* [0.000]	0.884* [0.000]	0.862* [0.000]	0.904* [0.000]	0.561* [0.000]
$\varphi_{i,2}$	0.130* [0.000]	0.096* [0.000]	0.050* [0.000]	0.087* [0.000]	0.127* [0.004]	0.772* [0.000]	0.020 [0.620]	0.096* [0.006]	0.136* [0.000]	0.144 [0.209]	0.143* [0.002]	0.511* [0.000]
$\varphi_{i,3}$	- -	- -	- -	- -	- -	- -	0.177* [0.009]	0.001 [0.978]	-0.070 [0.119]	-0.155 [0.197]	-0.112# [0.014]	0.657# [0.021]
$\varphi_{i,1} + \varphi_{i,2}$	<i>0.943</i>	<i>0.969</i>	<i>0.993</i>	<i>0.972</i>	<i>0.984</i>	<i>1.337</i>	<i>0.828</i>	<i>0.969</i>	<i>1.020</i>	<i>1.006</i>	<i>1.047</i>	<i>1.072</i>
ARCH LM	0.527 [0.898]	0.634 [0.814]	0.757 [0.695]	1.032 [0.410]	0.887 0.560	2.188 [0.011]	0.429 [0.952]	0.636 [0.812]	0.440 [0.947]	0.980 [0.450]	0.954 [0.492]	1.807 [0.044]
AIC	4.890	5.657	5.500	4.940	4.798	4.984	4.868	5.660	5.499	4.887	4.788	4.960
SIC	4.970	5.737	5.580	5.020	4.878	5.087	4.954	5.746	5.585	4.973	4.875	5.071
Selection		***	***	***	***		***					***

(\*), (#) and (§) significant at 1%, 5% and 10% respectively. Marginal significance levels (p-values) based on the robust Bollerslev-Woodridge standard errors are shown in parentheses [.]. (\*\*\*) indicates the model selected for each country. ARCH ( $q$ ) is the  $q$ th order Engle's LM test for conditional heteroskedasticity.

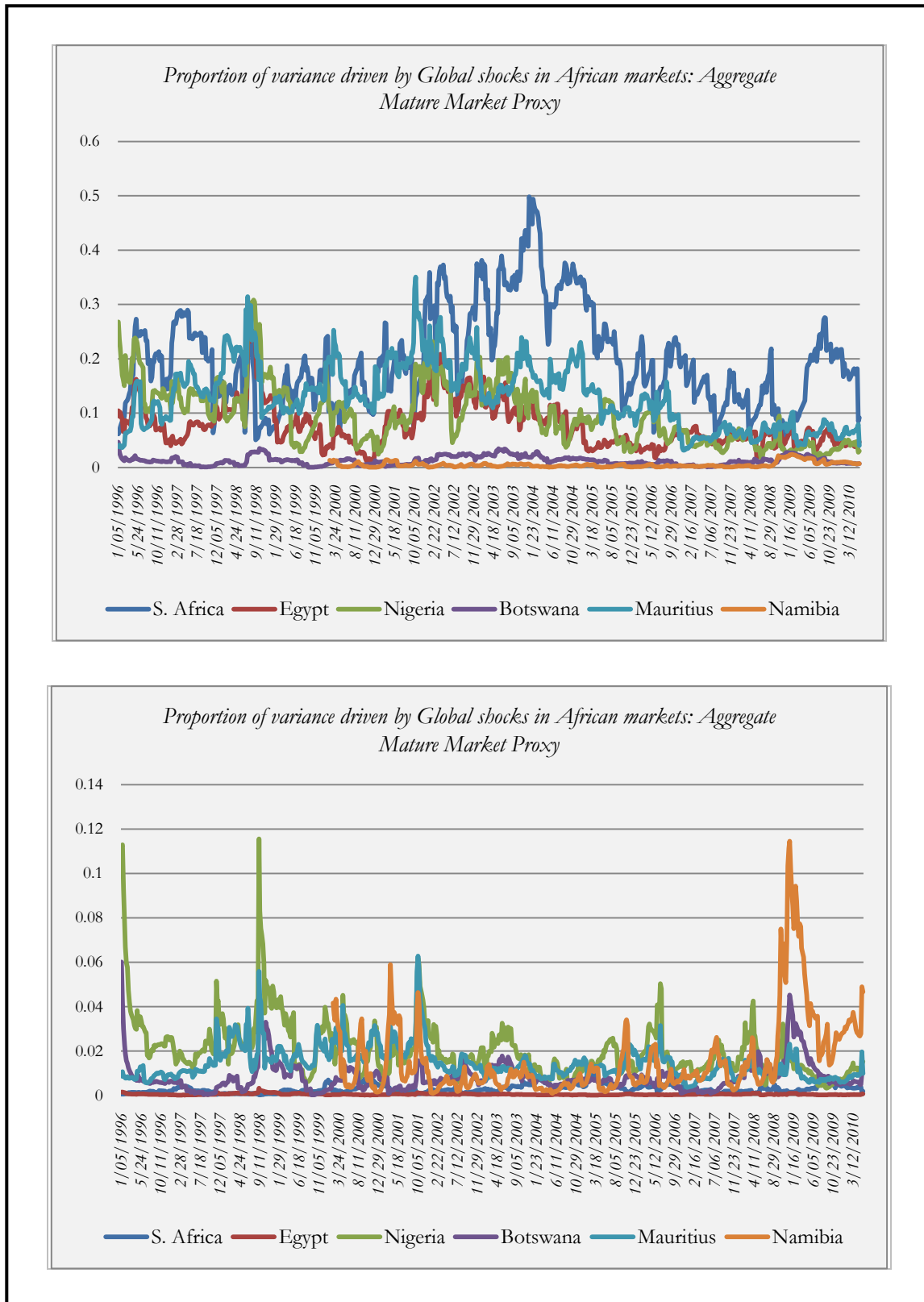
**Figure B-3**  
**Variance Ratios (Proportions) over Time: US Global Market Proxy**



The figure illustrates graphical plots of regional and global variance ratios associated with the aggregate mature global market proxies.

Figure B-4

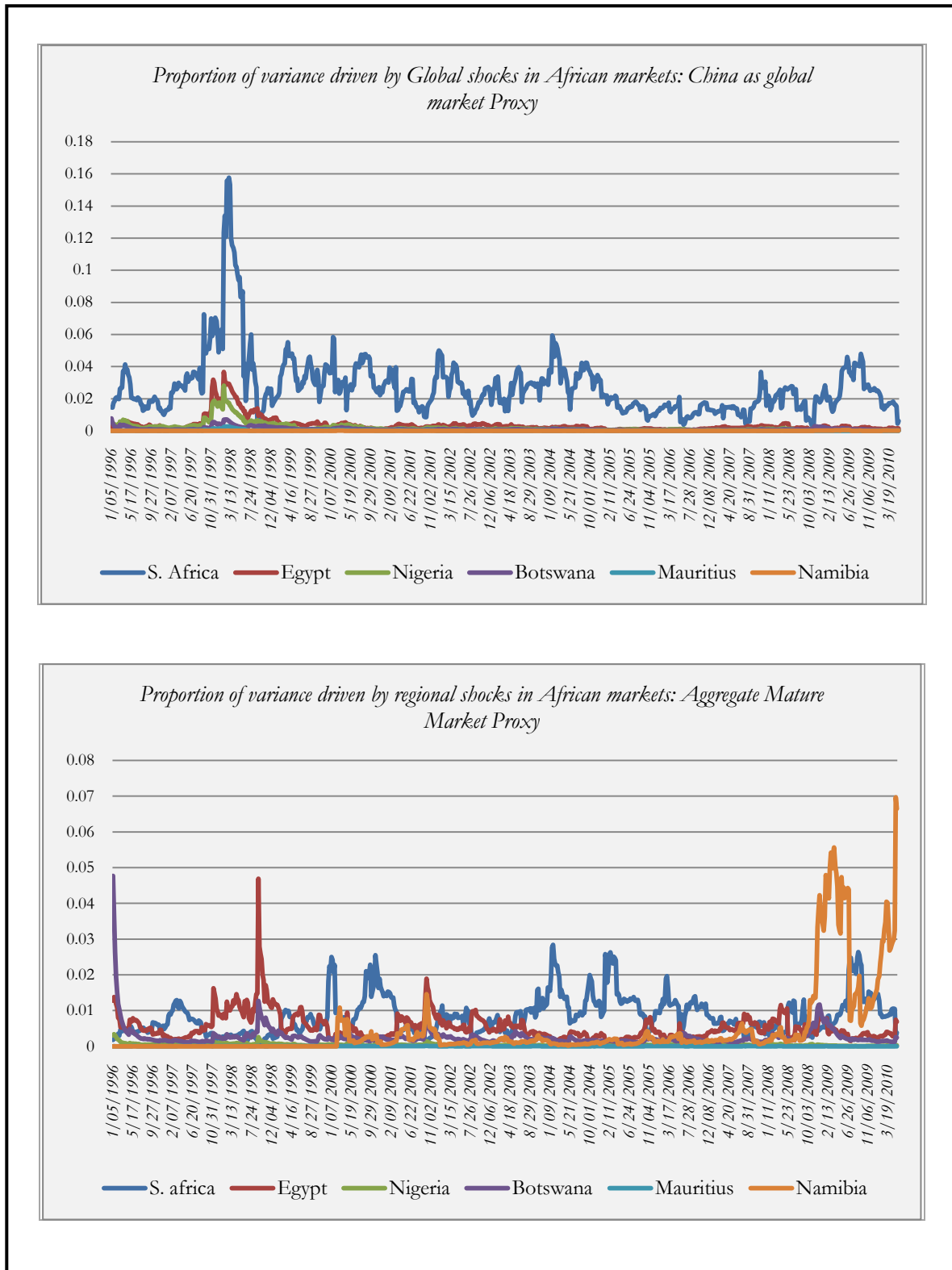
**Variance Ratios (Proportions) over Time: Aggregate Mature Global Market Proxy**



The figure illustrates graphical plots of regional and global variance ratios associated with the aggregate mature global market proxy

Figure B-5

**Variance Ratios (Proportions) over Time: China as Global Market Proxy**



The figure illustrates graphical plots of regional and global variance ratios associated with China as global market proxy

