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Lumengo Bonga-Bonga and Jamela Hoveni

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Abstract

This paper attempts to assess the extent of volatility spillovers between the equity market and the foreign exchange market in South Africa. The multi-step family of GARCH models are used for this end, whereby volatility shocks obtained from the mean equation estimation in each market are included in the conditional volatility of the other market, respectively. The appropriate volatility models for each market are selected, following criteria such as covariance stationarity, persistence in variance and leverage effects. The finding indicates that there is a unidirectional relationship in terms of volatility spillovers, from the equity market to the foreign exchange market. The paper supports the view that the extent of foreign participation in the South African equity market contributes to this pattern of volatility spillover.

JEL classification: F31, G10, C10

Keywords: equity market, foreign exchange market, spillover, GARCH models.

1 Introduction

The financial crisis notwithstanding, the period 2000 to 2010 was a great one for equity markets around the world. Emerging market equities in particular soared to new highs as financial liberalisation and deregulation opened up markets to new international investors (Gentzoglani, 2007). Largely fuelled by the abundance of liquidity, these equity markets expanded at a rapid pace. For example, between 2000 and 2010 equity markets capitalisation in South Africa, China, Brazil, India and Russia increased by an annualized rate of 15%, 10.5%, 13.6%, 15.6% and 23.4% respectively¹. The growing participation of international investors in emerging stock markets and the increasing capital inflows that follow have raised concerns about the impact of equity inflows on exchange rates. In general, higher levels of cross-border equity flows stimulate demand and supply for currencies in which stock prices are denominated, leading to some degree of interdependence between stock prices and exchange rates (Kanas, 2000). However, Aloui (2007) shows that the impact of exchange rate fluctuations on stock prices depends on whether the stock market is dominated by exporters or importers. The author indicates that in a market dominated by exporters (or importers), domestic currency depreciation (or appreciation) leads to an increase (or decrease) in stock prices. Thus stock prices or returns are prone to respond to exchange rate fluctuations. Stock market shocks, on the other hand, affect aggregate demand through wealth and liquidity effects, thereby influencing money demand, interest rates and exchange rates (Ajayi and Mougouè, 1996)

Emerging market central bankers have raised concerns about the pace of appreciation in their currencies due to equity inflows, particularly with emerging East Asian countries where the 1997/98 crisis was attributed to macroeconomic consequences of capital inflows and credit expansion (Mishkin,

*University of Johannesburg

¹Figures reported in Bloomberg at www.bloomberg.com [access 3 February 2011]

1999). An understanding of the links between the stock market and the foreign exchange market will help policy makers design appropriate policies to deal with the impact of equity inflows on the exchange rate. Understanding the interaction between stock prices and exchange rates is also important for the pricing of securities within and across markets and for the trading and hedging strategies of investors (Mishra, Swain and Malhotra, 2007:344). In addition, for international equity investors the total return from investing in a particular share or currency is the sum of the percentage change in the index and the percentage change in the currency. Thus exchange rate movements contain useful information about the expected returns from investing in a foreign market (Aloui, 2007).

On the other hand, recent financial and currency crises have stimulated an interest in understanding the nature of the interaction of stock market and exchange rate volatility. From a risk management point of view, understanding the interaction of exchange rate and stock price volatility is crucial given that exchange rate risk is one of the key risks facing modern corporations. Kanas (2000) argues that positive and significant volatility spillovers may increase the non-systemic residual international portfolio risk faced by international investors, reducing the gains from international diversification.

Volatility spillovers are a source of concern because they can propagate volatility shocks between the markets, and increase the risk of a financial crisis. Understanding volatility co-movement and associated spillover effects is therefore crucial to the management and prevention of financial crises.

A number of studies that attempt to measure volatility spillover between markets focus to a great extent on lead/lag volatility interaction between those markets. Thus, these studies rely on the methodologies that focus on a family of multivariate GARCH models for this end. For example, Koutmos (1996) uses multivariate VAR-EGARCH model to investigate the lead/lag relationship and volatility interaction among the stock markets of the UK, France, Germany and Italy. In addition, a number of multivariate GARCH models impose the same structural form in the estimation of conditional variances and covariance between specific markets or variables. Nonetheless, in this study we investigate volatility spillovers between stock prices and exchange rates in South Africa by making use of multi-step GARCH/EGARCH model as in Mishra, Swain and Malhotra (2007). Unlike their use of the model, however, in our study we selected the appropriate volatility models for each market following criteria such as covariance stationarity, persistence in variance and leverage effects. Thus, contrary to a number of multivariate methods used in assessing volatility spillover, this study does not impose a single structural representation of a volatility model for the two markets. In addition, the multi-step approach applied in this paper is appropriate to assess the contemporaneous effects or contemporaneous volatility spillover between exchange rate and equity markets.

This paper is structured as follows: section 2 presents the literature review on the linkage between equity prices or returns and exchange rates, section 3 deals with the methodology used in the paper, section 4 presents and discusses the results of the paper and section 5 concludes the paper.

2 Theory and literature review

A number of studies have attempted to explain the linkage between the stock market and the foreign exchange market. For example, Greenwood (2005) identified two main approaches in dealing with this linkage: the traditional and the portfolio approaches. These approaches describe the channels through which changes in the exchange rates are transmitted to stock prices and vice versa. According to the *traditional approach*, the appreciation (or depreciation) of a local currency has two major implications. Firstly, it will decrease (or increase) indebtedness in terms of foreign currency-denominated debts. In other words, outstanding debts of local companies will be worth less (or more) and thus they will have to pay less (or more) in terms of the domestic currency. As a result, companies' cash flows will improve (or deteriorate). Secondly, companies that rely heavily on imported inputs in their production activities will experience a decrease (or increase) in production costs.

The traditional approach predicts some degree of interdependence between stock prices and exchange rates. However, the precise sign of the correlation between the variables will depend on whether the stock market is dominated by importers or exporters, and thus making this channel uncertain (Aloui, 2007). To the extent that fluctuations in exchange rates cause fluctuations in cash flows, market uncertainty will increase, thus causing fluctuation in stock prices (Huzaimi and Liew, 2004).

The portfolio approach emphasises the centrality of the role of the capital account and movement in assets across borders. Here, exchange rates are like any other commodity where the price is determined by market demand and supply forces. Rising (or falling) stock prices will attract (or discourage) capital inflows from foreigners seeking high returns, who sell the foreign (local) currency in return for local (foreign) currency. Capital inflows (outflows) will thus lead to an appreciation (or depreciation) of the exchange rate. The increase (or decrease) in stock prices will have additional effects by increasing (or decreasing) the wealth of domestic investors, thereby increasing (or reducing) the demand for local currency and subsequently pushing up (or down) the local interest rates. The higher (or lower) interest rates will encourage more capital inflows (outflows), resulting in a further appreciation (or depreciation) of the currency (Huzaimi and Liew, 2004). According to this approach, changes in stock prices will lead to changes in exchange rates; therefore causality should run from stock prices to the foreign exchange market. The portfolio approach predicts a positive correlation between stock prices and exchange rates, and higher stock prices lead to an appreciation in the currency.

Both the traditional approach and the portfolio approaches predict a positive volatility relationship. Exchange rate volatility creates cash flow uncertainty for local firms which will be reflected in the stock market as increased trading activity, as foreign investors attempt to liquidate their positions or hedge against the anticipated price volatility. Likewise, volatile stock prices will increase uncertainty for both foreign and domestic investors. Foreign investors are generally more sensitive to market uncertainty; therefore, instability in the local stock market may cause capital outflows, inducing fluctuations in the exchange rates.

Research on the relationship between exchange rates and stock prices has produced mixed results. Some researchers argue that changes in stock prices lead changes in exchange rates (see Phylaktis and Ravazzolo, 2000), while others are of the view that exchange rates lead changes in stock prices (see Huzaimi and Liew 2004). Phylaktis and Ravazzolo (2000) found evidence of unidirectional causality from stock prices to exchange rates. On the other hand, Huzaimi and Liew (2004) found evidence of bi-directional causality between exchange rates and stock prices in Malaysia, while in Thailand they found evidence of unidirectional causality from exchange rates to stock prices. Empirical research on the interaction between stock prices and exchange rates traditionally has focused on the first moments of the variables, and has ignored trends in the second moments. In addition, the few studies that have modelled the second moments of exchange rates and stock prices have predominantly focused on developed countries, largely ignoring developments in developing countries (see for example Yang and Doong (2004), Aloui (2007) and Kanas (2000)).

Yang and Doong (2004) investigated the interactions of price and volatility spillovers between the stock market and the foreign exchange market for the G-7 countries. They examined the extent to which the markets are integrated by testing both price and volatility spillover effects. A multivariate version of Nelson's (1991) EGARCH model was estimated; this version was preferred because of the log form of the conditional variance guarantees that the variance will be positive. Their results indicated that there were significant price spillovers from the foreign exchange to the stock market for Canada and Japan. Currency depreciation (or appreciation) often dragged down stock prices (or pushed them up). The results also found significant price spillovers from the stock market to the foreign exchange market for Canada, France, Germany, Italy, and the UK. In the short run an increase (or decrease) in stock prices often caused currency depreciation (or appreciation), while in the long run, an increase (or decrease) in stock prices is associated with currency strength (or weakness).

On the volatility spillovers the results are even more mixed. Generally, empirical evidence supports the existence of volatility spillovers from the stock market to the foreign exchange market but not vice versa (Yang and Doong (2004), Kanas (2000), Choi, Fang and Fu (2009), and Aloui (2007)). In contrast, Dark, Raghavan and Kamepalli (2008) found evidence of volatility spillovers from the exchange rate to the stock market in Australia.

In their study on G7 countries Yang and Doong (2004) found the existence of volatility spillovers from the stock market to foreign exchange market for most of the countries. However, no volatility spillovers from the foreign exchange market to the stock markets were found. In terms of asymmetric spillover effects, negative innovations in the stock market had greater impacts on the conditional volatility of exchange rates than positive innovations; however, the effects did not apply to innovations in exchange rates on the stock markets.

Kanas (2000) examined volatility spillovers between the stock market and the foreign exchange market for six industrialised countries. He found evidence of volatility spillovers from stock returns to exchange rate changes for five of the six countries considered. All stock return spillovers were found to be symmetric, meaning that the effect of bad stock market news on the exchange rate is the same as the effect of good news. No volatility spillover effects from exchange rate changes to stock returns were found for any of the countries.

Choi, Fang and Fu (2009) investigated the volatility spillover between the stock market and the foreign exchange market in the New Zealand (NZ) economy. The EGARCH model was used to examine the dynamic volatility relationship between the NZ stock market and the foreign exchange rate changes. Results indicate the presence of volatility spillovers from the stock market to the foreign exchange market. No volatility spillovers from exchange rates to stock prices were found. Evidence of leverage effects was found in both the stock market and the foreign exchange market.

Aloui (2007) adopted an empirical approach based on a multivariate EGARCH model to investigate the dynamic price and volatility spillovers between exchange rates and stock indexes for major European markets. The analysis covers the pre and post-euro periods. For the first moment interdependence the results indicate significant spillovers from the foreign exchange market to the stock market in both periods. There were also significant spillovers from stock prices to exchange rates in both periods. Overall, changes in stock prices were found to be significant informational signals to foreign exchange dealers, but the exchange rate does not appear to be a significant factor. Significant volatility spillovers from the stock market to exchange rates were found for most of the countries in both periods. Volatility spillovers from the exchange rate market to the stock market were found in the post-euro period for three out of the five countries; however, no volatility spillovers were found in the pre-euro period.

Few studies have focused on the linkage between stock markets and exchange rates in the context of emerging markets and/or developing economies. Among studies on emerging economies is the work of Mishra, Swain and Malhotra (2007), who used the GARCH/EGARCH approach to examine volatility spillovers between stock and foreign exchange markets in India.² They found evidence of bi-directional volatility spillover between the stock market and the foreign exchange market, except in the case of the stock indices such as the S&P CNX NIFTY and the S&P CNX 500. For both these markets unidirectional spillovers from the stock market to the foreign exchange market were found. Results also suggested that in general both markets move together and that there is a long-run relationship between the two markets.

Using the EGARCH approach, Adjasi, Harvey and Agyapong (2008) studied the effect of the exchange rate volatility and volatility of other macro-economic variables (inflation, trade deficit and treasury bill rates) on stock market volatility in Ghana. Exchange rates and stock price volatility were found to be negatively related, meaning that high exchange rate volatility leads to a decrease in stock market volatility. Their findings also showed that in addition to volatility of exchange rates, stock market volatility is influenced by volatility of other macro-economic variables such as inflation

²The study was based on four broadbased stock indices and the exchange rate of the Indian rupee per US dollar.

and T-bill rates.

Contrary to a number of studies, this paper assesses contemporaneous volatility spillover between the equity market and foreign exchange market by making use of multi-step GARCH models whereby a volatility model for each market is selected based on criteria such as covariance stationarity, persistence in variance and leverage effects

3 Methodology

The aim of this study is to assess volatility spillovers between the foreign exchange and equity markets in South Africa. To assess volatility spillover between the two markets, this paper makes use of the multi-step GARCH model as in Mishra et Swain and Malhotra (2007). As regards the multi-step GARCH model, volatility spillover is assessed in two ways. First, shocks to volatility are generated from univariate models of stock returns and change in the exchange rates series. Secondly, the volatility shocks obtained in the first step are introduced in the conditional volatility equation for stock returns and the change in exchange rate. Unlike Mishra Swain and Malhotra (2007), this paper models conditional volatility of each market taking into account criteria such as covariance stationarity, persistence in variance and leverage effects. The reason behind the different selection of volatility models is that there is an a priori belief that stock returns depict asymmetric volatility in that stock return volatilities react differently to bad and good news; nonetheless, such asymmetric reaction in exchange rate volatility has no theoretical basis (Nelson, 1991). Thus, determining an appropriate model for market volatility should be a matter of empirical analysis.

Assuming that the data generating process of stock return (ΔY_t) and the change in exchange rate (ΔZ_t) are represented by an $AR(1)$ process, it follows that

$$\Delta Y_t = \alpha + \beta \Delta Y_{t-1} + \varsigma_t, \quad \varsigma_t \sim (0, \sigma_t^2(\Delta Y)) \quad (1)$$

$$\Delta Z_t = \gamma + \phi \Delta Z_{t-1} + \varepsilon_t, \quad \varepsilon_t \sim (0, \sigma_t^2(\Delta Z)) \quad (2)$$

where $\sigma_t^2(\Delta Y)$ is the conditional volatility of the change in stock price (Y_t) and $\sigma_t^2(\Delta Z)$ is the conditional volatility of the change in exchange rate, with Z_t as the exchange rate level. α , β , γ and ϕ are parameters. ε_t and ς_t are white noise error terms.

From Equations 1 and 2, when assuming that conditional volatility equations of the change in exchange rate and stock returns are represented by GARCH and EGARCH models, the volatility spillovers are estimated from the following equations:

$$\sigma_t^2(\Delta Z) = \omega_0 + \beta_1 \varepsilon_{t-1}^2 + \gamma_1 \sigma_{t-1}^2(\Delta Z) + \delta_1 \varsigma_t^2 \quad (3)$$

$$\ln(\sigma_t^2(\Delta Y)) = \omega_1 + \beta_2 \frac{\varsigma_{t-1}}{\sqrt{\sigma_{t-1}^2(\Delta Y)}} + \theta_2 \left| \frac{\varsigma_{t-1}}{\sqrt{\sigma_{t-1}^2(\Delta Y)}} \right| + \gamma_2 \ln \sigma_{t-1}^2(\Delta Y) + \delta_2 \ln(\varepsilon_t^2) \quad (4)$$

where ω_i , β_i , γ_i , δ_i and θ_i , for $i = 1, 2$, are parameters. It is important to note that in Equations 3 and 4, the coefficients δ_1 and δ_2 represent the volatility spillover coefficients. These coefficients indicate the extent to which shocks to volatility in one market contemporaneously influence the conditional volatility of another market. It is important to note that this paper makes use of $\ln(\varepsilon_t^2)$ in Equation 4 in order for the conditional volatility in the EGARCH equation to have any sign, positive or negative. In case exchange rate volatility is represented as an ARCH process, the coefficient γ_1 is assumed to be zero.

4 Data analysis and empirical results

To determine the extent and direction of volatility spillovers between the foreign exchange and equity markets, weekly data from 1 July 1995 to 31 October 2010 were used. The sample periods

correspond with the period after the liberalisation of the Johannesburg Stock Exchange (JSE), the main stock exchange in South African. The paper uses the first difference of the natural logarithm of real equity price ($d(EQT)$) represented by the JSE equity price index and the first difference of the natural logarithm of exchange rate ($d(EXCH)$). It is important to note that the first difference of the natural logarithm of real equity prices represents the stock returns series and that the first difference of the natural logarithm of exchange rate represents the change in exchange rates. Figure 1 shows the presence of volatility clustering in the two series, in which large changes tend to be followed by large changes of either sign, and small changes tend to be followed by small changes. This outcome indicates that a class of GARCH models can be used to estimate conditional volatility for each of the two time series.

To determine the volatility spillovers between the foreign exchange and equity markets, it is important first to determine the appropriate autoregressive model in order to ascertain the structure of the univariate model that characterises each of the series. A number of empirical studies support the use of an AR(1)-GARCH (1,1) process for modelling stock returns and testing the weak-form efficient market hypothesis in emerging stock markets (Abdmoulah, 2010; Shin, 2005; Salman, 2002; Zalewska-Mitura and Hall, 1999). The rationale for using AR(1) representation in modelling the mean process of equity returns and the change in exchange rate is based on weak-form efficiency and the random walk characteristics of the two variables (Fama, 1965). Nonetheless, the lag selection of the AR process is taken from the one that minimises the Schwarz Information Criteria (SIC). Table 1 presents the results of the SIC of the AR(1), AR(2) and AR(3) models for equity returns and the change in exchange rate. The paper limits the comparison to three lags, as it is proven that there is no evidence of long memory in the South African equity market (Jefferis and Thupayagale, 2008). The results of the SIC presented in Table 1 confirm that the data generating process of $d(EXCH)$ and $d(EQT)$ are better represented by an AR(1) process.

The next step in assessing the volatility spillover consists in estimating Equation 3 and 4 respectively. Nonetheless, it is important to assess the correct functional form of the conditional volatility representation of equity return and the change in exchange rate, respectively.

Table 2 shows that the conditional volatility of equity return can be represented by AR(1)-EGARCH(1,1) given the statistical significance of the coefficients β_1 , θ_1 and γ_1 . This indicates that there is asymmetric effect in the conditional volatility of equity return. With regard to the functional form for the conditional volatility of $d(EXCH)$, Figure 1 shows that the first third of the sample of equity returns is far less volatile than the last two thirds of the sample. Referring to such conditions, a number of authors have suggested that a strongly persistent GARCH can be found to fit the data well in the presence of switching heteroscedasticity (Morana, 2002; Lamoureux and Lastrapes, 1990). While these authors suggest the application of IGARCH models to account for the persistence in volatility, they nonetheless emphasise that caution should be exercised as high persistence in conditional volatility can arise when a GARCH model does not account for structural breaks that certainly cause a switch in volatility. Thus, to assess if there is true persistence in $d(EXCH)$ conditional variance, a AR(1)-GARCH(1,1) model is estimated with a number of dummy variables as deterministic variables that account for structural breaks in $d(EXCH)$ time series. Figure 1 suggests that there is a possibility of three main structural breaks in the sample data. These structural breaks are identified as the effects of the 1997-1998 Asian financial crisis, the 2002 Latin American currency crisis and the 2007-2008 global financial crisis on the South African economy. The periodicity of the dummy variables that identify these structural breaks is determined as follows in this paper; the 1997-1998 Asian financial crisis dummy, *crisis1*, takes the value of unity from 20 July 1998 to 30 December 2008 and zero otherwise. The 2002 Latin American currency crisis dummy, *crisis2*, takes the value of unity from 1 May 2002 to 23 April 2003 and zero otherwise. The 2007-2008 global financial crisis, *crisis3*, takes the value of unity from 21 May 2008 to 4 March 2009 and zero otherwise. The specific dates for each of those crises are identified with the aid of Figure 2 and correspond with the periods from the pick to the trough of a particular crisis.

Two dummy variables, *crisis1* and *crisis3*, are selected as deterministic variables in the AR(1)-

GARCH(1,1) model for $d(\text{EXCH})$, based on their statistically significant contribution to the likelihood of the model. Table 3 provides the estimation of this model.

The results reported in Table 3 show that although structural breaks are taken into account in the estimation of the GARCH model, nonetheless, the sum of β_2 and γ_2 is close to unity. This provides evidence that $d(\text{EXCH})$ is actually driven by the IGARCH process. This finding is confirmed by the diagnostic test of the estimated IGARCH model for $d(\text{EXCH})$, especially the Lagrange Multiplier (LM) test for ARCH in the residuals and the Ljung-Box Q-statistics for residual correlation up to one lag reported in Table 4. Both tests did not reject the null hypothesis of no ARCH and no residual correlation, respectively.

Having obtained the time series of volatility shocks to equity returns and to change in exchange rate from the estimation of their mean equations, a multi-step volatility approach is used to estimate volatility spillover between the equity market and foreign exchange market from their respective conditional volatility equations. Table 5 reports the results of the estimation of the contemporaneous effect of volatility shocks to equity returns on the conditional volatility of the change in exchange rate as in Equation 3. Given that the two series co-break, as indicated in Figure 1, dummy variables are not included as deterministic variables in the volatility equations. The coefficient δ_1 in Table 5 measures the magnitude of volatility spillover from the equity market to foreign exchange market, and ζ_t^2 represents the volatility shock to equity returns. The results reported in Table 5 show that volatility shocks to equity returns influence positively the conditional volatility of the change in exchange rate. The LM F-statistics of 0.374, with a probability of 0.5410, shows that the null hypothesis of no ARCH in the estimated model is not rejected. This finding indicates the validity of the conditional volatility model used.

Table 6 shows the contemporaneous effect of the volatility shocks to the change in exchange rate on equity returns' conditional volatility. The coefficient δ_2 measures the magnitude of this effect.

The coefficient δ_2 , which represents the degree of transmission of the volatility from the foreign exchange market to the equity market, is not statistically significant at the 5% level. This result indicates that volatility shocks from the foreign exchange market do not contemporaneously transmit to the equity market. The validity of the multi-step EGARCH model, which explains the transmission of volatility shocks from the foreign exchange market to the equity market, is confirmed by the diagnostic tests, especially the LM test for ARCH in the residual and the Ljung-Box Q-statistics for residual correlation up to 4 lags. The results of these diagnostic tests, reported in Table 7, indicate that the null hypothesis tests of no ARCH and no residual correlation are not rejected up to 1% level of significance.

The finding that volatility shocks to equity market are contemporaneously transmitted to the foreign exchange market should be expected in the case of emerging market economies in general and South Africa in particular. The rationale behind this finding has to do with the structure and the composition of emerging equity markets in general and the equity market in South Africa in particular. In fact, the structure of equity markets in emerging markets depends to a greater extent on foreign participation. High volatility in these equity markets, which signals an increasing degree of market risk, leads to the rapid sale of emerging market assets by foreign market participants in order for them to relocate funds to more stable equity markets. This phenomenon leads to massive capital outflow and, thus, volatility in the foreign exchange market. As regards the importance of foreign participation in the South African equity market, it is important to note that foreign trading volumes on the Johannesburg Securities Exchange (JSE), the sole licensed stock exchange in South Africa, have increased sevenfold from 1996 to 2007 (JSE, 2008), indicating the importance of foreign participation in the JSE. Thus, the activities of foreign investors in the South African equity market provide a channel through which shocks in the equity market are transmitted to the foreign exchange market. A number of studies have found a contemporaneous relationship between emerging equity market volatility and foreign portfolio flows (Brennan and Cao, 1997; Richards, 2004). It is important to note that the volatile nature of foreign portfolio flow, and its effect on the foreign exchange market, has led a number of emerging market economies to adopt the policy of

exchange control in order to mitigate the transmission of the destabilising effect of foreign portfolio flow on the foreign exchange and other markets.

While a number of studies have found a bidirectional relationship between equity and foreign exchange market volatilities in emerging markets (Wu, 2005; Muhammad and Rasheed, 2002), this paper finds a unidirectional relationship from the equity market to the foreign exchange market in South Africa. The rationale of this finding is threefold: firstly, volatility in emerging equity markets often emanate from instability in developed markets rather than from internal factors unique to emerging markets. Thus, when volatility pressures rise in emerging equity markets, foreign investors often unwind their position and relocate funds to more stable equity markets. The capital outflow that follows results in instability in the foreign exchange market. Secondly, exchange rate risk may not increase the risk of the equity market in emerging markets, as most foreign investors prefer to hedge against exchange rate risk before investing in emerging equity markets. Thirdly, it is likely that the repatriation of dividend payments, after the good performance of an emerging equity market, results in high demand for foreign currencies.

5 Conclusion

This paper endeavoured to assess the extent of contemporaneous volatility spillovers between the foreign exchange and equity markets in South Africa. The paper made use of the multi-step GARCH models for this end. Contrary to a number of multivariate GARCH models that focus on lead/lag relationships, the multi-step approach applied in this paper is appropriate to assess the contemporaneous effects or contemporaneous volatility spillovers between exchange rate and equity markets. The results of the paper indicate that there is a unidirectional volatility spillover from the equity market to foreign exchange market. The paper attributes this finding mainly to the extent of foreign participation in emerging markets in general and the South African equity market in particular, whereby foreign investors often unwind their positions in the local equity market when volatility pressure increases. This action leads to high capital outflows and, thus, high volatility in the foreign exchange market. The paper suggests that alternative asymmetric GARCH models, such as the Threshold ARCH (TARCH) model, as well as regime-switching GARCH models be used for future research to model the conditional volatilities of stock returns and the change in exchange rates, respectively.

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Table 1: SIC statistics for the AR(1), AR(2) and AR(3) models of d(EQT) and d(exch)

	d(EXCH)	d(EQT)
AR(1)	-4.7765	-4.1719
AR(2)	-4.7732	-4.1646
AR(3)	-4.7635	-4.155

The SIC indicates minimum values for AR(1) for the two series

Table 2: Estimation of the volatility equation of the AR(1)-EGARCH (1,1) for d(EQT)

Parameter	Coefficient
ω_1	-0.52*
β_1	-0.12*
θ_1	0.14*
γ_1	0.94*

Conditional volatility equation is: $\ln(\sigma_t^2) = \omega_1 + \beta_1 \frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \theta_1 \left| \frac{\xi_{t-1}}{\sqrt{\sigma_{t-1}^2}} \right| + \gamma_1 \ln \sigma_{t-1}^2$

Note: * and ** mean significant at 1% and 5%, respectively.

Table 3: Estimation of the volatility equation of the AR(1)-GARCH (1,1) for d(EXCH)

Parameter	Coefficient
ω_{01}	0.00000433*
β_2	0.11342*
γ_2	0.0.8600*
λ_2	0.0000898**
ψ_2	0.0000851***

The conditional volatility equation estimated in Table 3 is as:

$$\sigma_t^2 = \omega_{01} + \beta_2 \varepsilon_{t-1}^2 + \gamma_2 \sigma_{t-1}^2 + \lambda_2 \text{crisis1} + \psi_2 \text{crisis3}$$

Note: *, **and *** mean significant at 1%, 5% and 5%, respectively.

Table 4: The LM test for ARCH in the residual and the Ljung-Box Q-statistics for residual correlation of the IGARCH model

LM F-Statistics	Probability
0.2796	0.597
Ljung-Box Q-statistics	Probability
0.1153	0.734

Table 5: Results of the volatility spillover from equity market to foreign exchange market

Parameters	Coefficients
β_1	0.1813*
θ_1	0.8187*
γ_1	0.0150*

The conditional volatility equation is: $\sigma_t^2(\Delta Z) = \beta_1 \varepsilon_{t-1}^2 + \theta_1 \sigma_{t-1}^2(\Delta Z) + \delta_1 \zeta_t^2$

Note: * and ** mean significant at 1% and 5%, respectively. ΔZ represents the change in exchange rate.

Table 6: Results of the volatility spillover from the foreign exchange market to the equity market

Parameter	Coefficient
ω_1	-0.479*
β_2	0.135*
θ_2	-0.119*
γ_2	0.947*
δ_2	-0.00016

Volatility equation is : $\ln(\sigma_t^2(\Delta Y)) = \omega_1 + \beta_2 \frac{\zeta_{t-1}}{\sqrt{\sigma_{t-1}^2(\Delta Y)}} + \theta_2 \left| \frac{\zeta_{t-1}}{\sqrt{\sigma_{t-1}^2(\Delta Y)}} \right| + \gamma_2 \ln \sigma_{t-1}^2(\Delta Y) + \delta_2 \ln(\varepsilon_t^2)$

Note: * and ** mean significant at 1% and 5%, respectively. ΔY represents the change in equity prices.

Table 7: The LM test for ARCH in the residual and the Ljung-Box Q-statistics for residual correlation of the multi-step EGARCH model

LM F-Statistics	Probability
1.1612	0.2815
Ljung-Box Q-statistics	Probability
2.7653	0.596

Figure 1 Time series of $d(EQT)$ and $d(EXCH)$

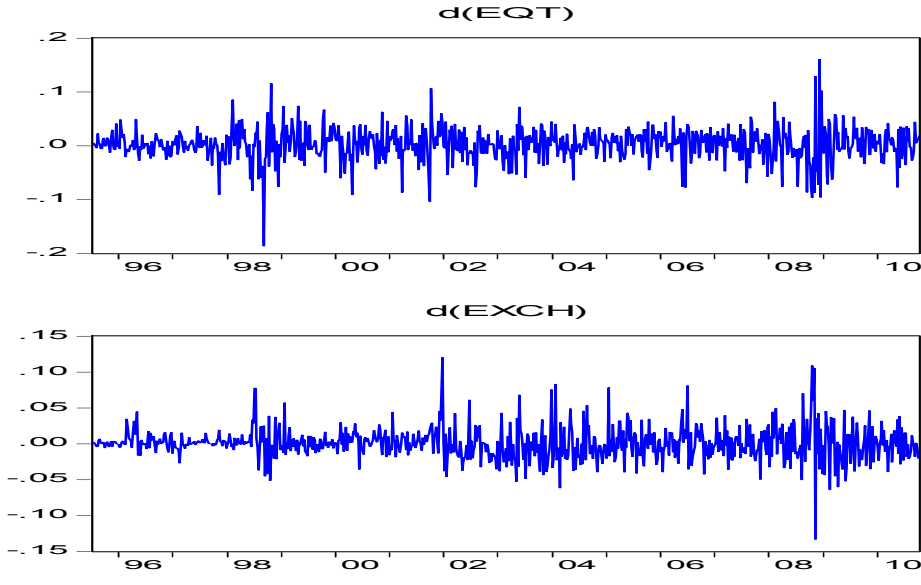


Figure 2 Time series of equity prices (EQT) and exchange rates (EXCH)

