THE SELF-FULFILLING PROPHECY OF UNCERTAINTY: A STUDY OF THE IMPACT OF UNCERTAINTY AND CONTAGION ON ECONOMIC OUTCOMES AND POLICY.

by

CHEVAUGHN VAN DER WESTHUIZEN

Submitted in fulfilment of the requirements for the degree

PhD (Economics)

in the

FACULTY OF ECONOMIC AND MANAGEMENT SCIENCES

at the

UNIVERSITY OF PRETORIA

NOVEMBER 2022

ACKNOWLEDGEMENTS

I would like to express my gratitude to the following people,

First and foremost, to my supervisor Reneé van Eyden, you have been the driving force that has kept me going. I will always be indebted by the vast knowledge, skills and guidance that you have contributed to my PhD journey. Your never-ending belief in me always gave me the push to carry on. Special thanks goes to my co-supervisor Goodness C. Aye and the National Research Foundation for the funding to achieve this dream.

To my mother, without you I would not be the woman I have become. You have supported me throughout this process, whether to celebrate the wins or provide a shoulder to lean on during the hard days. To my brother, you have always set the standard of excellence at home, pushing me to work harder. To my uncle, who has played the father role in my life, thank you for always being there for our family.

To my partner and number one cheerleader, Bula, you were always there to listen to me and always dissolved any doubts I had in myself. Thank you for your unwavering love and support.

To all my friends, your unrelenting support and boundless confidence in me will always be remembered.

Chevaughn van der Westhuizen

November 2022

THE SELF-FULFILLING PROPHECY OF UNCERTAINTY: A STUDY OF THE IMPACT OF UNCERTAINTY AND CONTAGION ON ECONOMIC OUTCOMES AND POLICY.

by

CHEVAUGHN VAN DER WESTHUIZEN

Supervisor:	Prof Reneé van Eyden
Co-supervisor:	Goodness C. Aye
Department:	Economics
Degree for which the thesis is submitted:	PhD (Economics)

Abstract

Economic globalisation has ushered in the integration of world financial markets, and the degree of interconnectedness has never been greater. In the face of a resurgence in global risks from trade, geopolitical tensions and global health risks, such as the outbreak of COVID-19, there has been an increasing focus on the impact of uncertainty on economic outcomes. Overall, uncertainty has been found to have significant negative impact on economies with the potential to compound recession and hinder economic recovery. The principal objective of this study is to address the impact of uncertainty and contagion on economic outcomes and policy in the South African context through a broad focus on the key markets – including the stock market, the currency market and the goods market – with particular focus on non-linear modelling and asymmetric effects, where the sign and size of a shock or uncertainty within markets have different impacts.

In order to meet this objective, this study first investigates the interdependence and volatility transmissions and contagion between the stock and currency markets through a bivariate Exponential Generalised Autoregressive Conditional Heteroscedasticity (EGARCH) framework. This approach is used to allow for asymmetric effects of the shocks, allowing both the size and the sign of the shock to have different impacts. The impact of COVID-19 on the transmission mechanism is also explored. The outcomes from this analysis provide strong evidence in support of the "stock-orientated" approach, where significant price and volatility spillovers propagate from the stock market into the foreign exchange market, whilst evidence of the "flow-orientated" approach is seen in the second moment, and significant shock and asymmetric spillovers from the exchange to the stock market are found. The results support the asymmetric and long-range persistence volatility spillover effect and show strong evidence of contagion between stock and foreign exchange markets. These spillovers became more pronounced during the COVID-19 pandemic, confirming heightened contagion in these markets during periods of crisis.

Secondly, attention turns to the goods market. The inflation-inflation uncertainty nexus is investigated through GARCH and GARCH-in-mean (GARCH-M) models to establish whether inflation uncertainty is a self-fulfilling prophecy, i.e., does higher inflation uncertainty leads to higher inflation and *vice versa*? The empirical outcomes from this study suggest the existence of a bidirectional relationship between inflation and inflation uncertainty, with stronger evidence in support of the Friedman-Ball hypothesis which states that heightened levels of inflation induce higher uncertainty about future inflation and weaker evidence in favour of the Cukierman-Meltzer hypothesis that proposes a reverse causation. The study also finds that inflation targeting has contributed significantly to reducing the level of inflation and inflation uncertainty. The Rossi-Wang (2019) time-varying Granger causality testing, which is robust in the presence of instabilities, further provides interesting insight into the relationship – notably that both the Friedman-Ball and Cukierman-Meltzer hypotheses break down during the inflation targeting period, which further hints towards the efficacy of inflation targeting as monetary policy framework.

Finally, the thesis determines how high and low states of uncertainty in the three key domestic markets – the stock market, currency market and goods market – and uncertainty in the global market impact the effectiveness of monetary policy in South Africa. High and low uncertainty states in the markets are examined by employing sign-restriction and the Self-Exciting Interacted VAR (SEIVAR) analysis. This framework is particularly appealing in that it allows for estimating the economy's response conditional on uncertainty states in the different markets. Impulse response analysis reveals that monetary policy is less effective in high uncertainty states in the different markets. Overall, the study attempts to inform policy in the face of uncertainty.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABREVIATIONS

AIC	Akaike information criterion
ARMA	Autoregressive moving average
ASI	All Shares Index
BIC	Bayesian information criterion
BRICS	Brazil, Russia, India, China and South Africa
BRICS_T	Brazil, Russia, India, China, South Africa and Turkey
CPI	Consumer price index
EGARCH	Exponential generalised autoregressive conditional heteroskedasticity
EM	Emerging market
FED	Federal Reserve System
FTSE	Financial Times Stock Exchange
G-7	Group of seven developed nations (US, Japan, France, Germany, Italy, UK and Canada)
GARCH	Generalised autoregressive conditional heteroskedasticity
GARCH-M	GARCH-in-mean
GDP	Gross domestic product
GFC	Global financial crisis
GIRF	Generalised impulse response functions
IBSA	India, Brazil, South Africa
IRF	Impulse response functions
IT	Inflation targeting
IVAR	Interacted vector autoregression
JSE	Johannesburg Stock Exchange
MPC	Monetary Policy Committee
OECD	Organisation for Economic Co-operation and Development
QE	Quantitative easing
SA	South Africa
SARB	South African Reserve Bank
SACU	Southern African Customs Union
SIC	Schwarz information criterion
SSA	Sub-Saharan Africa
UK	United Kingdom
U.S.(A)	United States (of America)
VAR	Vector autoregression

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND

In the last quarter century, economic globalisation has led to a vast expansion in international trade which has ushered in the integration of world financial markets, and the degree of interconnectedness has never been greater. The world has witnessed expeditious changes in the international financial system, such as the emergence of new capital markets, the adoption of more flexible exchange rate arrangements in emerging and transition economies, and the gradual eradication of capital flow barriers and foreign exchange restrictions (Aloui, 2007). Driven by advancements in information technology and improved worldwide processing of news, the international conveyance of returns and volatilities among financial markets has amplified. In the face of a resurgence in global risks from trade, geopolitical tensions, and global health risks, such as the outbreak of COVID-19 in 2020, researchers, policymakers, and market participants have become increasingly focused on the impact of uncertainty on economic outcomes (Cascaldi-Garcia *et al.,* 2020). The concept of uncertainty associated with Knight (1921) is the inability of people to forecast the likelihood of events happening in future i.e., "unknown unknowns". A closely related concept is risk which refers to a known probability distribution over a set of events i.e., "known unknowns" (Castelnuovo, 2019). These concepts are hard to differentiate empirically or in the data analysis, and to the extent of literature, the term uncertainty includes both Knight's definition and risk. There is no agreed-upon measure of uncertainty in the literature (Balcilar *et al.,* 2017), and a wide range of proxies are used, with the first initiated by Bloom (2009) who uses large shifts in U.S. stock market volatility as a proxy for exogenous changes in uncertainty. Overall, a large body of literature has highlighted the significant negative impact of uncertainty on output, prices, and consumption (see, among others, Xue-Jun *et al.*, 2014; Alam, 2015; Dima *et al.*, 2017), with studies also suggesting that uncertainty has the potential to compound recession and hinder economic recovery (Ren *et al.*, 2020).

A small-open economy such as South Africa is particularly vulnerable to global events, and it is imperative that policymakers have insight into the impacts of uncertainty and contagion and the degree of spillovers across markets. Monetary policy is typically the first line of defence an economy has against a number of internal and external shocks. Figure 1.1 displays the strategy of the South African Reserve Bank (SARB) to attain its policy objectives of price stability and highlights the relationship between monetary policy rules and the transmission mechanisms of monetary policy throughout the economy. Policy action (both current and expected) taken based on the SARB policy rules are directly transmitted to money and asset markets, including the stock markets and currency markets. Changes in these markets, in turn, affect the goods market and, ultimately, aggregate output and prices. Finally, changes in current and projected output and inflation feed back into monetary policy rules. This study addresses the issue of uncertainty and the impact of uncertainty and contagion on economic outcomes and policy in the South African context through a broad focus on the key markets highlighted in Figure 1.1 – including the stock market, the currency market and the goods market.

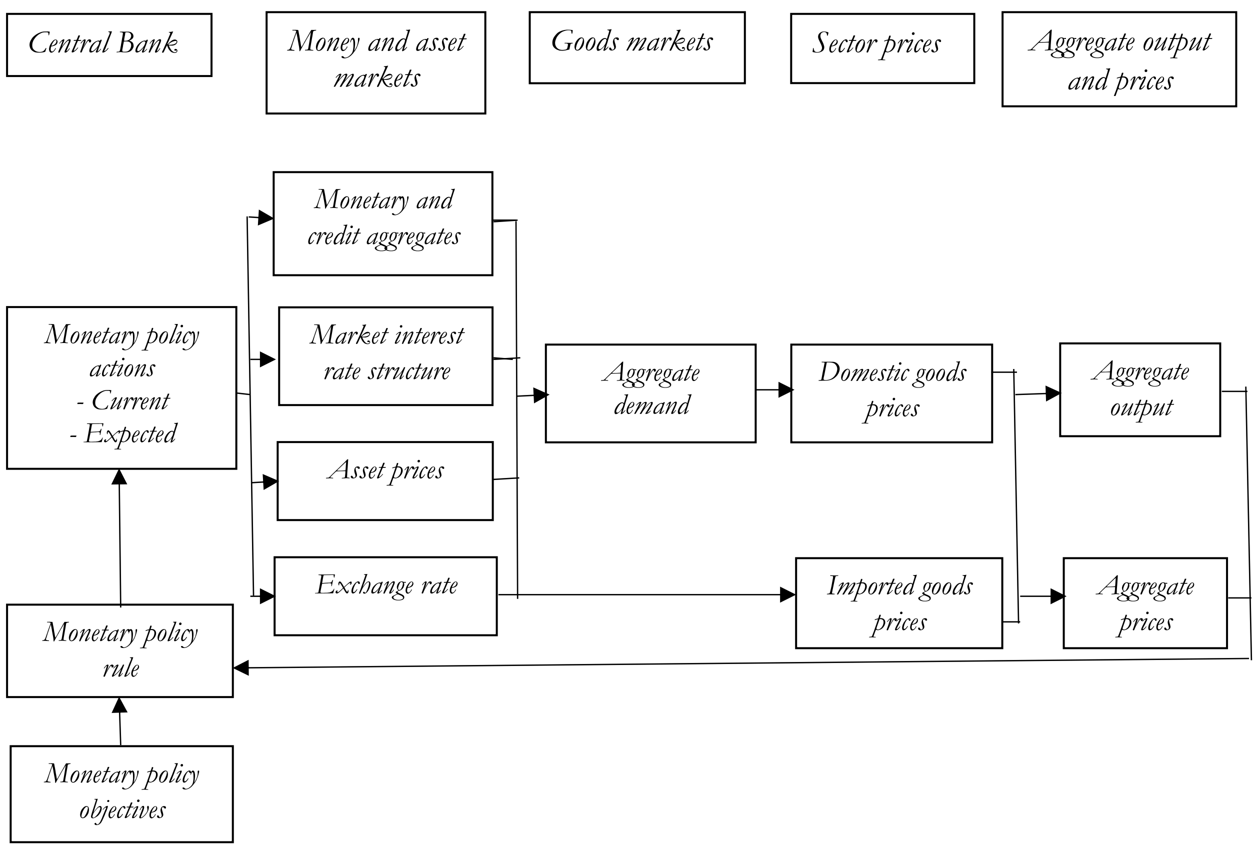


Figure 1.1: Monetary policy rule and transmission mechanism

The focus of this study is placed on non-linear modelling and asymmetric effects, where the sign and size of a shock or uncertainty within markets have different impacts – a phenomenon pointed out by Black (1976) who recognised that in stock markets, volatile periods are often initiated by a large negative shock, which suggests that positive and negative shocks may have an asymmetric impact. If uncertainty has symmetric effects, then decreases in uncertainty are offset by increases and temporary spikes in uncertainty should not have long-lasting effects. On the other hand, if uncertainty has asymmetric effects, increases have a more sizable effect than decreases of the same magnitude, and temporary spikes in uncertainty may persistently hold down economic activity. As a result, the temporary uncertainty episodes during the recovery phase may have long-lasting effects, leading to lower growth in output and employment. Considering the size (or magnitude) of the shock, firms and households may simply tune out small changes as uncertainty is constantly changing; however, large increases or decreases may trigger changes in behaviour. The aggregate economic cost of changes in uncertainty, therefore, may be dependent on both the sign and the size of the changes. Significant increases in uncertainty cause firms to postpone hiring and investing, consumers to postpone purchases, and the economy to slow down (Bloom, 2009). As uncertainty subsides, activity tends to increase, but not necessarily all at once as firms and consumers adjust slowly. Thus, periods of high uncertainty that dissipate quickly might have longer-lasting repercussions if the response to uncertainty is asymmetric (Foerster, 2014).

1.2 OUTLINE OF THE STUDY

The main part of this thesis is split into three chapters. Each chapter has an introduction to the topic that is investigated, a discussion of the theoretical underpinnings and a review of the relevant literature, a discussion of the stylised facts and data used, an overview of the econometric methodology implemented, a discussion of the empirical results and a concluding section summarising the key findings and policy implications.

Chapter 2 investigates the interdependence and volatility transmissions between the stock and currency markets, including the effect the COVID-19 pandemic has had on the interdependence and volatility transmissions, using bivariate Exponential Generalised Autoregressive Conditional Heteroscedasticity (EGARCH) modelling. The framework is implemented to facilitate the understanding of short-run movements and to explore the volatility transmission mechanism between these markets − allowing the quantity (size) and the quality (sign) of an innovation to significantly impact the degree of volatility spillovers across markets. That is, this study searches for evidence of asymmetry where adverse shocks originating in the stock market (foreign exchange market) exert more or less impact on the foreign exchange market (stock market) than a positive shock of equal magnitude.

Chapter 3 focuses on the goods market and investigates the inflation-inflation uncertainty nexus by utilising Generalised Autoregressive Conditional Heteroscedasticity (GARCH) and GARCH-in-mean (GARCH-M) models to establish whether the Friedman-Ball (1992) or the Cukierman-Meltzer (1986) hypothesis holds in SA, that is whether higher inflation causes higher inflation uncertainty or *vice versa*. Thereafter, it investigates the impact of the inflation targeting (IT) regime on inflation and its associated uncertainty within the GARCH framework. Finally, Rossi-Wang's (2019) time-varying Granger causality testing robust in the presence of instabilities further provides interesting insight into the relationship between inflation and inflation uncertainty and how it changes over time.

Chapter 4 seeks to discern how the uncertainty within the domestic stock, currency and goods market, as well as in the global market, impacts the real economy using a Vector autoregressive (VAR) framework and impulse response function analysis. The economy's response to a monetary policy shock is studied, and the effectiveness of monetary policy in the face of uncertainty is evaluated − distinguishing between regimes of high and low uncertainty by means of sign-restriction and Self-Exciting Interacted VAR (SEIVAR) analysis. This SEIVAR augments an otherwise standard VAR with an interaction term including two variables, i.e., the variable used to identify the monetary policy shock (the policy rate) and the conditioning variable that identifies the "uncertain times" and "tranquil times" states (the proxy for uncertainty in the different markets). Overall, the study attempts to inform policy in the face of uncertainty.

The final chapter, Chapter 5, concludes with the contributions to the literature, the key findings and the avenues for future research to be explored.

CHAPTER 2

CONTAGION ACROSS FINANCIAL MARKETS DURING COVID-19: A LOOK AT VOLATILITY SPILLOVERS BETWEEN THE STOCK AND FOREIGN EXCHANGE MARKETS IN SOUTH AFRICA[1]

2.1 INTRODUCTION

Economic globalisation has led to a vast expansion in international trade, foreign direct investments and capital inflows from global portfolio investors, ushering in the integration of world financial markets. In the last quarter century, the world has witnessed expeditious changes in the international financial system, such as the emergence of new capital markets, the adoption of more flexible exchange rate arrangements in emerging and transition economies, and the gradual eradication of capital flow barriers and foreign exchange restrictions (Aloui, 2007). Emerging economies, including South Africa, are no exception to this global trend (Živkov *et al.*, 2021). Rapidly increasing international equity flows create a higher demand for and supply of currencies in which international equity prices are denominated leading to interdependence between the stock and foreign exchange rate markets (Lakshmanasamy, 2021). Driven by advancements in information technology and improved worldwide processing of news, the international conveyance of returns and volatilities among the stock and foreign exchange markets has amplified and made these markets vulnerable to global economic fluctuations. With the stock and foreign exchange markets generally regarded as important indicators of a country's financial markets, there is considerable interest in the exchange rate–stock price linkage.

The empirical inquiry into the interdependence among the stock and exchange markets is made more interesting by the fact that economic theory states that there are various ways in which these markets can interact. The prevailing theoretical approaches take on two fundamental forms: (i) the "flow-oriented" approach proposed by Dornbush and Fisher (1980) which claims causality flows from exchange rates to stock prices, and (ii) the "stock-oriented" approach proposed by Branson (1983) and Frankel (1983) which claims causality flows from stock prices to exchange rates. To date, a cardinal disagreement exists as theoretical approaches have come short of reaching a consensus on the existence of a link between stock prices and exchange rates as well as the

[1] This study is published in *Annals of Financial Economics*, Vol 17 (1), 2022, https://doi.org/10.1142/S2010495222500026

direction of causality between the two markets (Chkili *et al.*, 2011). The theoretical ambiguity in the literature surrounding this relationship compels an empirical analysis.

Although the interactions between these markets have been deliberated extensively in the international finance literature, these studies are generally based on the first moments in the specification, and only a narrow body of research has attempted to detect volatility spillovers between the two variables. Volatility is an important gauge of financial performance, indicating uncertainty or risk, and volatility spillovers can provide a measure of the transmission of financial stress across the markets. Understanding the dynamics of volatility spillovers (namely crashes, distress and contagion) is paramount for: (i) determining if the extent of the spillovers across markets could point to some degree of market inefficiency; (ii) understanding the nature of shock propagation across markets in order to ascertain the magnitude and persistence of these innovations over time; (iii) specifying how markets are interconnected to advance an effective hedging strategy; (iv) and, ultimately from a policy standpoint, awareness of the inherent nature of volatility transmission across the two markets is imperative from a financial stability perspective as financial markets may be threatened by increasing financial volatility spillover effects while linkages across markets may influence policy efficacy (Aloui, 2007).

The occurrence of financial and currency crises in economies has ascribed even more interest – as the onset of heightened volatility in the stock prices and exchange rates has the potential to propagate volatility shocks between the markets. The recent coronavirus pandemic (COVID-19) which developed in Wuhan, China, in late-2019 presented a unique economic, geopolitical, and social challenge that triggered a new type of recession different from the past triggers of recessions. For instance, the 1997 Asian financial crisis was caused by the collapse of the Thai baht in July 1997, which caused a region-wide financial crisis and economic recession in Asia. The global financial crisis (GFC), a period of extreme stress in global financial markets and banking systems between mid-2007 and early 2009, was caused by loose monetary policy, which created a bubble, followed by subprime mortgages, weak regulatory structures, and high leverage in the banking sector. The COVID-19 pandemic has been termed a "black swan" event in the financial markets and brought a stark warning regarding the exceptional vulnerabilities and fragility that can quickly transpire and disseminate. Uncertainty due to the pandemic has led to an associated rise in the volatility of stock prices and exchange rates in economies (OECD 2020). Further, the literature on the impact of unanticipated events, like terrorist attacks and government shutdowns, suggests that unanticipated events contain valuable information and may improve financial variables' predictive power (Narayan *et al.*, 2018; Sharma *et al.,* 2019). The COVID-19 pandemic is an ideal context to test the hypothesis of whether the occurrence of an unanticipated event improves our understanding of the dynamic relationship between stock prices and exchange rates. Understanding volatility co-movement and associated spillover effects are crucial to managing and preventing financial crises.

Early empirical literature offers conflicting verdicts regarding the transmission of volatility, known as the 'meteor shower' effect according to Engle *et al.* (1990), between stock and foreign exchange markets. This literature can be divided into three distinct realms: first, the studies that claim significant bidirectional spillover between the two markets; second, the studies which found unidirectional flow either from stock to foreign exchange market or from foreign exchange market to stock market; third, those studies which reported no significant spillover between the two markets. A significant relationship between these markets assures that a negative shock that disrupts one market may be instantaneously transmitted to the other through contagious effects.

Most studies have also only focused on developed countries, and only recently have studies started to emerge that look at the interdependence between these financial markets in emerging economies (see Pan *et al.,* 2007; Diamandis & Drakos, 2011; Chkili & Nguyen, 2014; and Jebran & Iqbal, 2016). The role of developing economies cannot be ignored by global investors who need to diversify their international investment portfolio risk. South Africa (SA) has been identified as one of the top 20 emerging economies in the Emerging Markets Economic Outlook of 2021 by Focus Economics (2021). SA's economy is considered "very open", which lends itself to greater volatility as the local economy is largely influenced by global events and economies. SA is also home to the Johannesburg Stock Exchange (JSE), established in 1886, which is the oldest and largest stock exchange market in Africa and has developed into one of the biggest stock exchanges in the world comparable to those in developed countries, making it the most attractive and lucrative African investment destination for equity investors. By the end of 2020, the market capitalisation of the JSE stood at around US$1,052 trillion (World Federation of Exchanges, 2021). Furthermore, the COVID-19 pandemic highlighted the importance of capital flows for many emerging markets and the impacts of capital flows reversal shocks (Makrelov, 2021). South Africa saw large capital outflows at the beginning of the COVID-19 pandemic accompanied by a strong depreciation of the rand. These attributes make SA, a country that has not received much attention in the literature, an interesting case study for contagion across the stock and foreign exchange markets and whether contagion heightened during DOVID-19.

This paper employs a bivariate extension of the Nelson (1991) Exponential Generalised Autoregressive Conditionally Heteroscedastic (EGARCH) model in order to explore the dynamic volatility spillovers between stock returns and exchange rates for SA covering the period 1979:01

to 2021:08, as well as focusing on the dynamic volatility spillovers during the COVID-19 pandemic. The framework is implemented to facilitate the understanding of short-run movements and to investigate the volatility transmission mechanism between the two markets – allowing the quantity (size) and the quality (sign) of an innovation to significantly affect the degree of volatility spillovers across markets. That is, this study searches for evidence of asymmetry where negative shocks originating in the stock market (foreign exchange market) exert more or less impact on the foreign exchange market (stock market) than a positive shock of equal magnitude. This study contributes to the literature by: (i) extending the existing studies on the spillover between stock price and exchange rate in SA, providing a contribution to the debate between whether the "flow-orientated" or "stock-orientated' approach holds; (ii) being one of the very few studies that apply the multivariate EGARCH technique in the recent period to SA; (iii) and, is one of the first studies that investigate how the recent COVID-19 pandemic impacted these spillovers. The results of this paper provide evidence in support of the "stock-orientated" approach in which movements in stock prices will affect future exchange rate movements, whilst evidence of the "flow-orientated" approach is seen in the second moment, and significant shock and asymmetric spillovers from the exchange to the stock market are found. There is also evidence of bidirectional asymmetric volatility spillover effects between the stock and exchange market. This paper also finds that spillovers, both price and volatility, became more pronounced during the COVID-19 pandemic, confirming that there is heightened contagion during periods of crisis.

The rest of this chapter is structured as follows. Section 2.2 commences with a brief review of the theory related to the transmission mechanisms between currency markets and stock markets. Section 2.3 provides a literature review of previous empirical studies. Section 2.4 introduces the econometric framework through an analysis of the data and details the methodology implemented. Empirical results are reported and discussed in Section 2.5, while Section 2.6 concludes the paper.

2.2 LINKAGES BETWEEN EXCHANGE RATES AND STOCK MARKETS: THEORETICAL MOTIVATION

Orthodox economic theories suggest a relation between stock prices and exchange rates, where empirical inquiry into the interdependence of the stock and exchange markets is made interesting by the fact that economic theory states that there are various ways in which these markets can interact. Theoretical approaches have come short of reaching a consensus on the direction of causality between the two markets. It is also possible that movements in the stock and currency markets may well be interrelated due to "…some underlying economic variables that systematically affect both markets leading to convergence of some expectations among market participants."

(Ajayi *et al.*, 1998, p. 242). The prevailing theoretical approaches take on two fundamental forms: (i) the "flow-oriented" approach proposed by Dornbush and Fisher (1980) and (ii) the "stock-oriented" approach proposed by Branson (1983) and Frankel (1983).

According to the "flow-orientated" approach, the exchange rate hinges upon a country's current account balance or trade balance. These models posit that exchange rate changes affect a country's international competitiveness and trade balance, which subsequently affects real income and inputs. When a local currency depreciates, this leads to greater competitiveness of domestic firms given that exports will now be relatively cheaper in international trade. Higher exports will lead to higher domestic income; hence, the firm's stock prices will appreciate as they are evaluated as the present value of the firm's future cash flows. Based on this economic perceptive, the "flow-orientated" approach claims a positive link between exchange rates and the stock market, where causality runs from the exchange rate to the stock price. With this theory in mind, Heckman (1995) derived a present-value-based financial valuation model for multinational firms, where the exchange rate is an explanatory variable for the stock price. Sercu and Vanhulle (1992) observed the effect of exchange rate volatility on a firm's market value by focusing on the price and volume effects of exchange rate changes and found that an increase in exchange rate volatility has a positive effect on the market value of firms.

In contrast, the "stock-orientated" approach asserts that the exchange rate adjusts to equate the demand and supply of alternative financial assets – including domestic money, domestic bonds and equities, and foreign securities. In this approach, the capital account plays a significant role in dictating exchange rate dynamics (Yang & Doong, 2004). Two forms of "stock-orientated" models are stipulated in the literature, namely portfolio balance and monetary models.

The portfolio balance model proposed by Branson and Henderson (1985) and Frankel (1983) claims that causality runs from the stock price to the exchange rate. According to this model, as shareholders assign their wealth between alternative assets, the model reflects on an internationally diversified portfolio and the role of exchange rates in balancing domestic and foreign financial assets' demand and supply. An increase in domestic stock price returns will yield an appreciation of the currency through two central channels postulated in the literature –direct and indirect. The direct channel specifies that an increase in domestic stock price will entice international shareholders to revise their portfolios and substitute foreign assets for domestic assets. As a result, they have more domestic currency at hand to acquire more domestic assets, and accordingly, the domestic currency will appreciate. The notion of the indirect channel centres on the 'wealth effect' in that the increase in domestic stock assets will increase wealth and the demand for each of the assets in the model, where the surplus demand for money will lead to higher interest rates which cause a substitution from foreign securities to domestic assets (Phylaktis & Ravazzolo, 2005). All these transition mechanisms lead to domestic currency appreciation and a rise in the real exchange rate.

This line of causality was found in early empirical studies. Smith (1992) found that both the U.S. and German stock prices have a significant effect on the German mark–U.S. dollar exchange rate, and similarly that Japanese and U.S. stock prices affect the Japanese yen–U.S. dollar exchange rate. Gavin (1989) shows that using an open economy model in which stock prices determine domestic aggregate demand, stock prices may exercise a significant influence on exchange rate dynamics, especially if stock market effects are large, they can change the impact of an expansionary monetary policy on the exchange rate, leading to appreciation rather than the depreciation of the currency. Zapatero (1995) shows that, in fully integrated financial markets, there is an explicit linkage between the volatility of stock prices and the exchange rate volatility.

The monetary approach to exchange rate determination emerged as an important exchange rate paradigm (see Frenkel, 1976; Mussa, 1976; Bilson, 1978) and asserts that the exchange rate is incorporated into financial asset prices (Gavin, 1989). Centred on the view that the exchange rate is perceived as a value of a financial asset which is determined by the present value of anticipated cash flows, the dynamics inherent in the exchange rate are determined by all the relevant macroeconomic factors affecting the anticipated value (Macdonald and Taylor, 1993). Consequently, the presence of common factors affecting the two variables will result in stock price innovations potentially having an impact on, or being influenced by, the behaviour of the exchange rate. Since both exchange rates and stock prices may be influenced by a variety of common factors, the “stock-oriented” exchange rate model suggests that there is no linkage between exchange rates and stock prices (Gavin, 1989).

2.3 LITERATURE REVIEW

In conjunction with the orthodox theories stipulated in Section 2.2, the empirically acknowledged correlations between exchange rates and economic activity (e.g., Branson and Masson, 1977; Cornell, 1983; and Wolff, 1988) and between stock prices and economic activity (e.g., Fama, 1981; Mandelker & Tandon, 1985; and Chen *et al.*, 1986) advocates an implicit link between exchange rates and stock markets. As noted by Nieh and Lee (2001), macroeconomic fundamentals are seen by economists as providing a robust avenue to link stock prices and foreign exchange rates. The interactions between these markets have been extensively deliberated in the international finance literature by means of different frameworks and econometric models. Nevertheless, based on the existing empirical evidence, it is still challenging to infer if the relationship is unilaterally, bilaterally, or interactively significant (Sui & Sun, 2016).

Early empirical studies on the contemporaneous relation between stock returns and exchange rates originate with Franck and Young (1972) and Ang and Ghallab (1976). Franck and Young considered the reactions to exchange rate realignments of equity securities of low- and high-intensity multinational firms as well as the stock market in general and found no significant interaction between the two variables. On the contrary, Ang and Ghallab study how 15 U.S. multinational firms react to U.S. dollar devaluations for the period of August 1971 to March 1973 and conclude that, due to the efficiency of stock markets, the stock prices adjust quickly to changes in the exchange rate. The scarcity of early research may be attributed to the fixed exchange rate regime of the Bretton Woods[2] era when exchange rates hardly moved. A study by Aggarwal (1981) a few years later found that U.S. stock prices and the trade-weighted dollar exchange rate are positively correlated for the post-Bretton Woods Agreement period. In contrast, authors Soenen and Hennigan (1988), using monthly data for the U.S. dollar effective exchange rate and U.S. stock index during 1980–1986, established a strong negative correlation between the two variables – contesting that exchange rate volatility distresses business operations and international competitiveness of multinational firms. Other early studies focusing on the U.S. also found conflicting results: Roll (1992) found a positive relationship between the two markets over the period 1988−1991; whilst Chow *et al.* (1997) found no relationship over the period 1977−1989. However, upon repeating the analysis with longer than six-month horizons, Chow *et al.* (1997) reported a positive relationship between the markets. Ma and Kao (1990) offered insight into a possible reason for these conflicting correlations based on countries' export or import orientation. They considered the impact of changes in currency values on stock prices in six industrial economies, and their results proposed that for an export-dominant economy, a currency appreciation has a negative effect on the stock market, while a currency appreciation boosts the stock market for an import-dominant economy.

Thereafter, studies arose on the directions of causality between exchange rates and stock prices for major industrial economies. Bahmani-Oskooee and Sohrabian (1992) were among the first to

[2] An international system of stable but adjustable exchange rates was introduced under the International Monetary Fund Agreement at Bretton Woods in 1944. This system introduced formal devaluations and revaluations to adjust the exchange rate values of currencies *vis-à-vis* one another, using the U.S. dollar as the dominant international reserve currency.

implement cointegration techniques and Granger-causality tests to postulate the causality direction between the two variables for major industrial countries. Their results indicated that there was bidirectional causality between stock prices measured by the S&P 500 index and effective exchange rates of the U.S. dollar in the short run; however, no long-run co-movements exist between the two variables. Ajayi and Mougoué (1996) implement an error correction model (ECM) for eight industrial economies and find significant short-run and long-run feedback relations between the two variables. The outcome of their study indicates that an increase in stock prices has a negative short-run and a positive long-run effect on domestic currency value, whereas currency depreciation has a negative short-run and long-run impact on the stock market. Ajayi *et al.* (1998) utilised pairwise Granger-causality tests and found evidence to indicate unidirectional causality from the stock to the currency markets for advanced economies, whilst no consistent causal relations in emerging markets were found. They speculate that the contrasting result between the advanced and emerging economies is attributed to the differences in the structure and features of financial markets within the economies.

In addition to the studies on the linkages and interactions between exchange rates and stock prices, a rich body of research emerged that endeavoured to analyse the transmission of volatility or a volatility spillover effect between the stock and currency markets. Volatility is typically defined as a measure of the dispersion of returns of an asset or market index, where higher volatility generally translates to riskier assets. These studies primarily employed the autoregressive conditional heteroskedastic (ARCH) framework of Engle (1982)[3] along with Generalised ARCH (GARCH) models – which have been used extensively to study volatility spillovers between markets in different countries and between different assets (see Hamao *et al.*, 1990; Koutmos & Booth (1995); Chiang & Yang, 2003; Laopodis, 1998; and So, 2001). The majority of studies focusing on the link between the stock market and foreign exchange market have also implemented augmented GARCH models, as well as error correction models (ECM), vector autoregression (VAR) models and copula-based approaches[4], among others. Overall, the results of the studies find conflicting evidence between the "flow-orientated" or "stock-orientated" approach and evidence that the spillover effects are more pronounced during crisis periods. Studies focusing on advanced economies include Kanas (2000), Kanas (2002), Yang and Doong (2004), Aloui (2007), Ning (2010), Caporale *et al.* (2014), Morales-Zumaquero and Sosvilla-Rivero (2018), and Coronado *et al.* (2020). In view of the increasing significance of emerging economies in the global financial system,

[3] See Bollerslev *et al.* (1992) for a detailed summary of the literature.
[4] A copula is a function that connects the marginal distributions to restore the joint distribution. See Ning (2010) for more details.

more recent studies have directed emphasis on these economies. Mozumder *et al.* (2015) examine three developed (Ireland, Netherlands and Spain) and three emerging (Brazil, SA and Turkey) countries across the recent pre-financial-crisis, crisis and post-crisis periods. Chkili *et al.* (2011) focus on four emerging economies[5]; Chiang *et al.* (2000), Caporale *et al.* (2002), Pan *et al.* (2007), Lin (2012), Yau and Nieh (2009), Zhao (2010), Jebran and Iqbal (2016) focus on Asian economies; Diamandis and Drakos (2011) and Kutty (2010) focus on Latin American countries; Aydemir and Demirhan (2009) focus on Turkey; and Adjasi *et al.* (2011) and Živkov *et al.* (2021) consider African countries.

Živkov *et al.* (2021) investigate four African countries (Nigeria, SA, Egypt, and Morocco) employing daily data – with sample ranges from January 2005 to December 2019 – using a wavelet approach, an MS-GARCH model and measurement of the volatility spillover effect in the quantile regression framework. They find evidence of the bidirectional volatility spillover effect – which intensifies during periods of crisis – but the volatility impact from the exchange rate market to the stock market is stronger in all the African countries, except Nigeria. Regarding the direction from stocks to exchange rate, this study finds that the volatility spillover effect is the strongest in SA, attributed to the JSE being the most developed and liquid market. As for the reverse direction, the spillover effect is recorded in longer time horizons in the Egyptian and Moroccan cases, which points to a flow-oriented model, while for SA, the effect is found in shorter time horizons, which is in line with the portfolio-balance theory.

Looking more closely at BRICS economies, Chkili and Nguyen (2014) show that the unilateral impact from the stock market to the foreign exchange market is significant during the period of high volatility, except for SA. In contrast, Sui and Sun (2016) discover unilateral spillover effects from exchange to stock markets in BRICS economies (where stock-market shocks only slightly impact the foreign exchange market in Brazil and Russia) and insignificant long-run effects between the two markets, except for China. Kumar's (2013) results suggest the integration between stock and foreign exchange markets and indicate the existence of bi-directional volatility spillover between stock and foreign exchange markets in the IBSA countries and, in particular, that the stock market plays a relatively more important role than foreign exchange markets in the first and second moment interactions and spillovers. Also, looking at the IBSA countries, Mikhaylov (2018) found that a bidirectional spillover effect existed in the period 2009–2017, which was significantly stronger than it was before the global financial crisis. Mroua and Trabelsi (2020) found that exchange rate changes significantly affect the past and the current volatility of the BRICS stock

[5] Hong Kong, Singapore, Malaysia and Mexico.

indices. Rai and Garg (2022) examine the impact of the COVID-19 pandemic on dynamic correlations and volatility spillovers between the markets and found significant negative dynamic correlations and volatility spillovers between stock and exchange returns in most economies. Further, the relationship strengthened during the initial days of lockdowns[6].

Focusing on SA, Bonga-Bonga and Hoveni (2013) used a multistep GARCH model to assess the contemporaneous volatility spillover between exchange rate and equity markets for the period 1995–2010. They found a unidirectional relationship in terms of volatility spillovers from the equity market to the foreign exchange market. Their paper supports the view that the extent of foreign participation in the SA equity market possibly contributes to this phenomenon. Oberholzer and Von Boetticher (2015) employ a multivariate Constant Conditional Correlation GARCH (CCC-GARCH) model on daily data from 2002 to 2014 to examine the relationship between the SA rand and the five main indices of the JSE. These authors find a volatility spillover from the rand to the FTSE/JSE All Share Index, Top 40 Index, Fledgling Index, and the Mid Cap Index. Using yearly data over the post-Bretton Woods period 1979–2014 in SA and a cointegration estimator, Mitra (2017) finds that the relationship between exchange rates and stock returns is positive in the long term. Sikhosana and Aye (2018) implemented a multistep EGARCH model alongside other asymmetric GARCH models – the Glosten, Jagannathan and Runkle GARCH (GJR-GARCH) and Asymmetric Power ARCH (APARCH) models, from 1996–2016 and find a bidirectional volatility spillover effect between the two markets in the short-run – with these effects being asymmetric.

This study distinguishes itself from the previous studies by extending the existing studies on the spillover between stock price and exchange rate in SA, through an extensive data set spanning a period of more than 40 years, providing a contribution to the debate between whether the "flow-orientated" or "stock-orientated' approach holds. This study is also one of the very few studies that apply the multivariate EGARCH technique in the recent period to SA, allowing asymmetric volatility spillovers between the markets to be detected. Lastly, it is one of the first studies that investigate the contagion across these financial markets during the COVID-19 pandemic to investigate how the pandemic induced economic crisis affected the interdependence and volatility spillovers between these markets.

[6] Among others, some recent related important papers on financial market contagion include Ho and Tsui (2008), Qiao *et al.* (2008), Malik and Rashid (2017), Billio *et al.* (2019), Rajput *et al.* (2019), de Oliveira Passos *et al.* (2020), and Hassan *et al.* (2020).

2.4 DATA AND METHODOLOGY

2.4.1 Data and stylised facts

This paper is based on South African monthly FTSE/JSE All Share Index data and monthly averages of the nominal effective exchange rate for the period January 1979 to August 2021, containing 512 observations. The FTSE/JSE All Share Index data was procured from Bloomberg and the nominal effective exchange rate from South African Reserve Bank (SARB) database, where the data has been seasonally adjusted specifying 2015 as the base year. The nominal effective exchange rate is expressed as a trade-weighted basket of currencies of SA's main trading partners, relative to the domestic currency – the rand. The starting date is chosen to coincide with SA adopting a managed floating exchange rate regime. Monthly return series are considered as quarterly data does not capture the information content of changes in stock prices and exchange rates and make analysis during crisis periods worthless as crises tend to be relatively short-lived, whilst daily data contains too much noise to analyse, which leads to defective estimation results (Ramchand & Susmel, 1998). The extensive reach of the data in an era of increasing integration of financial markets envelopes the various exchange rate regimes that the South African Rand underwent, along with including major historical events that distressed both markets, such as the Apartheid era and its collapse in 1994 as well as major global events – such as the global financial crisis of 2008 and the COVID-19 pandemic. Thereafter, the stock returns and the percentage change in the exchange rate (hereafter referred to as exchange rate changes) denoted by r_t and e_t , respectively, are calculated by taking the natural log differential of the monthly average values of two consecutive months i.e. $r_t = 100 * \ln\left(\frac{P_t^S}{P_{t-1}^S}\right)$ and $e_t = 100 * \ln\left(\frac{P_t^E}{P_{t-1}^E}\right)$ where P_t^S and P_t^E are the stock price and the effective exchange rate at period t respectively.

The SA rand is a volatile currency (Hassan, 2014). As seen in Figure 2.1, the rand has seen a persistent downward trend through the years since its inception. As will be explained, despite enjoying a strong value amid an ever-changing international economic climate, the Apartheid regime – which governed from 1948 to 1994 – ultimately caused the rand to lose its footing in the global market. On 14 February 1961, the system of Rands and cents was introduced with USD1.00 equal to R0.714. The domestic exchange rate retained this value until December 1971 when the Bretton Woods Agreement ended, and SA's reaction was to devalue the rand. Thereafter, the rand was pegged against the U.S. dollar until 1974 when 67.12 cents bought USD1.00. In June 1974, the SA authorities decided to delink the rand from the dollar and introduced a policy of independently managed floating. During the five-year period from 1974 to 1978, the level at which the rand was pegged to the dollar had been changed six times.

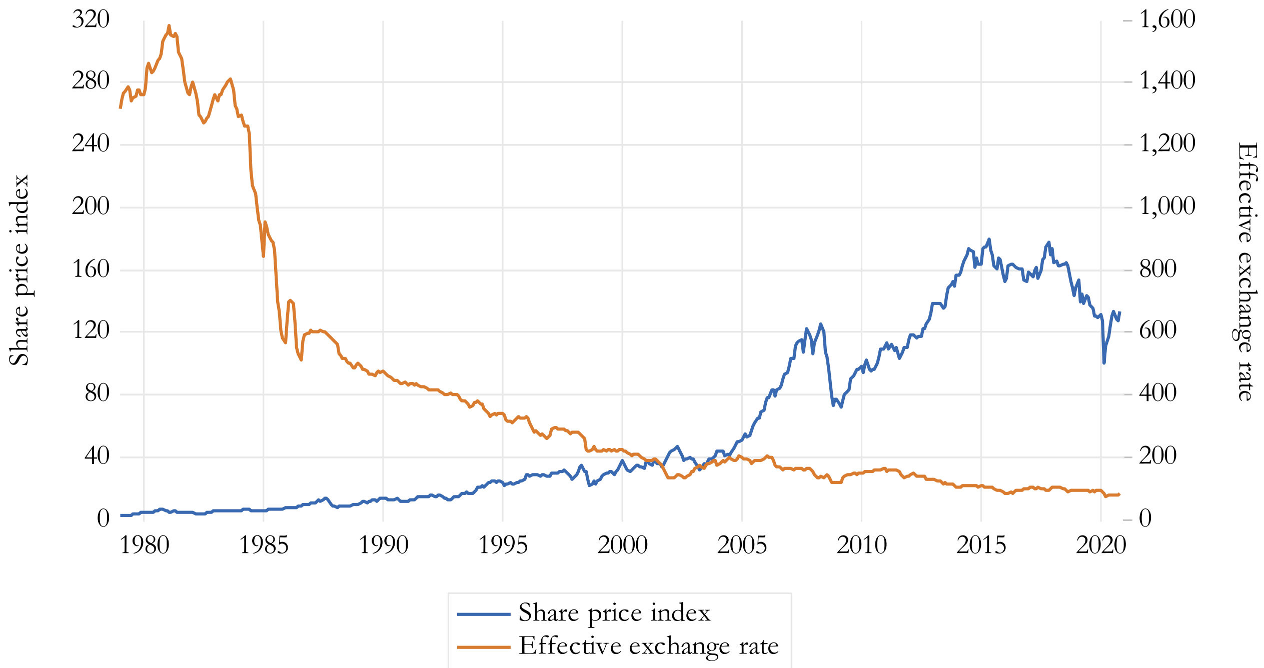


Figure 2.1: Share price index and nominal effective exchange rate for South Africa, 1979:01–2021:08

Source: Bloomberg, SARB and author's calculations.

On 7 February 1983, the SA government announced the abolishment of the financial rand[7]. After the then President PW Botha's infamous 'Rubicon speech' on 15 August 1985, during which he failed to announce immediate and major reforms in the country's Apartheid system and international confidence in SA plummeted. As a result, on 28 August 1985 the rand reached an all-time low as economic and political pressure against SA heightened following the announcement of a state of emergency earlier that year. The earlier easing of exchange control over non-residents could not be sustained as key international banks denied renewing credit lines for SA which compelled authorities to declare the momentary closure of the foreign exchange market six months later. On 1 September 1985, a standstill on SA's international debt repayments was declared, and exchange controls were reinstated.

[7] From June 1961 up until the first half of 1995 (except for a short period during the early eighties), SA utilised a dual exchange rate system of Commercial Rand and Financial Rand. The financial rand was intended to curb the outflow of foreign investments from SA. It was only applicable to investments by non-residents, and it was cheaper for foreigners than the Commercial Rand.

Since the release of former President Nelson Mandela in February of 1990, economic sanctions were gradually lifted, and after the democratic elections in 1994 a degree of normalcy resumed in SA's international relations. The depreciating trend, however, continued, albeit at a slower rate and for a period during the mid to late 1990s, the domestic currency was somewhat stronger than the equilibrium value dictated by economic fundamentals. The exchange rate of the domestic currency against foreign currencies in post-apartheid SA continued to be impacted by national and international social, political, and economic events.

During the Asian currency crisis, the rand was heavily affected and depreciated as much as 41.5% from 4.53 rand per U.S. dollar in June 1997 to 6.41 in August 1998. Between 1996 and 1998, the SARB intervened heavily in the forward exchange market to support the value of the rand thus dampening market volatility. The policy of continuously defending the rand from market forces had the negative consequence that the SARB was forced to accumulate a very large net open forward position (NOFP). The NOFP amounted to USD23.2 billion by the end of September 1998 (Myburgh Commission, 2002). The costliness of defending the rand during the 1990s may be regarded as a primary motivation for the change in policy stance that occurred in 2000. With the advent of inflation targeting, the SARB effectively abandoned the policy of consistently intervening in the foreign exchange market. Consequently, when pressure mounted against the rand in the latter parts of 2001, domestic market volatility increased substantially. The 2001 September 11 attacks on the World Trade Centre in the U.S. caused the rand to skyrocket to R13.84 to the dollar at the end of December 2001 – its worst level ever experienced at the time – with a recovery happening the following year. From this point on, the currency kept improving, and on the back of the commodity boom of 2003 to 2006, a low value of R5.71 against the U.S. dollar was registered in December 2004.

During the recent GFC, the rand had depreciated as much as 39.2% against the U.S. dollar from R7.33 in July 2008 to R10.20 in January 2009, but it recovered most of the losses in the following years. However, as of 4 December 2015, the rand had lost 24.3% of its value against the U.S. dollar and ended the year at R14.37 against the U.S. dollar. The currency's weakening may be partly attributed to weakened investor confidence after former President Jacob Zuma unexpectedly fired finance minister Nhlanhla Nene. The economy has seen some confidence returning to the market after the election of President Cyril Ramaphosa as president of the African National Congress (ANC) and the country at the end of 2017, which affected the value of the domestic currency favourably. Between December 2017 and March 2018, the rand strengthened from R13.25 to R11.84 against the U.S. dollar. Unfortunately, the positive trend was short-lived, and the currency lost some footing in the international currency market amidst uncertainty surrounding the issue of land expropriation without compensation. By the end of December 2018, the currency registered a value of R14.09 against the U.S. dollar.

The first official identification of COVID-19 by the World Health Organisation (WHO) was on 31 December 2019, with the organisation officially declaring that the coronavirus outbreak became a global pandemic on 11 March 2020[8]. Since then, a worldwide economic slowdown has thrust many countries into severe recessions, with the probability of a broad economic depression ever increasing. On 5 March 2020, The National Institute for Communicable Diseases (NICD) detected the first COVID-19 case in SA[9]. With the virus spreading at an exponential rate and the onset of community transmission in SA, the government declared a national state of disaster on 15 March 2020 and implemented a hard lockdown and stay-at-home order on 26 March 2020 to curb the spread of the virus. While the contagion effects of the pandemic began to take its toll on economic conditions, SA saw a major depreciation of the Rand as it hit a new all-time low in early April breaching R19 to the U.S. dollar – making it the worst-performing emerging market currency over the past year. This was also following a long-expected downgrade to junk status by credit rating agency Moody's Investors Service and a further downgrade by Fitch Ratings. The rand remained in the R17 - R18 range until October 2020 and strengthened to R14.69 against the U.S. dollar by the end of 2020. The rand initially depreciated at the turn of 2021 as sentiment towards the rand deteriorated amid further lockdown restrictions brought about by the second wave of COVID-19 infections. However, the external value of the rand then appreciated up to mid-June 2021, reflecting improved investor sentiment towards emerging market currencies amid continued accommodative monetary policy in the U.S. as well as better-than-expected domestic economic outcomes. Due to domestic civil unrest in July, which resulted in significant property damage, looting and affected movements of goods along an important trade corridor, as well as rising concerns about the impact of new COVID-19 outbreaks and the Delta variant on the global and domestic economic recovery, the rand weakened and breached R15 to the U.S. dollar during August 2021.

Figure 2.1 also depicts the FTSE/JSE All Shares Index, which was introduced in June 2002 to replace the old All Share index after adopting the FTSE global classification system, with data on the index spliced back to 1979. The FTSE/JSE Africa All Shares Index is a market capitalisation-weighted index. Companies included in this index make up the top 99% of the total pre-free-float market capitalisation of all listed companies on the Johannesburg Stock Exchange[10]. JSE Limited

---

[8] https://www.who.int/news/item/27-04-2020-who-timeline---covid-19
[9] https://www.nicd.ac.za/first-case-of-covid-19-announced-an-update/
[10] https://www.bloomberg.com/quote/JALSH:IND

(previously the JSE Securities Exchange and the Johannesburg Stock Exchange) is the oldest and largest stock exchange in Africa, in operation for almost 120 years.

From Figure 2.1, it is evident that the share price index displays an increasing trend following 1994, compared to the years leading up to the transition to democracy and the majority rule of 1994. Du Plessis and Smit (2007) describe the varying time trend pattern in terms of SA macroeconomic developments. The authors refer to the slow growth in both the share price index and real output in the SA economy as the "decade of decline", which ended in 1994.

The share price index trend picked up substantially from 1995 to 2004, although there was noticeable volatility in the stock market. During this period, described by Du Plessis and Smit (2007) as a "recovery period", real economic growth averaged 3.1% per annum, with varying growth rates in the All Shares Index (ASI), registering an average growth of 7.5% per annum. Political stability arising from the end of Apartheid and the adoption of sound economic policies have contributed to creating an atmosphere conducive to investment and growth in the economy, and in the stock market in particular. Further, until the onset of the GFC in 2008, SA was experiencing a period of high real economic growth: annual real GDP growth between 2005 and 2007 averaged 5.1% per annum. The associated growth in the ASI amounted to an average of as high as 36% per annum during this period. The improved growth may largely be attributed to increased domestic demand arising from high credit-financed consumer spending, public sector infrastructure investment and private sector fixed investment. This macroeconomic recovery could explain the persistent bullish market attributes depicted in the share price trend until 2007. However, the subsequent global recession distinctly disturbed this trend, such that real GDP only increased by an annualised quarterly average of 3.7% in 2008 and declined by an annualised quarterly average of 1.8% in the first three quarters of 2009. At the same time, the ASI declined by 34% between June 2008 and May 2009. Figure 2.1 clearly shows this adverse effect on the stock market due to the financial crisis. After a recovery following May 2009, the stock market displayed another bull run up until mid-2015.

Trade tension between the U.S. and China brought uncertainty to the stock market from 2018 onwards. In July 2018, U.S. President Donald Trump followed through on months of threats to impose sweeping tariffs on China for its alleged unfair trade practices. Over the months that followed, the two countries have been embroiled in countless back-and-forth negotiations, a tit-for-tat tariff war, introduced foreign technology restrictions, and fought several WTO cases, consequently leading U.S.-China trade tensions to the brink of a full-blown trade war. On 15 January 2020 the two sides signed the Phase One Deal, which officially agreed to the rollback of tariffs, expansion of trade purchases, and renewed commitments on intellectual property, technology transfer, and currency practices; a breakthrough in the nearly two-year trade war between the world's two largest economies.

On the back of this breakthrough, the COVID-19 pandemic began metastasising worldwide, and the ASI began losing value sharply when global risk-off sentiment heightened amidst the pandemic and the traditional flight-to-safety in safe-haven assets. Signals of profound economic repercussions increased alongside fears of surges in cases. In the first half of March, the JSE experienced extreme market volatility and unprecedented volumes causing it to widen its circuit breaker[11] trigger points, which enforce temporary trading halts for 5 minutes at a time. By 27 March 2020, the ASI had lost 25.5% of its value since the beginning of 2020. Oil price movements play a vital role in the performance of the foreign exchange and stock markets of oil-importing economies, such as SA. On 20 April 2020, due to the collapse in demand for oil as lockdown measures took place, combined with international geopolitical issues, the price of West Texas Intermediate (WTI) futures turned negative as increased supply and reduced storage capacity hindered standard market operations. The front-month May 2020 WTI crude contract dropped 306%, or $55.90, for the session to settle at negative $37.63 a barrel, the largest one-day plunge on records going back to 1983, and the settlement was the lowest on record, marking it the first and only time a contract closed with a negative value[12].

Once the possibility of vaccines was in sight, coupled with strong synchronised global support to financial recovery through monetary and fiscal support from governments across the world, markets received the support they needed, which boosted a very strong recovery. In particular, the SA Government implemented several relief measures which focused on providing tax relief, unemployment support, support for Small, Micro and Medium-Sized Enterprises (SMME's), and various loan funding – in partnership with the major banks, National Treasury, and the SARB – to help assist the country overcome the detrimental effects of COVID-19. In the U.S., the FED announced a series of extensive measures to help support the economy and markets in March 2020, including unlimited quantitative easing, cutting interest rates to zero and buying both investment-grade and high-yield corporate bonds[13]. This was the catalyst for stock market recovery

[11] Circuit Breakers are defined as a percentage in relation to the Static Reference Price (Previous Day's closing price or latest auction trade) and Dynamic Reference Price (Last Traded Price). Circuit breakers trigger temporary halts in trading of an equity on the JSE during market volatility and are imposed by regulators across the globe. This brief pause in trading is to assist investors to understand market conditions better and to try and curb the panic-selling of an equity. Circuit breakers are triggered automatically on an instrument level if the circuit breaker tolerance is breached, which will enforce a trading halt for periods of 5 minutes at a time (JSE, 2021).

[12] https://globalriskinsights.com/2020/05/making-history-coronavirus-and-negative-oil-prices/

[13] https://www.brookings.edu/research/fed-response-to-covid19/

in the U.S. and also in SA, as the ASI closely follows the U.S. stock market. The U.S. equity markets also saw a surge in demand as the public was stuck at home, which resulted in additional traders as well as sporting events being cancelled worldwide, leading to sports bettors rather taking part in stock market trading[14]. By August 2020, the ASI had recovered to pre-COVID levels. In the first week of November, with the announcement of vaccines being rolled out and being approved across the world, SA started seeing a broad-based recovery where sectors that were linked to the broader economy started participating in this rally[15].

Table 2.1: Descriptive statistics of stock returns and exchange rate changes in South Africa

Panel A: 1979:01 – 2021:08		
	Stock returns	Exchange rate changes
Mean	0.9508	-0.5305
Std. Dev.	5.4228	3.2702
Skewness	-1.0963	-1.0488
Kurtosis	8.3900	9.6630
Jarque-Bera	722.4	1041.0
Probability	0.0000	0.0000
Q(10)	18.5270**	68.4510***
$Q^2(10)$	18.0760*	83.3240***
Panel B: COVID-19 period 2020:03 – 2021:08		
	Stock returns	Exchange rate changes
Mean	1.5471	-0.1412
Std. Dev.	5.8972	4.2435
Skewness	-0.5375	-1.1569
Kurtosis	3.9740	3.4292
Jarque-Bera	1.5781	4.1536
Probability	0.4543	0.1253
Q(10)	8.1559	9.5573
$Q^2(10)$	4.7896	5.0764

*Note: *, **, *** indicate a rejection at 10%, 5% and 1% critical levels.*

Jarque-Bera is the test statistic for testing whether a time series is normally distributed. The test statistic is computed as $JB = \frac{N-k}{\sigma}\left(skew^2 + \frac{1}{4}(kur-3)^2\right)$

where skew is skewness, kur is kurtosis, N is the number of observations and k is the number of estimated coefficients.

Q(10) and $Q^2(10)$ are the Ljung–Box (1979) statistics for returns and squared returns, respectively, both with chi-square distribution with 10 degrees of freedom.

[14] https://www.axios.com/sports-betting-stock-market-surge-0e945773-d676-4f0a-a6a0-a0f92611b10b.html

[15] https://www.moneyweb.co.za/in-depth/ninety-one/jses-performance-for-the-past-12-months/

The inauguration of President Joe Biden saw Trump supporters storm the Capitol on January 6, 2021, which disrupted a joint session of Congress, which was convened to certify the results of the presidential election of 2020. Stock markets barely reacted to this news as it was known that this insurrection would not change the election outcome and would do nothing to change expectations around the near-term political and economic outlook, as President-elect Joe Biden will be able to push through more aggressive stimulus packages and fund spending with higher taxes[16]. From the low base of the market crash in March, the ASI saw strong runs and was up about 50% for the 12 months to the end of March 2021. It has since been trending upwards, and by August 2021, it was about 17% stronger than at the turn of 2020.

In order to gain insight into the univariate time series properties of the data series, descriptive statistics of the stock returns and exchange rate changes are presented in Table 2.1. Panel A provides the descriptive statistics of the full sample from 1979:01-2021:08 and shows that sample means of all the time series are significantly different from zero. The mean stock return is 0.95%, and the volatility associated with stock returns is relatively high indicated by the standard deviation of 5.42. The mean and associated volatility of the exchange rate changes are lower than stock returns at -0.53% and 3.27, respectively. The standard deviations for both stock and exchange rate returns are higher than their mean, indicating a higher level of risk in both markets. The skewness and excess kurtosis statistics show that the distributions of stock returns and exchange rate changes are negatively skewed (i.e., asymmetric distribution) and highly leptokurtic with respect to the normal distribution hypothesis. Thus, both time series exhibit a non-normal distribution, supported by the strong rejection of the Jarque-Bera statistic at the 1% level of significance. The Ljung–Box (1979) statistic, which tests for serial correlation, calculated for up to 10 lags[17] relative to the absolute returns and squared returns for stock and exchange rates indicates some linear and nonlinear dependencies. This result is consistent with the Breusch-Pagan-Godfrey (1978) test. The linear dependency contrasts with the 'informational efficiency' hypothesis and may be evidence of some form of market inefficiency[18]. The nonlinear dependencies may be captured by a certain autoregressive conditionally heteroskedastic (ARCH) model (Nelson, 1991). Panel B provides the descriptive statistics of the COVID-19 period and shows that the mean stock market returns were higher during the COVID-19 period, explained by the possibility of vaccines coupled with very

[16] https://www.marketwatch.com/story/why-stocks-and-financial-markets-shrugged-as-a-violent-mob-stormed-the-capitol-11609972407

[17] In-line with Yang and Doong (2004).

[18] The 2013 Nobel Prize winner, Eugene F. Fama, defined a market to be "informationally efficient" if prices always incorporate all available information. In this scenario, all new information about any given firm is certain and immediately priced into that company's stock.

strong synchronised global support to financial recovery and higher demand in the equity market; whilst the exchange rate changes saw a smaller mean as the full sample saw episodes of major depreciation around 1985, 1998, 2001 and 2008/9 which was not matched during the COVID-19 period. Both markets saw higher volatility with larger standard deviations during the COVID-19 period.

2.4.2 Methodology

Black (1976) recognised that in stock markets, volatile periods are often initiated by a large negative shock, which suggests that positive and negative shocks may have an asymmetric impact on the conditional volatility of subsequent observations. Black attributed this to the way firms are financed. When the value of (stock of) a firm falls, the debt-to-equity ratio increases, which in turn leads to an increase in the volatility of the returns on equity in a phenomenon commonly referred to as the 'leverage effect'. This is a well-documented empirical finding in the finance literature (see Bae & Karolyi, 1994; Koutmos & Booth, 1995; and Booth *et al.*, 1997). A different economic explanation than that given by Black (1976) would be required to explain a 'leverage effect' or asymmetries in foreign exchange markets. Bollerslev *et al.* (1992) review a significant body of empirical evidence and conclude that "whereas stock returns have been found to exhibit some degree of asymmetry in their conditional variances, the two-sided nature of foreign exchange markets makes such asymmetries less likely" (Bollerslev *et al.*, 1992, p. 38). Ho and Tsui (2008) also note that, unlike in stock markets, the asymmetric responses to positive versus negative shocks of the same magnitude in exchange rate volatility are not common.

The asymmetric phenomenon, in combination with the observed volatility clustering in financial market returns, validates the use of a bivariate EGARCH framework. A bivariate framework is implemented since one of the drawbacks of a univariate EGARCH process is that the model fails to consider the information of covariance between stock return and exchange rate change (Chiang *et al.,* 2000). The bivariate EGARCH model developed by Nelson (1991) captures the potential asymmetric behaviour of financial market returns and avoids imposing non-negativity constraints by specifying the logarithm of the variance – so that it is no longer necessary to restrict parameters, such as in GARCH modelling, in order to avoid negative variances (Bhar & Nikolova, 2008). The bivariate EGARCH model allows both "good" news and "bad" news to have a different impact on volatility while also allowing "big" news to have a greater impact on volatility.

This paper follows the bivariate EGARCH specification set out by Aloui (2007) to investigate whether the volatility of stock returns affects the volatility of exchange rate changes and *vice versa* within the South African economy. The framework is set out as follows:

$$S_t = \alpha_{S,0} + \sum_{i=1}^{r} \alpha_{S,i} S_{t-i} + \sum_{i=1}^{r} \alpha_{E,i} E_{t-i} + \varepsilon_{S,t}$$
$$\varepsilon_{S,t} / \Omega_{t-1} \sim N(0, \sigma_{S,t}^2) \quad (1)$$

$$E_t = \alpha_{E,0} + \sum_{i=1}^{r} \alpha_{E,i} E_{t-i} + \sum_{i=1}^{r} \alpha_{S,i} S_{t-i} + \varepsilon_{E,t}$$
$$\varepsilon_{E,t} / \Omega_{t-1} \sim N(0, \sigma_{E,t}^2) \quad (2)$$

where equations (1) and (2) specify the conditional mean equations for the stock returns, S_t, and exchange rate changes, E_t. These equations capture the mean spillover effects between stock returns and exchange rates and *vice versa*. In these equations, $\alpha_{S,0}$, $\alpha_{E,0}$, $\alpha_{S,i}$ and $\alpha_{E,i}$ for i = 1, 2, …, n are parameters to be estimated. The stochastic error terms are given by $\varepsilon_{S,t}$ and $\varepsilon_{E,t}$. Conditional on Ω_{t-1} (the information set at time t-1), the stochastic error terms are assumed to be normally distributed with zero mean and variance $\sigma_{S,t}^2$ and $\sigma_{E,t}^2$, respectively, where $\sigma_{S,t}^2$ and $\sigma_{E,t}^2$ are the conditional time-varying variances of stock returns and exchange rate changes. In the current study, a one-period lag of stock returns and exchange rate changes will be included in equations (1) and (2). This is determined using the general-to-specific approach attributed to Hendry (1995) and evaluating the different information criteria[19], keeping the parsimony principle in mind.

As maintained by the EGARCH specification, the variance is conditional on its own past values as well as on past values of the standardised residuals[20] (Kanas, 2000). The conditional variance equations for the stock returns, $\sigma_{S,t}^2$, and the exchange rate changes, $\sigma_{E,t}^2$, are given by:

$$\sigma_{S,t}^2 = \exp\{ c_{S,0} + \sum_{j=1}^{p_S} \mathrm{b}_{S,j} \log(\sigma_{S,t-j}^2) + \delta_{S,S}[(|z_{S,t-1}| - E|z_{S,t-1}|) + \theta_{S,S} z_{S,t-1}]$$
$$+ \delta_{S,E}[(|z_{E,t-1}| - E|z_{E,t-1}|) + \theta_{S,E} z_{E,t-1}] \} \quad (3)$$

$$\sigma_{E,t}^2 = \exp\{ c_{E,0} + \sum_{j=1}^{p_E} \mathrm{b}_{E,j} \log(\sigma_{E,t-j}^2) + \delta_{E,E}[(|z_{E,t-1}| - E|z_{E,t-1}|) + \theta_{E,E} z_{E,t-1}]$$

---

[19] The information criteria evaluated include Akaike, Schwarz and Hannon-Quinn.

[20] $z_{S,t}$ and $z_{E,t}$ are the standardised residuals of stock returns and exchange rate changes where: $z_{S,t} = (\varepsilon_{S,t}/\sigma_{S,t})$ and $z_{E,t} = (\varepsilon_{E,t}/\sigma_{E,t})$.

$$+\delta_{E,S}[(\left|z_{S,t-1}\right| - E\left|z_{S,t-1}\right|) + \theta_{E,S} z_{S,t-1}]\} \quad (4)$$

which represent the diagonal elements of the 2×2 covariance matrix Q_t. Equations (3) and (4) reflect the EGARCH(p,1) representation of the variances of $\varepsilon_{S,t}$ and $\varepsilon_{E,t}$ where the lag truncation length, p, is determined using Likelihood Ratio (LR) tests of alternative specifications. Specifically, this study tested EGARCH(2,1) against EGARCH(1,1) for SA[21]. Based on these results, an EGARCH(1,1) specification is selected for SA.

Equations (3) and (4) depict how the conditional variance in one market depends on its own lag values and past values of the standardized residuals. The persistence of the volatility is measured by $\sum_{j=1}^{p_S} \mathrm{b}_{S,j}$ for the stock returns and by $\sum_{j=1}^{p_E} \mathrm{b}_{E,j}$ for the exchange rate changes, where conditional variances are finite if $\sum_{j=1}^{p_S} \mathrm{b}_{S,j} < 1$ and $\sum_{j=1}^{p_E} \mathrm{b}_{E,j} < 1$. The persistence of volatility may be quantified by considering the half-life, given by $HL = \frac{\ln(0.5)}{\ln(\sum_{j=1}^{p_k} \mathrm{b}_{k,j})}$ $where\ \mathrm{k} = S \text{ or } E$, which indicates the time period required for the shocks to reduce to one-half of their original size. The terms $\delta_{S,S}[(\left|z_{S,t-1}\right| - E\left|z_{S,t-1}\right|) + \theta_{S,S} z_{S,t-1}]$ and $\delta_{E,E}[(\left|z_{E,t-1}\right| - E\left|z_{E,t-1}\right|) + \theta_{E,E} z_{E,t-1}]$ capture the ARCH effect. The expressions $(\left|z_{S,t-1}\right| - E\left|z_{S,t-1}\right|)$ and $(\left|z_{E,t-1}\right| - E\left|z_{E,t-1}\right|)$ capture the "size" effects of stock returns and exchange rates, respectively, where if the past absolute value of $z_{S,t-1}$ or $z_{E,t-1}$ is greater than its expected value, the current volatility will rise. The parameters $\theta_{S,S}$ and $\theta_{E,E}$ allow the effect to be asymmetric: if $\theta_{S,S}$ and $\theta_{E,E}$ are not statistically different from zero, then a positive and negative shock possess the same magnitude of effect; however, if $0 > \theta_{S,S}$ then negative shocks increase volatility more than positive shocks, which allows the asymmetry effect to be captured. This is called the 'leverage effect' documented by Black (1976) and Nelson (1991).

The volatility spillover effect from exchange rate changes to the stock returns is captured by the term $\delta_{S,E}[(\left|z_{E,t-1}\right| - E\left|z_{E,t-1}\right|) + \theta_{S,E} z_{E,t-1}]$ in equation (3), while the volatility spillover effect from stock returns to exchange rate change is captured by the term $\delta_{E,S}[(\left|z_{S,t-1}\right| - E\left|z_{S,t-1}\right|) + \theta_{E,S} z_{S,t-1}]$ in equation (4). In these equations, the parameter $\delta_{S,E}$ measures the spillovers from the exchange rate changes to stock returns, and the parameter $\delta_{E,S}$ measures the spillovers from the stock returns to the exchange rate changes. To determine whether asymmetric effects are present, the parameters $\theta_{S,E}$ and $\theta_{E,S}$ are considered: if $\theta_{S,E} < 0$ in equation (3) then a negative exchange rate shock increases the volatility of stock returns more than a positive shock; while if

[21] The likelihood ratio (LR) test is calculated as: $2\times|\ln_{\mathrm{EGARCH(2,1)}} - \ln_{\mathrm{EGARCH(1,1)}}|$.The best-suited model is selected on the basis of Davies (1987) critical values.

$\theta_{E,S} < 0$ in equation (4) then a negative stock returns shock increases the volatility of exchange rate changes more than a positive shock.

According to Bhar and Nikolova (2008), the asymmetric effect of standardised innovations on volatility may be measured as derivatives:

$$\frac{\partial\,(|z_{k,t-1}|-E|z_{kt-1}|)+\theta_{k,k}z_{k,t-1})}{\partial\, z_{k,t-1}} = \begin{pmatrix} 1+\delta_k & if\ z_k>1 \\ -1+\delta_k & if\ z_k<1 \end{pmatrix} \qquad (5)$$

where k = S or E. The relative asymmetry, or leverage effect, is defined as $\frac{|-1+\delta_k|}{(1+\delta_k)}$ and considers the differing impact of a market's own innovation on the current conditional variance. This quantity is greater than, equal to, or less than 1 for negative asymmetry, symmetry and positive asymmetry, respectively.

The conditional covariance, $\sigma_{S,E,t}$, represents the off-diagonal elements of the covariance matrix Q_t and is specified as:

$$\sigma_{S,E,t} = \rho_{S,E}\,\sigma_{S,t}\sigma_{E,t} \qquad (6)$$

where $\rho_{S,E}$ is the cross-market correlation coefficient between the standardised residuals from the stock returns and exchange rate change equations. In line with Bollerslev (1990), the conditional correlations are assumed to be constant over time. With the assumption of normality and given a sample of T observations, the abovementioned parameters are estimated by numerical maximisation of the log likelihood function of a bivariate EGARCH model given by:

$$L(\Theta) = -0.5(NT)\,ln(2\pi) - 0.5\sum_{i=1}^{T}(ln|\,Q_t| + \varepsilon_t'\,Q_t^{-1}\varepsilon_t) \qquad (7)$$

where N is the number of equations (two in this instance), Θ is the vector of parameters to be estimated, ε_t is the 1×2 vector of residuals at time t, and Q_t is the 2×2 conditional variance-covariance matrix with diagonal elements given by equations (3) and (4) and cross-diagonal elements given by equation (5). The log-likelihood function is estimated using the Broyden, Fletcher, Goldfarb and Shanno (BFGS) optimisation method (see Broyden, 1965, 1967; and Fletcher & Powell, 1963).

2.5 EMPIRICAL RESULTS

Following the prevailing empirical literature, estimating the conditional mean equations (1) and (2) of stock returns and exchange rate changes first requires unit root tests of the variables and cointegration tests to determine a possible relation between the variables for the period January 1979 to August 2021. These results are presented in Section 2.5.1. Thereafter, in Section 2.5.2 the bivariate EGARCH results are presented, followed by an analysis and discussion of the first and second moment outcomes.

2.5.1 Cointegration analysis

The cointegration analysis is critical – if the above variables under consideration are found to be cointegrated, the error correction terms need to be inserted into the conditional mean equations. To test for stationarity of the series, the Phillips-Perron (1988) test (PP) is implemented. This test is justified as autocorrelation and ARCH effects were detected in both financial time series, and the PP test is robust to strong autocorrelation and heteroscedasticity in the series (Yang & Doong, 2004). The bandwidth is based on Newey-West using the Barlett kernel spectral estimation method. The results of the PP stationarity tests are reported in Table 2.2, panel A, and conclude that both the time series are not stationary in level form. Whether or not a time trend is included in the unit root test estimation, the PP test shows that the first differences between the time series are stationary. The stock index and the nominal effective exchange rate time series are therefore integrated of the same order – I(1). This result is consistent when implementing the Augmented Dickey-Fuller (ADF) and the Ng-Perron unit root tests. The data series for stock returns and exchange rate changes are stationary in levels.

Table 2.2: Results of the Phillips-Perron unit root tests and Johansen cointegration test

Panel A: Phillips-Peron unit root test

	Level		First difference	
	No trend	With trend	No trend	With trend
Stock market index	1.8882	-0.9399	-23.6700***	-24.0684***
Effective exchange rate	-2.3380	-1.0924	-16.8200***	-17.0847***

Panel B: Johansen cointegration test

H_0	λ_{max}	Trace
$r \leq 0$	9.9409 (14.2646)	10.5974(15.4947)
$r \leq 1$	0.6566 (3.8415)	0.6566 (3.8415)

*Note: *, **, *** indicate a rejection at 10%, 5% and 1% significance levels.*
H_0 is the null hypothesis that the number of cointegrating vectors is less than or equal to the number specified, and λ_{max} *and Trace are the Johansen (1988) test statistics for testing for the existence of cointegration. The 5% critical values of* λ_{max} *and Trace are given in parentheses.*

Based on this finding, Johansen's (1988) cointegration test is implemented to establish whether any combinations of the time series have a long-run relationship or are cointegrated. Phylaktis and Ravazzolo (2005) suggest that the use of the cointegration technique overcomes the problem of non-stationarity and allows investigation into both the levels and differences of the stock index and exchange rates series. The Johansen test is used here as it is also shown to be robust in the presence of heteroscedasticity (Lee & Tse, 1996). The bivariate cointegration test results are presented in Table 2.2, panel B. The test results show that stock market indices and exchange rates are not cointegrated for the period under consideration. As a result, there is no significant long-run relationship between stock index prices and the effective exchange rate. Given this outcome, the conditional mean equations (1) and (2) will be estimated without the error correction terms. This result is consistent with those of Granger *et al.* (2000), Aloui (2007), Kutty (2010), Zhao (2010), Diamandis and Drakos (2011) and Sikhosana and Aye (2018); whilst being contrary to the reported results of Bahmani-Oskooee and Sohrabian (1992), Ajayi and Mougoué (1996) and Aydemir and Demirhan (2009), where the latter studies do find a cointegrated relationship to exist between the stock market indices and exchange rates for the respective economies under consideration, and therefore do include the error correction term in the conditional mean equations.

2.5.2 The bivariate EGARCH results

Table 2.3 reports the results of estimations of the bivariate EGARCH model specified in equations (1) to (6) for SA for the period from January 1979 to August 2021, and Table 5 reports the estimation results for the COVID-19 period from March 2020 to August 2021. A RATS 10.0 software routine has been developed based on the methodology cited for the bivariate EGARCH model. The model presented considers both price (mean) and volatility (variance) spillovers between the two markets.

Table 2.3: Bivariate EGARCH model for volatility spillovers between stock returns and exchange rate changes in South Africa, 1979:01–2021:08

		Stock returns		Exchange rate changes
Panel A: Parameter estimation				
Mean equation				
	$\alpha_{S,0}$	0.8773***	$\alpha_{E,0}$	-0.4334***
		(4.24)		(-4.52)
	$\alpha_{S,1}$	0.1746***	$\alpha_{S,1}$	0.0464**
		(4.1)		(2.37)
	$\alpha_{E,1}$	0.0047	$\alpha_{E,1}$	0.2443**
		(0.09)		(6.37)
Variance equation				
	$c_{S,0}$	3.1287***	$c_{E,0}$	0.2543**
		(9.67)		(2.22)
GARCH effect	$\sum_{j=1}^{p_S} b_{S,j}$	0.5177***	$\sum_{j=1}^{p_E} b_{E,j}$	0.8930***
		(5.69)		(56.52)
ARCH effect	$\delta_{S,S}$	0.4561***	$\delta_{E,E}$	0.2788***
		(5.36)		(4.68)
Asymmetric effect	$\theta_{S,S}$	-0.6637***	$\theta_{E,E}$	0.4998***
		(-5.29)		(8.08)
Shock spillover		-0.2805***		0.04*
		(-3.38)		(1.75)
Volatility spillover	$\delta_{S,E}$	0.0725	$\delta_{E,S}$	0.0019
		(1.48)		(0.08)
Asymmetric spillover	$\theta_{S,E}$	0.2657*	$\theta_{E,S}$	0.0504*
		(1.87)		(1.87)
Half-life		1.05		6.13
Relative asymmetry		4.94		0.33
$\rho_{S,E}$		0.1398***		
Panel B: Model diagnostic test				
Ljung-Box Q(5) statistics				
$z_S \cdot z_E$		11.84		

*Note: Note: *, **, *** indicate a rejection at 10%, 5% and 1% significance levels. The numbers in parentheses indicate t-statistics. Half-life represents the time it takes for the shocks to reduce their impact by one-half:* $HL = \frac{\ln(0.5)}{\ln(\sum_{j=1}^{p_k} b_{k,j})}$ $where\ k = S$ or E.

Relative asymmetry $= \frac{|-1+\delta_k|}{(1+\delta_k)}$ *and may be greater than, equal to or less than 1, indicating negative asymmetry, symmetry, and positive asymmetry, respectively.*

LB(5) and LB²(5) are the Ljung-Box statistics (of order 5) applied to the cross-correlation. A lag length of 5 is sufficient as it is unlikely that a relationship will only be apparent when longer lags are used (Estima, 2021).

Considering the first moment interdependence, Table 2.3 shows that the previous month's stock returns have a significant impact on the current month's stock returns. There are also positive price spillovers from the foreign exchange to the stock market. In SA, currency depreciation (appreciation) habitually drags up (down) stock prices. In the long run, for an economy with a significant import (export) sector, the unfavourable effects of currency depreciation (appreciation) on imports (exports) may induce a 'bearish' stock market. In 2020 SA was the 39th largest exporter in the world[22] leading exports in: (i) pearls, precious stones, metals, coins, (ii) ores slag and ash, (iii) vehicles other than railway, tramway, and (iv) mineral fuels, oils and distillation products.[23] In 2020, the top five export destinations include China, the U.S., Germany, the UK and Japan[24]. In the short run, currency depreciation may have a negative effect on the stock market as the domestic counterpart of currency depreciation is inflation, which may exert a dampening effect on the stock market (Yang & Doong, 2004). In addition, the inflationary effects of a declining domestic currency may encourage international investors to decrease their portfolio of domestic assets, thereby depressing the stock market in the long run. This price spillover is, however, found to be statistically insignificant.

Looking at exchange rate changes, the previous month's exchange rate change has a significant impact on the current month's exchange rate change. There are also significant positive price spillovers from the stock to the exchange market. In the SA economy, an increase (decrease) in stock price causes currency appreciation (depreciation). The short-run effect of increases in stock prices on the domestic currency value can be explained by the stock market's providing a barometer for the health of an economy (Solnik, 1987). This is attributed to the fact that stock returns forecast changes in economic activity as measured by industrial production, real growth in gross national product, employment rate, or corporate profits (Giovannini & Jorion, 1987). A 'bullish' market reflects economic expansion where an increase in domestic stock assets will: (i) entice international shareholders to revise their investment portfolio and substitute foreign assets for domestic assets, and (ii) increase wealth and the demand for each of the assets in the model where the surplus demand for money will lead to higher interest rates which cause a substitution from foreign securities to domestic assets (Phylaktis & Ravazzolo, 2005). This result is generally in line with the portfolio balance model proposed by Branson and Henderson (1985) and Frankel (1983). Overall, this empirical finding is consistent with those available in the literature – being similar to those of Nieh and Lee (2001), Yang and Doong (2004), and Sikhosana and Aye (2018). Changes in stock prices provide significant informational signals to foreign exchange brokers,

[22] https://en.graphtochart.com/economy/south-africa-exports-goods-services-constant.php#worldranking
[23] https://tradingeconomics.com/south-africa/exports-by-category
[24] https://tradingeconomics.com/south-africa/exports-by-country

whilst the exchange rate does not appear to be a significant factor for the stock markets in terms of price spillovers.

Looking at the variance equation, the persistence of volatility or GARCH effects is measured by $\sum_{j=1}^{p_S} b_{S,j}$ for stock returns and by $\sum_{j=1}^{p_E} b_{E,j}$ for exchange rate changes. As seen in Table 2.3, volatility persistence is common in both markets and is less than unity suggesting that the unconditional variance is finite, which is a necessary condition for the volatility process to be stable (Aloui, 2007). It is, therefore, possible to estimate the degree of volatility persistence based on the half-life of a shock in the stock and foreign exchange markets. The volatility in the stock market took an average of approximately one month to reduce the impact of its shocks by half, while volatility in the foreign exchange market took on average approximately six months to reduce the impact of its shocks by half. There are also significant ARCH effects in both markets which indicates volatility clustering – referring to the observation first noted by Mandelbrot (1963) where in financial series large changes tend to be followed by large changes, of either sign, or small changes tend to be followed by small changes. The asymmetric effect is captured in parameters $\theta_{S,S}$ and $\theta_{E,E}$. Since $0 > \theta_{S,S}$ and is statistically significant, a negative shock in the stock market increase volatility more than positive shocks – known as the 'leverage effect' documented by Black (1976) and Nelson (1991). Looking at the exchange rate market, $\theta_{E,E} > 0$ and is statistically significant implying that positive shocks in the exchange market have greater impact on volatility than negative shocks of the same magnitude. This finding could be attributed to the fact that SA is an export dominated country making it more sensitive to currency appreciations than depreciations, where a currency appreciation is viewed as 'bad news' as it harms the export industry.

The asymmetric effect of negative and positive shocks in each market is evaluated by the relative asymmetry statistic or leverage effect. The stock market presents with a relative asymmetry greater than 1, indicating that the stock market exhibits negative asymmetric effects, and a negative innovation will have a greater impact on conditional volatility than a positive innovation. This is telling of the 'leverage effect', where unexpected "bad" news will have greater impacts on current conditional volatility than "good" news. The exchange rate presents with a relative asymmetry of less than 1, indicating a positive asymmetric effect and the impact of "good" news will outweigh "bad" news of the same size. In other words, a local currency appreciation has a greater impact on current conditional volatility compared to a currency depreciation. The management of the exchange rate by SA authorities over the years may be a possible explanation for asymmetries since

"…interventions may affect important variables such as interest rates and inflation, which the market considers truly "bad" news." (Maya & Gomez, 2008).

Turning attention to the second moment interdependence, the off-diagonal elements of the ARCH effect capture the cross-market shock effects, and the results show evidence of significant bidirectional shock spillovers between stock returns and exchange rate returns. On the other hand, the results show no significant volatility spillover exists between the stock and exchange markets. Jorion (1990) asserts that a possible justification for the lack of exchange rate spillovers is that the positive exchange rate volatility effects on stock returns for some firms are negated by negative effects for others leading to a weak or zero net exchange rate effect. An alternative explanation, given by Bodnar and Gentry (1993), is that volatility spillovers are counteracted by the sound use of exchange rate risk hedges, such as forwards, futures and currency options – which creates a flow that reduces the exchange rate effects on profits after exchange rate transactions have been completed, thereby reducing the sensitivity of profit to exchange rate fluctuations.

In terms of asymmetric spillover effects, the results show significant asymmetric volatility spillovers from the exchange rate to the stock market and from the stock market to the exchange rate. This result has implications for the level of exchange rate risk faced by multinationals with costs and revenues denominated in more than one currency (Kanas, 2000). The volatility of stock returns in SA directly affects the exchange rate risk. This result supports the model of Zapatero (1995), in which, with integrated financial markets and free capital movements, the volatility of stock returns is a determinant of the exchange rate volatility. The results suggest that positive innovations in the stock market have greater impacts on the conditional volatility of exchange rates than negative innovations. This finding is not in line with those of Kanas (2000), Yang and Doong (2004) and Aloui (2007) based on the premise that investors are more skittish to "bad" news but does agree with the results of Sikhosana and Aye (2018). The results also suggest that positive innovations in the exchange rate market have greater impacts on the conditional volatility of exchange rates than negative innovations.

Moreover, based on the estimations of the multivariate EGARCH model, a simulation of the different impacts of good and bad news on cross-market volatility is performed. The results are presented in Table 2.4, which supports prior findings and shows that positive shocks in the stock market have greater impacts on the future volatilities for the exchange rate than negative shocks, as well as positive shocks in the exchange rate have greater impacts on the future volatilities for the stock market than negative shocks. Finally, the correlation coefficient between the standardised residuals of the stock return and the exchange rate changes are considered. The standardised residuals are interpreted as exchange rate changes and stock returns from which linear and nonlinear dependencies have been filtered through the bivariate EGARCH modelling (Kanas, 2000). As Table 2.3 displays, the correlation coefficients are positive and significant for SA, suggesting a statistically significant contemporaneous relationship between stock returns and exchange rate changes.

Table 2.4: Total impact of innovations on volatility in the markets

Total impact of innovations in the stock market on volatility in the exchange market	
Innovations	Percentage change in volatility of exchange market
+1% in stock market	0.0019
-1% in stock market	0.0018
Total impact of innovations in the exchange market on volatility in the stock market	
Innovations	Percentage change in volatility of stock market
+1% in exchange market	0.0917
-1% in exchange market	0.0550

Note: Entries represent the total impact of innovations in one market on the volatility in the other market, which is defined as $\delta_{i,j}(1 + \theta_{i,j})$ *for a positive 1% innovation and* $\delta_{i,j}|-1 + \theta_{i,j}|$ *for a negative 1% innovation.*

In general, these results imply that changes in stock prices signal important information about the economic fundamentals of the foreign exchange market in the first and second moment interactions, and exchange rate movements convey information about future stock price movements in the second moment interdependence. Therefore, findings suggest there is information transmission between the two markets and that the two markets are integrated. Generally, these findings align with the findings of Kumar (2013) and Sikhosana and Aye (2018).

Turning attention to Table 2.5, results are reported for the volatility spillovers between stock returns and exchange rate changes during the COVID-19 pandemic. Considering the first moment interdependence, there are significant price spillovers from the exchange rate to the stock market and *vice versa*. This contrasts with the full sample results where only significant spillovers were seen from the stock market to the exchange rate. During the COVID-19 pandemic, changes in stock prices provide significant informational signals to foreign exchange brokers; similarly, the exchange rate is a significant factor for the stock markets. Similar price spillovers are seen during the global and East-Asian financial crises[25]. Looking at the variance equation, volatility persistence remains common in both markets. Given that the volatility persistence is less than unity, it is possible to

[25] See Table A1 in Appendix A.

estimate the degree of volatility persistence during the COVID-19 pandemic based on the half-life of a shock in the stock and foreign exchange markets. The volatility in the stock market took an average of approximately 0.3 months, or about 9 days, to reduce the impact from its shocks by half, whilst volatility in the foreign exchange market took on average approximately 0.5 months, or 15 days, to reduce the impact from its shocks by half. Similarly, there are also significant ARCH effects in both markets, indicating volatility clustering. The asymmetric effect is captured in the parameters $\theta_{S,S}$ and $\theta_{E,E}$. Since both $0>\theta_{S,S}$ and $0>\theta_{E,E}$ are statistically significant at 1%, a negative shock in the stock market and exchange rate market increases volatility more than positive shocks – known as the "leverage effect" documented by Black (1976) and Nelson (1991).

Turning attention to the second moment interdependence, results show there is evidence of significant unidirectional shock spillovers from the stock returns to the exchange rate returns. Results also show that there exists significant volatility spillover from the stock to exchange markets and *vice versa*, suggesting that during COVID-19 an increase in volatility in one market leads to an increase in the volatility of the other market. This finding contrasts with the full sample, where no significant volatility spillovers were found, suggesting that spillovers are more pronounced during COVID-19. This finding can be attributed to the number of foreign investors in the SA stock markets. High volatility in equity markets, which signals an increasing degree of market risk, may lead to the rapid sale of assets by foreign market participants for them to relocate funds to more stable equity markets, which results in massive capital outflow and, thus, volatility in the foreign exchange market. Thus, the activities of foreign investors in the SA equity market provide a channel through which shocks in the equity market are transmitted to the foreign exchange market. To explain the reverse spillover, Živkov *et al.* (2021) assert that the exchange rate volatility carries various sets of news related to different macroeconomic regularities, such as trade news, real interest rate news and expected inflation news. These fundamentals affect stock markets in different ways, and thus when the foreign exchange market becomes more volatile, stock markets also become more uncertain in terms of higher conditional volatility. In terms of asymmetric spillover effects, the results show significant bidirectional asymmetric spillovers between the two markets. The results suggest that negative innovations in the stock market have greater impacts on the conditional volatility of exchange rates than positive innovations, while positive innovations in the exchange rate market have greater impacts on the conditional volatility of stock market returns than negative innovations. Table 2.6 supports these findings. Similar shock, volatility and asymmetric spillovers are seen during the global and East-Asian financial crises.

Table 2.5: Bivariate EGARCH model for volatility spillovers between stock returns and exchange rate changes in South Africa during COVID-19 from 2020:03–2021:08

		Stock returns		Exchange rate changes
Panel A: Parameter estimation				
Mean equation				
	$\alpha_{S,0}$	-0.6476***	$\alpha_{E,0}$	-1.4018***
		(-18.5)		(-1955)
	$\alpha_{S,1}$	0.3115***	$\alpha_{S,1}$	0.3884***
		(56.21)		(8289)
	$\alpha_{E,1}$	0.1559***	$\alpha_{E,1}$	0.2202***
		(42)		(3049)
Variance equation				
	$c_{S,0}$	-0.2263***	$c_{E,0}$	0.1911***
		(-13.87)		(13.81)
GARCH effect	$\sum_{j=1}^{p_S} b_{S,j}$	0.1***	$\sum_{j=1}^{p_E} b_{E,j}$	0.2709***
		(25.94)		(57.42)
ARCH effect	$\delta_{S,S}$	0.0325***	$\delta_{E,E}$	-0.8423***
		(30.81)		(-12.56)
Asymmetric effect	$\theta_{S,S}$	-2.9253***	$\theta_{E,E}$	-2.7295***
		(5.58)		(-6.13)
Shock spillover		-0.0154		-0.0267***
		(-0.22)		(-30.56)
Volatility spillover	$\delta_{S,E}$	-0.0844***	$\delta_{E,S}$	-0.3209***
		(-26.04)		(-59.5)
Asymmetric spillover	$\theta_{S,E}$	1.4243***	$\theta_{E,S}$	-2.7319***
		(8.22)		(-5.58)
Half-life		0.3		0.53
Relative asymmetry		-2.0388		-2.1564
$\rho_{S,E}$		0.4352***		
Panel B: Model diagnostic test				
Ljung-Box Q(5) statistics				
$z_S \cdot z_E$		44.9780		

*Note: Note: *, **, *** indicate a rejection at 10%, 5% and 1% significance levels. The numbers in parentheses indicate t-statistics. Half-life represents the time it takes for the shocks to reduce their impact by one-half:* $HL = \frac{\ln(0.5)}{\ln(\sum_{j=1}^{p_k} b_{k,j})}$ *where* $k = S$ or E.

Relative asymmetry considers the impact of a market's own innovation on the current conditional variance and may be greater than, equal to or less than 1, indicating negative asymmetry, symmetry and positive asymmetry, respectively.

LB(5) and LB²(5) are the Ljung-Box statistics (of order 5) applied to the cross-correlation. A lag length of 5 is sufficient as it is unlikely that a relationship will only be apparent when longer lags are used (Estima, 2021).

Table 2.6: Total impact of innovations on volatility in the markets

Total impact of innovations in the stock market on volatility in the exchange market	
Innovations	Percentage change in volatility of exchange market
+1% in stock market	0.5557
-1% in stock market	-1.1975
Total impact of innovations in the exchange market on volatility in the stock market	
Innovations	Percentage change in volatility of stock market
+1% in exchange market	-0.2046
-1% in exchange market	-0.0358

Note: Entries represent the total impact of innovations in one market on the volatility in the other market, which is defined as $\delta_{i,j}(1+\theta_{i,j})$ *for a positive 1% innovation and* $\delta_{i,j}|-1+\theta_{i,j}|$ *for a negative 1% innovation.*

Overall, the findings show significant price and volatility spillovers between the stock returns and exchange rate returns during the period of COVID-19. These findings suggest that the integration between stock and exchange rate returns intensified with the unfolding of the COVID-19 pandemic. In conclusion, the findings show support for volatility spillovers increasing the likelihood of financial crises, which is in line with previous studies that have documented the effect of extreme market turmoil on stock markets and foreign exchange (see, for example, Diamandis and Drakos, 2011; Lin, 2012; Mozumder *et al.*, 2015; Morales-Zumaquero and Sosvilla-Rivero, 2018; Živkov *et al.,* 2021). In comparison to previous studies, the multivariate EGARCH results for the COVID-19 crisis are in line with the studies focusing on the East-Asian and global financial crisis, which found that spillovers became more pronounced during economic turmoil. Similarly, with reference to volatility spillover during the COVID-19 pandemic, Rai and Garg (2022) found strong bidirectional volatility spillovers.

Diagnostic and sensitivity checks were implemented to assess the robustness of these results. Looking at the diagnostic tests in panel B of Tables 2.3 and 2.5, both the standardised innovations have zero mean and unit variance based on the Ljung–Box Q statistic and there is no mutually linear and nonlinear dependence in the series. Hence, modelling the multivariate EGARCH model can successfully capture the price volatility interactions between foreign exchange and stock markets. To gauge the sensitivity of results, the cointegration and EGARCH estimations are re-run using the real effective exchange rate instead of the nominal effective exchange rate. The results are broadly in line with those reported in Tables 2.3 and 2.5, thus corroborating the earlier findings.

2.6 CONCLUSION

This study tests for volatility spillovers between stock returns and exchange rate changes for SA using a multivariate EGARCH modelling approach for the period 1979:01– 2021:08, including an analysis of the COVID-19 pandemic in SA over 2021:03–2021:08. Empirical outcomes of this study provide evidence in support of the "stock-orientated" approach where both price and volatility information from the stock market has significant impacts on the behaviour of the exchange market, whilst evidence of the "flow-orientated" approach is seen in the second moment. Significant shock and asymmetric spillovers from the exchange to the stock market are found. There is also evidence of bidirectional asymmetric volatility spillover effects between the stock and the exchange market. During COVID-19, price and volatility spillovers between stock returns and exchange rate returns became more pronounced, confirming that there is heightened contagion during periods of crisis. Overall, findings indicate that there was a significant contagion between the two markets during COVID-19, which led to a decline in domestic stock returns and subsequent capital outflows, thereby weakening the exchange rates. Due to the elevated probability of the recurrence of pandemics in the future, it is crucial to understand the behaviour of investors in the aftermath of such events. The correlation coefficient between the EGARCH-filtered stock returns and exchange rate changes is positive and significant, signifying that there is a significant contemporaneous relationship between stock returns and exchange rate changes.

Important implications flow from these findings as improved knowledge of the price and volatility spillover effect between the stock and currency markets. Consequently, the degree of their integration will expand the information set available to international portfolio managers, multinational corporations, and policymakers alike. Evidence that stock and foreign exchange markets are interrelated implies that lagged information from one market can be used to forecast changes in the other – signifying those markets are 'informationally' inefficient, with one market having significant predictive power on the other. Investors who seek to hedge their investment risks in SA may use the information to manage their global portfolio risk and currency risk strategies, as the finding of the volatility spillover effect between these markets suggests that they should not include both assets in the same basket if aiming to diversify risk in their asset portfolio. This knowledge is also important for multinational firms which intend to manage their international currency exposures. Policymakers will benefit from this study by having a better understanding of how the stock market and foreign exchange market volatility affect each other and the economic consequences that may arise from integration of these two markets. This knowledge allows policymakers to implement policies from a financial stability perspective. Policy implications will be further discussed in Section 5.3.

CHAPTER 3

IS INFLATION UNCERTAINTY A SELF-FULFILLING PROPHECY? THE INFLATION-INFLATION UNCERTAINTY NEXUS AND INFLATION TARGETING IN SOUTH AFRICA[26]

3.1 INTRODUCTION

Central banks all over the world devote extensive resources to combat high inflation. Price stability is the primary objective of monetary policy, stemming from the irrefutable empirical evidence that it is only when an economy ensures a backdrop of price stability that sustainable growth is attained (Chen, 2022). Faust and Henderson (2004) maintained that "…best-practice monetary policy can be summarised in terms of two goals: First, get mean inflation right; second, get the variance of inflation right". Low and stable inflation rates ensure a stable business environment by allowing the different sectors of the economy to know what to expect in the future, necessitating fewer costly price adjustments and preventing tax distortions. On the contrary, high and unstable inflation creates uncertainty and distortions in the economy as it warps long-term expectations, leads to diminished capital and savings accumulation and thus reduces investment. It furthermore causes shifts in the distribution of real income and consequently leads to a misallocation of resources (Mandeya & Ho, 2021). The history of price instabilities in South Africa (SA) dates to the 1970s, and high inflation was a key concern with inflation rates in the double-digit range for an extended period following the oil price shocks of 1973 and 1979. To tame inflation, the South African Reserve Bank (SARB) pursued several policies that were unsuccessful until the adoption of inflation targeting (IT). SA officially implemented an IT band of 3-6% as part of the country's monetary policy framework in February 2000 (stating in 2017 that it prefers the 4.5% midpoint) in efforts to reduce inflation and the uncertainty surrounding it (Van der Merwe, 2004). Interestingly, SA is one of only two African countries (Ghana being the other) that have implemented IT as part of their monetary policy framework (Phiri, 2016).

Prominently, one of the major consequences of high and unstable inflation is the uncertainty that it creates around future inflation, as higher inflation may lead to erratic monetary policy, which generates uncertainty amongst economic agents regarding the future levels of inflation, which

[26] This study is under review at the *South African Journal of Economics*.

exacerbates macroeconomic instability and all its associated ills. This study is motivated to understand the inflation-inflation uncertainty nexus in SA and to determine whether higher inflation is driving higher inflation uncertainty, or whether higher inflation uncertainty is driving higher inflation. In the literature there are theoretical hypotheses for either direction of causality. Milton Friedman (1977) contended in his Nobel laureate lecture that heightened levels of inflation give rise to higher inflation uncertainty – as increases in the average inflation rate would prompt a volatile or unpredictable policy reaction by the monetary authority which would induce higher uncertainty about future inflation. Ball (1992) formalised this idea which led to the establishment of the Friedman-Ball hypothesis. The reverse causation was contended by the Cukierman and Meltzer (1986) hypothesis, which claims that higher levels of inflation uncertainty caused higher levels of inflation – as inflation uncertainty increases the incentive of central banks to act opportunistically and to generate inflation surprises to promote economic growth. Several empirical studies have sought to test whether the Friedman-Ball hypothesis or the Cukierman-Meltzer hypothesis governs the causality between inflation and inflation uncertainty, and with results being far from unanimous these opposing theoretical views compel an empirical analysis[27]. Furthermore, not many studies have considered whether the causality changes over time. It is also of interest to understand the impact that IT has had on the level of inflation and uncertainty surrounding.

As the financial capital, SA plays a significant role in Africa and has a prominent function in the Common Monetary Area (CMA)[28] under the Southern African Customs Union (SACU). Hegerty (2012), looking at sub-Saharan African (SSA) countries, proposes that the 'spillovers' into regions of SSA are strong for SA, further highlighting its importance in the region as most international effects are tied to it and country pairs. These attributes make SA an ideal setting for analysing the inflation-inflation uncertainty nexus Furthermore, the global financial crisis (GFC), the COVID-19 pandemic and the recent Russia-Ukraine conflict have affected liquidity and provoked monetary authorities around the globe to shift from conventional to unconventional monetary policies, triggering increased uncertainty which could influence how inflation uncertainty impacts inflation, and the economy in general (Barnett *et al.,* 2020). The significance of inflation uncertainty as a channel in determining the palpable influence of inflation is pertinent for policy analysis and will aid in developing policies that ensure macroeconomic stability and enhance economic welfare.

[27] Section 2 details the different theoretical linkages between inflation and inflation uncertainty.

[28] The Common Monetary Area is a monetary union which includes South Africa, Namibia, Lesotho and eSwatini (known as Swaziland prior to 2018). While each of these sovereign nations issues its own currency, all four currencies are governed by the South African Reserve Bank and are valued and exchanged at par with the South African Rand.

This study utilises a data set that extends half a century from 1970:01–2022:05, enveloping different monetary and political regimes and significant global events, to offer three main contributions to the literature. Firstly, it investigates the inflation-inflation uncertainty nexus by utilising Generalised Autoregressive Conditional Heteroscedasticity (GARCH) models to establish whether the Friedman-Ball or the Cukierman-Meltzer hypothesis holds in SA. Thereafter, it investigates the impact that the IT regime has had on inflation and its associated uncertainty within the GARCH framework. Studies focusing on SA using a GARCH specification to scrutinise the inflation-inflation uncertainty nexus and the link between IT and the level of inflation and its uncertainty are limited, cover a shorter sample period and present with conflicting results, which justifies further investigation in order to fill this gap in the literature. Finally, to date, to the best of the author's knowledge, this is the first study to employ the recent Rossi-Wang (2019) time-varying vector autoregression (VAR) based Granger causality tests to determine the dynamic relationship between inflation and inflation uncertainty and how it changes over time. At large, the existing literature only considers full-sample constant-parameter causality, which is susceptible to inconsistent results and conclusions in the presence of parameter instability due to structural changes in the relationships (Su *et al.,* 2017). In contrast, the Rossi-Wang (2019) test is robust in the presence of instabilities and regime changes.

The empirical analysis based on GARCH modelling suggests a bidirectional causality between inflation and inflation uncertainty to exist in the SA context, with strong evidence in support of the Friedman-Ball hypothesis and weaker evidence in support of the Cukierman-Meltzer hypothesis – that is, stronger evidence of increased inflation levels leading to increased inflation uncertainty, and weaker evidence in favour of a reverse causation. The Rossi-Wang (2019) time-varying Granger causality tests provide evidence that the relationship between inflation and inflation uncertainty varies across time. These results underscore the GARCH estimation result by evidencing that the Friedman-Ball hypothesis holds for the pre-IT period, while it breaks down in the IT period – with increased inflation not translating into increased uncertainty. Additionally, the results suggest that the Cukierman-Meltzer hypothesis only holds for the 10-year period prior to the adoption of IT and that it also breaks down during the IT period, indicating no transmission from higher uncertainty to higher levels of inflation following the adoption of IT as a monetary policy framework. Finally, the GARCH results also reveal that IT has been effective in reducing both the level of inflation and the volatility of inflation. This outcome contributes to the debate between economists that support IT and those who criticise the use of an IT Monetary Policy Framework by providing evidence that the IT regime has been beneficial in stabilising inflation and its associated uncertainty in SA.

The chapter proceeds as follows. Section 3.2 commences with the theoretical motivation for the linkages between inflation and inflation uncertainty. Section 3.3 provides a review of the body of literature that explores the Friedman-Ball and the Cukierman-Meltzer hypotheses, along with a review of selected studies focussing on inflation targeting. Section 3.4 introduces the econometric framework through an analysis of the data and details the different methodologies used in this study. Empirical results are reported and discussed in Section 3.5. Section 3.6 concludes the paper.

3.2 LINKAGES BETWEEN INFLATION AND INFLATION UNCERTAINTY: THEORETICAL MOTIVATION

The inflation-inflation uncertainty nexus has been considered in the literature throughout the past half century, and there are five key theoretical hypotheses outlined in the literature detailed in this section. This study, however, focuses on two of these hypotheses – the Friedman-Ball and Cukierman-Meltzer hypotheses.

The literature on the causality between the level of inflation and inflation uncertainty originates with Arthur Okun (1971) in his paper "The Mirage of Steady Inflation". Using data from 17 countries which form part of the Organisation for Economic Co-operation and Development (OECD), Okun contended that countries facing heightened inflation rates are also countries facing large standard deviations in inflation. Expanding on this work, Fischer (1981) pioneered research that tested the relationship between inflation and inflation uncertainty using the moving standard deviation of inflation to measure inflation uncertainty.

Nobel Laureate Friedman (1977) outlined the real effects of inflation and claimed a positive correlation between inflation and its associated uncertainty. Friedman's argument had two parts to it. Firstly, he claimed that an increase in the average inflation rate would prompt a volatile or unpredictable policy reaction by the monetary authority, and this reaction would induce higher uncertainty about future inflation. Rational economic agents are uncertain as to when the central bank will increase interest rates which in turn leads to uncertainty about future rents. As Friedman put it: "…a burst of inflation produces strong pressure to counter it. Policy goes from one direction to another, encouraging wide variation in actual and anticipated rates of inflation. ... in such an environment no one has single valued anticipations. Everyone recognises that there is greater uncertainty about what actual inflation will turn out to be ...". In the second part, the amplified inflation uncertainty impedes the workings of the price mechanism that assigns resources efficiently, which in turn will have adverse effects on output. Ball (1992) proposed a model that formalised Friedman's arguments that centre on the first part of the Friedman hypothesis. Ball

(1992) evaluates an asymmetric information game where the public is uncertain about the kind of policymaker that will take office. Two categories of policymakers are deliberated: a policymaker reluctant to consider disinflation due to the threat of recession and a policymaker inclined to bear the setback of disinflation. There is an ongoing random alternation of policymakers in office. He contends that if present inflation is high, the public is subject to growing uncertainty about future inflation – due to it being indefinite, which policymaker will be in office in the subsequent period and, therefore, what the policy response will be to the heightened inflation. This uncertainty fails to ensue in low inflation as monetary authorities will attempt to ensure that inflation rates are kept low (Ball, 1992). The role of Ball in formalising Friedman's argument led to the formulation of the Friedman-Ball hypothesis.

Agreeing with Friedman's study on the direction of the relationship between inflation and inflation uncertainty, studies by Pourgerami and Maskus (1987) and Ungar and Zilberfarb (1993) empirically tested inflation data of Israel covering the period 1980–1990 and argue for a negative relationship between inflation and inflation uncertainty. Their argument rests on the fact that in the incidence of escalating inflation, rational economic agents may invest additional capital in predicting inflation, which will reduce their uncertainty about future inflation.

Further research endeavours have focused on the reverse causality, where higher inflation uncertainty causes higher (or lower) inflation. According to Cukierman and Meltzer (1986) and Evans and Wachtel (1993), the two primary sources of inflation uncertainty stem from: (i) the diversity amongst international monetary policy regimes, like conventional versus unconventional monetary policies, and (ii) through policy regime uncertainty. Cukierman and Meltzer (1986) use the Barro-Gordon construct and illustrate that an escalation in uncertainty about money growth and inflation will cause the ideal average inflation rate to rise as it entices the policymaker to craft an inflation shock in the interest of fuelling output growth. Their argument implies a positive causal influence from inflation uncertainty to inflation, and Grier and Perry (1998) labelled it the Cukierman-Meltzer hypothesis. When there is a lack of a commitment mechanism and monetary policy is discretionary, Cukierman and Meltzer's model predicts that there is an inflationary bias during times of increased uncertainty. As it is arduous to assess monetary policy during periods of heightened uncertainty, central banks face a higher incentive to act opportunistically and create inflation surprises.[29] Conversely, Holland (1995) contends that policymakers could have long-term

[29] Gradually slashing down inflation is the key trait of opportunistic monetary policy. The opportunistic policymaker who faces inflation that is not too out of bounds will not try to decrease inflation further, but instead will wait to take advantage of beneficial supply shocks and recessions to reduce inflation. When a shock reduces inflation, the provisional inflation target is re-set to this new rate, and, in this gradual way price stability is ultimately achieved. An

stabilising motives and through the 'stabilising FED hypothesis' higher inflation uncertainty can prompt a lower average inflation rate, i.e., where the central bank aims to curtail the losses in welfare stemming from heightened inflation uncertainty through disinflation. Table 3.1 summarises the different causal relationships and signs of the relationships between inflation and inflation uncertainty that have been discussed.

Table 3.1: Theories regarding the relationship between inflation and inflation uncertainty

	Sign of relationship	
Relationship	**(+)**	**(-)**
Inflation causes inflation uncertainty	Friedman (1977)	Pourgerami and Maskus (1987)
	Ball (1992)	Ungar and Zilberfarb (1993)
Inflation uncertainty causes inflation	Cukierman and Meltzer (1986)	Holland (1995)

3.3 LITERATURE REVIEW

3.3.1 Empirical studies focussing on the inflation-inflation uncertainty nexus

It is imperative to understand the significance of inflation and inflation uncertainty and its detrimental impact on growth. There is extensive literature confirming on a theoretical and an empirical basis that high and unstable inflation and inflation uncertainty reduces real output across different economies around the globe (see Jansen, 1989; Judson and Orphanides, 1999; Dotsey and Sarte, 2000; Beaudry *et al.*, 2001; Elder, 2004; Apergis, 2004, 2005; Fountas *et al.*, 2004, 2006; Wilson, 2006; Miles, 2008; Bhar and Mallik, 2010; Jiranyakul and Opiela, 2011; Mallik and Chowdhury, 2011; Hartman and Roestel, 2013; Caglayan *et al.*, 2016; Balcilar *et al.*, 2017; Mandeya and Ho, 2021). One of the major penalties of high and unstable inflation is the uncertainty that it builds around future inflation, as higher inflation may lead to erratic monetary policy which generates uncertainty amongst economic agents regarding the future levels of inflation, which exacerbates macroeconomic instability and all its associated ills.

Due to inflation uncertainty being unobserved, estimating it presents a challenge. At the outset, the primary measures of inflation uncertainty used throughout the early empirical studies were

opportunistic policymaker leads to lower credibility as the public will be sceptical about the ultimate inflation target (Rudebusch, 1996).

survey-based individual forecasts dispersion and the moving standard deviation of inflation (Fountas, 2001). However, fundamental shortcomings of these measures were pointed out by Bomberger (1996) who contends that using the survey-based dispersion data determines disagreement rather than inflation volatility and that forecasters' inflation estimates may suffer from bias as they base expectations on their peers. To form a more comprehensive measure of uncertainty, Engle (1982) along with Bollerslev (1986) introduced a model recognised as the generalised autoregressive conditional heteroskedasticity (GARCH) model where the conditional variance of a one-step-ahead forecast error is utilised as a proxy of inflation uncertainty, and these GARCH models allow for deviations in the conditional variance to persist over time (Ajevskis, 2007). The use of GARCH modelling techniques became prevalent in the literature in testing the inflation-inflation uncertainty link (see Tas, 2012; Alimi, 2017; Jiranyakul, 2020; Apergis *et al.*, 2021 among others), with studies employing different classes of GARCH models, including symmetric and asymmetric models – such as the exponential GARCH (EGARCH) introduced by Nelson (1991), the threshold GARCH (TGARCH) introduced by Zakoian (1991), the Asymmetric Power ARCH (APARCH) model of Ding *et al.* (1993), and the Glosten, Jagannathan and Runkle GARCH (GJR-GARCH) model – among others.

An evaluation of the various studies on the inflation-inflation uncertainty nexus highlights the fact that the results have been far from unanimous, reflective of the differences in the countries considered, size of the data sets used, time periods covered and most importantly, the empirical techniques used – which exhibited the fundamental issue of including both predictable and unpredictable variability in the measure of inflation uncertainty. Included in the body of literature are studies by: Grier and Perry (1998), Bhar and Hamori (2004), Balcilar and Ozdemir (2013) and Chowdhury & Sarkar (2015) who considered the Group of Seven (G7); Fountas (2001), Fountas *et al.* (2004), Kontonikas (2004), Lawton and Gallagher (2020) who focussed on European countries; Jiranyakul and Opiela (2011), Jiang (2016), Su *et al.* (2017) and Jiranyakul (2020) who considered Asian economies; Asghar *et al.* (2011) and Chowdhury (2014) for South Asia; Daal *et al.* (2005) and Barnett *et al.* (2020) who looked at a subset of both developed and emerging economies – which allows the authors to investigate the inflation-inflation uncertainty nexus under different hypotheses which include: conventional versus unconventional monetary policy, explicit versus implicit inflation targets, independent versus dependent central banks, and calm versus crisis periods. Looking at developing economies, Nas and Perry (2000) and Apergis (2021) consider Turkey; Entezarkheir (2006), Pourshahabi *et al.* (2010) and Heidari *et al.* (2013) investigate

Iran and Payne (2008) examine three Caribbean countries[30]. Papers focusing on African countries – which have not procured much deliberation in the empirical literature – are studies by Achour and Trabelsi (2011) and Sharaf (2015) looking at Egypt; Valdovinos and Gerling (2011) focussing on eight affiliate countries of the West African Economic and Monetary Union (WAEMU)[31]; Hegerty (2012) looks at nine sub-Saharan African countries[32]; Barimah (2014) examine Ghana; Bamanga *et al.* (2016) examine Nigeria; and Alimi (2017) studies 44 African countries. Studies which are specific to SA that will be drawn on in this study are those of Thornton (2006), Kaseeram and Contogiannis (2011), Narayan and Narayan (2013) and Nasr *et al.* (2015).

An interesting observation of an early study by Grier and Perry (1998), when considering G7 economies, is how each country's inflation rate response to inflation uncertainty is strongly linked to Cukierman's ranking of central bank independence on a scale from 0 (minimal independence) to 1 – where an absence of independence parallels with 'opportunistic' behaviour, while central banks with high independence experience the "stabilising FED hypothesis". In a more recent study on the G7 countries, Balcilar and Ozdemir (2013) show that the relationship between inflation and inflation uncertainty is time-varying with frequent breaks. Chowdhury and Sarkar (2015) also found that the impact of inflation on inflation uncertainty differs over regimes, providing strong support for the Friedman-Ball hypothesis in the high-inflation regime. Su *et al.* (2017) use a bootstrap Granger full-sample causality test and a sub-sample rolling window estimation in China to find that the relationship between inflation and inflation uncertainty varies across time. Apergis *et al.* (2021) consider Turkey and employ time series methods with structural breaks and examine two subperiods to account for the shift in the monetary policy framework of the Central Bank of the Republic of Turkey (CBRT). The results show no causality between inflation and inflation uncertainty when the main objective of the CBRT was to achieve price stability. In contrast, when the CBRT tried to achieve both price stability and financial stability (and when the inflation was more heightened and volatile) the Friedman-Ball hypothesis held and rises in inflation led to heightened inflation uncertainty.

Focusing on SA, Thornton (2006) employed a GARCH model for the period 1957–2005 and only tested the Friedman-Ball hypothesis. The results found a positive short-run relationship between the mean and variance of inflation and evidence that the Friedman-Ball hypothesis reigns supreme in the SA context, with results robust to stints of heightened inflation. Kaseeram and Contogiannis (2011) consider 1960 to 2010 and employed GARCH and GARCH-M methodologies, as well as

[30] Bahamas, Barbados and Jamaica.
[31] Benin, Burkina Faso, Côte d'Ivoire, Guinea-Bissau, Mali, Niger, Senegal and Togo.
[32] Burkina Faso, Botswana, Côte d'Ivoire, Ethiopia, Gambia, Kenya, Nigeria, Niger and SA.

looking at the impact of IT. The study, in accordance with Thornton (2006), concluded that the Friedman-Ball hypothesis holds in the SA environment. The study also establishes that IT, since inception, has wielded no significant impact in the lessening of inflation uncertainty and inflation persistence in SA with the inclusion of a five-year post-IT period of data. Narayan and Narayan (2013) explore the relationship between inflation and output and their relative volatilities in an exponential GARCH (EGARCH) framework. For SA, they find evidence of a bidirectional relationship between inflation and inflation uncertainty, providing support for both the Friedman-Ball and Cukierman-Meltzer hypotheses. A study by Nasr *et al.* (2015) explores the asymmetric and time-varying causation between inflation and inflation uncertainty for just under a century (1921–2012) of data within a conditional Gaussian Markov Switching vector autoregressive (MS-VAR) model framework. The conditional and regime-prediction Granger causality tests find that the Friedman-Ball hypothesis holds, implying that information on past inflation can aid in refining the one-step-ahead expectation of inflation uncertainty. At the same time, no evidence was established for the Cukierman-Meltzer hypothesis.

The dated data in existing studies, lack of agreement between them, and insufficient consideration of the time-varying causality between inflation and inflation uncertainty in the presence of instabilities compel this study – which will use an extensive data set and a new technique to establish whether the Friedman-Ball or the Cukierman-Meltzer hypothesis holds for South Africa.

3.3.2 Empirical studies focussing on the impact of IT

In this section, studies on the impact of IT on inflation outcomes will be discussed. A growing number of countries have adopted IT as a means of achieving monetary policy's primary objective to pursue price stability. The effectiveness of the IT policy framework on lowering the level of inflation and the uncertainty around inflation remains contentious among policymakers, and researchers and studies that have investigated whether inflation targeting has aided in decreasing inflation uncertainty have resulted in mixed verdicts. Romer (2006) explains IT as 'conservative window dressing' where an IT regime does not make a difference in actual economic performance between IT and non-inflation targeting (NIT) countries if the NIT countries have committed to reducing inflation. Some authors also argue that monetary policymakers cannot completely monitor inflation since monetary policy consequences are unpredictable, which works against IT (Fromlet, 2010; Sudacevschi, 2011). Authors that disagree with this view maintain that IT matters through the anchoring of inflation expectations in the event of inflation shocks, which assists in lowering the level of inflation as well as expectations (and thus uncertainty) surrounding inflation, generating better economic performance (Miller *et al.*, 2012). An IT framework accompanied by accountability, transparency and communication with the public should result in higher credibility of the central bank (Blejer *et al.*, 1999). In the literature, more support exists for IT policies in developing countries, while IT policies garner less backing based on evidence from developed countries.

When comparing IT countries to NIT countries, Ball and Sheridan (2005), Gonçalves and Carvalho (2009) and Jiranyakul (2020) found no significant statistical improvement in the performance of inflation. Investigating seven industrialised economies, Lin and Ye (2007) found that IT had no significant effect on either inflation or inflation variability and, interestingly, Miles (2008) found that IT actually heightened inflation uncertainty in Canada. These authors lend strong support to the 'conservative window-dressing' view. On the contrary, Fountas *et al.* (2006) and Gonçalves and Salles (2008) present results specifying that IT countries exhibited lower inflation levels than their NIT counterparts. Even if IT might not substantially lessen the persistence of inflation, followers trust that the policy can reduce expectations of inflation and consequently reduce inflation uncertainty once its preconditions are satisfied. Lin and Ye (2009) examined 13 developing countries that implemented IT and found that IT had a substantial significant effect on reducing both inflation and inflation uncertainty. These authors note that the success of an IT regime can be impacted by country characteristics such as the central bank's desire to limit exchange rate movements, its drive to meet the preconditions of policy adoption, the length of time since the policy adoption and government's fiscal position. Tas (2012) looked at a group of 19 developing countries which shifted policy from monetary targeting to IT and found that the adoption of IT resulted in significantly lower inflation and inflation uncertainty. The study also reports lower inflation variances for emerging countries after adopting IT compared to developed countries.[33] In a panel study of 25 countries, Tas and Ertugrul (2013) implemented a Markov-switching ARCH model and found: (i) the adoption of IT assisted the majority of the countries to achieve lower inflation uncertainty, including SA, with the effectiveness being lower in developed countries, (ii) IT significantly increased the probability that a country is in a low-variance state, (ii) and the efficacy of IT adoption in reducing inflation variance rises as the country scores higher on transparency and economic freedom and score lower on institutional quality, fiscal freedom and government size scores.

Focusing on SA, Gupta and Uwilingiye (2012) found that the IT regime amplified the volatility of inflation as of the first quarter of 2000 – at the point of inception of IT in SA. The authors attribute

[33] More details pertaining to the country group, timing of IT, and how the regime was formulated in each country is given in Mishkin and Schmidt-Hebbel (2001) and Pétursson (2004).

this to the width of the target band of 3–6%, which could be causing an instrument instability problem whilst also resulting in a suboptimal setting of monetary policy and problems in controllability, causing inflation to fall outside target in the medium term. In an updated study using the same technique, Antonakakis *et al.* (2021) also found that IT lowered inflation volatility in 22 of the 24 developed and developing countries that established IT, including SA. These authors attribute the difference in their findings to Gupta and Uwilingiye (2012) using a first-differenced series of the inflation rate to ensure stationarity rather than the level of the inflation rate. Burger and Markinov (2008) found that the level of inflation was lower during IT but did concede the limited success IT had in maintaining inflation within the official target range. Rangasamy (2009) and Wolassa (2015) found that IT has significantly impacted decreasing inflation persistence in SA and has also been effective in decreasing inflation uncertainty. Nene *et al.* (2022) compared African IT (South Africa and Ghana) and European IT (Poland and the Czech Republic) countries and found that the IT policy had a significant impact in reducing inflation uncertainty in the European countries but was insignificant in reducing inflation uncertainty in SA. These authors conclude that IT regimes in European countries, when compared to African countries, are more credible regarding reducing the level of inflation uncertainty and sustaining economic growth.

Given this disagreement among studies, this study implements an updated data set and a different estimation technique to try to resolve the opposing results regarding the effect of IT on the level of inflation and its associated uncertainty in South Africa.

3.3.3 Time-varying Granger causality

To characterise dependence among time series, Granger (1969) causality testing methodology is used widely throughout the literature to examine whether lagged values of one variable help to predict another variable. However, as Rossi (2005) pointed out, traditional Granger causality tests consider the causality during the whole period, ignoring changes in the relationship, and assume stationarity which makes it unreliable in the presence of instabilities and can lead to an inconsistent inference. Therefore, when performing VAR-based statistical inference, it is imperative to allow for the dependence among time series to change over time and to account for the possibility of parameter instabilities.

This study employs the recent Rossi-Wang (2019) time-varying vector autoregression (VAR) based Granger causality tests that are robust in the presence of instabilities and regime changes. This technique has, however, not been used to address time-varying causality between inflation and inflation uncertainty, and this will be the first study to do so.[34]

3.4 DATA AND METHODOLOGY

3.4.1 Data and stylised facts

This paper is based on South African monthly consumer price index (CPI) data that spans the period 1970:01–2022:05, containing 629 observations. The data was procured from the International Monetary Fund's International Financial Statistics (IFS) database, where the data has been seasonally adjusted, specifying 2010 as the base year. The inflation rate is constructed by taking the year-on-year changes in the monthly CPI figures. An advantage of this paper is the extensive reach of the data that envelope the various monetary policy and political regimes in SA and significant global events, including the fall of the apartheid regime in 1994 and international events such as the GFC of 2008, the COVID-19 pandemic and the Russia-Ukraine conflict. Using the most recent data available, as well as data that extends half a century, ensures a comprehensive study that adds to the existing literature. A measure for inflation uncertainty is generated through a GARCH model estimation[35].

Figure 3.1 displays the monthly inflation rates and inflation uncertainty over the period 1970:01–2022:05. Important to notice is how inflation and inflation uncertainty generally move in tandem, with inflation uncertainty heightened during times of heightened inflation. Inflation and its uncertainty spiked significantly in the 1970s due to the 1973 oil crises, the 1973–1974 global stock market crash and the 1979 oil price hikes (Pretorius, 2012). The South African economy is heavily dependent on oil imports, and thus raised oil prices abroad result in 'imported inflation', which, in turn, results in higher production costs – where producers then pass on the burden to consumers.

[34] Recent studies that employ the technique focus on different topics, such as Coronado *et al.* (2020) who look at causality between bond and oil markets of the U.S., Fromentin (2021) who look at causality between the stock market and unemployment in the U.S., Balcilar *et al.* (2021) and Berisha *et al.* (2022) who look at the time-varying predictability of financial stress on inequality in the U.S. and UK, respectively, and Apergis et al. (2022) who investigate whether climate policy uncertainty affects the propensity to travel.

[35] The inflation uncertainty measure used in Figure 3.1 was taken from the conditional variance from the ARMA (3,2) GARCH (1,1) augmented model to test the impact of IT (Model 7 in Table 3.4, Section 3.5.2).

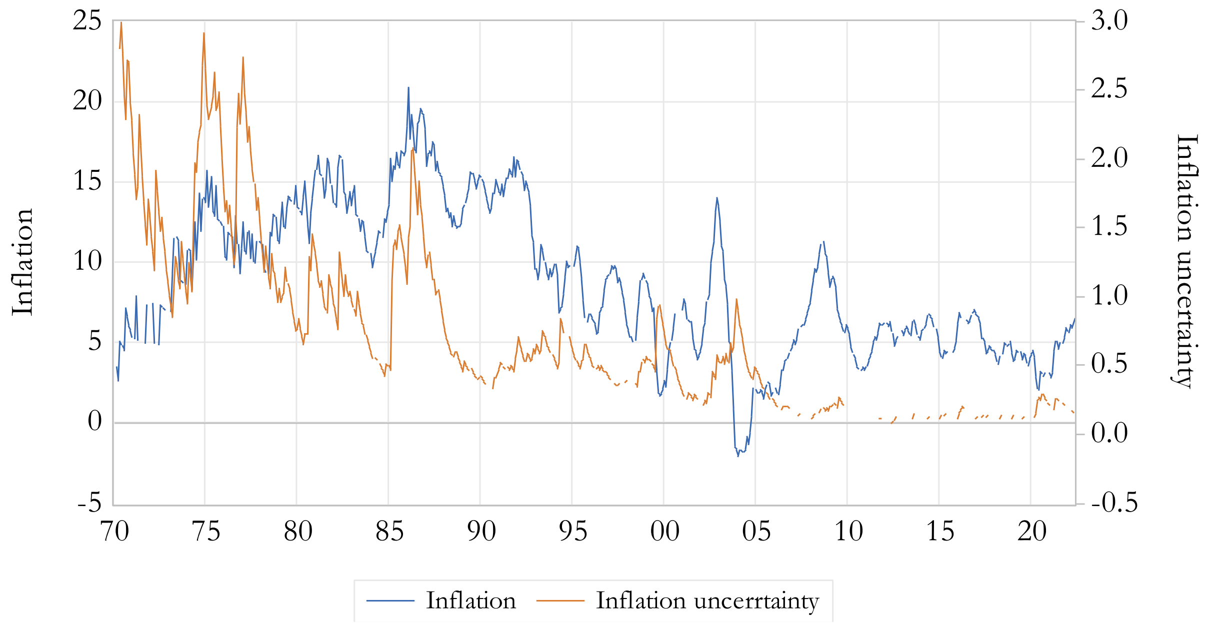


Figure 3.1: Inflation and inflation uncertainty for South Africa, 1970:01–2022:05

Source: IMF and author's calculations

Over the past half-century, inflation reached its peak in 1986, reaching 20.9%, coinciding with the debt-standstill agreement of 1985 and the imposition of trade sanctions on South Africa due to the political situation in the country (Pretorius, 2012). Thereafter, inflation and its associated uncertainty began a downward trend and became less volatile, following global trends in both developed and developing nations which was coined the *Great Moderation* (Chowdhury, 2014)[36]. During the 'informal' inflation targeting period, which started in 1990, the SARB pursued an implicit inflation target and significant emphasis was put on price stability by monetary policy to lower inflation rates (Nasr *et al.*, 2015). To further the moderation of inflation, the SARB took on a more comprehensive approach during the mid-to late-1990s, which in effect included monitoring an extensive set of indicators such as inflation movements and expectations, the exchange rate, the yield curve, overall liquidity in the banking sector, changes in bank credit extension and changes in official foreign reserves, to name a few (Gupta & Uwilingiye, 2012).

In February 2000, the SARB's sole objective became an inflation target of between 3 and 6% to be reached within a two-year horizon, with the intent of forming an environment that promotes

[36] IT was introduced in New Zealand in 1990. Thereafter, many countries started adopting IT in the 1990s which coincided with the period that inflation started a downward trend across most countries – regardless of whether or not countries adopted IT (Tas & Ertugrul, 2013).

low and stable inflation (South African Reserve Bank, 2021).[37] The move to IT was due to the failure of attempts to manage exchange rates, as inflation turned out to be more controllable and more relevant than other variables central banks had targeted. The four key elements of inflation targeting include: (i) an explicit mandate by the monetary policy to pursue low and stable inflation as the primary objective and a high level of operational autonomy; (ii) official targets or target ranges to be publicly announced for the inflation rate over one or more periods; (iii) central bank accountability, through transparency of policy strategy and implementation, to achieve the inflation objective; and (iv) a policy approach that is based on a forward-looking assessment of inflation pressures, which considers a wide range of information (Mishkin, 2004; Kaseeram and Contogiannis, 2011). Due to lags in monetary policy – the time it takes for a change in the interest rate to have a full impact on inflation – inflation targeting had to have a time horizon of around 18 months[38]. South Africa is one of a few countries that had refrained from announcing a point inflation target and used an inflation target range that exceeds a 1 percentage point. A target band permits more flexibility for absorbing external shocks outside the authority's control; however, it can bring about some uncertainty regarding the Monetary Policy Committee's (MPC) 'true' inflation target objective and can undermine efforts to anchor medium and long-term inflation expectations at a lower level – obscuring market participants' predictions regarding the future path of the interest rate and, more generally, the SARB's monetary policy stance (Klein, 2012). Mishkin (2003) also notes that sometimes too much focus is placed on the target bands being breached as opposed to how far inflation is from the midpoint of the target range. Since 2017, the MPC has emphasised that it would generally prefer inflation to be near the 4.5% midpoint.

Temporary inflation resurgences occurred in the 2000s, coinciding with the end of the dot-com boom in 2001, the U.S. attack on Iraq and the commencement of the GFC in 2008.[39] In the second half of 2001, price pressures initially stemmed from a steep depreciation of the exchange rate, and during 2002 it crystallised that inflationary expectations were becoming ever more entrenched coupled with higher trending wage settlements. Furthermore, the threat of a U.S. attack on Iraq and disruptions in oil supply from Venezuela and Nigeria had triggered persistently elevated oil

[37] Historically, IT grew out of two setbacks: (i) stagflation (stagnant growth and higher inflation) - which was experienced in the 1970s and 1980s when central banks all over the world took on higher inflation in hopes that economic growth would be boosted, but instead ended up with stagflation, and (ii) the failure of the 'monetarist' approaches where central banks uncovered that fluctuations in money supply was only roughly linked to the variables the public actually cares about, such as inflation.

[38] https://www.resbank.co.za/en/home/publications/publication-detail-pages/reviews/monetary-policy-review/2002/3981.

[39] The dotcom boom ensued in the late 1990s and occurred due to a sudden growth in equity markets caused by excessive investments in Internet-based companies. Following the 9/11 attacks on the World Trade Centre in the U.S., 2001 was also marked by a substantial depreciation of the domestic currency which caused the Rand to catapult to R13.84/U.S.$ in December 2001 (year average of R8.60/U.S.$), followed by a two-year restoration period.

prices. Inflation increased unabatedly and hit a high of 14% in November 2002, and as a result of these developments the MPC hiked the repo rate by 400 basis points in 2002 to anchor inflation. Consequently, this monetary policy stance ensured lower inflation in 2003, coupled with the exchange rate of the rand recovering, a favourable international inflation environment and a technical revision by Statistics South Africa (Stats SA) which adjusted the inflation data downward in May.[40] With an improved inflation outlook, the MPC stance was adjusted on four occasions in 2003, resulting in a total repo rate cut of 500 basis points. By 2004, headline inflation had been notably subdued, with downward pressures emanating from improved inflation expectations, responsible monetary and fiscal policies and the continued steadier performance of the rand. The stronger rand was a result of a strong rally in the commodity prices in the latter half of 2003 and early 2004 – attributed to higher economic activity (especially in the U.S. and China), dwindling inventory levels of specific commodities, and the depreciation of the U.S. dollar against other major currencies. The food component, a significant driver of inflation in 2002 and 2003, had not contributed more than 0.6 percentage points to inflation since April 2004.[41] The onset of the GFC in 2008 resulted in inflation once again hitting double-digits as global markets experienced financial turmoil, which heightened levels of uncertainty. Domestically, the economy was facing the persistent pass-through of inflation pressures from a series of international food and energy price shocks, domestic electricity price developments; and the depreciation of the exchange rate of the rand – which depreciated 49% against the U.S. dollar from R7.60 at the beginning of May 2008 to R11.31 on 27 October 2008.[42] The SARB's monetary policy stance became more accommodative after the GFC in 2009, emphasising economic output and ushering in an increase in the inflation target (Coco & Viegi, 2019).

The onset of the COVID-19 pandemic sparked rapid and strong monetary and fiscal responses by policymakers in an extraordinary move to cushion the impact of the pandemic on the economy. In particular, the South African Government's R500 billion support package employed numerous relief measures which focused on unemployment support, offering tax relief, support for small, micro and medium-sized enterprises (SMMEs), and several loan funding provisions – in partnership with the SARB, National Treasury and major banks – to aid the country in overcoming

[40] A review by Stats SA revealed an error in the calculation of the rental component. The October Household Survey collected annual data on the rentals for dwellings up until 1999. When this survey was discontinued, the only available rental data was from this 1999 survey, and Stats SA used the average annual increase in rents for the proceeding years' calculation of consumer price indices. However, the actual rental increases were much smaller, requiring Stats SA to revise their data for the period January 2002 to March 2003.

[41] https://www.resbank.co.za/content/dam/sarb/publications/reviews/monetary-policy-review/2004/2851/mprnov.pd.

[42]https://www.resbank.co.za/content/dam/sarb/publications/reviews/monetary-policy-review/2008/3355/mprnov08. pdf.

the detrimental impact of COVID-19. When the COVID-19 crisis hit South Africa, the economy was experiencing low and stable inflation rates and moderate inflation expectations, which offered the SARB substantial policy space to support households and firms. The SARB intervened in the market by buying longer-term government securities in the secondary market to increase the money supply and encourage lending and investment, as the pandemic triggered a severe liquidity crunch.[43] To provide liquidity in the market, stabilise markets and ensure the orderly functioning of the market, the SARB implemented numerous interest rate cuts since the start of the pandemic, cutting the interest rate by 275 basis points from 6.25% in March to 3.5% in July 2020 – a 54-year low. The interest rate remained at 3.5% for 16 months until November 2021, when the normalisation of the interest rate began with a 25 basis point increase, followed by two further hikes of the same magnitude at the January and March 2022 meetings, bringing it to 4.25%[44]. Inflation initially took a dip at the onset of COVID-19 reaching a 14-year low, at about 2% in May 2020, due to lockdown-enforced pauses which resulted in weak demand and lower oil prices, which single-handedly detracted 1.4 percentage points from the headline inflation in May and 1.1 percentage points in June 2020.[45] Core inflation remained low on the back of muted services inflation (education, medical insurance and housing) while also benefitting from the rand's strength, subdued labour market pressures and relatively well-anchored inflationary expectations. However, the increases in goods inflation far outweighed the deceleration in services inflation and headline inflation has risen above the target midpoint. It reached approximately 5% by September 2021 and rose sharply to 5.9% by December 2021, where much of the upward pressure has stemmed from higher food and administered price inflation, primarily due to high fuel and electricity price inflation, as part of the global and domestic economic recovery. The average Brent crude oil price was up 76% from US$55 in January 2021 to US$97 per barrel in February 2022, passing through to domestic fuel prices which saw an 18% price hike from October 2021 to March 2022. While monetary policy was still contending with a critical fiscal position, and the economy was labouring to recover from the COVID-19 crisis, economic prospects were depressed as Russia invaded Ukraine in February 2022[46]. This invasion resulted in higher inflation as production and trade of oil, food and a range of commodities were impaired, causing dramatically higher prices. Against this backdrop, headline inflation breached the target band from March to May 2022, seeing

[43] https://www.resbank.co.za/en/home/newsroom#Our.
[44] https://www.resbank.co.za/content/dam/sarb/publications/monetary-policy-review/2022/Monetary%20Policy% 20Review%20April% 202022.pdf
[45] https://www.resbank.co.za/en/home/publications/review/monetary-policy-review.
[46] The invasion of Ukraine by Russia is still ensuing at the end of our sample (May 2022).

the MPC increase the interest rate in May 2022 by 50 basis points to 4.75%[47]. Globally, mounting energy prices and robust demand and supply bottlenecks have resulted in heightened and persistent levels of global inflation – establishing a major risk to the global economic recovery[48].

Table 3.2: Descriptive statistics of inflation and inflation uncertainty in South Africa

Panel A: Descriptive statistics		
	Inflation	**Inflation uncertainty**[49]
Mean	8.779	0.7022
Std. Dev.	4.5548	0.6336
Skewness	0.2046	1.4127
Kurtosis	2.2345	4.4362
Jarque-Bera	19.7455	262.0296
Probability	0.0000	0.0000
Q (36)	196.37***	113.19***
Q^2(36)	487.06***	174.18***
ARCH LM test	52.2791***	7.1078***
Panel B: Unit root tests		
Phillips-Peron		
With intercept	-2.6027*	-3.4482***
With intercept and trend	-3.6704**	-4.8313***
ADF with Breakpoint[50]	-4.4573**	-5.8878***

*Note: *, **, *** indicate a rejection at 10%, 5% and 1% critical levels.*

Jarque-Bera is the test statistic for testing whether a time series is normally distributed. The test statistic is computed as $JB = \frac{N-k}{\sigma}\left(skew^2 + \frac{1}{4}(kur-3)^2\right)$

where skew is skewness, kur is kurtosis, N is the number of observations, and k is the number of estimated coefficients.

Q(36) and Q^2(36) are the Ljung-Box (1979) statistics for returns and squared returns, respectively, both with chi-square distribution with 36 degrees of freedom.

ARCH LM tests the null hypothesis that no ARCH effects are present in the residual.

In order to gain insight into the univariate time series properties of the data series, descriptive statistics of inflation and inflation uncertainty are presented in Panel A of Table 3.2. As can be seen, the mean of inflation over the period 1970:01–2022:05 is 8.8% and the volatility associated

[47] https://www.resbank.co.za/en/home/publications/publication-detail-pages/statements/monetary-policy-statements/2022/May-2022/statement-of-the-monetary-policy-committee-may-2022

[48] The U.S. inflation has spiked to levels last seen in the 1980s.

[49] The inflation uncertainty measure used in Table 3.2 was taken from the conditional variance from the ARMA (3,2) GARCH (1,1) augmented model to test the impact of IT (Model 7 in Table 3.4, Section 3.5.2).

[50] For the inflation series, the ADF breakpoint unit root test suggests a break point date in 1992:06. For inflation uncertainty, the ADF breakpoint unit root test suggests a break point date in 1986:08.

with inflation is relatively high represented by the standard deviation of 4.56. The mean and standard deviation of inflation before IT was implemented (1970:01–2000:01) was 11.43% and 3.81, while after IT (2000:02–2022:05) the mean of inflation was significantly lower at 5.21% and the standard deviation was also lower at 2.62. The mean of inflation uncertainty is 0.7 and the volatility associated with inflation uncertainty is represented by the standard deviation of 0.63. Positive skewness of inflation and inflation uncertainty implies that the distributions have a long right tail. Furthermore, the kurtosis of inflation is less than 3 and thus the distribution is platykurtic or short-tailed with respect to the normal. The kurtosis of inflation uncertainty is greater than 3 and thus the distribution is leptokurtic or heavy-tailed with respect to the normal distribution. The Jarque-Bera statistics for both inflation and inflation uncertainty indicate that the null hypothesis of the normal distribution is rejected at the 1% level of significance. The Ljung-Box (1979) statistic, which tests for serial correlation, calculated for up to 36 lags relative to the absolute returns and squared returns for inflation, indicates some linear and nonlinear dependencies. Certain autoregressive conditionally heteroskedastic (ARCH) models may capture the nonlinear dependencies (Nelson, 1991). We also check for the presence of ARCH effects in the inflation and the inflation uncertainty series, that is, whether the variances of the series are time-varying, by applying the ARCH Lagrange Multiplier (LM) test. This test reveals significant ARCH effects in both the inflation and inflation uncertainty series, supported by the Breusch-Pagan- Godfrey (1978) test. As Grier and Perry (1998) point out, the null hypothesis of homoscedasticity (constant variance) should be rejected before estimating a GARCH model and generating uncertainty measures.

To test for stationarity of the series, the Phillips-Perron (PP) (1988) unit root test is implemented, and the results are reported in Panel B of Table 3.2. This unit root test is justified as autocorrelation and ARCH effects were found in the inflation and inflation uncertainty series, and the PP test is robust to strong autocorrelation and heteroscedasticity in the series (Yang & Doong, 2004). The bandwidth is based on Newey-West using the Barlett kernel spectral estimation method. The results of the PP unit root tests conclude that the inflation series and the inflation uncertainty series are stationary in level form, with both series integrated of order 0, I(0). Considering structural breaks in the inflation and inflation uncertainty series, the Augmented Dickey-Fuller breakpoint unit root test also lends support that these series are stationary. This is reiterated by the fact that growth in prices, i.e., inflation, cannot drift infinitely and the series should ultimately revert to its mean. Figure 3.1 gives evidence of this fact, in that throughout all the spikes that occurred over the period covered, inflation does return to earlier lower rates. A stationary process warrants that the standard limit theorem holds and thus permits econometric estimation (Campbell *et al.*, 1997). Given that the inflation series is stationary, the use of GARCH, GARCH-M and Granger causality techniques throughout the paper is justified.

3.4.2 Methodology

In this section, the econometric techniques which this study implements are detailed. Firstly, the GARCH and GARCH-M model techniques are described in Section 3.4.2.1. Thereafter, Section 3.4.2.2 details how this study tests for the impact of inflation targeting. The time-varying Granger causality test is detailed in Section 3.4.2.3.

3.4.2.1 GARCH and GARCH-M models of inflation uncertainty

The use of ARCH and GARCH techniques denotes a method to proxy uncertainty by means of the conditional variance of volatile shocks to the inflation rate (Fountas *et al.*, 2004). The causal relationship between inflation and inflation uncertainty can be modelled within this structure to test the various hypotheses under investigation in this study. A common practice of most GARCH time series studies that explore the causal relationship begins by first modelling inflation as an autoregressive moving average ARMA (p, q) process (Kaseeram & Contogiannis, 2011). This paper follows suit:

$$\pi_t = \varphi + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j} + \varepsilon_t \qquad (8)$$

where π_t is the current monthly inflation rate, which relies on past values of inflation π_{t-i} (AR terms) and past values of the error term ε_{t-j} (MA terms) and φ is a constant. If $\beta_1 = \beta_2 = \ldots = \beta_q = 0$, the ARMA process reduces to an AR (p) process. This study implements a general-to-specific modelling approach, attributed to Hendry (1995), which stipulates an unrestricted statistically satisfactory dynamic ARMA (12, 12) model, termed the general model. This model will then be trimmed down by ignoring statistically insignificant AR or MA terms resulting in a specific model that is considered more parsimonious, economically sound and is a statistically valid representation (Kaseeram & Contogiannis, 2011).

Moreover, if economic agents have rational expectations around the level of inflation, then the residual ε_t will denote the forecast error. This paper further assumes that inflation uncertainty, measured by the time-varying variance (h_t), can be conveniently defined by the subsequent GARCH (p, q) model as presented by Bollerslev (1986):

$$\varepsilon_t = v_t h_t^{0.5} \quad \text{where} \quad \sigma_v^2 = 1;\ E(\varepsilon_t \mid \Omega_{t-1}) = 0\ ;\ var(\varepsilon_t \mid \Omega_{t-1}) = h_t \qquad (9)$$

$$\mathrm{h}_t = a_0 + \sum_{i=1}^{q} a_i\, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} \qquad (10)$$

where a_0 is a constant term; α_i>= 0, i = 1, …, q are the ARCH parameters; β_j>= 0, j = 1, …, p are the GARCH parameters and Ω_t is the information set obtainable at time t. The mean-reverting rate or persistence of a shock is measured by $(\sum_{i=1}^{q} a_i + \sum_{j=1}^{p} \beta_j)$. The smaller the mean-reverting rate, the less persistent the volatility expectations are to shocks in the past; in other words, shocks to conditional variance are not explosive and are characterised as transitory. Furthermore, v_t is white noise with variance equal to one, ensuring the residual, ε_t, maintains an expected value of zero based on the information set in the previous period. The conditional variance, h_t, of ε_t is an ARMA process specified by equation (10). This generalised ARCH (p, q) or GARCH (p, q) allows for both autoregressive (AR) and moving average (MA) components in the heteroscedastic variance (Kaseeram & Contogiannis, 2011).

In testing the Friedman-Ball hypothesis, lagged inflation is inserted into the conditional variance equation:

$$\mathrm{h}_t = a_0 + \sum_{i=1}^{q} a_i\, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \delta\pi_{t-1} \qquad (11)$$

where according to the Friedman-Ball hypothesis, δ >0. If $\delta > 0$ and is statistically significant, it can be concluded that higher inflation leads to higher inflation uncertainty.

In order to test the Cukierman-Meltzer hypothesis, this paper employs a GARCH-M method, in which the conditional variance affects the conditional mean:

$$\pi_t = \varphi + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j} + \theta h_t \qquad (12)$$

$$h_t = a_0 + \sum_{i=1}^{q} a_i\, \varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \mu_t \qquad (13)$$

An assessment of the influence of inflation uncertainty on inflation will be done by noting the sign and significance of the estimated parameter θ.

3.4.2.2 Testing the impact of inflation targeting within a GARCH framework

In order to observe the persistency of inflationary forces in the period since IT adoption, which is February 2000 for South Africa, this study will shadow the existing literature by using an ARMA model augmented with a dummy variable, D_t, in order to capture the IT period:

$$\pi_t = \varphi + \sum_{i=1}^{p} \alpha_i \pi_{t-i} + \sum_{j=1}^{q} \beta_j \varepsilon_{t-j} + \varsigma_0 D_t \qquad (14)$$

where D_t is the dummy variable to account for the IT era, equal to 1 from February 2000 onwards, otherwise zero. If the coefficient ς_0 is negative and significant, this indicates that IT lowered the level of inflation, which will be in accordance with the studies of Fountas *et al.* (2006) and Rangasamy (2009).

Equation (3) is augmented in the IT literature in order to grasp the impact IT has had on inflation uncertainty, denoted by:

$$\mathrm{h}_t = a_0 + \sum_{i=1}^{q} a_i \,\varepsilon_{t-i}^2 + \sum_{j=1}^{p} \beta_j h_{t-j} + \gamma_1 D_t \tag{15}$$

where D_t is the dummy variable to account for the IT period, otherwise zero. Tas (2012) and Sharaf (2015) employed this augmented GARCH model in their research to determine the effect that IT has had on inflation uncertainty, h_t. If the coefficient γ_1 is negative and significant, this indicates that IT lowered the uncertainty of inflation.

3.4.2.3 Time-varying Granger causality tests for inflation-inflation uncertainty

Considering the possibility of parameter instabilities, Rossi (2005) proposes tests to evaluate the predictive ability where the parameter might be time-varying by jointly testing the significance of the predictors and their stability over time. Consider one of the equations in a two-variable VAR with one lag and fixed prediction horizon h:

$$y_{t+h} = \beta_t x_{t-1} + \rho y_{t-1} + \varepsilon_{t+h},\ t = 2, 3, \dots, T. \tag{16}$$

Assume that $x_{t-1}, \varepsilon_{t+h} \overset{iid}{\sim}$ N(0, 1) and x_{t-1}, y_{t-1} and ε_{t+h} are independent of each other. Let β_t change at some unknown point in time, τ: $\beta_t = \beta_1 \times 1(t \leq \tau) + \beta_2 \times 1(t > \tau)$. Let $\hat{\beta}_{1\tau}$ and $\hat{\beta}_{2\tau}$ denote the ordinary least squares (OLS) estimates before and after the break[51]. Regarding the null hypothesis of no Granger causality at any point in time, that is, H_0: $\beta_t = \beta = 0$, the robust test builds on two components: $\left(\frac{\tau}{T}\right)\hat{\beta}_{1\tau} + \{1 - \left(\frac{\tau}{T}\right)\}\hat{\beta}_{2\tau}$ and $\hat{\beta}_{1\tau} - \hat{\beta}_{2\tau}$. A test on whether the first component (the full-sample estimate of the parameter) is zero detects situations in which the parameter β_t is constant and different from zero. A test on whether the second component (the

[51] Asymptotically, that is, because the regressors are independent:

$$\hat{\beta}_{1\tau} \approx \left(\frac{1}{\tau}\sum_{t-1}^{\tau} x_{t-1}^2\right)^{-1} \left(\frac{1}{\tau}\sum_{t-1}^{\tau} x_{t-1} y_{t+h}\right)$$

$$\hat{\beta}_{2\tau} \approx \left(\frac{1}{T-\tau}\sum_{t=\tau+1}^{\tau} x_{t-1}^2\right)^{-1} \left(\frac{1}{T-\tau}\sum_{t=\tau+1}^{\tau} x_{t-1} y_{t+h}\right)$$

difference between the parameters estimated in the two subsamples) is zero detects situations in which the parameter changes, which detects situations in which the regressor Granger-causes the dependent variable in such a way that the parameter changes, but the average estimate equals zero.

In light of this, this study uses the Rossi-Wang (2019) Granger causality tests in a vector autoregressive (VAR) framework that are robust in the presence of instabilities. In the presence of instabilities or regime change, the Granger causality robust test is more powerful than the traditional Granger causality test (Rossi & Wang, 2019). Specifically, the procedure is adopted to test the time-varying impact of inflation on inflation uncertainty and vice versa. Due to the monetary policy regime change in February 2000, a more reliable inference on predictability is offered with this approach compared to a constant parameter Granger causality method.

Formally, the following reduced-form VAR model with time-varying parameters is specified:

$$y_t = \kappa_{1,t}y_{t-1} + \kappa_{2,t}y_{t-2} + \cdots + \kappa_{p,t}y_{t-p} + \varepsilon_t \qquad (17)$$

where $\kappa_{j,t}, j = 1, \dots, p$ are functions of time-varying coefficient matrices, $y_t = [y_{1,t}, \dots y_{n,t}]'$ represents an $(n \times 1)$ vector, and ε_t is the idiosyncratic error[52]. The model will consist of the two endogenous variables of interest in this study, inflation (π_t) and inflation uncertainty (h_t).

The two null hypotheses that are tested are: (i) π_t does not Granger cause h_t; and (ii) h_t does not Granger cause π_t, formalised as $H_0\colon \Theta_t = 0$ for all $t = 1, .., T$, given that Θ_t is a suitable subset of $vec(\kappa_{1,t}, \kappa_{2,t}, \dots, \kappa_{p,t})$.

Following the work of Rossi and Wang (2019), four test statistics are employed, namely the exponential Wald (*ExpW*) test, the mean Wald (*MeanW*) test, the Nyblom (*Nyblom*) test, and the Quandt Likelihood Ratio (*QLR*) test. Andrews and Ploberger (1994) proposed the exponential Wald (designed for testing against more distant alternatives) and the mean Wald test (designed for the alternatives that are close to the null hypothesis). Nyblom (1989) proposed the optimal *Nyblom* test, which is the locally most powerful invariant test for the constancy of the parameter process against the alternative that the parameters follow a random walk process. The optimal *QLR* is based on Quandt (1960) and Andrew's (1993) *Sup-LR* test, which considers the supremum of the statistics over all possible break dates of the Chow statistic designed for a fixed point break. Detailed expressions of these statistics can be found in Rossi (2005). The two-variable VAR model in (17) is estimated with a lag length of 4, as determined by the Schwarz Information Criterion

[52] The case when the parameters in Equation (17) are time-invariant is the traditional Granger causality test.

(SIC), to establish parsimony in the set-up allowing a smaller endpoint trimming to validate extended data coverage of the time-varying test statistic.

3.5 EMPIRICAL RESULTS

Section 3.5.1 provides the estimation results of the GARCH and GARCH-M models, testing which hypothesis holds for South Africa. Section 3.5.2 shows the estimation results of whether IT impacted inflation and inflation uncertainty tested within a GARCH framework. Thereafter, Section 3.5.3 presents the time-varying Granger causality test results to further analyse the dynamic relationship between inflation and inflation uncertainty and if it changes over time.

3.5.1 GARCH and GARCH-M modelling results to test which hypothesis holds

Through the general-to-specific approach, it was determined that an ARMA (3, 2) model is the optimal model that best fits the inflation dynamics in South Africa when using monthly data from 1970:01–2022:05. This decision was attained by evaluating model selection criteria and selecting the model reporting the smallest values of the Schwarz Information Criterion (SIC). Furthermore, after applying a general-to-specific approach by testing various GARCH (p, q) models, it was established that a GARCH (1, 1) process is the best fit to describe the conditional variance, i.e., inflation uncertainty in South Africa[53]. This conclusion was reached by studying the autocorrelation function (ACF) graphs of their squared residuals of several GARCH (p, q) models (Kaseeram & Contogiannis, 2011). The Nyblom stability test also reveals that the parameters and therefore the GARCH model is stable.

Table 3.3 shows that Model 1 to Model 4 each have an adjusted R^2 value of above 0.95, indicating that approximately 95% of the variation in inflation is explained by the model. There is significant inertia in the rate of inflation as all three autoregressive terms are significant at the 1% level. Furthermore, all of the ARCH and GARCH terms in each of the models are statistically significant at the 1% level of significance. Moreover, the summation of the ARCH and GARCH coefficients is less than one, consistent with the fact that the conditional variance must be stationary (Thornton, 2006). Since the sum of ARCH and GARCH terms from this model is very close to one it is suspected that the effects of past shocks on current variance are very strong and, therefore, the persistence of volatility shocks is high. This finding is not ideal as central bankers prefer a lower persistence of inflation shocks (inflation shocks not having a long-lasting effect on the future path

[53] The Engle and Ng sign and size bias test was implemented and an asymmetric EGARCH model was also investigated but the GARCH model was found to be a better fit based on model selection criteria.

of prices) so that they can preserve low inflation when faced with disturbances[54] (Miles & Vijverberg, 2011).

Table 3.3: The results of the GARCH and GARCH-M estimations to test which hypothesis holds for South Africa, 1970:01–2022:05

	Model 1	**Model 2**	**Model 3**	**Model 4**
Inflation equation ARMA(3,2)	**Benchmark**	**Friedman-Ball hypothesis**	**Cukierman-Meltzer hypothesis**	**Both hypotheses**
intercept	0.1231**	0.1414**	0.1101*	0.1349**
	(0.0538)	(0.0585)	(0.0576)	(0.0651)
π_{t-1}	0.8185***	0.8137***	0.8296***	0.8234***
	(0.1096)	(0.1181)	(0.0967)	(0.1068)
π_{t-2}	0.8225***	0.8204***	0.8207***	0.8180***
	(0.0277)	(0.0288)	(0.0319)	(0.0286)
π_{t-3}	-0.6583***	-0.6524***	-0.6729***	-0.6646***
	(0.0962)	(0.1034)	(0.0846)	(0.0936)
ε_{t-1}	0.4186***	0.4198***	0.3998***	0.4105***
	(0.1291)	(0.1377)	(0.1145)	(0.1258)
ε_{t-2}	-0.5781***	-0.5769***	-0.5877***	-0.5863***
	(0.1291)	(0.1377)	(0.1127)	(0.1257)
h_t			0.1134*	0.0986
			(0.0652)	(0.0687)
Variance equation GARCH(1,1)				
intercept	0.0037*	-0.0065	0.0021	-0.0066*
	(0.0021)	(0.0040)	(0.0014)	(0.0040)
ARCH (ε^2_{t-1})	0.0766***	0.0759***	0.0523***	0.0721***
	(0.0189)	(0.0209)	(0.0125)	(0.0198)
GARCH (h_{t-1})	0.9147***	0.8984***	0.9406***	0.9019***
	(0.0160)	(0.0212)	(0.0109)	(0.0209)
π_{t-1}		0.0023***		0.0023***
		(0.0010)		(0.0010)
Goodness of fit tests				
$\bar{R}^2$	0.9649	0.9650	0.9651	0.9650
AIC	2.1402	2.1285	2.1457	2.1286
SC	2.2040	2.1994	2.2166	2.2066
HQ	2.1650	2.1560	2.1732	2.1589

*Notes: ***, ** and * imply significance at the 1%, 5% and 10% levels, respectively. Values in parentheses are standard errors.*

[54] For example, if the persistence of shocks is low a hike in commodity prices would not necessitate a severe monetary tightening.

Model 1 is the standard ARMA (3, 2) GARCH (1, 1) model for the South African economy. With all the coefficients being significant at the conventional levels, this indicates significant ARCH effects in the inflation series. The coefficient on h_{t-1}, which measures shock persistence, is large (0.9147) and statistically significant at the 1% level, implying that shocks to inflation take a long time to die out; thus, are persistent. This finding is held throughout Models 1 to 4.

Model 2 tests whether the Friedman-Ball hypothesis holds in South Africa. The results show that lagged inflation is statistically significant at the 1% level of significance in the variance equation, implying that inflation is significant in determining inflation uncertainty. This positive correlation proposes that higher inflation causes higher inflation uncertainty, supporting the Friedman-Ball hypothesis. This outcome resembles the study of Thornton (2006), Kaseeram and Contogiannis (2011), Hegerty (2012), Narayan and Narayan (2013) and Nasr *et al.* (2015) and is in accordance with numerous contemporary studies that have also utilised GARCH modelling techniques.

Model 3 tests whether the Cukierman-Meltzer hypothesis holds in South Africa by running a GARCH-M model. The coefficient on inflation uncertainty, h_t, in the mean equation is positive and statistically significant at the 10% level, and therefore the model shows that higher inflation uncertainty increases inflation, as Cukierman and Meltzer (1986) claimed. This is in line with the opportunistic monetary strategy, and this finding is in line with Narayan and Narayan (2013).

Model 4 tests whether the Friedman-Ball and Cukierman-Meltzer hypotheses hold if both hypotheses are accounted for in a model. As seen in the results, only the Friedman-Ball hypothesis still holds, while the Cukierman-Meltzer hypothesis does not.

In conclusion, the GARCH and GARCH-M estimations in Table 3.3 provide support for bidirectional causality between inflation and inflation uncertainty. However, it is noted that we find stronger evidence in favour of the Friedman-Ball hypotheses at the 1% level of significance across the models, while weaker evidence of the Cukierman-Meltzer hypothesis is established, given that the GARCH term, h_t, is only significant in model 3, and only at the 10% level. These results suggest that in SA higher inflation is driving higher inflation uncertainty and *vice-versa.* To combat surging inflation, the SARB should implement interest rate hikes expeditiously and transparently to alleviate any uncertainties about future inflation. Higher interest rates will encourage savings, discourage large purchases, and reduce wealth-driven consumption. Fiscal policy can help through deficit-reducing tax and spending changes, which should be aimed at tempering demand and boosting supply which will directly or indirectly lower prices in the economy[55].

It should be noted that the inclusion of a current period variance (uncertainty) term in the mean equation only represents the contemporaneous effect of increased uncertainty on inflation. For this reason, we also rely on a vector autoregression (VAR) model to represent a potential dynamic transmission process. We believe that Granger causality tests provided in Section 3.5.3 may assist in assessing the causal relationship within a dynamic and time-varying framework.

3.5.2 GARCH modelling results to test the impact of inflation targeting

To test if adopting an IT regime has contributed to lowering the level of inflation, Model 5 includes an IT dummy in the mean equation and shows that IT significantly reduced the level of inflation at the 1% level. Model 6 tests whether IT adoption has significantly reduced inflation uncertainty (volatility) by including the IT dummy in the variance equation. The result shows that IT significantly reduced inflation uncertainty at the 5% level. To test the effect of IT on both the level and the uncertainty around inflation simultaneously, Model 7 includes an IT dummy in both the mean and variance equations and shows that the results in Models 5 and 6 are robust. This result supports Rangasamy (2009), Tas and Ertugrul (2013), Wolassa (2015) and Antonakakis *et al.* (2021), who claimed that IT aids in significantly reducing the persistence of inflation as well as having a significant impact on the uncertainty of inflation in South Africa. It however contrasts the results of Kaseeram and Contogiannis (2011), who looked at a shorter sample of IT from 2000-2010, and Nene *et al.* (2022), who implemented a different technique.

Since inflation targeting was adopted, average inflation dropped by 6.2 percentage points from an average of 11.4% before the adoption of IT (1970:01–2000:01) to an average of 5.2% under inflation targeting (2000:02–2022:05). As can be seen by the results, the IT approach has been successful and has permitted a more realistic alignment between the SARB's tools and objectives. It has also enhanced transparency due to communication itself becoming a critical policy tool where the public understands what monetary policy is trying to achieve and trusts the central bank to deliver (Coco & Viegi, 2019). Improvements in the communication strategy of the SARB include the systematic publication of macroeconomic assumptions and forecasts after each MPC meeting and a press conference, complemented by a detailed analysis of prevailing macroeconomic conditions in its six-monthly monetary policy review. A further notable improvement has been the publication of its core Quarterly Projection Model in 2017, which gives the projected interest rate

[55] https://www.crfb.org/papers/fiscal-policy-time-high-inflation#_ftn7

path. It has also promoted accountability, as their performances can now be judged against clear metrics, giving the SARB a transparent and publicly visible objective (SARB, 2021). Effective communication is essential for the SARB to anchor inflation expectations and achieve its mandate.

Table 3.4: The results of the GARCH estimations to test the impact of inflation targeting in South Africa, 1970:01–2022:05

	Model 5	Model 6	Model 7
Inflation equation ARMA(2,1)	**IT effect on the level of inflation**	**IT effect on inflation uncertainty**	**IT effect on the level and uncertainty of inflation**
intercept	0.2889***	0.1245**	0.2874***
	(0.0891)	(0.0548)	(0.0953)
π_{t-1}	0.8892***	0.8182***	0.8920***
	(0.0856)	(0.1173)	(0.0894)
π_{t-2}	0.8061***	0.8208***	0.8038***
	(0.0282)	(0.0301)	(0.0305)
π_{t-3}	-0.7217***	-0.6563***	-0.7219***
	(0.0746)	(0.1017)	(0.0769)
ε_{t-1}	0.3283***	0.414***	0.3183***
	(0.105)	(0.1372)	(0.1101)
ε_{t-2}	-0.6679***	-0.5828***	-0.6779***
	(0.1050)	(0.1371)	(0.1102)
IT-Dummy	-0.1419***		-0.1408***
	(0.0498)		(0.0543)
Variance equation EGARCH (1,1)			
intercept	0.0031	-0.0257**	0.0263**
	(0.0020)	(0.0102)	(0.0108)
ARCH (ε^2_{t-1})	0.0753***	0.0858***	0.0842***
	(0.0182)	(0.0522)	(0.0252)
GARCH (h_{t-1})	0.9171***	0.8834***	0.8846***
	(0.0149)	(0.0278)	(0.0283)
IT-Dummy		-0.0194**	-0.0202**
		(0.0085)	(0.0091)
Goodness of fit tests			
$\bar{R}^2$	0.9655	0.9649	0.9656
AIC	2.1307	2.1296	2.1206
SC	2.2016	2.2006	2.1986
HQ	2.1582	2.1572	2.1509

*Notes: ***, ** and * imply significance at the 1%, 5% and 10% levels, respectively. Values in parentheses are standard errors.*

3.5.3 Time-varying Granger causality Wald test results

To analyse the causal impact of inflation on inflation uncertainty and *vice versa*, given the policy regime change in February 2000, the time-varying VAR-based Granger causality tests, which are robust in the presence of instability or regime change, as suggested by Rossi and Wang (2019), are used. The results for the exponential Wald (*ExpW*) test, the mean Wald (*MeanW*) test, the Nyblom (*Nyblom*) test, and the Quandt Likelihood Ratio (*QLR*) tests are reported in Table 3.5. When the full sample period from 1970:01 to 2022:05 is considered, there is evidence of bidirectional causality between inflation and inflation uncertainty. It is therefore of interest to also investigate the whole sequence of Wald statistics across time, which provides more information on when the Granger causality occurs. In fact, the optimal *QLR* is the supremum of the sequence of Wald statistics testing whether the parameters are zero at each point in time against an alternative that the parameters change at a given break date at time *tm* (Rossi & Wang, 2019). The Wald test results are displayed graphically in Figures 3.2 and 3.3.

Table 3.5: Time-varying parameter Granger causality tests, 1970:01–2022:05

Null-Hypothesis	*ExpW*	*MeanW*	*Nyblom*	*QLR*	*AIC Lags (p)*
π_t does not Granger-cause h_t in the presence of instabilities. (Friedman-Ball)	20.94*** [0.0000]	26.65** [0.0179]	15.84*** [0.0000]	53.17*** [0.0000]	4
h_t does not Granger-cause π_t in the presence of instabilities. (Cukierman-Meltzer)	13.54*** [0.0000]	19.29*** [0.0254]	10.89*** [0.0000]	37.10*** [0.0000]	4

*Notes: ***, ** and * imply significance at the 1%, 5% and 10% levels, respectively. Values in square brackets are p-values.*

The test of whether inflation (π_t) Granger-causes inflation uncertainty (h_t) is depicted in Figure 3.2, with the whole sequence of Wald statistics over the possible break dates reported on the x-axis. A trimming parameter of 0.10 is used, as is standard in the structural break literature, excluding the beginning and the end of the sample period. The sequence of Wald statistics is above the 5% critical line (the Wald statistic > critical value) for the duration of the pre-inflation targeting period. We, therefore, reject the null that inflation does not Granger-cause inflation uncertainty for the period up to around the adoption of IT and conclude that increases in inflation indeed did lead to increased inflation uncertainty, lending support to the Friedman-Ball hypothesis for the pre-inflation targeting period. The hypothesis breaks down in the inflation targeting period (after a short adjustment period including some adverse events around 2002 related to disruptions in oil supply and elevated oil prices), as the Wald tests consistently fail to reject the null of no Granger-causality in this period. The evidence that increased inflation did not lead to increased uncertainty in the IT period may be attributed to increased transparency, communication[56] and credibility of the SARB (Weber, 2018; Kabundi and Mlachila, 2019; Coco & Viegi, 2019). For South Africa, Coco and Viegi (2019) analysed the evolution of the SARB's monetary policy stance, communication and credibility since the adoption of the IT regime in 2000 and found a shift towards a more 'forward-looking' and balanced communication strategy, which, to some degree, complemented the infrequent changes of monetary policy rates. They concluded that the behaviour of inflation expectations and market interest rates confirm that monetary policy has gotten progressively more successful at anchoring expectations, especially in recent years.

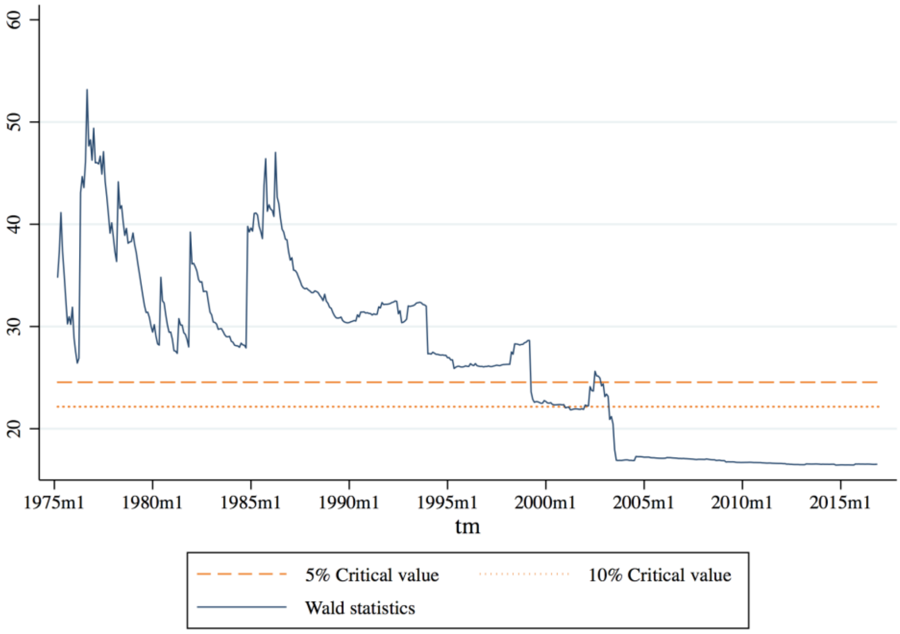


Figure 3.2: Time-varying Wald statistics testing whether inflation (π_t) Granger-causes inflation uncertainty (h_t) against the alternative of a break in Granger causality at time *tm* (reported on the x-axis)

[56] Improvements in the communication strategy of the SARB since IT adoption include the systematic publication of macroeconomic assumptions and forecasts after each MPC meeting and a press conference, complemented by a detailed analysis of prevailing macroeconomic conditions in its six-monthly monetary policy review. A further notable improvement has been the publication of its core Quarterly Projection Model in 2017, which gives the projected interest rate path.

The test of whether inflation uncertainty (h) Granger-causes inflation uncertainty (π_t) is depicted in Figure 3.3. Figure 3.3 does not offer strong support for the Cukierman-Meltzer hypothesis across the entire sample period. The Cukierman-Meltzer hypothesis that increased inflation uncertainty leads to higher levels of inflation only appears to hold from the early 1990s onwards, up and until the adoption of IT. Following the adoption of IT, however, the hypothesis breaks down (after a short adjustment period and a spike in uncertainty surrounding oil supply disruptions and elevated oil prices experienced in 2002) with a consistent failure to reject the null of no Granger causality during the IT period. The hypothesis also does not hold for the pre-1990 period, although following the oil price shocks in the 19970s, there is evidence of two brief incidents where higher uncertainty culminated in higher inflation but only at the 10% level of significance.

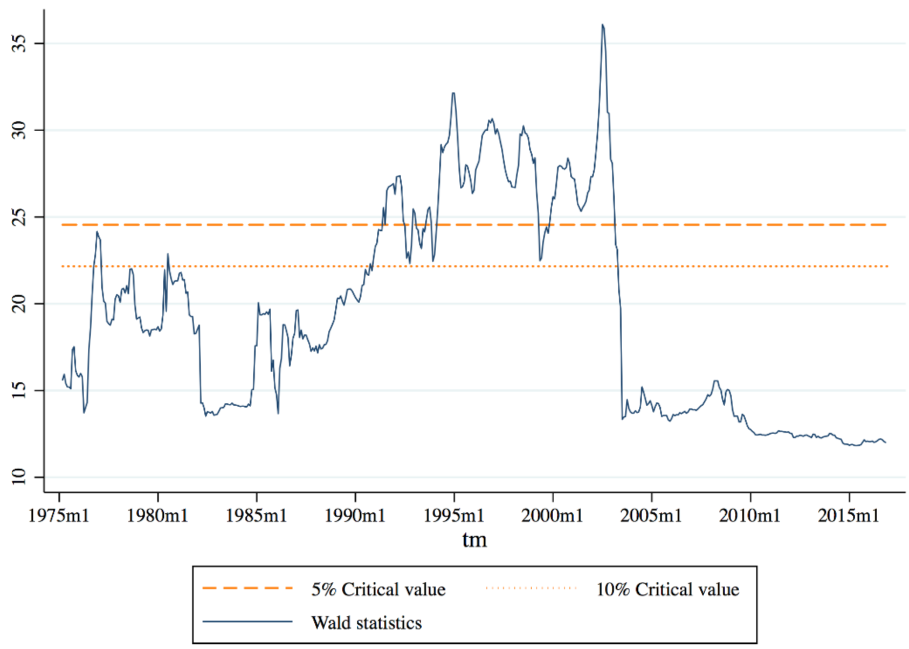


Figure 3.3: Time-varying Wald statistics testing whether inflation uncertainty ($\mathbf{h_t}$) Granger-causes inflation ($\boldsymbol{\pi_t}$) against the alternative of a break in Granger causality at time *tm* (reported on x-axis)

Overall, these findings are in line with the recent work of Apergis *et al.* (2021). Considering Turkey, they find that there is no causality between inflation and inflation uncertainty when the main objective of the CBRT was to achieve price stability, but when the CBRT tried to achieve both price stability and financial stability (and when the inflation was more heightened and volatile) the Friedman-Ball hypothesis held and rises in inflation led to increased inflation uncertainty.

3.6 CONCLUSION

This paper offers three main contributions. Firstly, it investigates the inflation-inflation uncertainty nexus in SA and investigates the effects that higher inflation may have on inflation uncertainty and *vice versa*; secondly, it considers whether the causal relationship between inflation and inflation uncertainty changes over time; and thirdly, it investigates the impact that IT has had on inflation and its associated uncertainty.

Using GARCH and GARCH-M models, this study validates that the Friedman-Ball hypothesis holds for SA in that higher inflation elevates inflation uncertainty based on monthly data covering an extensive period from 1970:01 to 2022:05. Weaker evidence is also established for the Cukierman-Meltzer hypothesis, suggesting that inflation uncertainty is potentially a self-fulfilling prophecy in South Africa.

The time-varying robust Granger-causality tests of Rossi and Wang (2019) provide further insight into the dynamic relationship between inflation and inflation uncertainty and how the causality changes over time. These results show that the Friedman-Ball hypothesis holds for the pre-IT period, when inflation and its associated uncertainty were generally higher, but breaks down after the adoption of IT as a monetary policy framework. The results also underscore the GARCH estimation result of weaker evidence in favour of the Cukierman-Meltzer hypothesis by showing that the hypothesis only holds for the period starting in the early 1990s up to the adoption of IT.

The last key contribution of this paper is the finding that the adoption of IT in February 2000 has a significant impact on reducing the level of inflation and had a significant effect on reducing the uncertainty surrounding inflation. This suggests that IT fosters transparency and clear communication, palpably reducing uncertainty over the future path of prices. While monetary policy is unable to directly contribute to economic growth and employment creation in the long run, by adopting an explicit IT regime, the SARB ensures a stable financial environment, a crucial prerequisite for these objectives to be achieved.

The results of this study heed important policy implications for the SARB, as it highlights that it is imperative that inflation is kept low, stable and predictable. This mandate can be achieved by the monetary authorities through speedy and efficient policy responses to inflation developments in efforts to restrain inflation and thus curtail the adverse effects of inflation uncertainty. A more detailed discussion follows in Section 5.3 of Chapter 5.

CHAPTER 4

MONETARY POLICY EFFECTIVENESS IN THE FACE OF UNCERTAINTY: THE REAL MACROECONOMIC IMPACT OF A MONETARY POLICY SHOCK IN SOUTH AFRICA DURING HIGH AND LOW UNCERTAINTY STATES

4.1 INTRODUCTION

Economies worldwide operate monetary policy with the primary objective of creating a stable macroeconomic environment for economic prosperity, with monetary policy typically being the first line of defence against a number of internal and external shocks. As South Africa (SA) saw an improved political dispensation in the early 1990s and became globally more integrated, evolving into an emerging market destination for investors, a monetary policy regime change to inflation targeting (IT) was implemented in February 2000 (Aron & Muellbauer, 2009). At present, monetary policy in SA serves to keep the rate of inflation within the target band of 3% to 6%. If the rate of inflation exceeds the upper limit of 6%, the South African Reserve Bank (SARB) would increase the official interest rate (the repo rate) in order to bring inflation down to within the target range – a practice common to many industrialised economies (Cesa-Bianchi *et al.*, 2016). Achieving its objective of price stability depends on the credibility of monetary policy, described as the degree to which various economic agents believe that the central bank will act to ensure that it meets its key policy objectives, and on whether monetary policy actions permeate the real sector of the economy[57] (Laopodis, 2013; Kabundi & Mlachila, 2019). The downward trend of inflation in SA since adopting an IT regime, associated with greater confidence in macroeconomic policies, has enhanced the scope for monetary policy as an effective tool to ensure macro-stability (Aron & Muellbauer, 2005, 2007, 2009).

The SARB has continuously sought to mitigate uncertainty by (i) increasing the clarity around the objectives of monetary policy to ensure price stability and the framework to achieve this objective (i.e., the IT regime); and (ii) protecting and enhancing financial stability by monitoring the environment and mitigating systemic risks that might disrupt the financial system. This is primarily

[57] See Aziakpono and Wilson (2013) for a discussion on the importance of the interest rate pass through in affecting price stability.

done by applying a macroprudential monitoring framework[58]. However, given the stark complexity of the real world, no research effort can completely eliminate uncertainty, and there exists 'Knightian uncertainty' where policymakers cannot reasonably measure or anticipate an event. Uncertainty is an integral part of the monetary policy decision making process (Naraidoo & Raputsoane, 2015), and a popular quote from Alan Greenspan (2003) defining this phenomenon is: "uncertainty is not just an important feature of the monetary policy landscape, it is the defining characteristic."

In the last 30 years, SA has experienced several periods of heightened uncertainty, including the 1998 Asian financial crisis, the 2007/8 GFC, the COVID-19 pandemic and the Russia-Ukraine war. Bloom (2009) pointed out the phenomenon where uncertainty remains high after major shocks to the economy, and this heightened uncertainty keeps economic activity down. This was found to apply to SA (see, among others, Kisten, 2020; Balcilar *et al.*, 2021; Aye, 2021; and Ahiadorme, 2022). During these episodes, policymakers implemented expansionary monetary policies to alleviate financial stress and help move the economy towards recovery. During the novel COVID-19 pandemic, which generated a high level of uncertainty similar to that realised during the GFC, the SARB quickly intervened to inject liquidity into the system in an attempt to limit the extent of the recession, which will inevitably come. The concurrent occurrence of high uncertainty and policy interventions has revived the debate on the interferences of high levels of uncertainty on the transmission of monetary policy shocks to the business cycle. This provokes an analysis to determine the effectiveness of monetary policy in the face of uncertainty – a Machiavellian concern of policymakers (Tillmann, 2020). Aastveit *et al.* (2017) note that recent research in macroeconomics has focused solely on how movements in uncertainty affect economic activity, while less attention has been directed to the empirical investigation into the role that uncertainty might play in influencing the effectiveness of monetary policy – a sentiment also held by Pellegrino (2021). The few existing studies primarily focus on advanced economies, and there is much less work done on emerging markets, even though they tend to experience higher levels of uncertainty. This is due to them having less-diversified economies which are more exposed to price and output fluctuations of volatile goods such as commodities (Bloom, 2014), which is the case for SA. Only two other studies, by Wei and Han (2021) and Prabheesh *et al.* (2021) were identified that touched on this topic for SA, with both these studies only focusing on the

[58] For more information see https://www.resbank.co.za/en/home/what-we-do/financial-stability/macroprudential-policy.

effectiveness of monetary policy transmission during COVID-19, only modelling over the COVID-19 period.

This study contributes the literature in the following ways. First, the study explores the macroeconomic impact of a monetary policy shock in a reduced form VAR framework to test the effectiveness of policy for SA to establish a baseline. To improve the effectiveness of monetary policies, central banks ideally should be able to identify the origin of uncertainties and how they impact the transmission channels of monetary policy. This is investigated through a non-linear Self-Exciting Interacted VAR (SEIVAR) methodology on monthly data, a technique that has not yet been implemented to investigate the impact of monetary policy in SA. It is one of the first to empirically investigate how different states of uncertainty (high vs low) in three key domestic markets − stock, currency and goods markets − and uncertainty in the global market[59] alters the effectiveness of monetary policy. The analysis covers the period February 2000 – May 2022, during which SA operated under an IT regime. The SEIVAR model is augmented with the GARCH and EGARCH measures that proxy uncertainty within the domestic markets (detailed in Section 2.5 of Chapter 2 and Section 3.5 of Chapter 3) as well as a measure of global uncertainty – the U.S. EPU. A global measure of uncertainty is considered as SA is a small open economy vulnerable to conditions abroad, and the fact that U.S. uncertainty is known to impact SA's macroeconomic variables (Trung, 2019; Gupta *et al.,* 2020) validates using the U.S. EPU as a proxy for global uncertainty[60]. This framework is particularly appealing to address the research question in that it enables us to estimate the economy's response conditional on uncertainty states in the different markets which will uncover the asymmetric effects. Findings show that monetary policy is effective in SA, as it works to stabilise inflation. The SEIVAR analysis reveals that monetary policy is less effective in high uncertainty states in the different markets, uncovering the relevant asymmetric effects. These findings lend support for the SARB to implement more aggressive monetary stimuli in the face of high-uncertainty events.

The rest of this chapter is structured as follows. Section 4.2 contains a literature review of relevant empirical studies. Section 4.3 presents an analysis of the data and introduces the econometric framework. Empirical results are reported and discussed in Section 4.4, while Section 4.5 concludes.

[59] Global uncertainty is proxied by the U.S. economic policy uncertainty (EPU) index constructed by Baker *et al.* (2016).

[60] The U.S. EPU is used over other measures, such as the VIX, in order to get a broader measure of uncertainty – where the VIX only captures volatility in the financial markets of listed companies, the U.S. EPU captures a host of uncertainty aspects related to policy (Balcilar *et al.*, 2017).

4.2 LITERATURE REVIEW

A review of the literature shows that the effects of monetary policy shocks is one of the most studied empirical issues in macroeconomics (Cheng & Yang, 2020). Despite half a century of empirical research and numerous econometric methodological advances, there is still much uncertainty around the effects of monetary policy (Miranda-Agrippino & Ricco, 2021).

Researchers have disagreed on the best means of identifying monetary policy shocks. To determine what constitutes a monetary policy shock depends on the tools utilised by the central bank and whether they make use of conventional monetary policy – such as the policy interest rate – or unconventional monetary policy – which includes large-scale asset purchases (quantitative easing (QE), forward guidance, term funding facilities, adjustments to market operations and negative interest rates (Sims & Wu, 2020). For several decades, central banks in advanced economies typically used a policy interest rate as their tool for conducting monetary policy. In response to the GFC of 2007–2009 and the deep recession it caused in parts of the world, central banks in many advanced economies lowered their policy interest rates to near-zero levels. As economic growth remained weak, interest rates persisted at near-zero levels, leaving no room for conventional monetary policy, and some central banks resorted to 'unconventional' monetary policy measures to stimulate economic activity (Swanson, 2021). These unconventional measures have again become prominent as central banks worldwide responded to the severe economic consequences of the COVID-19 pandemic, with a range of emerging market central banks joining in (Fowkes, 2022). Ramey (2016) provides an overview of the many recent innovations for identifying monetary policy shocks, including Cholesky decomposition, sign restrictions, high-frequency identification and narrative methods, among others. Considering this, the monetary policy shock investigated in each study should be cognizant of the monetary policy tools used by the specific country's central bank. This study will focus on the monetary policy framework implemented in South Africa under inflation targeting from February 2000 which uses discretionary changes in the policy interest rate as its main policy instrument.

To decipher the impact of a monetary policy shock, the literature emphasises five key transmission channels of monetary policy: the interest rate channel, the credit channel (bank lending channel and the balance sheet channel), the exchange rate channel, the asset price channel and the expectations channel (Mukherjee & Bhattacharya, 2011; Vo & Nguyen, 2017)[61]. These channels

[61] For a more detailed discussion on these channels see the prominent works of Romer and Romer (1989), Gertler and Gilchrist (1994), Bernanke and Gertler (1995) and Kashyap and Stein (2000). To understand the evolution over time of these channels see Boivin *et al.* (2010).

are not mutually exclusive in that more than one channel can work simultaneously to achieve the policy objective(s), and Cevik and Teksoz (2013) noted that the effectiveness of the channel transmission depends on: (i) the economic structure, (ii) the development of financial and capital markets, and (iii) the economic conditions at the time, among other factors. Given that these factors differ among developed and developing countries, monetary policy mechanism would likely differ for developed and developing countries (Mishra *et al.*, 2016).

In order to measure the effects of monetary policy shocks on macroeconomic variables, many researchers have followed the lead of Sims (1980) and Bernanke and Blinder (1992) and used the structural vector autoregression (SVAR) model (for a comprehensive literature review see Christiano *et al.,* 1999 and Ramey, 2016). Authors have also used different augmentations of the VAR to detect the impact of a monetary policy shock[62]. Most empirical studies investigating the impact of monetary policy shocks focus on developed economies: Romer and Romer (2004), Bernanke *et al.* (2005), Feldkircher and Hubar (2018), Cheng and Yang (2020), Swanson (2021), Miranda-Agrippino and Ricco (2021) investigate the U.S.; Champagne and Sekkel (2018) look at Canada; Rafiq and Mallick (2008), Arratibel and Michaelis (2014), Cloyne and Hürtgen (2016), Murgia (2020) focus on the Euro area; and Nagao *et al.* (2021) investigate Japan. Turning to emerging economies, Burdekin and Siklos (2008) study China; Khundrakpum (2017), Bhat *et al.* (2020) look at India; Berument and Dincer (2008), Ülke and Berument (2016) investigate Turkey; while Chuku (2009), Fasanya *et al.* (2013), and Ndikumana (2016) consider countries in Africa.

Literature that speaks to the effectiveness of SA's monetary policy is somewhat limited. Bonga-Bonga and Kabundi (2015) provide evidence supporting the view that monetary policy dampens output while not being effective in impacting prices. Ajilore and Ikhide (2013) find that a monetary policy shock is growth dampening while both anticipated and unanticipated shocks increase rather than moderate prices, causing these authors to doubt that inflation is a monetary phenomenon in SA. Mallick and Sousa (2012) investigate the (BRICS) countries and find that contractionary monetary policy has a strong and negative effect on output and that, in contrast to Bonga-Bonga and Kabundi (2015) and Ajilore and Ikhide (2013), the contractionary monetary policy shocks tend to stabilise inflation in these countries in the short term. They also found that a monetary policy shock produces a strongly persistent negative effect on real equity prices and generates an appreciation of the domestic currency. Ivrendi and Yildirim (2013) look at BRICS_T and corroborate the findings of Mallick and Sousa (2012). Gumata *et al.* (2013) find evidence that all five transmission channels work in SA, with their magnitudes and importance differing –

[62] See Twinoburyo and Odhiambo (2018) for a review of the international literature.

suggesting that the interest rate channel is the most important transmitter of the shock. Ndou (2022) contrasts the effects of contractionary monetary policy shocks on output in SA and South Korea – an interesting case study despite both countries being IT regime adopters, South Korea's economic growth has been consistently higher, inflation rates lower and the real growth recovers swiftly after economic crises such as the East-Asian financial crisis and the GFC. Findings show that for SA, a contractionary monetary policy shock significantly depresses real output for a sustained period, while output declines insignificantly and transitorily in South Korea, indicating monetary neutrality. The author attributes this difference to the transitory responses of both the monetary aggregate M2 and the exchange rate[63] to a monetary policy shock in South Korea compared to SA – implying that each country has a different monetary policy reaction function.

This study connects to a recent strand in the literature that explores the relationship between uncertainty and monetary policy. The theoretical discussion on the role of uncertainty on general policy effectiveness can be traced back to Brainard (1967). In the face of uncertainty, central banks can respond in two ways: the principle of attenuation, as discussed by Brainard (1967), puts forth that central banks' response is dampened when they are faced with uncertainty associated with the effect of rate changes and they adopt a 'wait-and-see' approach; while other authors, such as Giannoni (2002) or Söderström (2002), have put forth the argument that monetary authorities may react more aggressively under uncertainty[64]. Whether central banks' response is more subdued or aggressive, empirical and theoretical formulations of monetary policy should consider the quantitative relevance of uncertainty because it is a constant feature of monetary policy practice, and cross-country studies generally support the notion that there is a difference in how effective monetary policy is between normal times and crisis times (Burgard *et al.*, 2018). The theoretical literature establishes two important mechanisms in understanding how uncertainty can affect monetary policy's effectiveness: the nonlinearities in the interest rate and the credit transmission channel (Balcilar *et al.,* 2022).

The nonlinearities in the interest rate theory contend that the monetary policy efficiency diminishes through the course of high uncertainty states as a consequence of the following channels: real options effects, precautionary savings, productivity and risk premia channel and uncertainty-dependent price-setting mechanisms. According to the real options theory, in the face of high

[63] The author attributes the insignificant output impact to the potency of foreign exchange interventions via the use of the Exchange Stabilization Fund by the Bank of Korea, whose objective is to achieve foreign exchange market stability.

[64] See Svensson and Woodford (2003, 2004) for a description of the theoretical foundation of the monetary policy rules that address these responses and Mendes *et al.* (2017) for a discussion of the guiding principles for central banks decision making under uncertainty.

uncertainty firms adopt a wait-and-see approach and postpone their investment and hiring decisions (see, e.g., Dixit and Pindyck, 1994; Bloom, 2009, 2014 and Bloom *et al.,* 2018), which results in a more muted response of economic activity to a monetary policy expansion in times of high volatility. An analogous mechanism works through the precautionary savings theory, which claims that investors prefer precautionary saving and shift their consumption to the future owing to present uncertain circumstances (e.g., Fernandez-Villaverde *et al.,* 2015; Basu and Bundick, 2017). Bloom (2014) argued that when uncertainty is high, productive firms are less aggressive in expanding and unproductive firms are less aggressive in contracting, stalling productivity growth as the productivity-enhancing reallocation of resources across firms is thwarted. Greater uncertainty also brings about increased risk premia. Lastly, the uncertainty-dependent price-setting mechanism attributes the decrease in the effectiveness of monetary policy to the continuous price adjustment of firms due to uncertainty (see, e.g., Vavra, 2014). Overall, in response to high uncertainty these channels argue that economic agents are less responsive to policy shocks.

The evidence from various empirical studies confirms this view: looking at the U.S. is Bloom (2009), Vavra (2014), Eickmeier *et al.* (2016), Aastveit *et al.* (2017), Caggiano *et al.* (2017), Castelnuovo and Pellegrino (2018), Tillmann (2020), Pellegrino (2021); focussing on the Euro area is Abbassi and Linzert (2012), Bachmann *et al.* (2013), Balcilar *et al.* (2017), and Pellegrino (2018); looking at OECD countries is Bouis *et al.* (2013) and Gupta and Jooste (2018); looking at a group of developed economies is Bech *et al.* (2014); Lien *et al.* (2019) look at China; Nain and Kamaiah (2020), Kumar *et al.* (2021) and Pratap and Dhal (2021) look at India; and Pinshi (2020) look at the Democratic republic of Congo during COVID-19.

On the other hand, the credit transmission channel theory contends that monetary policy is more effective on economies during high uncertainty states – like an economic crisis – if a central bank can restore the functioning of the credit and interest rate channels. Firms and private households are more likely to be credit constrained during financial crises because of a decrease in the value of their financial assets and losses of collateral. In this situation, monetary policy may reduce the external finance premium by easing these constraints via the financial accelerator (see, among others, Bernanke *et al.,* 1999; and Mishkin, 2009). Furthermore, monetary policy can be more effective if it is able to raise confidence from very low levels by providing signals about future economic prospects (Barsky & Sims, 2012) or by decreasing the probability of worst-case outcomes, as well as by improving the ability of agents to make probability assessments about future events (Ilut & Schneider, 2014). The evidence from various empirical studies confirms this view: Garcia and Schaller (2002), Lo and Piger (2005), Dahlhaus (2014), Engen *et al.* (2015), Fry-

Mckibbin and Zheng (2016) consider the U.S.; Li and St-Amant (2010) look at Canada; Jannsen *et al.* (2019) study 20 advanced economies; Smets and Peersman (2001), Ciccarelli *et al.* (2013), and Burgard *et al.* (2019) investigate the Euro area; and Ren *et al.* (2020) consider China. An interesting finding of a recent study by Balcilar *et al.* (2022), who examined the monetary policy effectiveness of five major Asian economies[65], was that monetary policy shocks are more effective and potent in Asian economies during very low and very high uncertain times compared to normal economic periods.

This study is closely related to the work of Aastveit *et al.* (2017), Balcilar *et al.* (2017) and Pellegrino (2018, 2021), who utilise the Interacted Vector Autoregressive (IVAR) methodology developed by Tobin and Weber (2013) and Sá *et al.* (2014) treating uncertainty as an exogenous interaction variable. Most of the literature thus mentioned focuses on the broadly defined uncertainty measures and does not study the interaction of monetary policy with uncertainty. Aastveit *et al.* (2017) investigate the macroeconomic influence of monetary policy changes during different uncertainty states in the U.S. These authors also extend their analysis by estimating how the U.S.-based uncertainty measures interact with the transmission of monetary policy shocks in Canada, the UK, and Norway. This is done based on the growing debate that domestic financial conditions are increasingly determined by developments in the rest of the world, particularly developments in the U.S. – which spill over to other economies through global financial cycles and work to override the efforts of local monetary policy to steer domestic financial conditions (Georgiadis & Mehl, 2016; Walerych & Wesołowski, 2021). Findings provide evidence that the impact of monetary policy on an economy weakens significantly during periods of increased uncertainty, particularly for Canada and the U.S.

Similarly, Balcilar *et al.* (2017) examine the role of the U.S. economic policy uncertainty (EPU) on the effectiveness of monetary policy in the Euro area. Findings suggest that U.S. EPU has a significant bearing on the response of macro variables to monetary policy shocks in the Euro area, with heightened U.S. EPU dampening the effect of monetary policy shocks, while both price and output react more significantly to monetary policy shocks when the level of U.S. EPU is low. Pellegrino (2018) shows that monetary policy is less effective in the Euro area in periods of high uncertainty. Focusing on the U.S., Pellegrino (2021) reveal that monetary policy shocks are significantly less potent during uncertain times – where the peak reactions of a battery of real variables are about two-thirds milder than during tranquil times.

---

[65] China, Hong Kong, India, Japan, and South Korea.

While the theoretical mechanisms detail how uncertainty can impact the effectiveness of policy, empirical evidence on its macroeconomic importance in SA is limited. Studies that have touched on this topic for SA are restricted to only considering the impact that COVID-19 has had on the effectiveness of monetary policy. Wei and Han (2021) use event-study methodology to estimate the impact of COVID-19 on the transmission of monetary policy to financial markets (government bond, stock, exchange rate and credit default swap markets) based on a sample of 37 countries, including SA. Their results suggest that the emergence of the pandemic has weakened the transmission of monetary policy to financial markets to a more significant degree. During the period following the outbreak of COVID-19, neither conventional nor unconventional monetary policies were found to significantly affect the financial markets. Prabheesh *et al.* (2021) considered the effectiveness of monetary policy transmission in 14 emerging economies, one of which was SA, during the COVID-19 pandemic using the VIX as a measure of uncertainty. The study found that: (i) in most economies, the monetary policy transmission to inflation is weakened due to the uncertainty created by the COVID-19 pandemic, including SA; (ii) in a few economies, the transmission is found to be effective in stabilising credit and output, including SA; and (iii) the outbreak of the COVID-19 pandemic induced economic agents to follow a "cautionary" or "wait-and-see" approach. This confirms earlier findings by Naraidoo and Raputsoane (2015), who found that uncertainty has led to a more cautious monetary policy stance by the SARB MPC consistent with the principle of attenuation of Brainard (1967) that recognises that an excessively activist policy can increase economic instability.

This study will be the first to employ the IVAR method in the SA context to determine the effectiveness of monetary policy at different states of uncertainty. This study distinguishes itself from the other studies by considering different uncertainty states in three key domestic markets – stock, currency and goods – as well as in the global market, using U.S. EPU. where studies normally only consider one uncertainty measure.

4.3 DATA AND METHODOLOGY

4.3.1. Data and stylised facts

This study is based on SA monthly data for the period February 2000 to May 2022, containing 268 observations procured from the SARB database, the IMF International Financial Statistics (IFS) database and Bloomberg. The following macroeconomic variables are included in the analysis: real industrial production (IP), which is used as a proxy for real GDP[66], real investment (I), real consumption (C), inflation (CPI), broad money (M3), the 3-month treasury bill rate (TB3) and the policy rate (R). IP captures real activity, and I and C are included to allow investigation into the different transmission mechanisms of monetary policy shocks through these channels. This real data was converted from quarterly to monthly series using a linear conversion method[67]. The policy rate is expressed in percentage terms and is considered an indicator of the monetary policy stance. Financial market variables include the share price index (SP) and the nominal effective exchange rate (NEER). The uncertainty measures used in this study include measures of uncertainty in the domestic stock, currency and goods markets (as detailed and developed in Chapters 2 and 3) and a measure of U.S. EPU developed by Baker *et al.* (2016)[68] to account for global developments. This index is constructed from three types of underlying components: newspaper coverage of policy-related economic uncertainty, the number of federal tax code provisions set to expire and disagreement among economic forecasters.

Data series at a monthly frequency is used as quarterly data does not capture the information content of changes in the variables of interest and make analysis during crisis periods less useful (as crises often tend to be relatively short-lived) while daily data contains too much noise to analyse (Ramchand & Susmel, 1998). The starting point of the analysis is chosen to coincide with the beginning of the IT regime in SA. Prior to this, the SARB implemented different monetary policy frameworks, including exchange rate controls and broad money supply controls. A sample starting before the IT regime will likely be affected by a structural break since the analysis aims to study the economy's average response to a monetary policy shock (conditional on the state of uncertainty, high versus low). The period where the SARB implemented different monetary policy regimes needs to be excluded so that shocks to the short-term interest rate (policy rate) can be used as a consistent measure of a monetary policy shock (Bianchi *et al.,* 2016; Kim & Lim, 2018; Pellegrino, 2018, 2021). Given the sample end point of May 2022, the data encompasses a range of global events, such as the GFC, the COVID-19 pandemic and the Russia-Ukraine war.

Figure 4.1 displays developments in the policy rate and inflation rate from February 2000 when the SARB implemented an explicit IT regime by setting a short-term policy rate targeting and an inflation band of between 3-6% (emphasising recently it would like inflation close to the 4.5%

---

[66] Data on industrial production is collected on a monthly basis whereas GDP data is collected on a quarterly basis, making industrial production as output measure more suitable for this study.

[67] This was done in the EViews statistical package. The linear conversion technique assigns each value in the low frequency series to the first or last high frequency observation associated with the low frequency period, then places all intermediate points on straight lines connecting these points.

[68] Available at http://www.policyuncertainty.com/us_monthly.html.

midpoint of the range)[69]. This was also accompanied by a free-floating exchange rate, where the SARB had implemented fixed exchange rates in the 1960s and 1970s and experimented with managed floating rate regimes of various forms in the 1980s and 1990s (Mtonga, 2011). This is important as the effectiveness of monetary policy and its transmission is also dependent on the exchange rate regime, and since SA does not intervene in the currency market, this transmission

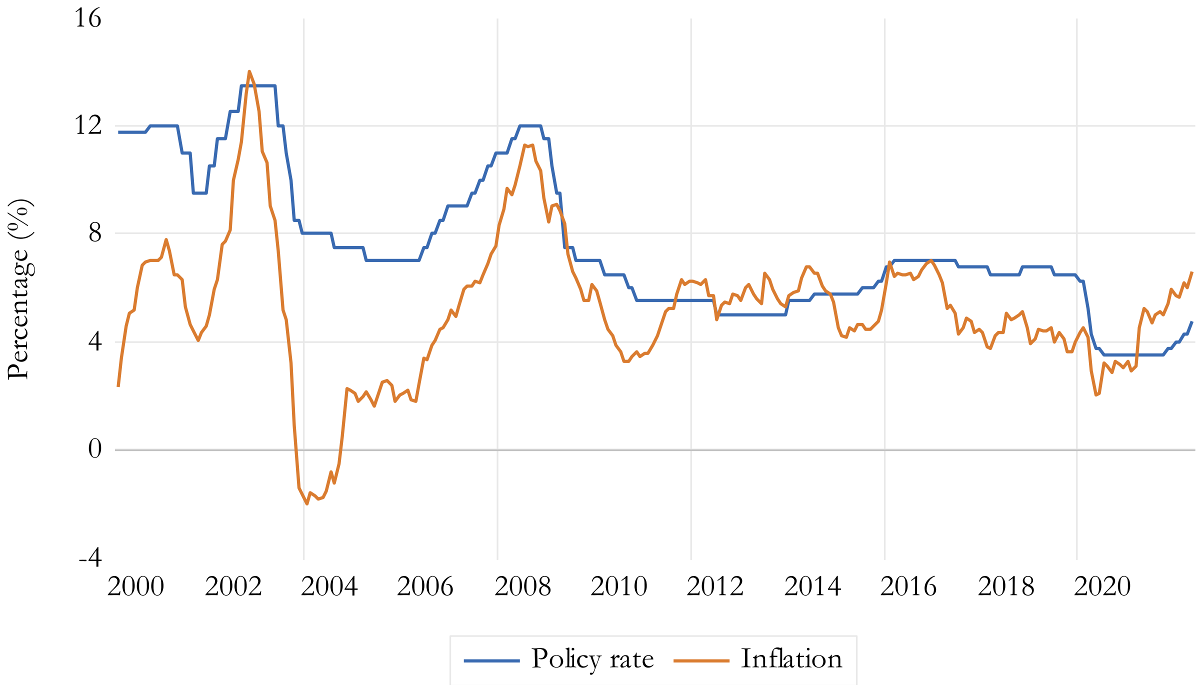


Figure 4.1: Policy rate and inflation for South Africa, 2000:02–2022:05

Source: SARB database.

channel is not distorted (Mallick & Sousa, 2012)[70]. Furthermore, adopting an IT regime in a more open economy aims to enhance policy transparency, accountability and predictability and align monetary policy more closely with widespread international practice (Aron & Muellbauer, 2009; Weber, 2018; Kabundi and Mlachila, 2019). As seen in Figure 4.1, the policy rate and inflation generally move in tandem, both experiencing their peaks in 2002 and around the 2008/2009 GFC.

During the GFC, SA was not severely affected by liquidity disruptions as the domestic banking system was relatively well insulated and hence did not require any unconventional monetary policy measures. However, during the COVID-19 pandemic there was heightened risk-off sentiment,

[69] See Figure B1 in Appendix B for a plot of the other variables.

[70] Emerging market economies grapple with surges in net capital inflows, in particular increased portfolio investment, and central banks resort to intervention in the foreign exchange market to manage this. This intervention usually takes the form of preventing currency appreciation and as a result generating inflationary pressure. This type of intervention undermines the exchange rate channel as an adjustment mechanism (Mallick & Sousa, 2012).

which led to a sell-off of financial assets globally – which had implications for emerging markets, and SA in particular, as investor appetite for rand-denominated equities and bonds remained weak. The SARB cushioned the blow with a 275 basis point cut over the four months from January to July 2020, bringing the policy rate to a record low of 3.5%, whilst also introducing liquidity measures to ensure the smooth functioning of the financial system. Liquidity measures included: intraday overnight supplementary repurchase operations, end-of-day standing facility rates, main refinancing operations, purchases of government bonds in the secondary market and the Prudential Authority[71] also introduced relief measures (SARB Quarterly Bulletin, 2020). SA has been cited as implementing QE; however, the SARB has opposed that portrayal and emphasised that purchasing government bonds was intended to preserve bond-market functioning rather than delivering stimulus. Fowkes (2022) highlights that QE is less effective than the policy interest rate tool in SA as the zero lower bound is not binding in SA, with rates bottoming out at 3.5% during COVID-19. He further notes that QE is unnecessary and inappropriate to adopt in SA due to: (i) the risk or creating moral hazard, diluting the incentive for fiscal consolidation without removing the need to consolidate; (ii) QE would transfer risk to the central bank's balance sheet, undermining the fiscal authority's prudent pre-COVID-19 debt management strategy of mainly issuing long-term debt; and (iii) government is already able to replicate the QE effect of lower borrowing costs by issuing more short-term debt, a tactic National Treasury used successfully during 2020.

Headline inflation decelerated markedly to a low of 2.1% in May 2020, suppressed mainly by a marked slowdown in fuel price inflation and the impact of the strict domestic lockdown on demand. Inflation remained broadly unchanged at around 3% up to March 2021 until global inflationary pressures increased sharply, with inflation accelerating to 5.9% in December, following the easing of the COVID-19 lockdowns in the second half of 2020 and driven largely by the significant increase in international crude oil prices. This saw the MPC implementing three consecutive 25 basis points increases in the policy rate between November 2021 and March 2022, after it had remained at a record low of 3.5% since July 2020. Russia's invasion of Ukraine further exacerbated inflationary pressures in February 2022, which elevated agricultural commodity prices,[72] adding a substantial risk premium to already high energy prices. The inflation rate

[71] The Prudential Authority is responsible for the regulation of the financial sector and operates as a juristic person within the administration of the SARB and consists of the following four departments: the Financial Conglomerate Supervision Department; the Banking, Insurance and Financial Market Infrastructures Supervision Department; the Risk Support Department; and the Policy, Statistics and Industry Support Department.

[72] Although the increase in international food prices was broad-based, it has largely been driven by higher grain prices, especially wheat and maize, which are staple foods in many countries. International vegetable oil prices have also increased significantly over the past two years. With Russia and Ukraine both being major global producers of wheat,

breached the upper limit of the 3–6% inflation target range for the first time in four years when it accelerated to 6.5% in May 2022. It then increased further to a 13-year high of 7.8% in July[73]. Consumer fuel prices reverted from a year-on-year decrease of 25.8% in May 2020 during the COVID-19 restrictions to an increase of 56.2% in July 2022 – the highest since 2008. Consumer fuel price inflation was primarily impacted by the increase in the international price of Brent crude oil, from an average of US$29.5 per barrel in May 2020 to an average of US$122.8 per barrel in June 2022. This reflected higher global demand following the easing of COVID-19 lockdown restrictions and later supply constraints following the sanctions on Russian petroleum products, with Russia being the third-largest crude oil producer in the world. In the face of this, the price of inland 95-octane petrol increased by 97.8% from May 2020 to June 2022, while the price of diesel more than doubled over the same period. This has a ripple effect as most goods are transported by road, and increased transport costs led to price increases of consumer goods. To address surging inflation, the MPC increased the policy rate by 50 basis points to 4.75% per annum in May 2022, further tightening monetary policy by 75 basis points in both July 2022 and September 2022. The ongoing conflict in Ukraine and the sanctions imposed on Russia by many countries have also exacerbated and prolonged the global supply chain disruptions, adding further upward pressure on consumer prices in most economies.

In order to gain insight into the univariate time series properties of the data series, descriptive statistics are presented in Table 4.1. Considering the monetary measures graphed in Figure 4.1, the mean of the policy rate and inflation over the period 2000:02–2022:05 is 7.5% and 5.2%, respectively, with similar standard deviations of 2.66 and 2.62, respectively. Inflation reached a maximum of 14.01% in November 2002 on the back of price pressures initially stemming from a steep depreciation of the exchange rate, coupled with higher trending wage settlements and elevated oil prices. As a result of these developments, the MPC hiked the policy rate by 400 basis points during 2002 to anchor inflation, and the policy rate hit its maximum of 13.5% in 2002. Considering the domestic uncertainty measures, the stock market exhibits the highest mean and volatility, followed by the currency market. The goods market uncertainty exhibits the lowest mean and volatility on the back of the IT regime that has seen the stabilisation of inflation, associated with greater confidence in macroeconomic policies. Most of the variables in Table 4.1 exhibit

maize and sunflower seed, and with the blockage of Ukraine's Black Sea ports, the prices of these commodities have increased significantly. Fears of global shortages in certain oil seeds have led to export bans by some countries, which caused a further surge in vegetable oil prices.

[73] https://www.resbank.co.za/content/dam/sarb/publications/quarterly-bulletins/quarterly-bulletin-publications/2022/september/01Full%20Quarterly%20Bulletin%20(2).pdf

positive skewness, which implies that the distributions have a long right tail, while only industrial production, investment and consumption display negative skewness, implying that these distributions have a long left tail. Furthermore, if the variable's kurtosis is less than 3 the distribution is platykurtic or short-tailed with respect to the normal, while if the variable's kurtosis is greater than 3 the distribution is leptokurtic or heavy-tailed with respect to the normal distribution. The Jarque-Bera statistics for all the variables indicate that the null hypothesis of the normal distribution is rejected at the 1% level of significance.

Table 4.1: Descriptive statistics of macroeconomic variables and uncertainty measures for South Africa, 2000:02–2022:05

Variable[74]	Mean	Std. Dev	Min	Max	Skewness	Kurtosis	Jarque-Bera
Industrial production	96.07	6.48	49.4	109.9	-1.82	12.95	1248.94 (0.0000)
Investment	162,452.3	36168.43	89,074.0	210,388.0	-0.80	2.25	34.58 (0.0000)
Consumption	619,466.2	108,937.8	406,180.3	799,270.0	-0.46	1.96	21.54 (0.0000)
Inflation rate	5.21	2.62	-2.0	14.01	0.16	4.64	31.09 (0.0000)
Broad money (M3)	2,170,269	1,159,797	476,619.0	4,467,812	0.20	1.91	14.86 (0.0000)
3-month treasury bill rate	7.31	2.18	3.45	12.74	0.49	2.69	11.92 (0.0003)
Policy rate	7.51	2.66	3.5	13.5	0.66	2.50	22.55 (0.0000)
Share price index	33,468.07	18,506.91	7,191.36	68,970.78	0.08	1.64	20.42 (0.0000)
Nominal effective exchange rate	135.35	39.14	74.3	220.37	0.25	1.81	18.52 (0.0000)
Stock market uncertainty[75]	26.61	17.13	7.97	117.9152	2.50	11.33	1027.13 (0.0000)
Currency market uncertainty[76]	12.29	13.68	1.64	140.7384	5.17	40.04	16508.73 (0.0000)
Goods market uncertainty[77]	0.25	0.16	0.11	1.0739	2.3201	8.9418	634.67 (0.0000)
U.S. EPU	138.05	66.15	504.0	45.0	1.9379	8.9666	565.27 (0.0000)

Note: Values in parenthesis are p-values.

74 Industrial production is the volume of production with index: 2015=100. Investment and consumption are measured in constant 2015 prices in R millions.

75 The stock market uncertainty measure used in Table 4.1 was taken from the conditional variance from the ARMA (2,1) EGARCH (1,1) model, refer to Table 2.3 in Section 2.5.2.

76 The exchange rate uncertainty measure used in Table 4.1 was taken from the conditional variance from the ARMA (2,1) EGARCH (1,1) model, refer to Table 2.3 in Section 2.5.2.

77 The inflation uncertainty measure used in Table 4.1 was taken from the conditional variance from the ARMA (3,2) GARCH (1,1) model augmented to test for the Friedman-Ball hypotheses, refer to Model 7 in Table 3.4 in Section 3.5.2.

Jarque-Bera is the test statistic for testing whether a time series is normally distributed. The test statistic is computed as $JB = \frac{N-k}{\sigma}\left(skew^2 + \frac{1}{4}(kur-3)^2\right)$
where skew is skewness, kur is kurtosis, N is the number of observations, and k is the number of estimated coefficients.

4.3.2 Methodology

In this section, the econometric techniques that this study implements are detailed. First, the reduced form VAR framework used to analyse the macroeconomic impact of a monetary policy shock is detailed in Section 4.3.2.1. Thereafter, the non-linear SEIVAR model specification, augmented with GARCH and EGARCH volatilities, is detailed in Section 4.3.2.2. This technique is used to assess the macroeconomic impact of a monetary policy shock in different uncertainty states (high versus low) within the three domestic markets and the global market. This method further allows the identification of time-varying uncertainty effects in the transmission of monetary and the identification of asymmetries.

4.3.2.1 Reduced form VAR

The following reduced form of the VAR model is considered:

$$Y_t = \sum_{j=1}^{L} A_j Y_{t-j} + \mu_t \qquad (18)$$

where Y_t is an $(n \times 1)$ vector of the endogenous variables, A_j are $(n \times n)$ matrices of coefficients, and μ_t is the $(n \times 1)$ vector of error terms, $E(\mu_t) = 0$ and $E(\mu_t \mu_t') = \Omega$. The endogenous variables included in $Y = [R, TB3, M3, CPI, IP, I, C, SP, NEER]$. The real and financial variables are taken in logs and multiplied by 100, implying that their VAR responses can be interpreted as percent deviations from the trend[78]. The VAR order was chosen after conducting the lag length criterion test, and the Schwarz Information Criterion (SIC) suggest 2 lags.

In this study, it is of interest to know the responses of the endogenous variables in the Y vector (inflation, industrial production, etc.) to an impulse in the policy interest rate, R. In a dynamic system, an innovation to a variable disrupts that variable and, in addition, is transmitted to all the additional endogenous variables in the system through the dynamic (lag) structure of the VAR. An impulse response function traces the impact of a once-off shock to one of the innovations on current and future values of the endogenous variables (Gil-Lafuente *et al.*, 2012). If there is a response of one variable to an impulse/innovation in another variable, then the latter variable is defined as being causal for the former variable. If the structural innovations, ε_t, are contemporaneously uncorrelated, the interpretation of the impulse response is straightforward:

[78] As done in Aastveit et al. (2017), Balcilar *et al.* (2017), Pellegrino (2018, 2021) and Ndou (2022). Bootstrap standard errors are used.

the *i-th* innovation $\varepsilon_{i,t}$ is simply a shock to the i-*th* endogenous variable in vector Y. However, innovations are generally correlated, and probably contain a mutual component, which should not be related to an explicit variable. In this case, it is routine to apply a transformation to the innovations so the impulses become uncorrelated so that one can interpret them. This paper implements generalised impulse response functions (GIRFs) proposed by Koop *et al.* (1996) as they have two important advantages. First, they allow for composition dependence in multivariate models, in that the effect of a shock to the policy rate is not isolated from having a contemporaneous impact on the other endogenous variables in the VAR and *vice versa* (see Lee & Pesaran, 1993; and Pesaran & Shin, 1996). Second, they are invariant to the reordering of the variables in a multivariate model and fully consider the historical patterns of correlations observed amongst the different shocks (Pesaran & Shin, 1998). That is, 'causal priority' is avoided, which ultimately ensures that an ordering of the inflation and inflation uncertainty within the VAR does not have any bearing on the outcomes of the impulse responses. Pesaran and Shin (1998) show that the maximum likelihood estimator of the GIRFs is $\sqrt{T}$-consistent and asymptotically normally distributed.

4.3.2.2 The Self-Exciting Interacted VAR

To test non-linear effects, this study employs the Self-Exciting Interacted VAR (SEIVAR) model, developed by Towbin and Weber (2013) and Sa *et al.* (2013), to empirically study whether the real effects of monetary policy shocks are different across high and low uncertainty regimes in the three markets. This model augments an otherwise standard linear VAR with an interaction term, which involves two endogenously modelled variables: the variable used to identify a monetary policy shock (the policy rate) and the uncertainty measure. This latter variable will serve as a conditioning variable allowing us to obtain the impact of monetary policy shocks during high and low uncertainty states.

The estimated SEIVAR model used in this study follows the Pellegrino (2021) specification:

$$Y_t = \alpha + \sum_{j=1}^{L} A_j Y_{t-j} + \left[\sum_{j=1}^{L} c_j R_{t-j} \cdot unc_{t-j}^{k}\right] + \mu_t \tag{19}$$

$$unc_t = e'_{unc} Y_t \tag{20}$$

$$R_t = e'_R Y_t \tag{21}$$

$$E(\mu_t \mu'_t) = \Omega \tag{22}$$

where Y_t is the $(n \times 1)$ vector of the endogenous variables comprising inflation, industrial production, investment, consumption, the policy rate and a measure of uncertainty. α is the $(n \times 1)$ vector of constant terms, A_j are $(n \times n)$ matrices of coefficients, and μ_t is the $(n \times 1)$ vector of error terms, whose variance-covariance matrix is Ω. The interaction term in brackets makes an otherwise standard VAR a SEIVAR model. It includes a $(n \times 1)$ vector of coefficients, c_j, a measure of uncertainty, unc_t^k, and the policy rate, R_t. The uncertainty measure, unc_t^k with $k = \{stock\ market, currency\ market, goods\ market, global\ market\}$, are the different uncertainty measures for the South African stock, currency and goods market (calculated using the EGARCH methodology stipulated in Table 2.3 of Section 2.5.2 and the GARCH methodology tabled in Model 7 in Table 3.4 in Section 3.5.2 respectively) and a measure of global uncertainty, U.S. EPU, to account for global developments, as done in Balcilar *et al.* (2017) and Aastveit *et al.* (2017). e_y is a selection vector for the endogenous variable y in Y. An important distinction of this methodology, which is novel compared to other studies employing IVAR, is that both interaction terms (policy rate and uncertainty) are treated as endogenous as it is important to compute monetary policy effectiveness conditional on high/low uncertainty, along with the fact that uncertainty may endogenously move after the policy shock (as monetary shocks themselves may affect uncertainty and uncertainty may irrespectively mean revert). This latter possibility is what generates a feedback effect which makes the model self-exciting in the iteration after a monetary policy shock (Pellegrino, 2021). This IVAR represents a special case of a Generalised Vector Autoregressive (GVAR) model (Mittnik, 1990), and the choice of working only with the $(R_{t-j} \cdot unc_{t-j})$ interaction term enables this study to focus on the possibly nonlinear effects of uncertainty shocks due to different levels of the policy rate while preserving stability[79]. The lag length criteria stipulate 2 lags according to the Schwarz information criterion.

Following Balcilar et al. (2017) and Aastveit et al. (2017), the estimated impulse responses of monetary policy shocks are computed at two different levels of the uncertainty indicator to evaluate the importance of the importance of the interaction effects. This study adopts the sign restriction of above and below the mean of the historical distribution of the uncertainty measure, denoted by $unc^{k,high}$ and $unc^{k,low}$, to report on the high and low uncertainty states within the markets under consideration – stock, currency, goods and global market. The estimated VAR then reduces to:

[79] In principle, GVAR models may feature higher order interaction terms, however multivariate GAR models have been shown to become unstable when higher powers of the interactions terms are included among the covariates (as pointed out by Mittnik (1990), Granger (1998), Aruoba *et al.* (2013) and Ruge-Murcia (2015).

$$Y_t^{high} = \widehat{D}_0^{high} + \sum_{j=1}^{L}\left(\widehat{D}_j^{high} R_{t-j}\right) + \hat{\mu}_t \tag{23}$$

$$Y_t^{low} = \widehat{D}_0^{low} + \sum_{j=1}^{L}\left(\widehat{D}_j^{low} R_{t-j}\right) + \hat{\mu}_t \tag{24}$$

where $\widehat{D}_0^{high} = \hat{\alpha} + \sum_{j=1}^{L} \hat{A}_j Y_{t-j}^{high}$ [80] and $\widehat{D}_0^{low} = \hat{\alpha} + \sum_{j=1}^{L} \hat{A}_j Y_{t-j}^{low}$.

Similarly, $\widehat{D}_j^{high} = \hat{c}_j unc_{t-j}^{high}$ and $\widehat{D}_j^{low} = \hat{c}_j unc_{t-j}^{low}$.

To correctly account for the feedback effect, this study implements GIRFs which consider that, in a fully non-linear model, the state of the system and, therefore system's future evolution can vary endogenously after a shock. As a result, GIRFs return fully non-linear empirical responses that depend nontrivially on the initial conditions in place when the system is shocked (as well as on the sign and size of the shock). Theoretically, the GIRF at horizon h of the vector Y to a shock in date t, δ_t, computed conditional on an initial history (or initial conditions), $\varpi_{t-1} = \{Y_{t-1}, \dots, Y_{t-L}\}$, is given by the following difference of conditional expectations between the shocked and non-shocked paths of Y:

$$GIRF_{Y,t}(h, \delta_t, \varpi_{t-1}) = E[Y_{t+h} | \delta_t, \varpi_{t-1}] - E[Y_{t+h} | \varpi_{t-1}] \tag{25}$$

In principle, there are as many history dependent GIRFs referring to a generic initial quarter $t-1$ as there are quarters in the estimation sample. Once these GIRFs are averaged, per horizon, over a particular subset of initial conditions of interest, the state dependent GIRFs are obtained, which reflect the average response of the economy to a monetary policy shock in a given uncertainty state. Theoretically, the state dependent GIRFs can be defined as:

$$GIRF_{Y,t}\left(h, \delta_t, \Omega_{t-1}^{high}\right) = E\left[GIRF_{Y,t}\left(h, \delta_t, \varpi_{t-1} \in \Omega_{t-1}^{high}\right)\right] \tag{26}$$

$$GIRF_{Y,t}\left(h, \delta_t, \Omega_{t-1}^{low}\right) = E\left[GIRF_{Y,t}\left(h, \delta_t, \varpi_{t-1} \in \Omega_{t-1}^{low}\right)\right] \tag{27}$$

where Ω_{t-1}^{i} denotes the set of histories characterizing regime $i = \{high;\ low\}$.

As Pellegrino (2021) points out, this method contributes to the literature in two respects. Firstly, it represents a novel and more general framework in the IVAR literature that allows endogenising conditioning variables. Secondly, application-wise, it contrasts with the strategy employed by recent VAR analyses on the uncertainty-dependent effectiveness of monetary policy shocks (e.g.,

[80] Important to note is that unc is modelled as an endogenous variable within the Y vector, so Y_{t-j}^{high} refers to when the uncertainty measure in the corresponding markets $k = \{stock\ market, currency\ market, goods\ market, global\ market\}$ is in the high uncertainty state, while Y_{t-j}^{low} refers to when the uncertainty measure is in the low uncertainty state.

Aastveit *et al.* (2017), Eickmeier *et al.* (2016) and Castelnuovo and Pellegrino (2018)) which work with non-linear VAR models featuring an exogenous conditioning variable and therefore compute conditionally linear IRFs for a fixed value of the uncertainty proxy. This enables consideration of both the possibly endogenous move of uncertainty (our conditioning indicator) after the policy shock and its feedback on the dynamics of the system.

To identify the monetary policy shocks[81], this study follows the literature and adopts the conventional short-run restrictions implied by the Cholesky decomposition. The vector of endogenous variables is ordered in the following way: $Y = [R, Unc, CPI, IP, I, C, SP, NEER]'$, containing the policy rate, an uncertainty proxy, inflation, industrial production, investment, consumption, the share price and the nominal effective exchange rate. The results presented in Section 4.4 are robust when the order of the variables in the Y vector is changed.

4.4 EMPIRICAL RESULTS

Section 4.4.1 presents the results of the impact of a monetary policy shock on the real economy in the reduced form VAR framework with GIRFs. Section 4.4.2 provides the estimation results of the SEIVAR model and reports the GIRFs, which represent the effectiveness of monetary policy in the face of different uncertainty states (high versus low) within the three domestic markets – stock, currency and goods markets as well as the global market.

4.4.1 Reduced form VAR results

Figure 4.2 contains the GIRFs, which detail the macroeconomic impact of a monetary policy shock in order to test policy effectiveness for SA. This serves as a baseline to compare with the results that follow in section 4.4.2, where the impact of uncertainty is explored.

[81] This study also considered the sign-restriction approach of Uhlig (2005) to identify monetary policy shocks. The identifying assumption here was that a monetary policy shock was associated with an increased interest rate and a fall in the price level. The Uhlig (2005) sign restriction method has become very popular at present, but not many previous studies investigated the issues in small open economies by using such a method, which makes the current study more interesting (Kim & Lim, 2018). However, application of the method revealed an increasing trend in inflation in some of the IRFs, which is not feasible.

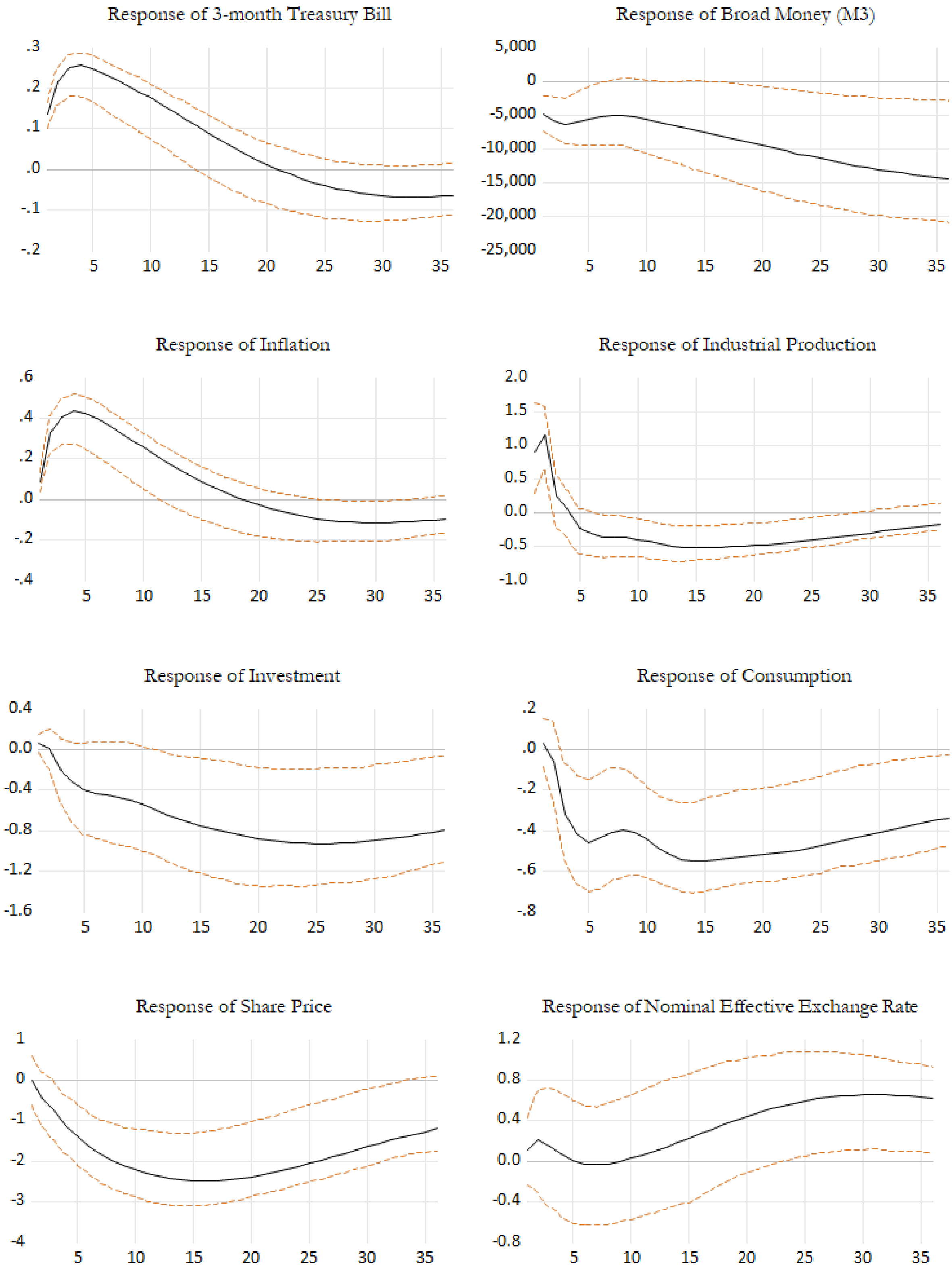


Figure 4.2: Response of real macroeconomic variables to a monetary policy shock
Note: The solid line reports the mean, and the dotted lines report the 90% confidence intervals computed using bootstrapping with 1,000 replications.

As can be seen, inflation exhibits an initial increase as a contractionary monetary policy shock takes effect – evidence of the well-documented "price puzzle", first documented by Sims (1992) and subsequently confirmed by other authors (reported by Romer & Romer (2004), Cloyne & Hurtgen (2016), Aastveit (2017) and Murgia (2020))[82]. After 4 months, the trend starts to decline and the contractionary policy shock lowers inflation. This is in line with the study of Ndou (2022) who confirms the effectiveness of contractionary monetary policy shocks in lowering inflation, while in contrast to Bonga-Bonga and Kabundi (2015) and Ajilore and Ikhide (2013), who found monetary policy to be ineffective at impacting inflation. Inflation rises incrementally for about 4 months, after which it starts its downward trend. This declining effect is significant for about 10 months.

Broad money (M3) outcomes align with *a priori* expectations, suggesting that a contractionary monetary policy shock should lead to a fall in M3, consistent with the liquidity effect, while the 3-month treasury bill rate follows the trend of the policy rate.

Output rises for the first 2 months and then starts its downward trend with the impact being significant (baring months 2-5), remaining depressed for several quarters. This finding is in line with Bonga-Bonga and Kabundi (2015), who found output rising for around 7 months, after which it starts to decline, and with Ndou (2022), who found that output contracts for a few quarters in response to a monetary policy contraction. Output then displays a sluggish adjustment taking over a year before the full effects are felt. This is consistent with the monetarist view that the economy responds gradually to monetary policy shocks. Investment and consumption also see a declining trend, with the effect becoming significant after 10 months for investment and after only two months in consumption. This finding shows that contractionary monetary policy shocks have real effects in SA.

There is a negative impact on stock markets, shown by the decline in the share price. This result shows that monetary policy actions affect stock prices, with its link to the real economy through the asset price transmission channel, which exerts influence on consumption and investment spending. This finding is in line with the theories of monetary policy-stock market nexus, including Modigliani's life cycle model, which postulates a direct relationship between the lifetime resources of consumers and stock prices, and Tobin q's Model, which postulates a direct relationship between investment spending and stock prices (Tobin, 1969; Modigliani, 1971; Miskin, 2001).

[82] Employing the Uhlig (2005) sign restriction avoids this by design.

A contractionary monetary policy shock generates an appreciation of the domestic currency – which gives rise to the idea that monetary policy is interested not only in optimal monetary conditions but also in external stability (Knedlick, 2006). Within a floating exchange rate regime, such as SA, the domestic currency becomes a shock absorber. This is in line with the findings of Ndou (2022), who found a persistent and prolonged appreciation following the policy intervention. The exchange rate provides information on the pass-through channel into the cost of imported intermediate inputs and impacts on the traditional interest rate channel in which monetary policy has immediate effects on changing the return on assets denominated in different currencies (Rafiq & Mallick, 2008). The appreciation of the domestic currency will make SA exports more expensive and less competitive globally, which will push down aggregate demand.

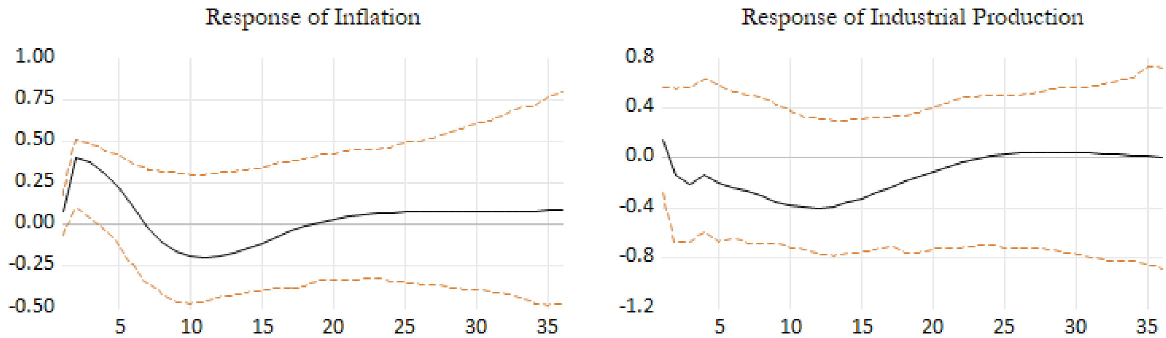
Overall, these results align with the literature, and it can be concluded that monetary policy is effective in SA.

4.4.2 SEIVAR results

Figures 4.3 to 4.6 display the inflation and industrial production response to a contractionary monetary policy shock within the different markets. The responses of the other variables in the SEIVAR can be found in Appendix B (Figures B2-B5). Throughout Figures 4.3 to 4.6 below, we see that in both the high and low volatility scenarios, there is a "price puzzle" as prices initially increase in response to the monetary tightening. Interestingly, the initial positive inflation response is practically insensitive to the level of uncertainty. The figures in the Appendix show that investment and consumption generally see declining trends in response to a contractionary monetary policy shock in the face of uncertainty, in line with the real options effect and precautionary savings effect, where the impact is generally more pronounced in low uncertainty states.

Figure 4.3 displays the response of inflation and industrial production to a monetary policy shock within the high and low uncertainty states in the stock market. The figure plots responses for three years (36 months) after the shock. As can be seen, inflation increase for two periods and then starts to decline in the high uncertainty state. In the low uncertainty state, inflation has a downward trend. In both uncertainty states, the impact on inflation is only significant for 2 or 3 months. Industrial production sees a downward trend in the high uncertainty state that lasts about a year, after which it starts to normalise, with the effect being insignificant. In the low uncertainty state, industrial production shows a significant upward trend after 5 months.

High uncertainty



Low uncertainty

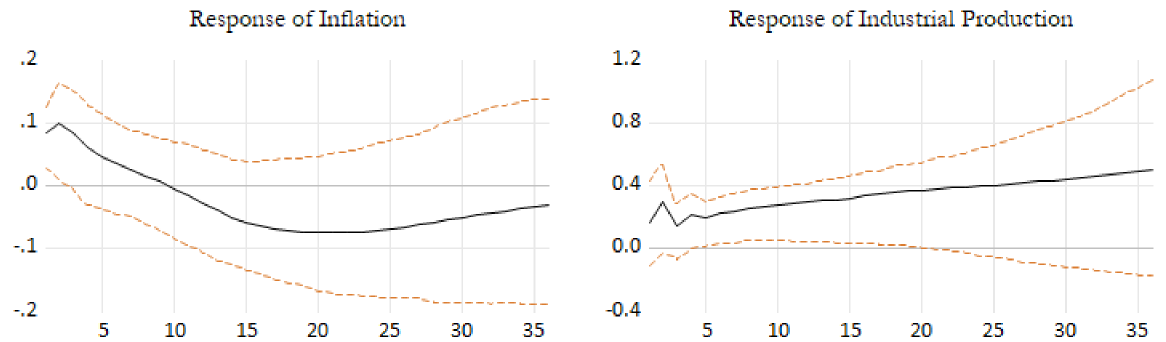


Figure 4.3: Impact of a monetary policy shock – Stock market

Note: The solid line reports the mean, and the dotted lines report the 90% confidence intervals computed using bootstrapping with 1,000 replications.

Figure 4.4 displays the response of inflation and industrial production to a monetary policy shock within the high and low uncertainty states in the currency market. The impact on inflation is short-lived as the decline is borderline significant for only a short period of 5 months in the high uncertainty state, while the impact remains significant for a much longer period in the low uncertainty state (up to 20 months). Notably, the share price shows a significant decline from 10 months (see Appendix B, Figure B2).

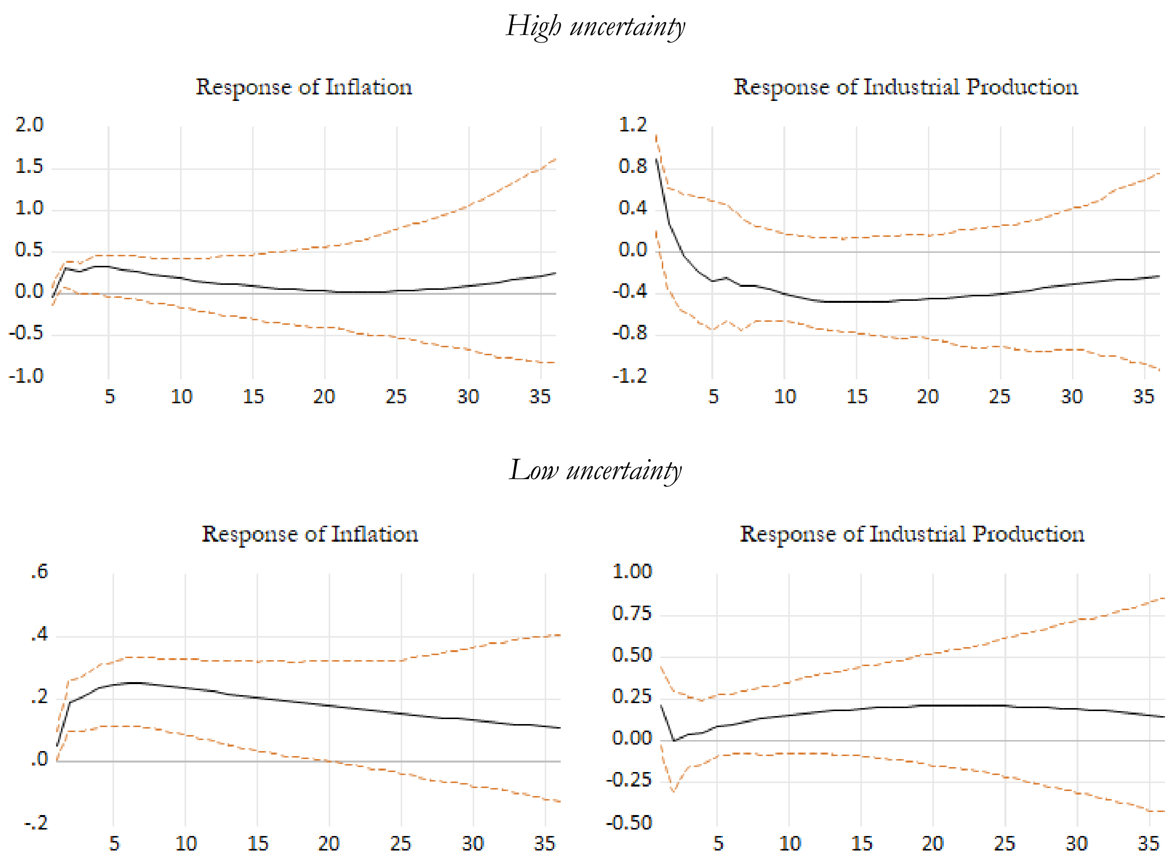


Figure 4.4: Impact of a monetary policy shock – Currency market

Note: The solid line reports the mean, and the dotted lines report the 90% confidence intervals computed using bootstrapping with 1,000 replications.

Figure 4.5 displays the response of inflation and industrial production to a monetary policy shock within the high and low uncertainty states in the currency market. While the initial impact on inflation is more pronounced in the high uncertainty state, it only remains significant for a short period of 5 months, whereas the impact remains significant for a longer period of about a year in the low uncertainty state. Industrial production sees a significant decline after about 4 months in the high uncertainty state, while the initial impact is significant in the low uncertainty state.

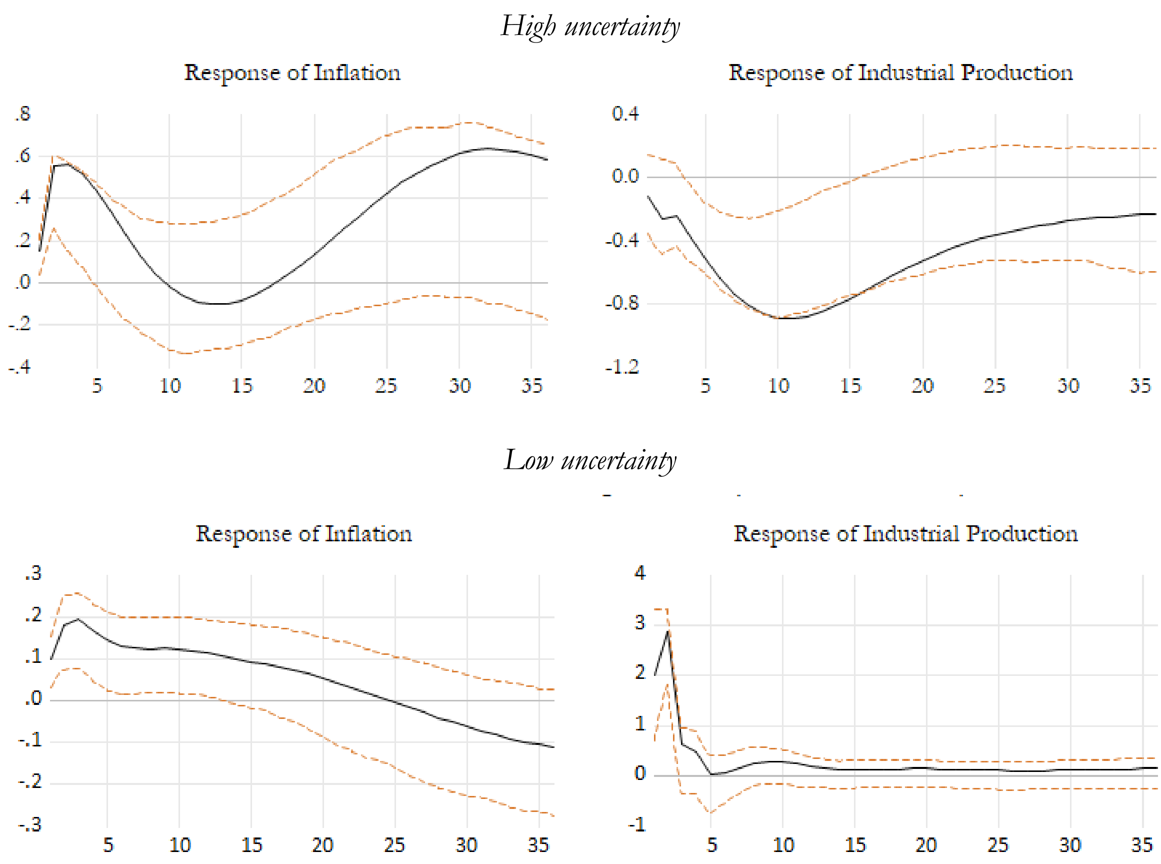


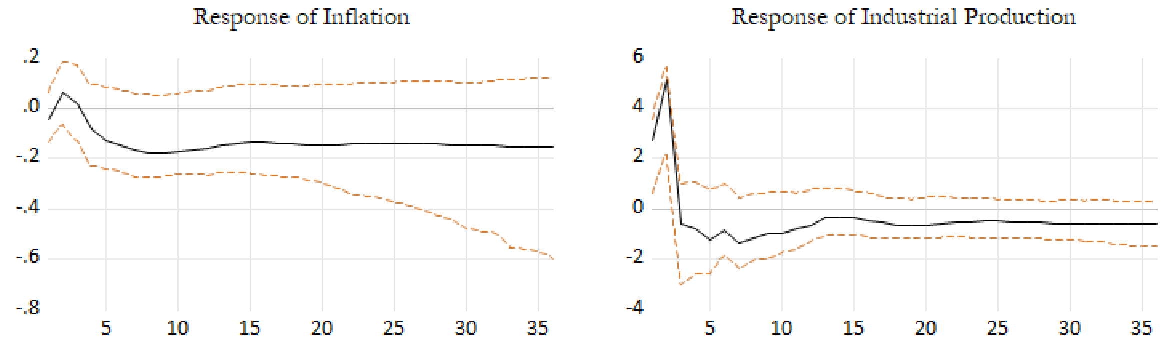
Figure 4.5: Impact of a monetary policy shock – Goods market

Note: The solid line reports the mean, and the dotted lines report the 90% confidence intervals computed using bootstrapping with 1,000 replications.

Figure 4.6 displays the response of inflation and industrial production to a monetary policy shock within the high and low uncertainty states in the global market[83]. The impact on inflation is only significant in the low uncertainty state, signifying that uncertainty in the U.S. dampens the effect of monetary policy shocks in SA.

[83] A measure of global EPU from Baker et al. (2016) was also considered and the results are broadly similar. See Figure B5 in Appendix B.

High uncertainty



Low uncertainty

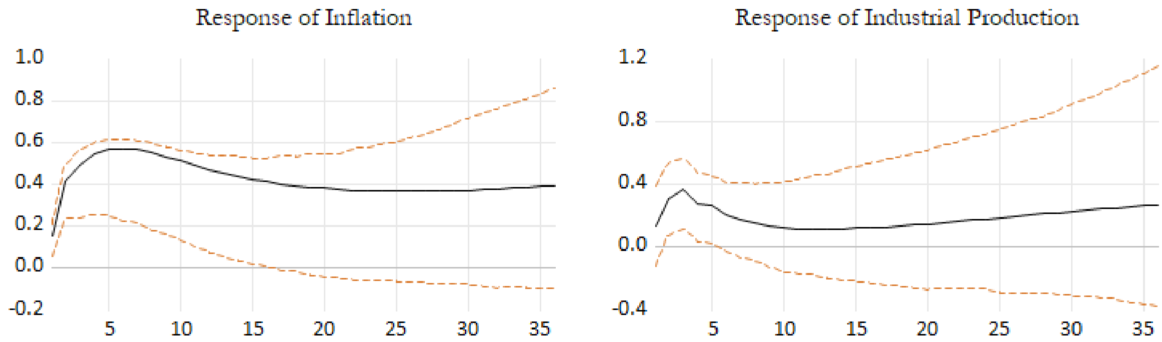


Figure 4.6: Impact of a monetary policy shock – Global market

Note: The solid line reports the mean, and the dotted lines report the 90% confidence intervals computed using bootstrap with 1,000 replications.

Overall, these findings suggest that the effectiveness of monetary policy is generally weaker in the high uncertainty states in the different markets considered, seen by the lower impact on inflation, which also tends to be short-lived when compared to the low uncertainty state. This finding is in line with the nonlinearities in the interest rate theory also found by other studies implementing the IVAR framework – those of Aastveit et al. (2017), Balcilar et al. (2017) and Pellegrino (2018, 2021). Results also point to the asymmetric effects of a monetary policy shock dependent on the uncertainty state.

4.5 CONCLUSION

This study contributes to the literature by investigating the impact of a monetary policy shock on macroeconomic variables as well as the efficiency of monetary policy in South Africa, over the IT regime from 2000:02–2022:05, conditional on different uncertainty states in the goods, stock, currency and global market. The impact of a contractionary monetary policy shock (a hike in the policy rate) is investigated through a reduced form VAR and analysing the GIRF. The results reveal that this type of shock: (i) stabilises inflation; (ii) has a negative effect on output; (ii) produces a liquidity effect and reduces broad money; (iii) has a negative impact on stock markets; and (iv) generate an appreciation of the domestic currency. This points to the effectiveness of monetary policy in influencing the real economy and provides support for IT as a monetary policy regime. The effectiveness of a monetary policy shock is analysed through a non-linear Self-Exciting Interacted VAR (SEIVAR) methodology, which allows investigation into how uncertainty states in markets affect the effectiveness of policy. Results find that monetary policy is weaker in the high uncertainty states in the domestic markets, which is evidence of the non-linearities in the interest rate theory. Furthermore, heightened uncertainty in the U.S. also dampens the effect of monetary policy in SA. This shows that when policymakers face high uncertainty, they experience a trade-off between acting decisively and acting correctly, and this study lends support to theoretical studies that recommend more aggressive stimuli in uncertain times (see, e.g., Bloom, 2009; Bloom *et al.*, 2018). Even after endogenising uncertainty, monetary policy is found to be less effective in high-uncertainty states, although to a lesser extent than what was found in previous studies.

The next chapter summarises the contributions and key findings of this study and contains a discussion of additional avenues of research.

CHAPTER 5
GENERAL CONCLUSIONS AND AREAS OF FUTURE RESEARCH

5.1 INTRODUCTION

In this concluding chapter, Section 5.2 highlights the contributions of the thesis and Section 5.3 summarises the study's main findings. The final section, Section 5.4, contains avenues for future research.

5.2 CONTRIBUTIONS OF THIS STUDY

Chapter 2 contributes to the literature by: (i) contributing to the debate between whether the "flow-orientated" or "stock-orientated' approach holds in SA by looking into the spillover between stock price and exchange rate; (ii) being one of the very few studies that applies the multivariate EGARCH technique in the recent period to SA; (iii) and, it is one of the first studies that investigate how the recent COVID-19 pandemic impacted these spillovers.

Chapter 3 offers three main contributions to the literature: (i) Studies focusing on SA using a GARCH and GARCH-M specification to scrutinise the inflation-inflation uncertainty nexus and the link between IT and the level of inflation and its uncertainty are limited, cover a shorter sample period and present with conflicting results, which justifies this investigation in order to fill this gap in the literature. (ii) This is the first study, to the best of the author's knowledge, to employ the recent Rossi-Wang (2019) time-varying vector autoregression (VAR) based Granger causality tests to determine the dynamic relationship between inflation and inflation uncertainty and how it changes over time. At large, the existing literature only considers full-sample constant-parameter causality, which is susceptible to inconsistent results and conclusions in the presence of parameter instability due to structural changes in the relationships (Su *et al.,* 2017), whereas the Rossi-Wang (2019) test is robust to the presence of instabilities and regime changes. (iii) The outcome contributes to the debate between economists that support IT and those who criticise the use of an IT monetary policy framework and offer lessons to emerging market economies which may consider adopting an IT framework.

Chapter 4 contributes to the literature by: (i) empirically investigating how different states of uncertainty (high vs low) in three domestic markets – stock, currency and goods – and uncertainty in the global market alters the effectiveness of monetary policy in SA, i.e., determining whether there are asymmetric effects, being one of the very few studies addressing this topic. This is investigated through a non-linear Self-Exciting Interacted VAR (SEIVAR) methodology augmented with GARCH and EGARCH volatilities on monthly data, a technique that has not yet been implemented to investigate SA.

5.3 SUMMARY OF KEY FINDINGS AND POLICY CONCLUSIONS

In Chapter 2, the empirical analysis based on the EGARCH model provides evidence in support of the "stock-orientated" approach in which movements in stock prices affect future exchange rate movements, whilst evidence of the "flow-orientated" approach is seen in the second moment and significant shock and asymmetric spillovers from the foreign exchange to stock market are found. There is also evidence of bidirectional asymmetric volatility spillover effects between the stock and foreign exchange market. The results of this paper also find that contagion heightens during periods of crisis as spillovers became more pronounced during the COVID-19 pandemic.

Policymakers will benefit from this study by having insights into the interconnectedness of the stock and currency market and the economic consequences that may arise from contagion between these markets, allowing them to consider policies from a financial stability perspective. Financial system stability is vital for sustained long-term economic growth, as a whole economy can be destabilised when the financial system is impaired. Monetary policy implemented by the SARB protects and enhances financial stability by monitoring the global and domestic environment and mitigating systemic risks that might disrupt the financial system – primarily done by applying a macroprudential monitoring framework, which includes stress-testing financial institutions. The SARB laid out that macroprudential policy focuses on a variety of intermediate targets including: reducing excessive growth in credit, asset prices and leverage; reducing excessive lending and funding maturity mismatches; reducing direct and indirect concentrated exposure to the same markets, products and institutions; ensuring liquidity in the market; and reducing 'moral hazard', where institutions have an expectation that they can increase their risk exposure as government will bail them out. There are three categories of macroprudential instruments, namely capital-based instruments (e.g. countercyclical capital buffers, sectoral capital requirements and dynamic provisions); asset-side instruments (e.g. loan-to-value (LTV) and debt-to-income (DTI) ratio caps); and liquidity-based instruments (e.g. countercyclical liquidity requirements). Macroprudential policy has become prominent within policy agendas due to the lack of policy options available to mitigate systematic risk that can build up within a financial system.

Although governments are known to frequently intervene in the foreign exchange markets, the question of the desirability of direct intervention in the stock market remains part of the broader economic debate. Proponents of intervention claim that intervention can avoid swift price declines in the stock market and restore investor confidence. Conversely, opponents claim that any form of intervention can seriously endanger the integrity of the market since the stock market stands as a leading financial indicator of the economy, and any tampering with it can transmit incorrect signals about the state of a nation's economy (Khan & Batteau, 2011).

In Chapter 3, the empirical analysis based on GARCH modelling suggests a bidirectional causality between inflation and inflation uncertainty exist in the SA context, with strong evidence in support of the Friedman-Ball hypothesis and weaker evidence in support of the Cukierman-Meltzer hypothesis – that is, stronger evidence of increased inflation levels leading to increased inflation uncertainty, and weaker evidence in favour of a reverse causation. The Rossi-Wang (2019) time-varying Granger causality tests provide evidence that the relationship between inflation and inflation uncertainty varies across time, showing that the Friedman-Ball hypothesis holds for the pre-IT period and breaks down in the IT period, while the Cukierman-Meltzer hypothesis only holds for the 10-year period prior to the adoption of IT. Finally, the results also reveal that IT has been effective in reducing both the level of inflation and the volatility of inflation.

The duties of monetary authorities are extraordinarily challenging as their models project output and inflation with relatively great uncertainty due to shocks emitted throughout the economy. It is crucial to understand how monetary authorities respond to these shocks. To combat surging inflation, the SARB should implement interest rate hikes expeditiously and transparently. Publicising and communicating the drivers of inflation along with inflation forecasts facilitates in divulging the monetary policy stance and developing transparency and accountability of the SARB. If market participants grasp current policy and exactly how future decisions are made and trust the bank to implement these decisions, the SARB can effectively manage inflationary expectations and uncertainties. Credibility should be a mantra of policy. The central bank should also ensure that a high degree of independence is maintained so that any decisions are shielded from political pressure for short-run monetary stimulation, ensuring that price stability will be the policy's key objective. Empirical studies back this idea and show that monetary policy independence ensures a lower level of inflation and decreases the associated variability (Grier & Perry, 1998; Aguir, 2018; Garriga & Rodriguez, 2020). The whole burden does not fall on monetary authorities as the fiscal policy responses to demand and supply shocks will also affect levels of inflation. Expansionary fiscal policy can undermine the effects of the monetary authorities, while contractionary fiscal policy can reinforce them. Government can help to temper demand, boost supply, and directly lower prices in the economy through tax, spending, and regulatory reforms. Overall, there is a need for coordination between both monetary and fiscal policy to reduce inflation (Nasr *et al.*, 2015).

In Chapter 4, the SEIVAR results suggest that monetary policy effectiveness is weaker and short-lived in periods of high market uncertainty. This is an important finding for policymakers as it is instructive for them to know where the uncertainties stem from and how this uncertainty will impact the transmission of monetary policy throughout the economy. When policymakers face high uncertainty, they experience a trade-off between acting decisively and acting correctly; this study lends support to more aggressive monetary stimuli in the face of high uncertainty.

5.4 AVENUES OF FUTURE RESEARCH

There are several areas for future research which is highlighted presently.

A potential limitation of Chapter 2 lies in not accounting for regime shifts with periods of higher volatility versus low volatility. The Time-varying parameter vector autoregressions (TVP-VAR) model suggested by Antonakakis and Gabauer (2017) or the quantile vector autoregression (QVAR) model-based spillover estimation approach of Balcilar *et al.* (2020) could be used to assess the magnitude of volatility transmission between the foreign exchange and equity markets during the tranquil and tumultuous periods in SA. Previous studies have provided strong evidence of regime-switching behaviour in stock market returns (see Turner *et al.*, 1989; Chu *et al.*, 1996; and Schaller & Van Norden, 1997). A future study can use a two-regime bivariate MS-EGARCH model motivated by at least three points: (i) this model allows the variance of stock returns to switch across different regimes; (ii) the model can detect regime dependence in the impact, persistence and asymmetric response to shocks since the conditional variance depends on past shocks and the present and past states of the economy; and (ii) this model is founded on the assumption that stock returns may shift across different volatility regimes, which is linked to the diverse perceptions and reactions of foreign exchange traders and stock market participants to volatility spillovers between exchange and stock markets (Chkili *et al.,* 2011). It is also possible that more could be learnt from using higher frequency data, particularly from the use of daily data during the COVID-19 period, to attain more information about the contagion. Avenues for future research could include a study that investigates the 'meteor shower' effect from global financial markets to stock and foreign exchange markets in SA, as SA's financial markets are vulnerable to global events (Živkov *et al.,* 2021).

In terms of Chapter 3, Hegerty (2012) outlined that SA's monetary influence will endure in sub-Saharan Africa (SSA) and due to most of the international effects being hinged on it, it will be interesting to conduct a regional study to encompass the impact that interdependent inflation shocks have across SSA countries. Additionally, a study can be conducted on whether a common monetary policy for the whole of the sub-Saharan region would be a suitable instrument to anchor inflation in the whole region. Following Jiang (2016), in addition to SA's national level, the interaction between inflation and inflation uncertainty in urban and rural areas could be investigated, motivated by the substantial urban–rural divide. Threshold models or endogenous break-point tests might be valuable in detecting 'critical inflation thresholds' beyond which the influence of inflation is particularly harmful to economic activity in South Africa (Valdovinos & Gerling, 2011).

Another exciting avenue of research to pursue would be a regional study to assess the efficacy of adopting an IT monetary policy regime on inflationary outcomes, conditional on country-and period-specific institutional quality measures like central bank independence, transparency, economic freedom, the rule of law, government size, etc. A difference-in-difference estimator may be used to compare countries that adopted an IT regime with non-adopters, as well as compare the magnitude of the impact across developed and developing economies.

With reference to Chapter 4, the role of uncertainty has been traditionally linked to real frictions (Bloom, 2009; 2014). However, recent research has focused on the role played by the toxic "high uncertainty-high financial stress" tandem, which argues that credit markets are the critical link in the propagation of uncertainty shocks. It would be interesting to follow the recent work of Caggiano *et al.* (2021) and determine the finance-uncertainty multiplier (FUM), coined by Alfaro *et al.* (2019), to explore the role played by financial frictions in magnifying the real effects of uncertainty shocks in SA. This will be important for policymakers as the size of the FUM warrants different policy responses. If the FUM is large, policymakers should inject liquidity following shocks to avoid deep recessions. However, if the FUM is small, rapid interventions to kill uncertainty (e.g., clear and credible communication of future policy moves or the quick development of a testing, tracing, and treating plan for pandemics like COVID-19) should be the agenda.

REFERENCES

Aastveit, K.A., Natvik, G.J., & Sola, S. (2017). Macroeconomic uncertainty and the effectiveness of monetary policy. *Journal of International Money and Finance, 76,* 50-67.

Abbassi, P., & Linzert, T. (2012). The effectiveness of monetary policy in steering money market rates during the financial crisis. *Journal of Macroeconomics*, *34*(4), 945-954.

Achour, M., & Trabelsi, A. (2011). Markov Switching and State-Space Approaches for Investigating the Link between Egyptian Inflation Level and Uncertainty. *Review of Middle East Economics and Finance*, *6*(3), 46-62.

Adjasi, C. K., Biekpe, N. B., & Osei, K. A. (2011). Stock prices and exchange rate dynamics in selected African countries: A bivariate analysis. *African Journal of Economic and Management Studies*, 2(2), 143-164.

Aggerwal. (1981). Exchange Rates and Stock Prices: A Study of the US Capital Markets Under Floating Exchange Rates. *Akron Business Economic Review*, *12*, 7-12.

Aguir, A. (2018). Central bank credibility, independence, and monetary policy. *Journal of Central Banking Theory and Practice*, *7*(3), 91-110.

Ahiadorme, J. W. (2022). On the aggregate effects of global uncertainty: Evidence from an emerging economy. *South African Journal of Economics*, *90*(3), 390-407.

Ajayi, R. A., & Mougoue, M. (1996). On the Dynamic Relation between Stock Prices and Exchange Rates. *Journal of Financial Research*, *19*(2), 193-207.

Ajayi, R. A., Friedman, J., & Mehdian, S. M. (1998). On the Relationship between Stock Returns and Exchange rates: Tests of Granger causality. *Global Finance Journal*, *9*(2), 241-251.

Ajevskis, V. (2007). Inflation and Inflation Uncertainty in Latvia. *Latvijas Banka*, 4.

Ajilore, T., & Ikhide, S. (2013). Monetary policy shocks, output and prices in South Africa: A test of policy irrelevance proposition. *The Journal of Developing Areas*, *47*(2), 363-386.

Alam, M. R. (2015). Economic Policy Uncertainty in the US: Does It Matter for Canada? *Economics Bulletin*, *35(4)*, 2725–2732.

Alfaro, I., Bloom, N, & Lin, X. (2018) .The Finance Uncertainty Multiplier. *National Bureau of Economic Research Working Paper 24571.*

Alimi, R. S. (2017). Inflation rates and inflation uncertainty in Africa: A quantile regression approach. *International Journal of Academic Research in Business and Social Sciences*, *7*(11), 937-952.

Aloui, C. (2007). Price and Volatility Spillovers between Exchange Rates and Stock Indexes for the pre- and post-Euro Period. *Quantitative Finance*, *7*(6), 669-685.

Andrews, D. W. K. (1993). Tests for parameter instability and structural change with unknown change point. *Econometrica, 61*(4), 821-856.

Andrews, D. W. K., & W. Ploberger. (1994). Optimal tests when a nuisance parameter is present only under the alternative. *Econometrica, 62*(6), 1383-1414.

Antonakakis, N., & Gabauer, D. (2017). Refined measures of dynamic connectedness based on TVP-VAR. *MPRA Paper 78282*.

Antonakakis, N., Christou, C., Gil-Alana, L. A., & Gupta, R. (2021). Inflation-targeting and inflation volatility: International evidence from the cosine-squared cepstrum. *International Economics*, *167*, 29-38.

Apergis, N. (2005). Inflation uncertainty and growth: Evidence from panel data. *Australian Economic Papers*, *44*(2), 186-197.

Apergis, N., Bulut, U., Ucler, G., & Ozsahin, S. (2021). The causal linkage between inflation and inflation uncertainty under structural breaks: Evidence from Turkey. *The Manchester School*, *89*(3), 259-275.

Apergis, N., Gavriilidis, K., & Gupta, R. (2022). Does climate policy uncertainty affect tourism demand? Evidence from time-varying causality tests. *Tourism Economics*, *0*(0).

Aron, J. & Muellbauer, J. (2007). Review of Monetary Policy in South Africa since 1994. In Aron, J. and Kingdon, G. (eds.), Special issue on "South African Economic Policy under Democracy", *Journal of African Economies*, Oxford University Press, 16(5), 705-744.

Aron, J., & Muellbauer, J. (2009). *Monetary policy and inflation modeling in a more open economy in South Africa.* Monetary policy frameworks for emerging markets. Edward Elgar Publishing.

Aruoba, S. B., Bocola, L., & Schorfheide, F. (2017). Assessing DSGE model nonlinearities. *Journal of Economic Dynamics and Control*, *83*, 34-54.

Arratibel, O., & Michaelis, H. (2014). The impact of monetary policy and exchange rate shocks in Poland: Evidence from a time-varying VAR. *European Central Bank Working Paper Series 1636*

Asghar, A., Ahmad, K., Ullah, S., Zaman, B., & Rashid, M. T. (2011). The relationship between inflation and inflation uncertainty: a case study for SAARC region countries. *International Research Journal of Finance and Economics*, *66*, 85-98.

Aydemi, O., & Demirhan, E. (2009). The Relationship between Stock Prices and Exchange Rates Evidence from Turkey. *International Research Journal of Finance and Economics*, *1,* 207-215.

Aye, G. C. (2021). Effects of fiscal and monetary policy uncertainty on economic activity in South Africa. *Advances in Decision Science, 25(1),* 1-20.

Aziakpono, M. J., & Wilson, M. K. (2013). Interest rate pass-through and monetary policy regimes in South Africa. *African Economic Research Consortium, 259,* 1-67.

Bachmann, R., B. Born, S. Elstner, & C. Grimme. (2013). Time-Varying Business Volatility, Price Setting, and the Real Effects of Monetary Policy. *National Bureau of Economic Research Working Paper 19180.*

Bae, K. H., & Karolyi, G. A. (1994). Good News, Bad News and International Spillovers of Stock Return volatility between Japan and the US. *Pacific Basin Finance Journal*, *2*(4), 405-438.

Bahmani-Oskooee, M., & Sohrabian, A. (1992). Stock Prices and the Effective Exchange Rate of the Dollar. *Applied Economics*, *24*(4), 459-464.

Baker, S. R., Bloom, N. & Davis, S.J. (2016). Measuring economic policy Uncertainty. *The Quarterly Journal of Economics, 131*(4), 1593-1636.

Balcilar, M., Berisha, E., Gupta, R., & Pierdzioch, C. (2021). Time-varying evidence of predictability of financial stress in the United States over a century: The role of inequality. *Structural Change and Economic Dynamics*, *57*, 87-92.

Balcilar, M., Demirer, R., Gupta, R., & Van Eyden, R. (2017). The impact of US policy uncertainty on the monetary effectiveness in the Euro area. *Journal of Policy Modeling*, *39*(6), 1052-1064.

Balcilar, M., Gupta, R., & Jooste, C. (2017). South Africa's economic response to monetary policy uncertainty. *Journal of Economic Studies, 44*(2), 282-293.

Balcilar, M., Gupta, R., & Kisten, T. (2021). The impact of uncertainty shocks in South Africa: The role of financial regimes. *Review of Financial Economics*, *39*(4), 442-454.

Balcilar, M., & Ozdemir, Z. A. (2013). Asymmetric and time-varying causality between inflation and inflation uncertainty in G-7 countries. *Scottish Journal of Political Economy*, *60*(1), 1-42.

Balcilar, M., Ozdemir, Z.A, Ozdemir, H., Wohar, M.E. (2020) Transmission of US and EU Economic Policy Uncertainty Shock to Asian Economies in Bad and Good Times. *Institute of Labor Economics Discussion paper 13274*.

Balcilar, M., Ozdemir, Z. A., Ozdemir, H., Aygun, G., & Wohar, M. E. (2022). Effectiveness of monetary policy under the high and low economic uncertainty states: evidence from the major Asian economies. *Empirical Economics*, *63*, 1741–1769.

Ball, L. (1992). Why does High Inflation Raise Inflation Uncertainty? *Journal of Monetary Economics, 29*(3), 371-388.

Bamanga, M. A., Musa, U., Salihu, A., Udoette, U. S., Adejo, V. T., Edem, O. N., Bukar, H & Udechukwu-Peterclaver, C. T. (2016). Inflation and inflation uncertainty in Nigeria: A test of the Friedman's hypothesis. *CBN Journal of Applied Statistics*, *7*(1), 147-169.

Barnett, W. A., Jawadi, F., & Ftiti, Z. (2020). Causal relationships between inflation and inflation uncertainty. *Studies in Nonlinear Dynamics & Econometrics*, *24*(5).

Barsky, R. B., & Sims, E. R. (2012). Information, animal spirits, and the meaning of innovations in consumer confidence. *The American Economic Review, 102*(4), 1343-1377.

Basu, S., & Bundick, B. (2017). Uncertainty shocks in a model of effective demand. *Econometrica, 85*(3), 937-958.

Beaudry, P., Caglayan, M., & Schiantarelli, F. (2001). Monetary instability, the predictability of prices, and the allocation of investment: An empirical investigation using UK panel data. *American Economic Review*, *91*(3), 648-662.

Bech, M. L., Gambacorta, L., & Kharroubi, E. (2014). Monetary policy in a downturn: are financial crises special? *International Finance*, *17*(1), 99-119.

Berisha, E., Gabauer, D., Gupta, R., & Nel, J. (2022). Time-varying predictability of financial stress on inequality in United Kingdom. *Journal of Economic Studies*, (ahead-of-print).

Bernanke, B. & Blinder, A. (1992). The Federal Funds Rate and the Channels of Monetary Transmission. *American Economic Review, 82*(4), 901-921.

Bernanke, B. S., & Gertler, M. (1995). Inside the black box: the credit channel of monetary policy transmission. *Journal of Economic perspectives*, *9*(4), 27-48.

Bernanke, B. & Mihov, I. (1998). Measuring Monetary Policy. *Quarterly Journal of Economics,113*(3), 869-902.

Bernanke, B., Boivin, J. & Eliasz, P. (2005). Measuring the Effects of Monetary Policy: A Factor-Augmented Vector Autoregressive (FAVAR) Approach. *Quarterly Journal of Economics, 120*(1), 387-422.

Berument, H., & Dincer, N. N. (2008). Measuring the effects of monetary policy for Turkey. *Journal of Economic Cooperation*, *29*(1), 83-110.

Bhar, R., & Hamori, S. (2004). The link between inflation and inflation uncertainty: evidence from G7 countries. *Empirical Economics*, *29*(4), 825-853.

Bhar, R., & Mallik, G. (2010). Inflation, inflation uncertainty and output growth in the USA. *Physica A: Statistical Mechanics and its Applications*, *389*(23), 5503-5510.

Bhar, R., & Nikolova, B. (2008). Return, Volatility Spillovers And Dynamic Correlation in the BRIC Equity Markets: An Analysis using a Bivariate EGARCH Framework. *Global Finance Journal*, *19*(3), 1-16.

Bhat, S. A., Kamaiah, B., & Acharya, D. (2020). Examining the differential impact of monetary policy in India: A policy simulation approach. *Journal of Economics, Finance and Administrative Science*, *25*(50), 339-362.

Billio, M., Casarin, R., Costola, M. & Frattarolo, L. (2019). Opinion Dynamics and Disagreements on Financial Networks. *Advances in Decision Sciences,* 23(4), 1-27.

Bilson, J. F. (1978). *Rational expectations and the exchange rate.* The economics of exchange rates. Routledge.

Black, F. (1976). The Pricing of Commodity Contracts. *Journal of Financial Economics*, *3*(1), 167-179.

Blejer, M., Ize, A., Leone, A., & Werlang, S. (1999). Inflation Targeting in Practice: Strategic and Operational Issues and Application to Emerging Market Economies. *International Monetary Fund Seminar.*

Bloom, N. (2009). The Impact of Uncertainty Shocks. *Econometrica, 77(3),* 623-685.

Bloom, N. (2014). Fluctuations in uncertainty. *Journal of Economic Perspectives, 28*(2), 153-175

Bloom, N., Floetotto, M., Jaimovich, N., Saporta-Eksten, I., & Terry, S. J. (2018). Really uncertain business cycles. *Econometrica, 86*(3), 1031-1065.

Bodnar, G., & Gentry, W. M. (1993). Exchange Rate Exposure and Industry Characteristics: Evidence from Canada, Japan and the USA. *Journal of International Money and Finance*, *12*(1), 29-45.

Boivin, J., Kiley, M. T., & Mishkin, F. S. (2010). How has the monetary transmission mechanism evolved over time? *Handbook of monetary economics*, 3, 369-422.

Bollerslev, T. (1990). Modeling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalised ARCH Approach. *Review of Economics and Statistics, 72*(3), 498-505.

Bollerslev, T., Chou, R. Y., & Kroner, K. F. (1992). ARCH Modeling in Finance: A Review of the Theory and Empirical Evidence. *Journal of Econometrics*, *52*(1), 5-60.

Bomberger, W. A. (1996). Disagreement as a Measure of Uncertainty. *Journal of Money, Credit and Banking*, *28*(3), 381-392.

Bonga-Bonga, L., & Hoveni, J. (2013). Volatility Spillovers between the Equity Market and Foreign Exchange Market in South Africa in the 1995-2010 Period. *South African Journal of Economics*, *81*(2), 260-274.

Bonga-Bonga, L., & Kabundi, A. (2015). Monetary policy instrument and inflation in South Africa: Structural vector error correction model approach. *MPRA Paper 63731*.

Booth, G. G., Martikainen, T., & Tse, Y. (1997). Price and Volatility Spillovers in Scandinavian Stock Markets. *Journal of Banking and Finance*, *21*(6), 811-823.

Bouis, R., Rawdanowicz, Ł., Renne, J. P., Watanabe, S., & Christensen, A. K. (2013). The effectiveness of monetary policy since the onset of the financial crisis. *Organisation for Economic Co-operation and Development Economics Department Working Paper 1081*.

Brainard, W. C. (1967). Uncertainty and the Effectiveness of Policy. *The American Economic Review*, *57*(2), 411-425.

Bransen, W. H., & Hendrson, D. W. (1985). The Specification and Influence of Assets Markets. *Handbook of International Economics, 2, 749-805*.

Branson, W. (1983). Macroeconomic Determinants of Real Exchange Risk. *National Bureau of Economic Research Working Paper 801*.

Breusch, T. S. (1978). Testing for autocorrelation in dynamic linear models. *Australian Economic Papers*, *17*(31), 334-355.

Burdekin, R. C. K. & Siklos, P. L. (2008). What has driven Chinese monetary policy since 1990? Investigating the People's Bank's policy rule. *Journal of International Money and Finance, 27*(5), 847–859.

Burger, P., & Marinkov, M. (2008). Inflation targeting and inflation performance in South Africa. *Trade and Industrial Policy Strategies Annual Forum Papers,* 1-19.

Caggiano, G., Castelnuovo, E., Delrio, S., & Kima, R. (2021). Financial uncertainty and real activity: The good, the bad, and the ugly. *European Economic Review*, *136*, 103750.

Caggiano, G., Castelnuovo, E., & Nodari, G. (2017). Uncertainty and monetary policy in good and bad times. *Melbourne Institute Working Paper 9/17*.

Campbell, J., Lo, A., & MacKinlay, A. (1997). *The Econometrics of Financial Markets*. Princeton university Press.

Caporale, G. M., Pittis, N., & Spagnolo, N. (2002). Testing for causality-in-variance: An application to the East Asian markets. *International Journal of Finance & Economics*, *7*(3), 235-245.

Caporale, G. M., Hunter, J., & Ali, F. M. (2014). On the Linkages between Stock Prices and Exchange Rates: Evidence from the banking Crisis of 2007–2010. *International Review of Financial Analysis, 33*, 87-103.

Cascaldi-Garcia, D., Sarisoy, C., Londono, J. M., Rogers, J. H., Datta, D., RT Ferreira, T., ... & Zer, I. (2020). What is certain about uncertainty. *International Finance Discussion Paper 1294*.

Castelnuovo, E. (2019). Domestic and global uncertainty: A survey and some new results. *CESifo Working Paper Series 7900*.

Castelnuovo, E., & Pellegrino, G. (2018). Uncertainty-dependent effects of monetary policy shocks: A new-Keynesian interpretation. *Journal of Economic Dynamics and Control*, *93*, 277-296.

Cesa-Bianchi, A., Thwaites, G., & Vicondoa, A. (2016). Monetary policy transmission in an open economy: new data and evidence from the United Kingdom. *Bank of England Working Paper* 1612.

Cevik, S. & Teksoz, K. (2013). Lost in transmission? The effectiveness of monetary policy transmission channels in the GCC countries. *Middle East Development Journal, 5*(3), 1350018.

Champagne, J., & Sekkel, R. (2018). Changes in monetary regimes and the identification of monetary policy shocks: Narrative evidence from Canada. *Journal of Monetary Economics*, *99*, 72-87.

Chen, B. Y. (2022). The Review and Analysis of Inflation and its Effects: Will Current High Inflation Lead to an Economic Crisis? J*ournal of Business & Economic Policy, 9(2),* 1-21.

Chen, N. F., Roll, R., & Ross, S. (1983). Economic Forces and the Stock Market. *Journal of Business*, *59*(3), 383-403.

Cheng, K., & Yang, Y. (2020). Revisiting the effects of monetary policy shocks: Evidence from SVAR with narrative sign restrictions. *Economics Letters*, *196*, 109598.

Chiang, T. C., Yang, S. Y., & Wang, T. S. (2000). Stock Return and Exchange Rate Risk: Evidence from Asian Stock Markets Based on a Bivariate GARCH Model. *International Journal of Business*, *5*(2), 97-117.

Chiang, T., & Yang, S. (2003). Foreign Exchange Risk Premiums And Time-Varying Equity Market Risks. *International Journal of Risk Assessment and Management*, *4*(4), 310-331.

Chkili, W., Chaker, A., Masood, O., & Fry, J. (2011). Stock Market Volatility and Exchange Rates in Emerging Countries: A Markov-state Switching Approach. *Emerging Markets Review*, *12*(3), 272-292.

Chkili, W., & Nguyen, D. C. (2014). Exchange Rate Movements and Stock Market Returns in A Regime-Switching Environment: Evidence from BRICS Countries. *Research in International Business and Finance*, *31*, 46-56.

Chow, E., Lee, W., & Solt, M. (1997). The Exchange Rate Risk Exposure of Asset Returns. *Journal of Business*, *70*(1), 105-123.

Christiano, L., Eichenbaum, M. & Evans, C. (1999). Monetary Policy Shocks: What Have We Learned and to What End? *Handbook of macroeconomics*, *1*, 65-148.

Chowdhury, A. (2014). Inflation and inflation-uncertainty in India: the policy implications of the relationship. *Journal of Economic Studies*, *41(1)*, 71-86.

Chowdhury, K. B., & Sarkar, N. (2015). The effect of inflation on inflation uncertainty in the G7 countries: a double threshold GARCH model. *International Econometric Review*, *7*(1), 34-50.

Chu, C., Santoni, G., & Liu, T. (1996). Stock Market Volatility and Regime Shifts in the Return. *Information Science*, *94,* 179-190.

Chuku, C. A. (2009). Measuring the effects of monetary policy innovations in Nigeria: A structural vector autoregressive (SVAR) approach. *African Journal of Accounting, Economics, Finance and Banking Research*, *5*(5), 112-129.

Ciccarelli, M., Maddaloni, A., & Peydro, J. L. (2013). Heterogeneous transmission mechanism: monetary policy and financial fragility in the eurozone. *Economic Policy, 28(75),* 459-512.

Cloyne, J., & Hürtgen, P. (2016). The macroeconomic effects of monetary policy: a new measure for the United Kingdom. *American Economic Journal: Macroeconomics*, *8*(4), 75-102.

Coco, A., & Viegi, N. (2020). The monetary policy of the South African Reserve Bank: Stance, communication and credibility. *South African Reserve Bank Working Paper Series 20/06*.

Corbet, S., Hou, Y. G., Hu, Y., Oxley, L., & Xu, D. (2021). Pandemic-related financial market volatility spillovers: Evidence from the Chinese COVID-19 epicentre. *International Review of Economics & Finance*, *71*, 55-81.

Cornell, B. (1983). The Money Supply Announcement Puzzle: Review and Interpretation. *American Economic Review*, *73*(4), 644-657.

Coronado, S., Gupta, R., Hkiri, B., & Rojas, O. (2020). Time-Varying Spillovers between Currency and Stock Markets in the USA: Historical Evidence from More than Two Centuries. *Advances in Decision Sciences*, *24*(4), 1-32.

Cukierman, A., & Meltzer, A. (1986). A Theory of Ambiguity, Credibility, and Inflation Under Discretion and Asymmetric Information. *Econometrica, 54*(5), 1099-1128.

Daal, E., Naka, A., & Sanchez, B. (2005). Re-examining Inflation and Inflation Uncertainty in Developed and Emerging Countries. *Economics Letters, 89*(2), 180-186.

Dahlhaus, T. (2014). Monetary policy transmission during financial crises: An empirical analysis. *Bank of Canada Working Paper 2014-21*.

Davies, R. (1987). Hypothesis Testing when a Nuisance Parameter is Present only under the Alternative. *Biometrika*, *74*(1), 33-43.

de Oliveira Passos, M., Tessmann, M. S., Ely, R. A., Uhr, D., & Taveira, M. T. (2020). Effects of Volatility Among Commodities in the Long Term: Analysis of a Complex Network. *Annals of Financial Economics*, *15*(3), 2050014.

Diamandis, P., & Drakos, A. (2011). Financial Liberalization, Exchange Rates and Stock Prices: Exogenous Shocks in four Latin American Countries. *Journal of Policy Modeling*, *33*(3), 381-394.

Dima, B., Dincă, M. S., Dima, Ş. M., & Dincă, G. (2017). Does economic policy uncertainty affect economic activity? Evidence from the United States of America. *Romanian journal of economic forecasting, 20*(1), *60-74*.

Ding, Z., Granger, C. W., & Engle, R. F. (1993). A long memory property of stock market returns and a new model. *Journal of empirical finance*, *1*(1), 83-106.

Dixit, A., & Pindyck R. S. (1994). *Investment Under Uncertainty*. Princeton University Press.

Dornbush, R., & Fisher, S. (1980). Exchange Rates and the Current Account. *The American Economic Review 70*(5), 960-971.

Dotsey, M. & Sarte, P. D. (2000). Inflation uncertainty and growth in a cash-in-advance economy. *Journal of Monetary Economics*, *45*(3), 631–655.

Dumas, B., & Solnik, B. (1995). The World Price of Foreign Exchange Risk. *Journal of Finance*, *50*(2), 445-477.

Du Plessis, S., & Smit, B. (2007). South Africa's growth revival after 1994. *Stellenbosch Economic Working Paper Series 01/06*.

Eickmeier, S., Metiu, N., & Prieto, E. (2016). Time-varying volatility, financial intermediation and monetary policy. *Deutsche Bundesbank Discussion Papers 46*.

Elder, J. (2004). Another perspective on the effects of inflation uncertainty. *Journal of Money, Credit and Banking*, *36*(5), 911-928.

Engen, E. M., Laubach, T.T., & Reifschneider, D. (2015). The Macroeconomic Effects of the Federal Reserve's Unconventional Monetary Policies. *Finance and Economic Discussion Series 2015-005.*

Engle, R. F., Ito, T., & Lin, W.-L. (1990). Meteor showers or heat waves? Heteroskedastic intra-daily volatility in the foreign exchange market. *Econometrica,* 58(3), 525–542.

Entezarkheir, M. (2006). The relation between inflation and inflation uncertainty in Iran. *Iranian Economic Review*, *10*(17), 1-20.

Estima. (2021, September 16). *MVARCHTEST Procedure.* https://estima.com/ratshelp/index.html?mvarch testprocedure.html

Fama, E. (1981). Stock Returns, Real Activity, Inflation and Money. *American Economic Review*, *71*(4), 545-565.

Fasanya, I. O. and Onakoya, A.B. O. (2013). Does monetary policy influence economic growth in Nigeria? *Asian Economic and Financial Review, 3*(5), 635-646.

Faust, J., & Henderson, D. W. (2004). Is inflation targeting best-practice monetary policy? *Review of the Federal Reserve Bank of St. Louis, 86,* 117-144.

Feldkircher, M., & Huber, F. (2018). Unconventional US monetary policy: new tools, same channels? *Journal of Risk and Financial Management*, *11(4),* 71.

Fernandez-Villaverde, J., Guerron-Quintana, P., Kuester, K., & Rubio-Ramírez, J. (2015). Fiscal volatility shocks and economic activity. *The American Economic Review, 105(11),* 3352-3384.

Focus Economics. (2018, August 16). *Emerging Markets Economic Outook 2018/2019*. Retrieved January 04, 2018, from Focus Economics: https://www.focus-economics.com/blog/emerging-markets-2019-economic-outlook

Foerster, A. (2014). The asymmetric effects of uncertainty. *Economic Review, 99, 5-26.*

Fountas, S., Ioannidis, A., & Karanasos, M. (2004). Inflation, inflation uncertainty and a common European monetary policy. *The Manchester School, 72(2)*, 221-242.

Fountas, S., Karanasos, M., & Kim, J. (2006). Inflation uncertainty, output growth uncertainty and macroeconomic performance. *Oxford Bulletin of Economics and Statistics*, *68*(3), 319-343.

Fowkes, D. (2022). Not so easy: why quantitative easing is inappropriate for South Africa. *South African Reserve Bank Working Paper Series 11026*.

Franck, P., & Young, A. (1972). Stock Price Reaction of Multinational Firms to Exchange Realignments. *Financial Management*, *1*(3), 66-73.

Frankel, J. (1983). Monetary and Portfolio Balance Models of Exchange Rate Determination. *Economic Interdependence and Flexible Exchange Rates*, *1*, 84-114.

Frenkel, J. A. (1976). A monetary approach to the exchange rate: Doctrinal aspects and empirical evidence. *Scandinavian Journal of Economics*, *78*(2), 200-224.

Friedman, M. (1977). Inflation and Unemployment. *Journal of Political Economy, 85*(3), 451-472.

Fromentin, V. (2021). Time-varying Granger causality between the stock market and unemployment in the United States. *Applied Economics Letters*, *30*(3), 371-378.

Fromlet, P. (2010). Do Inflation Targeting Central Banks Focus on Inflation—An Analysis for Ten Countries? *Uppsala University, Department of Economics,* 1-45.

Fry-Mckibbin, R., & Zheng, J. (2016). Effects of the US monetary policy shocks during financial crises–a threshold vector autoregression approach. *Applied Economics*, *48*(59), 5802-5823.

Garcia R, Schaller H (2002) Are the effects of monetary policy asymmetric? *Economic Inquiry, 40(1),* 102-119.

Garriga, A. C., & Rodriguez, C. M. (2020). More effective than we thought: Central bank independence and inflation in developing countries. *Economic Modelling*, *85*, 87-105.

Gavin, M. (1989). The Stock Market and Exchange Rate Dynamics. *Journal of International Money and Finance*, *8*(2), 181-200.

Georgiadis, G., & Mehl, A. (2016). Financial globalisation and monetary policy effectiveness. *Journal of International Economics*, *103*, 200-212.

Gertler, M., & Gilchrist, S. (1994). Monetary policy, business cycles, and the behavior of small manufacturing firms. *The Quarterly Journal of Economics*, *109(2),* 309-340.

Giannoni, M. P. (2002). Does model uncertainty justify caution? Robust optimal monetary policy in a forward-looking model. *Macroeconomic Dynamics*, *6*(1), 111-144.

Gil-Lafuente, A. M., Gil-Lafuente, J., & Merigó-Lindahl, J. M. (2012). *Soft Computing in Management and Business Economics.* Springer.

Giovannini, A., & Jorion, A. (1987). Interest Rates and Risk Premia in the Stock Market and in the Foreign Exchange Market. *Journal of International Money and Finance*, *6*(1), 107-124.

Gonçalves, C. E. S., & Carvalho, A. (2009). Inflation targeting matters: Evidence from OECD economies' sacrifice ratios. *Journal of Money, Credit and Banking*, *41*(1), 233-243.

Gonçalves, C. E. S., & Salles, J. (2008). Inflation targeting in emerging economies: What do the data say? *Journal of Development Economics, 85*(12), 312-318.

Granger, C. W. J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica, 37,* 424-438.

Granger, C. W. (1998). Overview of nonlinear time series specification in economics. *Berkeley NSF-Symposia,* 1-23.

Granger, C. W., Huang, B. N., & Yang, C. W. (2000). A Bivariate Causality between Stock Prices and Exchange Rates: Evidence from Recent Asian Flu. *Quarterly Review of Economics and Finance*, *40*(3), 337-354.

Grier, K., & Perry, M. (1998). On inflation and inflation uncertainty in the G7 countries. *Journal of International Money and Finance, 17*(4), 671-689.

Gumata, N., Kabundi, A., & Ndou, E. (2013). Important Channels of Transmission of Monetary Policy Shock in South Africa. *South African Reserve Bank Working Paper Series* 2013/06.

Gupta, R., & Jooste, C. (2018). Unconventional monetary policy shocks in OECD countries: how important is the extent of policy uncertainty? *International Economics and Economic Policy*, *15*(3), 683-703.

Gupta, R., & Reid, M. (2013). Macroeconomic surprises and stock returns in South Africa. *Studies in Economics and Finance*, *30*(3), 266-282.

Gupta, R., & Uwilingiye, J. (2012). Comparing South African inflation volatility across monetary policy regimes: an application of Saphe cracking. *The Journal of Developing Areas*, *46*(1), 45-54.

Hamao, Y., Masulis, R., & Ng, V. (1990). Correlations in Price Changes and Volatility Across International Stock Exchanges. *The Review of Financial Studies*, *3*(2), 281-307.

Hassan, K., Hoque, A., Gasbarro, D., & Wong, W. K. (2020). Are Islamic stocks immune from financial crises? Evidence from contagion tests. *International Review of Economics & Finance*.

Hegerty, S. W. (2012). Does high inflation lead to increased inflation uncertainty? Evidence from nine African Countries. *African Economic and Business Review, 10*, 1-15.

Heidari, H., Katircioglu, S. T., & Bashiri, S. (2013). Inflation, inflation uncertainty and growth in the Iranian economy: an application of BGARCH-M model with BEKK approach. *Journal of Business Economics and Management*, *14*(5), 819-832.

Hekman, C. R. (1995). A Financial Model of Foreign Exchange Exposure. *Journal of International Business Studies*, *16*(2), 83-99.

Hendry, D. (1995). *Dynamic Econometrics*. Oxford University Press.

Ho, K. Y., & Tsui, A. K. (2008). Volatility dynamics in foreign exchange rates: further evidence from the Malaysian Ringgit and Singapore Dollar. *Annals of Financial Economics*, *4*(1), 0850004.

Holland, S. (1995). Inflation and Uncertainty: Test for Temporal Ordering. *Journal of Money, Credit, and Banking, 27*(3), 827-837.

Ilut, C., & Schneider, M. (2014). Ambiguous business cycles. *American Economic Review, 104*(8), 2368-99.

International Monetary Fund. (2022). *International Financial Statistics (IFS)* [Data file]. Retrieved from IMF: http://www.imf.org/en/Data.

Ivrendi, M., & Yildirim, Z. (2013). Monetary policy shocks and macroeconomic variables: evidence from fast growing emerging economies. *Economics Discussion Papers 2013-61*.

Jansen, D.W. (1989). Does inflation uncertainty affect output growth? Further evidence. *Federal Reserve Bank of St Louis Review, 71*, 43–54.

Jannsen, N., Potjagailo, G., & Wolters, M.H. (2019). Monetary policy during financial crises: Is the transmission mechanism impaired? *International Journal of Central Banking, 15*(4), 81–126

Jebran, K., & Iqbal, A. (2016). Dynamics of Volatility Spillover between Stock Market and Foreign Exchange Market: Evidence from Asian Countries. *Financial Innovation*, *2*(3), 1-20.

Jiang, D. (2016). Inflation and inflation uncertainty in China. *Applied Economics*, *48*(41), 3935-43.

Jiranyakul, K., & Opiela, T. P. (2011). The impact of inflation uncertainty on output growth and inflation in Thailand. *Asian Economic Journal*, *25*(3), 291-307.

Jiranyakul, K. (2020). The Linkages between Inflation and Inflation Uncertainty in Selected Asian Economies: Evidence from Quantile Regression. *Journal of Advanced Studies in Finance*, *11*(22), 74-80.

Johansen. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control* , *12*(2), 231–254.

Jorion, P. (1990). The Exchange Rate Exposure of the U.S. Multinationals. *Journal of Business*, *63*(3), 331-345.

Jorion, P. (1991). The Pricing of Exchange Rate Risk in the Stock Market. *Journal of Financial and Quantitative Analysis*, *26*(3), 363-376.

Judson, R., & Orphanides, A. (1999). Inflation, volatility and growth. *International Finance*, *2*(*1*), 117-138.

Kabundi, A., & Mlachila, M. (2019). The role of monetary policy credibility in explaining the decline in exchange rate pass-through in South Africa. *Economic Modelling*, *79*, 173-185.

Kanas, A. (2000). Volatility Spillovers between Stock Returns and Exchange Rate Changes: International Evidence. *Journal of Business Finance & Accounting*, *27*(3-4), 447-467.

Kaseeram, I., & Contogiannis, E. (2011). The Impact Of Inflation Targeting On Inflation Volatility In South Africa. *The African Finance Journal, 13*, 34-52.

Kashyap, A. K., & Stein, J. C. (2000). What do a million observations on banks say about the transmission of monetary policy? *American Economic Review*, *90*(3), 407-428.

Khan, S., & Batteau, P. (2011). Should the government directly intervene in stock market during a crisis? *The Quarterly Review of Economics and Finance*, *51*(4), 350-359.

Khundrakpam, J. K. (2017). Examining the asymmetric impact of monetary policy in India. *Margin: The Journal of Applied Economic Research*, *11*(3), 290-314.

Kim, K. (2003). Dollar exchange rate and stock price: evidence from multivariate cointegration and error correction model. *Review of Financial Economics*, *12*(3), 301-313.

Kisten, T. (2020). Macroeconomic implications of uncertainty in South Africa. *South African Journal of Economic and Management Sciences*, *23*(1), 1-15.

Klein, N. (2012). Estimating the implicit inflation target of the South African Reserve Bank. *International Monetary Fund Working Paper 2012/177.*

Kontonikas, A. (2004). Inflation and inflation uncertainty in the United Kingdom, evidence from GARCH modelling. *Economic Modelling, 21*(3), 525–543.

Koop, G., Pesaran, M. H., & Potter, S. M. (1996). Impulse response analysis in nonlinear multivariate models. *Journal of Econometrics*, *74*(1), 119-147.

Koutmos, G., & Booth, G. G. (1995). Asymmetric volatility transmission in international stock markets. *Journal of International Money and Finance*, *14*(6), 747-762.

Kumar, M. (2013). Returns and volatility spillover between stock prices and exchange rates: Empirical evidence from IBSA countries. *International Journal of Emerging Markets, 8*(2), 108-128.

Kutty, G. (2010). The Relationship between Exchange Rates and Stock Prices: The Case of Mexico. *North American Journal of Finance and Banking Research*, *4*(4), 1-12.

Lakshmanasamy, T. (2021). The Relationship Between Exchange Rate and Stock Market Volatilities in India: ARCH-GARCH Estimation of the Causal Effects. *International Journal of Finance Research, 2(4), 245-259.*

Laopodis, N. (1988). Asymmetric Volatility Spillovers in Deutsche Mark Exchange Rates. *Journal of Multinational Financial Management*, *8*(4), 413-430.

Lawton, N., & Gallagher, L. A. (2020). The negative side of inflation targeting: revisiting inflation uncertainty in the EMU. *Applied Economics*, *52*(29), 3186-3203.

Lee, T. H., & Tse, Y. (1996). Cointegration Tests with Conditional Heteroscedasticity. *Journal of Econometrics*, *73*(2), 401-410.

Laopodis, N. T. (2013). Monetary policy and stock market dynamics across monetary regimes. *Journal of International Money and Finance*, *33*, 381-406.

Lin, C. H. (2012). The Comovement between Exchange Rates and Stock Prices in the Asian Emerging Markets. *International Review of Economics and Finance*, *22*(1), 161–172.

Lin, S., & Ye, H. (2007). Does inflation targeting really make a difference? Evaluating the treatment effect of inflation targeting in seven industrial countries. *Journal of Monetary Economics*, *54*(8), 2521-2533.

Lin, S., & Ye, H. (2009). Does inflation targeting make a difference in developing countries? *Journal of Development economics*, *89*(1), 118-123.

Ljung, G., & Box, G. (1979). On a Measure of Lack of Fit in Time Series Models. *Biometrika*, *65*(2), 297-303.

Lo, M.C., & Piger, J. (2005) Is the response of output to monetary policy asymmetric? Evidence from a regime switching coefficients model. *Journal of Money, Credit and Banking, 37*(5), 865-886

Ma, C., & Kao, G. (1990). On Exchange Rate Changes and Stock Price Reactions. *Journal of Business and Accounting*, *17*(3), 441-449.

Macdonald, R & Taylor, M. P. (1993). The monetary approach to the exchange rate: Rational expectations, long-run equilibrium, and forecasting. *IMF Staff Papers*, *40,* 89-107.

Malik, M. I., & Rashid, A. (2017). Return and volatility spillover between sectoral stock and oil price: evidence from Pakistan stock exchange. *Annals of Financial Economics*, *12*(2), 1750007.

Mallik, G., & Chowdhury, A. (2011). Effect of inflation uncertainty, output uncertainty and oil price on inflation and growth in Australia. *Journal of Economic Studies, 38*(4), 414-429.

Mallick, S. K., & Sousa, R. M. (2012). Real effects of monetary policy in large emerging economies. *Macroeconomic Dynamics*, *16*(2), 190-212.

Mandelbrot, B. (1963). New Methods in Statistical Economics. *The Journal of Political Economy*, *71*(5), 421-440.

Mandelker, G., & Tandon,. (1985). Common Stock Returns, Real Activity, Money and Inflation: Some International Evidence. *Journal of International Money and Finance*, *4*(2), 267-286.

Mandeya, S. M. T., & Ho, S. Y. (2021). Inflation, inflation uncertainty and the economic growth nexus: An impact study of South Africa. *MethodsX*, *8*, 101501.

Makrelov, K., Davies, R., & Harris, L. (2021) The impact of capital flow reversal shocks in South Africa: a stock- and-flow-consistent analysis. *International Review of Applied Economics, 35*(3-4), 475-501.

Maya, C., & Gomez, K. (2008). What Exactly is 'Bad News' in Foreign Exchange Markets? Evidence from Latin American Markets. *Cuadernos de Economía, 45,* 161-183.

Mendes, R., Murchison, S., & Wilkins, CA. (2017). Monetary policy under uncertainty: Practice versus theory. *Bank of Canada Staff Discussion Paper 2017-13.*

Miles, W. (2008). Inflation targeting and monetary policy in Canada: What is the impact on inflation uncertainty? *North American Journal of Economics and Finance, 19*(2), 235-248.

Miranda-Agrippino, S., & Ricco, G. (2021). The transmission of monetary policy shocks. *American Economic Journal: Macroeconomics*, *13*(3), 74-107.

Mishkin, F. S. (2009). Is monetary policy effective during financial crises? *American Economic Review*, *99*(2), 573-77.

Mishkin, F. S., & Schmidt-Hebbel, K. (2001). One decade of inflation targeting in the world: What do we know and what do we need to know? *National Bureau of Economic Research Working Paper Series* 8397.

Mishkin, F. S. (2003). Inflation Targeting in Emerging Market Economies: Comment. *NBER Macroeconomics Annual*, *18*, 403-413.

Mishra, P., Montiel, P. & Sengupta, R. (2016). Monetary transmission in developing countries: Evidence from India. *Monetary Policy in India,* 59-110.

Mitra, R. (2017). Stock market and foreign exchange market integration in South Africa. *World Development Perspectives*, *6*, 32-34.

Mittnik, S. (1990). Modeling nonlinear processes with generalized autoregressions. *Applied Mathematics Letters*, *3*(4), 71-74.

Modigliani, F. (1971). Monetary Policy and Consumption, in Consumer Spending and Monetary Policy: The Linkages. *Federal Reserve Bank of Boston Conference Series No.* 5, 9–84.

Morales-Zumaquero, A., & Sosvilla-Rivero, S. (2018). Volatility spillovers between foreign exchange and stock markets in industrialized countries. *The Quarterly Review of Economics and Finance*, *70*, 121-136.

Mozumder, N., De Vita, G., Kyaw, S., & Larkin, C. (2015). Volatility spillover between stock prices and exchange rates: New evidence across the recent financial crisis period. *Economic Issues*, *20(1)*, 43-64

Mroua, M., & Trabelsi, L. (2020). Causality and dynamic relationships between exchange rate and stock market indices in BRICS countries: Panel/GMM and ARDL analyses. *Journal of Economics, Finance and Administrative Science, 25*(50), 395-412.

Mtonga, E. (2011). Did it matter? Monetary policy regime change and exchange rate dynamics in South Africa. *Centre for the Studies of African Economies 25th Anniversary Conference*.

Murgia, L. M. (2020). The effect of monetary policy shocks on macroeconomic variables: Evidence from the Eurozone. *Economics Letters, 186*, 108803.

Mussa, M. (1976). The exchange rate, the balance of payments and monetary and fiscal policy under a regime of controlled floating. *Scandinavian Journal of Economics*, *78*(2), 229-248.

Nagao, R., Kondo, Y., & Nakazono, Y. (2021). The macroeconomic effects of monetary policy: Evidence from Japan. *Journal of the Japanese and International Economies, 61*, 101149.

Nain, Z., & Kamaiah, B. (2020). Uncertainty and Effectiveness of Monetary Policy: A Bayesian Markov Switching-VAR Analysis. *Journal of Central Banking Theory and Practice*, *9(1*), 237-265.

Naraidoo, R., & Raputsoane, L. (2015). Financial markets and the response of monetary policy to uncertainty in South Africa. *Empirical Economics*, *49*(1), 255-278.

Narayan, P. K., Narayan, S., Khademalomoom, S., & Phan, D. H. B. (2018). Do terrorist attacks impact exchange rate behavior? New international evidence. *Economic Inquiry*, *56*(1), 547-561.

Nas, T., & Perry, M. (2000). Inflation, Inflation Uncertainty and Monetary Policy in Turkey : 1960-1998. *Contemporary Economic Policy, 18*(2), 170-180.

Nasr, A., Balcilar, M., Ajmi, A., Aye, G., Gupta, R., & van Eyden, R. (2015). Causality between Inflation and Inflation Uncertainty in South Africa: Evidence from a Markov-Switching Vector Autoregressive model. *Emerging Markets Review, 24,* 46-68.

Ndikumana, L. (2016). Implications of monetary policy for credit and investment in sub-Saharan African countries. *Journal of African Development*, *18*(2), 1-18.

Nelson, D. B. (1991). Conditional Heteroscedasticity in Asset Returns: A New Approach. *Econometrica*, *59*(2), 347-370.

Nene, S. T., Ilesanmi, K. D., & Sekome, M. (2022). The Effect of Inflation Targeting (IT) Policy on the Inflation Uncertainty and Economic Growth in Selected African and European Countries. *Economies*, *10*(*2*), 37.

Nieh, C. C., & Lee, C. F. (2001). Dynamic Relationship between Stock Prices and Exchange Rates for G-7 Countries. *The Quarterly Review of Economics and Finance*, *41*(4), 477-490.

Ning, C. (2010). Dependence Structure between the Equity Market and the Foreign Exchage Market – a Copula Approach. *Journal of International Money and Finance*, *29*(5), 743-759.

Nyblom, J. (1989). Testing for the constancy of parameters over time. *Journal of the American Statistical Association, 84*(405), 223-230.

Oberholzer, N., & von Boetticher, S. T. (2015). Volatility spill-over between the JSE/FTSE indices and the South African Rand. *Procedia Economics and Finance*, *24*, 501-510.

OECD. (2021, February 21). *COVID-19 and Global Capital Flows*. http://www.oecd.org/coronavirus/policy- responses/covid-19-and-global-capital-flows-2dc69002/

Okun, A. (1971). The Mirage of Steady Inflation. *Brookings Papers on Economic Activity, 2*, 485-498.

Pan, M., Fok, R.-W., & Liu, Y. (2007). Dynamic linkages between exchange rates and stock prices: evidence from East Asian markets. *International Review of Economics and Finance*, *16*(4), 503-520.

Payne, J. E. (2008). Inflation and inflation uncertainty: evidence from the Caribbean region. *Journal of Economic Studies*, 35(6), 501-511.

Pellegrino, G. (2018). Uncertainty and the real effects of monetary policy shocks in the Euro area. *Economics Letters, 162,* 177-181.

Pellegrino, G. (2021). Uncertainty and monetary policy in the US: a journey into nonlinear territory. *Economic Inquiry, 59*(3), 1106-1128.

Pesaran, M. H., & Shin, Y. (1996). Cointegration and speed of convergence to equilibrium. *Journal of econometrics*, *71*(1-2), 117-143.

Pesaran, M. H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics letters*, *58*(1), 17-29.

Pétursson, P. G. (2004). The effects of inflation targeting on macroeconomic performance. *Central Bank of Iceland Working Paper 23.*

Phillips, P., & Perron, P. (1988). Testing for Unit Root in Time Series Regression. *Biometrika*, *75*(2), 335–346.

Phiri, A. (2016). Inflation persistence in African countries: Does inflation targeting matter? *Economics and Business Letters*, *5*(3), 65-71.

Phylaktis, K., & Ravazzolo, F. (2005). Stock Prices and Exchange Rate Dynamics. *Journal of International Money and Finance*, *24*(7), 1031-1053.

Pinshi, C. P. (2020). Monetary policy, uncertainty and COVID-19. *Journal of Applied Economic Sciences*, *15*(69), 579-593.

Pourgerami, A., & Maskus, K. (1987). The Effects of Inflation ofi the Predictability of Price Changes in Latin America: Some Estimates and Policy Implications. *World Development, 15*(2), 287-290.

Pourshahabi, F., Dahmarde, N., & Mojtaba, K. Z. A. (2010). Asymmetry Effect of Inflation on Inflation Uncertainty in Iran: Using from EGARCH Model, 1959-2009. *American Journal of Applied Sciences*, *7*(4), 535-539.

Pratap, B., & Dhal, S. (2021). Monetary transmission mechanism, confidence and uncertainty: evidence from a large emerging market economy. *Reserve Bank of India,* 1-29.

Prabheesh, K. P., Juhro, S. M., & Harun, C. A. (2003). Covid-19 Uncertainty and Monetary Policy Responses: Evidence from Emerging Market Economies. *Bulletin of Monetary Economics and Banking*, *24*(4), 489-516.

Pretorius, K. (2012). The relationship between Inflation, Inflation Uncrtainty, and Economic Growth in South Africa. *University of Johannesburg*, 1-60.

Qiao, Z., Chiang, T. C., & Wong, W. K. (2008). Long-run equilibrium, short-term adjustment, and spillover effects across Chinese segmented stock markets and the Hong Kong stock market. *Journal of International Financial Markets, Institutions and Money*, *18*(5), 425-437.

Quandt, R. E. (1960). Tests of the hypothesis that a linear regression system obeys two separate regimes. *Journal of the American Statistical Association, 55*(290), 324-330.

Rafiq, M. S., & Mallick, S. K. (2008). The effect of monetary policy on output in EMU3: A sign restriction approach. *Journal of Macroeconomics*, *30*(4), 1756-91.

Rai, K., & Garg, B. (2022). Dynamic correlations and volatility spillovers between stock price and exchange rate in BRIICS economies: evidence from the COVID-19 outbreak period. *Applied Economics Letters*, *29*(8), 1-8.

Rajput, S. K. O., Ghumro, N. H., & Anjum, N. (2019). Do exchange rate changes have symmetric or asymmetric effects on international trade integration? *Annals of Financial Economics*, *14*(03), 1950013.

Ramchand, L., & Susmel, R. (1998). Volatility and Cross Correlation across Major Stock Markets. *Journal of Empirical Finance*, *5*(4), 397-416.

Ramey, V. A. (2016). Macroeconomic shocks and their propagation. *Handbook of macroeconomics*, *2*, 71-162.

Rangasamy, L. (2009). Inflation persistence and core inflation: The case of South Africa. *South African Journal of Economics, 77*, 430-444.

Ren, Y., Guo, Q., Zhu, H., & Ying, W. (2020). The effects of economic policy uncertainty on China's economy: evidence from time-varying parameter FAVAR. *Applied Economics*, *52*(29), 3167-85.

Roll, R. (1992). Industrial Structure and the Comparative Behaviour on International Stock Market Indices. *Journal of Finance*, *47*(1)*,* 3-41.

Romer, C. D. (2006). *Advanced macroeconomics*. McGraw-Hill/Irwin, New York.

Romer, C. D., & Romer, D. H. (1989). Does monetary policy matter? A new test in the spirit of Friedman and Schwartz. *National Bureau of Economic Research Macroeconomics Annual*, *4*, 121-170.

Romer, C. D., & Romer, D. H. (2004). A new measure of monetary shocks: Derivation and implications. *American Economic Review*, *94*(4), 1055-1084.

Rossi, B. (2005). Optimal tests for nested model selection with underlying parameter instability. *Econometric Theory, 21*(5), 962-990.

Rossi, B. & Wang, Y. (2019). VAR-Based Granger-Causality Test in the Presence of Instabilities. *The Stata Journal, 19*(4), 883-899.

Rudebusch, G. D. (1996). Is Opportunistic Monetary Policy Credible? *Federal Reserve Bank of San Francisco Economic Letter 28*.

Ruge-Murcia, F. (2014). Indirect inference estimation of nonlinear dynamic general equilibrium models: with an application to asset pricing under skewness risk. *Centre interuniversitaire de recherche en economie quantitative, CIREQ*.

Sá, F., Towbin, P., & Wieladek, T. (2014). Capital inflows, financial structure and housing booms. *Journal of the European Economic Association*, *12*(2), 522-546.

Schaller, H., & Van Norden, S. (1997). Regime Switching in Stock Market Returns. *Applied Financial Economics*, *7*(2), 177-192.

Sercu, P., & Vanhulle, C. (1992). Exchange Rate Volatility, International Trade, and the Value of Exporting Firms. *Journal of Banking and Finance*, *16*(1), 155-182.

Sharma, S. S., Phan, D. H. B., & Narayan, P. K. (2019). Exchange rate effects of US government shutdowns: Evidence from both developed and emerging markets. *Emerging Markets Review*, *40*, 100626.

Sikhosana, A., & Aye, G. C. (2018). Asymmetric volatility transmission between the real exchange rate and stock returns in South Africa. *Economic Analysis and Policy*, *60*(2), 1-8.

Sims, C.A. (1980). Macroeconomics and reality. *Econometrica, 48*(1), 1-48.

Sims, C. A. (1992). Interpreting the Macroeconomic Time Series Facts: The Effects of Monetary Policy. *European Economic Review, 36*(5), 975-1000.

Smets, F. & Peersman, G. (2001). Are the effects of monetary policy in the euro area greater in recessions than in booms? *European Central bank Working Paper Series 052*

Smith, C. E. (1992). Stock Markets and the Exchange Rate: A Multi-Country Approach. *Journal of Macroeconomics*, *14*(4), 607-629.

So, W. (2001). Price and Volatility Spillovers between Interest Rate and Exchange Value of the US Dollar. *Global Finance Journal*, *12*(1), 128-139.

Söderström, U. (2002). Monetary policy with uncertain parameters. *Scandinavian Journal of Economics*, *104*(1), 125-145.

Soenen, L., & Hennigan, E. (1988). An Analysis of Exchange Rates and Stock Prices: The US Experience between 1980 and 1986. *Akron Business Economic Review*, *19,* 141-149.

Solnik, B. (1987). Using Financial Prices to Test Exchange Rate Models: A Note. *Journal of Finance*, *42*(1), 141-149.

South African Market Insights. (2018, November 6). *South Africa's Trade Data Page*. Retrieved January 4, 2018, from South African Market Insights: https://www.southafricanmi.com/south-africas-trade-data-page.html.

South African Reserve Bank. (2021). *Inflation Targeting Framework*. Retrieved September 29, 2021, from South African Reserve Bank: https://www.resbank.co.za/MonetaryPolicy/DecisionMaking/Pages/default.aspx

South African Reserve Bank. (2022) *Online database* [Data File]. Retrieved from South African Reserve Bank: https://www.resbank.co.za/en/home/publications/quarterly-bulletin1/download-information-from-xlsx-data-files

Su, C. W., Yu, H., Chang, H. L., & Li, X. L. (2017). How does inflation determine inflation uncertainty? A Chinese perspective. *Quality & Quantity*, *51*(3), 1417-1434.

Sudacevschi, M. (2011). Pros and Cons of Inflation Targeting Strategy. *LESIJ-Lex ET Scientia International Journal, 18*, 228-235.

Sui, L., & Sun, L. (2016). Spillover Effects between Exchange Rates and Stock Prices:Evidence from BRICS around the Recent Global Financial Crisis. *Research in International Business and Finance*, *36,* 459–471.

Svensson, L. E. O. & Woodford, M. (2003). Indicator Variables for Optimal Policy. *Journal of Monetary Economics, 50(3)*, 691-720.

Svensson, L. E. O. & Woodford, M. (2004). Indicator Variables of Optimal Policy Under Asymmetric Information. *Journal of Economic Dynamics and Control, 28(4),* 661-690.

Swanson, E. T. (2021). Measuring the effects of federal reserve forward guidance and asset purchases on financial markets. *Journal of Monetary Economics*, *118*, 32-53.

Syed, Q. R., Malik, W. S., & Chang, B. H. (2019). Volatility Spillover Effect of Federal Reserve's Balance Sheet on The Financial and Goods Markets of Indo-Pak Region. *Annals of Financial Economics*, *14*(3), 1950015.

Taş, B. K. O. (2012). Inflation targeting and inflation uncertainty. *Scottish Journal of Political Economy*, *59*(3), 283-297.

Tas, B. K. O., & Ertugrul, H. M. (2013). Effect of inflation targeting on inflation uncertainty: a SWARCH analysis. *Australian Economic Review*, *46*(4), 444-459.

The World Federation of Exchanges. (2021, May 13). *2020 Annual Statistics Guide.* https://www.world-exchanges.org/our-work/articles/2020-annual-statistics-guide

Thornton, J. (2006). High and Variable Inflation: Further Evidence on the Friedman Hypothesis. *South African Journal of Economics, 74*(2), 167-171.

Tillmann, P. (2020). Monetary policy uncertainty and the response of the yield curve to policy shocks. *Journal of Money, Credit and Banking, 52(4),* 803-833.

Tobin, J. (1969). A general equilibrium approach to monetary theory. *Journal of Money, Credit and Banking, 1*(1), 15–29.

Towbin, P., & Weber, S. (2013). Limits of floating exchange rates: The role of foreign currency debt and import structure. *Journal of Development Economics*, *101*, 179-194.

Trung, N. B. (2019). The spillover effects of US economic policy uncertainty on the global economy: A global VAR approach. *The North American Journal of Economics and Finance*, *48*, 90-110.

Turner, M., Startz, R., & Nelson, C. (1989). A Markov Model of Heteroscedasticity, Risk, and Learning in the Stock Market. *Journal of Financial Economics*, *25*(1), 3-22.

Uhlig, H. (2005). What are the effects of monetary policy on output? Results from an agnostic identification procedure. *Journal of Monetary Economics*, *52*(2), 381-419.

Ülke, V., & Berument, M. H. (2016). Asymmetric effects of monetary policy shocks on economic performance: empirical evidence from Turkey. *Applied Economics Letters*, *23*(5), 353-360.

Ungar, M., & Zilberfarb, B. (1993). Inflation and Its Unpredictability-Theory and Empirical Evidence. *Journal of Money, Credit and Banking, 25*(4), 709-720.

Valdovinos, C., & Gerling, K. (2011). Inflation Uncertainty and Relative Price Variability in WAEMU Countries. *International Monetary Fund Working Paper 11/59*.

Van der Merwe, E. (2004). Inflation targeting in South Africa. *The South African Reserve Bank Occasioanl Paper*, *19,* 1-15.

Van Der Westhuizen, C., Van Eyden, R., & Aye, G. (2022). Contagion across financial markets during COVID-19: A look at volatility spillovers between the stock and foreign exchange markets in South Africa. *Annals of Financial Economics*, *17*(1), 2250002.

Vavra, J. (2014). Inflation dynamics and time-varying volatility: New evidence and an ss interpretation. *The Quarterly Journal of Economics*, *129*(1), 215-258.

Walerych, M. & Wesołowski, G. (2021). Fed and ECB monetary policy spillovers to Emerging Market Economies. *Journal of Macroeconomics, 70,* 103345.

Weber, C.S. (2018). Central bank transparency and inflation (Volatility) – New evidence. *International Economics and Economic Policy, 15*, 21-67.

Wilson, B. K. (2006). The links between inflation, inflation uncertainty and output growth: New time series evidence from Japan. *Journal of Macroeconomics*, *28*(3), 609-620.

Wolassa, L. K. (2015). Inflation Targeting Monetary Policy, Inflation Volatility and Economic Growth in South Africa. *African Development Bank Group Working Paper* 216.

Wolff, C. C. (1988). Exchange Rates, Innovations and Forecasting. *Journal of International Money and Finance*, *7*(1), 46-61.

Xue-Jun, J. I. N., Yi, Z., & Yi-Zhong, W. A. N. G. (2014). Macroeconomic consequences of policy uncertainty. *Economic Theory and Business Management*, *34*(2), 17.

Yang, S., & Doong, S. (2004). Price and Volatility Spillovers between Stock Prices and Exchange Rates: Empirical Evidence from the G-7 Countries. *International Journal of Business and Economics*, *3*(2), 139-153.

Yau, H. Y., & Nieh, C. C. (2009). Testing for Cointegration with Threshold Effect between Stock Prices and Exchange Rates in Japan and Taiwan. *Japan and the World Economy, 21*(3), 292-300.

Zakoian, J. M. (1994). Threshold heteroskedastic models. *Journal of Economic Dynamics and control*, *18*(5), 931-955.

Zapatero, F. (1995). Equilibrium Asset Prices and Exchange Rates. *Journal of Economic Dynamics and Control*, *19*(4), 787-811.

Zhao, H. (2010). Dynamic Relationship between Exchange Rate and Stock Price: Evidence from China. *Research in International Business and Finance*, *24*(2), 103-112.

Živkov, D., Kuzman, B., & Andrejević-Panić, A. (2020). Nonlinear bidirectional multiscale volatility transmission effect between stocks and exchange rate markets in the selected African countries. *Economic Research-Ekonomska Istraživanja*, *34*(1), 1-28.

APPENDIX A

Appendix to Chapter 2

Table A1: Bivariate EGARCH model for volatility spillovers between stock returns and exchange rate changes in South Africa during the East-Asian Financial crisis (1997:07–1998:12)[84] and Global Financial Crisis (2007:08–2009:03)[85]

		East-Asian Financial Crisis				Global Financial Crisis		
		Stock returns		Exchange rate changes		Stock returns		Exchange rate changes
Panel A: Parameter estimation								
Mean equation								
	$\alpha_{S,0}$	2.067***	$\alpha_{E,0}$	-0.196***	$\alpha_{S,0}$	-2.284***	$\alpha_{E,0}$	-0.439***
	$\alpha_{S,1}$	0.041***	$\alpha_{S,1}$	-0.056***	$\alpha_{S,1}$	0.595***	$\alpha_{S,1}$	0.672***
	$\alpha_{E,1}$	2.183***	$\alpha_{E,1}$	0.148***	$\alpha_{E,1}$	-0.735***	$\alpha_{E,1}$	-0.549***
Variance equation								
	$c_{S,0}$	0.000	$c_{E,0}$	0.000	$c_{S,0}$	4.027***	$c_{E,0}$	-2.576***
GARCH effect	$\sum_{j=1}^{p_S} b_{S,j}$	0.009***	$\sum_{j=1}^{p_E} b_{E,j}$	0.001***	$\sum_{j=1}^{p_S} b_{S,j}$	0.239***	$\sum_{j=1}^{p_E} b_{E,j}$	0.196***
ARCH effect	$\delta_{S,S}$	1.101***	$\delta_{E,E}$	-1.408***	$\delta_{S,S}$	0.954***	$\delta_{E,E}$	-0.521***
Asymmetric effect	$\theta_{S,S}$	1.188***	$\theta_{E,E}$	-0.008***	$\theta_{S,S}$	0.363***	$\theta_{E,E}$	-0.153***
Volatility spillover	$\delta_{S,E}$	0.511***	$\delta_{E,S}$	-0.001***	$\delta_{S,E}$	-0.307***	$\delta_{E,S}$	-0.153***
Asymmetric spillover	$\theta_{S,E}$	-0.322***	$\theta_{E,S}$	0.441***	$\theta_{S,E}$	-0.124***	$\theta_{E,S}$	0.184***
Half-life		0.148		0.102		0.484		0.425
Relative asymmetry		0.0859		1.0161		0.4674		1.3597
$\rho_{S,E}$		0.3208***				0.4067***		

84 Dates in-line with Bonga-Bonga and Hoveni (2013).
85 Dates in-line with Mozumder *et al.* (2015).

Panel B: Model diagnostic test		
Ljung-Box Q(20) statistics		
$z_S \cdot z_E$	778.74	419.08

*Note: Note: *, **, *** indicate a rejection at 10%, 5% and 1% critical levels.*
Half-life represents the time it takes for the shocks to reduce their impact by one-half: $HL = \frac{\ln(0.5)}{\ln(\sum_{j=1}^{p_k} b_{k,j})}$ *where* $k = S$ or E.
Relative asymmetry $= \frac{|-1+\delta_k|}{(1+\delta_k)}$ *and may be greater than, equal to or less than 1, indicating negative asymmetry, symmetry, and positive asymmetry, respectively.*
LB(5) and LB²(5) are the Ljung-Box statistics (of order 5) applied to cross-correlation. A lag length of 5 is sufficient as it is unlikely that a relationship will only be apparent when longer lags are used (Estima, 2021).

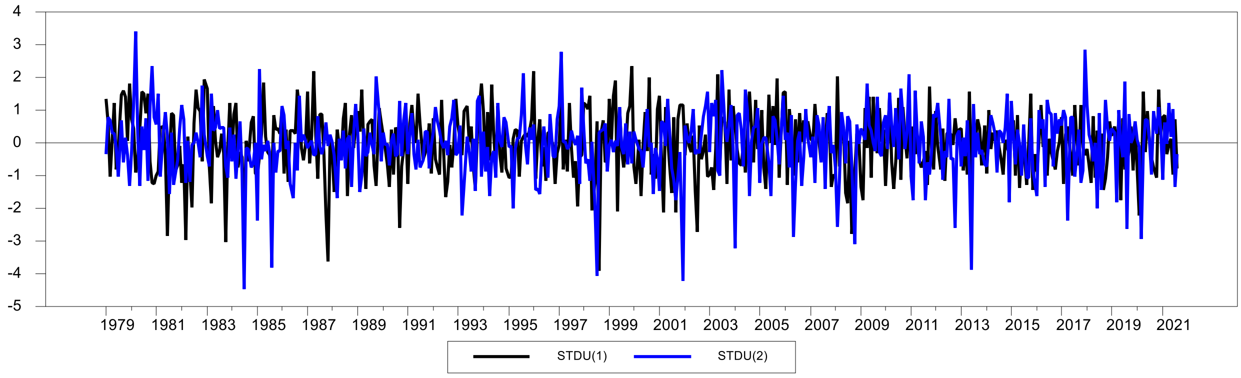


Figure A1: Standardised Residuals from Bivariate EGARCH Estimation, 1979:01–2021:08

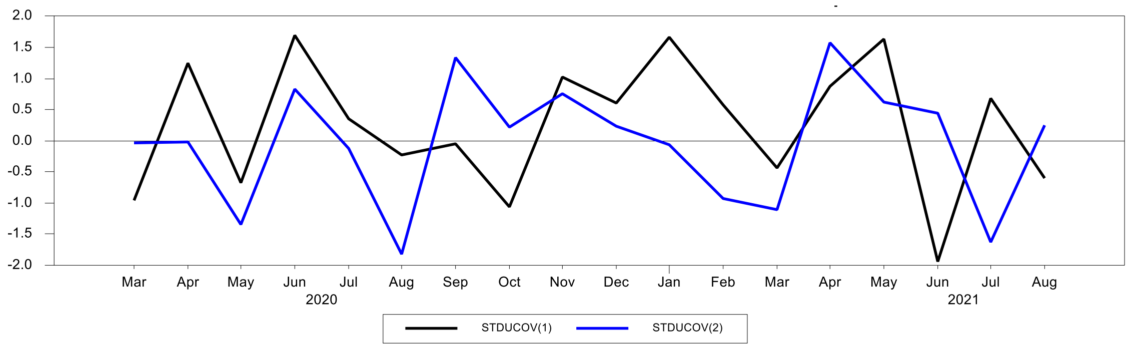
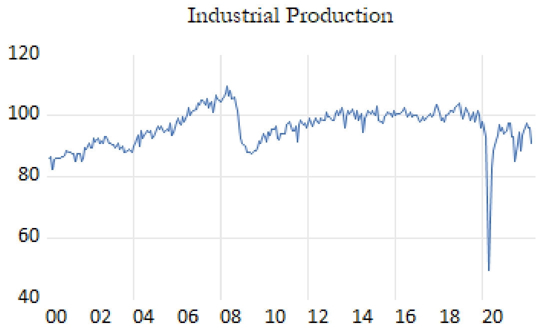
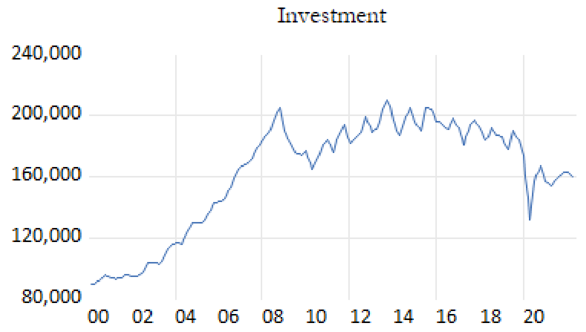


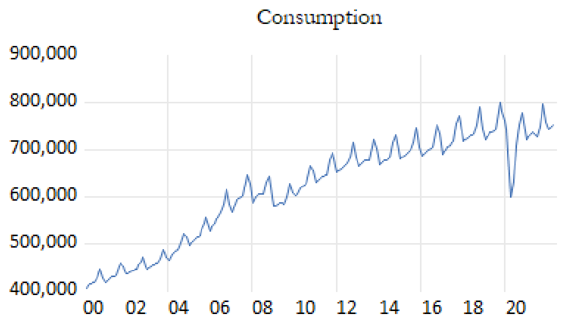
Figure A2: Standardised Residuals from Bivariate EGARCH Estimation during the COVID-19 pandemic, 2020:03–2021:08

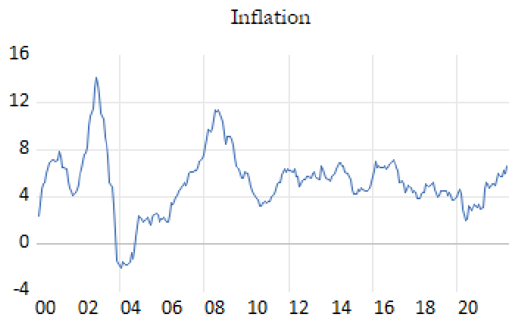
APPENDIX B

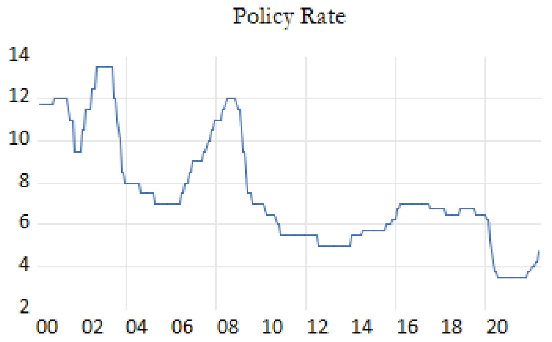
Appendix to Chapter 4

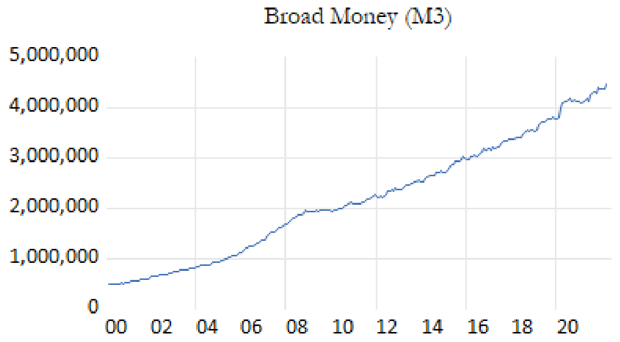


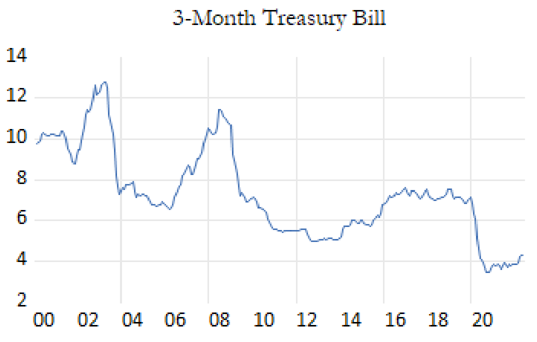


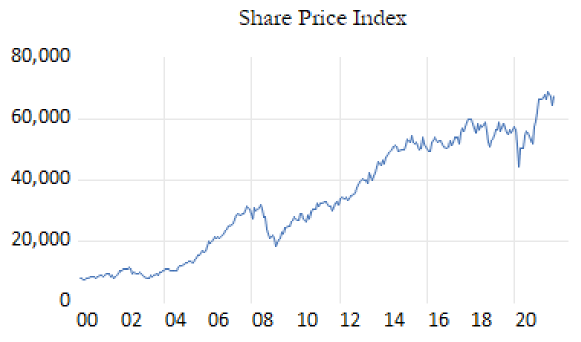












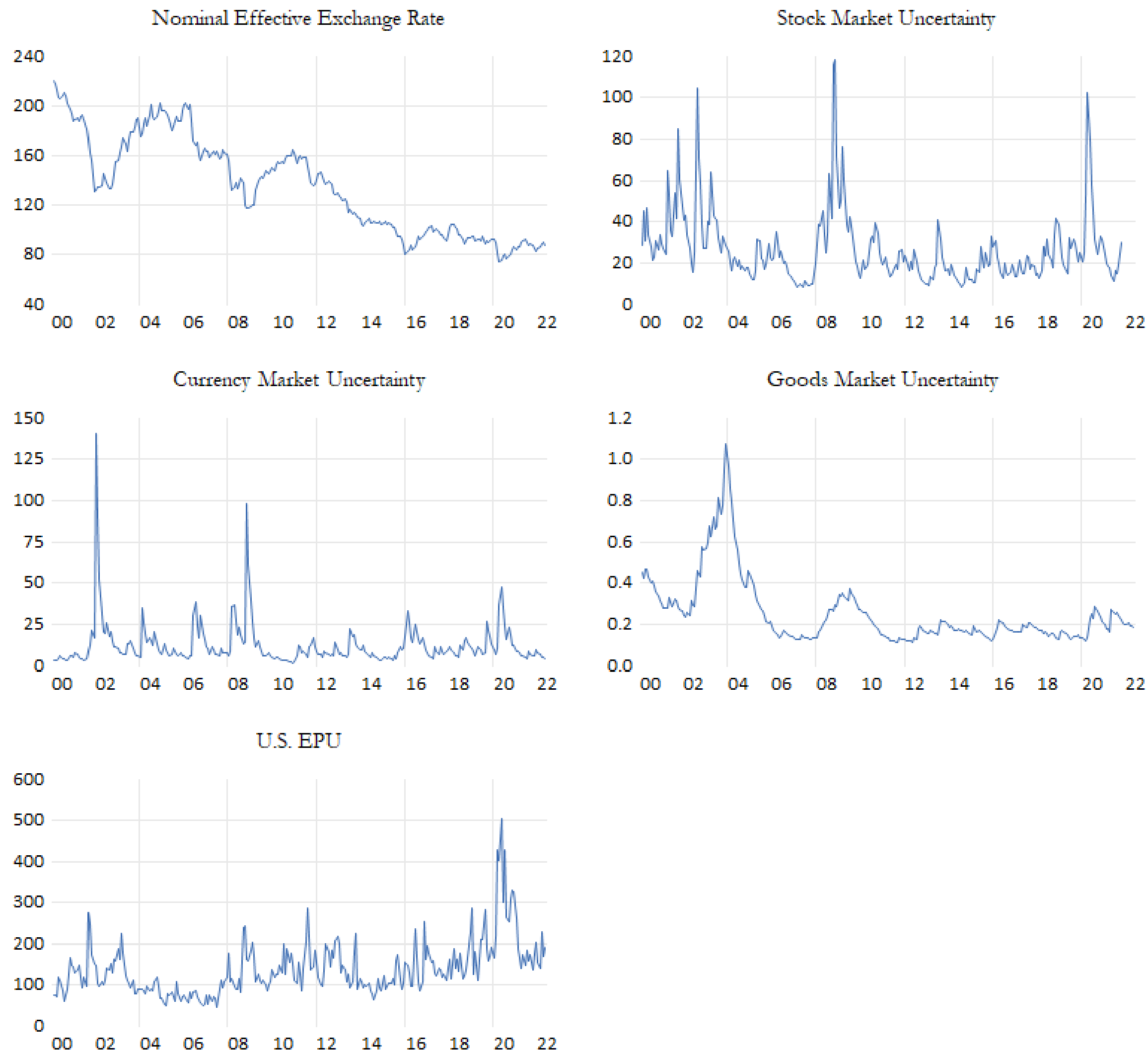


Figure B1: The plot of all variables

Source: SARB database, IMF IFS database, Bloomberg and Baker et al. (2016). Note: Industrial production is the volume of production with index: 2015=100. Investment and consumption are measured in real 2015 prices in R millions.

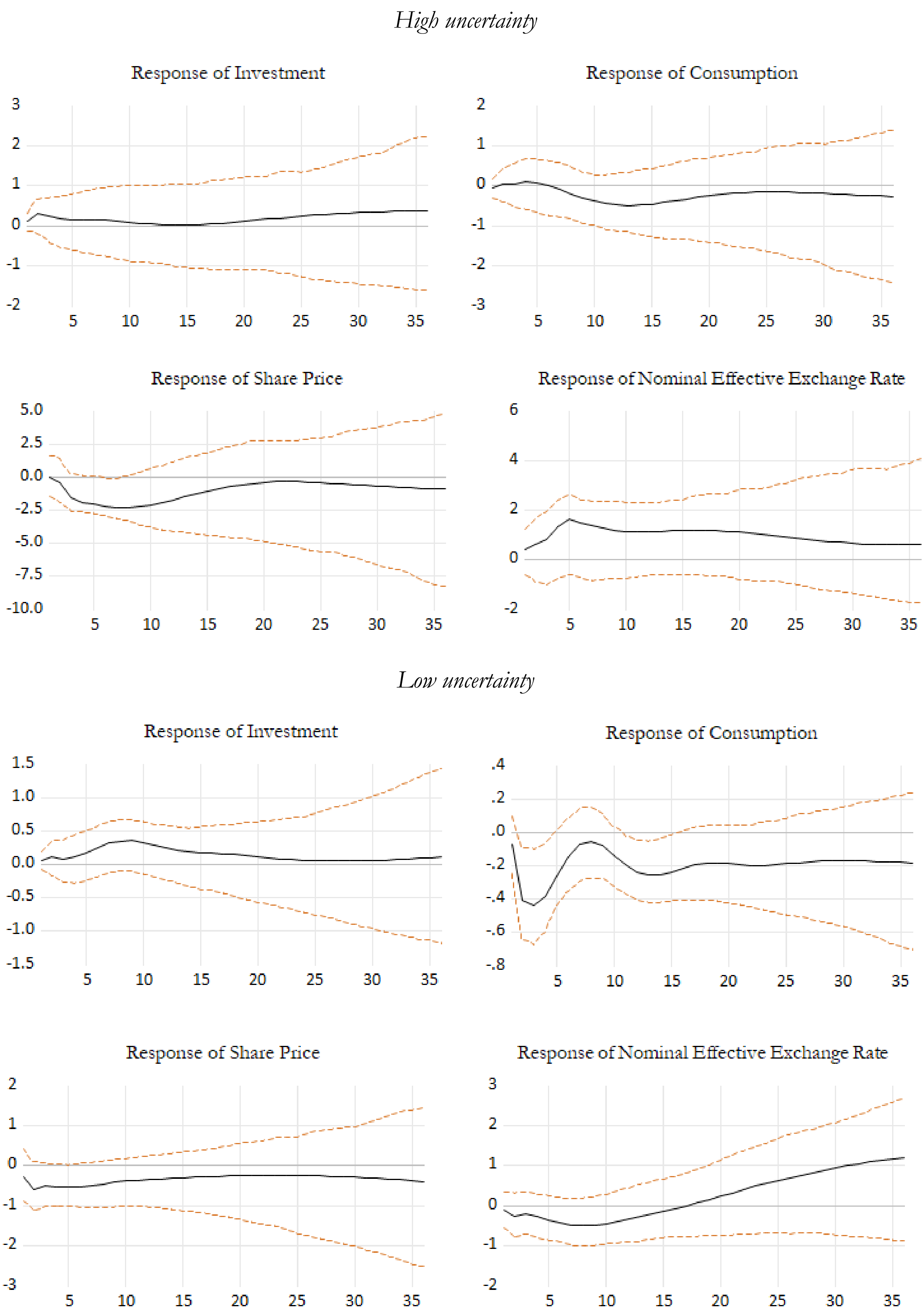
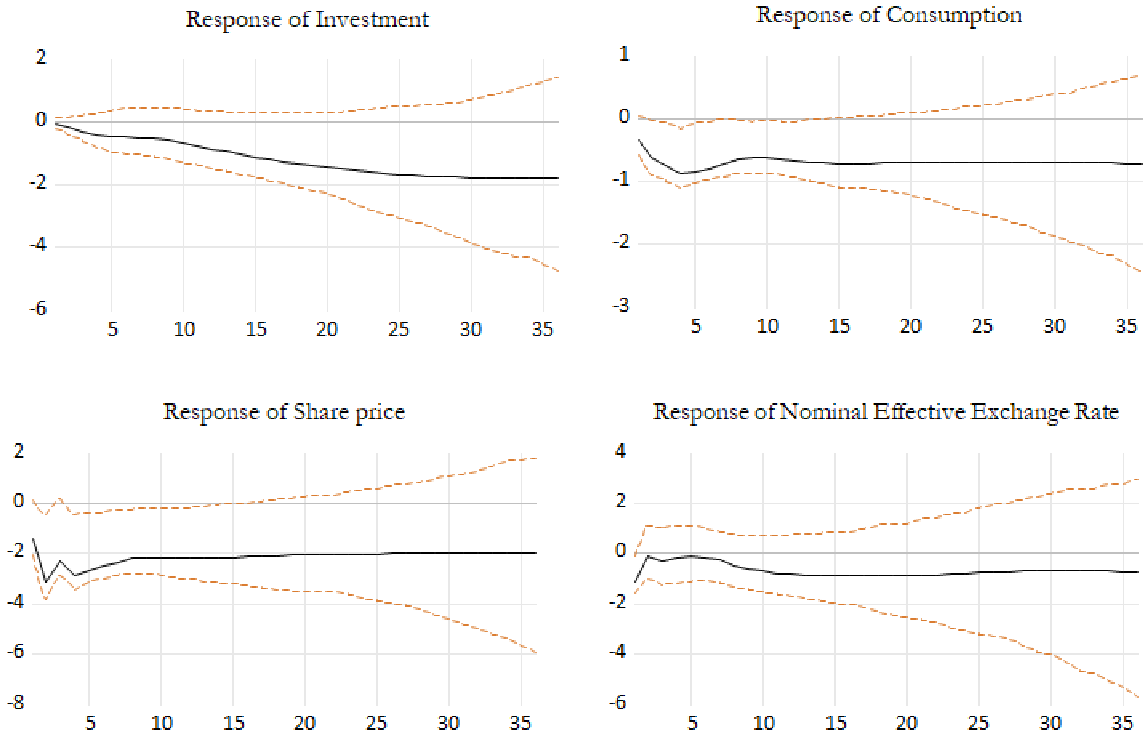


Figure B2: Impact of a monetary policy shock – Stock market

High uncertainty



Low uncertainty

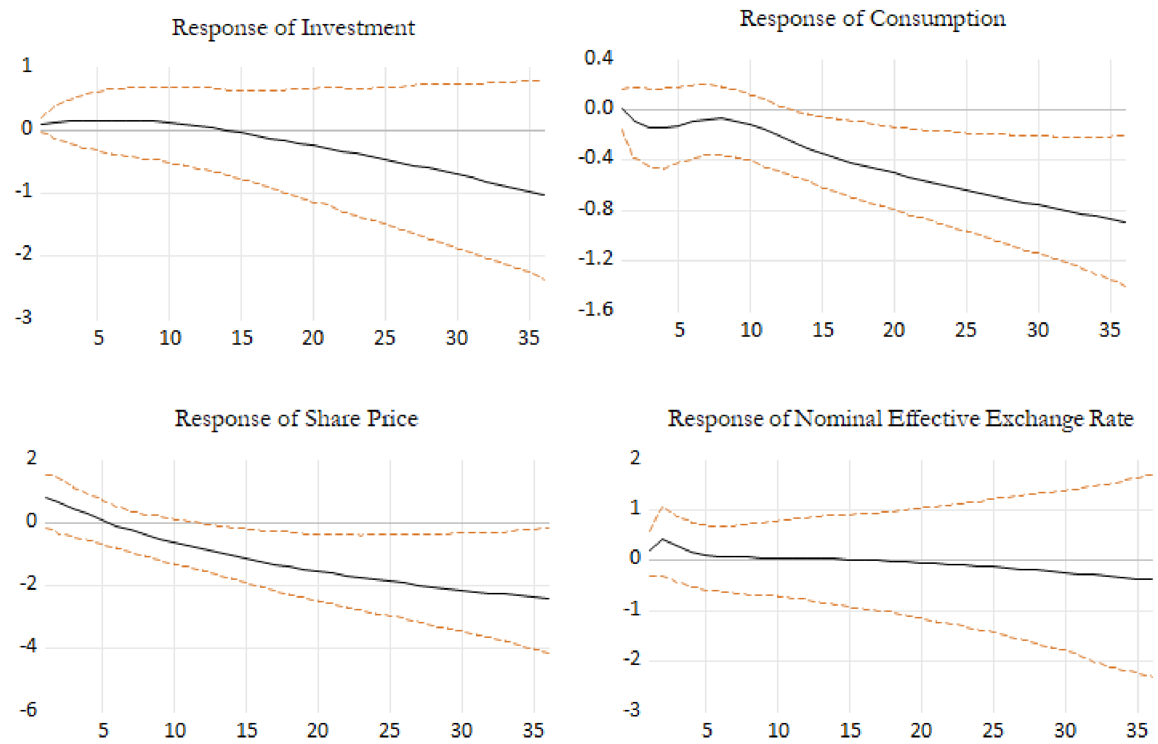


Figure A3: Impact of a monetary policy shock – Currency market

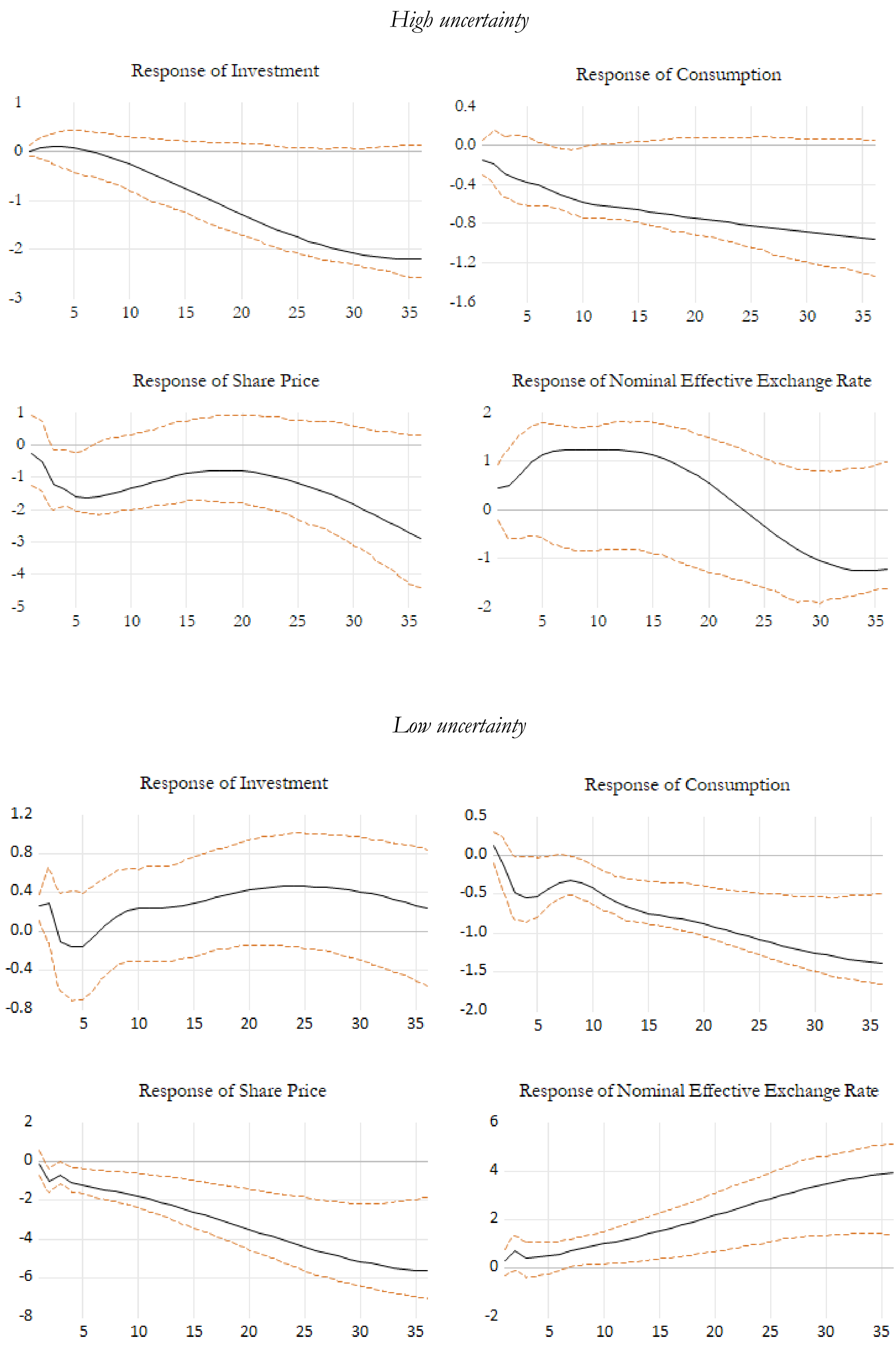


Figure A4: Impact of a monetary policy shock – Goods market

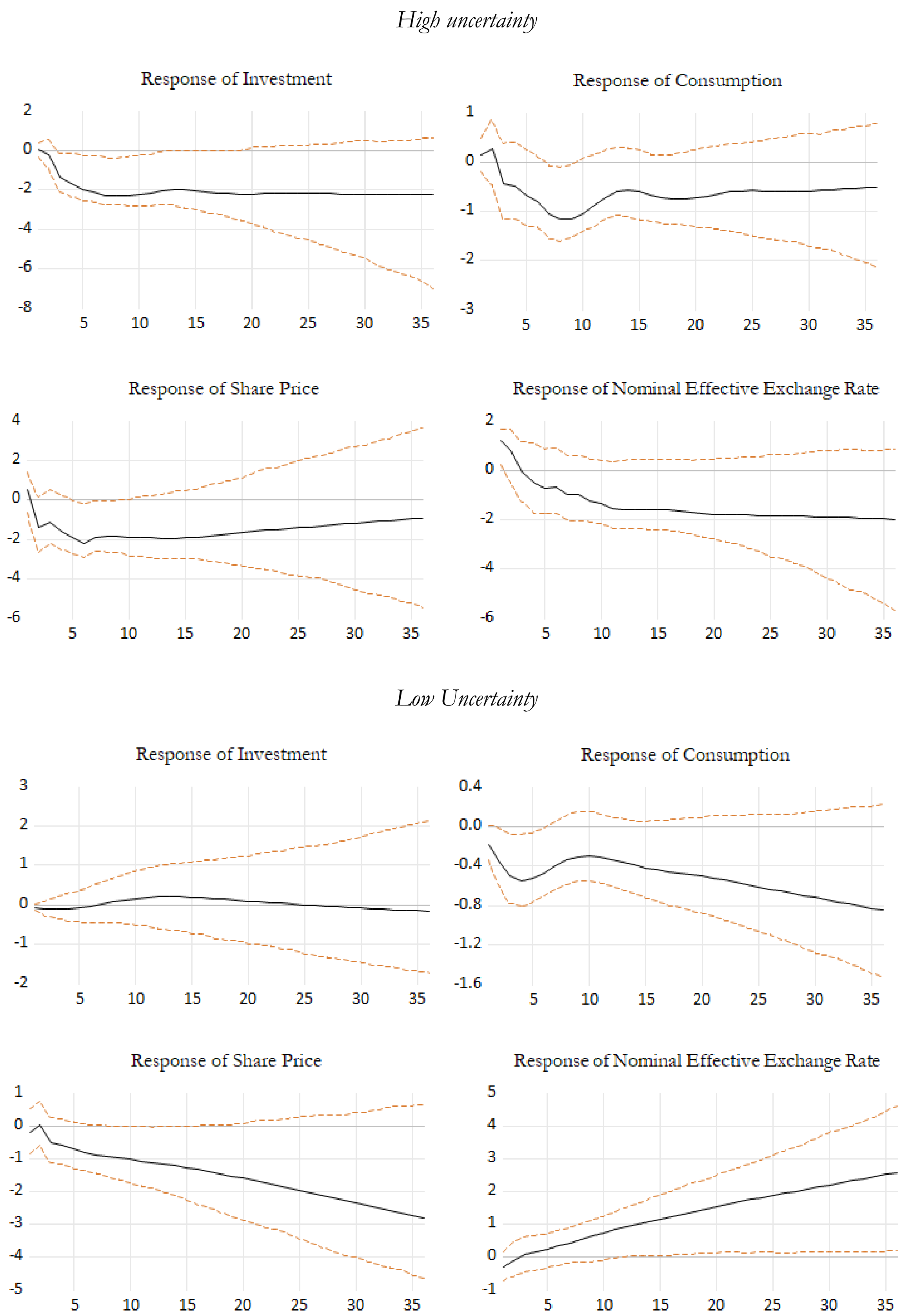


Figure A4: Impact of a monetary policy shock – Global market (U.S. EPU)

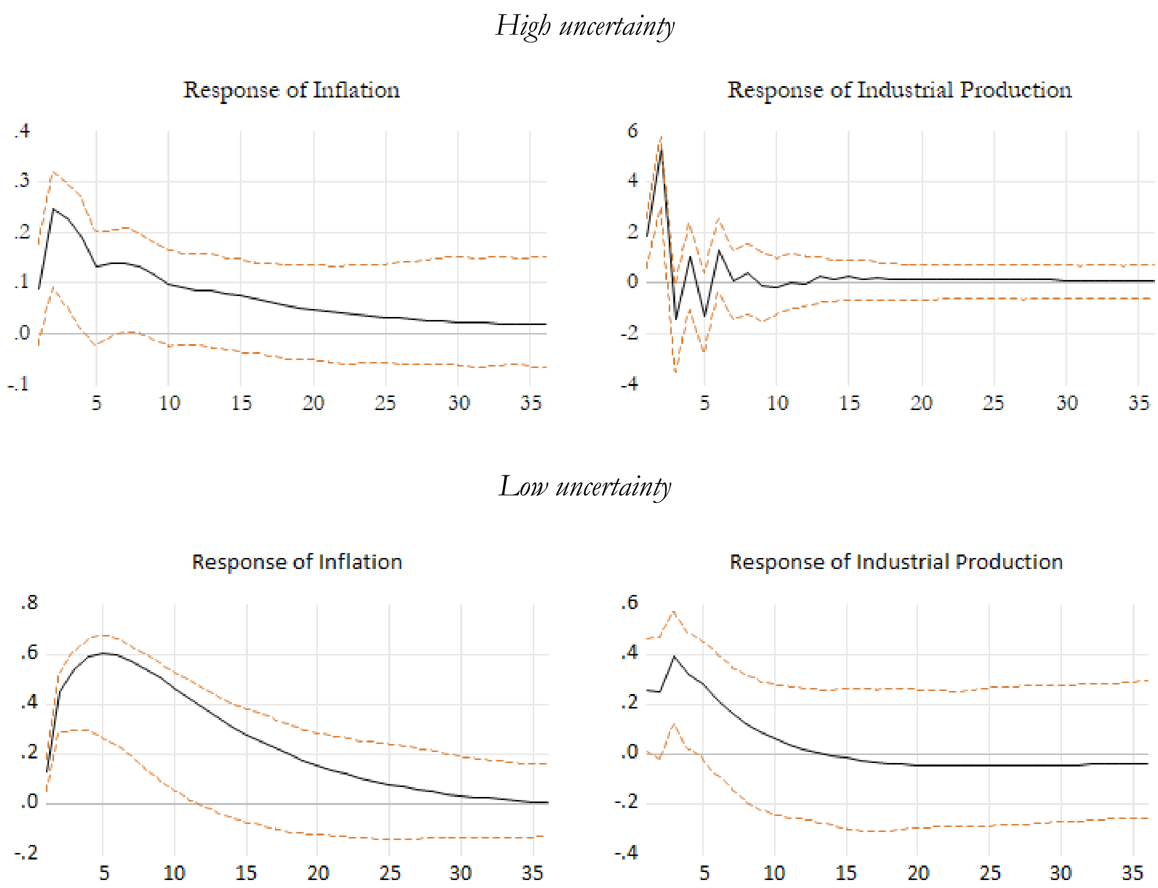


Figure A5: Impact of a monetary policy shock – Global market (Global EPU)