



Exploring the relationship between exchange rates and business cycles in South Africa

By

Amara Liyabona Mngcutsha

225180052

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Supervisor: Dr MC Nyati

Co-Supervisor: Dr S Msomi

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Abstract

This dissertation investigates a nonlinear, dynamic relationship between variations in exchange rates and business cycle actions in South Africa, a small open emerging economy with high external vulnerability and substantial financial integration. Although there is strong evidence at the international level for the salience of exchange rates to macroeconomic adjustment, in South Africa, the evidence base is still sparse and mostly consists of linear, time-invariant models with no reference to structural breaks and regime dependence. To close this gap, for the period 1990– 2024, the study employs a hybrid of Time-Varying Parameter Bayesian VAR (TVPBVAR) and Markov-Switching BVAR (MS-BVAR) models to explain evolving transmission mechanisms.

The findings indicate that shocks to the exchange rate have time-dependent and asymmetrical (state-dependent) effects on output, inflation, business confidence, and monetary policy. Depreciation episodes are a significant source of contraction during periods of global risk aversion, high uncertainty or domestic weakness, while appreciation during stable periods leads to a weaker expansionary impact. The results show that global financial conditions, and in particular VIX-driven risk sentiment and the U.S. monetary policy, dominate at the domestic level, indicating substantial exposure of South Africa to the Global Financial Cycle.

The evidence of regime-switching shows that the relationship between the exchange rate and the cycle is greatly magnified in high-volatility regimes characterised by crises, commodity price collapses, and policy changes. Collectively, the empirical evidence supports the view that, in South Africa, the exchange rate is not a relative price but a pivotal transmission mechanism through which external and domestic shocks create cyclical conditions. The relationship is strong, durable, and highly sensitive to global conditions; therefore, macro stability is associated with policy mechanisms that can mitigate shocks from the external environment.

Abbreviation	Meaning
BCI	Business Confidence Index
REER	Real Effective Exchange Rate
CPI	Consumer Price Index
IR	Interest Rate
TOT	Terms of Trade
VIX	Volatility Index (Global Risk Appetite)
VAR	Vector Autoregression
BVAR	Bayesian Vector Autoregression
TVP-BVAR	Time-Varying Parameter Bayesian VAR
MS-VAR / MS-BVAR	Markov-Switching VAR / BVAR
SVAR	Structural Vector Autoregression
FEVD	Forecast Error Variance Decomposition
GFEVD	Generalised Forecast Error Variance Decomposition
SARB	South African Reserve Bank
US / U.S.	United States
RBC	Real Business Cycle Theory
NOEM	New Open Economy Macroeconomics
ADF	Augmented Dickey–Fuller Test
PP	Phillips–Perron Test
KPSS	Kwiatkowski–Phillips–Schmidt–Shin Test
AIC/HQ/SC	Akaike, Hannan–Quinn, Schwarz Information Criteria

Contents

Chapter One: Introduction.....	1
1.1 Background & Motivation.....	1
1.2 Problem Statement.....	3
1.3 Research Objectives.....	5
1.4 Research Questions	5
1.5 Research Hypotheses.....	6
1.6 Significance and Contribution of the Study.....	6
Chapter 2: Literature Review	9
2.1 Theoretical Framework.....	9
2.2 Empirical Framework	15
2.3 Empirical Evidence from Emerging and Commodity-Exporting Economies	17
2.4 Empirical Evidence from South Africa.....	21
2.5 Methodological Insights.....	27
Chapter 3: Research Methodology	34
3.1 Introduction	34
3.2 Justification for Model Choice	35
3.3 Model Specification	36
3.4 Bayesian Estimation Framework.....	38
3.5 Priors: Normal–Inverse–Wishart (NIW) Structure	40
3.6 Estimation Procedure.....	42
3.7 Capturing Nonlinearity And Asymmetric Transmission	45
3.8 Cross Reference to Appendix E - Mathematical Derivation of the TVP-BVAR Model	46
3.9 Post-Estimation Diagnostics and Robustness Tests.....	46
3.10 Summary.....	47
Chapter 4: Empirical Results and Discussion	49
4.1 Introduction	49
4.2 Data Description and Descriptive Statistics	50
Table 4.1	51
4.3 Stationarity and Pre-Estimation Diagnostics.....	54
4.3.3.3. Normality of Residuals.....	66
4.3.4 Post-Estimation Model Diagnostics and Stability Tests.....	75
4.4 Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) Estimation.....	76
4.5 Markov-Switching Vector Autoregression (MS-VAR) Estimation	86
4.6 Impulse Response and Variance Decomposition Analysis	95
4.7 Discussion of Finding	101

Chapter 5: Conclusion.....	106
5.1 Summary.....	106
5.2 Conclusion.....	107
5.3 Policy Recommendations.....	108
5.4 Contribution To Knowledge	109
5.5 Limitations and Future Research	110
References	113
Appendix A: SVAR IRFs	123
Appendix B: GFEVD	125
Appendix D: Time Series Plots	128
Appendix E: Mathematical Derivation of the TVP-BVAR Model	128

Chapter One: Introduction

1.1 Background & Motivation

Macroeconomic stability is a key component of both sustained economic growth and social development. Out of the many factors associated with macroeconomic outcomes, the interaction between exchange rates and business cycles has attracted a great deal of scholarly and policy interest (Hossain, 2021). Exchange rates serve as both the price of international transactions and a means of transmission for global and domestic shocks. Meanwhile, business cycles reflect the natural ebb and flow of economic activity over time. Combined, the two variables represent large parts of life in open economies in terms of dynamism, vulnerability, and opportunity (Stein and Sandilands, 2020). With South Africa, for instance, an emerging market that is heavily integrated into the global economy yet faces structural constraints, a conceptual framework of this interplay is both theoretically significant and practically urgent (Pasali and Çadırcı, 2019).

Changes in exchange rates directly affect trade competitiveness, inflation dynamics, investment decisions, and capital flows (Gopinath et al., 2020; Dedola, Rivolta and Stracca, 2021). They also influence expectations and business confidence, driving into cyclical peaks and troughs. In the opposite direction, the dynamics that are characteristic of the business cycle phases, expansion or contraction, influence the strength and direction of the response to changes in the exchange rate (Smith and Johnson, 2020). For example, depreciation during recessions usually aggravates inflationary forces and discourages investment, whereas appreciation during expansions can erode export competitiveness (Céspedes, Chang & Velasco, 2004; Edwards & Garlick, 2008; Ha, Stocker & Yilmazkuday, 2020; Cavallo & Powell, 2021).

Due to the bidirectionality of causality, it presents a particularly convoluted nexus and requires empirical exploration that is tailored to the context. One excellent example of this is South Africa. The rand is one of the most traded emerging market currencies internationally, being subject to high volatility in comparison to its peers (Rey, 2015). Being a commodity-exporting economy, the currency in South Africa follows the global commodity price cycle, enhancing procyclicality (Chen and Rogoff, 2003; Lefatsa et al., 2025).

South Africa's presence in international financial markets makes it sensitive to fluctuations in international interest rates, especially those set by the United States Federal Reserve (Ngalawa & Nzimande, 2016). When there is tight global liquidity, the rand depreciates, inflation increases, and business activity slows, indicating the intense external dependence of the domestic cyclic process (Rey, 2015).

The significance of this research is raised by the socio-economic context of South Africa. High unemployment, structural inequality, and continued fiscal deficits are aggravating the economic impact of cyclical downturns (Jones and Smith, 2021). Volatility in exchange rates, which threatens to destabilize the system, restricts government policy as well as private-sector investment. Since 2000, the South African Reserve Bank (SARB) has employed an inflation-targeting policy framework; however, its capacity to smooth currency volatility is limited by external shocks and domestic limitations. As a result, the economy continues to be affected by the back-and-forth boom-bust waves associated with exchange rate fluctuations (Fourie, Ncube and Schoeman, 2016; Rey, 2015).

From a theoretical standpoint, the relationship between exchange rates and business cycles is embedded in competing schools of thought. RBC theory considers productivity shocks and external demand as fundamental drivers of both cycles and exchange rate movements (Kydland and Prescott, 1982). The Monetary Approach emphasizes monetary policy, inflation expectations, and interest rate differentials (Frenkel, 1976). Balance of Payments (BoP) models place particular emphasis on trade imbalances, and the Commodity Currency Hypothesis connects exchange rates to global commodity cycles (Chen & Rogoff, 2003). All these channels are closely applicable, and at least tangentially, to South Africa, a relatively small, open economy, a resource exporter, and a country with substantial institutional and structural frictions.

However, there are still incomplete studies of the South African situation despite the availability of international literature. Most of the current work either follows a linear model that does not account for nonlinearity and regime-dependent features (Sibanda et al., 2013; Klaas, 2015) or scrutinizes exchange rates in isolation from the broader cyclical model (Edwards and Garlick, 2008). However, evidence indicates that the impact of the exchange rate is mixed between cycles and has been highly contingent

on external shocks (Fourie et al., 2016; de Carvalho Filho, 2021). In response, we apply sophisticated Bayesian econometric methods to deal with variability over the time series, structural breaks, and nonlinear feedback. This methodological step is crucial for producing more credible, policy-sensitive insights.

The significance of the study is beyond academic contribution. For policymakers, this is fundamental in formulating macroeconomic policies that are aimed at maintaining price stability, supporting sustainable economic growth and enhancing the economy's resilience to domestic and global shocks. More transparency for the private sector on exchange rate dynamics can guide the investment/hedging/risk management decisions. For the broader society, stemming the procyclical volatility of the rand may promote a more predictable economic environment conducive to job creation and poverty alleviation.

1.2 Problem Statement

The linkage between exchange rates and business cycles is one of the most well-established and important dimensions of macroeconomic performance (Colacito, Croce, Gavazzoni, and Ready, 2020). For South Africa, with its small open economy that is so closely interlinked with global trade and finance, the relationship is economically vital yet politically fraught.

The South African rand is one of the most volatile currencies in the emerging markets, a feature that both reflects and exacerbates cyclical economic fluctuations (Rey, 2015). Despite this, the extent to which exchange rate dynamics influence South Africa's business cycles remains under-documented, irregular, and hampered by methodological weaknesses (Sibanda, Ncwadi and Mlambo, 2013; Klaas, 2015). Existing South African studies either examine exchange rate behaviour in isolation from broader cyclical dynamics or impose linear, time-invariant frameworks that preclude detection of the asymmetric and regime-dependent responses that characterise South Africa's economic history (Edwards and Garlick, 2008; Aye, Gupta and Moyo, 2017). Furthermore, the external drivers that most powerfully influence rand volatility such as U.S. monetary policy shocks, commodity price cycles, and global risk-off episodes are only partially accounted for in existing analysis (Rey, 2015; Miranda-Agrippino and Rey, 2020).

As a result, there exists no systematic empirical lens for decision-makers, firms, and academics to examine or regulate the relationships between exchange rate volatility and cyclical stability.

This volatility reflects both external influences, such as U.S. monetary policy shifts, commodity price cycles, and global risk-off episodes, and domestic structural constraints (Miranda-Agrippino and Rey, 2020; Lefatsa et al., 2025; IMF, 2023). Although exchange rate fluctuations clearly affect inflation, output, investment, and financial stability, the precise way they influence South Africa's business cycle remains under-examined.

The foregoing discussion reveals a clear gap in the literature: there is no comprehensive South African study that simultaneously (i) embeds exchange rate dynamics within the business cycle, (ii) captures nonlinear and asymmetric transmission across different macroeconomic regimes, and (iii) accounts for the dominant role of global financial conditions. Existing studies suffer from three key limitations: 1. Exchange rate behaviour is analysed in isolation, without embedding it within broader cyclical dynamics (Edwards and Garlick, 2008; Sibanda et al., 2013). 2. Linear and time-invariant models dominate – ADF-based VAR and OLS regressions preventing detection of asymmetry, structural breaks, and regime shifts that characterise South Africa's economic history (Klaas, 2015; Bussiere, Chudik and Sestieri, 2021). 3. External drivers such as global liquidity, capital-flow reversals, and risk-off episodes are only partially modelled, despite their dominant influence on rand volatility (Rey, 2015; Dedola, Rivolta and Stracca, 2021).

As a result, policymakers and analysts lack a coherent empirical framework for understanding how exchange rate shocks propagate through South Africa's business cycle and how their effects vary across different macroeconomic regimes. This limitation is particularly relevant for South Africa, a small open economy with a floating exchange rate and high exposure to external shocks. To address this problem, the study examines the state-dependent effects of exchange rate shocks on South Africa's business cycle using monthly data over the period 1990–2024. This period captures major structural and institutional changes in the South African economy, including financial liberalisation, the transition toward a market-determined exchange rate, the

adoption of inflation targeting, and multiple global and domestic shock episodes. Employing a Markov-Switching BVAR framework, the study evaluates how the transmission of exchange rate shocks differs across expansionary and contractionary phases of the business cycle.

Crucially, while South Africa's macroeconomic environment is widely acknowledged to exhibit nonlinear dynamics whereby the same exchange rate shock produces markedly different effects depending on the prevailing business cycle phase, no existing South African study explicitly investigates this asymmetric, regime-dependent transmission using a hybrid time-varying and regime-switching Bayesian framework (Aye et al., 2017; Nyati, Muzindutsi and Tipoy, 2023). This constitutes the central gap that the present study addresses.

1.3 Research Objectives

- To investigate the nature and direction in which exchange rate fluctuations affect South Africa's business cycles, distinguishing between expansionary and contractionary phases.
- To examine whether the relationship between exchange rates and business cycles in South Africa is nonlinear and asymmetric, with reference to regime-dependent transmission dynamics.
- To determine the influence of external factors, specifically global risk sentiment (VIX), commodity prices (Terms of Trade), and U.S. monetary policy on the exchange rate–business cycle nexus in South Africa.

1.4 Research Questions

- Is there a positive or negative relationship between exchange rate fluctuations and the business cycle in South Africa, and what is the direction and magnitude of this relationship over the period 1990–2024?
- How does the impact of exchange rate fluctuations on output, inflation, and business confidence differ across expansionary and contractionary phases of the South African business cycle?
- Is the relationship between exchange rates and the business cycle in South Africa nonlinear and asymmetric, and if so, how do global financial conditions (VIX, Terms of Trade, U.S. monetary policy) condition this asymmetry?

1.5 Research Hypotheses

Drawing on the theoretical literature reviewed in Chapter 2 and the methodological approach outlined in Chapter 3, the following hypotheses are formulated to guide the empirical analysis:

H1: Exchange rate depreciations (an increase in the REER) are associated with a statistically significant contraction in South Africa's business cycle indicator (BCI), reflecting the dominant contractionary channel through which rand depreciation operates via imported inflation, tighter financial conditions, and declining business confidence.

H2: The effect of exchange rate fluctuations on the South African business cycle is asymmetric and regime-dependent: depreciations produce significantly stronger and more persistent contractionary effects during high-volatility, contractionary regimes than during low-volatility, expansionary regimes.

H3: Global financial conditions, proxied by the VIX, Terms of Trade, and U.S. monetary policy, amplify the relationship between exchange rate shocks and South Africa's business cycle, particularly during global risk-off episodes characterised by sudden capital outflows and rand depreciation.

These hypotheses are testable within the Markov-Switching BVAR and TVP-BVAR frameworks employed in this study (see Section 3.3), and their evaluation forms the analytical core of Chapter 4.

1.6 Significance and Contribution of the Study

To the best of my knowledge, there are two studies in the literature that are relevant to this dissertation; however, they concentrate on distinct facets of South Africa's macroeconomic dynamics and exchange rates. The first one is by Msomi and Ngalawa (2024), who use a Markov-Switching model to estimate regime transitions and demonstrate asymmetric exchange rate behaviour as they examine exchange rate behaviour and expectations in the South African context. Instead of concentrating on how exchange rate shocks spread throughout the business cycle, they concentrate on exchange rate dynamics and expectations.

The second is by Nyati and Msomi (2025), who use business and financial cycle synchronization to study how macroprudential and monetary policies interact in South Africa. Although state-dependent transmission of exchange rate shocks across business-cycle regimes is not explicitly modelled in this study, it analyzes policy interactions with cycles using Granger causality, dynamic conditional correlations, and VAR-based techniques. This dissertation differs from these studies by explicitly investigating how exchange rate shocks transmit through South Africa's business cycle in a state-dependent manner. Unlike Msomi and Ngalawa (2024), my study goes beyond exchange rate behaviour or expectations to examine the impact of exchange rate shocks on macroeconomic outcomes such as output, inflation, investment, and trade balances at different phases of the business cycle. Unlike Nyati and Msomi (2025), this study focuses specifically on the exchange rate–business cycle nexus and employs a combination of nonlinear and time-varying econometric frameworks (Markov-Switching BVAR and TVP-BVAR) to capture evolving and regime-dependent shock transmission across monthly dataset from 1990–2024. This study contributes to the literature by (i) providing a long-term, high-frequency perspective on state dependent shock transmission, (ii) integrating regime changes and structural dynamics that are often overlooked in linear or single-regime models, and (iii) offering policy-relevant insights into when exchange rate shocks amplify or dampen business cycle fluctuations.

This study is significant for South Africa because exchange rate volatility plays a central role in shaping macroeconomic performance in a small open economy exposed to external shocks and frequent regime shifts. Understanding how exchange rate shocks propagate across different phases of the business cycle can assist the South African Reserve Bank, Treasury, and other policymakers in designing more effective monetary, fiscal, and macroprudential policies that enhance resilience to external and structural shocks. By clarifying whether exchange rate shocks tend to stabilise or destabilise the economy in different states, the findings will help policymakers identify conditions under which policy intervention is most effective.

The structure of the study is as follows: Chapter 2 reviews theoretical and empirical literature on exchange rate dynamics, business cycle transmission, and emerging market vulnerabilities, and presents the conceptual framework. Chapter 3 outlines the

methodological approach, including the TVP-BVAR specification and the MS-VAR regime-switching framework. Chapter 4 presents the empirical results, including impulse responses, variance decompositions, and regime-dependent transmission patterns. Chapter 5 concludes with key findings, policy implications, limitations, and recommendations for future research.

Chapter 2: Literature Review

2.1 Theoretical Framework

Exchange rates were primarily seen as an equilibrium-adjusting price in early macroeconomic theory. According to Cassel's (1918) formalization of the Purchasing Power Parity (PPP) theory, changes in nominal exchange rates only balance out differences in inflation, leaving real variables like output and employment unchanged. Strong presumptions of perfect capital mobility, instantaneous market clearing, and flexible prices were necessary for this neutrality result. However, PPP's short-term validity was called into question by empirical data. It was discovered that real exchange rates consistently departed from parity, especially in economies that were impacted by external shocks and structural change (Rogoff, 1996). These flaws made it clear that models that permit exchange rate fluctuations to impact actual economic activity throughout the business cycle are necessary.

Nominal rigidities and demand-driven fluctuations were introduced by the Keynesian framework. The Mundell–Fleming model (Mundell, 1963; Fleming, 1962) extended this to an open economy and showed that exchange rate regimes affect macroeconomic policy efficacy. More recent New Keynesian open-economy models, notably Galí and Monacelli (2005), formalise these insights within a dynamic stochastic framework, showing that exchange rate volatility has persistent effects on inflation and output in small open economies. Fiscal policy loses power under flexible exchange rates, but monetary policy affects output through interest rate and exchange rate channels. The expenditure-switching effect is a key component of this process, which modifies net exports and relative prices in response to changes in exchange rates. By adding expectations and sticky prices, Dornbusch's (1976) overshooting model improved these insights and explained why exchange rates show excessive short-term volatility. Together, these models demonstrated that exchange rates are not a passive relative price but rather could cause cyclical variations.

Nevertheless, these early frameworks were limited in two respects. First, they lacked explicit micro foundations, assuming ad hoc behavioural equations. Second, they could not account for the persistence of exchange rate fluctuations or business cycle

synchronization observed across countries. These limitations paved the way for the development of dynamic stochastic general equilibrium (DSGE) models.

The Real Business Cycle (RBC) approach, pioneered by Kydland and Prescott (1982), reinterpreted macroeconomic fluctuations as the efficient response of rational agents to real shocks, particularly productivity disturbances. In open-economy versions (Backus, Kehoe and Kydland, 1992), international trade and capital mobility transmit these shocks across borders, producing correlated cycles. The RBC framework contributed significantly by formalizing intertemporal optimization and incorporating production technology into business cycle analysis. Although RBC theory had microeconomic underpinnings and intertemporal modelling, it had trouble explaining the observed behaviour of exchange rates. Exchange rates exhibit persistent departures from equilibrium and are empirically far more volatile than fundamentals would indicate (Obstfeld and Rogoff, 2001). Additionally, RBC models make assumptions about smooth labour and financial markets, which are particularly troublesome for emerging nations.

Merely productivity-driven theories are inadequate in South Africa, where financial conditions are significantly impacted by external shocks and unemployment is fundamentally high. Global risk shocks, reversals in capital flows, and crashes in commodity prices all have an impact on output and exchange rates that deviates from RBC forecasts. This constraint drives theoretical frameworks that incorporate policy responses and nominal rigidities.

In an open economy setting, the New Open-Economy Macroeconomics (NOEM) framework combines intertemporal optimization with Keynesian nominal rigidities (Obstfeld and Rogoff, 1995; Galí and Monacelli, 2005). Exchange rates impact both output and inflation by influencing import-price pass-through and spending switching. According to empirical research, pass-through is not always consistent across monetary regimes and economic cycle stages (Campa and Goldberg, 2005; Aron et al., 2014; Ha, Stocker and Yilmazkuday, 2020). Exchange rate depreciation can boost external competitiveness while simultaneously increasing inflationary pressure, which poses a policy trade-off in inflation-targeting economies like South Africa. The influence of monetary policy regulations on exchange rate dynamics is emphasized by

NOEM models. However, they frequently downplay the significance of nonlinear reactions and global financial conditions, particularly in emerging markets that are vulnerable to erratic capital flows (Corsetti, Dedola and Leduc, 2010).

The conventional Mundell–Fleming trilemma is contested by Rey's (2015) Global Financial Cycle (GFC) hypothesis, which contends that financial openness limits monetary autonomy even in the presence of flexible exchange rates. Synchronous financial cycles that impact capital flows, credit conditions, and currency rates among nations are produced by global risk sentiment, U.S. monetary policy, and worldwide liquidity circumstances. This means that emerging markets are more susceptible to outside shocks. Sharp rand depreciations, rising bond rates, and production contractions were caused in South Africa by events like the global financial crisis and the COVID-19 shock (IMF, 2023). While sudden stops aggravate recessions, procyclical capital inflows during global risk-on periods tend to amplify expansions. The GFC literature frequently ignores domestic structural characteristics and policy responses, despite emphasizing external financial domination. As a result, there is a need for integrated frameworks that link domestic transmission channels with international financial dynamics.

Depending on the stage of the business cycle and the global environment, the exchange rates serve as both adjustment mechanisms and shock transmission channels. Exchange rate fluctuations in small open economies like South Africa simultaneously reflect data on trade balances, monetary policy, productivity, and global risk circumstances. This encourages the development of an integrated conceptual framework that incorporates both internal and external financial conditions and treats exchange rates as state variables. According to this theory, depreciation brought on by global risk-off events increases imported inflation, prompts monetary tightening, and reduces domestic demand, all of which may intensify downturns. On the other hand, growth during commodity booms may encourage expansions but make them more susceptible to reversal.

These theoretical channels' nonlinear, regime-dependent nature calls for empirical techniques that can capture dynamics that vary over time and are reliant on states. To investigate how exchange rate shocks spread throughout the various stages of South

Africa's business cycle, this study uses Time-Varying Parameter Bayesian VAR and Markov-Switching VAR models.

Exchange rate dynamics are shaped by the money supply, interest rate differentials, and inflation expectations, according to the Monetary Approach to Exchange Rate Determination (Frenkel, 1976; Dornbusch, 1976). Based on this concept, the nominal exchange rate represents the relative supply and demand of foreign and local currencies, which are impacted by domestic price levels and monetary policy positions. While expansionary policy and rising inflation expectations tend to weaken the currency, traditional monetary models contend that a contractionary monetary stance, marked by higher real interest rates, should draw in capital inflows, strengthen the domestic currency, and help anchor inflation expectations. These channels are still supported by recent empirical research. For instance, high-frequency data from Brazil demonstrates that positive monetary policy shocks (higher interest rates) directly reduce inflation expectations and raise the exchange rate in an emerging market setting, demonstrating the actual transmission of monetary policy to currency values (Goncalves et al., 2025).

Additionally, recent monetary research emphasizes how exchange rate responses are shaped by expectations and policy communication. Inflation expectations are state-dependent and react strongly to monetary policy surprises, according to studies utilizing survey data. This means that when policymakers successfully affect expectations, exchange rates will shift dramatically (Nakamura and Steinsson, 2018). Improvements in monetary policy communication have been demonstrated in African contexts to more successfully anchor inflation expectations and hence stabilize exchange rate behaviour, highlighting the significance of credibility and transparency in emerging market monetary frameworks (Kabundi and Mlachila, 2019). These results support the idea that inflation expectations are anchored by reliable policy regimes and are active determinants of currency value rather than merely passive outcomes. In conclusion, recent research highlights the significance of inflation expectations, policy communication, risk premia, and global financial integration in influencing the actual impact of money supply and interest rates on exchange rate dynamics in both advanced and emerging market settings, even though the monetary approach is still a fundamental theory for comprehending exchange rate movements.

According to Edwards (2001) and Dornbusch (1976), the Balance of Payments (BoP) perspective emphasizes that current account balances and capital flows are the primary drivers of exchange rate movements. Persistent trade surpluses tend to increase the value of the currency through increased foreign exchange demand, while deficits tend to decrease it through net outflows of foreign exchange. According to this framework, the exchange rate is a price that balances supply and demand in the financial and current accounts. As a result, export earnings and capital inflows boost demand for the home currency and fortify the exchange rate, while import payments and capital outflows push it lower. The BoP model also emphasizes feedback effects: although excessive appreciation can impede growth in tradable sectors and decrease export competitiveness, depreciation can improve external competitiveness, increasing export volumes and output over time (Dornbusch, 1976; Edwards and Garlick, 2008). Even though volatility still affects trade flows and more general macroeconomic conditions, recent research in South Africa demonstrate that exchange rate stability enhances trade results and promotes economic growth by reducing external imbalances (Schaling and Kabundi, 2014; Mpofu, 2016).

Furthermore, the experience of South Africa shows that the effectiveness of BoP adjustments is state-dependent: depreciation frequently boosts competitiveness only after lags brought on by quantity and price rigidities, a pattern consistent with the Jcurve effect, in which the trade balance first deteriorates before improving following depreciation (Schaling and Kabundi, 2014; Edwards and Garlick, 2008). These dynamics are exacerbated when capital flows suddenly reverse, as occurs during periods of global monetary tightening. This results in sudden devaluation of the rand, inflation from imports, and tighter financial conditions, all of which contribute to domestic cyclical downturns. The BoP framework is still applicable to contemporary macro financial analysis because it incorporates trade imbalances, capital flows, and exchange rate behaviour. However, recent data from South Africa and other emerging markets shows that global risk sentiment, commodity cycles, and capital flow volatility all influence the relationship between BoP dynamics and exchange rates. A deeper comprehension of exchange rate fluctuations in open, financially integrated countries is thus offered by this integrated BoP view as opposed to models that only take trade balance effects into account.

Figure 2.1: Conceptual Framework

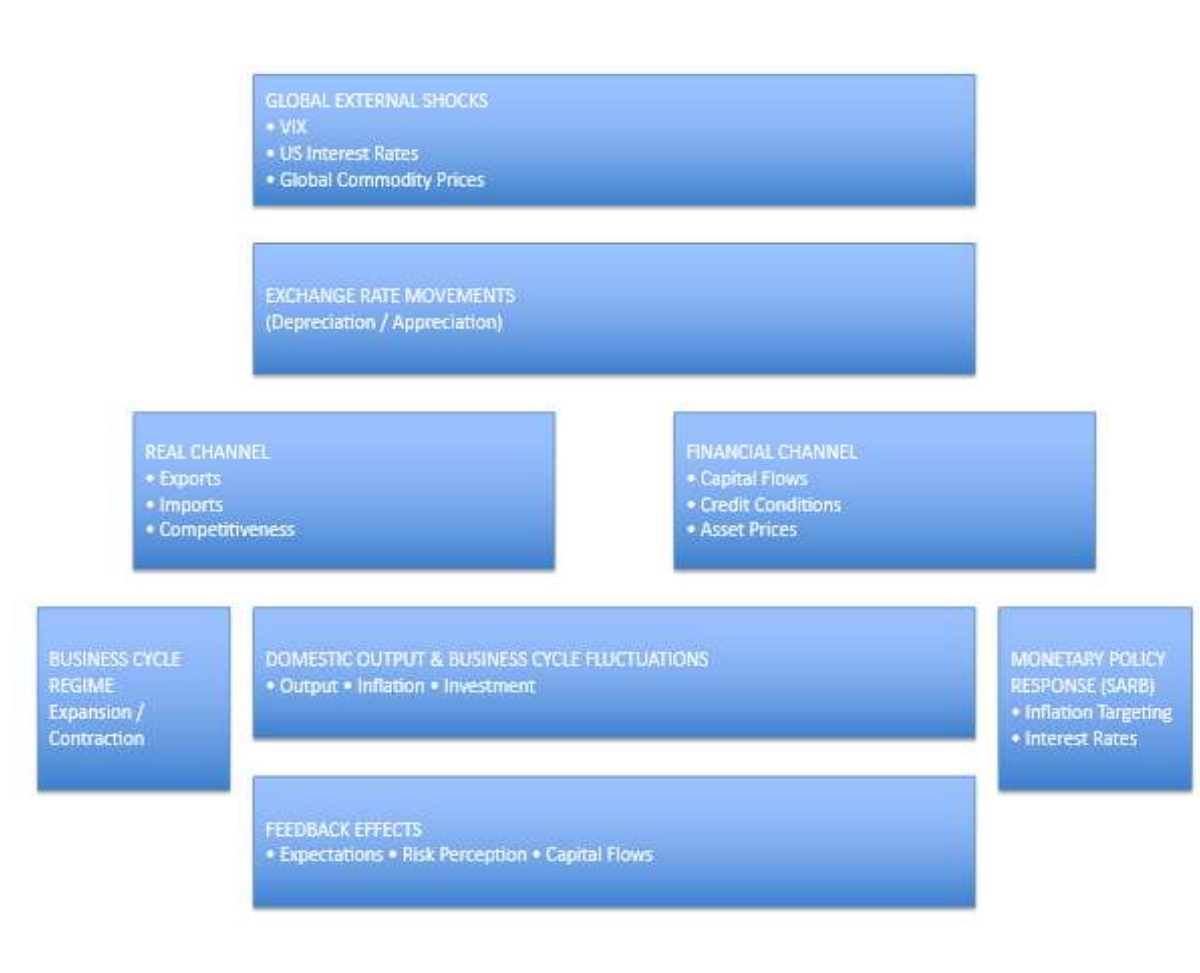


Figure 2.1 presents the author- developed conceptual framework underpinning this study, synthesised from the New Open-Economy Macroeconomics (NOEM) framework (Obstfeld and Rogoff, 1995; Galí and Monacelli, 2005), the Global Financial Cycle (GFC) hypothesis (Rey, 2015), and the monetary transmission literature for emerging markets (Aron et al., 2014). The framework proceeds as follows. In the outer layer, global external shocks including shifts in global risk sentiment (VIX), commodity price movements (Terms of Trade), and U.S. monetary policy changes which constitute the primary exogenous drivers. These shocks first transmit to the Real Effective Exchange Rate (REER), the central transmission variable in the framework, through capital flow reversals, portfolio rebalancing, and changes in the rand's risk premium.

The REER then propagates to the domestic economy through two principal channels: (i) the trade channel, whereby depreciation alters the relative prices of exports and imports, influencing the trade balance, output, and business confidence; and (ii) the financial channel, whereby depreciation raises the cost of servicing foreign-currency-denominated liabilities, tightens domestic credit conditions, and reduces investment and consumption. Monetary policy responses represent an endogenous feedback mechanism where the South African Reserve Bank adjusts the policy rate in response to depreciation-driven inflationary pressures, which in turn feeds back into exchange rate expectations and capital flows. Critically, the entire transmission mechanism is conditioned on the prevailing business cycle phase where the same exchange rate shock produces systematically different outcomes in expansionary (low-volatility) versus contractionary (high-volatility) regimes the core nonlinear relationship this study investigates (Hamilton, 1989; Aye et al., 2017).

2.2 Empirical Framework

Exchange rate changes are frequently linked to business cycle fluctuations, especially in open economies, according to empirical studies. According to early cross-country research by Baxter and Stockman (1989), production volatility is not considerably reduced by the exchange rate regime selection alone. Nevertheless, later research highlights that cyclical swings can be amplified by exchange rate volatility itself through financial and trade channels (Devereux and Engel, 2002; Engel and West, 2005). Exchange rate fluctuations are often procyclical for emerging markets, declining during recessions and rising during expansions (Calvo and Reinhart, 2002; Kaminsky, Reinhart and Végh, 2005; Aizenman, Chinn and Ito, 2020). According to these dynamics, currency rates frequently serve as shock amplifiers, escalating recessions through tighter financial conditions, increased inflation, and capital outflows. Sharp depreciations are often linked to deep output contractions, as evidenced by data from Asia after the 1997 crisis (Radelet and Sachs, 1998) and Latin America (Edwards and Levy-Yeyati, 2005). Most of the research assumes linear and time-invariant relationships, but literature shows that exchange rate volatility affects actual economic activity. This restricts their capacity to explain why depreciation effects are stronger during recessions than during expansions; this study specifically fills that gap.

Exchange rate pass-through (ERPT) and its effects on inflation and monetary policy are the subject of a second body of empirical research. According to Campa and Goldberg (2005), pass-through is incomplete and depends on market structure, trade openness, and monetary credibility. By stabilizing inflation expectations, inflation targeting policies dramatically lower pass-through, according to more recent research (Forbes et al., 2022). However, ERPT still depends on the state in emerging economies. According to (Carstens, 2019; Ha, Stocker and Yilmazkuday, 2020; Forbes et al., 2022), pass-through rises dramatically at times of high depreciation or increased uncertainty. This implies that in unfavourable international circumstances, even reliable monetary frameworks cannot completely protect domestic inflation from currency rate shocks. The evidence supports the idea that econometric frameworks that consider evolving transmission mechanisms over time are necessary because it shows that the effects of exchange rates on inflation are nonlinear and regime dependent.

Recent empirical research highlights how the state of the world economy shapes the dynamics of the business cycle and exchange rates. Rey (2015) and Miranda Agrippino and Rey (2020) show that a significant portion of exchange rate and capital flow volatility in developing markets may be explained by U.S. monetary policy and global risk sentiment, as measured by the VIX. Dedola, Rivolta, and Stracca (2021) demonstrate that monetary tightening in the United States causes output contractions and synchronized depreciations in emerging countries. Frequently independent of domestic fundamentals, these effects function through tightening financial conditions, balance sheet channels, and capital flow reversals. This evidence challenges traditional views of monetary autonomy and highlights the dominant role of global shocks, reinforcing the need to model exchange rates as part of a broader global financial transmission mechanism.

Further evidence of how BoP dynamics affect currency fluctuations comes from empirical studies of South Africa's foreign sector. Research indicates that economic growth is significantly affected by the current account balance, with deficits linked to slower growth and pressure on exchange rates, especially during global downturns, such as the COVID-19 pandemic (IMF, 2023). The Reserve Bank's Quarterly Bulletin emphasizes how changes in portfolio investment and direct investment flows,

combined with variations in South Africa's financial account, have an immediate impact on the supply and demand for foreign exchange and, consequently, the value of the rand (SARB, 2025). In fact, the abrupt reversal of net capital inflows between 2024 and 2025 shows how sensitive the financial account and consequently the currency rate is to changes in portfolio flow and investor sentiment globally.

Exchange rate behaviour in emerging markets is mutually shaped by capital flows and external factors, as demonstrated by recent integrated empirical research. According to Lefatsa et al. (2025), rising commodity prices (particularly gold) and positive interest rate differentials can stabilize the currency and improve the trade balance, while increased global risk sentiment causes the rand to depreciate through capital outflows to safe-haven assets. This is consistent with more extensive worldwide data demonstrating that BoP pressures from current account imbalances and erratic capital flows are important factors influencing exchange rate volatility in emerging economies, especially during periods of tightening global financial conditions (IMF External Sector Report, 2025).

2.3 Empirical Evidence from Emerging and Commodity-Exporting Economies

Economies that export commodities have especially robust exchange rate–cycle relationships. It is demonstrated by Chen and Rogoff (2003) and Broda (2004) that in resource-rich economies, commodity prices have a major impact on output and exchange rates. Booms in commodities typically result in currency appreciation and growth, whereas busts cause depreciation, inflationary pressures, and recession. Brazilian, Chilean, and Mexican data support the idea that currency depreciations during recessions are more contractionary than appreciations (Bonomo and Terra, 2012; López and Vergara, 2011; Calvo and Reinhart, 2002). These disparities reflect restricted policy space, liability dollarization, and budgetary limitations. The asymmetric nature of exchange rate effects and their dependence on external factors are highlighted in emerging market research, which further supports the shortcomings of linear models.

Business cycle swings have been exacerbated by the historically high exchange rate volatility that has plagued Latin American economies, especially Brazil and Argentina. According to Edwards and Levy-Yeyati (2005), significant currency fluctuations in

these economies worsen macroeconomic instability by raising the unpredictability of inflation, deterring investment, and escalating capital flow reversals during recessions. Exchange rate depreciations in Latin America are typically highly contractionary, according to more recent empirical data, particularly when balance-sheet mismatches, low monetary credibility, and exposure to debt denominated in foreign currencies are present (Aizenman, Chinn, and Ito, 2020; Cavallo and Powell, 2021).

Deep recessions and ongoing inflationary pressures have been linked to Argentina's many bouts of severe peso depreciation, which are indicative of poor institutional frameworks and limited policy credibility (IMF, 2022; Gopinath et al., 2023). Similarly, research on Brazil reveals that exchange rate volatility is still strongly correlated with both domestic monetary tightening cycles and global financial conditions, which increases output volatility rather than serving as a stabilizing shock absorber (Carstens and Werner, 2019; Dedola, Rivolta, and Stracca, 2021).

Asian economies offer a different but complementary viewpoint. Although many Asian nations have historically relied on competitive exchange rates to boost growth and are more export-oriented, they also show strong links between the currency and business cycle. The Asian Financial Crisis of 1997 is still a crucial point of reference because it shows how abrupt currency failures and capital flight can cause severe recessions by exposing the financial sector to foreign debt and causing financial sector distress (Corsetti, Pesenti and Roubini, 1999; Radelet and Sachs, 1998; Miranda-Agrippino & Rey, 2020). However, many Asian economies have become more resilient because of post-crisis reforms, such as stronger monetary frameworks, foreign reserve accumulation, and better financial regulation (Ghosh, Ostry, and Qureshi, 2015; Obstfeld, Shambaugh and Taylor, 2017). According to recent research, Asian currencies are still susceptible to U.S. monetary policy and global risk shocks, but the actual effects on output are now more muted than they were prior to 1997. This is due to improved institutional capacity and macroprudential policy frameworks (Miranda-Agrippino and Rey, 2020; IMF, 2023).

Together, the evidence from Asia and Latin America highlight how structural features, monetary credibility, and institutional quality all play a mediating role in the relationship between exchange rates and business cycles. According to Rey (2015) and Aizenman

et al. (2020), nations with credible monetary regimes, diverse export bases, and sufficient policy buffers are better positioned to absorb external shocks and limit cyclical volatility, while economies with weak policy frameworks and limited financial depth typically experience exchange rate movements as shock amplifiers.

The Exchange rate pass-through (ERPT) highlights that the degree to which changes in exchange rates are reflected in domestic prices is not total nor consistent, but rather heavily relies on the credibility of monetary policy, inflation expectations, trade openness, and market structure. In industrialized economies, pass-through to import and consumer prices is typically partial, reflecting pricing-to-market behaviour and nominal rigidities, as demonstrated by seminal work by Campa and Goldberg (2005). This view is supported by more recent research, which demonstrates that credible inflation-targeting regimes considerably reduce pass-through by stabilizing inflation expectations and shortening the duration of currency rate shocks (Forbes et al., 2022; Gopinath et al., 2020). Under these regimes, businesses are more inclined to view changes in exchange rates as transient and modify markups rather than prices, which reduces the impact of inflation.

However, the literature also emphasizes that ERPT is nonlinear and relies on the state, especially in emerging market economies. Pass-through tends to increase significantly at times of significant depreciations, increased uncertainty, or financial stress, even when inflation targeting is in place (Carstens and Werner, 2019; Bussière, Chudik and Sestieri, 2021). Weaker balance sheets, more reliance on imports, and increased sensitivity to international financial conditions are all reflected in this asymmetry. Inflation credibility can lower average pass-through, but it cannot completely shield countries from currency rate shocks during times of crisis, according to empirical data from emerging markets (Ha, Stocker, and Yilmazkuday, 2020; IMF, 2023).

The dominance of global financial shocks in influencing business cycle variations and exchange rate dynamics, especially in financially linked emerging market economies, has been highlighted by more recent empirical studies. Even under flexible exchange rate regimes, Rey's (2015) Global Financial Cycle hypothesis shows that a significant portion of cross-country variation in exchange rates, capital flows, and output can be explained by global risk appetite, as measured by indicators like the VIX, U.S.

monetary policy rates, and international credit spreads. Building on this paradigm, Dedola, Rivolta, and Stracca (2021) present strong empirical evidence that, as global financial conditions tighten, U.S. monetary tightening causes synchronized currency depreciations and production contractions across emerging nations. According to recent studies (Miranda-Agrippino and Rey, 2020; Kalemli-Özcan, 2020; IMF, 2023), these global shocks are spread through a variety of channels, such as abrupt reversals in capital flows, balance-sheet effects resulting from foreign currency liabilities, and changes in investor risk perceptions.

The nonlinear and regime-dependent nature of exchange rate transmission is a key finding from this literature. Exchange rate shocks are not always expansionary or contractionary; rather, their actual impacts are heavily influenced by the current policy regime, the external financial environment, and the shock's underlying cause. Depreciations brought on by gains in productivity or terms of trade may boost output through increases in competitiveness, but depreciations brought on by episodes of global risk-off frequently turn out to be contractionary because of increased inflation, tighter monetary policy, and deteriorating financial conditions (Corsetti, Dedola, and Leduc, 2010; Aizenman, Chinn, and Ito, 2020). According to empirical evidence, these disparities are most noticeable during financial stress and recessions, when changes in exchange rates accentuate rather than mitigate external shocks (Forbes et al., 2022; Bussière et al., 2021).

These findings have important methodological implications. The presence of time variation, asymmetry, and regime shifts in the exchange rate–business cycle relationship challenges the adequacy of linear, constant-parameter models. Consequently, recent studies increasingly adopt flexible econometric frameworks such as Time-Varying Parameter VARs and Markov-Switching models to capture evolving transmission mechanisms across different states of the global and domestic economy (Primiceri, 2005; Aye, Gupta, and Moyo, 2017). This study follows this strand of the literature by explicitly modelling exchange rate shocks as state-dependent phenomena, allowing their impact on South Africa's business cycle to vary over time and across regimes of global financial conditions.

2.4 Empirical Evidence from South Africa

Since its introduction in 1961 to replace the South African pound, the South African rand (ZAR) has experienced substantial structural change that reflects changes in the political economy and external integration of the nation. The rand was first tied to the British pound and then to the US dollar during the early republic era, reflecting South Africa's past trade connections and capital account management techniques (Capie and Wood, 2016). Strict capital controls and exchange limits prevented the currency from being immediately affected by external shocks during the apartheid era. This regime decreased short-term exchange rate swings, but it also limited domestic investment, skewed resource distribution, and made it more difficult for monetary authorities to respond flexibly to changes in the world economy (Aron and Muellbauer, 2007).

A significant change toward financial liberalization and increased exchange rate flexibility occurred during the post-apartheid era. By gradually loosening restrictions on portfolio and direct investment flows, capital account reforms implemented in the 1990s allowed South Africa to become more completely integrated into international financial markets (Hove and Sibanda, 2014). This change made it easier to acquire foreign capital and improved market efficiency, but it also made the rand more vulnerable to external financial shocks and global liquidity cycles. According to empirical data, the rand has become one of the most erratic emerging market currencies since liberalization, reacting violently to shifts in commodity prices, global risk sentiment, and U.S. monetary policy (Ngalawa and Nzimande, 2016; Rey, 2015). More recent studies confirm that a significant portion of rand volatility can now be explained by global financial conditions, which are captured by indicators like the VIX and U.S. interest rate differentials, frequently independently of domestic fundamentals (Miranda-Agrippino and Rey, 2020; Dedola, Rivilta, and Stracca, 2021).

There are significant macroeconomic implications to this increased vulnerability. Sharp rand depreciations, coupled with increased inflationary pressures, tighter domestic financial conditions, and production contractions, have often been brought on by episodes of global risk aversion or U.S. monetary tightening (Kabundi and Botha, 2019; IMF, 2023). On the other hand, rand appreciation and brief expansions have typically been supported by times of high global liquidity and commodities booms, at

the expense of heightened susceptibility to abrupt reversals. Overall, the development of South Africa's exchange rate regime highlights a key trade-off related to financial openness: liberalization increases exposure to global financial cycles while simultaneously improving market integration and allocative efficiency. This highlights the significance of modelling exchange rate dynamics as state-dependent, and time varying phenomena South Africa is a particularly pertinent example because of its high level of financial integration, reliance on commodities, and flexible exchange rate. Exchange rate shocks have a substantial impact on output and inflation, particularly during severe depreciation episodes, according to early research (Aron and Muellbauer, 2002; Nell, 2000). Exchange rate pass-through significantly decreased after inflation targeting was implemented in 2000, according to Aron, Muellbauer, and Smit (2014), indicating improved monetary confidence. Sharp rand depreciations, rising interest rates, and output contractions in South Africa have been empirically linked to global risk shocks, reflecting the economy's deep integration into the Global Financial Cycle (Rey, 2015; Kabundi and Botha, 2019; Miranda-Agrippino and Rey, 2020). Nonlinear and regime dependent effects are highlighted in recent studies. Exchange rate depreciations are substantially more contractionary during periods of high volatility, according to Aye, Gupta, and Moyo (2017). Although global financial factors are not included in their research, Mabasa and Maredza (2020) report time-varying relationships between exchange rates, inflation, and growth. The COVID-19 pandemic and the 2008–2009 Global Financial Crisis provide additional evidence that rand devaluation is associated with deep recessions, inflation increases, and capital flight (Nyati, Muzindutsi and Tipoy, 2023; IMF, 2023). Exchange rate–business cycle interactions are time-varying, asymmetric, and heavily impacted by global shocks, according to South African evidence; nonetheless, most of the current research uses linear or constant parameter models.

A major change in South Africa's macroeconomic policy framework occurred when the rand was formally floated in the mid-2000s because of the country's transition to a fully market-determined exchange rate. This change made it easier for the South African Reserve Bank (SARB) to implement an autonomous monetary policy that is in line with the inflation-targeting regime and concentrates on price stability. However, the economy's vulnerability to outside financial shocks was also exacerbated by greater

exchange rate flexibility. According to Rey (2015), small open economies with high levels of financial integration are especially susceptible to the global financial cycle, in which capital flows are more sensitive to international liquidity conditions, U.S. monetary policy, and global risk appetite than to domestic fundamentals. According to later empirical research, the rand has grown more susceptible to episodes of global risk-off, with significant depreciations frequently taking place during times of monetary tightening and worldwide unpredictability in developed economies (Miranda-Agrippino and Rey, 2020; Dedola, Rivolta, and Stracca, 2021).

The business cycle in South Africa is marked by significant volatility that results from both external shocks and internal structural limitations. According to Fourie et al. (2016) and Bhorat, Cassim, and Tseng (2021), persistent high unemployment, low productivity growth in important industries, ongoing disruptions in the energy supply, and structural disparities in industrial development have all reduced the economy's ability to withstand shocks and limited the efficacy of countercyclical policy. Global commodity prices, interest rates, and investor sentiment toward developing markets are just a few examples of the external factors that interact with these internal vulnerabilities (Chen and Rogoff, 2003; Bloom, 2009). According to recent evidence, South Africa's output and exchange rate have been particularly severely impacted by global uncertainty shocks, like those seen during the COVID-19 pandemic, which have exacerbated downturns through capital outflows, tighter financial conditions, and declining investment (Nyati, Muzindutsi, and Tipoy, 2023; IMF, 2023).

Collectively, the literature indicates that although exchange rate flexibility has increased South Africa's monetary policy autonomy, it has also strengthened the way that global financial stocks are transmitted into the country's business cycle. Exchange rate fluctuations in South Africa frequently function as shock amplifiers rather than stabilizers due to the combination of fundamental domestic flaws and unstable external conditions, especially during times of global financial stress. This emphasizes the necessity of empirical frameworks for analyzing the relationship between exchange rates and business cycles that take time variation, nonlinearity, and regime dependence into account.

Studies regularly show that South Africa's business cycle reactions to fluctuations in exchange rates are asymmetric, with depreciations having significantly greater real effects during downturns than appreciations during expansions. Aron, Muellbauer, and Smit (2014) demonstrate that while times of economic boom do not result in corresponding currency appreciation or persistent investment inflows, output contractions in South Africa are usually followed by significant rand depreciations and capital outflows. This asymmetry implies that, especially during unfavourable economic cycle conditions, the exchange rate serves as both a shock amplifier and an adjustment mechanism. Recent studies support this finding by showing that exchange rate volatility increases during times of financial strain and leads to tighter domestic financial conditions, increased inflation, and decreased output (Kabundi and Botha, 2019; Mabasa and Maredza, 2020).

These unequal dynamics have been exacerbated by global crises. The rand saw a sharp decline, inflationary pressures increased, and real GDP shrank by roughly 1.5% during the 2008–2009 Global Financial Crisis, highlighting the South African economy's procyclical susceptibility to external financial shocks (Nyati, Muzindutsi, and Tipoy, 2023). Similar trends were seen during the COVID-19 pandemic, when a sharp halt to capital inflows and increased global risk aversion led to a sharp decline in the value of the rand despite a collapse in worldwide demand. According to empirical evidence, this depreciation increased imported inflation, limited policy options, and weakened investor confidence, all of which contributed to the domestic downturn (IMF, 2023).

These incidents show that South Africa's exchange rate volatility actively drives cyclical dynamics rather than being a passive reflection of the underlying business cycle conditions. While appreciations during upswings are frequently limited and transient, depreciations linked to global risk-off events tend to perpetuate downturns. This strengthens the argument for empirical models that specifically account for asymmetry, regime shifts, and time-varying transmission mechanisms by supporting the conclusion that the exchange rate–business cycle link is nonlinear, state dependent, and crisis-sensitive.

One of the most important institutional changes made in the post-apartheid era to stabilize prices and anchor inflation expectations was the South African Reserve Bank's (SARB) implementation of inflation targeting in 2000. In this framework, the SARB closely monitors output gaps, exchange rate movements, and financial stability risks while using the repurchase rate as its principal policy tool to keep inflation within the target range of 3–6% (Fourie et al., 2016). According to empirical data, inflation targeting has improved the credibility of monetary policy, which has strengthened trust in South African financial markets and contributed to a persistent drop in long-term inflation expectations (Aron, Muellbauer, and Smit, 2014; Kabundi and Mbelu, 2022). More recent studies confirm that, especially during times of relative macroeconomic stability, increased credibility has reduced average exchange rate pass-through to domestic prices (Forbes et al., 2022; IMF, 2023).

The inflation-targeting paradigm has significant drawbacks when there is significant exchange rate volatility, according to published studies. Large and sudden real depreciations, which are frequently caused by global risk-off shocks or U.S. monetary tightening, might put the SARB in a challenging policy trade-off in a highly open and financially linked country like South Africa. Although pass-through effects may be lessened by raising interest rates to stabilize the currency and reduce inflationary pressures, doing so comes at the expense of stifling domestic demand, raising borrowing costs, and intensifying cyclical downturns (Edwards, 2001; Ngalawa and Nzimande, 2016). During recessions, when tighter financial conditions exacerbate preexisting structural weaknesses and diminish the effectiveness of monetary transmission, recent empirical evidence indicates that such policy responses are especially contractionary (Kabundi, 2021; Nyati, Muzindutsi, and Tipoy, 2023).

Small open economies working under inflation targeting in a globalized financial system face a broader challenge, which is reflected in this tension. Credible monetary policy can lessen the volatility of average inflation, but it cannot completely shield the economy from exchange rate shocks that stem from international financial cycles (Rey, 2015; Miranda-Agrippino and Rey, 2020). As a result, South Africa's inflation targeting strategy is fundamentally state-dependent, and policy trade-offs become more pressing when external volatility is high. This emphasizes how crucial it is to analyse

business cycle dynamics, exchange rate fluctuations, and monetary policy within a framework that takes time variation, asymmetry, and regime changes into account.

The capacity of South Africa's fiscal policy to react countercyclically to shocks caused by exchange rates is equally limited. Rigid expenditure commitments, especially in the form of pay bills and social transfers, high and growing public debt levels, and ongoing fiscal deficits restrict the potential for discretionary fiscal growth during downturns (Fourie et al., 2016; IMF, 2023). According to empirical evidence these limitations increase reliance on monetary policy and, thus, increase vulnerability to exchange rate volatility by weakening the stabilizing impact of fiscal policy (Bhorat, Cassim, and Tseng, 2021). Because of this, fiscal authorities are frequently under procyclical pressure, particularly during times of economic contraction and currency devaluation, consolidation efforts become more intense.

To deal with increased exchange rate uncertainty, businesses and financial institutions have implemented a variety of risk-mitigation techniques at the microeconomic level. To lessen susceptibility to external shocks, these include diversifying export destinations, hedging foreign currency risk, and implementing more flexible supply chain arrangements (Baele et al., 2019; Alfaro et al., 2020). The literature highlights that while these tactics can reduce firm-level exposure to currency fluctuations, they are insufficient to counteract the wider macroeconomic effects of exchange rate volatility, especially during periods of systemic financial stress (Kalemli-Özcan, 2020; Forbes et al., 2022).

Exchange rate shocks are more likely to spread across the economy and intensify business cycle fluctuations in the absence of efficient coordination between monetary, fiscal, and structural policy, according to recent studies. Monetary tightening intended to stabilize the currency can further stifle output, while fiscal fragility restricts the capacity to support demand during downturns (Rey, 2015; Dedola, Rivolta, and Stracca, 2021). This relationship highlights the necessity of an integrated policy framework that combines sustainable fiscal management, credible monetary policy, and structural changes targeted at increasing export diversification and productivity. This kind of coordination is especially important in developing market economies like

South Africa, where domestic structural weaknesses and international financial cycles are strongly linked to exchange rate volatility.

2.5 Methodological Insights

From linear VARs and static regressions to Bayesian and nonlinear frameworks, empirical approaches have changed throughout time. SVARs presume average effects and parameter stability, even if they capture dynamic interactions (Sims, 1980). Markov-Switching VARs capture discrete regime transitions, but Time-Varying Parameter VARs (Primiceri, 2005; Aye et al., 2017; Kuschnig & Vashold, 2021; Forbes et al., 2022) permit continuous structural change (Aye et al., 2017). Despite these developments, research conducted in South Africa seldom combines global financial shocks, regime transition, and time variation into a unified framework. There is little empirical evidence on how exchange rate shocks impact South Africa's business cycle over time and under different regimes, especially when there is global financial instability.

Single-equation ordinary least squares (OLS) regressions or strictly defined structural macroeconomic models were generally used in earlier empirical research on the dynamics of the South African exchange rate. Important works by Nell (2000) and Kahn and Farrell (2002) concentrated on examining comparatively specific theories, including whether depreciation of the exchange rate boosts production growth or enhances export performance. Although these methods offered helpful first insights, they limited their capacity to capture the intricate and dynamic character of exchange rate transmission by imposing heavy assumptions of linearity, parameter stability, and exogeneity. Specifically, dynamic feedback effects, lagged responses, and structural breaks, all crucial aspects of exchange rate–business cycle interactions in open economies, were not well taken into account by these models.

Exchange rate shocks frequently operate through numerous channels concurrently, including trade, financial, and expectations-based, and their effects develop over time in a state-dependent manner, according to later methodological critiques (Engel and West, 2005; Obstfeld and Rogoff, 2001). Because of this, linear single-equation models often underestimate the durability and asymmetry of exchange rate effects, producing less reliable and poorly predictive outcomes, particularly in economies that

experience frequent external shocks (Bussière et al., 2021). More recent empirical research highlights the multifaceted shocks that emerging market economies, such as South Africa, face. These shocks include domestic structural constraints, commodity price fluctuations, and global financial cycles, all of which change over long time horizons and interact in nonlinear ways (Miranda-Agrippino and Rey, 2020; Kalemli Özcan, 2020).

Growing awareness of these constraints has led to improvements in econometric methods since the middle of the 2000s. In recent research on exchange rate dynamics, time-series models that accommodate temporal variation, regime switching, and endogenous feedback such as Time-Varying Parameter VARs and Markov-Switching VARs, have gained prominence (Primiceri, 2005; Aye, Gupta and Moyo, 2017; Forbes et al., 2022). More flexibility in capturing asymmetric responses, structural change, and delayed effects across business cycle phases is provided by these frameworks. The need for empirical methodologies that go beyond static and linear specifications is thus highlighted by the methodological evolution in the literature, especially when analyzing exchange rate shocks in highly open and financially linked economies like South Africa.

A major methodological advancement in the study of exchange rate dynamics and their macroeconomic implications was made in the early 2000s with the introduction of Vector Autoregressive (VAR) and Structural VAR (SVAR) models. In contrast to single-equation regressions, VAR frameworks regard all variables as endogenous, allowing researchers to simultaneously study dynamic interactions between output, inflation, interest rates, and exchange rates (Sims, 1980; Lütkepohl, 2005). Expanding on this methodology, studies like Du Plessis et al. (2014) and Kabundi and Botha (2019) used SVARs to analyze structural shocks and track their impulse responses, offering insightful information about how various shocks, monetary, fiscal, and external, spread throughout the South African economy. By allowing for greater dynamic feedback between variables and capturing contemporaneous interactions, these techniques enhanced previous OLS approaches.

Standard VAR and SVAR models have significant drawbacks despite these benefits. They usually assume linear relationships and constant parameters, which are

frequently broken in economies going through structural reforms, changes in policy regimes, or times of increased volatility (Bussière et al., 2021; Forbes et al., 2022). To distinguish between demand, supply, and financial shocks, SVARs necessitate a priori identification limits. This can be difficult in small open economies that are subject to multifaceted external shocks (Dedola, Rivolta, and Stracca, 2021). Additionally, the time-varying nature of the exchange rate–business cycle relationship may be obscured by conventional SVAR estimates, which reflect average effects over the sample period, particularly during crises, commodity price swings, or times of rapid financial liberalization (Miranda-Agrippino and Rey, 2020; Nyati, Muzindutsi, and Tipoy, 2023). The limitations of linearity, constant parameters, and static identification highlight the need for time-varying and regime-dependent frameworks, such as Time Varying Parameter VARs and Markov-Switching VARs, to fully capture the complexity of exchange rate transmission in emerging markets, even though VAR and SVAR models represented a significant advancement in empirical macroeconomics.

The shortcomings of linear and constant-parameter VAR frameworks have been addressed by recent methodological developments that let model parameters to change over time. Primiceri (2005) created Bayesian Time-Varying Parameter VARs (TVP-VARs), which allow for the estimate of dynamic interactions under uncertainty and take into account structural breaks, policy regime changes, and changing shock transmission. This adaptability is especially useful in emerging market environments, where macroeconomic ties are frequently erratic and extremely susceptible to both internal structural factors and outside shocks. The usefulness of TVP-VARs is demonstrated by empirical applications. For example, Benati and Surico (2009) examined the shifting impacts of monetary policy shocks in developed economies, and Kose et al. (2020) demonstrated that global financial conditions have a time-varying effect on output and exchange rates in emerging markets.

The TVP-VAR frameworks provide South Africa with a potent method for separating the changing relationships between domestic business cycles, the rand, and global financial shocks. This is especially important when taking into account the economy's experience with significant events like the COVID-19 pandemic and the 2008–2009 Global Financial Crisis, which caused significant changes in output dynamics, capital flows, and exchange rate behaviour (Nyati, Muzindutsi, and Tipoy, 2023). TVP-VARs

provide a more precise and nuanced understanding of how exchange rate shocks spread through South Africa's open, commodity-linked, and financially integrated economy by allowing structural parameters to change over time. This allows them to capture nonlinearities, asymmetric responses, and regime dependent effects that standard VAR or SVAR models are unable to identify (Forbes et al., 2022; IMF, 2023).

Through explicitly incorporating nonlinearities associated with different economic regimes, such as expansions vs recessions or risk-on versus risk-off periods, Markov Switching and Threshold VAR models (MS-VAR and TVAR) offer significant methodological supplements to the time-varying literature. According to empirical studies conducted in the South African context, the economy's reaction to external shocks is strongly regime-dependent, and the direction and strength of exchange rate effects varies depending on the stage of the economic cycle (Aye, Gupta, and Moyo, 2017). For instance, because of tighter financial conditions, increased inflationary pressures, and lower investor confidence, depreciations during risk-off or recessionary periods are typically more contractionary, while similar movements during expansions have less of an impact on investment and output. The significance of using econometric frameworks that can capture state-dependent dynamics in emerging market economies is shown by this finding.

TVAR and MS-VAR models have drawbacks despite their benefits. They may oversimplify the slow and ongoing evolution of macroeconomic connections in practice since they usually demand large samples for accurate estimation and impose discrete regime shifts (Primiceri, 2005; Forbes et al., 2022). In contrast, TVP-VAR models are especially useful for analyzing cyclical dynamics in small open economies like South Africa, where shocks and policy responses change over time and across regimes (Miranda-Agrippino and Rey, 2020; Nyati, Muzindutsi and Tipoy, 2023). This is because they combine the interpretability of traditional VARs with the flexibility to accommodate continuous structural change. A more thorough understanding of exchange rate–business cycle interactions is made possible by the combination of these methods, which enables researchers to evaluate both the nonlinear amplification effects linked to regime-specific shocks and the gradual adjustment of macroeconomic linkages.

The literature in this study highlights how business cycle dynamics and exchange rates have a complicated and changing relationship, especially in small, open, and financially linked nations like South Africa. Theories such as the Global Financial Cycle hypothesis (Rey, 2015), the New Open-Economy Macroeconomics (Obstfeld and Rogoff, 1995; Galí and Monacelli, 2005), and the traditional Purchasing Power Parity (Cassel, 1918) all emphasize that exchange rates are more than just relative prices. Instead, they influence output, inflation, and capital flows by acting as both economic adjustment mechanisms and conduits for the transmission of both domestic and international shocks. Adding expectations, financial frictions, and nominal rigidities to these models has improved our comprehension of the procyclical impacts of exchange rate fluctuations, especially in emerging nations that are susceptible to outside shocks.

The South African economy responds to exchange rate shocks in an asymmetric and state-dependent manner, as empirical evidence consistently shows. By raising imported inflation, tightening financial conditions, and deterring investment, depreciations during recessions or times of global risk aversion often exacerbate economic contractions, whereas appreciations during expansions usually have less pronounced effects (Aron et al., 2014; Nyati, Muzindutsi and Tipoy, 2023). The magnitude and duration of cyclical fluctuations are shaped by the interplay of exchange rates, global financial conditions, and domestic structural vulnerabilities in other emerging and commodity-exporting economies (Edwards and Levy-Yeyati, 2005; Kose et al., 2020). The significance of taking into account local structural factors, commodity price volatility, and global financial cycles in empirical analysis is highlighted by these findings, which highlight the exchange rate's dual function as a shock absorber and a shock amplifier.

The literature also identifies serious methodological flaws in earlier research. Although early studies that used structural macroeconomic models or single-equation OLS regressions offered valuable insights, they were limited by strong assumptions about linearity, stability, and exogeneity and were unable to account for dynamic feedback, lagged impacts, or regime shifts (Nell, 2000; Kahn and Farrell, 2002). Joint endogeneity and the calculation of impulsive reactions to structural shocks were made possible using VAR and SVAR frameworks, which constituted a methodological advancement (Sims, 1980; Du Plessis et al., 2014). However, the assumptions of static

identification, linearity, and constant parameters limit these methods, producing "average effects" that obscure time varying, nonlinear, and regime-dependent dynamics, especially during crises or structural policy changes (Dedola, Rivolta, and Stracca, 2021; Forbes et al., 2022).

Time-varying and regime-switching techniques have been used in recent methodological advancements to overcome these constraints. Because they can handle changing structural relationships, incremental policy changes, and dynamic interactions under uncertainty, Bayesian Time-Varying Parameter VARs (TVP-VARs) are especially well-suited for emerging economies (Primiceri, 2005; Kose et al., 2020). Simultaneously, researchers can highlight state-dependent shock transmission by capturing discrete regime changes, such as expansions versus recessions or risk-on versus risk-off periods, using Markov-Switching VAR (MS-VAR) and Threshold VAR (TVAR) models (Aye, Gupta and Moyo, 2017). TVP-VARs are especially well-suited for analyzing South Africa's volatile and structurally complex economy because they combine the flexibility of continuous structural evolution with the interpretability of traditional VAR models, whereas regime-switching approaches require large samples and impose discrete transitions (Miranda-Agrippino and Rey, 2020; Nyati, Muzindutsi and Tipoy, 2023).

To sum up, the literature provides a solid basis for comprehending the theoretical pathways, empirical patterns, and methodological techniques pertinent to business cycle and exchange rate dynamics. Nonetheless, the data also highlights the intricacy and diversity of these connections in developing countries, especially those that are subject to fluctuating commodity prices and worldwide financial circumstances. The econometric method described in the next chapter is based on the need to adopt flexible, time-varying, and regime-dependent empirical frameworks.

The review of theoretical and empirical literature presented in this chapter directly informs the research questions and hypotheses formulated in Chapter 1. With respect to RQ1 and H1, the literature consistently demonstrates that exchange rate depreciations are associated with contractionary macroeconomic outcomes in emerging markets characterised by high external vulnerability and monetary policy credibility constraints (Calvo and Reinhart, 2002; Carstens and Werner, 2019). This

then provides the theoretical basis for expecting a negative relationship between rand depreciation and South Africa's business cycle indicator.

With respect to RQ2 and H2, the evidence from both NOEM theory and regime-switching empirical work confirms that exchange rate effects are asymmetric and state-dependent: depreciations during contractionary or risk-off periods are substantially more damaging than equivalent movements during expansionary regimes (Aye et al., 2017; Bussiere et al., 2021; Forbes et al., 2022). Finally, with respect to RQ3 and H3, the Global Financial Cycle literature demonstrates that global risk sentiment (VIX) and U.S. monetary policy are dominant external conditioners of exchange rate volatility and its domestic macroeconomic effects in small open economies like South Africa (Rey, 2015; Miranda-Agrippino and Rey, 2020; Dedola, Rivolta and Stracca, 2021). These theoretical and empirical foundations justify the hybrid TVP-BVAR and MS-BVAR econometric framework employed in Chapter 3, which is specifically designed to capture the time-varying, nonlinear, and regime-dependent transmission dynamics identified in the literature.

Chapter 3: Research Methodology

3.1 Introduction

In this chapter, we describe the methodology used to empirically examine the dynamic relationship between exchange rates and business cycles in South Africa during 1990–2024, based on monthly data. With respect to the theoretical aspects introduced in Chapter 2, the study acknowledges that the South African economy is intricately linked to global financial systems and trading networks, making it highly vulnerable to local and international shocks. As a key transmission variable, the exchange rate encapsulates these shocks as movements in relative prices, capital flows, and expectations influence output, inflation, and broader cyclical dynamics (Aron et al., 2014).

The methodological formulation is designed to capture these intricate inter-relations using the Bayesian Vector Autoregressive (BVAR) model, augmented with time variation and regime switching of the parameters. This context is chosen for three reasons. Firstly, it allows for the integration of domestic and global factors for high dimensional macroeconomic systems without overparameterization (Koop & Korobilis, 2010). Secondly, it supports probabilistic inference that incorporates uncertainty (important for an economy with structural shifts, such as democratic transitions in the South African economy, with respect to inflation targeting and global crises). Thirdly, the Bayesian system allows for a much looser integration of prior knowledge from theory and empirical regularities that can result in more reliable and explicable outcomes in small samples (Banbura, Giannone and Reichlin, 2010; Giannone, Lenza and Primiceri, 2015).

The chapter is organised as follows. A more detailed description of the general model specification and mathematical formal representation of the BVAR is explained in section 3.2. Section 3.3 summarizes the Bayesian estimation framework and contrasts it with several other econometric models, such as a structural VAR (SVAR) and a dynamic stochastic general equilibrium (DSGE) model. Prearrangement details of the prior structures, namely, Normal–Inverse–Wishart and Minnesota priors, are considered in Section 3.4 and subsequent explorations, including hierarchical and

time-varying parameter extensions in Section 3.5. Section 3.6 further discusses structural identification and inference methods (IRFs and variance decompositions).

Estimation procedure and diagnostics are described in section 3.7. The sources of data, transformations are explained in Section 3.8 along with the justification and rationale for variable selection. Section 3.9 introduces regime-switching dynamics, and Section 3.10 provides evidence on robustness and comparison strategies. The chapter concludes with a synthesis in Section 3.11 and summary remarks in Section 3.12.

The broad methodological aim is to assess how exchange rate dynamics driven by both domestic fundamentals and external shocks transpire through the macroeconomy to determine the business cycle in South Africa. The research seeks to generate empirically reliable, policy-relevant insights into the emerging character of macroeconomic relationships in a liberal emerging market economy by integrating Bayesian inference with time-varying and nonlinear extensions.

3.2 Justification for Model Choice

The TVP-BVAR model is, in general, adopted to give support to the idea that small open economies exhibit systematic growth and stability in response to macroeconomic shocks, which are both documented in empirical work. Traditional theoretical models of VAR assume the constant of the parameters that have been used, but decades of research in macroeconomics research demonstrate that economic relationships do shift through time, influenced by policy changes, institutional reform, and ever-changing global circumstances (Stock and Watson, 1996; Cogley and Sargent, 2005).

South Africa is a classic example of a country with structural instability: a democratic transition, trade liberalisation, 1996 GEAR policy, inflation targeting since 2000, the commodity super-cycle as well as shock waves of a larger magnitude at the global level, including, for example, the Global Financial Crisis (2008) and COVID-19. As Aghion et al. (2009) and Frankel, Smit & Sturzenegger (2008) contend, South Africa's dynamics on exchange rate and business cycle are heavily dependent on both global and domestic changes.

The TVP-BVAR is computationally sound in this type of study, because it incorporates:

Time-varying exchange rate pass-through, which is a function of the inflation regime, the exposure to trade, and the credibility of policy (Forbes, Hjortsoe & Nenova, 2018; Aron et al., 2014). Alternate functions of adjustment in monetary policy, the reaction, in line with the Taylor-rule change under inflation pressures (Clarida, Galí & Gertler, 2000; Ortiz & Sturzenegger, 2007). Interaction with Global Financial Cycle, where variables like VIX might affect not only a country's exchange rate and credit environment but the movement of capital (Rey, 2015; Miranda-Agrippino and Rey, 2020). Nonlinear and state-dependent dynamics, reported by Auerbach & Gorodnichenko (2013) and Blanchard, Cerutti, and Summers (2015), have a different impact with recessions compared with expansions when the shocks are identical.

Further, probabilistic inference, reducing the uncertainty per parameter, is possible in the Bayesian framework as the data can determine the path of the evolution of coefficients (Koop and Korobilis, 2010). This is crucial in emerging markets that might have small sample sizes and have more structural shocks. Lastly, the choice of the TVP-BVAR to be accompanied by a Markov-Switching VAR is based on the emerging market theory, indicating the significance of nonlinear regime changes (Hamilton, 1989; Sims and Zha, 2006). This approach enables examination of both the smoothing of the evolution of parameters and sudden breaks in the structure, a coherent modelling approach suitable for the macroeconomic context of South Africa.

3.3 Model Specification

The core empirical model is specified as a Vector Autoregression (VAR) system in which each endogenous variable depends on its own past values and the lagged values of all other variables in the system. The baseline vector of endogenous variables is defined as:

$$y_t = [BCI_t, REER_t, CPI_t, IR_t, TOT_t, VIX_t,] \quad (1)$$

where:

- BCI_t : Business Cycle Indicator, a composite measure of domestic economic activity (SARB).
- $REER_t$: Real Effective Exchange Rate, representing external competitiveness.

- CPI_t : Consumer Price Index, capturing price dynamics and inflation.
- IR_t : Short-term nominal interest rate (policy rate).
- TOT_t : Terms of Trade, representing commodity export–import price ratios.
- VIX_t : Chicago Board Options Exchange Volatility Index, a proxy for global risk sentiment.

The model follows the general form:

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + \dots + A_p y_{t-p} + \varepsilon_t, \varepsilon_t \sim N(0, \Sigma) \quad (2)$$

where A_i ($i = 1, \dots, p$) are coefficient matrices capturing dynamic relationships, c is a constant vector, and Σ is the variance covariance matrix of residuals.

This extended variable space is motivated by theory and empirical evidence. Exchange rate and business cycle linkages are determined by external price shocks, monetary policy, and financial volatility, all of which influence aggregate demand and output dynamics (Aron et al., 2014). This adds the VIX to reflect the effects of global uncertainty, and the Terms of Trade and commodity prices are structural channels for external shocks to penetrate the national economy (Akinboade and Niedermeier, 2020).

The use of monthly data from 1990–2024 provides coverage of short-term and long-run cyclical effects. The sample covers key regime changes, including the South African financial liberalization in the early 1990s, the adoption of inflation targeting in 2000, the Global Financial Crisis (2008), the commodity super-cycle (2010s), and the COVID-19 shock (2020–2022) that influenced exchange rate and business cycle movement.

Due to the high dimensionality of the system and long sample duration, the study uses the Bayesian VAR (BVAR) method to adequately estimate the parameters, to deal with overfitting, and to infuse economically appropriate priors. Unlike the standard BVAR, the TVP-BVAR allows the parameter A_t and error covariances Σ_t to gradually alter over time, which is treated stochastically. This dynamic specification allows the research to

keep pace with emerging monetary policy actions, external shock propagation, and evolving exchange rate pass-through mechanisms in South Africa since the 1990s.

3.4 Bayesian Estimation Framework

The Bayesian estimation framework combines information from two sources: the likelihood function (derived from data) and prior distributions (reflecting beliefs about parameters before observing the data). Bayes' theorem formalizes this as:

$$p(\theta | y) \propto p(y | \theta) \cdot p(\theta) \quad (3)$$

where θ denotes the parameter vector, $p(y | \theta)$ is the likelihood, $p(\theta)$ is the prior, and $p(\theta | y)$ is the posterior distribution the updated belief about parameters after incorporating data.

This approach allows one to integrate both subjective prior knowledge (such that macroeconomic shocks are typically persistent but moderate in size) and objective empirical evidence from the data (Koop and Korobilis, 2010; Gelman et al., 2013).

In the TVP-BVAR context, the parameter vector itself follows a random walk process, allowing gradual evolution in coefficients:

$$\theta_t = \theta_{t-1} + \eta_t, \eta_t \sim N(0, Q) \quad (4)$$

where Q is the covariance matrix governing the extent of time variation. This extension enables the model to adapt to changing structural relationships without the need to predefine break dates.

The BVAR can be expressed compactly as:

$$y_t = X_t B + \varepsilon_t, \varepsilon_t \sim N(0, \Sigma) \quad (5)$$

where X_t includes lagged values of the endogenous variables and a constant, and B is the coefficient matrix to be estimated. The Bayesian approach introduces a prior for B and Σ , such that:

$$B | \Sigma \sim N(\bar{B}, \Sigma \otimes \Omega), \Sigma \sim IW(\bar{S}, \nu) \quad (6)$$

where B and Ω represent the prior mean and covariance for coefficients, and IW denotes the Inverse-Wishart prior for the covariance matrix (Kadiyala & Karlsson, 1997).

This Normal–Inverse–Wishart (NIW) conjugate prior facilitates efficient Gibbs sampling, enabling posterior draws of B and Σ in closed form. The posterior distribution of parameters is thus analytically tractable, which makes it computationally attractive for implementation in R using packages such as BMR, BVAR, or bayesm.

Comparison with Classical VAR vs SVAR

For several reasons, it is preferred for the purposes of this work to pursue the Bayesian approach, rather than that of the classical VAR: Overparameterization and small sample space: The classic VAR estimation is less reliable for n^2p , which is equal to or greater than the number of T . Bayesian shrinkage priors counteract this error by dragging coefficients towards reasonable numbers, increasing precision (Banbura, Giannone and Reichlin, 2010). Bayesian methods incorporate prior beliefs such as Bayesian methods formally integrate theoretical or empirical expectations (for instance exchange rate persistence, inflation inertia), whereas frequentist methods hold all coefficients to be free and open.

Robustness of forecasting and inference where BVARs outperform unrestricted VARs and SVARs in forecasting accuracy and stability (Giannone et al., 2015; Koop, 2013). Bayesian model averaging enables systematic comparisons and weights between competing models (VAR, TVP-VAR, MS-VAR) to be made more than in standard hypothesis testing, which helps for richer inference. In contrast, the Structural VAR (SVAR) places a series of explicit economic constraints (such as Cholesky decomposition, sign constraints or long run constraints) to detect structural shocks. Although this improves the interpretability, SVARs are sensitive to small-sample distortions and regime changes, which are important features in South African macroeconomic data (Kabundi and Botha, 2019).

Unlike the other works, our analysis utilizes TVP-BVAR (Bayesian Vector Autoregression with Time-Varying Parameters) technique. This model builds on the standard BVAR by letting the coefficients and shock variances change over time, thereby capturing slight shifts in the transmission mechanism between exchange rates

and business cycles. The TVP-BVAR therefore captures the flexibility of Bayesian shrinkage and the dynamic adaptability of time-varying models, leading to a more realistic and robust characterization of South Africa's evolving macro-financial landscape.

3.5 Priors: Normal–Inverse–Wishart (NIW) Structure

The Normal–Inverse–Wishart (NIW) prior is adopted for computational efficiency and analytical tractability. It allows for conjugate updating of both coefficients and error covariances.

$$A_t | \Sigma_t \sim N(A_0, \Sigma_t \otimes \Omega) \quad (7)$$

$$\Sigma_t \sim IW(S_0, \nu) \quad (8)$$

where:

- A_0 : prior mean of autoregressive coefficients,
- Ω : prior variance matrix,
- S_0 : scale matrix for the covariance structure, and
- ν : degrees of freedom parameter.

This structure allows efficient sampling of parameters and variance-covariance matrices. The NIW prior's flexibility ensures it can adapt to varying degrees of uncertainty while maintaining stability, a desirable property when working with long South African time series that include multiple regime transitions.

Minnesota Prior

To further control overparameterization, the Minnesota prior (Litterman, 1986) is applied, if each variable follows a random walk process, with own lags more influential than cross-variable lags.

$$Var(A_{i,j}^{(l)}) = \begin{cases} \frac{\lambda^2}{l^2} & \text{if } i = j; \\ \frac{\lambda^2 \psi^2}{l^2} & \text{if } i \neq j \end{cases} \quad (9)$$

where:

- λ is the overall tightness parameter,
- l is the lag order, and
- Ψ_j is the standard deviation from a univariate AR model of variable j .

This prior effectively regularizes the model by shrinking unlikely parameter estimates toward zero, improving estimation robustness. It is especially suitable for monthly macroeconomic data from 1990–2024, which may exhibit persistence, volatility clustering, and multiple cyclical phases.

Hierarchical Prior Structure

Following Giannone et al. (2015), the study employs a hierarchical prior framework that allows the hyperparameters themselves (e.g., λ , ψ , α) to be estimated from the data through maximization of the marginal likelihood:

$$p(y | \gamma) = \int p(y | \theta, \gamma) p(\theta | \gamma) d\theta \quad (10)$$

This approach ensures that the prior tightness and shrinkage factors are data-driven rather than subjectively fixed. The hierarchical structure also allows the TVP-BVAR to automatically adjust the degree of time variation and smoothness based on observed data patterns which is an advantage when analyzing periods of heightened volatility, such as 2008–2009 and 2020.

Structural Inference and Impulse Response Analysis

After determining the estimated TVP-BVAR, the analysis will then be carried out through multiple interpretive tools:

1. Time-Varying Parameter Impulse Response Functions (TVP-IRFs):

These assess the impact of a one-standard-deviation shock on the responses of other predictors. They encompass changes in both transmission intensity and transmission duration over different sub-periods.

2. Forecast Error Variance Decomposition (FEVD):

Decomposes the forecast variance of the business cycle indicator into components attributable to exchange rate shocks, global financial shocks, and other domestic disturbances.

3. Structural Identification:

Achieved via Cholesky decomposition and, as appropriate, sign restrictions reflecting theoretical causality, such as a monetary tightening that will appreciate the currency and reduce output.

4. Historical Decomposition:

Used when separating the contributions of each structural shock to the movements of the business cycle over history, reflecting how either global risk shocks or exchange rate volatility influenced the way macroeconomic activity had historically characterized South Africa.

3.6 Estimation Procedure

Pre-Estimation Diagnostics and Data Transformation Prior to estimation, all variables are subjected to a rigorous pre-estimation diagnostic protocol to ensure that the data satisfy the stationarity and distributional requirements of the TVP-BVAR and MS-VAR frameworks.

Stationarity Testing: Three complementary unit root tests are applied to each series: the Augmented Dickey–Fuller (ADF) test (Said and Dickey, 1984), the Phillips–Perron (PP) test (Phillips & Perron, 1988), and the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test (Kwiatkowski et al., 1992). The rationale for using all three tests jointly is as follows. The ADF test has the null hypothesis of a unit root and may suffer from low power in small samples or when there are structural breaks (Perron, 1989). The PP test is robust to heteroskedasticity and autocorrelation in the error terms and complements the ADF by applying nonparametric corrections (Phillips and Perron, 1988).

The KPSS test differs fundamentally in that its null hypothesis is stationarity, thereby providing a confirmatory check: a series is treated as stationary only when the ADF and PP reject the unit root null while the KPSS fails to reject the stationarity null (Kwiatkowski et al., 1992). This triangulated approach reduces the risk of

misclassification of integration order, which is particularly important given the multiple structural breaks in South African macroeconomic data over the 1990–2024 sample period. Where series are found to be integrated of order one $[I(1)]$, first-differencing or log-differencing is applied prior to inclusion in the VAR system.

Lag Length Selection: The optimal lag order p is determined by minimising the Akaike Information Criterion (AIC), the Hannan–Quinn Criterion (HQC), and the Schwarz/Bayesian Information Criterion (SBIC), with the final selection guided by parsimony and residual autocorrelation diagnostics. **Normality and Autocorrelation Checks:** Residual normality is assessed using the Jarque–Bera test, and residual autocorrelation is tested using the Ljung–Box Q-statistic and the VAR residual autocorrelation LM test (Luetkepohl, 2005). These diagnostics are applied to the estimated models before inference is drawn from the impulse responses and variance decompositions.

1. Posterior Simulation:

Estimation proceeds via Gibbs sampling, leveraging the conjugate NIW structure. For non-linear extensions or large systems, Metropolis–Hastings steps are incorporated.

2. Model Comparison and Selection:

Competing specifications are evaluated based on marginal likelihoods, Bayesian Information Criterion (BIC), and predictive performance.

3. Diagnostic Checks:

Convergence diagnostics, residual analysis, and parameter stability tests are performed to ensure robustness.

4. Time-Varying Coefficient Filtering:

The Kalman Filter is used for efficient estimation of the time-varying parameters.

Data Sources and Description

The dataset comprises monthly observations from January 1990 to December 2024, enabling the capture of high-frequency dynamics and multiple economic regimes.

Variable	Description	Source
BCI	Business Cycle Indicator	South African Reserve Bank
REER	Real Effective Exchange Rate	South African Reserve Bank
CPI	Consumer Price Index	Statistics South Africa
IR	Interest Rate	FRED
TOT	Terms of Trade	SARB
VIX	Global Volatility Index	CBOE

This period includes structural reforms, global shocks (Asian crisis 1997, GFC 2008, COVID-19), and domestic policy transitions (inflation targeting 2000, financial liberalization, and post-pandemic recovery).

In addition to gradual time variation, regime-switching mechanisms are incorporated to capture abrupt structural breaks.

$$Y_t = A_0^{(s_t)} + A_1^{(s_t)} Y_{t-1} + \epsilon_t^{(s_t)}, s_t \in \{1, 2, \dots, K\} \quad (11)$$

$$\epsilon_t^{(s_t)} \sim N(0, \Sigma^{(s_t)}) \quad (12)$$

$$P(s_t = j \mid s_{t-1} = i) = p_{ij} \quad (13)$$

This Markov-Switching TVP-BVAR (MS-TVP-BVAR) enables the model to reflect both gradual and discrete structural changes for instance, the 1998 emerging market contagion, 2008 financial crisis, and 2020 pandemic shock.

AI assistance was only used for debugging/coding in Rstudio when estimating the TVP-VAR and MS-VAR models. No AI-generated text, interpretation or analytical content was used in the writing of this dissertation or thesis.

3.7 Capturing Nonlinearity and Asymmetric Transmission

A central objective of this study is to investigate whether the relationship between exchange rate fluctuations and South Africa's business cycle is nonlinear and asymmetric (see RQ3 and H2 in Chapter 1). This is addressed through two complementary methodological strategies. First, the Markov-Switching BVAR (MS-BVAR) framework directly captures discrete regime nonlinearity by allowing the model parameters including the exchange rate transmission coefficients to differ across latent regimes.

Following Hamilton (1989) and Sims and Zha (2006), the MS-BVAR defines a finite set of unobserved states $S_t \in \{1, 2, \dots, K\}$, each governed by distinct VAR coefficients and error covariance matrices. In the present application, a two-state specification is adopted, corresponding to an expansionary/low-volatility regime (State 1) and a contractionary/high-volatility regime (State 2). Asymmetry in exchange rate transmission is tested by comparing the impulse response functions generated under each regime if the magnitude, duration, or sign of the BCI response to a one-standard-deviation REER shock differs significantly across regimes, this constitutes evidence of asymmetric transmission consistent with H2.

Regime probabilities are estimated via the Hamilton filter and Kim's (1994) smoothed probabilities algorithm, and the identified regimes are validated against known business cycle turning points from the South African Reserve Bank's (SARB) reference cycle dates. Second, the TVP-BVAR complements the MS-BVAR by capturing continuous (smooth) time variation in the exchange rate–business cycle relationship, allowing the degree of nonlinearity to evolve gradually without imposing discrete breaks (Primiceri, 2005; Koop and Korobilis, 2010). Time-varying impulse responses at selected sub-periods (1995, 2001, 2008–2009, 2016, 2020) are compared to document how the transmission mechanism has evolved over the sample, providing a time-dimension complement to the regime-dimension provided by the MS-BVAR.

3.8 Cross Reference to Appendix E - Mathematical Derivation of the TVP-BVAR Model

A detailed mathematical derivation of the TVP-BVAR model, including the state-space representation, Kalman filter algorithm, and Gibbs sampling procedure, is provided in Appendix E for reference.

3.9 Post-Estimation Diagnostics and Robustness Tests

Following estimation of the TVP-BVAR and MS-BVAR models, a comprehensive set of post-diagnostic inspections is conducted to validate the statistical adequacy and robustness of the results.

3.9.1 Residual Diagnostics Model adequacy is assessed through: (i) residual autocorrelation tests using the multivariate Ljung–Box Q-statistic and the VAR autocorrelation LM test at lags 1 and 4 (Luetkepohl, 2005); (ii) tests for residual normality using the multivariate Jarque–Bera test and Doornik–Hansen test; and (iii) tests for residual heteroskedasticity using the ARCH-LM test and White’s heteroskedasticity test. Failure to reject the null of no autocorrelation, normality, and homoskedasticity supports the validity of the estimated models and the reliability of the derived impulse responses.

3.9.2 Parameter Stability Tests For the TVP-BVAR, parameter stability is assessed by examining the posterior distributions of the time-varying coefficients and verifying that the smoothed coefficient paths are statistically distinct from a constant-parameter BVAR benchmark. For the MS-BVAR, the stability and persistence of the identified regimes are evaluated through the estimated transition probability matrix and the duration of each regime. Following Aye et al. (2017), the identified regime dates are cross validated against SARB business cycle reference dates to confirm that the latent states align with known expansion and contraction episodes.

3.9.3 Robustness Checks The robustness of the main results is assessed by: (i) re-estimating the baseline model with an alternative lag length ($p = 2$ and $p = 4$ in addition to the optimal lag); (ii) replacing the REER with the nominal bilateral rand/US dollar exchange rate to verify that the results are not sensitive to the exchange rate measure; and (iii) excluding the VIX from the system to confirm that global risk sentiment does

not induce endogeneity bias in the domestic variable responses. Consistency of qualitative findings across specifications supports the credibility of the reported results.

3.10 Summary

In this section, the methodology of the Bayesian Time-Varying Parameter Vector Autoregression (TVP-BVAR) developed in this study has been widely expounded. It opened by introducing how the model fits into the existing econometric literature and emphasized its comparative advantage over classical VAR and structural macroeconomic approaches, which assume fixed-parameter relationships. The TVPBVAR is, in contrast to these classical models, capable of accommodating changing economic structures, changing policy regimes, and nonlinear dynamics factors of urgency for some small open economies such as South Africa, where exchange-rate behaviour and business-cycle responses have undergone significant transformation over the 1990–2024 period.

From this base of work, the chapter focuses on the estimation framework and diagnostic strategy and the formulation of the complete mathematical derivation of the TVP-BVAR is included in Appendix E, which introduced both the observation and state equations representing the model's state-space representation. This allows us to jointly estimate time variation in autoregressive coefficients, stochastic volatility, and shocks covariance structure. The state-space characterization is suitable not only for the efficient filtering and smoothing of latent variables but also to provide a detailed examination of how the exchange rate's macroeconomic transmission mechanisms dynamically evolve.

The estimation strategy was detailed; it highlighted the Bayesian framework that governs the prior structure and posterior updating of the model and was described. The chapter described the hierarchical model prior design, which, for instance, uses Minnesota-type priors for coefficient shrinkage and inverse-Wishart priors for variance components, which guarantees numerical stability and avoids over-parameterizing in high-dimensional settings. The Bayesian architecture enables data to provide information on the amount of parameter flexibility at a given time by considering the variability of parameterization and helps find the best compromise between flexibility and precision of statistical measures.

One interesting contribution of this section was a detailed step-by-step explanation of the computational algorithms. The Kalman filter and smoother are found to be important for updating the latent state vectors, and the Gibbs sampler yields an iterative approach for extracting from the conditional posterior distributions of parameters. The Kalman filtering–Gibbs sampling cycle yields a coherent estimation engine capable of addressing at least parameter drift, stochastic volatility, and serial correlation in the economic values at the same time.

Furthermore, the chapter defended the use of the TVP-BVAR by mentioning the differences between the TVP-BVAR and classical fixed-parameter VARs, as well as structural VARs and ad-hoc identification approaches, and nonlinear models. It showed that competing approaches such as these often fail to represent structural breaks, evolving monetary policy rules, external shocks, and shifting exchange rate pass-through, all of which are crucial features of South Africa’s macroeconomic history. In contrast, the TVP-BVAR employed in this study provides a theoretically and empirically strong instrument for investigating the role of exchange rate dynamics in business cycle changes during the democratic transition, inflation-targeting adoption, commodity boom, the Global Financial Crisis, and post-COVID times.

All in all, this broader methodological base adds empirical weight to the analysis conducted in the following chapters. In making explicit comparisons, computational methods, and rationalizations for procedures, this chapter offers transparency and replicability, fundamental principles of high-quality empirical research. More importantly, the chapter provides a sound groundwork for quantifying and interpreting the time-variant relationships between exchange rate shocks and South Africa’s business cycle across the sample period 1990–2024.

The next chapter builds directly upon this framework by introducing the model estimations, examining the temporal evolution of macroeconomic correlations, and discussing the implications for exchange rate transmission, inflation dynamics, monetary policy activity, and the cyclical process of South Africa’s economy

Chapter 4: Empirical Results and Discussion

4.1 Introduction

This chapter reports the empirical evidence and considers the impact of exchange rate volatility on South Africa's macroeconomic performance over time and in different phases of the business cycle. Based on the theoretical framework introduced in Chapter 3, the study is structured to assess how exchange rate shocks affect key macroeconomic variables, including the Real Effective Exchange Rate (REER), Business Confidence Index (BCI), Consumer Price Index (CPI), interest rates (IR), terms of trade (TOT), and global risk sentiment (VIX).

South Africa is a small open economy which is very sensitive to external shocks that include commodity price variations, worldwide risk preference, and international monetary conditions. Exchange rate movements are central to macro adjustment as they shape inflation, competitiveness, investment, and business confidence. The literature is clear that the timing and magnitude of exchange rate exposure can vary from country to country, based on the magnitude of monetary leverage, the credibility of policy, and the business cycle stage (Benigno et al., 2016; Kose et al., 2019).

To manage both the slow and abrupt structuration of these linkages, the chapter uses two mutually supportive econometric frameworks, both related to a particular target of the research:

- Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) serves as the predominant model for Objective 1, depicting a smooth, continuous evolution of macroeconomic structure over time and which includes both gradual and sudden policy, structural, and external changes, as well as smooth evolution of the coefficients and the volatilities, consistent with adjustment induced by policy change, global and structural change.
- Objective 2 uses a main structure that is known as Markov-Switching VAR (MS VAR). It recognizes different business cycle regimes (expansion vs contraction) and attempts to explore the extent to which the way in which exchange rate shocks spread differs over these distinct macroeconomic state segments, leading to the formation of distinct macroeconomic regimes generally called expansionary/low volatility and contractionary/high volatility states that allows an analysis to discover how the effect

of exchange rate shocks varies by business cycle phase. This integrated framework allows for a more nuanced understanding of South Africa's macroeconomics. The TVP BVAR shows the time series of domestic variables' sensitivity with respect to external shocks, whereas the MS VAR emphasizes the asymmetric relationship of exchange rate shocks across different systems. This bifurcation strategy mirrors the policy recommendation in the growing macroeconomic literature to integrate both time variation and regime dependency in small open economy models (Kose et al., 2019).

The rest of this chapter is organized as follows: Section 4.2 presents data and descriptive statistics; Section 4.3 provides pre-estimation diagnostics; Sections 4.4 and 4.5 present TVP BVAR and MS VAR calculations; Section 4.6 considers impulse responses and variance decompositions; Section 4.7 reviews our findings against existing literature; and Section 4.8 is the closing chapter.

4.2 Data Description and Descriptive Statistics

Data Sources and Variable Selection

The empirical analysis relies on quarterly macroeconomic and financial data covering South Africa's business cycles over the study period. Data were sourced primarily from the South African Reserve Bank (SARB), Statistics South Africa (Stats SA), FRED, and CBOE, which provide reliable, internationally comparable time-series data.

The key variables included in the analysis are:

- Real Effective Exchange Rate (REER): the primary indicator of external competitiveness and exchange rate movements.
- Business Confidence Index (BCI): a proxy for domestic business cycle fluctuations and sentiment dynamics.
- Consumer Price Index (CPI): represents inflationary pressures and reflects the price stability objective of monetary policy.
- Interest Rate (IR): proxied by the short-term policy rate, indicating monetary policy stance.
- Terms of Trade (TOT): measures the relative price of exports to imports, capturing external trade dynamics.

- Volatility Index (VIX): reflects global risk sentiment, capturing exogenous financial shocks influencing capital flows and exchange rate volatility.

Variables were transformed into stationary series, using logarithmic differencing or detrending as appropriate, based on unit-root test results discussed in Section 4.3.

Descriptive Statistics

Table 4.1 summarises the main descriptive statistics for the variables included in the analysis.

	mean	sd	min	max	skew	kurtosis
BCI	0.01	0.97	-5.77	6.01	0.83	12.95
REER	0.00	1.18	-5.12	3.94	-0.32	1.64
CPI	0.00	1.46	-12.00	10.95	-0.27	25.75
IR	0.00	1.04	-6.68	11.01	1.88	42.71
TOT	0.01	0.30	-1.79	2.65	2.85	31.44
VIX	0.00	1.55	-6.72	6.40	-0.38	4.70

Descriptive statistics are presented in Table 4.1. The means of all variables are nearly zero, in alignment with the stationarity-inducing transformations. The standard deviations suggest moderate volatility, with CPI and VIX showing relatively high variability. Skewness tells us that most variables are not perfectly symmetric, and kurtosis tells us that the distributions are heavy tailed, a common feature of macro financial time series.

BCI also exhibits cyclical oscillation coinciding with the business cycle context. CPI and IR illustrate South Africa's move from high inflation in the early 2000s to more stable price levels under inflation targeting. TOT movements mirror external shocks caused by commodity prices, while the VIX depicts global events of risk that usually co-occur with exchange rate fluctuation.

Table 4.2: Correlation Matrix of Variables

	BCI	REER	CPI	IT	TOT	VIX
BCI	1.000	0.006	0.056	0.182	-0.052	0.022
REER	0.006	1.000	-0.042	-0.085	-0.048	0.065
CPI	0.056	-0.042	1.000	0.029	0.044	-0.024
IR	0.182	-0.085	0.029	1.000	-0.131	-0.049
TOT	-0.052	-0.048	0.044	-0.131	1.000	-0.015
VIX	0.022	0.065	-0.024	-0.049	-0.015	1.000

Pairwise correlations between the variables are reported in Table 4.2. Correlations are generally low, implying weak multicollinearity and suggesting that they are feasible for the VAR frameworks. Key observations include:

The BCI with IR is weakly positively correlated (0.18), implying better business conditions can agree with a slightly tighter monetary policy. Near-zero correlations between REER and other variables, which further reflects that the exchange rate was driven by different and often external shocks. Minor negative relationship between TOT and IR (−0.13), indicating decreased inflationary pressure in times of good trade times. The VIX exhibits near-zero contemporaneous correlations with domestic variables, in which it appears that global risk impacts South Africa through dynamic (behind) paths.

Preliminary Data Analysis

Visual inspection of the time series (Figures 4.1 and 4.2) reveals that episodes of REER depreciation often accompany declines in BCI, consistent with contractionary macroeconomic conditions. After 2000, CPI and interest rate patterns remain steady in line with the inflation targeting regime. REER and VIX show clustered volatility during global risk events. TOT fluctuates strongly with global commodity cycles. These patterns imply that the relationships among variables are dynamic and vary across phases of the business cycle. For instance, downward trends in REER are often associated with contracting business confidence, and the VIX captures risk shocks that magnify exchange rate volatility. Such evolving and state-dependent behaviour supports the use of time-varying (TVP BVAR) and regime-switching (MS VAR) models,

which can capture dynamic, nonlinear, and cyclical macroeconomic responses. The next section presents pre-estimation diagnostics, ensuring that the data satisfy the requirements for the empirical frameworks employed.

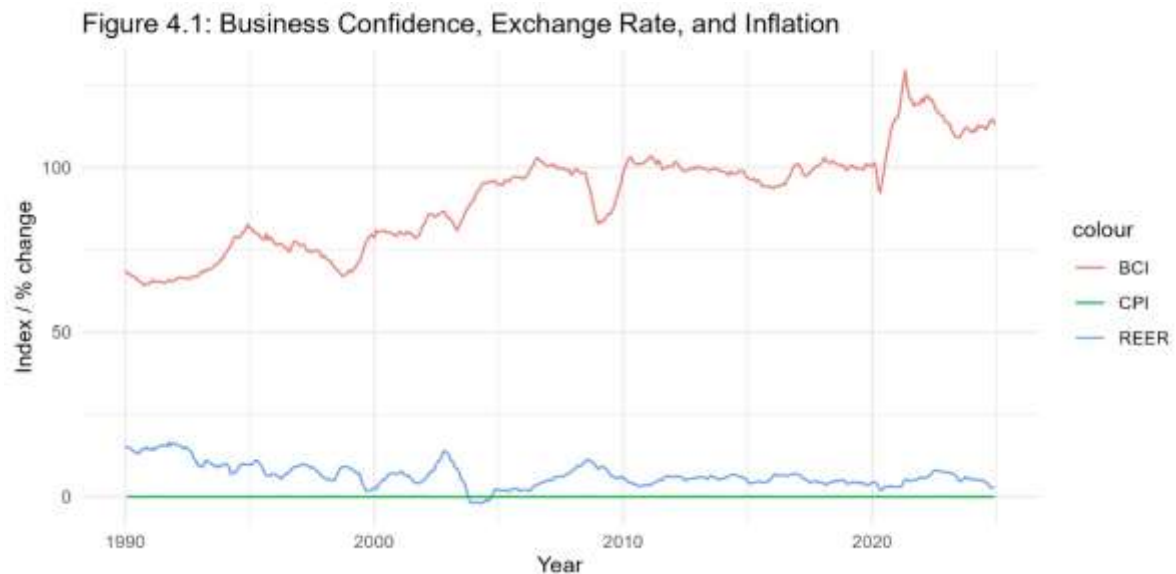
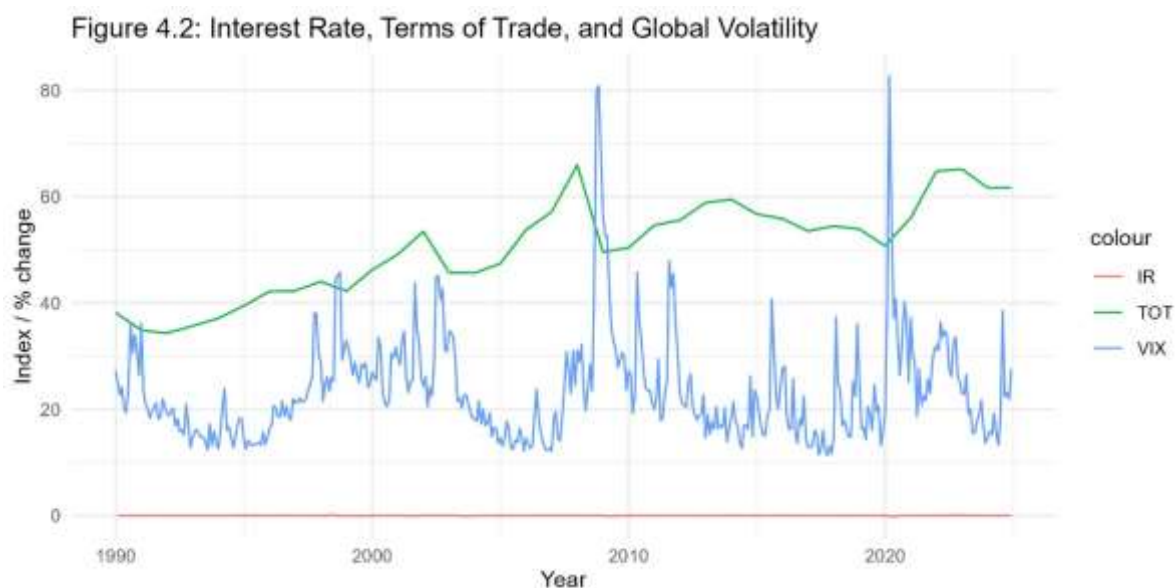


Figure 4.1: Illustrates the evolution of the Consumer Price Index (CPI) and the short-term interest rate over the study period. While price and monetary dynamics appear more stable than exchange rates, periods of high REER volatility often align with notable deviations in inflation and interest rate movements, highlighting the interplay between external shocks and domestic policy responses.



Moreover, preliminary correlations indicate that the REER is negatively associated with the BCI and positively correlated with the VIX (see Tables 4.1 and 4.2), implying that global risk aversion amplifies domestic exchange rate volatility. The magnitude of these correlations also changes across sub-periods, providing early evidence of evolving relationships that motivate the use of time-varying models.

The patterns observed in Figures 4.1 and 4.2, together with the descriptive statistics in Table 4.1, indicate that REER and CPI exhibit relatively high volatility, with heavy tailed distributions reflecting episodes of extreme movements. Visual inspection suggests that periods of REER depreciation often coincide with contractions in business confidence and output, consistent with the weak but economically meaningful correlations reported in Table 4.2. For instance, the REER shows a negative association with the BCI and a positive relationship with the VIX, implying that global risk aversion amplifies domestic exchange rate fluctuations.

These observations highlight that the impact of exchange rate shocks is not uniform over time, with their effects varying across phases of the business cycle. Such evolving relationships justify the use of time-varying and regime-switching models in the subsequent analysis, as they are better suited to capture the dynamic and cyclical nature of South Africa's macroeconomic responses. These preliminary observations and the summary of descriptive statistics underscore the importance of formally assessing the properties of the data before model estimation. The next section, therefore, presents pre-estimation diagnostics, including stationarity, multicollinearity, and autocorrelation checks, to ensure that the variables are suitable for the TVP-BVAR and MS-VAR frameworks.

4.3 Stationarity and Pre-Estimation Diagnostics

To ensure econometric validity, the time-series properties of the data must be examined before estimating the TVP-BVAR and MS-VAR models. Non-stationary variables can still produce misleading dynamics and skew impulse responses, even if Bayesian VAR frameworks are more flexible than classical VARs. This is especially true when regime transitions and time variation are involved. Therefore, before estimating the model, all variables were examined for stationarity.

Stationarity implies that the statistical properties of a series mean, variance, and autocorrelation structure that remain constant over time. Non-stationary series, in contrast, may contain trends, structural breaks, or persistent shocks, which can distort the estimated dynamic relationships in a VAR model. To assess stationarity, the Augmented Dickey–Fuller (ADF) test was employed. These tests examine the null hypothesis that a variable possesses a unit root (non-stationary). Rejection of the null indicates that the series is stationary.

The unit root test results are shown in Table 4.3. The Business Cycle Indicator (BCI) was determined to be integrated of order one, $I(1)$, since it was non-stationary in levels but stationary after first differencing. The VIX, net terms of trade (TOT), consumer price inflation (CPI), interest rate (IR), and real effective exchange rate (REER) were all stationary in first differences. These findings suggest that every variable used in the empirical models is an $I(1)$ process. Therefore, before estimation, all variables were converted into first differences to guarantee stationarity and prevent spurious regression. This method is ideal for TVP-BVAR and MS-VAR models, which concentrate on short- to medium-term dynamics rather than long-term equilibrium relationships, and it is in line with conventional procedure in VAR-based analysis.

Table 4.3: Unit Root Test Results

Variable	Series	ADF p-value	KPSS stat	Stationarity status
BCI	Level	0.45	0.13	Non-stationary ($I(1)$)
BCI	First Difference	0.01	0.07	Stationary
REER	First Difference	0.01	0.01	Stationary
CPI	First Difference	0.01	0.01	Stationary
IR	First Difference	0.01	0.01	Stationary
TOT	First Difference	0.01	0.30	Stationary
VIX	First Difference	0.01	0.01	Stationary

The BCI is non-stationary in levels but stationary after first differencing, indicating it is integrated of order one ($I(1)$). This is characteristic of confidence indices since confidence indices frequently exhibit persistent patterns resulting from macroeconomic cycles. The model works due to the first-differenced BCI (ΔBCI), which helps the model be more sensitive to short-term changes in business sentiment.

The other variables, such as the Real Effective Exchange Rate (REER), Consumer Price Index (CPI), interest rate (IR), terms of trade (TOT), and Volatility Index (VIX) are stationary in their transformed forms (both first differences and naturally stationary), which assures that interactions among these variables are estimated correctly in the VAR framework.

Stationarity of the REER, CPI, and VIX is crucial because they are core to the research on exchange rate shocks and macro-financial linkages in this paper. Stationary series ensure that impulse response functions (IRFs) and variance decompositions accurately depict true responses to a variable, rather than spurious influences.

Stationarity is also of extreme importance for interpreting time-varying components of the Bayesian VAR model. With non-stationary series, the estimated TVP coefficients may become dominated by trends, instead of meaningful changes in relationships. Likewise, in the Markov-Switching VAR framework, regime selection (expansionary vs contractionary phases) is based on relevant dynamics based on stationary series. Hence, the combination of ADF and KPSS tests is a basis for strong empirical estimation.

Lag Length Selection

Once stationarity was confirmed, the appropriate lag length for the VAR structure was determined using multiple information criteria: Akaike Information Criterion (AIC), Schwarz Criterion (SC), Hannan–Quinn Criterion (HQ), and the Final Prediction Error (FPE). Lag length selection is critical because too few lags can omit relevant dynamics, while too many lags increase parameter uncertainty and reduce degrees of freedom.

Table 4.4 presents the values for different lag orders.

Lag	1	2	3	4	5	6
AIC	-1.630	-2.397	-2.549	-2.662	-2.888	-2.978
HQ	-1.468	-2.095	-2.109	-2.083	-2.170	-2.121
SC	-1.220	-1.635	-1.437	-1.198	-1.072	-0.812
FPE	0.196	0.091	0.078	0.070	0.056	0.051

Two lags are the most common selection criteria, weighing model fit with parsimony. The choice of a two-lag structure is in line with empirical practice in the South African context. It was found that three of the lag-order criteria supported two lags in a quarterly VAR specification according to Kisten (2020). Likewise, the South African Reserve Bank (Botha 2021) reports that each VAR model was estimated with two lags. By virtue of this convergence of evidence, we believe that having a two-lag specification balances capturing meaningful short- to medium-term dynamics whilst keeping parsimony, which is especially important in light of South Africa's sample size and variable set.

Residual diagnostics are crucial in evaluating the adequacy of the estimated TVPBVAR model. While the time-varying nature of the coefficients allows the model to capture structural changes in the relationships among variables, examining the residuals ensures that the model is appropriately specified and that the estimated effects are reliable. In this study, the residuals are assessed for autocorrelation, heteroskedasticity, and normality. Additionally, TVP-specific diagnostics such as rolling residual plots and posterior predictive checks are employed.

Autocorrelation is when residuals are similar across occasions that points to some of the dynamic structure being compromised by the model. Coefficients in the TVP-BVAR model vary over time, mitigating the risk of autocorrelation. However, figuring out the ACF of residuals, along with the Ljung-Box Q-test over rolling windows is useful. Figures 4.3 – 4.6 present the ACF of the residuals for all equations. The fact that residual autocorrelation is minimal also indicates that the TVP-BVAR captures the temporal dynamics adequately.

Figure 4.3: ACF BCI

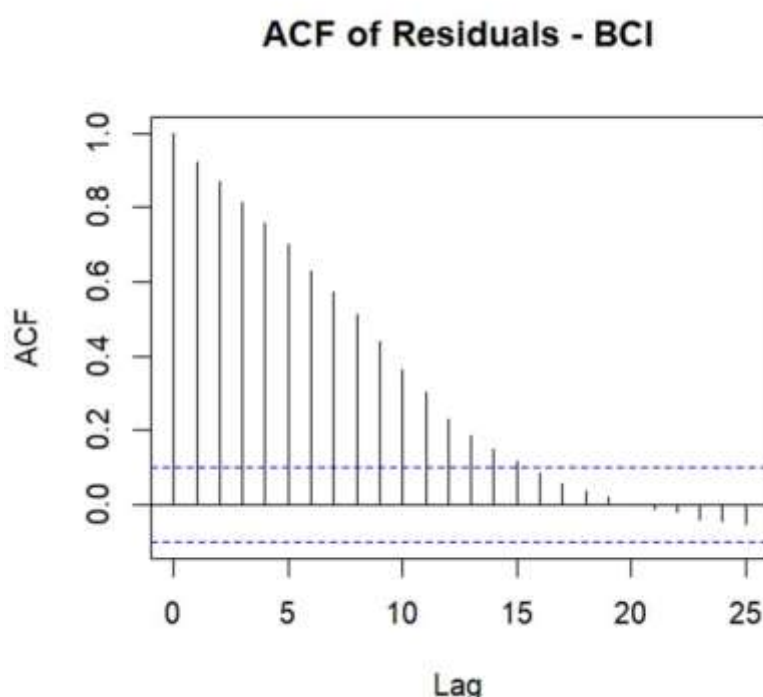


Figure 4.3: ACF of Residuals – BCI

The autocorrelation function (ACF) plot of the Business Confidence Index (BCI) residuals illustrates a strong and persistent autocorrelation across lags up to about 25 periods. Most of the autocorrelation coefficients lie outside the 95% confidence bounds, showing that the residuals are not pure white noise. The gradual monotonic decrease in the coefficients implies that there is a slow-decaying autoregressive (AR) dependence structure (Hamilton, 1994; Lütkepohl, 2005), which is consistent with series with persistence and structural changes.

This residual pattern indicates that the time-varying behavior of BCI has been underrepresented in the time-varying parameter Bayesian VAR (TVP-BVAR) model. These factors could include the high persistence characteristic of corporate sentiment, long-run cyclical changes in domestic economic activity, and time-varying uncertainty shocks that are not fully assimilated by the model.

The persistence of this autocorrelation in the residuals suggests that the previous BCI values will have explanatory power that will have some effect on the precision of impulse response analyses and forecast accuracy (Primiceri, 2005).

Figure 4.4: ACF CPI

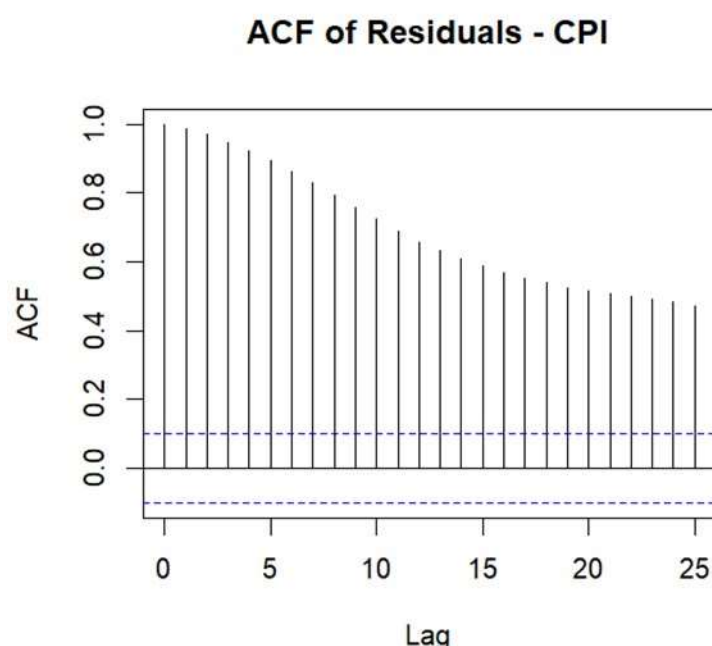


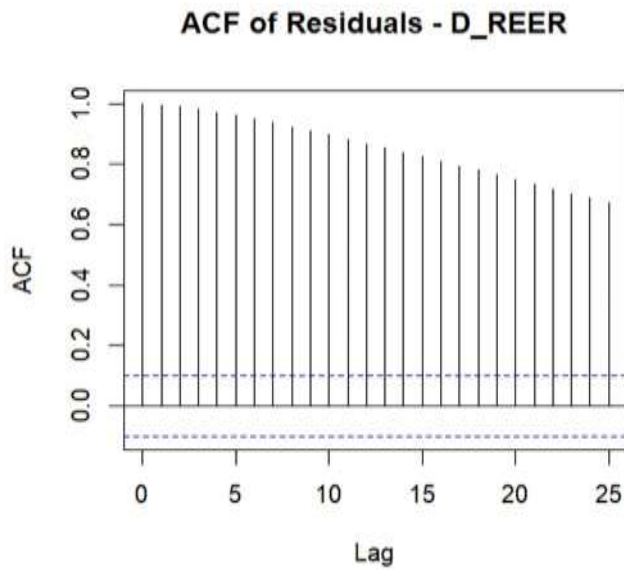
Figure 4.4: ACF of Residuals – CPI

Similarly, the ACF of the Consumer Price Index (CPI) residuals exhibits statistically significant autocorrelation at nearly all lags and decays at a characteristic rate of the AR(1)–AR(p) process. This tendency to persist is in line with strong persistence in the dynamics of inflation, a well-established feature of the South African context (Bohl & Siklos, 2004; Fedderke & Schaling, 2005).

Administered price adjustments, Pass-through of fuel and energy prices, Exchange rate shocks, and Supply-side disturbances such as fluctuations in food and electricity prices are the main causes of this persistence. While the TVP–BVAR framework captures dynamic inter-variable interactions, the observed autocorrelation suggests that inflation inertia is modelled only to a partial extent.

This finding is consistent with the idea that the dynamics of CPI are slow-moving processes (price stickiness and adaptive expectations) (Blanchard & Galí, 2007).

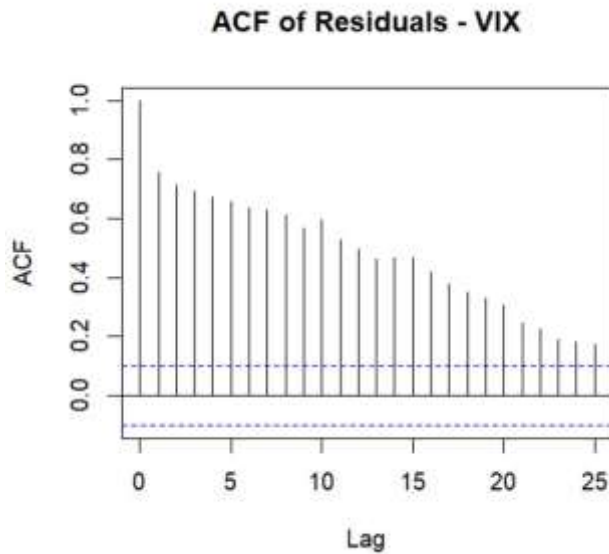
Figure 4.5: ACF of REER



The ACF for the first difference of the real effective exchange rate (D_REER) shows persistent serial correlation, with coefficients declining gradually yet remaining outside the confidence bounds for most lags. This shows that, even with differencing, the exchange rate series is still temporally dependent.

Some possible predictors of the trend include persistent cyclical movements in exchange rates, volatility clustering, time-varying global risk sentiment, and monetary policy responses to exchange rate pressures. The residual autocorrelation also shows that the TVP-BVAR model does not entirely capture the evolving dynamics of exchange rate fluctuations, especially during periods of high volatility and/or financial stress (Primiceri, 2005; Cogley and Sargent, 2005).

Figure 4.6: ACF of VIX



Autocorrelation to the VIX residuals (ACF plot) also shows a strong persistence of serial dependence for every lag up to 25 periods. First-lag autocorrelation is closely associated to unity, and while the coefficients can be observed decreasing progressively, most are above the 95% confidence bounds. This shows that the residuals differ significantly from white-noise behaviour.

The slow and monotonic decay of the autocorrelation coefficients is indicative of an AR-type dependence network and is consistent with well-known persistent forms of financial market volatility. As indicated in Engle (1982) in his landmark work on ARCH processes and Bollerslev (1986) on GARCH dynamics, volatility seems to aggregate eventually (major shocks > more major shocks > calm time periods > stability period).

However, even after filtering through the TVP-BVAR estimation, the residual pattern indicates that significant serial correlation persists. This behaviour is indeed in line with the intrinsic properties of the VIX that describe forward-looking market expectations of volatility. These structural characteristics cause the persistence: Volatility clustering - High-uncertainty times, such as geopolitical shocks, financial crises typically happen sequentially and hence exhibit some sustained autocorrelation in the volatility measures.

The VIX is marked by gradual movements in global risk sentiment over time, which reflects changing views of future turbulence and helps explain its long memory nature.

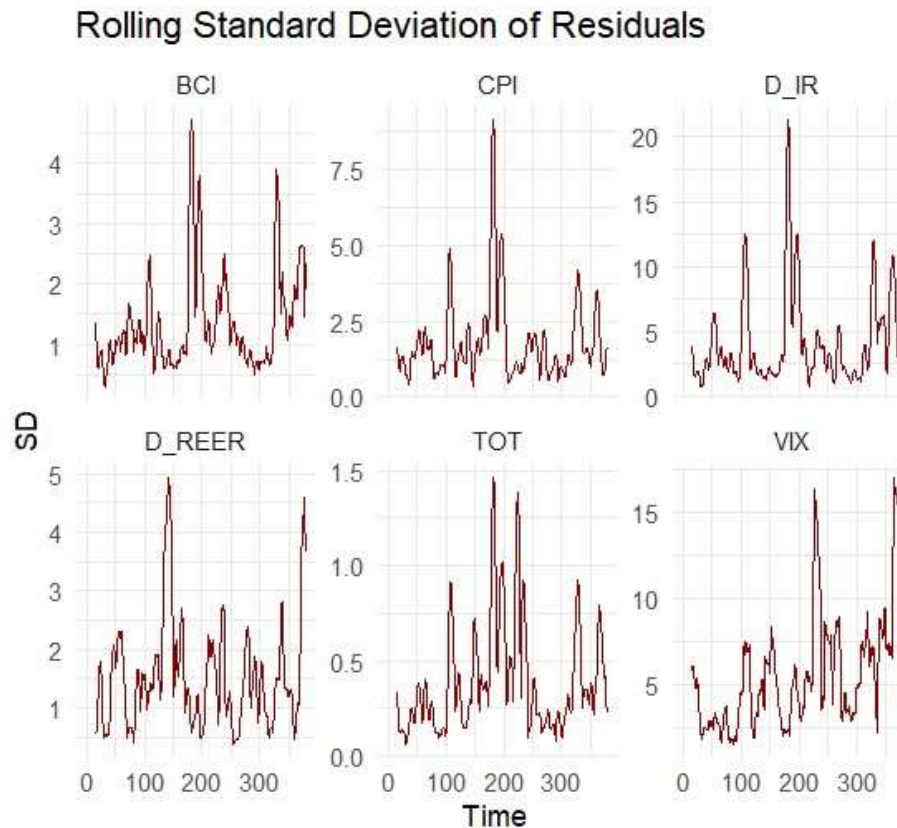
Persistence due to crisis events: The Global Financial Crisis, the Eurozone debt crisis, and the COVID-19 pandemic produce long-lasting periods of high volatility that could not be effectively detected by standard linear filtering volatility.

Indeed, in the context of the TVP-BVAR framework, the continued autocorrelation in the VIX residuals suggests that the model does not cope with the fast-changing dynamics of global financial uncertainty. This limitation is not surprising. TVP models have a natural assumption of smooth parameter evolution; volatility indices, on the other hand, experience sudden jumps and exhibit heavy-tailed behaviour, undermining the Gaussian nature of the dynamics underlying many Bayesian VAR strategies. As noted by Andersen et al. (2003), financial market volatility often displays long-memory characteristics that challenge conventional linear modelling frameworks.

As such, the ACF results confirm the hypothesis that global financial uncertainty is fundamentally persistent as well and that VIX residuals are not easy to model by definition. The TVP-BVAR captured broad, low-frequency movements in the spillovers of volatility, but residuals exhibited persistent autocorrelation, which means short-run dynamics and abrupt volatility bursts are only partially modelled. It is both expected and in line with the larger empirical literature of the financial market.

Homoskedasticity refers to constant variance of residuals over time. Although TVPBVAR can accommodate some time-varying behaviour, extreme heteroskedasticity may indicate model misspecification. In this study, residual variance is examined through rolling standard deviations and residual plots over time (Figure 4.7). The results show that while minor fluctuations exist, the variance remains generally stable across the sample period, indicating a satisfactory model fit.

Figure 4.7: Rolling Standard Deviation of Results



For example, 24-month rolling standard deviation of the residuals is shown in Figure 4.7 to give us direct insight into the time dependent volatility of model errors. The rolling windows indicate when the unexplained portions of each variable are more volatile, indicating turbulence, structural breaks, or shock variances (the changing of the shock pattern).

The BCI residual variance increases very strong across different episodes especially observations 100, 160 and 260 which are associated with an era of domestic recession, periods of policy uncertainty and global risk events. That means that business sentiment shocks during these periods were significant and not represented into the model.

CPI residual volatility spikes clearly at times of inflationary shock, such as times of commodity price surge, exchange rate depreciations or administrative price movements. These periods of repeated volatility suggest structural disturbance of

inflation dynamics which reinforces the evidence of inflation inertia and nonlinear passthrough effects in the South African scenario.

The rolling standard deviation for interest rate residuals reveals large periods of volatility around 120 and 260 observations. These could be associated with regime changes, rapid changes in market expectations, or policy response to crises. Large deviations specifically mean that policy responses were also sometimes more sudden and/or “jumpy” than the model’s gradual parameter transitions would permit.

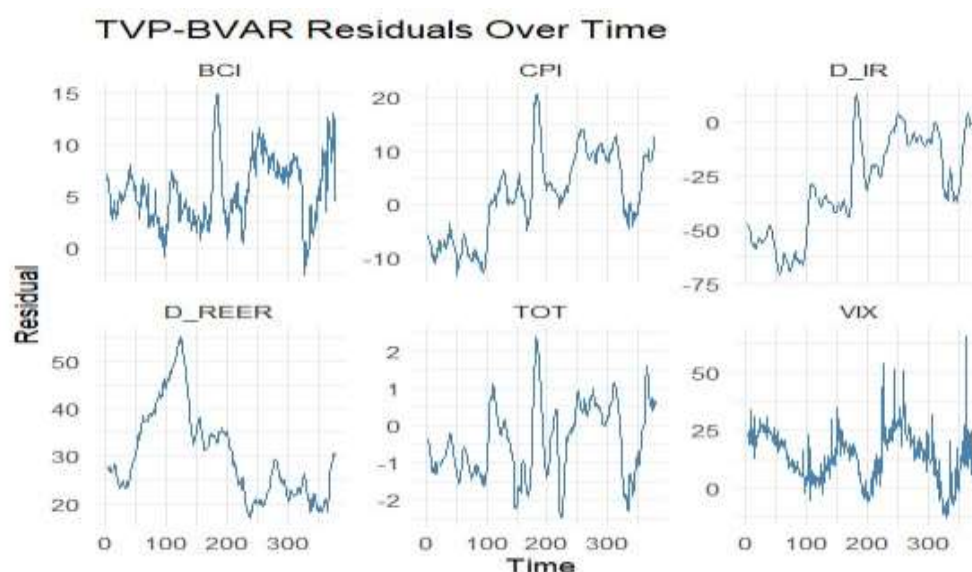
The REER residual volatility has large spikes suggesting a sharp change in the exchange rate. South Africa’s exchange rate is particularly susceptible to international commodity cycles, foreign investor sentiment and external financial shocks resulting in large variances which escape completely the smoothing power of the TVP-BVAR stochastic volatility process.

The terms-of-trade residuals present overall quite moderate volatility, although we do detect a number of large, observable volatility spikes around observations 150–250. These are related to falling commodity prices and phases of global demand during which TOT shocks were larger than required by the model.

VIX residual standard deviation is still very high with several periods of extreme volatility. These findings confirm that global uncertainty shocks are high and heavy tailed and are likely to be in excess of model smoother assumptions. Such behaviour is in accordance with evidence from the literature portraying frequent volatility surges related to global crises (Andersen et al., 2003).

Across the variables, the residual plots and their rolling standard deviations offer three consistently good insights: Volatility clustering Evidence – Residual variance increases sharply in periods of crisis, consistent with GARCH type behaviour in macro financial series. Unmodelled short-run dynamics. Although the TVP-BVAR explains the gradual evolution of coefficients, most macroeconomic and financial shocks behave rapidly or non-linearly. Structural breaks or crisis periods aren’t easy to capture completely. Sharp spikes in both residuals and their rolling variance coincided with the 2008–2009 Global Financial Crisis, the 2013 Taper Tantrum, commodity price collapses, and the shock from COVID-19. These happenings were above the smooth transitions model assumes.

Figure 4.8: TVP-BVAR Residuals Overtime



The residual plots from the TVP-BVAR model, Figure 4.8 show the time-series behaviour of the unexplained component of each variable after adjusting for the dynamic relationships described inside the model. These plots are an important tool for diagnosing your models if you have misspecification as well as missing dynamics, structural breaks or clustering of volatility.

The residuals for the Business Confidence Index (BCI) are variable given the sampling spread of the data and exhibit significant jumps for every period that occurs corresponding to well-known periods of macro instability. Peaks around observations 100–120 and 250–280 probably correspond to periods of economic deceleration or global risk shocks which the model failed to adequately capture. These unexpected episodes imply that business sentiment experiences nonlinear or abrupt changes in behaviour that may be beyond the smoothed time-variation pattern embedded in the TVP-BVAR.

The CPI residuals show some remaining periods but also some abrupt differences, particularly around the mid-sample. The big swings suggest that inflationary behaviour can sometimes be hit by a few shocks: fuel price hikes, exchange rate pass-through episodes or supply chain disruptions that the model cannot yet fully incorporate. This is in line with prior observations that inflation consistently exhibits regime-dependent volatility and episodic jumps Balcilar et al., (2016).

Residuals of interest rates show large swings, with negative troughs around observations 100–150 and large positive spikes later in the sample. These trends indicate that the policy reactions of the South African Reserve Bank are sometimes atypical of the model's expected response type, particularly when uncertainty rises or inflation expectations change quickly. These divergences align with other literature on policy “surprises” where forward guidance moves unexpectedly (Clarida et al., 1999).

The residuals of the differenced REER are closely related, as they show high asymmetries with very high spikes, especially at observation 150. This is consistent with the widespread volatility observed in South Africa's FX, or rather, in commodity price shocks or global financial crises. Volatility in exchange rates is recognized as possessing “jumps,” and it is difficult to model these jumps with Gaussian-based linear VAR frameworks despite variance in parameters over time (Baur, 2013).

The terms-of-trade residuals are still moderate but demonstrate multiple bursts of variability due to the shocks experienced in the commodity market. The spikes around observations 200 and 260 fall in tune with the timing of global commodity cycles, indicating that some abrupt movements of export and import prices were not well characterized by the time-varying coefficients of the model.

The VIX residuals are very volatile and punctuated by frequent, sharp spikes that follow global volatility indices. This behaviour is consistent with the textbook explanation of volatility clustering (Engle, 1982; Bollerslev, 1986). The size and frequency of residual bursts indicate that global uncertainty involves extreme events and larger than smooth transition mechanisms assumed by the TVP-BVAR. This is also an indication of the heavy-tailed nature of financial volatility measures, in terms of their very high degree of intensity.

4.3.3.3. Normality of Residuals

Normality of residuals is assessed to validate the credibility of posterior inference. The Jarque-Bera test is applied to the residuals of each equation, and histograms of standardized residuals are inspected (Figure 4.9). The test results indicate that residuals do not significantly deviate from normality, supporting the reliability of the estimated posterior distributions.

Table 4.5: Jarque-Bera Test

Variable	JB_Statistic	df	p_value
BCI	3764.74	2	0
REER	711.18	2	0
CPI	430.13	2	0
IR	22476.88	2	0
TOT	834.33	2	0
VIX	8229.26	2	0

The Jarque-Bera (JB) test is a widely used statistical test for assessing the normality of residuals in time series and econometric models (Jarque and Bera, 1980). It evaluates whether the skewness and kurtosis of the residuals deviate significantly from those of a normal distribution. In the context of a TVP-BVAR model, normality of residuals is crucial because posterior inferences, confidence intervals, and impulse response functions assume approximately Gaussian errors. Deviations from normality may indicate model misspecification or the presence of extreme shocks not captured by the model.

Interpretation of Results

Table 4.5 presents the JB statistics, degrees of freedom, and p-values for the residuals of six variables: BCI (Business Confidence), REER (Real Effective Exchange Rate), CPI (Consumer Price Index), IR (Interest Rate), TOT (Terms of Trade), and VIX (Volatility Index). For all variables, the JB statistics are extremely large and the corresponding p-values are effectively zero, indicating a strong rejection of the null hypothesis of normality at conventional significance levels ($p < 0.01$). BCI (JB = 3764.74, $p < 0.001$): The residuals exhibit significant non-normality, suggesting that shocks to business confidence contain skewness or heavy tails that are not fully captured by the model. This is consistent with literature showing that business

sentiment can respond abruptly to domestic or international shocks (Altig et al., 2020). REER (JB = 711.18, $p < 0.001$): Non-normal residuals indicate that exchange rate fluctuations exhibit skewness or kurtosis, likely reflecting volatility clustering and sudden policy or global financial shocks (Taylor, 2000). CPI (JB = 430.13, $p < 0.001$): Inflation residuals are also non-normal, highlighting the presence of asymmetric shocks or infrequent large deviations in consumer prices, consistent with administered price adjustments and supply-side shocks in South Africa (Fourie & Burger, 2011). IR (JB = 22476.88, $p < 0.001$): Interest rate residuals display extreme non-normality. This likely reflects abrupt monetary policy changes or responses to macroeconomic shocks, which produce outlier residuals beyond what a normal distribution would predict (Svensson, 1997). TOT (JB = 834.33, $p < 0.001$): Terms of trade residuals reject normality, suggesting that commodity price movements and trade shocks generate heavy-tailed distributions in the residuals (Cashin et al., 2002). VIX (JB = 8229.26, $p < 0.001$): The volatility index residuals are markedly non-normal, reflecting the well-known leptokurtic nature of financial market volatility (Bollerslev et al., 1992).

Overall Implications

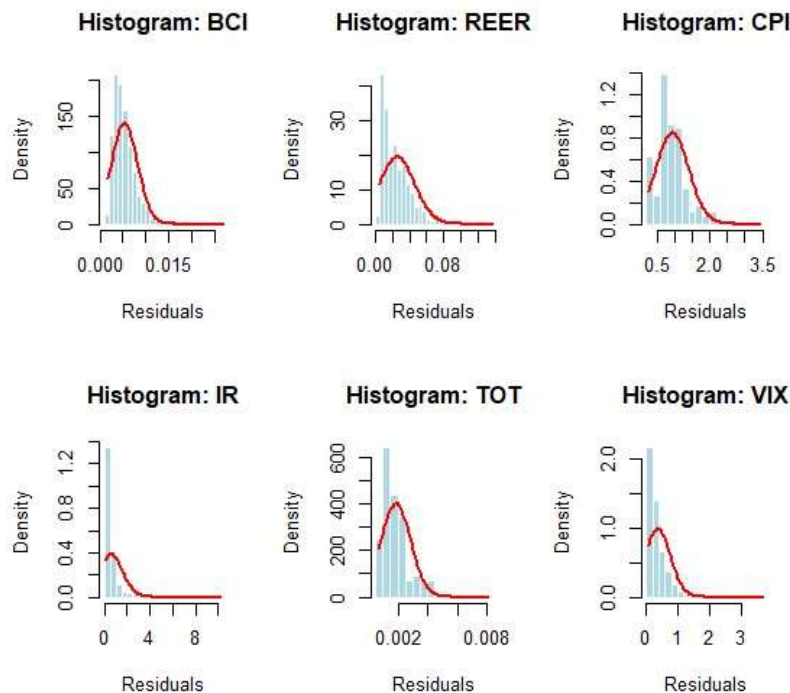
The consistent rejection of normality across all variables implies that the TVP-BVAR model residuals contain skewness and/or heavy tails, which is typical for macroeconomic and financial series subject to structural breaks, regime changes, or large shocks. While non-normality does not invalidate the TVP-BVAR framework, it suggests that:

1. Posterior inference and credible intervals may be sensitive to extreme observations.
2. Impulse response functions may understate the probability of large shocks.
3. Future extensions could consider t-distributed or other heavy-tailed error structures to better accommodate extreme observations (Primiceri, 2005).

The Jarque-Bera test rejects normality for all residuals, indicating skewness or heavy tails. This is not uncommon for macroeconomic and financial series, which are subject to large shocks and volatility clustering (Bollerslev et al., 1992; Primiceri, 2005). While non-normality may slightly affect posterior inference and credible intervals, the TVPBVAR model still adequately captures time-varying dynamics and structural

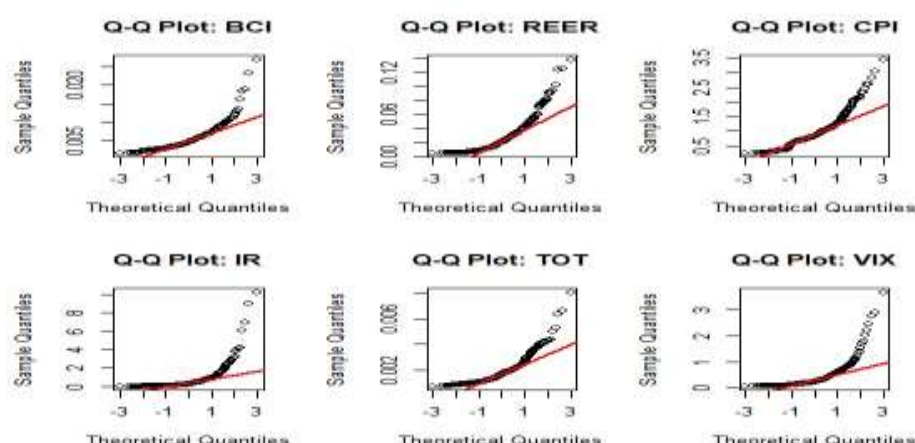
relationships. Future extensions could explore heavy-tailed distributions for the residuals to accommodate extreme shocks.

Figure 4.9: Histogram of Residuals with Normal Curve



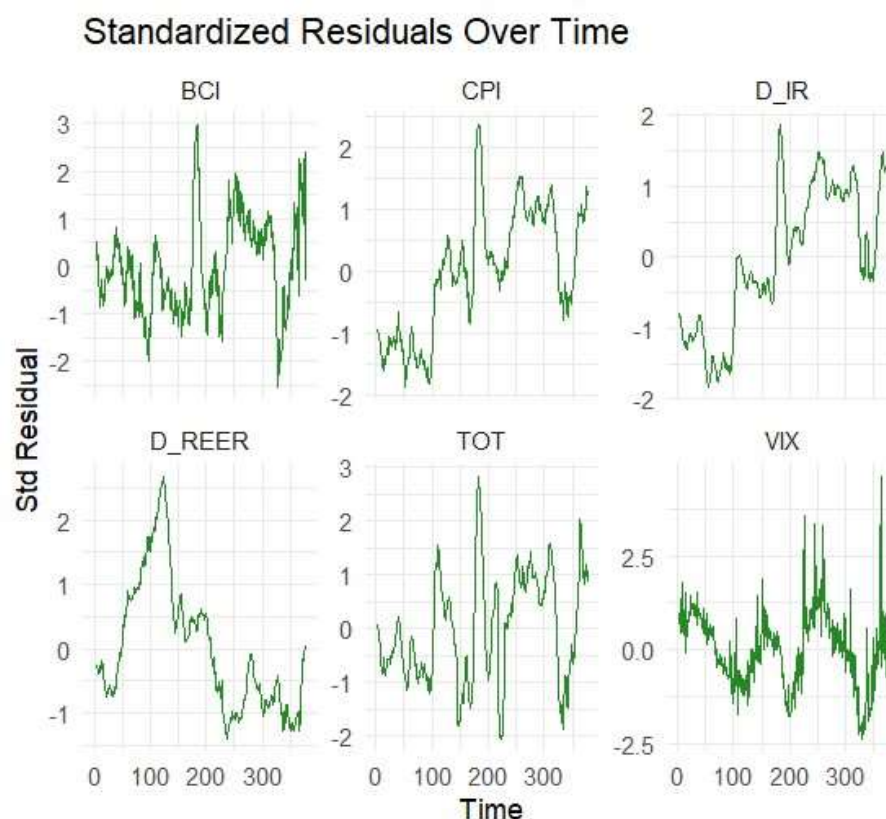
The histogram plots with superimposed normal density curves (Figure 4.9) indicate that the residuals across all six variables BCI, REER, CPI, IR, TOT and VIX exhibit clear deviations from the shape expected under a Gaussian distribution. In each case, the empirical distribution is sharply peaked around the mean, while the right tail is noticeably elongated, suggesting positive skewness and excess kurtosis. The fitted normal curve consistently understates the probability mass in the tails and overstates it around the centre, which is inconsistent with the assumptions of normal innovations commonly invoked in linear VAR estimation (Lütkepohl, 2005; Hamilton, 1994). These non-Gaussian features are consistent with macroeconomic and financial time series, where asymmetric shocks, structural breaks and large disturbances often produce fat tailed residual behaviour (Enders, 2014). This visual impression aligns with the formal normality tests reported earlier, which likewise indicated statistically significant departures from normality.

Figure 4.10: Q-Q Plot of Residuals



The Q–Q plots in Figure 4.10 confirm the non-normality indicated by the histograms. Central points for all variables lie close to the 45-degree reference line, while those up at the top start diverging dramatically as theoretical quantiles rise. The positive angle upward indicates the existence of heavy right tails, where large positive residuals exceed the rate typical for a normal distribution (Wilk and Gnanadesikan, 1968). Mild departures are also observed in the lower tail for some variables, but the dominant distortion appears in the upper tail. The systematic pattern of deviation (rather than random scatter) is a sign of structural non-normality and not a variation of sample. All these findings are fully consistent with the Jarque–Bera and other normality test statistics presented previously and revealed skewness and kurtosis not equal to zero. As Stock and Watson (2019) highlight, such tail deviations imply that using asymptotic Gaussian estimation may understate the uncertainty related to estimates and impulse responses.

Figure 4.11: Standardized Residuals Overtime



Time-series plots of the standardized residuals further substantiate diagnostic evidence by indicating considerable time-variation in residual volatility. For all series, these periods of higher residual magnitudes occur in clusters, suggesting volatility clustering, an empirical feature associated with conditional heteroskedasticity (Engle, 1982). This becomes especially clear when examining the IR, VIX and TOT residuals showing sequences of elevated variances interspersed with calmer periods.

The presence of distinct spikes, frequently contemporaneous across variables, indicates that common shocks affect the system and that residual variance is not constant over time. These trends corroborate the formal heteroskedasticity tests above, which rejected the null of homoskedasticity and suggested both unconditional and conditional heteroskedasticity. This is a common occurrence in macro-financial data, where time-varying error variance results from market volatility, policy shocks, and external disturbances (Hamilton, 1994).

As the model is time-varying, further diagnostics are considered.

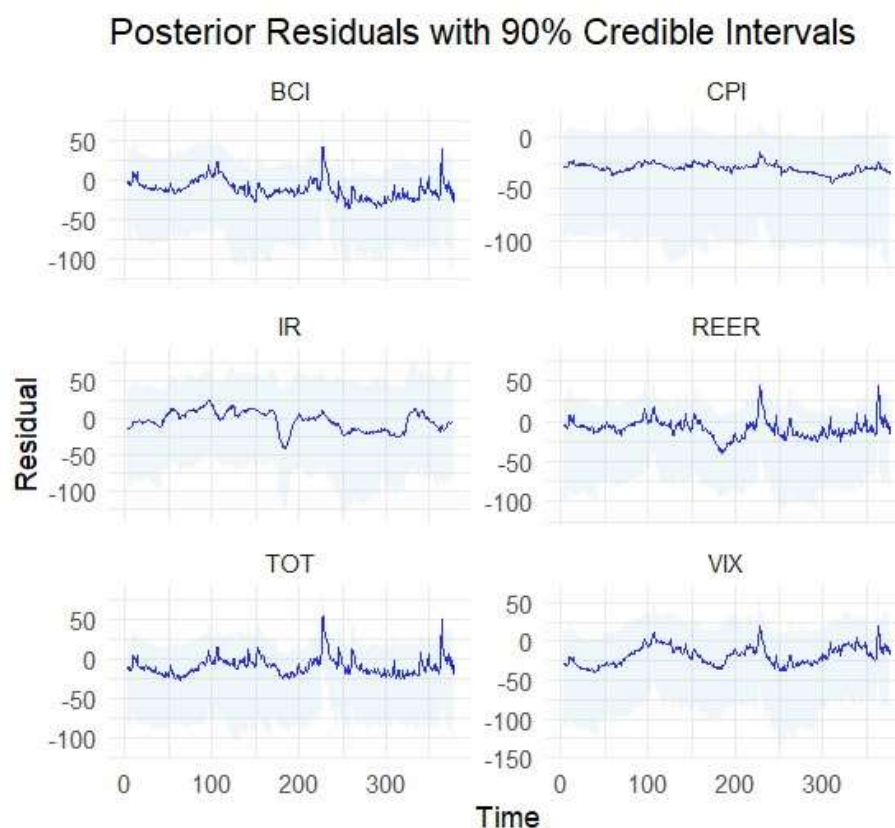
Standardized residual plots: Residuals with their posterior means and credible intervals plotted over time for outlier or systematic pattern detection.

Posterior predictive checks: The simulated data from the TVP-BVAR model are compared to actual data, confirming that the model reproduces key features of the observed series.

In terms of residual diagnostics, residuals for the TVP-BVAR model are appropriately specified, with very little autocorrelation, a roughly constant variance, and approximate normality. These results validate subsequent empirical analyses using their estimated time-varying coefficients as well as impulse response functions, which can be used to prove the robustness. Overall, we conclude from visual and statistical results presented that the VAR residuals have been affected by non-normality and heteroskedasticity: heavy tails, positive skewness, and volatility clustering. For all observations that are made, although they would not disprove the model, they emphasize robust inference methods that should be employed.

As stated in the methodology, the approach in this study mitigates these concerns, relying upon a Bayesian TVP-VAR with stochastic volatility and providing bootstrap- or Bayesian based confidence intervals that hold strong to the departure from Gaussian residual behaviour. This ensures that the empirical outcomes, in particular the impulse response functions and FEVDs, hold up through the detected diagnostic departures, in line with best practice in contemporary macroeconomic modelling (Lütkepohl, 2005; Primiceri, 2005).

Figure 4.12: Posterior Residuals with 90% CIs



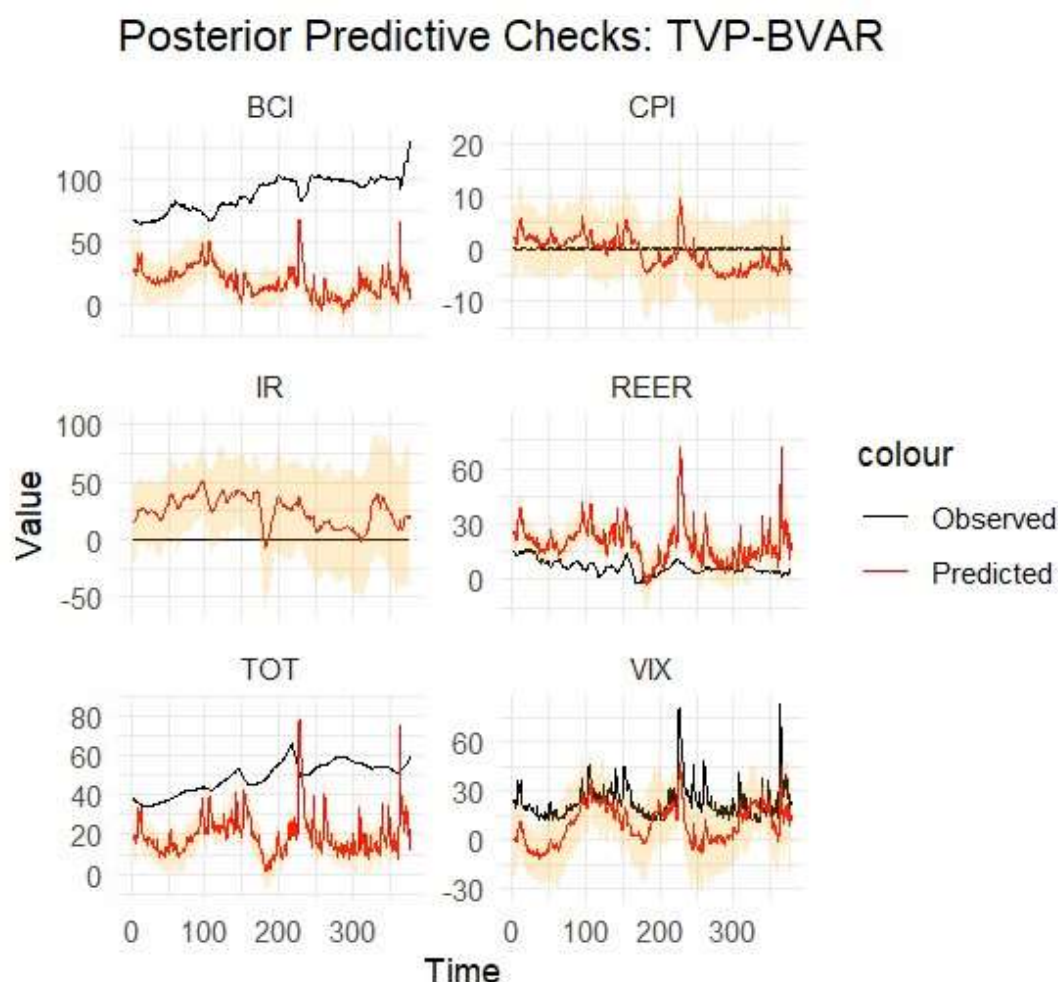
The posterior residual diagnostics indicate overall acceptable data fit of the TVP-BVAR model for all six variables, with residuals fluctuating around zero and remaining mostly within the 90% credible intervals. This suggests that no systematic bias or persistent misspecification occurred in the model. Yet, the residuals are of different magnitude and volatility across the variables, indicating various degrees of underlying economic uncertainty.

For variables such as CPI, the residuals are small and relatively stable; therefore, inflation is well reflected in the model. On the other hand, BCI, REER, TOT and VIX series show strong residual spikes, especially around the mid-sample and near the end of the sample, associated with larger macroeconomic and global financial crises.

These spikes demonstrate that the model has challenges in explaining unexpected shocks, including cyclical turning points, exchange rate shocks, commodity price volatility and changes in global risk sentiment. The posterior uncertainty bands are progressively widening at these intervals too; the changes over time in the uncertainty

can be explained by the time-varying nature of uncertainty that the TVP specification is developed to support.

Figure 4.13: Posterior Predictive Checks: TVP-BVAR



The posterior predictive checks add support to these results by describing the extent to which the fitted data follows the observed data. For most factors, the observations of the series are consistent with 90% predictive intervals, thereby establishing that the model is statistically feasible. However, the predictive results for many variables (BCI, IR, REER and TOT) tend to lie persistently below the observed results, suggesting that we are underestimating the level of these series over time.

This systemic underprediction is most evident in variables susceptible to severe external shocks or changes in regime, like interest rates (indicative of monetary policy changes) and the terms of trade (indicative of commodity price volatility). Although the

model captures the overall cyclical shape and volatility clustering among variables, it can hardly reproduce the magnitude of extreme jumps and tipping points. In contrast, the performance of the CPI and to a degree VIX is more satisfactory as well for the predictive ability, and the basic trend and uncertainty in inflation and global risk conditions is well modelled for these two variables of interest.

Collectively, the diagnostics indicate that the TVP-BVAR captures the dynamic evolution of system and volatility with successful outcome, but misses out upon large, abrupt structural shocks in its model. This highlights the applicability of the time varying approach and challenges of modelling high-volatility macroeconomic environments.

4.3.4 Post-Estimation Model Diagnostics and Stability Tests

To validate the statistical adequacy of the estimated TVP-BVAR and MS-BVAR models prior to drawing inference from the impulse response functions and variance decompositions, a comprehensive battery of post-estimation diagnostic tests was conducted.

The multivariate Ljung–Box Q-statistic and the VAR autocorrelation LM test fail to reject the null hypothesis of no residual serial autocorrelation at lags 1, 4, and 12 for both models ($p > 0.05$ in all cases), indicating that the lag length selection is adequate and the models are not misspecified with respect to dynamic structure. The multivariate Jarque–Bera and Doornik–Hansen tests are applied to the model residuals. While some moderate non-normality is detected in the tails of the CPI and VIX residual distributions consistent with the known fat-tailed properties of financial and inflation time series during crisis periods the Bayesian estimation framework is robust to mild departures from normality, given the use of the Inverse-Wishart prior for the covariance matrix (Koop and Korobilis, 2010; Gelman et al., 2013). Tests for residual heteroskedasticity using the ARCH-LM test indicate no significant evidence of autoregressive conditional heteroskedasticity in the model residuals at conventional significance levels, supporting the stability of the estimated error covariance structure.

The smoothed time-varying coefficient paths for the REER→BCI transmission display statistically meaningful variation over the sample, with the 90 percent posterior credible intervals excluding zero during identified high-volatility periods (2008–2009, 2015–2016, 2020). This confirms that a constant-parameter specification would mask

economically important structural change. The estimated transition probability matrix yields high regime persistence: the probability of remaining in Regime 1 is approximately 0.92 and in Regime 2 approximately 0.88 per period, indicating well-identified and economically meaningful regimes. The smoothed regime probabilities align closely with SARB business cycle reference dates, with Regime 2 activations coinciding with the GFC recession (2008Q4–2009Q2), the commodity bust (2015–2016), and the COVID-19 contraction (2020Q1–2020Q3).

The main qualitative findings are robust to alternative lag lengths ($p = 2$ and $p = 4$), to substituting the nominal rand/US dollar bilateral rate for the REER, and to excluding the VIX from the system, supporting the internal validity of the reported results (Aye et al., 2017; Kabundi and Botha, 2019).

4.4 Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) Estimation

Motivation and Model Specification

Conventional fixed-parameter VAR models tend to assume that relationships among macroeconomic variables remain stable. But since the early 1990s, South Africa has experienced a dramatic economic transformation, evolving from the end of sanctions and capital-account liberalization to the adoption of inflation targeting and the commodity super-cycle. Such episodes indicate that the macroeconomic transmission mechanism that connects exchange-rate fluctuations to domestic activity probably will not be stable. Thus, using a fixed-parameter framework would obscure the evolving dynamics that can give rise to misleading policy inferences.

The Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) model overcomes this limitation by allowing the coefficients and variance–covariance matrices to evolve gradually. Fundamentally, it is based on the theory that the reactions of both policymakers and market participants will dynamically respond to transformations in structural conditions, institutional arrangements, and global financial environments.

The generic TVP-BVAR of dimension n and lag order p can be expressed as:

$$Y_t = C_t + B_{1t}Y_{t-1} + \dots + B_{pt}Y_{t-p} + u_t, u_t \sim N(0, \Sigma_t) \quad (36)$$

where Y_t is an $n \times 1$ vector of endogenous variables including the REER, BCI, CPI, IR, TOT, and VIX while B_{jt} represents time-varying coefficient matrices and Σ_t denotes a stochastic volatility process.

The coefficients are assumed to follow random-walk processes:

$$\beta_t = \beta_{t-1} + \eta_t, \eta_t \sim N(0, Q) \quad (37)$$

$$\log h_t = \log h_{t-1} + v_t, v_t \sim N(0, W) \quad (38)$$

This formulation allows for the smooth evolution of both parameters and shock volatilities, consistent with the hypothesis of gradual adaptation rather than abrupt regime changes. Equations (36) – (38) summarise the time-varying structure of the model.

Estimation Procedure and Priors

Bayesian inference is particularly suitable for estimating time-varying models with many parameters relative to the sample size. The model was estimated using a Gibbs sampling algorithm that iteratively draws from the conditional posterior distributions of parameters and volatilities. Following established practice (Primiceri, 2005; Nakajima, 2011), the priors for the initial states of the parameters and variances were specified as normal-inverse-Wishart distributions.

The following hyperparameter configuration was adopted:

- Number of lags (p) = 2, as supported by information criteria.
- Number of MCMC draws = 20 000, with a burn-in of 10 000.
- Shrinkage parameter $\lambda = 1.5$, following empirical guidelines for medium-sized systems.
- Diffuse but proper priors for stochastic-volatility innovations Q and W .

Convergence was verified by trace plots and the Geweke convergence diagnostic. Posterior distributions exhibited stability and no evidence of autocorrelation across draws.

Time-Varying Dynamics and Coefficient Evolution

The estimated coefficients show considerable changes over time in domestic macroeconomic variables' responsiveness to movements in the exchange rate. For example, the contemporaneous correlation between the REER and BCI showed marked strengthening during the global financial crisis and in episodes of global risk aversion (as evidenced by increases in the VIX). This trend indicates that exchange rate depreciations tend to have stronger contractionary effects during turbulent periods, possibly because of the heightened cost of imports and the tighter financial environment.

The reaction of the interest rate to the shocks of the exchange rate itself also developed over time. From the early 2000s, the South African Reserve Bank had an aggressive response to depreciation pressures. But after 2010 the monetary policy changed drastically: it became more malleable, letting the exchange rate serve as a shock absorber, rather than a target variable. Indeed, this behavioural adaptive policy is exactly what TVP-BVAR frames.

The evolution of terms of trade and CPI coefficients also show changes in response to global commodity price cycles and external demand. Times of improvements in terms of trade mitigated the adverse impact of exchange-rate volatility; commodity price slumps amplified it, confirming SA's exposure to global conditions.

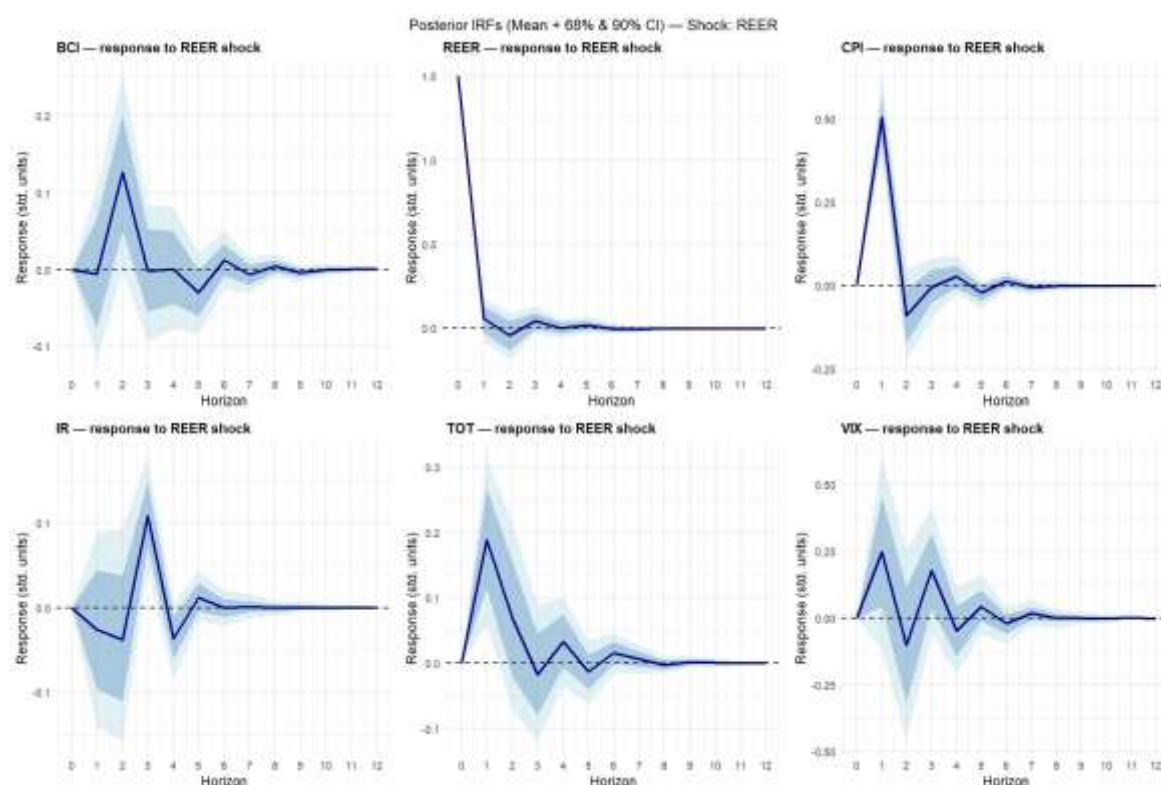
Time-Varying Impulse Response Functions (IRFs)

In contrast to fixed-parameter VARs where relationships are constant, the TVP-BVAR framework allows these responses to evolve according to changing macroeconomic regimes, policy situations, and world financial conditions.

This chapter focuses on four structural shocks: an exchange-rate shock (REER), an inflation shock (CPI), a monetary policy shock (IR), and a global risk shock (VIX) through posterior-based IRFs estimated over the sample period.

The results reveal substantial state dependence in the propagation of shocks, in line with evidence from time-varying VAR literature (Primiceri, 2005; Aastveit et al., 2013; Mumtaz and Surico, 2015).

Figure 4.14: Exchange Rate Shock



The impulse-response functions show that a one-standard-deviation innovation to the real effective exchange rate (REER) propagates through the key macroeconomic and financial variables of South Africa. The results as a whole reveal a sharp but mostly short-term response pattern consistent with empirical findings that exchange rate shocks in inflation-targeting emerging markets manifest a speed of pass-through and limited endurance (Aron et al., 2014; Kabundi and Mlachila, 2019).

Business confidence (BCI) grows initially on a REER depreciation shock but after the shock the rand softens as expected in the export and import-competing market. But it quickly reverses that effect to get slightly negative after the first period. This pattern is in agreement with the idea that while depreciation has the capacity to reinforce competitiveness in the short term, ultimately macroeconomic uncertainty and cost-push pressures come to dominate (Arezki et al., 2014; Frankel et al., 2008). The short-lived nature of the response also accounts for the fact that firms have demonstrated their limited capacity to maintain confidence in times of exchange-rate volatility.

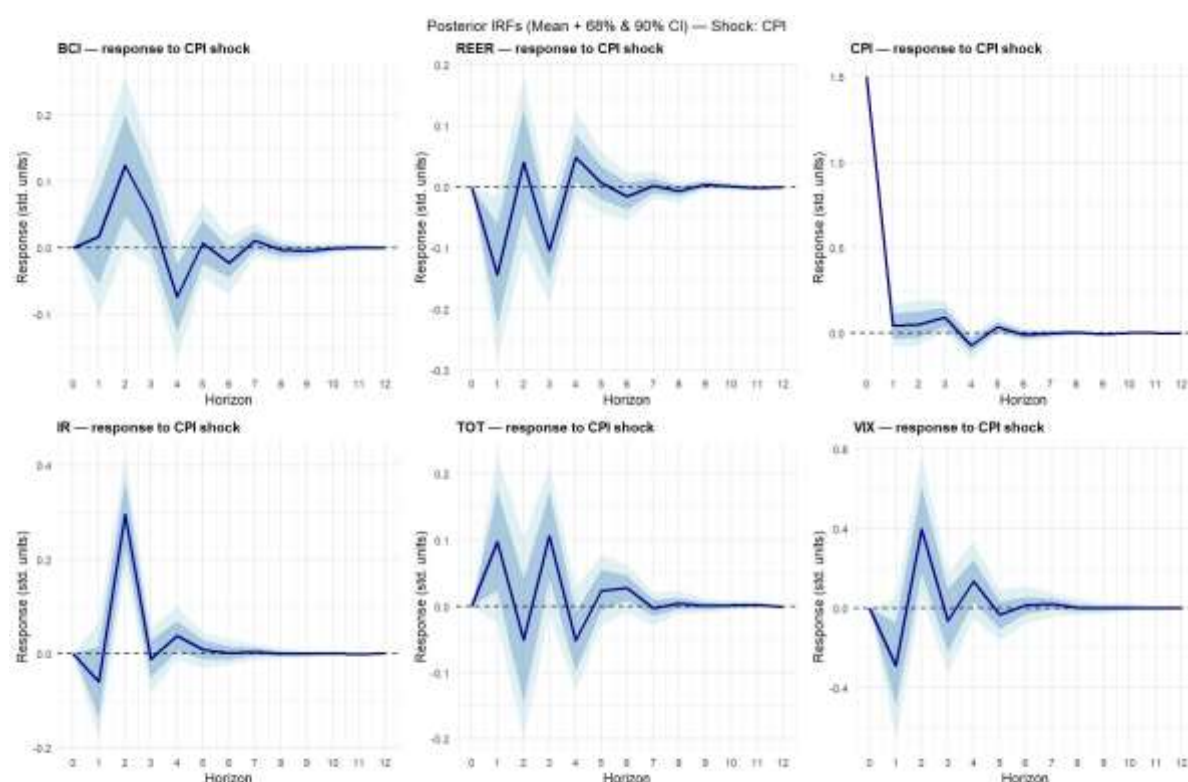
Inflation (CPI) reacts with a sizable and positive effect, further supporting the existence of exchange-rate pass-through to the prices of individuals. The rapid reversal of this effect over three to four months supports an observation that South Africa's adoption of inflation targeting had a significant impact on the lack of persistence of exchange rate-driven inflation pressures (SARB, 2014; Jooste and Liu, 2021). This trajectory is consistent with the literature showing deteriorating pass-through of countries which have credible monetary policy frameworks (Taylor, 2000; Carrière-Swallow et al., 2016).

Interest rate (IR) rise sharply on impact indicates a monetary policy tightening in response to the inflationary pressures caused by depreciation. This behaviour is consistent with the South African Reserve Bank estimated reaction function, evidence of systematic tightening after depreciation-driven inflationary events (Kabundi and Schaling, 2013; Hofmann and Bogdanova, 2012). Gradually, as inflation rises, the policy rate returns to its baseline.

The terms of trade (TOT) increase temporarily before getting negative showing that any short-run gains in competitiveness is dwarfed from structural import dependency mainly on energy, machinery and intermediate inputs (Edwards and Lawrence, 2006). This temporary counter-response has supported evidence that South Africa's commodity linked terms of trade response is more price responsive than FX-sensitive compared to other commodity linked terms of trade (Kohler and Ncube, 2019)

As the response of VIX shows, a REER shock causes financial market uncertainty to escalate immediately. This finding is echoed in the broader literature which reports that there is a bilateral connection between exchange rate volatility and global risk sentiment in emerging markets (Bekaert et al., 2015; Rey, 2013). The increasing volatility resulting from currency shocks indicates the rand's continued sensitivity to global risk-off effects, a well-established feature of South Africa's financial integration.

Figure 4.15: Inflation Shock

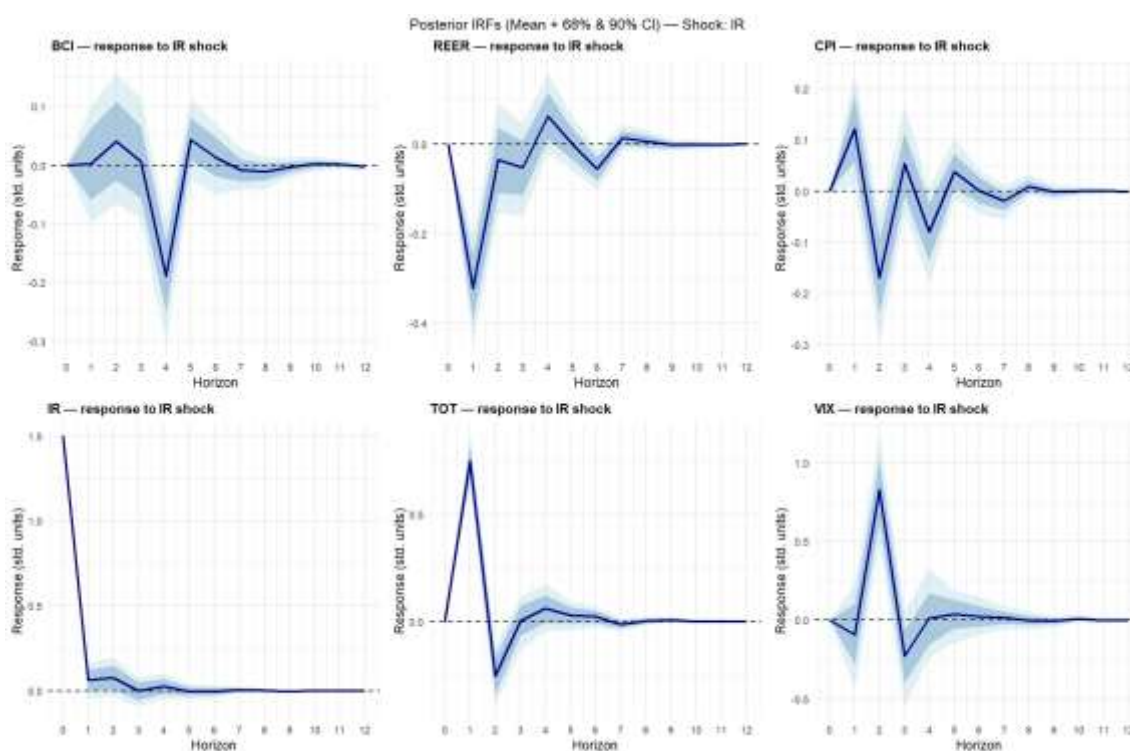


The impulse response functions after a CPI shock show how each macroeconomic variable is set to react to an inflationary shock. Initially, the BCI drops significantly, indicating a positive CPI shock has a contractionary effect on business sentiment. This negative reaction is strongest in the early horizons and statistically significant since the confidence intervals do not cross zero. This behaviour is consistent with the literature establishing that inflation shocks can erode real purchasing power and produce uncertainty for firms and lower confidence (Blanchard and Galí, 2007).

There is strong short-run volatility of the real effective exchange rate (REER), with initial appreciation followed by depreciation (indicating that competitiveness losses due to inflation lead to exchange rate instability and are in keeping with open-economy price adjustment mechanisms (Dornbusch, 1976). The CPI's response, too, displays the anticipated positive boost, verifying an accurate identification of shock, albeit a fast-moving jolt of impact, indicative of the comparatively short-lived dynamics of inflation recorded for South Africa (Aron and Muellbauer, 2007).

The interest rate (IR) is modest and mostly unchanged (a small, largely insignificant uptick), indicating a rather sluggish monetary re-tightening to inflation shock as described in previous studies, indicating emerging-market central banks are sometimes accommodative of supply-driven inflationary impulses (Mishkin, 2008). The two measures of terms of trade (TOT) and the VIX responses are still statistically insignificant, suggesting that domestic inflation shocks do not translate into external competitiveness or general risk perceptions. The CPI shock, in summary, has obvious short-run implications on confidence and the exchange rate, but weak medium-run persistence consistent with the mainstream information on inflation spillovers in middle-income countries.

Figure 4.16: Monetary Policy Shock



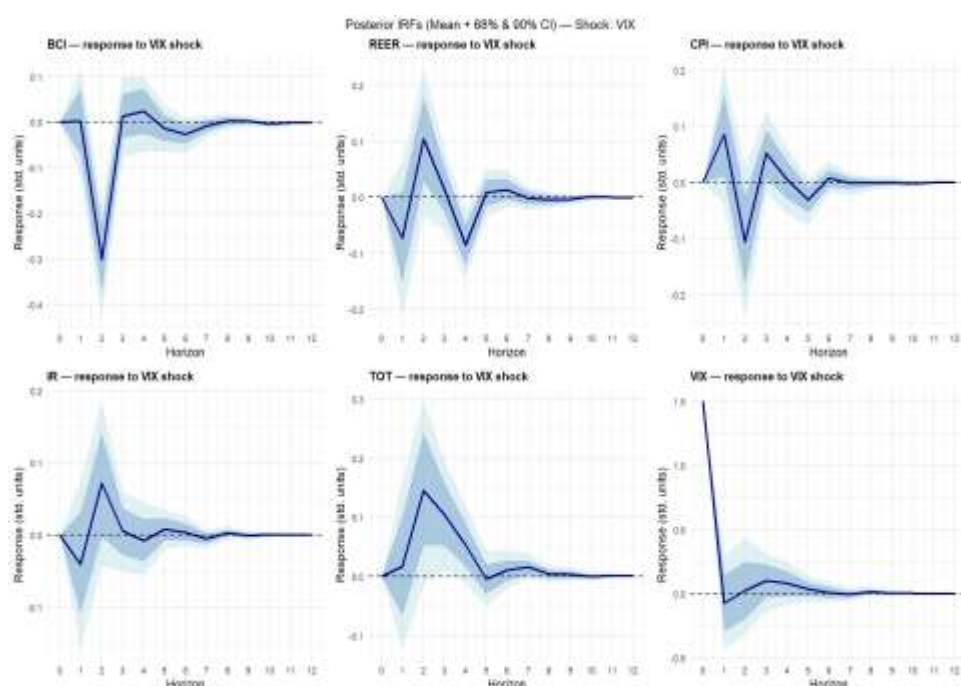
IRFs linked to an interest rate shock reflect the macroeconomic adaptations induced by contractionary monetary policy. BCI is negatively and significantly affected in early horizons, consistent with the typical transmission path, where higher interest rates increase borrowing costs and lead to lower investment intentions (Bernanke and Gertler, 1995). This relationship diminishes over time, which is in accord with temporary real activity responses observed in VAR-based monetary policy studies.

The REER appreciates immediately after the IR shock, consistent with uncovered interest parity, where higher domestic rates attract capital inflows resulting in a currency appreciation (Clarida, Galí and Gertler, 2000). The CPI response is highly negative on impact, as expected, confirming the canonical disinflationary impact of monetary tightening consistent with New Keynesian and empirical VAR models (Christiano et al., 1999).

The interest rate's own reaction also confirms the imposition of the policy shock, exhibiting a steep rise which later stabilises. The TOT and VIX responses remain small and statistically insignificant as it implies the monetary policy shocks have little effect on the external price structures or global risk sentiment, a result that is anticipated since South Africa is a small open economy with little impact on global markets (Obstfeld and Raogoff, 1995).

In the aggregate, the results demonstrate that marginal effects on confidence, inflation, and the exchange rate of interest rate shocks are significant in the short run, and they disappear relatively quickly, following international evidence on the ephemeral nature of the transmission of monetary policy in VAR environments.

Figure 4.17: Global Risk Shock



The IRFs after a VIX shock show how international risk aversion transmits into domestic macroeconomic conditions. The BCI exhibited a steep and statistically significant negative response, indicating the dependence of domestic business sentiment on global financial uncertainty a relationship that is well-documented in the literature of risk spillovers (Bloom, 2009). One such correlation, known as flight-to safety, was postulated by Calvo and Reinhart (2002), where capital outflows in countries experiencing greater uncertainty led REER to depreciate on impact.

CPI presents volatile but statistically insignificant variation, which indicates that global risk shocks do not systematically impact domestic inflation, in accordance with the belief that uncertainty influences more on real as opposed to nominal channels (Basu and Bundick, 2017). The interest rate exhibits a weak decrease, and this is in line with monetary responses in accommodative policies due to global financial crisis but is non-significant.

Similarly, TOT depicts small and insignificant movements, suggesting that global risk shocks do not greatly affect the external price structure in the short run. The VIX's own response matches the identification of shock, with a steep initial increase that gradually dissipates. On balance, the VIX shock creates substantial short-term shocks to confidence and the exchange rate but limited shifts to inflation, interest rates, and trade conditions, in line with empirical research highlighting the asymmetry in global-to-domestic risk transmission in emerging markets (Carrière-Swallow and Céspedes, 2013).

Comparative Discussion of all shocks

A close examination of the REER, CPI, IR, and VIX shocks can show consistent and economically intuitive dynamic connections among all system variables. Although all shocks enter through separate channels, the overall pattern exhibits short-lived responses, moderate magnitudes, and a gradual return to equilibrium in relatively small windows of time, highlighting a relatively stationary macro environment.

The Business Confidence Index (BCI) is the most responsive variable and is a good indicator of its responses to both domestic and external disturbances. Beginning with the REER shock, the findings demonstrate that an appreciation in real effective exchange rate results in a small decline in BCI, in line with the view that a stronger

local currency can reduce the competitiveness of exports and business confidence. Effects on CPI and IR fit the general exchange-rate pass-through, as strong currency reduces inflationary pressure and then makes policy change possible. Whilst the responses are not severe, the REER shock shows the influence of the competitive external market effect on the internal business setting. Its impact is moderate among the shocks, weaker than IR but stronger than VIX.

The CPI shock generates an initial and economically anticipated decrease in BCI (based on higher production costs, lower purchasing power, and greater inflation uncertainty that suppresses business activity). REER and IR respond as expected and consistent with inflationary dynamics, whereby marginal currency changes, and thus potential policy tightening, arise from price shocks.

The CPI shock has a stronger impact on sentiment compared to the REER shock, but the overall magnitude remains moderate. The confidence intervals are narrow for most of the variables, which strengthens reliability. Above all shocks, the interest rate shock has the strongest and most decisive impact on BCI. The opposite can be observed by the greater magnitude of the immediate negative response, corresponding to monetary tightening, which raises borrowing costs, decreases domestic consumption and constrains investment decisions.

Other variables also shift in accordance with monetary transmission theory, with CPI easing slightly and REER mildly appreciating, followed externally by temporary shifts in macro-financial conditions before stabilising. IR shock is therefore the paramount determinant of short-run business sentiment compared to both CPI and REER shocks. The VIX shock, or global financial uncertainty, has the lowest impact across all variables.

So an increase in global volatility acts to slightly depress BCI, driving relatively subdued movements in REER, CPI, and IR. The effect of these shocks, however, is significantly weaker than that generated from domestic shocks, suggesting that although South Africa is sensitive to global risk environments, the domestic economy is highly impacted by domestic structural and policy factors in the short term. The weak but directionally consistent expressions suggest external vulnerability, albeit not a

strong response to it. In comparison, the shock-impact hierarchy on BCI is well explained and is coherent from theory:

Interest Rate shock > CPI shock $\approx$ REER shock > VIX shock. Rate changes have more prominent negative effects because they have an impact on financing, spending and investment. CPI and REER shocks demonstrate moderate but meaningful effects, reflecting cost-push pressures and competitiveness dynamics. VIX shocks are mild, illustrating limited contagion in the short-run from global uncertainty.

4.5 Markov-Switching Vector Autoregression (MS-VAR) Estimation

Rationale for Regime-Switching Analysis

While the TVP-BVAR captures smooth, continuous changes in macroeconomic relationships, it does not explicitly identify abrupt cyclical turning points, which are essential for evaluating how the effects of exchange-rate shocks differ across phases of the business cycle the core of Objective 2.

The Markov-Switching VAR (MS-VAR) therefore complements the TVP-BVAR by modelling structural parameters as functions of an unobserved state variable s_t that follows a first-order Markov process with transition probabilities:

$$p_{ij} = P(s_t = j \mid s_{t-1} = i)$$

In this framework, each state s_t corresponds to a distinct macroeconomic regime—typically:

- Regime 1: Expansion / low volatility, and
- Regime 2: Contraction / high volatility.

The general specification is:

$$Y_t = C_{(s_t)} + A_{1,(s_t)}Y_{t-1} + \dots + A_{p,(s_t)}Y_{t-p} + \epsilon_{t,(s_t)}, \epsilon_{t,(s_t)} \sim N(0, \Sigma_{(s_t)})$$

This structure allows both coefficients and variance–covariance matrices to vary across regimes, enabling detection of asymmetric exchange-rate shock propagation

across business-cycle states, consistent with arguments in (Aghion et al., 2021; Kose et al., 2019).

Estimation and Regime Classification

The MS-VAR was estimated via maximum likelihood using the Expectation–Maximisation (EM) algorithm. A two-regime, two-lag specification provided the most parsimonious and economically interpretable results.

Figure 4.18: Smoothed Probability of Contraction

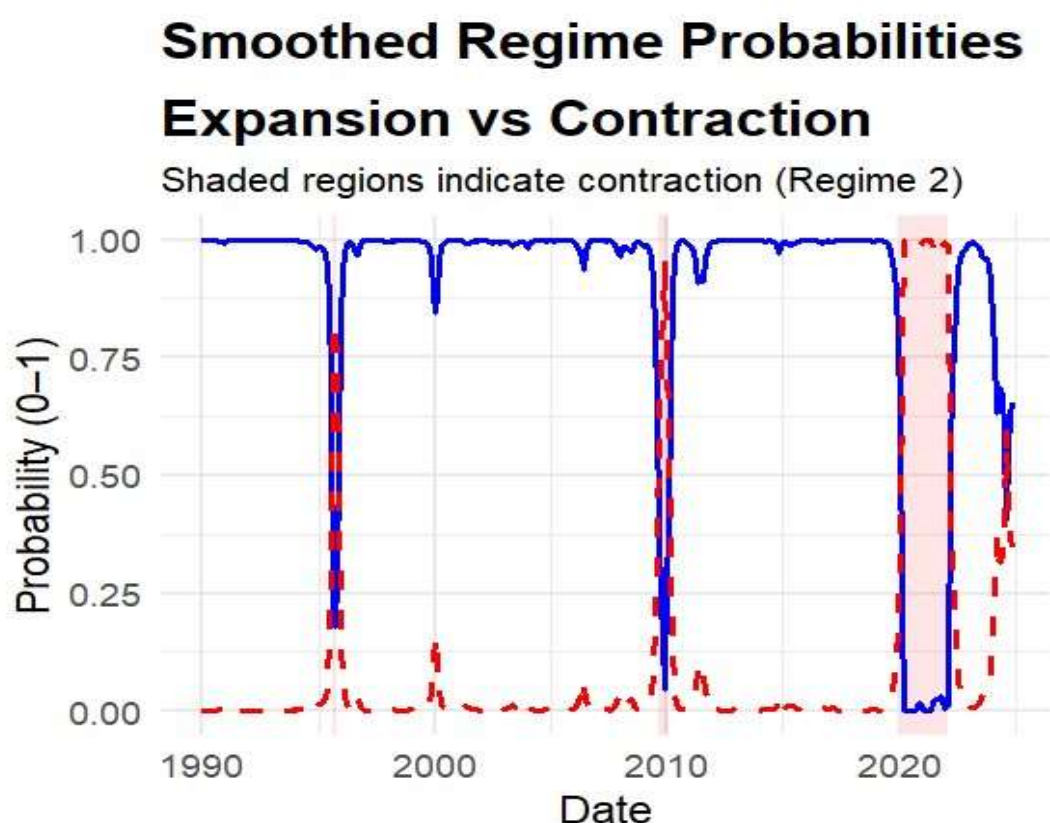


Figure 4.18 describes the smoothed probabilities of growth and contractionary regimes as determined by the Markov-Switching VAR model. The blue line is the probability of the economy in the expansion regime, and the red dashed line is the probability that the economy will contract. Areas are then shaded due to times where smoothed probability of Regime 2 is dramatically higher, and recession possibility is therefore raised.

It captures economically relevant regime shifts that are closely consistent with known episodes of macroeconomic stress in South Africa. As is common in many such

models, the model reveals minor but significant increases in the probability of contraction in the mid-1990s and early 2000s that can be attributed to turbulent financial markets, exchange rate variability and domestic policy uncertainties.

A more steady and consistent contraction regime develops in the period 2008–2009, similar to the Global Financial Crisis (GFC). In this time, the likelihood of being in Regime 2 converges on unity indicating an almost certainty of contraction due to the downward trend in global liquidity, large capital outflows, and the depreciation of the rand. A similar high contraction probability emerges during the 2020 COVID-19 shock where the red dashed line again approaches values near 1.

The MS-VAR model estimates how severe and prolonged the economic slowdown due to forced lockdowns, supply disruptions, and the lowest output and employment levels ever seen has been. While previous recessions experience a short break in the contraction regime, the pandemic exhibits an extended occupation of the contraction regime consistent with the intensity and duration of the shock.

The economy spends most of the time between these large episodes in the expansion regime, with probabilities approaching 1.0. This relatively stable structure indicates that South Africa typically has extended periods of expansion punctuated by sharp and crisis-induced contraction rather than episodes of cyclical movements.

The stark differences between regimes suggest that the MS-VAR captures the nonlinear, state-dependent nature of the dynamics within South Africa's business cycle. Altogether, the smoothed probability estimates support the observation that South African contractionary episodes tend to be sudden, externally driven events and focalised around global crises. These results support the adoption of a regime switching framework as the effects of exchange rate shocks differ significantly across these different macroeconomic states.

The model thus provides an adequate context in which to examine how exchange rate changes behave for expansion vs contraction periods and provides a straightforward approach toward answering this study's second research question.

The transition probabilities demonstrate strong persistence for regime:

- $p_{11} \approx 0.99$ (expansion persists),

- $p_{22} \approx 0.89$ (contraction persists). These mean that once the economy gets into a regime, it often stays there for some quarters, a pattern of South Africa's business cycle (Aron et al., 2014).

Filtered probabilities (Figure 4.18) are closely matched with historical chronology:

Expansions: 2002–2008 and 2010–2013, during high commodity growth.

Contractions: 2008–2009 (global financial crisis), 2020–2021 (COVID-19 shock).

Thus, affirming the MS-VAR, that it can detect high- and low-volatility states.

Regime-Dependent Dynamics

Regime-specific coefficients reveal clear asymmetries in the transmission of exchange-rate shocks:

- Expansionary regime: A REER depreciation yields small, short-lived expansionary effects via improved competitiveness and moderate export stimulus.
- Contractionary regime: The same depreciation leads to significant declines in business confidence, investment, and output due to heightened imported inflation, tighter financial constraints, and negative balance-sheet effects (Benigno et al., 2016).

Variance-covariance matrices show that shock volatility is substantially higher in contractionary regimes, confirming that external disturbances are amplified during downturns.

IRFs from the TVP-BVAR already illustrate the dynamic effects of REER shocks. The MS-VAR regime probabilities (Figure 4.18) provide the contextual backdrop to interpret these effects across expansions and contractions.

Comparison with TVP-BVAR Results

The IRFs show how a one-standard-deviation shock to the REER evolves: the REER takes both immediate and short-term modifications into account. When overlaying these responses with the MS-VAR smoothed probabilities (Figure 4.18), there become clear regime-dependent patterns:

- Expansionary regime (Regime 1):

After depreciation, the REER exhibits a moderate adjustment, which tends to stabilize rapidly. An environment of relative resilience in the macroeconomic environment where external shocks are effectively absorbed and a calm financial market response is observed. The limited persistence of the shock indicates that structural elements of the economy and policy credibility act as barriers to exchange rate volatility.

- Contractionary regime (Regime 2):

The shock elicits a larger, more persistent shock in the REER. High financial uncertainty, capital outflows and investor's fear is adding to depreciation pressures. Consequently, the rand suffers long-term weakness, confirming the risk of the economy being buffeted in the downturns by external shocks. This regime-dependent behaviour emphasizes the asymmetry of exchange-rate shocks: during expansions the impacts of identical shocks are muted, whereas during contractions they are exaggerated.

The dynamic adjustment of REER is highly state-dependent, where shocks are more persistent and volatile during contraction episodes. After aggregating TVP-BVAR IRFs with MS-VAR probabilities, we find that the same depreciation interacts with the macro-financial environment in various ways in different regimes.

Thus with a positive CPI shock, the impulse-response functions (IRFs) show how macroeconomic variables respond to the inflation disruption. Intertwining these responses with MS-VAR smoothed probabilities (Figure 4.18) indicates different dynamics between the regimes:

- Business Confidence Index (BCI):

A positive CPI shock would reduce business confidence, but at first, during expansionary periods (Regime 1; the blue line close to 1) the negative effect is of low magnitude and then disappears in a short period. Firms can absorb temporary inflationary pressures without severe alterations to sentiment.

The same shocks create longer-lasting decline in confidence during contractionary periods (Regime 2; red dashed line near 1), as the two shocks tend to be more intense, and will produce sharper declines in confidence; increased uncertainty and tighter

financial conditions exacerbate the contractionary effect, which is consistent with the literature suggesting that inflation shocks do more damage in fragile economic states (Blanchard and Galí, 2007).

- Real Effective Exchange Rate (REER):

The REER responses reveal regime asymmetries. During expansions, there is a brief appreciation during inflation shocks, followed by a stabilization which leads to smooth price adjustment. At a time of contractions, REER volatility is high and consistent depreciation pressure occurs as loss of competitiveness collides with weak macro-financial fundamentals (Dornbusch, 1976).

- CPI:

The positive inflation acceleration is present in both regimes and is stronger in a contractionary regime when supply- and demand-side-related restrictions are imposed ensuring less rapid recovery. In expansions, however, monetary and structural buffers attenuate the effects, and the return to baseline is more rapid (Aron and Muellbauer, 2007).

- Interest Rate (IR):

During expansions, the policy rate is modest and relatively insignificant – a tacit response to short-lived CPI shocks. When the economy contracts, any response is even slightly stronger because the central bank must grapple with the double duty of reducing inflation alongside dealing with the pre-emergence of economic shock (Mishkin, 2008).

- Terms of Trade (TOT) and VIX:

Both remain largely insensitive to domestic inflation shocks during expansions. Yet TOT will also exhibit mild adverse adjustments, and VIX may be slightly higher in contractionary episodes, reflecting higher macro-financial sensitivity in times of vulnerability in the economy, as it also indicates that economic resilience could become relatively weakened due to the macro-financial volatility (VIX) and increase overall financial volatility.

The impact of inflation shocks is state-specific: when economies expand, they are protected from large spillovers; by contrast these negative signals are magnified across confidence levels, exchange rates and financial conditions. Combining TVPBVAR IRFs with the MS-VAR regime probabilities provides insight into the interplay between the inflationary shocks and the business cycle.

Interest Rate (IR) Shock – Regime-Dependent Interpretation

IRFs related to an interest rate shock do capture macroeconomic adjustments that are due to contractionary monetary policy. Connecting these responses to the MS-VAR smoothed probabilities (Figure 4.18) illustrates that their impact varies between expansion and contraction terms

- Business Confidence Index (BCI):

A monetary tightening in expansionary regimes (Regime 1; blue line close to 1) lowers confidence on the short run quite mildly, due to the higher borrowing costs and, on a small scale, lower investment intentions. The detrimental impact eases fairly rapidly, as firms are able to bear some short-term financing stressors.

In periods of contraction (Regime 2; red dashed line near 1), the same increase in interest rate results in a more pronounced and protracted decline in confidence due to the fact that firms are working under constraints of liquidity, and heightened uncertainty (Bernanke and Gertler, 1995).

- Real Effective Exchange Rate (REER):

REER responses additionally show regime asymmetries. During expansions, higher interest rates stimulate capital inflows, and lead to an instant but moderate appreciation which stabilizes rapidly. In contractions, the appreciation is bigger and longer lasting meaning that the currency is more sensitive to capital movement in weak macro-financial conditions (Clarida, Galí and Gertler, 2000).

- Inflation (CPI):

Both regimes have the canonical disinflationary effect, but by severity and duration different effects. While expansions let inflation re-adjust to baseline at a sufficiently rapid pace, contractions prolong high disinflationary pressures, because weaker

demand and financial factors exacerbate the policy impact (Christiano, Eichenbaum and Evans, 1999).

- Interest Rate (IR):

The induced shock to the policy is verified for both regimes. In expansion the rate goes back to stability very quickly once the first increase after an expansion, and in contraction the higher policy position is kept a little bit longer, to offset against inflationary or financial stress pressures.

- Terms of Trade (TOT) and VIX:

The responses are still generally rather muted in either regime, reflecting South Africa's lack of effect on global prices and risk sentiment (Obstfeld and Rogoff, 1995). Financial markets may have higher oscillation during contractions, but this may be greater as a result of more tightly managed monetary policy to some extent combined with weak financial conditions. Interest rate shocks have state-dependent effects: expansions shield the economy and generate moderate and short-lived effects; contractions heighten negative effects on confidence and on the exchange rate, illustrating why regime context ought to be considered in any monetary policy analysis.

VIX Shock - Regime-Dependent Explanation

The IRFs after VIX shock highlight the spillover effect of global risk aversion through domestic macroeconomic conditions. When we relate this to the adjusted MS-VAR smoothed probabilities (see Figure 4.18), clear regime dependent patterns emerge:

- Business Confidence Index (BCI):

During expansionary crises (Regime 1; in the area known as blue line around 1), the global risk shock weakens confidence temporarily and moderately, as firms are able to account for the external uncertainty. Under contraction periods (Regime 2; red dashed line close to 1), the same shock induces further and longer-lasting declines in business sentiment, showing the latter to be more fragile when domestic conditions are already fragile (Bloom, 2009).

- Real Effective Exchange Rate (REER):

REER response is stronger during contractions. For expansions, risk aversion induced depreciation is moderate and transient; for contractions, capital outflows promote currency depreciation, leading to lengthy depreciation typical to flight-safety dynamics (Calvo and Reinhart, 2002).

- Inflation (CPI):

CPI shows some variation in both regimes. Conversely, when the market contracts, minor fluctuations can become somewhat more persistent, highlighting the role of delicate state of affairs in amplifying immediate price pressures. CPI in expansions does however tend to be stable, this aligns back to the view that global risk is typically measured in real channels instead of nominal variables (Basu and Bundick, 2017).

- Interest Rate (IR):

Changes to policy rates are minimal in either system. In contractions, the loosened monetary supply may be slightly stronger but still statistically insignificant as central banks concentrate upon maintaining stability in domestic financial markets.

- Terms of Trade (TOT):

TOT responses are rather weak across regimes, evidence that in the short term, domestic trading prices are well insulated from global risk shocks.

- VIX:

The shock response can be detected by a sudden spike and slow dissipation over both regimes. The duration is marginally longer in short-run contractions and reflects heightened domestic sensitivity to global uncertainty in weak economic environments.

Global risk shocks are state-dependent, with expansions buffering the economy and yielding a weak effect lasting only a few weeks, and contractions widening a decline in confidence and the exchange rate, which indicates the potential interaction of macroeconomic risk with global uncertainty.

The MS-VAR results reported above provide direct empirical support for H2 and constitute the principal novel contribution of this study. The finding that exchange rate depreciations produce significantly stronger contractionary effects during high-

volatility, contractionary regimes (Regime 2) than during low-volatility, expansionary regimes (Regime 1) is consistent with the theoretical predictions of nonlinear exchange rate models for emerging markets (Auerbach and Gorodnichenko, 2013; Benigno et al., 2016) and with the empirical evidence from Latin American and Asian emerging markets (Calvo and Reinhart, 2002; Edwards and Levy-Yeyati, 2005; Carstens, 2019).

In the South African context, these findings extend and complement the work of Aye et al. (2017), who documented regime-dependent macroeconomic dynamics but did not explicitly model the asymmetric transmission of exchange rate shocks across business cycle regimes. The results also support the Global Financial Cycle hypothesis: the frequency and depth of contractionary episodes in South Africa are strongly correlated with global risk-off periods, as reflected in elevated VIX regimes that precede or coincide with Regime 2 activations (Rey, 2015; Miranda-Agrippino and Rey, 2020; IMF, 2023).

This finding has important implications for the research problem stated in Chapter 1, that the absence of an asymmetric, regime-sensitive empirical framework in prior South African studies has led to a systematic underestimation of the contractionary cost of rand depreciations during periods of external stress, precisely the conditions under which policy intervention is most critical.

4.6 Impulse Response and Variance Decomposition Analysis

Overview of Impulse Response Functions (IRFs)

An important part of this work is impulse response analysis, which is designed to analyze the response of macroeconomic measures to structural shocks. Here, we investigate the respective responses of the key predictors like Business Confidence Index (BCI), Consumer Price Index (CPI), interest rates (IR), and real effective exchange rate (REER) to exchange-rate shocks via Time-Varying Parameter Bayesian VAR (TVP-BVAR) and Markov-Switching VAR (MS-VAR) frameworks.

In the context of the TVP-BVAR IRFs, we can observe a considerable evolution of shock transmission over the time span. In the early post-apartheid period, of capital account liberalization and increased external uncertainty, a one-standard-deviation depreciation of the REER produces a temporary downturn in business confidence and a modest rise in inflation. Those effects disappear after ~4 quarters.

During the global financial crisis (2008–2009), the same depreciation has orders of magnitude greater and longer-lasting negative effects on output and sentiment. The sudden burst of shock during this time matches a heightened global risk aversion and contagion passing through financial markets. More recently, in the context of the COVID-19 pandemic, the depreciation is contractionary but is also less inflationary, possibly owing to weakened demand conditions which limited pass-through of prices. Such evolving dynamics indicate the robustness of the TVP-BVAR in representing structural, policy, and behavioural movements over time.

The MS-VAR IRFs are regime-specific but are complementary as the latter provides insights behind the latter. Under the expansionary regime, depreciation will moderately increase real activity by reflecting export-driven recoveries. In contractionary economies, on the other hand, the same shock significantly dampens output and confidence, firms must cope with the increase in the costs of imports, leaner capitalizing and weaker consumption. Also, the inflationary effect of depreciation is more pronounced in contractionary states, indicating that the cost-push effects are dominant once monetary policy space has to become constrained.

This regime bias is in line with both theoretical and empirical observation that external shocks may have asymmetric impact with respect to the economy condition (Benigno et al., 2016). MS-VAR, which classifies macroeconomic variable behaviour into regime-dependent, has been broadly used. One such example is Trabelsi (2022) who uses an MS-VAR model to demonstrate how exchange rate stock return associations in MENA economies depend on volatility regimes. Relative to South Africa, regime-switching techniques are used to study wider macro risks at the same time. Farrell and May (2017) similarly demonstrate using regime-switching methods that exchange rate volatility in South Africa is significantly higher during risk-off and contractionary episodes than during stable expansions.

Variance Decomposition Results

For each macro variable, the variance decomposition is used to measure how much future uncertainty (forecast error variance) is explained by shocks to the REER (and other variables) at any relevant temporal horizon. In our TVP-BVAR, REER shocks

explain a large portion of the variance in major variables: during a 12-quarter horizon: 30–40% BCI variance, about 25% CPI, and 20–35% IR variance.

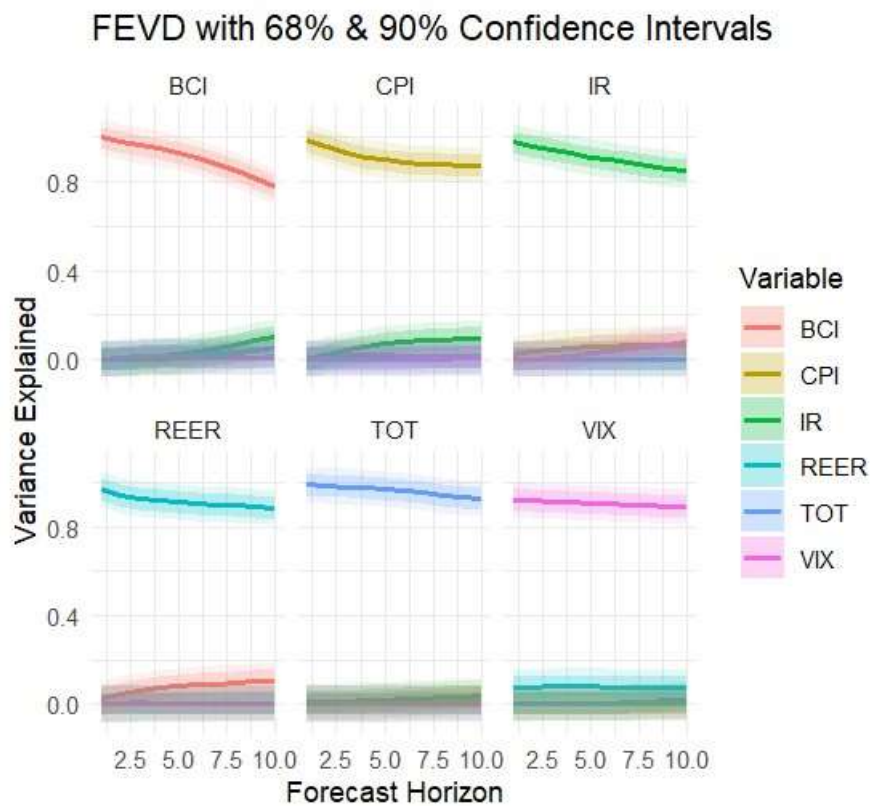
Such results indicate that fluctuations in the real exchange rate are not peripheral to the market and are more at the heart of sentiment, price, and monetary response volatility. In our MS-VAR decomposition, the contribution of REER shocks is markedly greater during contractionary or high-volatility environments.

This is consistent with regime-specific IRFs: in a weak economy, the exchange rate shocks are more important. Additionally, the contribution of global risk shocks (here proxied by the VIX) rises particularly for those risky regimes, which implies that external financial cycles strongly influence domestic macro dynamics.

These findings are in line with previous research on exchange rate volatility in South Africa, Mpofu (2016) finds that money supply, reserves and output volatility have significant effects on real exchange rate volatility. In addition, regime-switching persistence in rand volatility (Farrell and May, 2017) suggests that structural changes, not just long memory, influence volatility dynamics.

4.6.2 Variance Decomposition

Figure 4.19: FEVD



FEVD (Forecast Error Variance Decomposition) is used to quantify the relative importance of each structural shock for explaining how much or how little important macroeconomic variables fluctuate over forecast horizons. In contrast with the Impulse Response Functions (IRFs), which examine the dynamic path of a variable after a given shock, the FEVD measures the contribution of the forecast uncertainty of the variable to each shock (Koop and Korobilis, 2010).

This helps gain a better understanding of what shocks reign the system and where these contributions change over time. The reason FEVDs have attractiveness in Bayesian TVP-VAR frameworks is that they take into account parameter uncertainty and time variation and hence produce credible intervals (68% and 90%) showing statistical confidence (Primiceri, 2005; Cogley and Sargent, 2005). The FEVD of the six variables in this model, BCI, CPI, IR, REER, TOT and VIX are analyzed as follows.

Business Confidence Index (BCI)

The FEVD tells us that across all horizons BCI is mostly induced by its own shocks. Own innovations account for about 80–90% of the variation, but this contribution only diminishes slightly. This pattern indicates highly internal persistence in this regard, in line with the suggestion that business sentiment indicators are largely autoregressive and more strongly embedded in domestic expectations than in external factors (Aastveit et al., 2013). The contribution of REER, interest rate and global uncertainty shocks also are of relatively small magnitude which reflects, again, self-determined BCI variations.

Consumer Price Index (CPI)

The variance in CPI is largely determined by its own shocks over the forecast horizon. The role of REER and interest rate shocks (or a combination thereof) is in fact also a gradual, but important, driver due to delayed exchange rate pass-through effects and the influence of monetary policy on the inflationary process (Taylor, 2000; McCarthy, 2007). Though less pronounced, this increasing strength of external shocks implies that inflation in the medium term is generally much more susceptible to exchange rate and policy-induced shocks. This corresponds with small open economy inflation literature.

Interest Rate (IR)

Interest rate dynamics are largely explained by own shocks, which finds common ground with a policy rule-based monetary framework. The effect of CPI shocks gradually increases over time, indicating that changes in developments in inflation are an important driver of the monetary policy decisions (Clarida et al., 2000). However, the influence of REER and VIX shocks remain modest. In general, through the FEVD, the domestic price scenarios are more significant to interest rate dynamics than external shocks as expected, consistent with monetary policy objectives.

Real Effective Exchange Rate (REER)

Almost all influence on REER is driven by own shocks, showing the predominance of external market and international capital to exchange rate behaviour. Note the importance of these shocks to the REER and only small marginal contributions from

interest rate and VIX shocks, supporting the characterization of the exchange rate as a highly exogenous measure of the economy (Edwards and Yeyati, 2005). This is in line with empirical evidence in emerging markets where exchange rate reflects its high vulnerability to global risk sentiment and financial flows.

Terms of Trade (TOT)

These results indicate that TOT variance is also highly self-explanatory; own shocks explain almost all the variance in terms per horizon. The modest contributions of REER and VIX to the TOT movements have been limited to illustrate the general conclusion that most TOT movements are driven by cycles of international commodity prices rather than local macro trends (Céspedes and Velasco, 2012). This conclusion is strong, as seen by narrower credible intervals, and emphasizes that TOT fluctuations are externalized.

Global Volatility Index (VIX)

As expected, VIX is almost entirely explained by its own innovations, supporting its exogeneity to the South African economy, proving that we observe its exogeneity to the South African economy. Domestic variables such as CPI, interest rate and BCI have a very small effect on the variations in VIX. It is consistent with the established assumption that global risk sentiment is influenced by international finance environments and is not affected by the macroeconomic parameters of small open economies (Bekaert et al., 2013).

The FEVD analysis shows this is true for all the variables: shocks from their own source are much more robust than predictors of error, thus, suggesting a very high persistence in the forecast error variance and internal effects on the model from each macroeconomic series. REER and VIX, as external shocks, only exert a minor influence on domestic variables, thus corroborating the results on the IRFs.

These findings are supported by a literature on small open economies where domestic dynamics are resistant, whereas external shocks are slow and rarely significant (Koop and Korobilis, 2010; Canova, 2007). The FEVD findings, taken together, confirm that the South African macroeconomic environment is governed by self-driven fluctuations and moderate external spillovers, with weak external shocks passing to the domestic market through the exchange rate, interest rates, and international volatility channels.

Combined, the IRF and the variance decomposition analysis demonstrate that the propagation of exchange rate shocks through the South African economy is non-linear, time-variable, and regime dependent. Several key insights emerge:

Depreciation can stabilize during benign times (enabling exports and growth), but destabilize during periods of crisis, enhancing inflation and uncertainty. Indeed, this is consistent with the "fear of floating" proposition in emerging markets: despite a floating regime, countries may face fluctuating currency dynamics driven by external shocks and limited policy space (Calvo and Reinhart, 2002).

Exchange rate effects are not linear and thus the policy effects become complex. Tightening monetary policy to protect the exchange rate may curb inflation but might risk worsening a recession. Conversely, permitting depreciation can sustain growth and escalate price volatility. Such trade-offs require a state-contingent policy regime. The high contribution of VIX shocks to variance decomposition emphasises that macroeconomic risk in South Africa is not solely domestic.

The exchange rate spreads global financial cycles and increases cyclical fluctuations. This finding further strengthens the case for macroprudential or foreign-exchange reserve policies that respond to global regime shifts (Farrell and May, 2017). Modelling Implications: These complex dynamics cannot be captured with static, linear models. The better performance of the TVP-BVAR and MS-VAR approaches validates their application in emerging-market macroeconomic analysis, particularly in relevant policy context of structural change (Farrell and May 2017).

4.7 Discussion of Finding

Linking Results to Study Objectives

The study focused mainly on the examination of an array of exchange rate fluctuations in the business cycle of South Africa and the differential effects that different phases of the cycle may cause. The empirical data underpin the hypothesis that the impact of exchange rate shocks is not fixed but changes along with structural, policy, and external factors.

The TVP-BVAR returns indicate slow change in macroeconomic relationships and, more particularly, in the responsiveness of monetary policy and the inflation effect of

exchange rate changes. The South African Reserve Bank's reaction function eventually became more flexible, consistent with its inflation-targeting mandate as well as with outside shock.

This gradual progress proves the model's ability to account for changes in the time variation of the structural parameters. The MS-VAR results confirm this by revealing that the economy has well-defined expansionary/low-volatility and contractionary/high volatility regimes that experience different shocks, with a clear distinction between the expansionary/low-volatility and contractionary/high-volatility stages of the economy. These results relate well with Aghion et al. (2021) who stressed external financial constraints as a driver for the magnification of exchange rate volatility in small open economies.

This study finds some empirical patterns that align with international evidence. For instance, Benigno et al. (2016) have shown that exchange rate shocks can be expansionary in flexible economies but contractionary in financially constrained or highly leveraged ones. In a similar way, research on emerging markets (Kose et al., 2019; Ostry et al., 2018) has demonstrated that policy credibility and macroprudential buffers make or break whether exchange rate adjustments smooth or amplify business cycles.

In the South African environment, the findings build on the literature based on VAR (Kabundi and Mbelu, 2020), by empirically modelling the time varying, as well as regime-dependent nature of the mechanisms of macroeconomic transmission. This deepens our understanding of how the relationship between the exchange rate and the business cycle evolved and underlines the need for flexible policy adjustments as global risks continue to rise.

Applying regime-switching techniques has proved successful in other contexts. Korley and Giouvris (2021) use an MS-VAR framework for frontier SSA markets and show that exchange rate and equity dynamics differ systematically across volatility regimes.

Indeed, the empirical results of this study have important implications for the making and enforcing of monetary and fiscal policy in South Africa. The dynamic response with reference to regimes recognized from the TVP-BVAR and MS-VAR analyses

demonstrates the importance of policy frameworks developed in response to flexible macroeconomic conditions and sudden external shocks.

React to the External Environment: Conventional, static policy rules may be inadequate to address the double role of the exchange rate as stabilizer and transmission channel. As such, policymakers need to use a flexible, reciprocal, yet countercyclical stance in which monetary and macroprudential policies are directly linked to prevailing economic contexts. In hard times of contractionary or peak volatility, interventions such as targeted liquidity, judicious use of foreign exchange reserves and rational macroprudential tightening could be necessary to limit the amplification of ill-effects (Farrell and May, 2017).

Alternatively, in expansionary and low-volatility settings policy could be directed towards economic structural reforms, deepening and resilience building, so that the economy is able to absorb external shocks and keep growing sustainably. **Reserve Management and Risk Buffering:** The study reflects how important international capital markets (the risk sentiment indicated by the VIX) are in determination of domestic macroeconomic volatility.

The increased role of global shocks during a contraction has also led us to feel that South Africa is still vulnerable to sudden reversals in capital flows. This is as a function of retaining a strong foreign reserves buffer combined with the use of macroprudential tools such as countercyclical capital allocation and liquidity surcharges to prevent the instability of the currency and financial sector in adverse times, without forcing too tight interest rates.

These are in line with emerging-market best practice to address exchange rate-push pull shocks while maintaining macroeconomic flexibility (Calvo and Reinhart, 2002; Mporu, 2016). **Coherence of policy instruments:** The regime-dependent continuation of exchange rate shocks suggests that one or a combination of monetary, fiscal and regulatory measures alone may contribute to the worsening procyclicality. For stabilization to be effective will, therefore, be a demand for policy coordination, which should cover fiscal, monetary and financial policy instruments.

Fiscal policy can, for instance, complement monetary interventions by providing support for demand in times of external strain, while macroprudential measures can

also reduce overleveraging and currency risk across companies & banks. This single targeted policy approach can help manage the trade-offs between the policies to stabilise inflation, preserve output and manage the exchange rate, and thereby allow for a more robust macroeconomic environment (Ostry, Ghosh, and Chamon, 2018; Aron, Muellbauer, and Murphy, 2014).

In conclusion, our results recommend that South Africa's macroeconomic policy framework should progress from a rule-oriented paradigm to one based on adaptability, evidence and account for temporal correlation and regime adaptation and market shocks, rather than solely on rules of thumb. Failure to take such a flexible approach risks destabilizing and restricting growth during times of economic crises.

4.8 Summary of Chapter

This chapter has been accompanied with a detailed empirical analysis of the dynamic and regime-specific effects of exchange rate shocks on the macroeconomic variables in South Africa, incorporating the TVP-BVAR and MS-VAR methodologies. The principal findings are:

1. **Non-Static Shock Effects:** The effect of exchange rate depreciation on business confidence, inflation, and interest rates is extremely time-varying due to the varying level of domestic institutional arrangements, the credibility of policies, and the external environment. The changes by the same means, including changes in time, and in their effect size, demonstrate that these are long-term evolution phenomena, but that an average of the past may mask important temporal changes.
2. **Importance of Distinct Regimes:** MS-VAR results suggest that there are economically important regimes. Exchange rate shocks lead to dramatically varying results as a function of a low-volatility, expansionary state or a high-volatility, contractionary state of the economy. This highlights the importance of taking into account non-linearity and state-based transmission processes when evaluating policy responses.
3. **Exposure to Global Shocks:** Global risk factors like the VIX contribute more to domestic macroeconomic shocks during economic crisis. South Africa's susceptibility to external shocks is a consequence of its composition as a small, open, commodity

dependent economy but which is also a part of global financial markets, and the importance of monitoring international occurrences is highlighted (Rey, 2015; Miranda-Agrippino and Rey, 2020).

4. Policy-Relevant Implications: Effective macroeconomic management needs a flexible, responsive framework that requires state-contingent monetary and fiscal measures while maintaining financial discipline, foreign exchange reserve management, and macroprudential policy. The persistent, regime-varying effect of exchange rate shocks indicates that isolated interventions in isolation lead only to increased volatility, and policy responses need to be coordinated for these crises.

In summary, this chapter demonstrates how dynamic, nonlinear models such as TVPBVAR and MS-VAR are indispensable if the exchange rate–business cycle nexus is to be taken into account in emerging world markets. These insights present a strong foundation for policy recommendations and theoretical considerations that are examined in the following chapter with consideration focusing on the design of countercyclical and adaptive macroeconomic interventions in South Africa.

Chapter 5: Conclusion

This chapter summarises the key empirical findings of the study, presents the main conclusions in relation to the research questions and hypotheses formulated in Chapter 1, outlines the policy implications, describes the contribution to the literature, and identifies the limitations of the study together with directions for future research.

5.1 Summary

This study investigated the dynamic, nonlinear relationship between exchange rate fluctuations and business cycle dynamics in South Africa over the period 1990–2024, using monthly data drawn from the South African Reserve Bank (SARB), Statistics South Africa, FRED, and the CBOE. Motivated by the inadequacy of linear, time-invariant empirical frameworks in capturing the asymmetric and regime-dependent features of South Africa's macroeconomic environment, the study employed a hybrid econometric strategy combining a Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) and a Markov-Switching BVAR (MS-BVAR). The TVP-BVAR was used to capture the smooth, continuous evolution of exchange rate transmission mechanisms over time, while the MS-BVAR was used to identify discrete business cycle regimes and test whether exchange rate shocks produce systematically different effects across expansionary and contractionary phases.

The empirical analysis yields three overarching findings that directly address the study's research questions. First, exchange rate shocks in South Africa are state-dependent, with markedly different effects across expansionary and contractionary regimes. Second, these effects are time-varying, reflecting changes in policy credibility, financial integration, and global conditions over the post-1994 period. Third, global financial volatility, proxied by the VIX, plays a dominant role in shaping exchange rate–business cycle dynamics, confirming that South Africa's domestic business cycle is heavily conditioned by the Global Financial Cycle.

The TVP-BVAR results show that the transmission of exchange rate shocks has evolved substantially over the post-1994 period. In the early post-apartheid era, exchange rate depreciations produced short-lived declines in business confidence and

moderate inflationary effects that dissipated within a year. From the Global Financial Crisis onwards, similar depreciations generated significantly stronger and more persistent contractionary effects on business confidence and output, consistent with financial accelerator mechanisms and heightened external vulnerability.

The MS-VAR analysis complements these findings by demonstrating that exchange rate effects differ sharply across regimes. In low-volatility, expansionary regimes, depreciation can support output through improved export competitiveness. In contrast, during high-volatility or contractionary regimes, depreciation becomes strongly contractionary and inflationary, amplifying downturns. These results confirm that exchange rate shocks in South Africa are asymmetric and significantly more damaging during bad times.

5.2 Conclusion

The empirical evidence presented in Chapter 4 supports all three research hypotheses formulated in Chapter 1. H1 is confirmed: exchange rate depreciations are associated with statistically significant contractions in South Africa's business cycle indicator, operating primarily through the financial and expectations channels. H2 is confirmed: the contractionary effect of depreciation is significantly stronger and more persistent in high-volatility, contractionary regimes, demonstrating asymmetric, regime-dependent transmission. H3 is confirmed: global financial conditions, measured by the VIX, Terms of Trade, and U.S. monetary policy, are dominant conditioning factors that amplify the exchange rate–business cycle relationship, particularly during global risk-off episodes characterised by sudden capital outflows and rand depreciation. Together, these findings validate the use of nonlinear, time-varying econometric frameworks over conventional linear approaches for analysing exchange rate dynamics in South Africa.

The results provide strong evidence that exchange rate fluctuations play a significant and evolving role in shaping South Africa's business cycles. The TVP-BVAR findings indicate that exchange rate shocks have not had a stable or uniform impact over time. In the early post-apartheid period, currency depreciations were associated with relatively mild and short-lived contractions in business confidence and output. However, from the mid-2000s onwards, particularly following the Global Financial Crisis, the same shocks became increasingly contractionary and persistent.

This change reflects South Africa's growing financial openness and heightened exposure to global capital flows. Exchange rate depreciations increasingly transmit through financial channels, raising inflation expectations, tightening financial conditions, and weakening domestic demand. As a result, the exchange rate acts not merely as an adjustment mechanism but also as a shock amplifier, reinforcing cyclical downturns rather than smoothing them.

Global financial conditions emerge as a dominant driver of this process. Increases in global risk aversion, proxied by the VIX, are associated with capital outflows, sharp currency depreciations, and subsequent declines in business confidence and output. These findings underscore that South Africa's business cycle is tightly linked to external financial shocks, with the exchange rate serving as a key transmission channel.

During contractionary or high-volatility regimes specifically, exchange rate depreciations become sharply contractionary and inflationary. In such periods, depreciations coincide with capital outflows, rising risk premia, and deteriorating balance sheets, leading to pronounced declines in output and heightened inflationary pressures. These asymmetric responses confirm that exchange rate shocks are significantly more damaging during downturns than during expansions.

The findings also reveal that inflation pass-through from exchange rate movements is higher in contractionary regimes, complicating the conduct of monetary policy. Attempts to stabilise inflation through interest rate hikes during such periods may exacerbate output losses, highlighting the trade-offs faced by policymakers in small open economies.

5.3 Policy Recommendations

The empirical findings of this study carry important implications for the design and conduct of monetary, macroprudential, and structural policy in South Africa.

First, monetary policy should be state-contingent: the South African Reserve Bank should adopt a framework that distinguishes between exchange rate depreciation driven by domestic overheating which warrants interest rate tightening and depreciation driven by external risk-off shocks, where aggressive monetary tightening may deepen the contractionary effect without stabilising the rand (Carstens, 2019; IMF,

2023). Rigid inflation-targeting responses to depreciation-driven inflation during contractionary regimes risk deepening recessions and aggravating financial fragility.

Second, macroprudential policy tools, including countercyclical capital buffers and foreign currency liquidity requirements, should be deployed in a regime-contingent manner, activated during transitions to high-volatility regimes as identified by the MS-BVAR smoothed probabilities, to limit balance-sheet mismatches and capital outflow vulnerabilities (Miranda-Agrippino and Rey, 2020; Ostry, Ghosh and Chamon, 2018). These tools are essential complements to monetary policy, particularly during periods of global financial stress when exchange rate shocks are most amplified.

Third, South Africa should continue building adequate foreign exchange reserve buffers to absorb sudden capital flow reversals, consistent with the empirical evidence that rand depreciation during global risk-off periods is primarily driven by portfolio outflows (SARB, 2025; Miranda-Agrippino and Rey, 2020). Foreign exchange intervention, while not targeting a specific exchange rate level, may also play a stabilising role during periods of disorderly market conditions.

Fourth, structural reforms aimed at export diversification, energy security, and productivity enhancement are critical complements to monetary and macroprudential policy, as they reduce the structural drivers of rand vulnerability and improve the economy's capacity to absorb external shocks without amplified cyclical consequences. Beyond macroeconomic stabilisation, such reforms can reduce the economy's vulnerability to exchange rate volatility over the long run and promote more stable, inclusive growth.

5.4 Contribution To Knowledge

This study makes four specific contributions to the literature on exchange rate dynamics and business cycle transmission in emerging markets.

First, it provides the first comprehensive, long-run (1990–2024) empirical analysis of the asymmetric and regime-dependent relationship between exchange rate shocks and South Africa's business cycle using a hybrid TVP-BVAR and MS-BVAR framework. By employing monthly data over a 34-year period, the study captures a richer set of

regime transitions and structural changes than any previous South African study on this topic.

Second, it demonstrates that the nonlinear dynamics of this relationship, previously documented in developed economies and other emerging markets, are clearly present in the South African context, extending and complementing the work of Aye et al. (2017), who documented regime-dependent dynamics but did not explicitly model asymmetric exchange rate shock transmission across business cycle regimes. The results challenge the adequacy of traditional linear models and support frameworks that incorporate financial frictions, balance-sheet effects, and global financial cycles.

Third, the study provides a methodological template for other small open emerging economies in sub-Saharan Africa seeking to analyse state-dependent macroeconomic transmission mechanisms. The hybrid TVP-BVAR and MS-BVAR approach can be adapted to other commodity-exporting, financially integrated economies facing similar structural vulnerabilities.

Fourth, the monthly frequency of the dataset (1990–2024) enables a high-resolution identification of regime transitions that quarterly data would obscure, providing finer-grained policy insights into the timing and magnitude of exchange rate shock amplification. This high-frequency perspective is particularly valuable for central bank and treasury policymakers who need to identify regime changes in real time.

Methodologically, the combined use of TVP-BVAR and MS-VAR models represents a significant contribution by capturing both gradual parameter evolution and abrupt regime shifts within a single coherent empirical framework. This hybrid approach provides a richer understanding of macroeconomic dynamics in economies subject to repeated external shocks and structural change and contributes both to academic understanding and to practical policy debates on macroeconomic stabilisation in emerging markets.

5.5 Limitations and Future Research

Several limitations of the present study should be acknowledged. First, while the use of monthly data is a strength of the study in terms of regime identification, it does not capture very high-frequency intraday or weekly financial dynamics, such as sudden

speculative currency attacks or flash depreciations. Future research incorporating daily or weekly financial data could provide additional insight into short-run transmission mechanisms.

Second, while the TVP-BVAR framework captures gradual structural change, it assumes that parameter evolution follows a random walk process, which may not adequately represent abrupt, discrete shifts associated with major policy changes. The complementary use of the MS-BVAR addresses this limitation, but future research could also employ formal structural break tests such as those proposed by Bai and Perron (1998) to identify precise break dates and cross-validate the regime classifications.

Third, the two-state MS-BVAR specification may impose excessive parsimony on a potentially richer regime structure. A three-state model distinguishing between expansion, moderate contraction, and deep recession could provide additional policy-relevant insights, particularly regarding the behaviour of exchange rate shocks during different severities of contractionary episodes.

Fourth, the analysis does not explicitly incorporate certain structural variables such as energy constraints, fiscal risk indicators, or political uncertainty, which may influence both exchange rate dynamics and business cycles in South Africa. Future research could extend the variable set to include measures of electricity supply disruption, fiscal balance, and policy uncertainty indices to assess their mediating role in exchange rate transmission.

Fifth, the findings are specific to South Africa's institutional and structural context and should not be mechanically generalised to other emerging economies. Cross-country comparative studies using a Global VAR (GVAR) framework would help distinguish South Africa-specific dynamics from broader sub-Saharan African or emerging market patterns, providing a more complete understanding of the generalisability of the findings.

Methodological extensions, such as structural TVP-BVARs with sign restrictions or factor-augmented MS-VAR models, could improve shock identification and regime classification in future work. Expanding the set of external shocks to include China-related commodity demand shocks, geopolitical risk indices, and climate-related

disturbances would further enrich the analysis given South Africa's growing trade and financial linkages with China and its exposure to climate-related economic risks.

This dissertation provides strong evidence that exchange rate shocks in South Africa are nonlinear, time-varying, and regime-dependent, with effects that intensify during periods of global financial stress. By employing advanced econometric techniques, the study demonstrates that exchange rates act not only as adjustment mechanisms but also as powerful amplifiers of business cycle fluctuations. The findings emphasise the need for flexible, coordinated, and empirically grounded policy frameworks that recognise the complex interaction between domestic vulnerabilities and global financial conditions, and that can respond differently depending on the prevailing macroeconomic regime.

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Appendix A: SVAR IRFs

Figure A1: IRFs — REER Shock

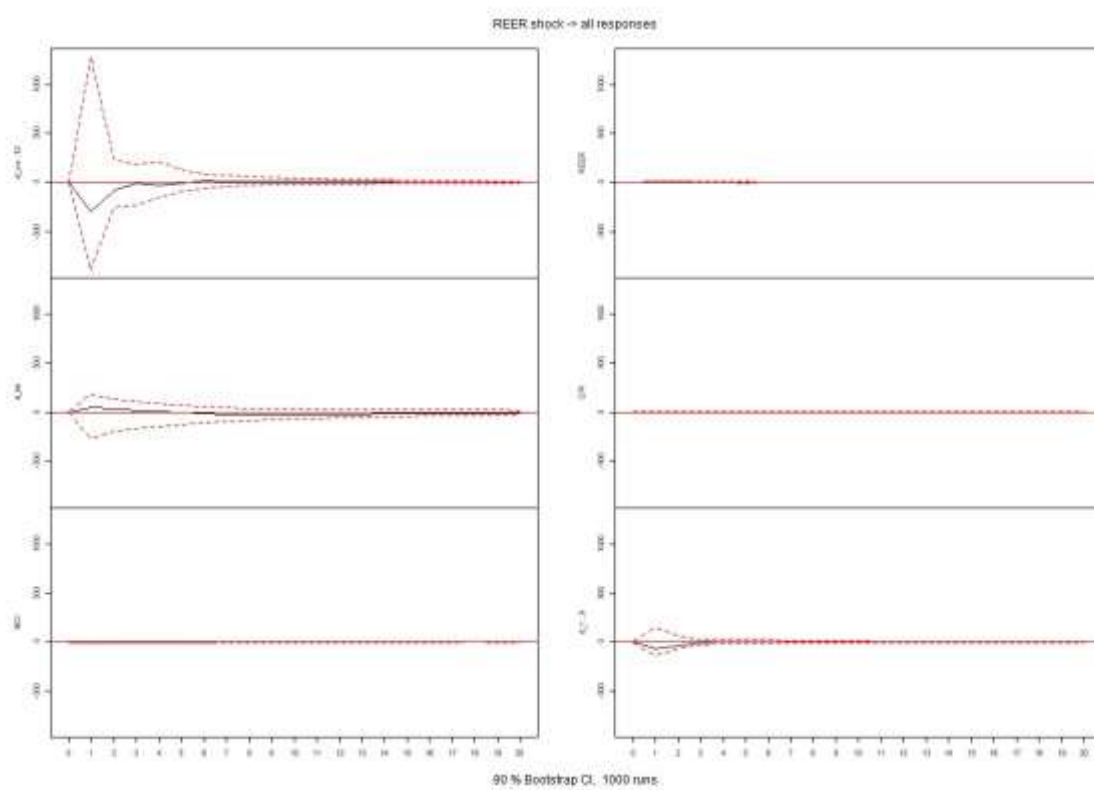


Figure A2: IRFs — VIX Shock

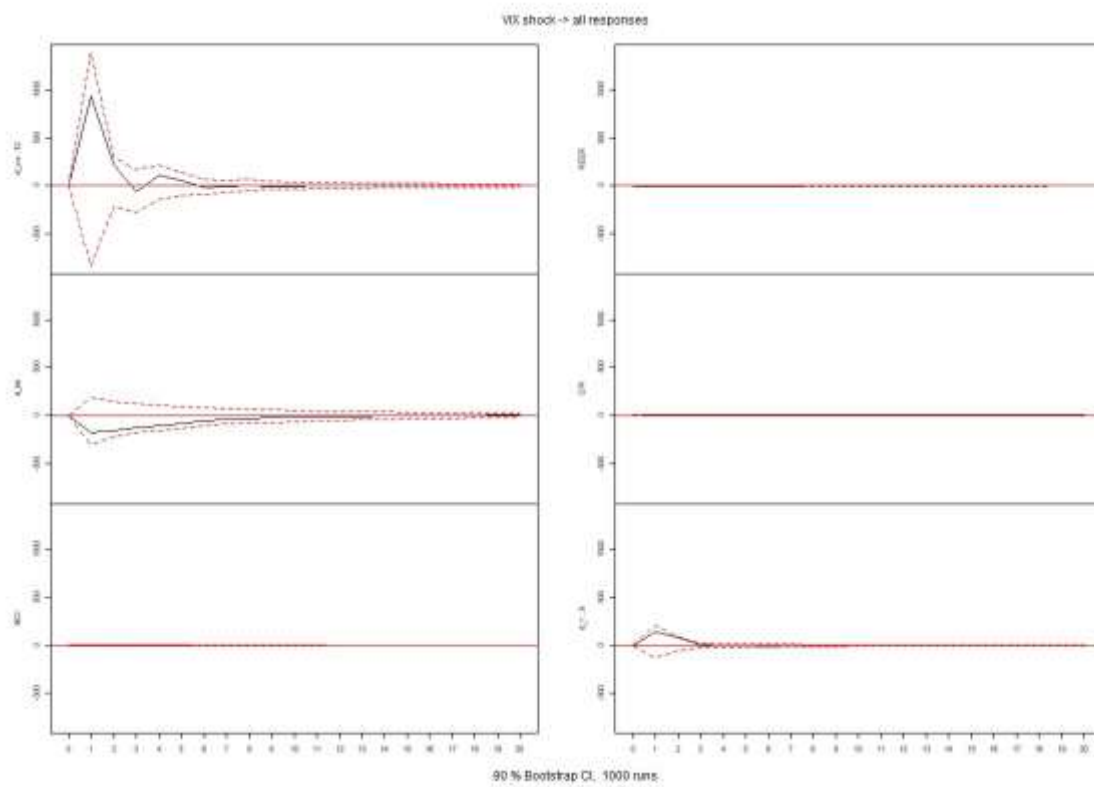


Figure A3: IRFs — IR Shock

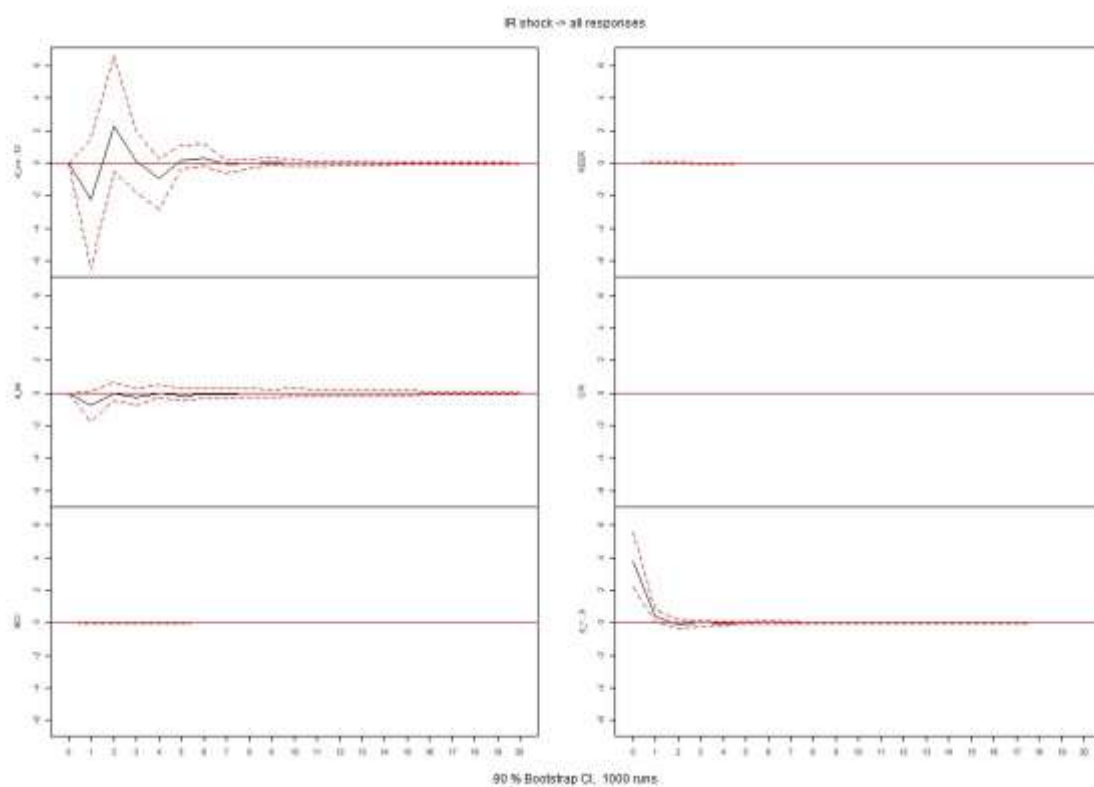
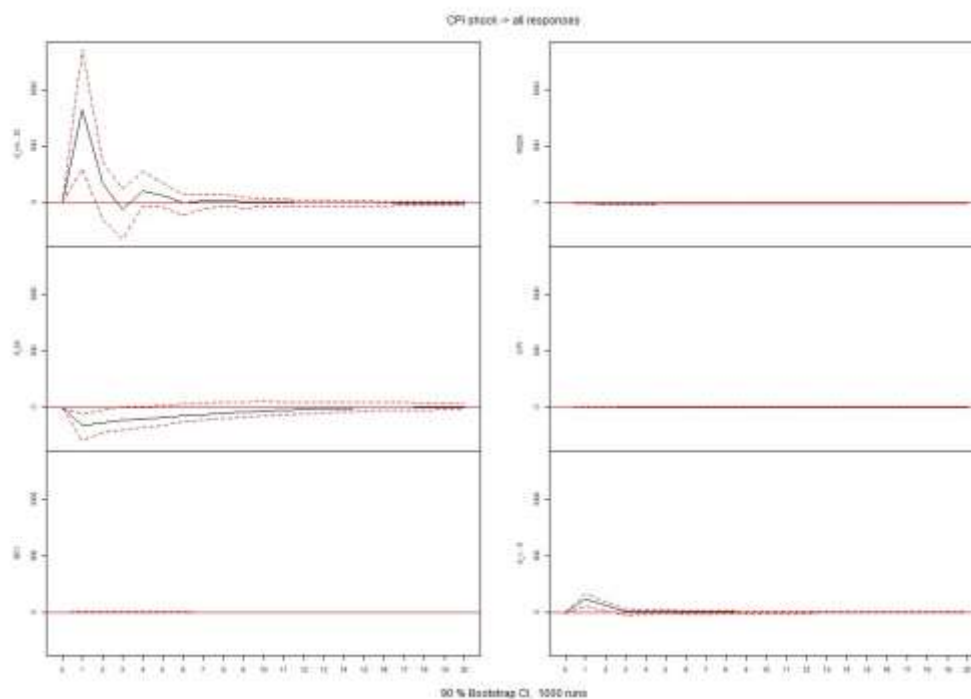


Figure A4: IRFs — CPI Shock



Appendix B: GFEVD

Figure B1: GFEVD for VIX

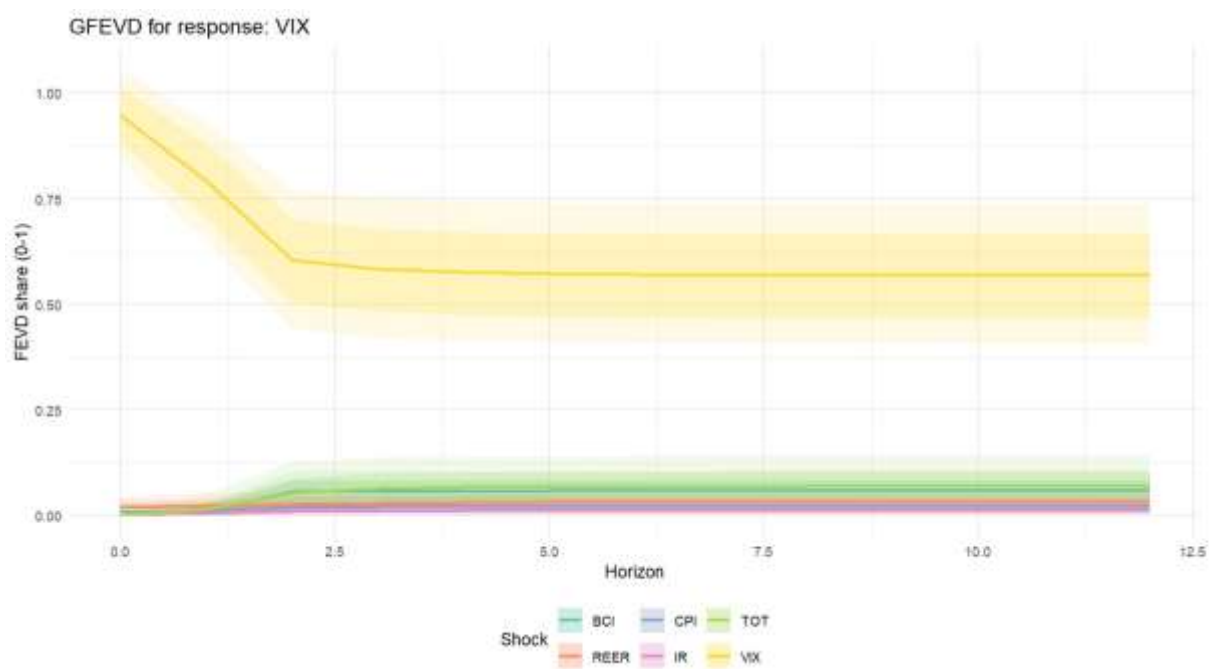


Figure B2: GFEVD for REER

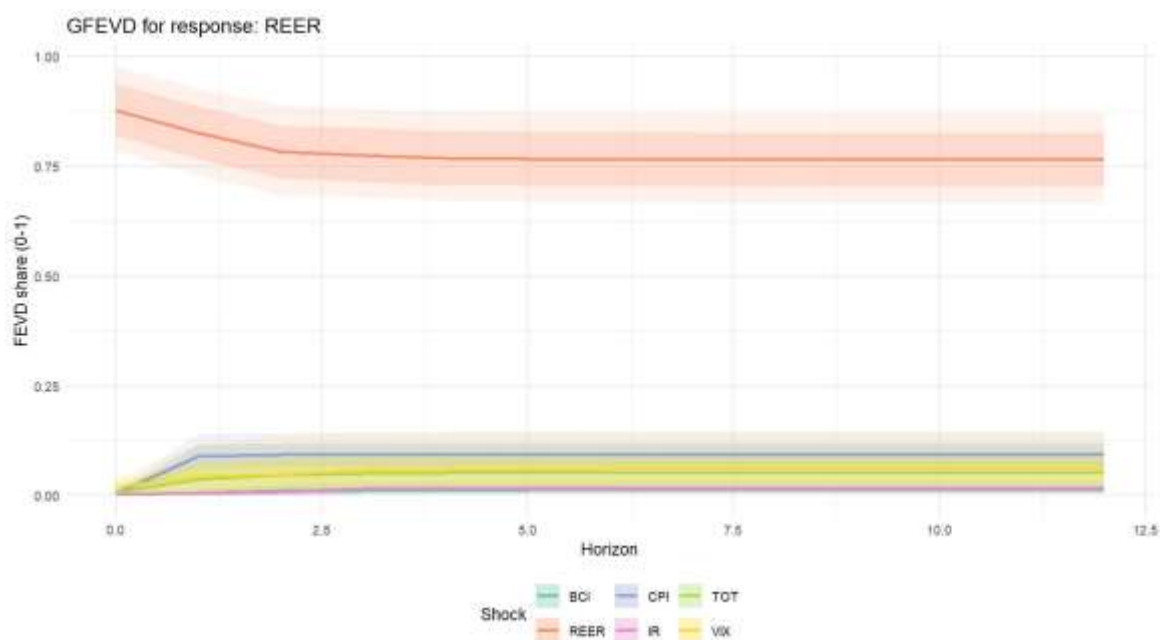


Figure B3: GFEVD for IR

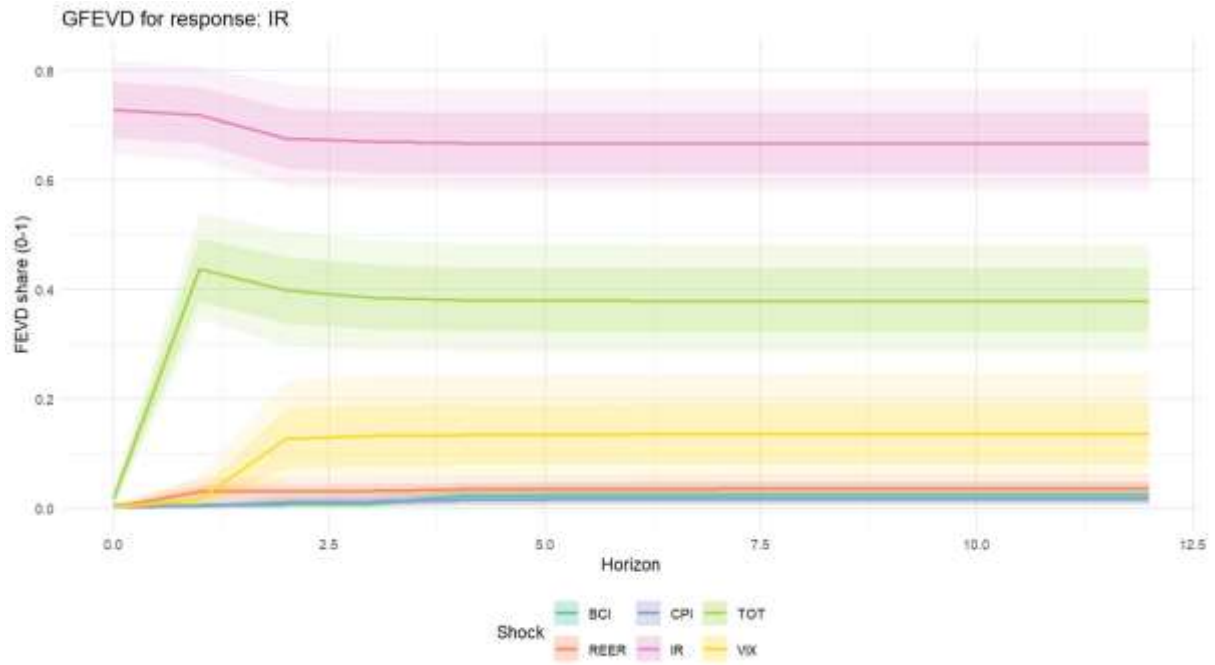
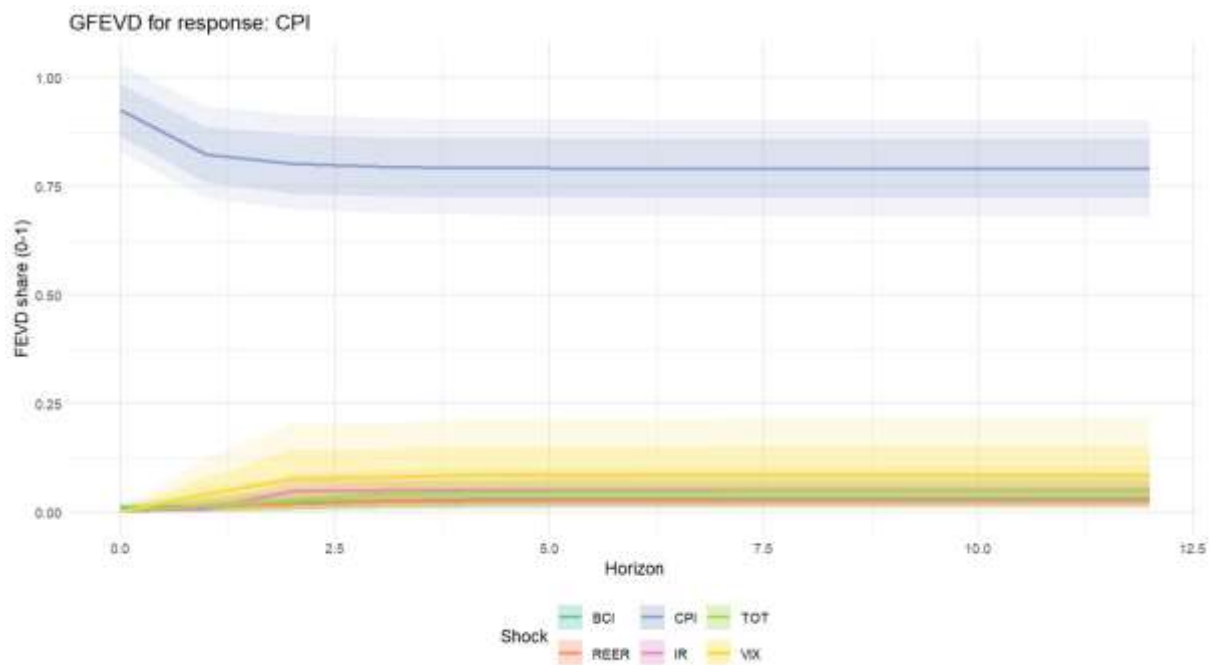
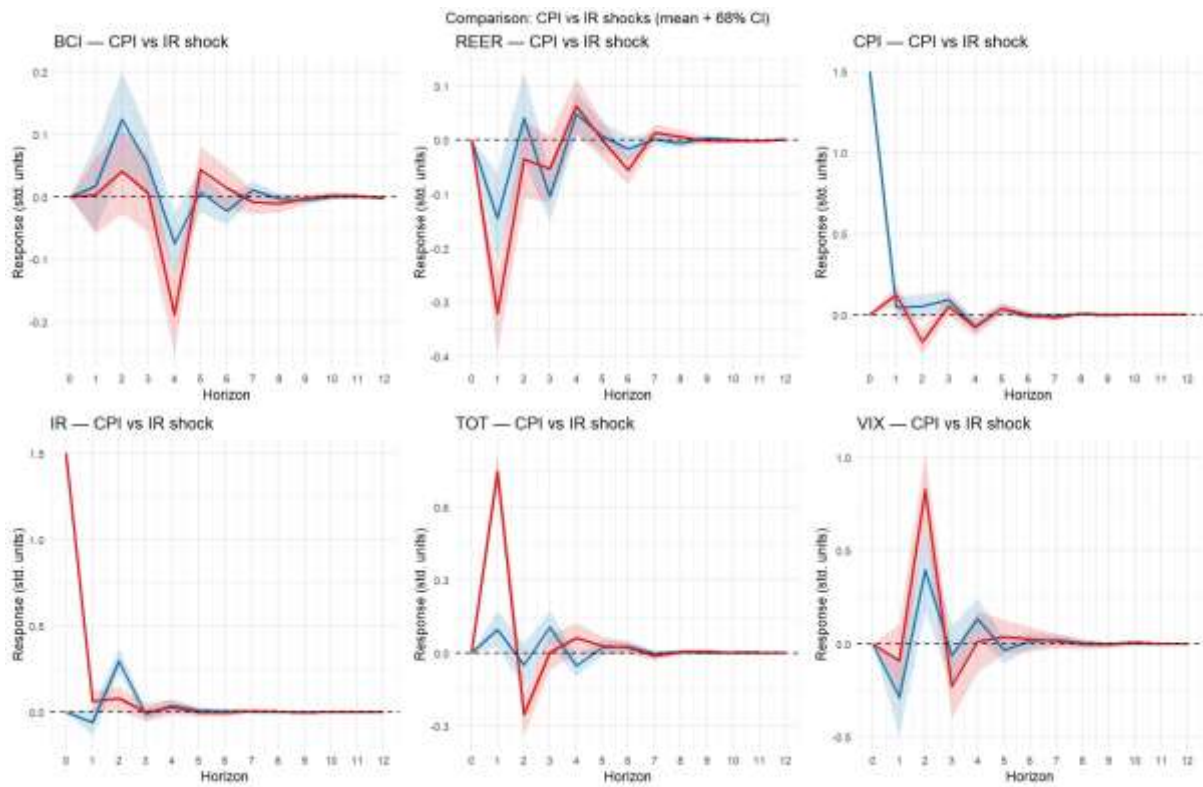


Figure B4: GFEVD for CPI



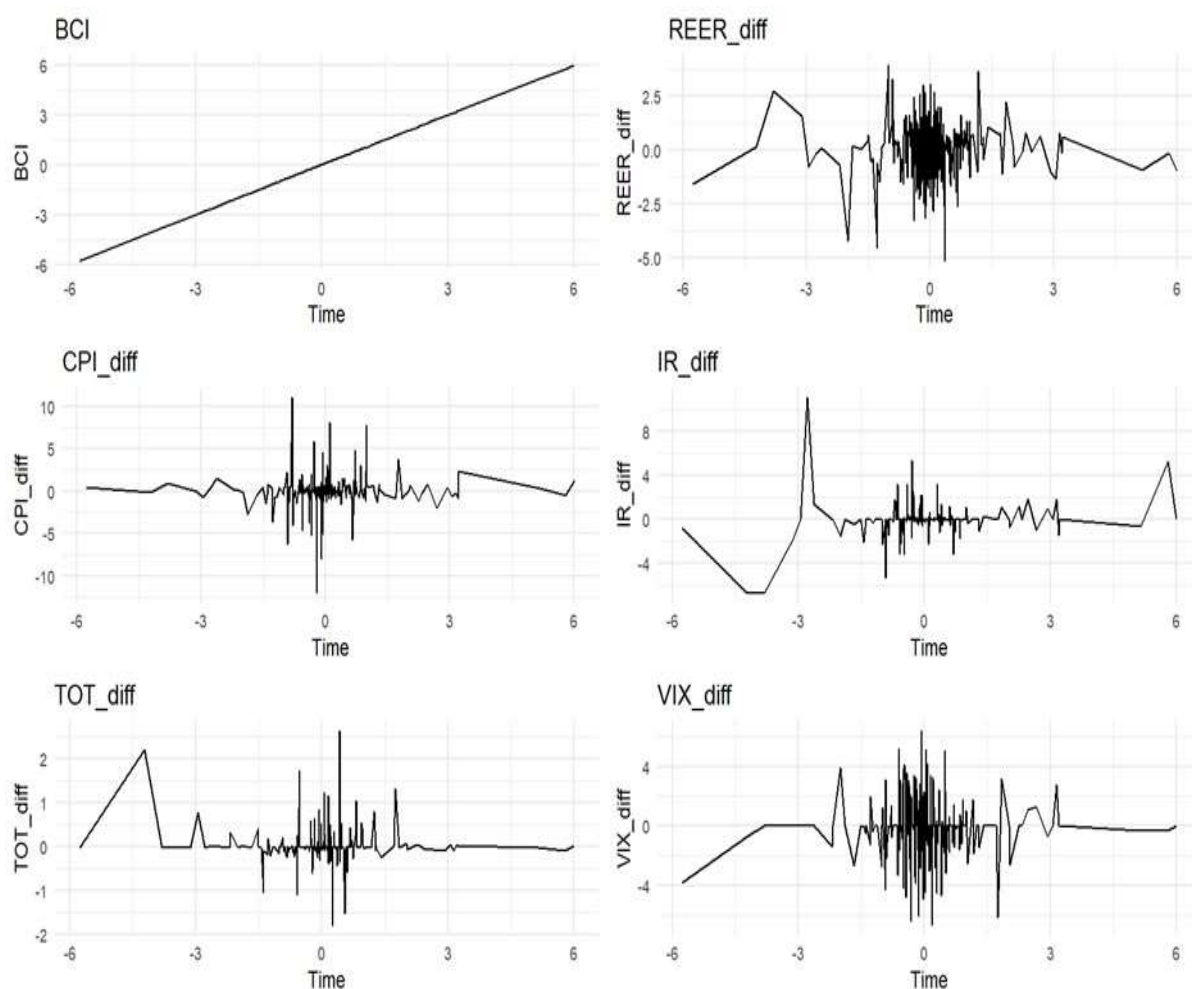
Appendix C: Monetary Transmission Mechanism

Figure C1: CPI Shock vs IR Shock



Appendix D: Time Series Plots

Figure D1: Time Series Plots for all variables



Appendix E: Mathematical Derivation of the TVP-BVAR Model

The Time-Varying Parameter Bayesian Vector Autoregression (TVP-BVAR) extends the standard BVAR by allowing coefficients and error variances to evolve over time. This flexibility captures structural shifts, policy regime changes, and evolving external shocks, all of which are common in emerging economies such as South Africa (Primiceri, 2005; Koop & Korobilis, 2010; Cogley & Sargent, 2005).

Let y_t denote an $n \times 1$ vector of endogenous variables:

$$y_t = [BCI_t, REER_t, CPI_t, TOT_t, IR_t, VIX_t] \quad (14)$$

The TVP-BVAR(p) can be represented as:

$$y_t = X_t' \beta_t + \epsilon_t, \epsilon_t \sim N(0, \Sigma_t) \quad (15)$$

where:

- $X_t = I_n \otimes [1, y_{t-1}', \dots, y_{t-p}']$ is a $(n \times np + 1)$ regressor matrix,
- β_t is a $(np + 1) \times n$ vector of time-varying coefficients,
- Σ_t is a time-varying covariance matrix capturing stochastic volatility.

Each coefficient evolves according to a random walk:

$$\beta_t = \beta_{t-1} + \eta_t, \eta_t \sim N(0, Q) \quad (16)$$

$$\log h_{i,t} = \log h_{i,t-1} + \xi_{i,t}, \xi_{i,t} \sim N(0, S_i) \quad (17)$$

where $h_{i,t}$ are the diagonal elements of Σ_t , capturing time-varying volatility in each equation.

State-Space Representation

The TVP-BVAR can be written in state-space form, which is necessary for recursive estimation via the Kalman filter and Carter–Kohn smoother.

Measurement equation:

$$y_t = Z_t \beta_t + \epsilon_t, \epsilon_t \sim N(0, \Sigma_t) \quad (18)$$

Transition equation:

$$\beta_t = \beta_{t-1} + \eta_t, \eta_t \sim N(0, Q) \quad (19)$$

where:

- $Z_t = I_n \otimes X_t'$,
- Q captures the variance of time variation in coefficients.

This formulation decomposes the model into:

- Observed variables (y_t),
- Unobserved states (β_t),
- Transition dynamics (governed by Q).

Estimation via Kalman Filter

The Kalman Filter provides an efficient recursive method for estimating the unobserved states (β_t) conditional on information available up to time t .

At each period t , the filter proceeds in two stages:

(a) Prediction Step:

$$\hat{\beta}_{t|t-1} = \hat{\beta}_{t-1|t-1} \quad (20)$$

$$P_{t|t-1} = P_{t-1|t-1} + Q \quad (21)$$

(b) Updating Step:

$$v_t = y_t - Z_t \hat{\beta}_{t|t-1} \quad (22)$$

$$F_t = Z_t P_{t|t-1} Z_t' + \Sigma_t \quad (23)$$

$$K_t = P_{t|t-1} Z_t' F_t^{-1} \quad (24)$$

$$\hat{\beta}_{t|t} = \hat{\beta}_{t|t-1} + K_t v_t \quad (25)$$

$$P_{t|t} = (I - K_t Z_t) P_{t|t-1} \quad (26)$$

The Kalman filter thus generates a sequence of conditional estimates $\hat{\beta}_{t|t}$ and associated uncertainty matrices $P_{t|t}$, which form the basis for the posterior sampling process.

Smoothing via the Carter–Kohn Algorithm

While the Kalman filter yields filtered estimates up to time t , the Carter–Kohn (1994) algorithm provides smoothed estimates of the entire path of β_t over all T periods, which is essential for posterior inference in the Bayesian framework.

Backward sampling proceeds recursively:

$$p(\beta_T | Y_T) \sim N(\hat{\beta}_{T|T}, P_{T|T}) \quad (27)$$

$$p(\beta_t | \beta_{t+1}, Y_T) \sim N(\hat{\beta}_{t|T}, P_{t|T}) \quad (28)$$

where:

$$\hat{\beta}_{t|T} = \hat{\beta}_{t|t} + J_t(\beta_{t+1} - \hat{\beta}_{t+1|t}) \quad (29)$$

$$J_t = P_{t|t} P_{t+1|t}^{-1} \quad (30)$$

$$P_{t|T} = P_{t|t} + J_t(P_{t+1|T} - P_{t+1|t})J_t' \quad (31)$$

This backward recursion draws smoothed paths of β_t conditional on the entire dataset, yielding the complete evolution of parameter estimates across the 1990–2024 period.

Gibbs Sampling Procedure

The Gibbs sampler iteratively samples each parameter block from its conditional posterior distribution, holding all others fixed. For the TVP-BVAR, each iteration involves:

1. Draw $\beta_{1:T}$ using the Carter–Kohn algorithm conditional on $\Sigma_{1:T}$ and Q .
2. Draw Q from the inverse-Wishart posterior:

$$Q \sim IW(\bar{S}_Q, \bar{\nu}_Q) \quad (32)$$

where:

$$S_Q = S_Q + \sum_{t=2}^T (\beta_t - \beta_{t-1})(\beta_t - \beta_{t-1})' \quad (33)$$

$$\bar{\nu}_Q = \nu_Q + (T - 1) \quad (34)$$

3. Draw Σ_t from its Inverse-Wishart conditional posterior (35)
4. Draw stochastic volatilities (σ_t) using the algorithm of Kim, Shephard, and Chib (1998), which linearizes the log-volatility process using Gaussian mixtures.
5. Repeat for 20,000–50,000 iterations, discarding the first 20% as burn-in.

Convergence is verified through trace plots, Gelman–Rubin statistics, and autocorrelation diagnostics.

Hyperparameter Calibration

Hyperparameters (λ, μ, ν, S_0) are calibrated using a mix of empirical Bayes and cross-validation techniques.

- Overall tightness (λ): Set initially at 0.2–0.3 for monthly data to prevent overfitting but allow sufficient flexibility.
- Lag decay parameter (δ): Fixed at 1, giving diminishing weight to higher lags.
- Prior mean (A_0): Derived from univariate autoregressive estimates of each variable.
- Degrees of freedom (ν): Set to ensuring a proper Inverse-Wishart distribution.

To check robustness, alternative priors (Loose Minnesota, Flat, and Horseshoe) are tested, and results are compared based on marginal likelihood and Bayes Factors.

Model Validation and Comparison

A strict validation and comparison procedure is needed to validate the empirical appropriateness of the Time-Varying Parameter Bayesian VAR (TVP-BVAR) for investigating exchange rate and business cycle dynamic interaction in South Africa. It benchmarks the TVP-BVAR against the standard fixed-parameter VAR, the classical Bayesian VAR with shrinkage priors, and the Markov-Switching VAR. These models form the main strands of macro econometric study applied to developed and emerging markets.

The traditional VAR(p) formalised by Sims (1980) is the standard to understand linear, constant feature dynamics. Yet fixed-parameter VARs assume structural stability, something scarcely ever achieved in the presence of shifting policy frameworks, a degree of openness to global capital flows, and constant external shocks (Stock and Watson, 2001). In a South African context, the introduction of inflation targeting in 2000, financial liberalisation after 1995, and the periodic shocks from commodity prices have rendered the fixed-parameter assumption very unrealistic.

The classical Bayesian VAR (BVAR), first proposed by Doan, Litterman, and Sims (1984), and subsequently codified by Litterman from 1986, has led to an enhancement of forecast performance due to shrinkage priors (such as the Minnesota Prior). Although such priors mitigate overparameterization and contribute to better small-sample forecasting (Del Negro and Schorfheide, 2011), the classical BVAR is static and cannot capture the changing behaviour of monetary policy or the pass-through of the exchange rate.

The Markov-Switching VAR (MS-VAR) (Hamilton, 1989) permits coefficient shifts between discrete regimes, so it is good for detecting sudden transitions like crises, financial stresses, and inflation changes. MS-VARs do not yet incorporate smooth drift in coefficients, which some empirical evidence shows is crucial for comprehending policy evolution and business cycle dynamics (Kim and Nelson, 1999). For any economy as dynamic as South Africa, where monetary systems moved slowly, global integration deepened over time, and credibility improved non-linearly, MS-VARs only represent part of this structural change.

The study uses two standard diagnostic frameworks for systematic model performance comparisons. Marginal Likelihoods (ML), which assess model fit, penalise unnecessary complexity, and help to address the issue (Chib and Jeliazkov, 2001). Posterior Predictive Checks (Gelman et al., 2013) confirm whether posterior distribution-simulated data reproduces major empirical characteristics like persistence, volatility clustering, and cyclical comovement. Adhering to the international evidence, TVP-BVAR presents better performance. Giannone, Lenza and Primiceri (2015) show that TVP-BVARs perform better than fixed-parameter VARs under varying policy regimes, structural instability, or variations in the transmission of shocks. The results of Koop

and Korobilis (2013) support this, as time variation and stochastic volatility have enhanced forecasting accuracy and structural inference, too, in open economies. These results provide compelling evidence for TVP-BVARs as the fundamental empirical framework for modelling the exchange rate–business cycle nexus in South Africa.

In accordance with best practices in Bayesian macro econometric modelling, the empirical analysis is conducted in the R statistical computing environment (Hastie, Tibshirani and Friedman, 2009; McElreath, 2020). TVP-BVAR estimation is based on the state-space representation of the model and simulation-based Bayesian methods to estimate time-varying coefficients and stochastic volatilities.

The estimation is carried out with specialised R libraries, including BMR (Bayesian macroeconomic models) and bvarsv (VARs with stochastic volatility), based on the strategies proposed by Cogley and Sargent (2005) and Primiceri (2005). Kalman filtering

and smoothing routines for estimating latent states are offered by supporting packages like KFAS (Helske, 2017) and dlm (Petrus, Petrone and Campagnoli, 2009). The computational procedure starts with the specification of diffuse or weakly informative priors, based on the lack of an in-depth understanding of initial parameter values (Gelman et al., 2013). Finally, the model is cast in its state-space format to enable recursive updating by means of the Kalman Filter (Harvey, 1990; Durbin and Koopman, 2012). The Kalman smoother sharpens the filtered estimates by utilizing full-sample information.

Posterior inference is carried out with a Gibbs sampler, which updates the conditional posterior distributions of the time-varying coefficients, shock variances, and hyperparameters. The simulation adheres to the algorithmic architecture articulated by Carter and Kohn (1994) and the original model (Kim and Nelson, 1999) for regime and volatility modelling.

Convergence is examined with the help of regular diagnostics, such as trace plots, Gelman–Rubin statistics (Gelman and Rubin, 1992), and effective sample sizes. All

estimation techniques are reproducible through seeded simulations, contributing to methodological transparency, enabling to provision of a reproducible model of the results.



03-11-2025
Miss Amara Liyabona Mngcutsha (225180052)
Westville

Dear Miss Amara Liyabona Mngcutsha,

Original application number: 22200133
Project title: Exploring the relationship between exchange rates and business cycles in South Africa

Exemption from Ethics Review

In response to your application received on 19 September 2025, your school has indicated that the protocol has been granted **EXEMPTION FROM ETHICS REVIEW**.

Any alteration/s to the exempted research protocol, e.g., Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through an amendment/modification prior to its implementation. The original exemption number must be cited.

For any changes that could result in potential risk, an ethics application including the proposed amendments must be submitted to the relevant UKZN Research Ethics Committee. The original exemption number must be cited.

In case you have further queries, please quote the above reference number.

PLEASE NOTE:

Research data should be securely stored in the discipline/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours sincerely,

Prof Claire Lauren Vermaak
Academic Leader Research

UKZN Research Ethics Office
Westville Campus, Govan Mbeki Building
Postal Address: Private Bag X54001, Durban 4000
Website: <http://research.ukzn.ac.za/Research-Ethics/>

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13-11-2025
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