

ESSAYS ON THE MALAWIAN BANKING SECTOR

DOCTOR OF PHILOSOPHY (ECONOMICS) THESIS

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UNIVERSITY OF MALAWI

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DOCTOR OF PHILOSOPHY (ECONOMICS) THESIS

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UNIVERSITY OF MALAWI

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DECLARATION

I solemnly declare that this work is a result of my own effort and has never been presented to any university or institution of higher learning for academic purposes. All information from other sources has been duly acknowledged.

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Full Legal Name

Signature

Date

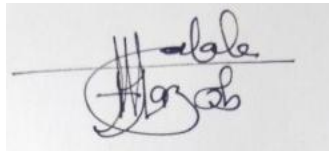
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DEDICATION

I dedicate this thesis to my children, Shaun Chimango Kumwenda and Sandra Cindy Kumwenda, as a future inspiration, encouragement, call to a life of hard work and pursuit for excellence. This is an epitome of hard work, and demonstration of a life dedicated to the pursuit of dreams and excellence. Work hard my children, and may the Almighty GOD bless your labour, make it meaningful and fruitful.

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ABSTRACT

This dissertation presents essays on the Malawian banking sector. The first essay examines Malawian business cycles and banks' asset allocation strategies. The analysis indicates that banking sector shocks from public debt financing explain short- and long-term output changes in Malawi. This research shows that domestic banking sector public debt shocks of between 1%-20% affect investments by 5%–15%, consumer loans by 2%–10%, corporate loans by 1%–5%, bank capital by 5%–15%, and bank financing by 1%–5%. The second essay examines changes in banking regulations and how their adoption impact bank lending activities. The non-risk weighted asset Basel III leverage ratios have significant and negative impacts on Malawi's bank sector lending growth. The liquidity coverage ratio (LCR) had a positive and significant effect in explaining variability in lending in Malawi's banking overall; whilst the introduction of a stable funding ratio (SFR) has a positive and significant impact on banking sector-wide lending growth effects. The study also found that the Basel III Capital and Liquidity rules have different effects on firm-level lending for the eight (8) banks in Malawi. The third essay studies the determinants of financial sector reforms in Malawi. Our study finds that macroeconomic, monetary and fiscal drivers such as the ratio of external debt stock to gross national income ratio, broad money to GDP ratio, domestic credit to GDP ratio, short term debt to export and non-export revenues, short term debt to external debts, changes in inflation, changes in GDP and total reserves to external debt have a negative and significant impact in accelerating financial sector reforms in Malawi. The analyses do not only contribute to the existing limited literature on banking, but also demonstrate how applied econometrics methodologies can be used in the field of banking studies in Malawi.

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LIST OF ABBREVIATIONS AND ACRONYMS

AASF	-	Adjusted Available Stable Funding
ADMARC	-	Agricultural Development and Marketing Company
ASF	-	Available Stable Funding
BIS	-	Bank of International Settlements
BLUE	-	Best Linear Unbiased Estimates
B-P/LM	-	Breusch Pagan/Lagrangian Multiplier
BRICS	-	Brazil, Russia, India, China and South Africa
CBM	-	Commercial Bank of Malawi
CD	-	Cross Sectional Dependency
CPI	-	Consumer Price Index
DPE	-	Dynamic Panel Estimations
DSGE	-	Dynamic Stochastic General Equilibrium
DWH	-	Durbin-Wu-Hausman
ECL	-	Expected Credit Losses
EU	-	European Union
FE	-	Fixed Effects
FED	-	Federal Reserve
FGLS	-	Feasible Generalised Least Square
FIH	-	Financial Instability Hypothesis
FINCOM	-	Finance Company of Malawi
FMB	-	First Merchant Bank
FOC	-	First Order Condition
G10	-	Group of Ten
GAM	-	Generalised Additive Models
GDP	-	Gross Domestic Product
GLS	-	Generalised Least Square
GNI	-	Gross National Income
GoM	-	Government of Malawi
HQLA	-	High Quality Liquid Assets
IAS	-	International Accounting Standards

IDA	-	International Development Association
IFRS	-	International Financial Reporting Standards
IMF	-	International Monetary Fund
INDEBANK	-	Investment and Development Bank of Malawi
IRB	-	Internal Rating Based
LCR	-	Liquidity Coverage Ratio
LDR	-	Loan to Deposit Ratio
LM	-	Lagrangian Multiplier
LRE	-	Linear Rational Expectation
LRR	-	Liquidity Reserve Requirement
LTV	-	Loan to Value
MBC	-	Mybucks Banking Corporation
MoF	-	Ministry of Finance
NBM	-	National Bank of Malawi
NBS	-	New Building Society
NFB	-	New Finance Bank
NFC	-	National Finance Company
NSFR	-	Net Stable Funding Ratio
NSO	-	National Statistics Office
OECD	-	Organisation for Economic Cooperation and Development
OIBM	-	Opportunity International Bank of Malawi
OLS	-	Ordinary Least Squares
POSB	-	Post Office Savings Bank
QTM	-	Quantity Theory of Money
RBM	-	Reserve Bank of Malawi
RE	-	Random Effects
RF	-	Risk Factor
RFR	-	Risk Free Rate
ROA	-	Return on Assets
ROE	-	Return on Equity
RSF	-	Required Stable Funding

RWA	-	Risk-Weighted Assets
SAP	-	Structural Adjustment Programme
SFR	-	Stable Funding Ratio
TB	-	Treasury Bills
TN	-	Treasury Notes
US	-	United States
USD	-	United States Dollar
WEO	-	World Economic Outlook

CHAPTER ONE

INTRODUCTION

1.1 Overview

The banking sector plays a key role in Malawi's socio-economic development. This thesis presents three essays that offer comprehensive analyses of several emerging issues in the country's banking sector. There is limited literature on banking studies in Malawi, particularly those that investigate the effects of government borrowing from the banking sector on the wider economy using workhorse macroeconomic models such as DSGEs. There is, similarly, limited literature on banking regulations in Malawi and how they affect the lending to the real sector of the economy. Lastly, the literature on banking sector reforms in Malawi is also scarce. This thesis contributes to, and spearheads, discussions that lead to narrowing these research gaps. The specific objectives of the study are; a) to investigate the extent to which shocks resulting from the financing of public domestic debt from the banking sector in Malawi affects the economy; b) to investigate the impact of adopting Basel III liquidity and capital regulations on bank lending across various banks in Malawi, and; c) to investigate the determinants of financial/banking sector reforms in Malawi. The analyses do not only contribute to the existing limited literature on banking, but also demonstrate how applied econometrics methodologies can be used in the field of banking studies in Malawi.

Studies on banking often waver between the Keynesian and Monetarism schools of thought. These schools of thought form the bedrock and background of the analyses employed in the essays. Keynes's central theme was that governments should solve economic problems in the short term rather than wait for market forces to clear markets in the long run, because, as he wrote, "In the long run, we are all dead" (Keynes, 1923).

The cure for slow economic growth and inflation, according to the Keynesians, was fiscal operation (counter-cyclical fiscal policy, which is targeted government spending in the opposite direction of business cycles). According to the Keynesians, government deficits or unbalanced government budgets are not wrong in themselves. However, they noted problems in the direction of government spending during economic crises. As a solution to recessions, they advocated the implementation of countercyclical fiscal policies that move in the opposite direction of the business cycle. The policy prescription by typical Keynesians during economic downturns is heavy government spending on labour-intensive infrastructure projects to stimulate employment and stabilize wages.

Keynesians encourage raising taxes to cool down the economy and prevent inflation when there is abundant demand-side growth, and reduction of interest rates to encourage investment. Hence government borrowing (expansionary fiscal policies) is not bad, and thus, justifies government spending and intervention when the economy is performing below its potential (below full employment) (Keynes, 1923). After the first and second world wars, many governments accumulated significant public debt stocks with the Keynesian model, underinvested as the debt to GDP ratios skyrocketed, and saw investment in public infrastructure dwindling due to reduction in fiscal space on account of excessive debt repayments (debt-overhang). The Keynesian strand of economics dominated economic theory and policy after World War II until the 1970s, when many advanced economies suffered both inflation and slow growth, a condition dubbed “stagflation” (Friedman & Schwartz, 1963). Keynesian theory’s popularity waned because it had no appropriate policy response for stagflation. Again, the original Keynesian theory was criticised for ignoring the banking sector in economic modelling. These criticisms led to the rise of Monetarism in the 1970s. The central theme of Monetarism (positive approach) was that markets or economies are generally stable and that government interventions make business cycles or economic crises severely worse. It criticizes Keynesian economics and offers policy solutions to stagflation problems through theoretical underpinning of the quantity theory of money (QTM) (Friedman & Schwartz, 1963).

The discussions above form the theoretical foundation for the research questions we explored in all the three chapters of this thesis. The second chapter discusses the Bank Domestic Debt Financing (Government Borrowing) and its effects on the Malawian Economy (Business Cycles). Here we actively investigate the role that excessive government borrowing through the domestic banking system has on the wider economy. The justification of government borrowing is mostly a Keynesian perspective. It promotes government intervention in the economy to help the economy move out of recessions, address market failure, and reallocate resources. In this chapter, I use a Bayesian Dynamic Stochastic General Equilibrium Model (DSGE) to aid the policy analysis. In Appendix A2.5, I have provided a detailed examination of the implementation of the Bayesian DSGE modelling approach in the study. In addition, I have provided a thorough examination of the solution methods for Linear Rational Expectations Difference models, including DSGEs as one of them, as well as the implementation of the Dynare software that we used.

The third chapter of the thesis has its theoretical foundations in both the Keynesian and Monetarist schools of thought. It analyses the effects of implementing Basel III, liquidity, and capital rules on the banking industry in Malawi. Banking regulations have their foundation in Keynesian economics (normative approach), which view regulation as a public good that has both positive and negative externalities. This approach justifies state interventions to correct the excesses of the markets. The Keynesian school justifies the interventions of government in markets due to market failures, and argues that markets are inherently unstable, particularly on the supply side, necessitating regulation (Marshall, 1997 [1920]; Pigou, 1932 [1920]; Frey, 1981; Varian, 2001; Blankart, 2006; Akerlof, 1970; Stiglitz & Weiss, 1981; Mishkin, 2013; Arrow, 1985; Varian, 2004; Tirole, 1988; Greenbaum & Thakor, 2007 [1995]; Burghof & Rudolph, 1996; Goodhart et al., 1998; Laffont & Martimort, 2002).

Under the positive approach, the proponents postulate that market players have good intentions and that naturally regulations work in their best interest. According to monetarists such as Friedman (1962), Hertog (2010), Stigler (1971), and Peltzman (1976), the positive approach focuses on objective facts and is not influenced by any specific

ethical attitude or normative judgements. It involves providing the economic justifications for regulation and analysing of the effects of regulation, and it encompasses the political decision-making process and includes the development of the content and structure of banking regulation. The positive approach classifies regulation as a public good that is subjected to the market driven principles of supply and demand. The positive approach encompasses private interest theory, which comprises the capture theory, the economic theory of regulation, the bureaucracy theory, and the public funding approach. However, changing rules in banking and the introduction of newer innovative products destabilized the popular monetarist quantity theory of money. The era from 1970 to 2000 saw the introduction of the Basel Banking Regulation that fostered harmonisation of global banking systems. These regulations brought new rules that changed the velocity of money. The evolution of banking services also brought new products on the market, unlike the old banking system on which the Keynesian and Monetarist theories were based.

The change in the predictability of the velocity of money was as a result of changes in banking rules and other financial innovations. Hence the discussions in Chapter Three of the thesis highlight changes the manner in which monetarists viewed the economy, as the changes in banking regulations and innovations permanently altered the velocity of money. In the 1980's banks were allowed to offer interest-earning current accounts, eroding some of the distinction between current and savings accounts. Moreover, many people found that money markets, mutual funds, and other assets were better alternatives to traditional bank deposits. As a result, the relationship between money and economic performance changed. The innovations in the banking sector challenged the core monetarist quantity theory of money, as the velocity for money completely changed its dynamics or became unobservable. The Basel I, II, and III, regulations, and in particular the capital and liquidity requirements, contributed to the changing velocity of money. The third chapter analyses the effects of implementing Basel III, liquidity and capital rules on the banking industry in Malawi. The study uses the Feasible Generalised Least Square (FGLS) model. Appendix B3.2 contains an examination of the FGLS model used in the study. This work has been published and can be obtained online at the following link: <https://doi.org/10.55217/102.v18i1.748>. One of the major criticisms of Keynesian and

Monetarist strands of economics was their ignorance of banking sector influences in precipitating business cycles, even though this was later corrected by neo-Keynesians and Monetarists. All major economic crises have been exacerbated by banking crises. Examples include the Great Depression of the 1930s, and the 2007-08 Financial Crisis. Banking crises or fragilities have the potential to amplify economic recessions even if the economic shocks were not endogenously originated from the banking sector; banks tend to magnify macroeconomic shocks through their adherence to prudential requirements of sound capital and liquidity management which affects the demand and supply of loans and deposits, even if banks are passive responders to shocks and even if depositors avoid engaging in unwarranted runs or panics. This underscores the importance of understanding the economics of banking. Without a good understanding of a banking system, Keynesian and Monetarist economics will not accurately solve economic problems and offer potent policy solutions.

The fourth part of the study focuses on analysing the factors that contribute to financial sector reforms, specifically in the context of Malawi. For nearly a century, scholars have engaged in discussions regarding the significance of the financial sector in the context of economic development. Since Schumpeter (1911) presented arguments highlighting the productivity and growth enhancing effects of the services offered by a developed financial sector, a significant body of theoretical and empirical literature has developed. Initially, this literature examined whether the financial sector has a causal influence on economic development or if financial intermediaries simply emerge from swift industrialization. Proposed by Robinson (1952), this perspective held significant influence until the mid-1960s. Gerschenkron (1962), Patrick (1966), and especially Goldsmith (1969), emphasised the dynamic influence that the financial sector can exert in the context of economic development. This ground-breaking work has significantly influenced the trajectory of thought, yet the question of causality continues to be a crucial topic in theoretical discussions to this day.

During the 1970s, the focus was on the phenomenon of financial repression, a strategy employed by numerous governments to stimulate growth and revenue by maintaining

artificially low interest rates and implementing inflationary monetary policies. The theoretical foundations of financial repression were laid by Keynes (1936) and Tobin (1965), who supported the notion of government intervention in the credit market. McKinnon & Shaw (1973) inadvertently presented critiques of Keynesian financial repression policies. Their arguments mainly stemmed from a Monetarist stance (positive approach), where much emphasis was on letting market forces of demand and supply determine the structure of interest rates in an economy. McKinnon & Shaw's (1973) work led to significant financial sector reforms in the developing world, including Malawi. The importance of the financial sector in enhancing savings volumes through the establishment of suitable incentives was highlighted. To achieve elevated savings and investment rates, it was suggested that governments eliminate interest rate ceilings and refrain from increasing seigniorage through inflationary monetary policies. Consequently, real interest rates ought to increase to levels that clear the market, thereby promoting higher savings.

During the early 1980s, the Neo-structuralists offered critiques of the McKinnon-Shaw school, forecasting that financial liberalisation would impede growth. Their arguments reflect the ideas presented by Keynes (1936) and Tobin (1965). Stiglitz (1989) critiques financial liberalisation based on theoretical considerations regarding market failures within financial markets. A distinct aspect of the theory that establishes a positive connection between finance and growth surfaced in the early 1990s, evolving as a segment of the literature on endogenous growth. King & Levine (1993) adhere to Schumpeter's perspective by highlighting the significance of innovation in the financial systems, effectively directing savings towards their most efficient applications while also mitigating the risks linked to these endeavours. By accomplishing these tasks, they enhance the likelihood of successful innovation and accelerate the pace of technological advancement. Levine (1997) outlines several fundamental roles of financial systems that promote capital accumulation and productivity growth: they enable trading, hedging, diversifying, and pooling of risk; they allocate resources; they oversee managers and enforce corporate governance; they mobilise savings; and they facilitate the exchange of goods and services.

Hence the importance of Chapter Four, which focuses on the determinants of financial sector reforms in Malawi's banking sector. The study uses the logistic regression approach to conduct this analysis. The entire study of logistic models, which are founded on conditional probabilities, is presented in Appendix C4.1. We also examine their uses in the field of the study.

1.2 Thesis Conclusions

The three chapters of this thesis are interconnected and share a unified theme. Our analysis begins with an examination of the dynamics of the Malawian banks' balance sheet and the funding of domestic debt, exploring its impact on the Malawian business cycles. In Chapter Three, we will investigate the emerging regulatory changes within the Malawian banking sector and their influence on intermediation levels across various banks in Malawi. Finally, Chapter Four will focus on banking sector reforms and the factors that determine them.

The second chapter of the thesis explores how shocks from the domestic banking sector's financing of public debt affect the dynamics of the business cycle in the Malawian economy. The central argument is that the government of Malawi, confronted with ongoing fiscal deficits, must resort to domestic borrowing. In recent years, this has been achieved primarily through two key actions: (i) a significant rise in the issuance of longer-term securities (Treasury Notes) to the domestic banking sector, starting in January 2017, and (ii) a steady increase in the issuance of short-term securities (Treasury Bills) to the domestic banking sector since approximately 2013 (Figure 2.3). The dynamics of fiscal funding can potentially lead to a reduction in private investment, as banks find themselves with diminished capital for lending to the private sector. This situation, in turn, obstructs productive investment opportunities for firms and entrepreneurs. The investigation was initiated due to the significant debt sustainability challenges faced by Malawi. The research employs a closed-economy DSGE model that incorporates a banking sector providing loans to both private and public sectors, alongside patient and impatient households, entrepreneurs, capital goods manufacturers, the government sector, and a central bank. The primary conclusions of the study reveal that shocks in the banking sector, arising from the financing of public debt, significantly influence variations in output, investments, loans to

households and businesses, as well as the volatility in bank funding and capital levels in Malawi, both in the short and long term. Our findings indicate that these shocks from public financing displace the supply of credit from the private sector when the central government faces liquidity constraints.

Chapter Three of the thesis examines the effects of implementing the Basel III Liquidity Coverage Ratio, Stable Funding Ratio, and Leverage Ratio on the banking sector in Malawi. Malawi adopted the Basel I capital regulations in January 2000 and later transitioned to Basel II in January 2014, reflecting its commitment to the international alignment of financial systems. Currently, the nation is preparing to adopt Basel III, which is scheduled for formal implementation in January 2025. The essential aspects of Basel III include the implementation of more rigorous liquidity standards, specifically the Liquidity Coverage Ratio (LCR) and the Stable Funding Ratio (SFR). Basel III additionally established a non-risk weighted asset capital ratio referred to as the Leverage Ratio (LR), complementing the requirement to adhere to the existing risk-weighted capital ratios of Tier 1 and Tier 2. The implementation of Basel III will require financial institutions to enhance their capital reserves, with the objective of fortifying their balance sheets to better withstand losses arising from their own risk-taking activities or fluctuations in the business cycle. In addition, these financial institutions must maintain high-quality liquid assets (HQLA) and a stable funding level to safeguard their capacity against adverse liquidity shocks and funding withdrawals. Nonetheless, the crucial inquiry persists: how will these supplementary liquidity and capital regulatory frameworks for banks influence their capacity to optimise balance sheets for the purposes of compliance, intermediation, and profitability in Malawi? The main conclusion of our research indicates that authorities ought to consider the varied characteristics and behaviour of banks when enforcing the more stringent Basel III Liquidity Standards. This could involve utilising segmentation criteria as a guide for the adoption of these standards and permitting banks of different sizes a compliance window or waiver. This method is essential for ensuring financial stability and serves both microprudential and macroprudential objectives, as it enables numerous financial institutions to endure, and prevents market consolidations that could lead to unwarranted monopolistic behaviour within the sector.

Chapter Four of the thesis delves into the factors influencing financial sector reforms within the Malawian banking sector. Reforms in the financial sector consist of policy measures aimed at deregulating the financial system and altering its structure to establish a market-oriented system that operates within a suitable regulatory framework. A summary of the primary financial sector policy reforms that occurred in Malawi from 1980 to 2023 can be found in Table 4.2. The findings from our analysis suggest that the reforms in the financial sector of Malawi are chiefly shaped by macroeconomic (fiscal) and monetary elements. The findings suggest that certain aspects of financial repression persist within Malawi's financial sector, highlighting the need for the implementation of reforms in this area. Financial repression is a notable and unintended form of financial limitation, often regarded as a less-than-ideal approach for governments facing challenges with fiscal space, particularly in terms of tax collection capabilities. In these constrained fiscal environments, many governments in developing nations turn to seigniorage revenue, raise reserve requirements, and acquire substantial government bonds from the domestic financial sector.

CHAPTER TWO

BANK DOMESTIC DEBT FINANCING AND ITS EFFECT ON THE MALAWIAN ECONOMY

Abstract

This essay examines Malawi's business cycles and banks' asset allocation strategies. The developing nation's banking sector is incorporated into a Bayesian DGSE model using 2004–2020 Malawi data. We extended the model by Gerali et al. (2010) by introducing a public debt accumulation channel and fiscal sector to the model. Financial intermediation in the model comprises household and corporate loans, deposit mobilisation, and active public debt financing in a cash-constrained central government treasury. Our analysis indicates that banking sector shocks from public debt financing explain short- and long-term production changes in Malawi. This research shows that domestic banking sector public debt shocks affect investments by 5%–15%, consumer loans by 2%–10%, corporate loans by 1%–5%, bank capital by 5%–15%, and bank financing by 1%–5%. The study supports the theory of domestic debt crowding-out.

2.1 Introduction

Since the 2007 financial crisis, there has been a re-emergence of studies focusing on understanding the interactions between bank asset allocation choices and business cycles. The crisis renewed interest in macroeconomics and financial interdependence; there has been growing literature following the seminal works of Fisher (1932), Keynes (1936), Minsky (1964), Minsky (1977) and Minsky (1982). With the advancement in economic modelling and forecasting, many studies have concentrated on a strand of literature called

financial frictions, whose dominant approach has consisted of financial frictions in a dynamic stochastic general equilibrium (DSGE) framework. Financial frictions are limits on a company's ability to get the money it needs for investments from outside sources. The company itself or the terms of the credit can set these limits. These are further discussed in Section 2.3.

The paper investigates the extent to which shocks resulting from the financing of public debt by the domestic banking sector influence business cycle dynamics in Malawi's economy. The main narrative is that the Malawi government, faced with persistent fiscal deficits, needs to borrow domestically. It has done so in recent years, mainly by (i) drastically increasing the stock of longer-term securities (Treasury Notes) sold to the domestic banking sector since January 2017, and (ii) gradually increasing the stock of short-term securities (Treasury Bills) sold to the domestic banking sector since around 2013 (Figure 2.3). These fiscal funding dynamics, in turn, have the potential to crowd out private investment (banks now have less capital available for lending to the private sector), which hinders productive investment by firms and entrepreneurs.

The analysis was prompted by Malawi's debt sustainability issues, which are discussed in Section 2.2. The study uses a closed-economy DSGE model that includes a banking sector that lends to the private and public sectors, patient and impatient households, entrepreneurs, capital goods manufacturers, the government sector, and a central bank. Some parameters of the model are calibrated, while others are calculated using Bayesian methods. The study's primary conclusions indicate that public debt shocks lead to a decrease in investments by 5%-15%, loans to consumers by 2%-10%, and loans to businesses by 1%-5%.

Additionally, these shocks of between 1%-20% result in a 5%-15% rise in bank capital and a 1%-5% reduction in bank core financing when interest rates are low, reflecting an expansionary monetary policy. The results are illustrated in Appendix A2.2, namely in Figures 2.8, 2.9, 2.10 and 2.11. The findings of our study align with the research conducted by Gennaioli et al. (2018), which discovered a significant inverse relationship between a

bank's loan-to-asset ratio and its holdings of domestic government bonds during times of sovereign financial difficulty. Banks that held a substantial amount of Treasury Notes and Bills experienced a 7% decrease in loan growth compared to those with lesser holdings of government bonds.

To this end, to the best of our knowledge, we do not know any studies in Malawi that have taken this approach, studied this subject matter, and modelled the Malawian banking sector in the manner we have done in this paper. The rest of the paper is organised as follows: Section 2.2 discusses the context of the study; Section 2.3 looks at the review of relevant literature; Section 2.4 discusses the modelling framework used in the paper; Section 2.5 discusses the empirical modelling approach; Section 2.6 presents the data and sources for the study, while Section 2.7 outlines the process of calibration that was observed; Section 2.8 discusses results from the modelling experiments; and Section 2.9 concludes the paper.

2.2 The Context of the Study

The Malawi government has largely depended on issuing domestic bonds as a primary means of funding its budgetary deficits. According to the World Economic Outlook database (2023), the general government debt is 78.6% of the gross domestic product (GDP), and the general government net borrowing—also referred to by the IMF as overall balance—is negative 6.8% of the GDP. Private debt stands at 8.4% of the GDP. This refers to government's non-concessional (commercial) borrowings from lenders outside Malawi. The International Monetary Fund (IMF) and International Development Association (IDA) have deemed Malawi's public debt as unsustainable (Alam et al., 2021). The domestic bonds (debt) that government issues are primarily taken by the central bank, commercial banks, and non-banking institutions (mostly pension and insurance companies).

This study focuses on domestic debt dynamics emanating from the commercial banking sector in Malawi. As of December 2022, the commercial banking industry in Malawi held total assets amounting to MK3.6 trillion (USD3.5 billion), as stated in the Reserve Bank of Malawi (RBM) Bank Supervision Annual Report and Banks Audited Annual Reports for

December 2022. Out of this total, 42% consisted of Treasury Notes and Bills—loans provided to the government—while 28% were loans and advances given to firms and households. As shown in Figure 2.2 in Appendix A2.1, the banks interest-earning portfolio in 2015 mostly consisted of 22% Treasury Notes and Bills and 39% loans and advances to firms and individuals. Since 2015, commercial banks have been shifting their portfolio towards predominantly lending to the government and reducing their overall lending to the private sector. Banks have increased their holding of government bonds by 20% from 2015 to 2022 and reduced their lending to the private sector by 11% within the same period.

As shown in Figure 2.3 in Appendix A2.1, all along, the central government's main borrowing instruments in the local commercial banking market were in the form of Treasury Bills. The Treasury Bill stock for banks as a percentage of GDP in 2004 was 2%, Treasury Notes were 0%, and commercial bank holdings of public debt were 2%. They were mainly made up of Treasury Bills and short-term instruments. The Central Government started financing its activities using Treasury Notes in 2011, which were 0.01% of GDP and grew to 8.56% of GDP by 2022. Meanwhile, Treasury Bills have largely remained at an average of 2% of GDP over the years. The main difference between Treasury Bills and Treasury Notes is their maturity profile: bills have a tenure of one year, while notes extend tenures up to 10 years. It is important to understand this decomposition of the balance sheet structure of banks and the granulation of their assets in various classes in the context of our study.

Figure 2.4 in Appendix A2.1 shows the trajectory of various interest rates in Malawi between 2020 and 2023. We used a shorter time frame to make the rates more comparable because the Reserve Bank of Malawi did not start collecting data for Treasury Note yields until around 2020. The government previously relied on Treasury Bills for borrowing. Therefore, Treasury Notes, which are longer-dated papers, were not very important until the government switched its borrowing strategy.

The maximum lending rate to the private sector has moved from about 23% in 2020 to 32% in 2023, and the Treasury Note yield has moved from 23% in 2020 to 29% in 2023. The

two rates have been moving in tandem: the government of Malawi has been borrowing from the banking sector at the same rate that the private sector assesses capital from the banking system, both chasing the same private capital at competitive rates.

When the sovereign borrows at competitive rates like the private sector, banks, as profit-making enterprises, lend to a party that minimises loss and maximises their profits at low cost. Sovereign lending is risk-free under Basel rules. Tier 1 and 2 capital ratios, which are calculated as shareholder equity contributions adjusted by regulatory adjustments and divided by risk-weighted assets, are important for bank capital management. Treasury Notes and Bills, which make up a substantial percentage of banks' assets, carry a 0% risk-weight, unlike loans to businesses and individuals, which attract between 70% and 100% risk-weights. Banks lend money to governments and make borrowing easier since these exposures do not negatively affect their capital ratios unless banks experiencing liquidity problems conduct fire sales on the sovereign portfolio. The question is—from the extensive investment in government bonds in a country with recurrent fiscal deficits and that are funded largely by domestic borrowing—how much this asset accumulation channel induces crowding-out and production fluctuations, as well as how it affects bank capital management and funding strategy. It is important to understand these fiscal funding dynamics, as they also form part of the objectives of our study. The central government uses Treasury Notes and Bills to absorb significant capital in the banking sector that could have been used for other productive sectors of the economy. The effect of these have not been empirically tested for Malawi in the manner that our paper attempts to do.

2.3 Theoretical Literature Review

2.3.1 Minsky's Financial Instability Hypothesis (FIH)

According to Minsky, the financial instability hypothesis (FIH) is a theory of how business cycle dynamics systematically respond to financial cycles. The financial instability hypothesis (hereinafter referred to as the FIH) is based on Minsky's theories of money, financial evolution, and investment, as well as on Fisher's (1933) concept of debt deflation. The FIH is the “theory of how a capitalist economy endogenously generates a financial structure that is inherently prone to financial crises” (Minsky, 1983). A financial structure

in this context is defined as “the market interactions between borrowers and lenders and the balance sheets of non-financial firms, intermediaries, and households that reflect these interactions” (Pollin, 1994).

According to the FIH, economic agents’ investment financing decisions have a significant impact on economic cycles. Under the FIH, economic agents are categorised in three stages according to their borrowing orientation and ability to service the debts (revenue-debt or borrower-lender relationships), which in the end creates a conducive environment for financial crises: they are either hedge finance-oriented, speculative finance-oriented, or Ponzi finance-oriented. Economic agents that are deemed “hedging financing oriented” under the FIH are those that can meet the contractual payments of their maturing liabilities as they fall due without difficulties. Economic agents that are categorised as “speculative finance-oriented” are those that can service a portion of their maturing liabilities. These economic agents often resort to debt restructuring and rollovers to create additional fiscal and cash-flow space for maturing debt repayments. Governments with floating debts, corporations with floating issues of commercial paper, and banks are typically speculative finance units. Economic agents that are categorised as “Ponzi-oriented” are those whose cash flows from their main operating activities are insufficient to fulfil their debt repayments, both principal and interest.

These agents are technically insolvent, and they either resolve to be in a perpetual debt trap or they must liquidate their other asset portfolios to make good on their debt repayments. As described in Section 2.2, the Malawi government fits in this category, and we would like to empirically check the effects of this Ponzi-style public debt accumulation through the domestic commercial banking system on output, investments, loans to firms and households, and bank capital levels. The way the government predominantly funds itself has significant consequences for the wider economy. If the government funds itself significantly using speculative and Ponzi finance, that will destabilise the business cycles according to the FIH.

2.3.2 Debt Overhang Theory (DOT)

Debt overhang refers to the existence of large debt that has adverse effects on investments and growth because investors expect that current and future taxes will be increased to affect the transfer of resources abroad as loan repayments. And in the context of a nation, it is a situation wherein the amount of debt owed by said nation surpasses its capacity to repay said debt.

In his seminal work, Krugman (1988) provides a comprehensive explanation of the concept known as debt overhang. According to Krugman, debt overhang occurs when the anticipated sum of debt repayment surpasses the initial contractual amount at which the debt was incurred. Krugman (1988) defines debt overhang as a situation where “the expected present value of future country inflows is less than the current face value of its debts”. In an overhang situation it may still be profitable for debt providers, both foreign and domestic (lenders), to roll over the debt to recoup part of their repayments and extract some future country resources. This is similar to Speculative-financed or Ponzi-financed agents under Minsky’s FIH theory. Krugman (1988) hypothesized that if all of a country’s future earnings are used to service debts (pay creditors), there will be little incentives for that country to follow prudent macroeconomic growth enhancing policies.

The higher the level of debt, the harder it becomes to preserve incentives. When the optimal incentive-compatible contract implements a positive level of effort, a suboptimal contract—like the one that forces maximum repayment—will reduce effort, expected growth and consequently lower the present value of repayments as well. This is the basis for what is termed the “debt Laffer curve”: the present value of debt repayments first increases in debt’s face value, up to a point beyond which the correlation becomes negative. Then a higher face value of debt is associated with lower effort, and lowers the present value of repayments. As long as the ability to repay depends on growth performance, the negative portion of the debt Laffer curve also corresponds to a negative correlation between debt and growth, where increasing debt tends to be associated with worsening economic policy choices.

The debt Laffer curve was analysed first by Sachs (1988) in the context of debt overhang. He showed that in this case, debt forgiveness leads not only to maintaining the current market value of securities, but also to an increase in the expected value of monetary flows related to repayment of obligations of debtor countries. When a country is borrowing too much, its ability to finance decreases and thus the risk of default occurs. Creditors calculate the expected value of reimbursements they receive according to risk of default. If the expected value is less than the face value of the debt, reducing the nominal (or face) value of debt reduces the risk of default and leads to an increase in expected value of future repayments.

An important question is why some countries are on the right side of the debt Laffer curve, even though debt forgiveness would be Pareto-improving. A classical explanation builds on a free rider problem (over-indebted countries continue to borrow knowing that they will have their debts forgiven). While all lenders collectively would be better-off financing a portion of the debt and forgiving the rest, each lender taken individually would prefer to opt out of the roll-over and demand full repayment. The phenomenon known as the “debt overhang effect” manifests itself when a substantial accumulation of debt dissuades potential investors from allocating their resources towards the private sector due to concerns over the imposition of onerous taxation policies by the government.

The debt overhang effect is also commonly referred to as a tax disincentive. This is because investors interpret the build-up of public debt build as a signal that the government will, in future, raise taxes, which will affect investors’ future earnings or returns. It is this negative future taxation signalling effect that discourages investors from investing in highly indebted countries, as they become aware of the debt servicing burden that the countries will face, which will only be solved domestically by raising taxes. This taxation is intended to mitigate the burden of debt service. Unfortunately, it discourages potential investors, resulting in disinvestment within the broader economy and, consequently, a decline in the growth rate. Hence the government remains trapped in the vicious circle of domestic and foreign borrowing, which can only be broken when there is significant output growth. Such growth will spur domestic savings that should propel investments and additional avenues

for government to mobilise domestic resources due to expansion of the tax base and earnings.

Finally, the political economy analysis of debt overhang also sheds some light on the reasons why countries end up highly indebted. For instance, Velasco (1997) shows that fragmentation in fiscal authorities can create a tragedy of commons, which results in overspending and excessive debt accumulation. Alesina & Tabellini (1989), in turn, explain why successions of government with different distributional goals create fiscal uncertainty that generates capital flight, low investment and over-accumulation of external debt. There, high debt and low growth prevail simultaneously because of institutions that are prone to over-borrowing and that tend to divert investment from efficient uses, rather than as cause and consequence. High levels of debt do not inherently alter borrowers' behaviour or incentives. Most importantly, debt relief alone would not prevent renewed debt accumulation, low investment and low growth.

2.3.3 Dual Gap Theory (Two Gap Theory)

Two-Gap models are rooted in the post-Keynesian growth models for closed economies as designed by Harrod (1939) and Domar (1946) who tried to identify the pre-conditions which were needed in order to enable an industrialized economy, in this case the U.S., to reach a steady-state equilibrium of growth. As the analysis shows, the steady state in a Harrod-Domar world is always challenged by short-term instabilities which are triggered by changes in aggregate demand and which materialize in boom times through cyclical inflation, and in times of recession through cyclical unemployment.

In the early 1960's the Harrod-Domar approaches were adapted to open economies in the so-called Third World (Little, 1960; Chenery & Bruno, 1962; McKinnon, 1964; Chenery & Strout, 1966). In the Third-World context, the fight against cyclical unemployment caused by a "labour demand gap" lost most of its importance in the light of unlimited supplies of labour assumed to be prevalent in developing countries (Lewis, 1954; Bliss, 1989). The labour demand gap was replaced by a savings gap and by a foreign currency gap as a consequence of the diagnosis that, for realizing a given growth target, first, domestic savings are insufficient to finance the investment needed (savings gap), and

secondly, the inflows of foreign exchange are too small to finance the imports of capital goods needed (foreign currency gap). Both gaps, as proposed by the Two Gap model, can be bridged by foreign aid or borrowing or by net capital imports, respectively, so that a specific country can reach a pre-defined growth target.

The seminal work by Chenery & Strout (1966) has served as the foundation for numerous subsequent studies, both theoretical and empirical, that delve into specific instances of the “two-gap approach.” The Two-Gap model is an extension of the Harrod-Domar growth model which argued that the economic growth and development of developing countries are faced with two gaps: (a) the gap between savings and investments (S-I), where domestic savings are insufficient in supporting the desired level of output growth; and (b) the gap between export revenue and imports, which is equal to a foreign exchange gap (X-M), where purchasing power for imports is inadequate to support the desired level of output growth. Various formulations of the two-gap model have also been proposed by other scholars as well. Thirwall (1978) provided a simplified version of the Two-Gap model in the following manner: If the economy operates under conditions of openness, it is possible for shortfall in saving to be augmented through external assistance (aid and borrowing). It has been posited that the expansion of economic activity is purportedly limited by the presence of trade. The growth is constrained by the larger of these two gaps. If the saving-investment gap is the larger of the two gaps, it is imperative that foreign and domestic borrowing becomes adequate to bridge this gap. In countries like Malawi that experience the dual gap, the government resorts to both domestic and foreign borrowings.

2.3.4 Crowding-Out Theory

In their respective studies, Cohen (1993) and Clements et al. (2003) have made noteworthy observations regarding the impact of high debt stock on investment. They argue that external debt, in addition to its direct effect on investment, can also influence economic growth through the accumulation of debt service payments. These payments, it is argued, have the potential to “crowd out” investment, whether it be private or public, within the economy. The crowding-out effect, in the context of national economics, pertains to the scenario in which a country’s revenue derived from foreign exchange earnings is allocated

towards the repayment of debt service obligations. The allocation of resources for the domestic economy is constrained due to the substantial absorption of these resources by the burden of servicing external debt. Consequently, the level of investment is diminished. Taylor (1993) posits that the deleterious effects of debt servicing on economic growth stem from the imposition of liquidity constraints caused by excessive debt, leading to a reduction in government expenditure within the economy, and constrained fiscal space. The aforementioned liquidity constraints manifest themselves due to the obligations of debt service, thereby diverting attention away from the advancement of the domestic economy towards the fulfilment of debt repayments. The reduction in public expenditure on social infrastructure has a substantial impact on the level of public investment in the economy.

The phenomenon of crowding-out effects typically arises because of exorbitant real interest rates, whereby the terms of trade of an excessively indebted nation deteriorate, potentially rendering foreign credit markets inaccessible. In their seminal work, Claessens et al. (1996) astutely discern the decline in investment to be the consequence of a reduction in a nation's pool of resources that can be utilised to finance investment and macroeconomic endeavours. The reduction in the nation's capability to maintain its debt is a consequence of the crowding-out effect. Consequently, as the nation endeavours to fulfil some of its obligations, there is a limited amount of capital available for domestic investment (Patenio & Agustina, 2007).

2.3.5 Empirical Literature Review

As improvements to the earlier studies by Fisher (1932), Keynes (1936), Minsky (1964), Minsky (1977), and Minsky (1982), recent literature has been dominated by the modelling of financial frictions embedded in a dynamic stochastic general equilibrium (DSGE) framework. These models are based on the foundations of the collateral constraint models created by Kiyotaki & Moore (1997), Carlstrom & Fuerst (1997), and Bernanke et al. (1999), as well as the financial accelerator model created by Bernanke & Gertler (1989). The financial accelerator is the empirical operationalization of Minsky's FIH theory and is the one that is better implemented within the DSGE framework. This literature intends to underpin the role of financial intermediation and how shocks emanating from the

intermediation process could potentially affect the borrowing and lending processes. There are some new ideas in the literature on financial frictions in macroeconomic models. These include a banking sector that is not perfectly competitive (Gerali et al., 2010), asset price bubbles (Galí, 2014), and the banking sector becoming more mature (Gertler & Karadi, 2013). According to the financial accelerator model developed by Bernanke et al. (1999), borrowers must pay an “external finance premium” when they access credit to finance investment projects due to information asymmetry and moral hazard. Some researchers, including Bernanke et al. (1999), concluded that changes in credit markets can make shocks to the economy as a whole worse and that the financial accelerator has a big effect on how the business cycle moves.

According to the “collateral constraint” model by Kiyotaki & Moore (1997), borrowers must pledge collateral, such as real assets, for them to obtain a loan. The collateral constrained model displays the changing relationship between credit limits and asset prices. This is a strong way for shocks to make their effects last longer, get stronger, and spread to other areas. Kiyotaki & Moore (1997) show that small, temporary shocks to technology or income distribution can generate large and persistent fluctuations in output and asset prices. Instability in the financial markets and the process of intermediation have real effects on economic activity and output, as shown by studies like Bernanke (1983), Anari & Kolar (1999), Gertler & Kiyotaki (2010), Fisher (1933), Barro (1978) and Gurley & Shaw (1955).

Gennaioli et al. (2018) used a large bank-level sample containing 20 default episodes in 17 countries between 1998 and 2012. They document two robust facts. First, there is a strong negative correlation between a bank’s holdings of government bonds and its lending during sovereign defaults. Second, banks tend to hold large amounts of government bonds during normal periods. This is especially true for banks that make fewer loans and are in financially undeveloped countries. Their findings are consistent with theories of imperfect creditor discrimination, such as that proposed by Broner et al. (2010), and with theories in which sovereign defaults damage domestic banks (Gennaioli et al., 2014). Gennaioli et al. (2018) used a parsimonious panel data regression framework.

The empirical literature on debt and growth has followed two strands. A first set of papers have attempted to test directly the potential crowding-out effect of debt on investment. The second approach fits in the empirical growth literature and investigates the reduced form (conditional) effects of debt on growth in cross-country regressions, with particular focus on the presence of non-linear relations.

Cohen (1993) finds that the level of debt had no significant impact on investment during the debt crisis of the early eighties. Over the same period, however, the surprise increase in debt payments correlated negatively with investment, suggesting a crowding-out effect. In contrast, Warner (1992) shows that some significant determinants of investment which are unrelated to debt can sufficiently explain the decline observed in highly indebted countries in the eighties. In particular, the combination of an increase in world interest rates and a fall in commodity prices can account for much of the observed decline in investment.

Patillo et al. (2002) follow the alternative route. They estimate the conditional correlation between debt and growth in the context of standard panel growth regressions and investigate whether the sign reverts at high enough debt levels. They find clear evidence that debt becomes detrimental for growth in highly indebted economies and quantify the threshold levels in the thus confirmed debt Laffer curve using a variety of debt measures. Cohen & Sachs (1986) and Cohen (1995) develop an infinite horizon model of debt and growth with a risk of debt repudiation. First, high growth is financed with increasing debt to GDP ratios until an endogenous debt ceiling is reached. When the credit constraint binds, growth performance depends on the repayment strategy followed by creditors, and its implication on debtors' incentives.

The optimal repayment strategy is to let the performing debt assets grow with the expected growth of the economy. If this is implemented, growth is faster than that under autarky and a crowding-in effect ensues, with debt service negatively correlated with the borrower's investment decisions. But such a "smooth payments" policy requires that the creditor be able to monitor the borrower's investment strategy. If the nature of institutions or

contractual arrangements are such that monitoring cannot be ensured, the creditors' optimal strategy is to claim a constant share of output. This amounts to a distortionary debt tax on output, leading to inefficiently depressed levels of investment and low growth. The terms of borrowing for highly indebted economies should once again worsen observably once the overhang zone is reached, and the severity of this response should depend on the creditors' ability to monitor borrowers' investment policies.

Various scholars have provided substantial support for the theoretical argument in favour of debt overhang. Several notable studies have been conducted in this field, including the works of Warner (1992), Cohen (1993), and Sachs (1988). Several scholars, such as Green & Villaneva (1991), Elbadawi et al. (1997), Fosu (2009), Pattillo et al. (2002), and Chowdhury (2001), have provided additional evidence that supports the existence of the debt overhang phenomenon. Moreover, it has been asserted by Clements et al., (2003) that the accumulation of external debt has the potential to facilitate investment, albeit only until a specific threshold is reached, at which point the phenomenon of debt overhang emerges and the eagerness of investors to supply capital begins to decline. Borensztein (1990) further elucidates the concept of debt overhang, positing that in such a scenario, the debtor nation reaps minimal advantages from the proceeds of supplementary investments owing to the substantial burden of debt service obligations.

The Dual Gap theory has been regarded as possessing the most comprehensive elucidation regarding the preference for external financing over internal/domestic financing in the pursuit of sustainable growth, particularly when considering the prevailing condition of domestic savings in the majority of developing nations. McKinnon (1964) posits that the progress of developing nations can be impeded by the presence of two distinct gaps, namely the savings gap and the foreign exchange gap. There is a notable disparity in savings, characterised by insufficient domestic savings that may lead to a shortfall in meeting the necessary investment for achieving the desired growth rate.

Solow (1956), in the neoclassical growth theory, posited that the economic growth of a nation is contingent upon its levels of savings and investments. The financing of economic

activities in a nation can be achieved through either internal or external means. Internally, this is accomplished through the collection of taxes, while externally, borrowing is utilised when the internal sources of funding are inadequate to cover budget deficits.

Other scholars such as Diwan (1967) conducted a comprehensive analysis of the two-gap model, focusing on a production function that incorporates imports and capital as the primary inputs. This study aimed to shed light on the intricate dynamics and interplay between these crucial factors. Cochrane (1972) posits that within the framework of the Chenery-Strout model, one can discern the existence of two distinct models, specifically a short-term model and a long-term model. Blomgvist (1976) conducted an empirical investigation into the two-gap phenomenon, utilising cross-sectional data obtained from a sample of thirty-three developing nations. In Gersovitz's (1982) seminal work, he undertakes an analysis of five Latin American countries to estimate a modified version of the two-gap model.

The gap that our study tries to fill in the reviewed literature is the modelling of bank-driven public debt accumulation effects on the business cycles of a revenue-challenged government treasury and the consequences for a developing country. The studies that we have reviewed, including DSGE studies, have focused on financial frictions in advanced economies where central governments do not face debt sustainability problems, and as such, modelling public debt has not been a key feature of the studies. This is the first of its kind in banking literature in Malawi.

2.3.6 Modelling Framework

We adopt the DSGE model proposed by Gerali et al. (2010)—which incorporates the banking sector—by introducing banks and the government sector, hence permitting public debt financing or asset accumulation by the Malawian banks. The economy hypothetically consists of banks, patient households, impatient households, entrepreneurial firms, fiscal authorities, and a central bank. Type P households are savers, while those of type I are borrowers. In this economy, banks offer two types of one-period financial instruments:

savings (bank deposits) and lending (loans to the government, households, and entrepreneurs).

By borrowing, the agents face a credit constraint that is linked to the value of their collateral in the following period. Respectively, the credit limits faced by households and entrepreneurs are functions of the value of their resource endowment and the value of their physical capital. The technical analysis of the model and competitive equilibrium conditions of the model are available as supplementary material in Appendix A2.5.5. Figure 2.1 illustrates the general relationship among agents in the economy. In this figure, we present the model proposed by Gerali et al. (2010), with modifications. The orange lines, the government block and the public debt accumulation avenue show the main components that we have added as our contribution to the Gerali et al. (2010) model.

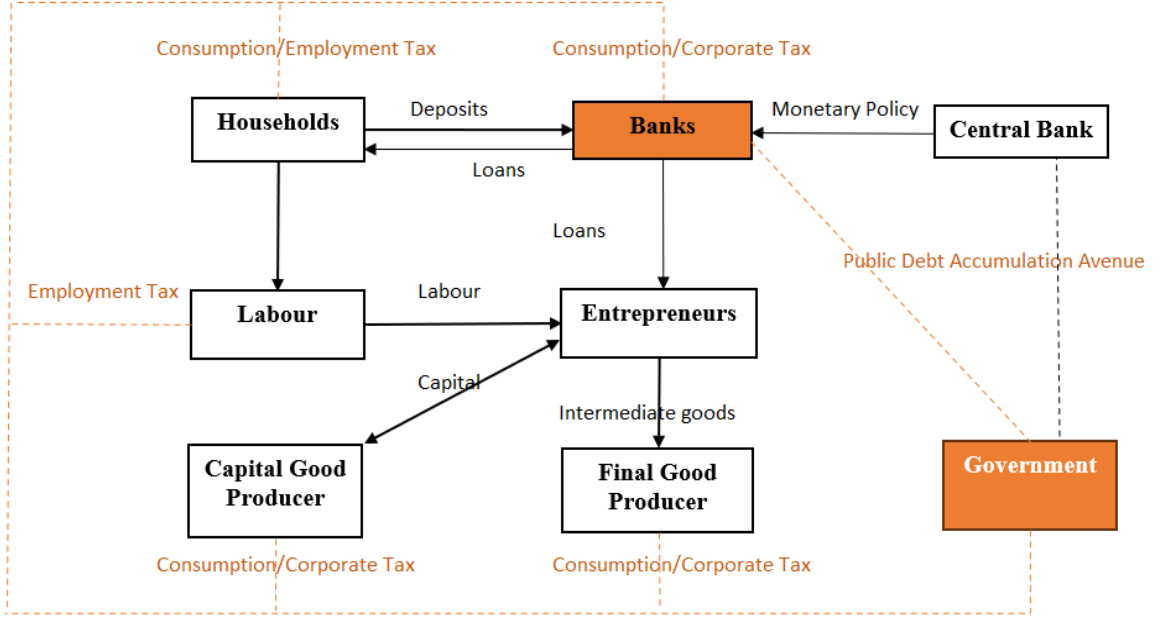


Figure 2.1: General relationship among economic agents

2.3.7 Patient and Impatient Households

The representative household maximizes the expected utility given by

$$\max_{\{c_t^l, d_t^l\}} E_0 \sum_{t=0}^{\infty} \beta_{p/l}^t \left[(1 - a^{p/l}) \varepsilon_t^z \log(c_t^{p/l}(i) - a^{p/l} c_{t-1}^{p/l}) + \varepsilon_t^h \log h_t^{p/l}(i) - \frac{l_t^{p/l}(i)^{1+\phi}}{1+\phi} \right], \quad (2.1)$$

Where the superscripts p/I are used interchangeably, (p) is for patient households, and (I) is for impatient households. The same interpretation applies to the subscript on $\beta_{p/I}$ where β_p , and β_I , are intertemporal discount factors for the patient households and impatient households, respectively, such that $\beta_p > \beta_I$ depends on the deviation of current individual consumption ($c_t^{p/I}(i)$) from the aggregate consumption of the previous period ($c_{t-1}^{p/I}$), stock of housing ($h_t^{p/I}(i)$) and hours worked ($l_t^{p/I}(i)$). The parameter $a^{p/I}$ measures the degree of habit formation in consumption. The disutility of labour is parametrized by ϕ . Preferences are subject to two types of shocks: one that affects consumption (ε_t^z), and another that affects the demand for housing (ε_t^h). The model terms are also explained in appendix A2.9.

These shocks are represented by an $AR(1)$ process with normal distribution. They are also *i.i.d*, and their respective autoregressive coefficients are ρ_z and ρ_j , with coefficient standard deviations given as σ_z and σ_j , respectively. The decisions of these households are subject to the following budget constraint (in real terms):

For patient households:

$$c_t^p(i) + q_t^h \left(h_t^p(i) - h_{t-1}^p(i) \right) + d_t^p(i) \leq w_t^p l_t^p(i) + \frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^p(i) + t_t^p(i) \quad (2.2)$$

Patient households' expenditures include current consumption, the variation of housing (the housing prices in real terms, given by q_t^h), and deposits made in the period d_t^p . Revenues consist of remuneration for work $w_t^p l_t^p$, expansion of income arising from deposits made in the previous period $\frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^p$ (where $\pi_t \equiv P_t/P_{t-1}$ is the rate of inflation), and transfers lump-sum, t_t^p which is equivalent to dividends from companies and banks, that are owned by patient households.

For impatient households:

$$c_t^l(i) + q_t^h(h_t^l(i) - h_{t-1}^l(i)) + \frac{1+r_{t-1}^{bH}}{\pi_t} b_{t-1}^l \leq w_t^l l_t^l(i) + b_t^l(i) + t_t^l(i) \quad (2.3)$$

where the resources with consumer spending ($c_t^l(i)$), stock of real estate ($q_t^h(h_t^l(i) - h_{t-1}^l(i))$), and loan repayments $\frac{1+r_{t-1}^{bH}}{\pi_t} b_{t-1}^l$, have to be financed by labour income $w_t^l l_t^l(i)$, new loans b_t^l , and transferred lump-sum $t_t^l(i)$.

Impatient households are still subject to borrowing constraints, where the expected value of their real estate assets, which can be offered as collateral, must be sufficient to honour the debt with the banks in case of default, that is

$$(1 + r_{t-1}^{bH}) b_t^l \leq m_t^l E_t[q_{t+1}^h h_t^l(i) \pi_{t+1}] \quad (2.4)$$

In expression 2.4 above, m_t^l is the ratio of loan-to-value (LTV) mortgages. In the model, we have used an LTV of 70% in line with the practice in Malawi's banking sector.

From the macroeconomic point of view, m_t^l represents the volume of credit that banks are willing to offer to households. m_t^l follows an AR(1) process with autoregressive coefficient ρ_{mI} and *i.i.d* normal innovations with standard deviation σ_{mI} .

2.3.8 Entrepreneurs

There are an infinite number of entrepreneurs. In its utility function, entrepreneurs care about the dispersion of their consumption ($c_t^E(i)$), about the aggregate consumption, and their habit formation parameter is given by a^E , which is symmetrical with respect to households. Therefore, their utility function to be maximised is:

$$E_0 \sum_{t=0}^{\infty} \beta_E^t \log(c_t^E(i) - a^E c_{t-1}^E) \quad (2.5)$$

It is assumed that the intertemporal discount factor β_E is strictly greater than β_p , which means that, in equilibrium, entrepreneurs are net borrowers (debtors). Moreover, their decisions are subject to the following budget constraints:

$$c_i^E(i) + W_t l_t^E(i) + \frac{(1 + r_{t-1}^{bE}) b_{t-1}^E(i)}{\pi_t} + q_t^k k_t^E + \psi(u_t(i)) k_{t-1}^E(i)$$

$$= \frac{y_t^E(i)}{x_t} + b_t^E(i) + q_t^k(1 - \delta)k_{t-1}^E(i) \quad (2.6)$$

In the expression above, W_t is the aggregate wage index, δ is the depreciation rate of capital k_t^E , q_t^k is the price of capital in terms of consumption, $\psi(u_t(i))k_{t-1}^E$ is the real cost of establishing a given level u_t of capacity utilisation, with $\psi(u_t(i)) = \xi_1(u_t - 1) + \frac{\xi_2}{2}((u_t - 1)^2 \cdot x_t = \frac{P_t}{P_t^w}$ The relative price of wholesale goods in the competitive market is represented by $x_t = \frac{P_t}{P_t^w}$, where P_t is the nominal price, and production technology is given by $y_t^E(i) = a_t^E[k_{t-1}^E(i)u_t(i)]^\alpha[l_t^E(i)]^{1-\alpha}$, with a_t^E being an exogenous $AR(1)$ process for total factor productivity with an autoregressive coefficient equal to ρ_a and *i.i.d* normal innovations with standard deviation σ_a . The aggregate work l_t^E combines the input of labour supplied by impatient and patient households as follows: $l_t^E = (l_t^{E,P})^\mu (l_t^{E,I})^{1-\mu}$, where μ is the share of a patient, relative to the sum of the patient and impatient households' income.

Entrepreneurs borrow against housing (commercial real estate). This is subject to borrowing constraints, where the expected value of real estate assets, which can be offered as collateral, must be sufficient to honour the debt with the banks in case of default, that is

$$(1 + r_{t-1}^{bE})b_t^E \leq m_t^E E_t(q_{t+1}^k \pi_{t+1}(1 - \delta)k_t^E(i)) \quad (2.7)$$

m_t^E follows an $AR(1)$ process with autoregressive coefficient ρ_{mE} and *i.i.d* normal innovations with standard deviation σ_{mE} .

2.3.9 Labour market

We assume that there exists a continuum of labour types and one union for each labour type n . Each union is representative of the whole household population, i.e. it includes γ^p patient and γ^I impatient. Its discount factor β_U is a weighted average of those its members. The typical union n sets nominal wages for workers of its labour type by maximising a weighted average of its members' utility, subject to a constant-elasticity (ε_l) demand schedule and to adjustment costs, with indexation to a weighted average lagged and steady-

state inflation. The union equally charges each member household lump-sum fees to cover adjustment costs. In a symmetric equilibrium, the labour choice for each single household in the economy will be given by the (non-linear) wage-Phillips curve:

$$\begin{aligned} & \left(\frac{\gamma^p}{c_t^p - a^p c_{t-1}^p} + \frac{\gamma^l}{c_t^l - a^l c_{t-1}^l} \right) \left[\kappa_w \left(\pi_t^w - \pi_{t-1}^\zeta \pi^{1-\zeta} \right) \pi_t^w - (1 - \varepsilon_l) l_t^T \right] = \\ & = (\gamma^p + \gamma^l) \varepsilon_l \frac{l_t^{T1+\sigma_l}}{w_t} + \kappa_w \beta_U E_t \left\{ \left(\frac{\gamma^p}{c_t^p - a^p c_{t-1}^p} + \frac{\gamma^l}{c_t^l - a^l c_{t-1}^l} \right) \left(\pi_t^w - \pi_t^\zeta \pi^{1-\zeta} \right) \right\}. \end{aligned} \quad (2.8)$$

We also assume the existence of perfectly competitive labour packers who buy differentiated labour services from unions, transform them into homogeneous composite labour input and sell it, in turn, to intermediate-good-producing firms. This assumption yields a demand for each kind of differentiated labour service $l_t(n)$ equal to

$$l_t(n) = \left[\frac{W_t(n)}{W_t} \right]^{-\varepsilon_l} l_t \quad (2.9)$$

where W_t : $W_t = \left[\int_0^1 (W_t(i, j))^{1-\varepsilon_l} \right]^{\frac{1}{1-\varepsilon_l}}$ (2.10) is the aggregate wage in the economy.

ε_t^l is the elasticity of substitution in the labour market and it follows an *AR (1)* process with autoregressive coefficient ρ_l and *i.i.d* normal innovations with standard deviation σ_l .

2.3.10 Retailers

Retailers buy a homogenous good from entrepreneurs and attach a brand to differentiate it. Next, they sell in an imperfect market characterised by monopolistic competition and nominal price rigidity which are denoted by parameter k_p denoting the size of these costs and ι_p that measures the degree of indexation to past prices. This price is indexed by a convex combination of the inflation of the previous period and steady-state inflation with relative weights parametrized by ζ . If the retailer adjusts the price of his goods beyond what the indexation rule suggests, they will be subject to quadratic adjustment costs, parameterized by κ_p . The problem for the retailer is to solve:

$$\max_{P_t(j)} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t(j) y_t(j) - P_t^w y_t(j) - \frac{k_p}{2} \left(\frac{P_t(j)}{P_{t-1}} - \pi_{t-1}^{\iota_p} \pi^{1-\iota_p} \right)^2 P_t y_t \right] \quad (2.10)$$

Subject to:

$$y_t(j) = \left(\frac{P_t(j)}{P_t} \right)^{-\varepsilon_t^y} y_t \quad (2.11)$$

Where $y_t(j)$ stands for output, ε_t^y is the elasticity of substitution faced by retailers that follows an *AR (1)* process with autoregressive coefficient ρ_y and *i.i.d* normal innovations with standard deviation σ_y . In a symmetric equilibrium, the (non-linearized) Phillips curve is given by the retailers' problem first-order condition:

$$1 - \varepsilon_t^y + \frac{\varepsilon_t^y}{x} - \kappa_p (\pi_t - \pi_{t-1}^\zeta \pi^{1-\zeta}) \pi_t + \beta_p E_t \left[\frac{c_t^p - a^p c_{t-1}^p}{c_{t+1}^p - a^p c_t^p} \kappa_p (\pi_{t+1} - \pi_t^{ip} \pi^{1-ip}) \pi_{t+1} \frac{y_{t+1}}{y_t} \right] = 0 \quad (2.12)$$

where $x_t = P_t / P_t^W$ is the gross mark-up earned by retailers.

2.3.11 Capital goods producers

The capital goods-producing sector is introduced in the model to derive an equation for the market price of capital. This is necessary to determine the value of the collateral that entrepreneurs present when seeking loans from banks.

In a perfectly competitive market, these producers buy an amount i_t of final goods from retailers, at a nominal price P_t^k , using the undepreciated capital stock from the entrepreneurs' earlier period $(1 - \delta)k_{t-1}$. Furthermore, they buy a certain number of units of the final good from retailers at a price P_t that remains unsold. The undepreciated capital of the previous period is converted at the rate of 1×1 into new capital.

The final good bought from the retailers has its conversion subject to quadratic adjustment costs. Thus, the effective capital stock k_t , which, in turn, is sold to entrepreneurs at a price P_t^k , has its accumulation equation given by:

$$k_t = (1 - \delta)k_{t-1} + \beta_E E_t \left[1 - \frac{K_i}{2} \left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} \right)^2 \right] i_t \quad (2.13)$$

Where k_i represents the adjustment cost of the investment, ε_t^{qk} is a shock to the productivity of the investment, and $q_t^k \equiv \frac{p_t^k}{p_t}$ is the price in real terms of the capital. The shock has an *AR (1)* representation with autoregressive coefficient ρ_{qk} and *i.i.d* normally distributed with zero mean innovations with standard deviation equal to σ_{qk} . As a result, the problem for the capital producer is given in equation 2.14 subject to equation 2.13.

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E \{q_t^k [k_t - (1 - \delta)k_{t-1}] - i_t\} \quad (2.14)$$

2.3.12 Banks in the model

Intermediation is done by banks' deposit, loan, treasury and wholesale departments. Individualised patient household deposits are collected by the deposit unit, whilst the wholesale department manages wholesale deposits. The loan unit distributes varied loans to individuals and enterprises. Treasury manages government lending. Loan and deposit units can alter rates based on entrepreneur demand and adjustment costs. Deposit unit funds are used to grant wholesale credits to the lending unit and bank treasury units.

Subject to capital and liquidity rules, the wholesale unit optimises the bank's balance sheet, displayed in Table 2.1, below. I incorporate government domestic debt instruments into the bank balance sheet in the model by Gerali et al. (2010). The asset side of the balance sheet consists of two types of assets: (i) Treasury Notes and Bills, and (ii) loans and advances to households and firms.

Table 2.1: Bank balance sheet

Assets	Equity and Liabilities
Treasury Notes and Bills ($T_t = TN_t$ and TB_t)	Equity Capital (K_t^b)
Loans and advances ($B_t = BH_t + BE_t$)	Deposits (D_t)

The derivation of demand functions for loans, deposits and Treasury Notes and Bills are shown in respective sections below and the terms in the equations are also fully described in Appendices A2.9 and A2.10. The bank profit maximisation problem is as shown in:

$$\begin{aligned}
& \max_{\{r_t^{tn}, r_t^{tb}\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[r_t^{bH} b_t^H + r_t^{bE} b_t^E - mc_{t-1}^b [b_t^H + b_t^E] + r_t^{tn} t n_t^b + r_t^{tb} t b_t^b - \right. \\
& mc_{t-1}^{tn} [t n_t^b + t b_t^b] - (r_t^{ib} - r_t^d) d_{t-1} - \frac{k_{kb}}{2} \left(\frac{K_t^b}{B_t} - v^b \right)^2 - \frac{k_d}{2} \left(\frac{r_{t-1}^d}{r_{t-2}^d} - \right. \\
& \left. 1 \right)^2 r_{t-1}^d d_{t-1} - \frac{k_{bh}}{2} \left(\frac{r_{t-1}^{bh}}{r_{t-2}^{bh}} - 1 \right)^2 r_{t-1}^{bh} b_{t-1} - \frac{k_{be}}{2} \left(\frac{r_{t-1}^{be}}{r_{t-2}^{be}} - 1 \right)^2 r_{t-1}^{be} b_{t-1} - \\
& \left. \frac{k_{tn}}{2} \left(\frac{r_{t-1}^{tn}}{r_{t-2}^{tn}} - 1 \right)^2 r_{t-1}^{tn} t n_{t-1} - \frac{k_{tb}}{2} \left(\frac{r_{t-1}^{tb}}{r_{t-2}^{tb}} - 1 \right)^2 r_{t-1}^{tb} t b_{t-1} \right] \quad (2.15)
\end{aligned}$$

2.3.12.1 Loans to Households and Firms

The banks get several resources from its matrix, in real terms, at an interest rate. Such loans are distinguished, without charge, to be resold (relent) to households' firms applying two different mark-ups. The bank faces quadratic adjustment costs to provide intertemporal changes in their lending rates. These costs are parameterized by k_{bH} and k_{bE} , associated, respectively, for households and firms. The bank j aims to choose interest rates $\{r_t^{bH} (j), r_t^{bE} (j)\}$, in order to maximize revenue from lending to households and entrepreneurs, respectively:

For households

$$\max_{\{b_{it}^h\}} \left[\int_0^1 r_{it}^{bh} (i, j) b_{it}^h dj \right], \quad (2.16)$$

and entrepreneurs

$$\max_{\{b_{it}^e\}} \left[\int_0^1 r_{it}^{be} (i, j) b_{it}^e dj \right]. \quad (2.17)$$

The gross loans to households and firms are assumed to follow the Constant Elasticity of Substitution (CES) technology, which is motivated by the Dixit & Stiglitz (1977) model of monopolistic competition as follows:

$$BH_t = \left[\int_0^1 (BH_{it}(i, j))^{\frac{\varepsilon_t^{bh}-1}{\varepsilon_t^{bh}}} \right]^{\frac{\varepsilon_t^{bh}}{\varepsilon_t^{bh}-1}} \quad (2.18)$$

$$\text{and } BE_t = \left[\int_0^1 (BE_{it}(i, j))^{\frac{\varepsilon_t^{be}-1}{\varepsilon_t^{be}}} \right]^{\frac{\varepsilon_t^{be}}{\varepsilon_t^{be}-1}} \quad (2.19)$$

and the pricing structure is as follows:

$$r_t^{bh}(j) = \left[\int_0^1 r_{it}^{bh}(i, j)^{1-\varepsilon_t^{bh}} \right]^{\frac{1}{1-\varepsilon_t^{bh}}} \quad (2.20)$$

$$r_t^{be}(j) = \left[\int_0^1 r_{it}^{be}(i, j)^{1-\varepsilon_t^{be}} \right]^{\frac{1}{1-\varepsilon_t^{be}}} \quad (2.21)$$

The demand equations for household loans and loans to firms are Jacobians derived from setting up and solving Lagrangian functions. Hence the demand functions will be as follows:

$$bh_{it}(i, j) = \left[\frac{r_{it}^{bh}(i, j)}{r_t^{bh}} \right]^{-\varepsilon_t^{bh}} BH_t \quad (2.22)$$

and

$$be_{it}(i, j) = \left[\frac{r_{it}^{be}(i, j)}{r_t^{be}} \right]^{-\varepsilon_t^{be}} BE_t \quad (2.23)$$

ε_t^{bh} is the elasticity of substitution faced by banks as they lend to households and it follows an AR (1) process with autoregressive coefficient ρ_{bH} and *i.i.d* normal innovations with standard deviation σ_{bH} . ε_t^{be} is the elasticity of substitution faced by banks as they lend to firms and it follows an AR (1) process with autoregressive coefficient ρ_{bE} and *i.i.d* normal innovations with standard deviation σ_{bE} .

2.3.13 Government Borrowing from the Banking Sector

The bank j gets several resources $T_t(j)$ from its matrix, in real terms, at an interest rate. Some of these loanable funds are allocated to the government in the form of Treasury Notes and Bills, applying two different mark-ups for shorter dated papers and longer dated ones. The banks face quadratic adjustment costs to provide intertemporal changes in their lending rates. These costs are parameterized by k_{tn} and k_{tb} , associated, respectively, with their investments in Treasury Notes and Treasury Bills, and are proportional to the aggregate returns on Treasury Notes and Bills. The bank j aims to choose $\{r_t^{tn}(j), r_t^{tb}(j)\}$, in order to maximize revenue from lending to government in the form of Treasury Notes

$$\text{Max}_{\{tn_{it}^{tn}\}} \left[\int_0^1 r_{it}^{tn}(i, j) tn_{it}^{tn} dj \right] \quad (2.24)$$

and Treasury Bills

$$\text{max}_{\{tb_{it}^{tb}\}} \left[\int_0^1 r_{it}^{tb}(i, j) tb_{it}^{tb} dj \right] \quad (2.25)$$

The gross Treasury Notes and Bills to the government are assumed to follow the CES technology as follows:

$$TN_t = \left[\int_0^1 (TN_{it}(i, j))^{\frac{\varepsilon_t^{tn}-1}{\varepsilon_t^{tn}}} \right]^{\frac{\varepsilon_t^{tn}}{\varepsilon_t^{tn}-1}} \quad (2.26)$$

and

$$TB_t = \left[\int_0^1 (TB_{it}(i, j))^{\frac{\varepsilon_t^{tb}-1}{\varepsilon_t^{tb}}} \right]^{\frac{\varepsilon_t^{tb}}{\varepsilon_t^{tb}-1}} \quad (2.27)$$

And pricing structure is as follows:

$$r_t^{tn}(j) = \left[\int_0^1 r_{it}^{tn}(i, j)^{1-\varepsilon_t^{tn}} \right]^{\frac{1}{1-\varepsilon_t^{tn}}} \quad (2.28)$$

$$r_t^{tb}(j) = \left[\int_0^1 r_{it}^{tb}(i,j)^{1-\varepsilon_t^{tb}} \right]^{\frac{1}{1-\varepsilon_t^{tb}}} \quad (2.29)$$

The demand equations for Treasury Notes and Bills are Jacobians derived from setting up and solving Lagrangian functions. Hence the demand functions will be as follows:

$$tn_{it}(i,j) = \left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{-\varepsilon_t^{tn}} TN_t \quad (2.30)$$

and

$$tb_{it}(i,j) = \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{-\varepsilon_t^{tb}} TB_t \quad (2.31)$$

ε_t^{tb} is the elasticity of substitution faced by banks as they lend to the government in the form of Treasury Bills and it follows an *AR (1)* process with autoregressive coefficient ρ_{tb} and *i.i.d* normal innovations with standard deviation σ_{tb} . On the other hand, ε_t^{tn} is the elasticity of substitution faced by banks as they lend to the government in the form of Treasury Notes and it follows an *AR (1)* process with autoregressive coefficient ρ_{tn} and *i.i.d* normal innovations with standard deviation σ_{tn} .

2.3.14 Deposits

The bank branch j receives deposits $d_t^b(j)$, from the households and transfers it to the bank treasury that pays an interest rate $r_{it}^d(i,j)$. The banks face quadratic adjustment costs to provide intertemporal changes in their deposits rates.

These costs are parameterized by k_d . The bank branch j aims to choose $\{r_t^d(j)\}$, in order to maximize revenue from lending to bank treasury

$$\max_{\{d_{it}\}} \left[\int_0^1 r_{it}^d(i,j) d_{it}^T dj \right] \quad (2.32)$$

The gross deposits are assumed to follow the CES technology as follows:

$$D_t = \left[\int_0^1 (d_{it}(i,j))^{\frac{\varepsilon_t^d - 1}{\varepsilon_t^d}} \right]^{\frac{\varepsilon_t^d}{\varepsilon_t^d - 1}} \quad (2.33)$$

and pricing structure is as follows:

$$r_t^d(j) = \left[\int_0^1 r_{it}^d(i,j)^{1-\varepsilon_t^d} \right]^{\frac{1}{1-\varepsilon_t^d}} \quad (2.34)$$

The demand equation for deposits is a Jacobian derived from setting up and solving the Lagrangian function. Hence the demand function will be as follows:

$$d_{it}(i,j) = \left[\frac{r_{it}^d(i,j)}{r_t^d} \right]^{-\varepsilon_t^d} D_t \quad (2.35)$$

ε_t^d is the elasticity of substitution faced by banks as they raise deposits to households and it follows an AR (1) process with autoregressive coefficient ρ_d and *i.i.d* normal innovations with standard deviation σ_d .

2.3.15 The Bank's Treasury

A bank's treasury manages its capital position to retain the ratio $(\frac{K_t^b}{B_t})$ at its optimal level, given deviation costs. The bank's treasury accumulates treasury bond assets as a public debt mechanism for a cash-constrained central government, as a variation of the Gerali et al. (2010) model. The bank pays a quadratic cost (parameterized by K_{kb}) when the ratio deviates from its ideal value. Bank deposits and equity are liabilities, whereas loans and Treasury Notes and Bills are assets. The capital accumulation equation considers quarterly income and resources utilised to manage the bank's capital position. Profit maximisation involves choosing the volume of loans, treasury instruments, and deposits that maximises the discounted cash flow (in real terms): 2.15 subject to the bank balance sheet's identity $B_t + TB_t + TN_t = D_t + K_t^b$ and assuming the loan rate, Treasury Bill rate, Treasury Note yield rate, and deposit rate as given. Retail banks compete monopolistically in lending and deposit markets.

2.3.16 Optimal Interest Rate Structure

Using the bank profit maximisation equation 2.15 with adjustment costs subject to Jacobians (first-order partial derivatives) for loans, Treasury Notes and Bills, and deposits as obtained in the previous sections, the optimal interest structure may be calculated.

The ideal Treasury Bill interest rate structure assumes asymmetric equilibrium for Treasury Bills: 2.36

$$\begin{aligned}
& 1 - \varepsilon_t^{tb} + \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} - k_{tb} \left(\frac{r_{it}^{tb}(i,j) - r_{it-1}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} \right) \frac{r_t^{tb}}{r_{it-1}^{tb}(i,j)} + \\
& + \left\{ \beta_{tb} E_0 k_{tb} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{tb}(i,j) - r_{it}^{tb}(i,j)}{r_{it}^{tb}(i,j)} \right) \frac{r_{t+1}^{tb}}{r_{it}^{tb}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\} = 0
\end{aligned} \tag{2.36}$$

Equation 2.15 with constraints equations for loans, Treasury Notes and Bills and deposits yields first-order optimum interest conditions. Treasury Notes' ideal interest structure is reflected below:

$$\begin{aligned}
& 1 - \varepsilon_t^{tn} + \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} - k_{tn} \left(\frac{r_{it}^{tn}(i,j) - r_{it-1}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} + \\
& + \left\{ \beta_{tn} E_0 k_{tn} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{tn}(i,j) - r_{it}^{tn}(i,j)}{r_{it}^{tn}(i,j)} \right) \frac{r_{t+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\} = 0
\end{aligned} \tag{2.37}$$

The ideal interest structure for households and entrepreneur loans is reflected in equations 2.38 and 2.39:

$$\begin{aligned}
& 1 - \frac{\varepsilon_t^{bh}}{r_t^{bh}} + \varepsilon_t^{bh} \frac{mc_t^b}{r_t^{bh}} - k_{bh} \left(\frac{r_{it}^{bh}(i,j) - r_{it-1}^{bh}(i,j)}{r_{it-1}^{bh}(i,j)} \right) \frac{r_t^{bh}}{r_{it-1}^{bh}(i,j)} + \\
& + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{bh}(i,j) - r_{it}^{bh}(i,j)}{r_{it}^{bh}(i,j)} \right) \frac{r_{t+1}^{bh}}{r_{it}^{bh}(i,j)} \frac{bh_{t+1}(i,j)}{bh_t(i,j)} \right\} = 0
\end{aligned} \tag{2.38}$$

$$\begin{aligned}
& 1 - \frac{\varepsilon_t^{be}}{r_t^{be}} + \varepsilon_t^{bh} \frac{mc_t^b}{r_t^{be}} - k_{be} \left(\frac{r_{it}^{be}(i,j) - r_{it-1}^{be}(i,j)}{r_{it-1}^{be}(i,j)} \right) \frac{r_t^{be}}{r_{it-1}^{be}(i,j)} + \\
& + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{be}(i,j) - r_{it}^{be}(i,j)}{r_{it}^{be}(i,j)} \right) \frac{r_{t+1}^{be}}{r_{it}^{be}(i,j)} \frac{be_{t+1}(i,j)}{be_t(i,j)} \right\} = 0
\end{aligned} \tag{2.39}$$

The ideal deposit interest structure is expressed below:

$$-1 - \frac{\varepsilon_t^d}{r_t^d} + \varepsilon_t^{bh} \frac{mc_t^d}{r_t^d} - k_d \left(\frac{r_{it}^d(i,j) - r_{it-1}^d(i,j)}{r_{it-1}^d(i,j)} \right) \frac{r_t^d}{r_{it-1}^d(i,j)} +$$

$$+ \left\{ \beta_{bh} E_0 k_d \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^d(i,j) - r_{it}^d(i,j)}{r_{it}^d(i,j)} \right) \frac{r_{t+1}^d}{r_{it}^d(i,j)} \frac{d_{t+1}(i,j)}{d_t(i,j)} \right\} = 0 \quad (2.40)$$

The optimal interest rate equation (2.36–2.40) is crucial to the model, and equations 2.36 and 2.37 are the major interest rate channels via which domestic public debt interacts with, and accumulates against, private sector lending in equations 2.38 and 2.39. Model banking block equations include these equations.

2.3.17 Fiscal Policy

The fiscal authority offers domestic currency-denominated government bonds to the banking sector to secure domestic government borrowing to partly fund fiscal deficits. Fiscal authority taxes business earnings (τ_k), household labour income (τ_w), and household consumption expenditures (τ_c), producing tax revenues (T_t). The monetary authority M_{t+1} also transfers profits to the fiscal authority. First, we describe government budget limitations 2.41. The ratio of B_{t+1} to R_t^B represents discounted government bonds, TR_t represents government tax revenue, $M_{t+1} - M_t$ represents seigniorage/currency issuance, $P_t G_t$ represents government expenditures, and $P_t I_t^G$ represents public investments. $P_t TRANS_t$ pertains to income transfers (social programmes), while 2.42 links government bond issuance to demand functions for Treasury Notes and Bills from the banking block section, and aggregate tax revenue is represented by 2.43.

Government budget constraints are represented by:

$$\frac{B_{t+1}}{R_t^B} - B_t + TR_t + M_{t+1} - M_t = \varepsilon_t^G P_t G_t + \varepsilon_t^{IG} P_t I_t^G + P_t TRANS_t \quad (2.41)$$

Domestic bonds enter the banking sector and the government's budget constraint through the public debt accumulation route, as presented in Section 4.7. Below is the domestic bond equivalence:

$$\frac{B_{t+1}}{R_t^B} - B_t = \left[\int_0^1 (TN_{it}(i,j))^{\frac{\varepsilon_t^{tn}-1}{\varepsilon_t^{tn}}} \right]^{\frac{\varepsilon_t^{tn}}{\varepsilon_t^{tn}-1}} + \left[\int_0^1 (TB_{it}(i,j))^{\frac{\varepsilon_t^{tb}-1}{\varepsilon_t^{tb}}} \right]^{\frac{\varepsilon_t^{tb}}{\varepsilon_t^{tb}-1}} \quad (2.42)$$

Below is the aggregate tax revenue model:

$$TR_t = \int_0^1 \tau_c \varepsilon_t^{CoT} P_t^c C_t^h dh + \int_0^1 \tau_w \varepsilon_t^{ET} W_t^c L_t^h dw + \int_0^1 \tau_k \varepsilon_t^{CT} (P_{(f,t)}^Y Y_{(f,t)} - W_{(f,t)} L_{(f,t)} - \Phi_t^F) df \quad (2.43)$$

ε_t^G , ε_t^{IG} , ε_t^{CoT} , ε_t^{ET} , and ε_t^{CT} are shocks affecting government expenditure, public investments, consumer tax, employment tax and capital tax. These shocks are represented by an AR (1) process with normal distribution. They are also *i.i.d*, and their respective autoregressive coefficients are ρ_G and ρ_{IG} , with coefficient standard deviations given as σ_G , σ_{IG} , σ_{CoT} , σ_{ET} and σ_{CT} , respectively.

2.3.18 Monetary Policy

The central bank sets the interest rate by Taylor's rule as indicated in (2.44): where ϕ_π and ϕ_y are the weights assigned to the stabilisation of inflation and output, respectively, and r_t is the nominal interest rate at a steady state and is an exogenous shock to monetary policy. The central bank sets the interest rate r_t by Taylor's rule as follows:

$$(1 + r_t) = (1 + r_t)^{1-\phi_\pi} \left(\frac{\pi_t}{\pi_{t-1}} \right)^{\phi_\pi(1-\phi_\pi)} \left(\frac{y_t}{y_{t-1}} \right)^{\phi_y(1-\phi_y)} (1 + \varepsilon_t^r) \quad (2.44)$$

2.4 Empirical Model

The model will be estimated using Bayesian methods, which require the specification of priors (beliefs). We will run the analysis using MATLAB 2015a software and Dynare version 5.4.0. The technical discussions of the methodology are outlined in Appendix A2.5, A2.6, and A2.7.

2.5 Data and Sources

In the empirical analysis, we will use quarterly macroeconomic variables of the Malawian economy. The data covers the full quarters between 2004 and 2020. Sources of Data have been outlined in Table 2.3 in Appendix A2.4.

Let $\mathbf{y}_t = [y_t]_{t=1}^T$ the set of observables

$$\mathbf{y}_t = \begin{pmatrix} \log C_t, \log K_t, \log \pi_t, r_t^d, r_t^{be}, r_t^{bh}, r_t^{tn}, \\ r_t^{tb}, r_t, \log K_t^b, \log TNotes_t, \\ \log TBills_t, \log Loans_t, \log DD_t, \log BK_t, \log G_t, \log IG_t, \log Tax_t \end{pmatrix} \quad (2.45)$$

It is assumed that the period t in the model corresponds to one quarter, y_t is the vector of observables, C_t is the Household final Consumption (Real Consumption), K_t is the Gross Capital Formation (Real Investments), π_t is the CPI inflation, r_t^d is the deposit rates, r_t^{be} is the interest rate to entrepreneur borrowers, r_t^{bh} is the interest rate to household borrowers, r_t^{tn} is the interest rate for Treasury Notes lending, r_t^{tb} is the Treasury Bill interest rate lending, $r_t^{tb} R_t$ is the Monetary Policy Rate (Policy Rate), K_t^b is the aggregate bank capital, B_t ($BH_t + BE_t$) is the aggregate loans, $TNotes_t$ is the aggregate Treasury Notes, $TBills_t$ is the aggregate Treasury Bills, DD_t is the aggregate Deposits, G_t is the aggregate government expenditure, IG_t is the aggregate public investments and Tax_t is the aggregate taxes. The parameters to estimate are contained in vector Θ .

$$\Theta = \begin{bmatrix} \kappa_p, \kappa_w, \kappa_i, \kappa_d, \kappa_{bE}, \kappa_{bH}, \kappa_{Kb}, \\ \phi_\pi, \phi_R, \phi_y, l_p, l_w, a^h, \rho_z, \rho_a, \rho_j, \rho_{mE}, \rho_{mI}, \rho_d, \\ \rho_{bH}, \rho_{bE}, \rho_{qk}, \rho_y, \rho_l, \rho_{Kb}, \rho_{TB}, \rho_{TN}, \rho_G, \sigma_z, \sigma_a, \sigma_j, \sigma_{mE}, \sigma_{mI}, \sigma_d, \sigma_{bH}, \\ \sigma_{bE}, \sigma_{qk}, \sigma_R, \sigma_y, \sigma_l, \sigma_{Kb}, \sigma_{TN}, \sigma_{TB}, \sigma_G, \sigma_{IG}, \sigma_{CoT}, \sigma_{ET}, \sigma_{CT} \end{bmatrix} \quad (2.46)$$

The parameter vector Θ , is made up of the quadratic adjustment costs, stabilizers, autocorrelation slopes and the standard deviations of the exogenous shocks that are a source of fluctuations in the general equilibrium model. The quadratic adjustment costs, autocorrelation slopes, standard deviations of exogenous shocks, price and output stabilizers have been fully described in Appendix A2.9.

2.6 Calibration

As is the common in the DSGE literature, several parameters will be calibrated upfront and will not be included in the estimation process. DSGE models have inherent problems of finding parameters of interest because the estimated variables may contain insufficient information. This method works in small-scale models, where we can solve our problem by carefully considering each equation. However, in medium- or large-scale models like ours, it is virtually impossible. Fixed parameters in the estimate technique enforce a strict

prior, which Bayesian estimation supports. Table 2.2 in Appendix A2.4 lists the calibrated parameters. The calibration strategy's parameters were chosen for three reasons: those needed to determine the steady state (which can be easily identified from steady-state relationships among observable variables), those with reliable estimates from other sources (in our case, those that characterise the exogenous processes' Law of Motion), and those needed to replicate the main steady-state key.

As stated in the introduction, limited research exists in this area to make conclusions. Gregory & Smith (1987) regard calibration as an estimation strategy. We may assign general equilibrium model parameters from several sources using this method. Estimates and historical figures are used for several parameters. We will set the subjective discount factor, β , to 0.9943, in line with the literature. Our discount factors for impatient families and companies were 0.975, matching those from Iacoviello (2005) and Iacoviello & Neri (2009). Based on Malawi's mortgage data, we set steady-state LTV ratios at 0.70. The remaining DSGE banking literature parameters are in Appendix A2.4.

2.7 Results

This section presents the results obtained. Cyclical fluctuations in output and other variables of interest are analysed using two tools: the decomposition of the historical variance, and impulse response functions, which are based on the quarterly data used, as shown in Figure 2.14 and Figure 2.15 in Appendix A2.3.

2.7.1 Application of the Model and Model Shocks

We use the estimated results and propagation mechanics to address the research question posed in the introduction, which is to investigate the extent to which banks' domestic debt financing affects business cycle fluctuations in Malawi.

The model has three groups of shocks namely: macroeconomic shocks, which include, among others, government spending shocks, tax shocks, and public financing shocks; banking shocks, which include bank lending shocks, public debt financing shocks, bank capital shocks, and bank funding shocks; and monetary policy shocks, which include interest rate shocks.

2.7.2 The Role of Financial Shocks in the Business Cycle in Malawi

As indicated above, the model's shocks are divided into three groups: macroeconomic, banking/financial, and monetary policy. The results show that a mixture of banking or financial shocks and macroeconomic shocks are the primary drivers behind business cycle fluctuations and credit supply in Malawi's economy. These shocks explain about 30% of the slowdown in economic activity up to period 32 in Figure 2.15. Public debt financing shocks are prominent in influencing output fluctuations, as banks hold a significant portion of non-loan book assets in Malawi. This crowds out private sector consumption and investment as economic agents' impatient households, entrepreneurs, and firms compete for the same available credit supply as the banking sector. Banks find it rewarding and capital-preserving to finance the accumulation of public debt-linked assets. The results are shown in Figure 2.14 and Figure 2.15 in Appendix A2.3.

2.7.3 Policy Transmissions

The transmission of various policy shocks can be studied by analysing the corresponding benchmark impulse response functions at 1% and then at 5%, 10%, and 20%. The transmission mechanism works through dynamic effects on output, consumption, investments, available loans to households, firms, deposits and bank capital. The results of different shocks are shown in Appendix A2.2. In all the figures below, the blue line represents the baseline, the red line indicates a 5% shock, the pink one shows a 10% shock, whereas the green line represents a 20% shock.

2.7.4 Monetary Policy Shock

A negative shock to the interest rate implies a positive money supply (expansionary monetary policy). This policy direction triggers an interest rate channel effect on patient households, firms, entrepreneurs, and banks. As a response to a low-interest rate regime, entrepreneurs increase borrowing. As a result, we see an increase in investments, and banks increase lending to households and firms. But at the same time, the low-interest rate regime also has a negative impact on the levels of banks' capital through depressing effects on the banks' level of profitability. Additionally, an expansionary monetary policy has a positive impact on output. As economic activities grow on account of increases in investments and

available capital for firms and households, output also increases accordingly. This is indicated in Figure 2.5 in Appendix A2.2.

When we compare our results to the benchmark model by Gerali et al. (2010), a positive shock to interest rates attenuated the impact response of real variables to the monetary policy shock, while the presence of bank capital amplified them. After an interest rate shock in the presence of quadratic adjustments costs, this triggered an interest rate channel modified by the presence of borrowing constraints: aggregate consumption fell, due to the standard response of patient agents, who decide to postpone consumption in the face of higher interest rates. Entrepreneurs respond to the decrease in demand by cutting production and investment, which in turn depresses labour and capital income for households.

As for the role of banks, Christiano et al. (2007) find that, in general, adding banks and financial frictions strengthens significantly the propagation mechanism of the monetary policy: the output response is both bigger and more persistent compared to a model that does not feature these channels. In Goodfriend and McCallum's (2007) banking model, the effect occurs only when the monetary impulse is very persistent, since marginal costs in the banking sector become procyclical in that case (otherwise the effect is of the opposite sign), as also indicated by Andres and Arce (2012) and Aslam and Santoro (2008), Iacoviello and Neri (2009) and Calza et al. (2007).

2.7.4.1 Bank Core Deposit Funding Shock

A positive shock to core deposit funding implies a positive money supply (expansionary monetary policy). This policy direction triggers an interest rate channel effect on patient households, firms, entrepreneurs, and banks. As a response to a low-interest rate regime, entrepreneurs increase borrowing. As a result, we see an increase in investments, and banks increase lending to households and firms which in turn has a positive effect on output. But at the same time, the low interest rate regime also has a negative impact on banks' capital levels, which in turn affects their profitability, as shown in Figure 2.6 in Appendix A2.2.

2.7.4.2 Bank Capital Shock

A negative shock to bank capital implies a decrease in bank capital. This triggers different reactions from banks, which in turn affects patient households, firms, entrepreneurs, and banks themselves. As a response to a volatile capital level, banks naturally engage in a deposit mobilisation drive. The initial reaction to the capital shock is for banks to increase lending to firms and households so that they augment capital decline with growth in earnings, but when the capital shock persists, banks will reduce lending to entrepreneurs and households, thereby leading to a negative effect on investments and consumption, as a strategy to preserve the low capital levels. Overall, the challenges that banks face due to shocks to capital levels result in a reduction in output at each shock level. This is indicated in Figure 2.7 in Appendix A2.2.

In Gerali et al (2010), the presence of banking capital as an input in the production of loans widened the spread between the loan rate and the policy rate, and thus magnified the impact of monetary tightening.

2.7.4.3 Treasury Notes and Bills Interest Rate Shock

As earlier hypothesized, the government's public debt accumulation mechanism through the banking sector has crowding-out effects. It can be clearly seen in Figure 2.8 and Figure 2.9 that a negative shock to Treasury Notes and Bills results in a permanent decrease in investments, lending to firms and households, and deposits. As a response to a low treasury interest rate regime, the government borrows more, thereby decreasing the amount of available loans to households and firms. Investments drop at each shock level, loans to households and firms decrease; this is crowding-out in action. Inadvertently, bank capital increases as banks invest more in risk-free instruments that carry low capital charges as per the Basel risk-weighted asset classification, as discussed in Section 2. But the reduction in investments in the real sector has a negative effect on output. Figure 2.8 and Figure 2.9 in Appendix A2.2 highlight this phenomenon.

The impact of a public debt shock has similar results to the debt-deflation channel effect in the standard Gerali et al (2010) model. The contraction spurred by the increase in real rates in the Gerali et al. (2010) model induces a fall in the general price level and this puts

additional strain on borrowers' balance-sheets by raising the real cost of current debt obligations. The opposite effect occurs on patient agents, since their real remuneration on savings rises. The net effect of this redistribution of wealth (from impatient households and entrepreneurs to patient households) is a further contraction in aggregate demand (output) since impatient households and entrepreneurs have a higher propensity to consume. Again, as a result of the work of the financial accelerator in the Gerali et al. (2010) model, on impact, the rise of real interest rates reduces the net present value of tomorrow's real estate collaterals and capital holdings, causing banks to cut the amount of loans they are willing to supply to impatient households and entrepreneurs as a result both household and firm lending fall. The contraction in borrowing, by reducing resources available to constrained agents, puts additional downward pressure on aggregate demand (output).

2.7.4.4 Public Investment Spending Shock

The public investment spending shock is the mirror image of the shocks emanating from Treasury funding, and the policy transmission moves in a similar direction. As noted, there is a significant amount of bank resources that goes towards the government domestic borrowing program. This inadvertently crowds-out investments and lending to firms and households. This is indicated in Figure 2.10 and Figure 2.11 in Appendix A2.2.

2.7.4.5 Consumption and Employment Tax Shocks

A reduction in consumption and employment taxes has a positive impact on investments, increases disposable income revenues for firms, and enables households and firms to be eligible for more loans. Patient households react by reducing consumption and increasing savings, leading to an increase in deposits as well. As a result, a reduction in consumption tax has positive effects on output, as indicated in Figure 2.12 and Figure 2.13 in Appendix A2.2.

2.8 Conclusion and Policy Recommendations

Our study establishes that banking sector shocks emanating from financing public debt play a significant role in explaining variations in output, investments, loans to households and businesses, volatility in bank funding and capital levels in Malawi both in the short and long run. We also found that these shocks from public financing crowd-out private

sector credit supply in the face of a liquidity-constrained central government. The findings of our study are important for policymakers. It is undeniable that banks play a very important financial intermediation role and that they are a conduit through which the Central Bank's monetary policy transmission is used to affect the asset composition of the bank's balance sheets at any given point. Banks also play a very important role in allocating scarce resources between savers and borrowers. The main finding of our study is that public debt instrument accumulation by banks had a pronounced effect on business cycle fluctuation in Malawi during the period of the study. In other words, banks are more inclined to hold treasury instruments than supply credit to households and firms.

This is encouraged by the high yields and zero risk attached to the accumulation of public debt for credit risk-weighted asset purposes. The main reason why public debt shocks negatively affect output is that the resources from Treasury Notes and Bills do not support real output growth-adjusting investments that have the potential to stimulate the growth of the tax base.

One of the policy recommendations of this study is that the central government should encourage its ministries, departments and agencies (MDAs) to hold treasury accounts with the central bank and consolidate their deposits. This will reduce the likelihood of the central government borrowing its own funds, which endogenously creates fiscal domestic debt through the banking channel out of its own resources. The government introduced an additional 10% profitability tax on banks in addition to the 30% corporate tax. This was done as a special tax to the supernormal profits banks make from Treasury Notes and Bills. Banks, therefore, have double capital augmenting benefits from their lending to the government: firstly, the easy profits they make from the treasury portfolio strengthens their capital position through retained earnings, and secondly, the treasury portfolio is treated as sovereign portfolio and attracts zero capital weight. With these benefits, this explains why we have seen a big shift in banks' portfolio reallocation from loans to private sector to increased lending to the government. In the end, these profits are channelled to their investors as dividends with a lower tax rate of 10%.

The economic rationale of the special tax is in line with what Pigou (1932) asserts, that the shifting of lending from the private sector to the central government should be treated as a negative externality that affects economic growth, and that the tax will act as a deterrence to discourage banks from aggressively starving the real sector (private sector) with financial resources. The real sector has been touted as the engine for growth in Malawi, but that will only be possible if it is able to access resources timely and at affordable cost of funding.

However, we also find this policy stance of a special treasury tax of 10% to be inefficient and pareto sub-optimal, because the government is not forced to borrow from banks, as the market for credit or loanable funds is determined by forces of demand and supply and recourse on bank capital management rules (all the income banks make from investing in Treasury Notes and Bills is a direct risk-free lending to the government which also attracts zero risk weighted rating according Basel capital regulation metrics). So instead of imposing pareto-inefficient tax regimes, we believe the best recommendation is that there must be regulations that set a minimum lending ratio to the private sector, or a maximum lending ratio to the government.

Appendix A2.1: Bank Asset Portfolio Graphs

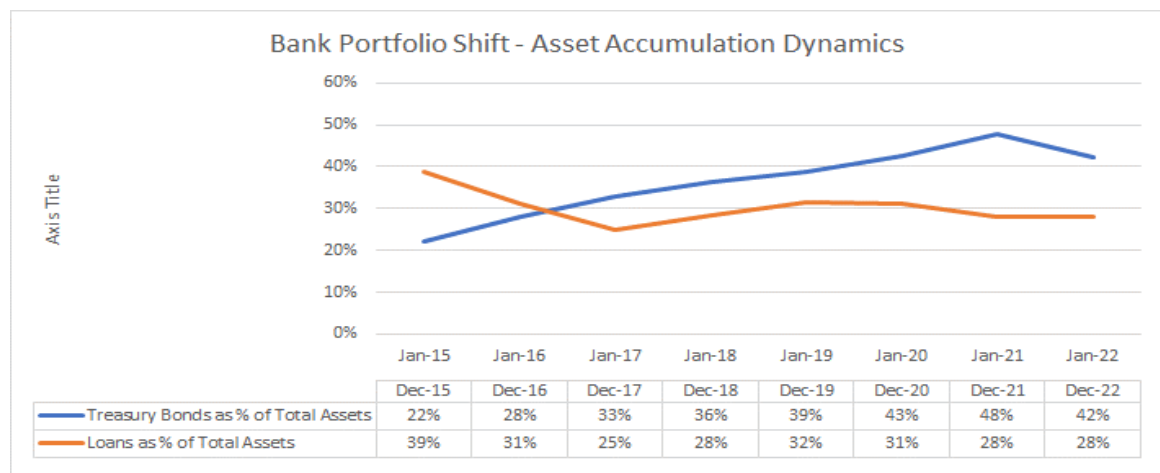


Figure 2.2: Banks' portfolio shifts. Source: Author calculations from Banking Sector Bank Supervision Reports

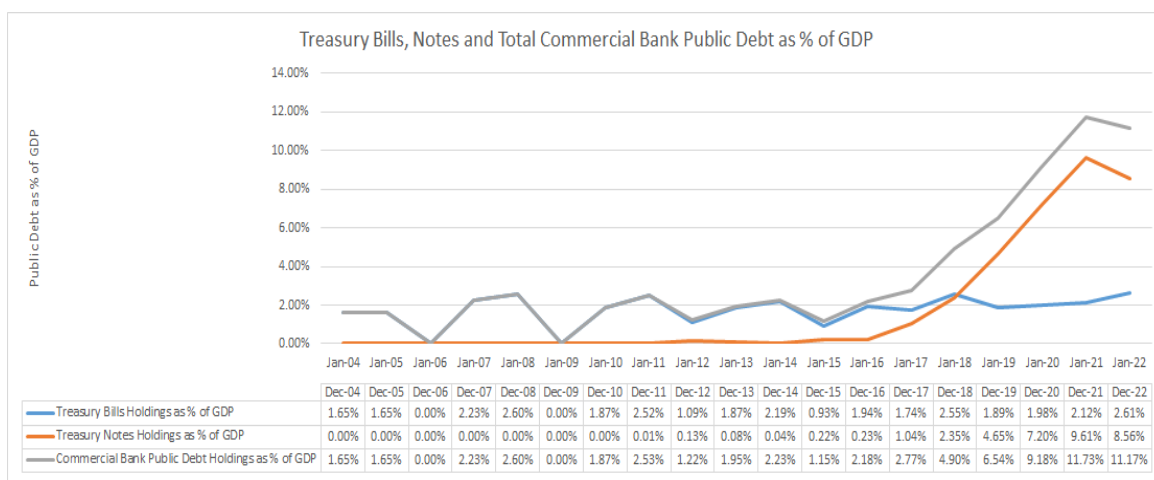


Figure 2.3: Commercial banks' public debt holdings as a percentage of GDP
Source: Reserve Bank of Malawi

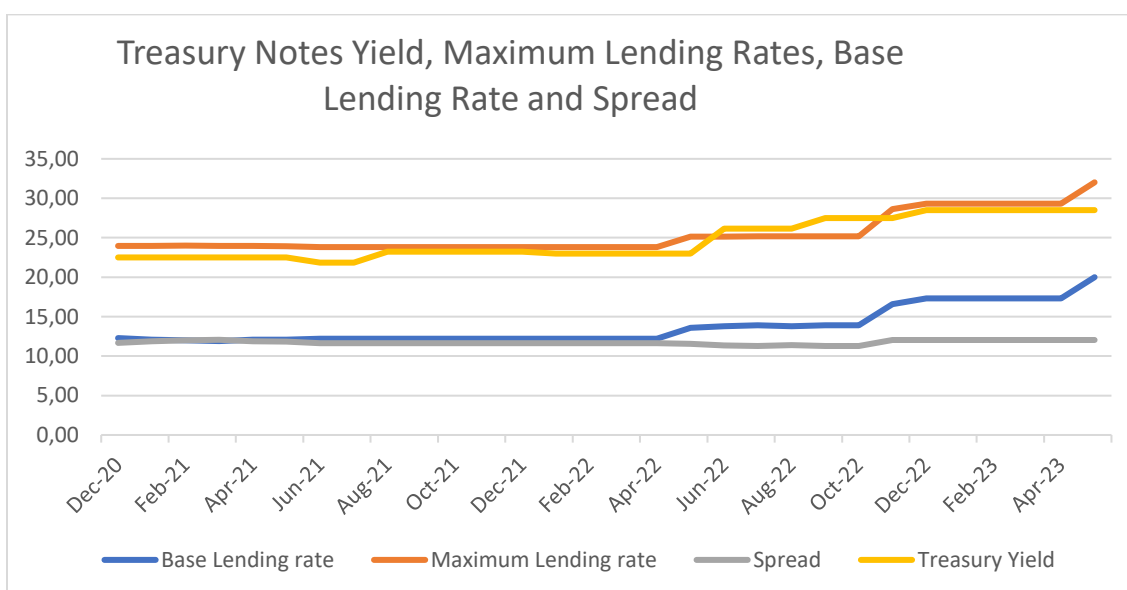


Figure 2.4: Interest rates in Malawi
Source: Reserve Bank of Malawi.

Appendix A2.2: Policy Transmission Mechanism Graphs

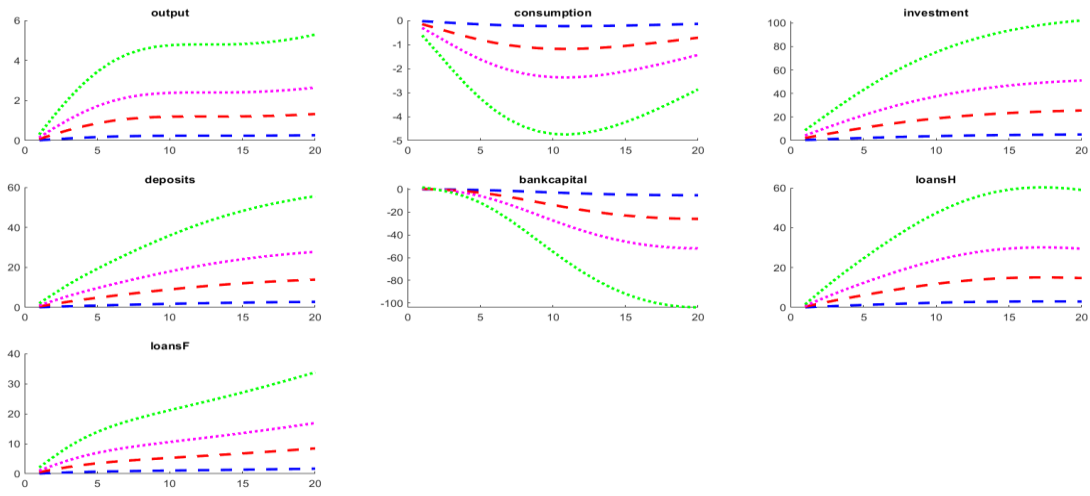


Figure 2.5: Effect of a Base 1%, 5%, 10%, and 20% expansionary monetary policy shock (e_{r_ib})

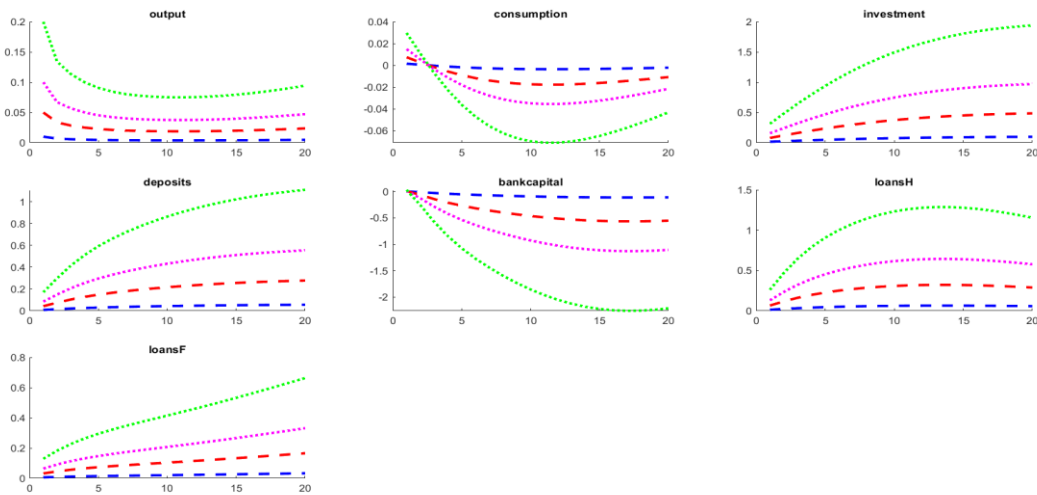


Figure 2.6: Effect of a Base 1%, 5%, 10%, and 20% expansionary banking core deposit funding shock (e_{mk_d})

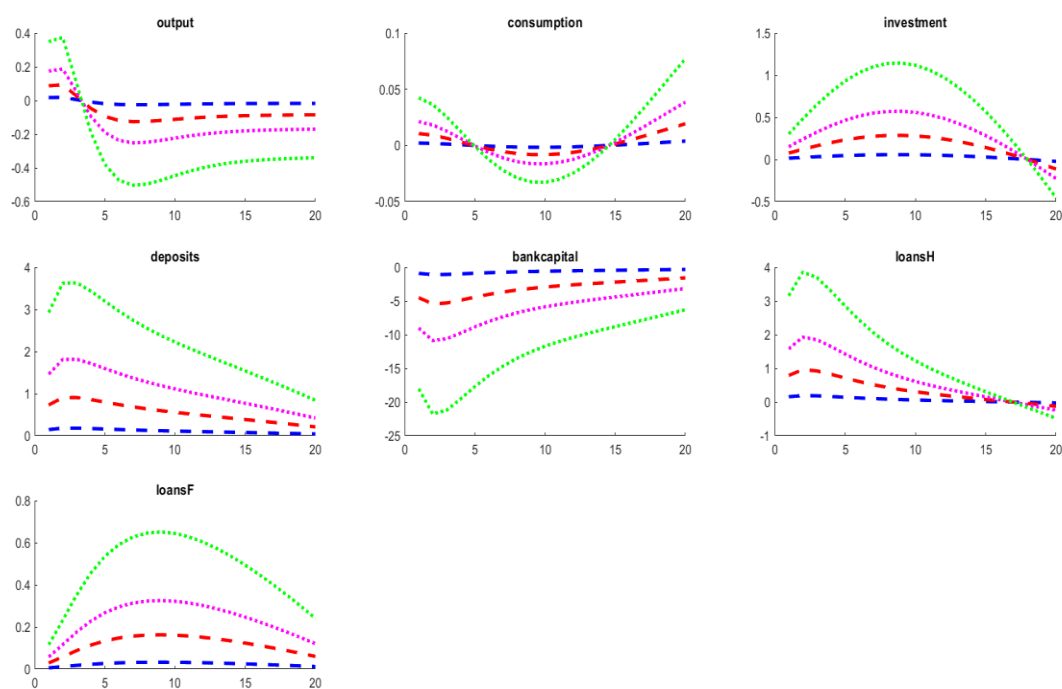


Figure 2.7: Effect of a Base 1%, 5%, 10%, and 20% expansionary capital shock (e_eps_kb)

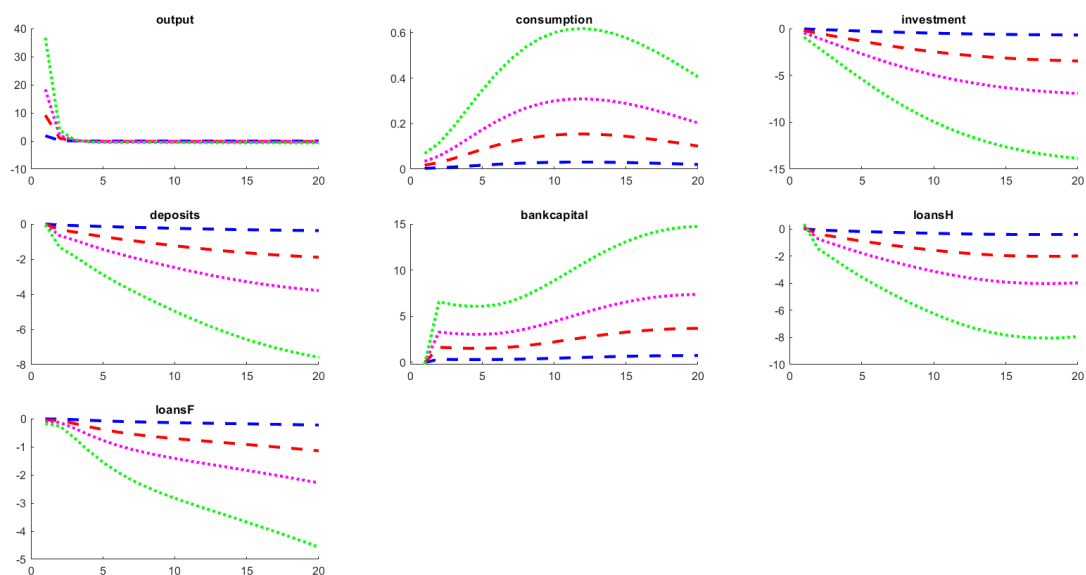


Figure 2.8: Effect of a Base 1%, 5%, 10%, and 20% expansionary public debt shock (e_t_notes)

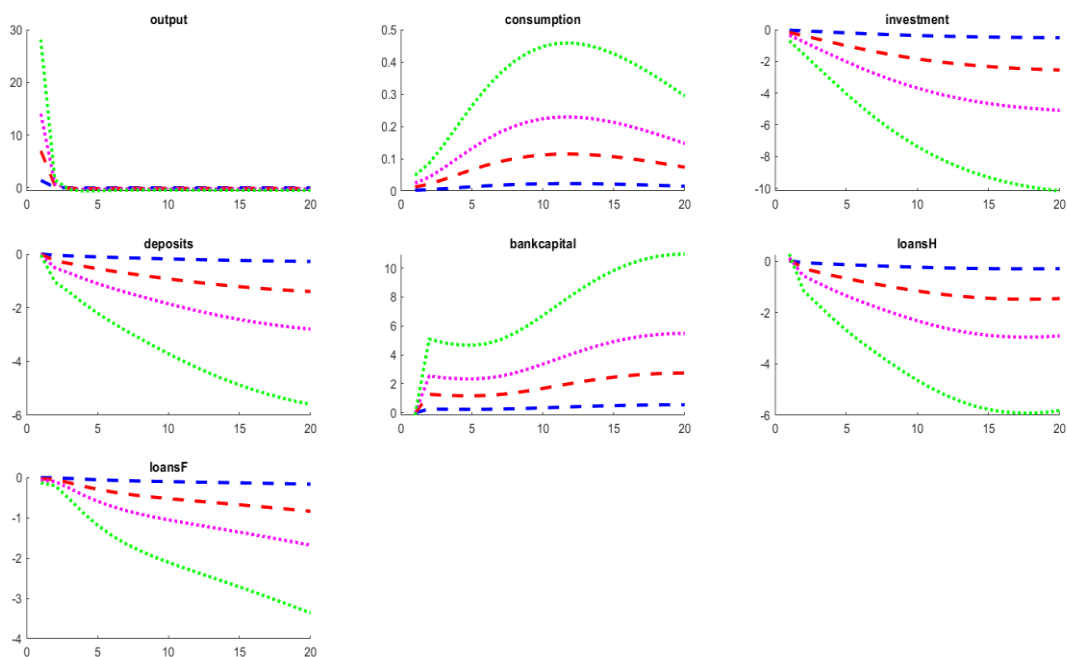


Figure 2.9: Effect of a Base 1%, 5%, 10%, and 20% expansionary public debt shock (e_{t_bills})

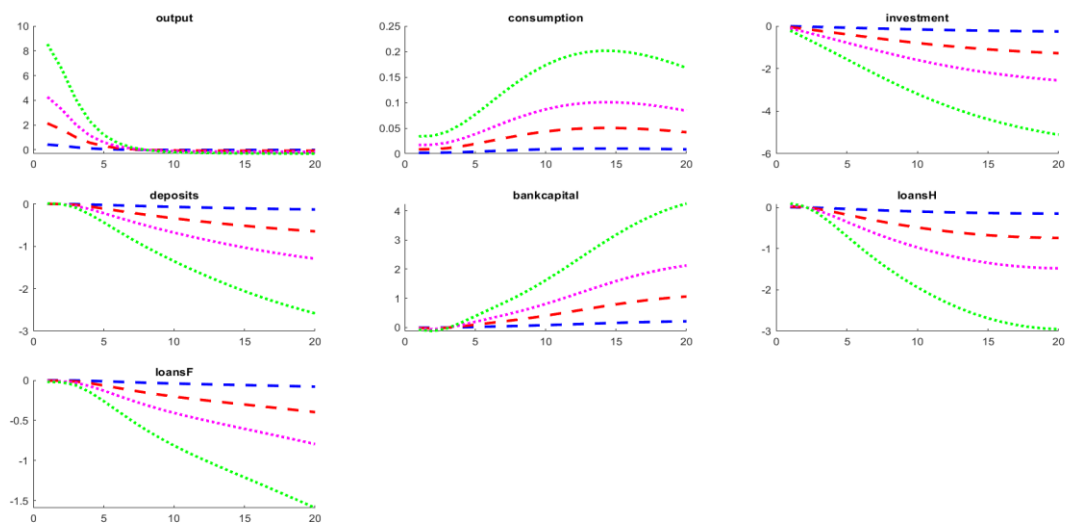


Figure 2.10: Effect of a Base 1%, 5%, 10%, and 20% expansionary government spending shock (e_G)

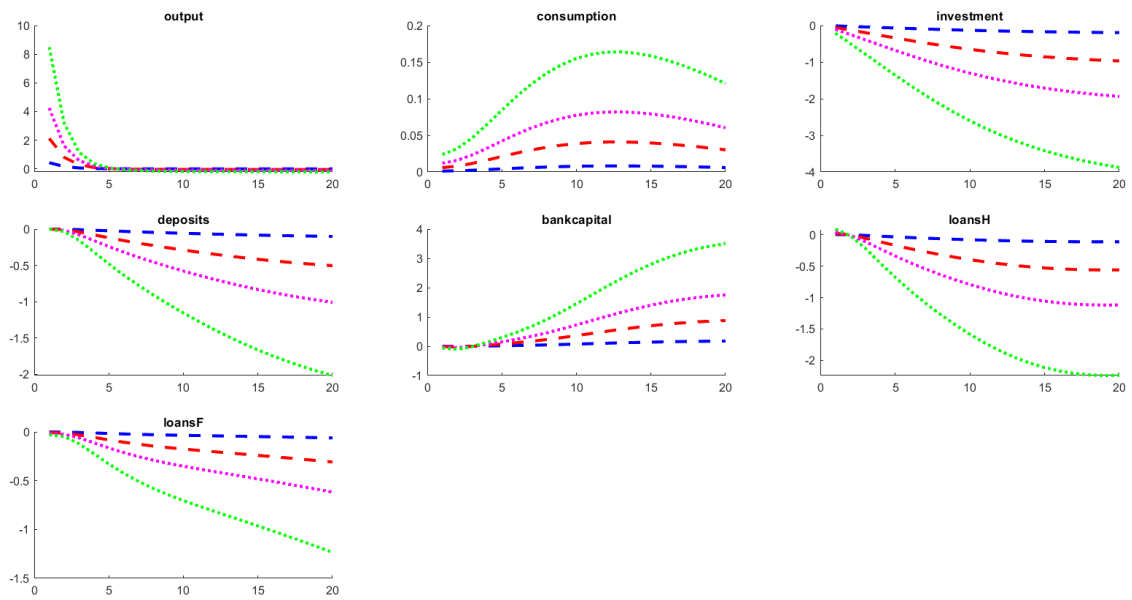


Figure 2.11: Effect of a Base 1%, 5%, 10%, and 20% expansionary public investment shock (e_{IG})

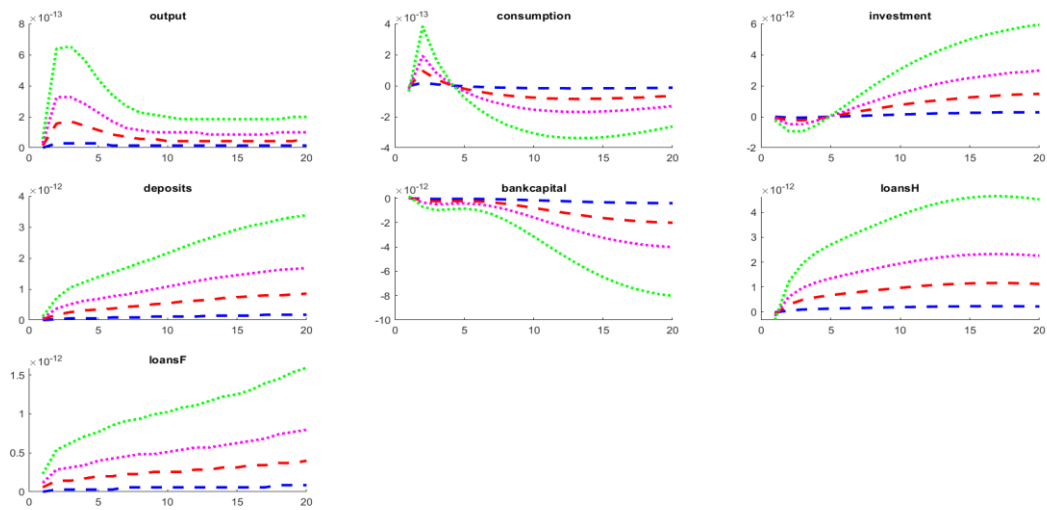


Figure 2.12: Effect of a Base 1%, 5%, 10%, and 20% expansionary consumption tax (e_{τ_c})

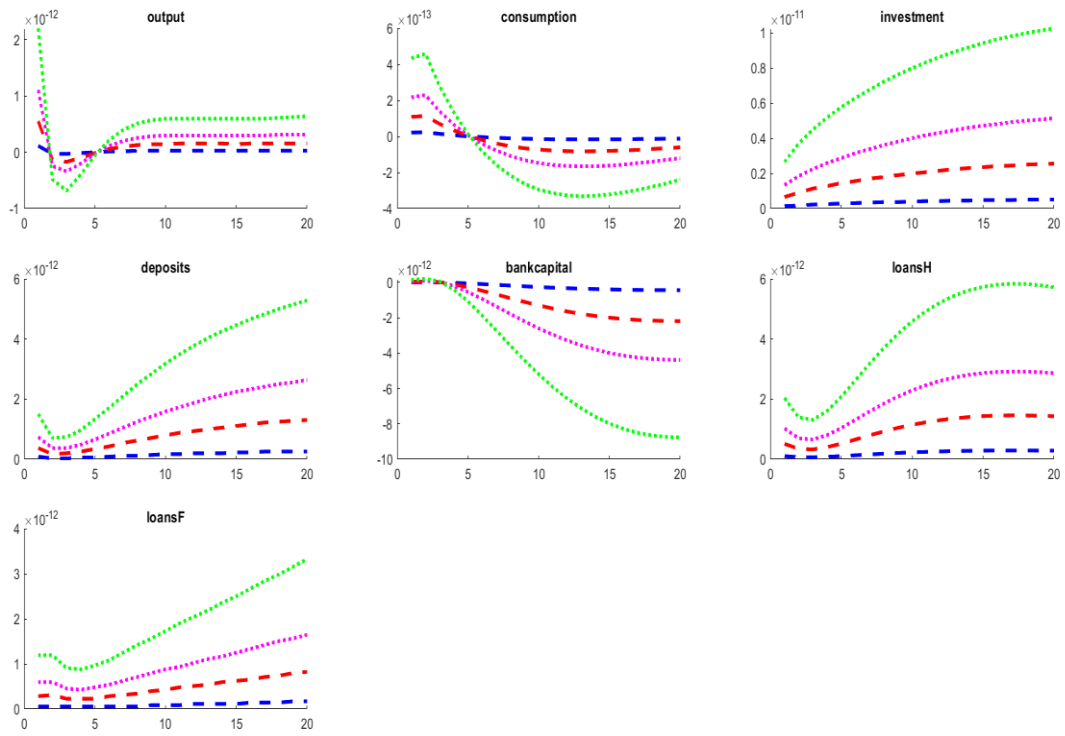


Figure 2.13: Effect of a Base 1%, 5%, 10%, and 20% expansionary employment tax (e_{τ_I})

Appendix A2.3: Decomposition of Variance Conditional Forecast Errors (%) Graphs

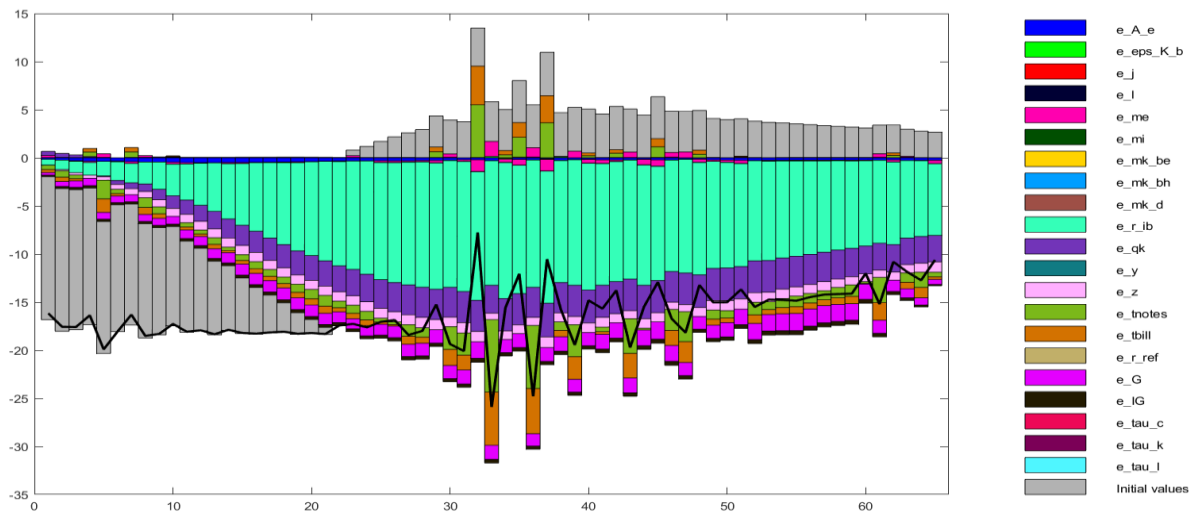


Figure 2.14: Historical shock decomposition of main macro variables: Dynamic effects of respective shocks on output (GDP)

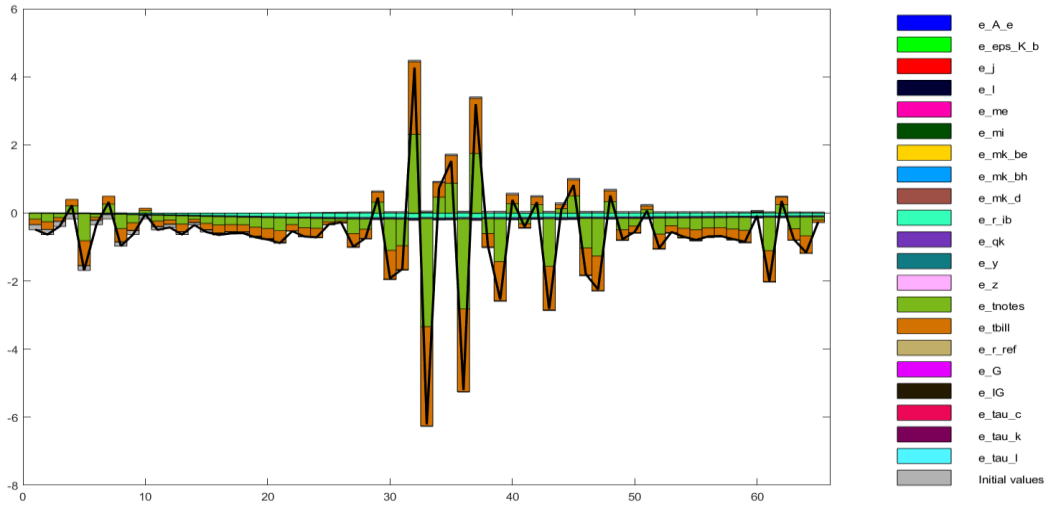


Figure 2.15: Historical shock decomposition of main macro variables: Dynamic effects of respective shocks on government bonds

Appendix A2.4: Calibrated Parameters

Table 2.2: Calibrated parameters

Parameter	Value	Description	Source
β_p	0.9943	Patient households' discount factor	Economic literature
β_l	0.975	Impatient households' discount factor	Economic literature
β_E	0.975	Entrepreneurs' discount	Economic literature
Φ	1.0	The inverse of the Frisch elasticity	Economic literature
μ	0.8	Share of unconstrained households	
ε^h	0.2	Weight of housing in the households' utility function	
α	0.25	Capital share in the production function	Economic literature
δ	0.025	The depreciation rate of physical capital	Economic literature
ε^y	6	$\varepsilon^y / \varepsilon^y - 1$ is the markup in the goods market	Economic literature
ε^l	5	$\varepsilon^l / \varepsilon^l - 1$ is the markup in the labor market	Economic literature
m^l	0.70	Households' LTV ratio	Malawi Banking Practice

m^E	0.70	Entrepreneurs' LTV ratio	Malawi Banking Practice
ν^b	0.10	Target capital to loans ratio	Basel I & II
ε^d	-1.46	$\varepsilon^d / \varepsilon^d - 1$ is the mark-up on deposit rate	Economic literature
ε^{bH}	2.79	$\varepsilon^{bH} / \varepsilon^{bH} - 1$ is the mark-up on loans to households	Economic literature
ε^{bE}	3.12	$\varepsilon^{bE} / \varepsilon^{bE} - 1$ is the mark-up on loans to firms	Economic literature
ε^{tn}	2.12	$\varepsilon^{tn} / \varepsilon^{tn} - 1$ is the mark-up on treasury loans to government	Economic literature
ε^{tn}	2.12	$\varepsilon^{tn} / \varepsilon^{tn} - 1$ is the mark-up on treasury loans to government	Economic literature
ε^{tb}	2.12	$\varepsilon^{tb} / \varepsilon^{tb} - 1$ is the mark-up on treasury loans to government	Economic literature
δ^b	0.1049	Cost of managing the bank's capital position	Basel I & II

Table 2.3: Data Sources

Description	Source
Output	Source: National Statistical Office (NSO) and IMF WEO Database. Transformed as per Appendix A2.7.6
Consumption	Real Consumption: Source: National Statistics Office (NSO). Transformed as per Appendix A2.7.6
Gross Fixed Capital Formation	Real Investment: Source: National Statistics Office (NSO) and IMF World Economic Outlook (WEO) Database. Transformed as per Appendix A2.7.6
Loans	Reserve Bank of Malawi (RBM)
Deposits	Reserve Bank of Malawi (RBM)
Treasury Notes and Bills	Reserve Bank of Malawi (RBM)
Inflation	National Statistics Office
Interest rates	Reserve Bank of Malawi (RBM)
Bank Capital	Reserve Bank of Malawi (RBM)
Government Expenditure	National Statistics Office. Transformed as per Appendix A2.7.6
Government Taxes	National Statistics Office and IMF WEO

Appendix A2.5: Technical Analysis

Appendix A2.5.1: General Bayesian Theorem Formulation

Bayesian modelers recognize that “all models are false”, rather than assuming they are working with the correct model. This perspective contrasts with the classical frequentist analytical methods that search for a single model with the highest posterior probability, given the evidence. To demonstrate how the general principles of Bayesian Theory work, we will use a simple example case of the interaction between two random variables, X and Y . As is in Bayesian literature, let $p(V)$ represent a probability mass function or density, depending on whether the variables are discrete or continuous. The general rule of conditional probability will be as follows:

$$p(X | Y) = \frac{p(X,Y)}{p(Y)} \quad (\text{A2.1.1})$$

and can be used to generate the Bayes' Theorem as below:

$$p(X | Y) = \frac{p(Y|X)p(X)}{p(Y)} \quad (\text{A2.1.2})$$

In statistical problem generalization, we start with a data vector y , that is presumed to be a sample from a probability model with an unknown parameter vector θ . We present the model using the likelihood function $L(\theta; y) = f(y, \theta) = \prod_{i=1}^n f(y_i | \theta)$, where $f(y_i | \theta)$ shows the PDF (probability density function) of y_i given θ . The next objective is to deduce the properties of θ based on the data y . In Bayesian theory, the model that is parameterized by θ is a random vector. We presume that θ has a probability distribution $p(\theta) = \pi(\theta)$, which is referred to as a prior distribution. Because both y and θ are random, we can apply Bayes' Theorem to derive the posterior distribution of θ given data y :

$$p(\theta | y) = \frac{p(y|\theta)p(\theta)}{p(y)} = \frac{f(y;\theta)\pi(\theta)}{m(y)} \quad (\text{A2.1.3})$$

where $m(y) = p(y)$, known as the marginal distribution of y , is defined by

$$m(y) = \int f(y; \theta)\pi(\theta)d\theta \quad (\text{A2.1.4})$$

Since the marginal distribution $m(y)$ does not depend on the parameter of interest θ , we, therefore, reduce our posterior distribution equation to:

$$p(\theta | y) \propto L(y; \theta)\pi(\theta) \quad (\text{A2.1.5})$$

This equation is important in Bayesian statistics and says that the posterior distribution of model parameters is proportional to their likelihood and probability distribution. The above equation is often presented computationally in a more convenient log-scale form as indicated below:

$$\ln\{p(\theta | y)\} = l(y; \theta) + \ln\{\pi(\theta)\} - c \quad (\text{A2.1.6})$$

where $l(\cdot; \cdot)$ depicts the log-likelihood of the model. Depending on the analytical approach used, the log-posterior $\ln\{p(\theta | y)\}$, the actual value of the constant $c = \ln\{m(y)\}$ may or may not be relevant. For credible statistical analysis, however, it is always assumed that c is finite.

The likelihood function can be computed via the state-space representation of the model together with the measurement equation linking the observed data and the state vector. The model state-space representation will be:

$$S_{t+1} = \Gamma_1 S_t + \Gamma_2 w_{t+1} \quad (\text{A2.1.7})$$

$$Y_t = \Lambda S_t + \mu_t \quad (\text{A2.1.8})$$

Where $S_t = \{x_t, y_t\}$ x_t and y_t are the equilibriums described by the matrices of the deep parameters, Y_t is the vector of observed variables, μ_t is the measurement error, matrices Γ_1 and Γ_2 are functions of the model's deep parameters and Λ defines the relationship between observed and state variables. The likelihood function will be computed under the assumption of normally distributed disturbances by combining the state-space representation implied by the solution of the linear rational expectations model and the Kalman filter. Posterior draws will be obtained using MCMC methods. After obtaining an approximation of the mode of the posterior, we will rely on an RWMH algorithm to generate posterior draws, as discussed in Herbst & Schorfheide (2014). Point estimates of θ will be obtained from the generated values by using various location measures such as mean or median. Similarly, measures of uncertainty will follow from the computation of the percentiles of the draws.

Appendix A2.5.2: Specific Application of Bayesian Theorem to our Model Framework

The prior density $p(\theta | M_R)$, which is equivalent to $p(\theta | y)$ in the general framework above, assumes that prior information about the parameter vector can be summarized by a

joint probability density function. These have a Gamma, Beta and Inverse Gamma distribution, respectively. The likelihood function describes the density of the observed data, given the model and the parameter vector. It is estimated using the Kalman filter, which evaluates the likelihood function associated with the solution of the space-state system of the model.

This function can be represented recursively

$$\mathcal{L}(\Theta | y_T, M_R) \equiv p(y_0 | \Theta, M_R) \prod_{t=1}^T p(y_t | Y_{t-1}, \Theta, M_R) \quad (A2.1.9)$$

where $\mathcal{L}(\Theta | y_T, M_R)$ is the likelihood function and $p(y_t | Y_{t-1}, \Theta, M_R)$ is the density conditional on the information available up to $t-1$.

$$\Theta = \begin{bmatrix} \kappa_p, \kappa_w, \kappa_i, \kappa_d, \kappa_{bE}, \kappa_{bH}, \kappa_{Kb}, \phi_\pi, \phi_R, \phi_y, l_p, l_w, a^h, \rho_z, \rho_a, \rho_j, \rho_{mE}, \\ \rho_{mI}, \rho_d, \rho_{bH}, \rho_{bE}, \rho_{qk}, \rho_{TN}, \rho_{TB}, \rho_G, \rho_y, \rho_l, \rho_{Kb}, \sigma_z, \sigma_a, \sigma_j, \sigma_{mE}, \sigma_{mI}, \\ \sigma_d, \sigma_{bH}, \sigma_{bE}, \sigma_{qk}, \sigma_R, \sigma_y, \sigma_l, \sigma_{Kb}, \sigma_{TN}, \sigma_{TB}, \sigma_G, \sigma_{IG}, \sigma_{CoT}, \sigma_{ET}, \sigma_{CT} \end{bmatrix}$$

Where Θ is the vector of model parameters.

The posterior distribution is given by Bayes' theorem.

$$p(\Theta | y_T, M_R) = \frac{\mathcal{L}(\Theta | y_T, M_R) p(\Theta | M_R)}{p(y_T | M_R)} \quad (A2.1.10)$$

The term $p(y_T | M_R)$ is the marginal density of the data and appears as a normalization constant in the denominator. The logarithm of the marginal density of the data can be interpreted as a function of maximized log-likelihood penalized by the dimension of the model. The term $p(\Theta | y_T, M_R)$, is the posterior density proportional to the product of the likelihood function and the prior.

$$p(\Theta | y_T, M_R) \propto \mathcal{L}(\Theta | y_T, M_R) p(\Theta | M_R) \equiv \mathbb{K}(\Theta | y_T, M_R) \quad (A2.1.11)$$

This equation is of fundamental interest because it summarizes everything that is known about Θ , after using the data. The posterior kernel $\mathbb{K}(\Theta | y_T, M_R)$, corresponds to the numerator of the posterior density.

To complete a Bayesian specification of the model, we choose priors for each of the parameters of Θ .

Appendix A2.5.3: Choice of Priors

In Bayesian analysis, we seek a balance between prior information in the form of expert knowledge or belief (results from prior or earlier research or literature) and evidence from data at hand. Achieving the right balance is one of the difficulties in Bayesian modelling and inference. In general, we should not allow the prior information to overwhelm the evidence from the data, especially when we have a large data sample. A famous theoretical result, the Bernstein–von Mises theorem, states that in large data samples, the posterior distribution is independent of the prior distribution and, therefore, Bayesian and likelihood-based inferences should yield essentially the same results. On the other hand, we need strong enough support for the weak evidence that usually comes from insufficient data. It is always good practice to perform a sensitivity analysis to check the dependence of the results on the choice of a prior.

Bayesian inference starts from the prior distribution of the model's non-calibrated parameters. Priors' density function reflects our beliefs about parameter values. The Bayesian estimation technique allows us to use this prior information from earlier studies at both the macro and micro levels. When evidence is weak or non-existent, we will impose more diffuse priors. The gamma distribution will be defined for the parameters that are assumed to be positive (Real Numbers) which include all the quadratic adjustments. Gamma distributions are used to model continuous variables that are always positive and have skewed distributions. They are often used to describe the time between independent events that have consistent average time intervals.

The gamma distribution function has two parameters: a shape parameter and a rate parameter (Figure 2.16). The shape parameter α represents the number of independent events we are modelling. When the shape parameter (α) is equal to one, the gamma distribution becomes an exponential distribution.

Thus, the gamma distribution is essentially the summation of several exponential distributions. The rate parameter β represents the average time between these events. If we keep everything else the same, reducing the rate parameter (which means increasing the

scale parameter) will cause it to take longer to observe the same number of events, resulting in a flatter PDF curve. The PDF for gamma distribution is given as follows: $P(x) =$

$$\frac{x^{\alpha-1} e^{-\frac{x}{\beta}}}{\beta^{\alpha} \Gamma(\alpha)}$$

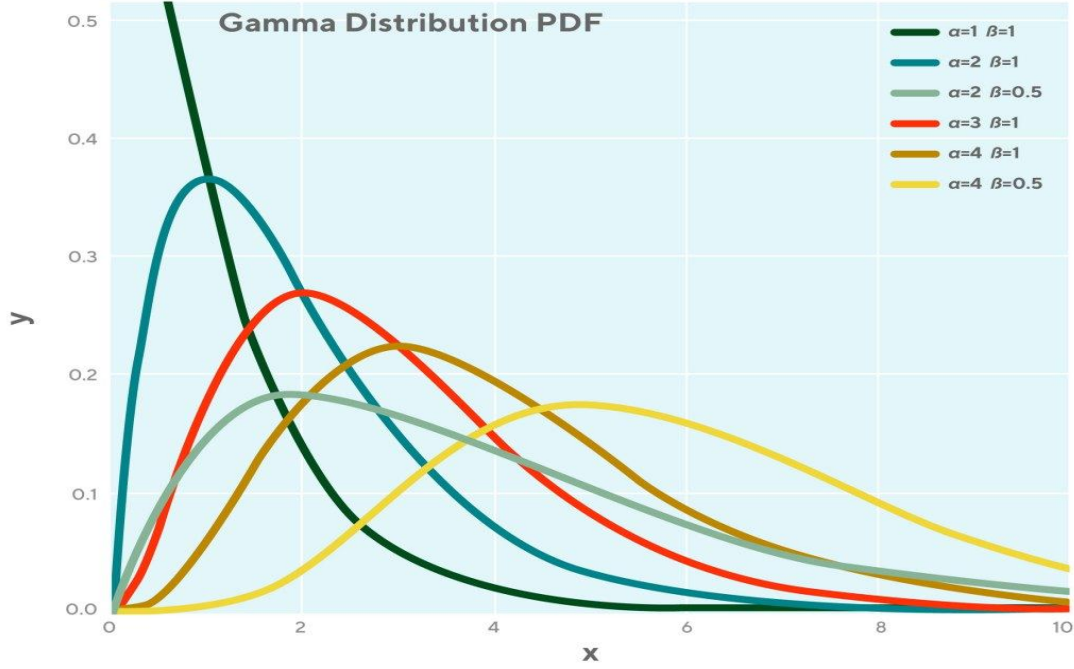


Figure 2.16: Gamma distribution PDF curve with various parameters

Therefore, the priors were completely harmonized, with their means set at a range of 0.1 to 2 in line with the literature, and with a standard deviation of 0.1 to 0.5 for all the parameters. Θ with Gamma Distribution = $[\kappa_p, \kappa_w, \kappa_i, \kappa_d, \kappa_{bE}, \kappa_{bH}, \kappa_{tn}, \kappa_{tb}, \kappa_{Kb}]$.

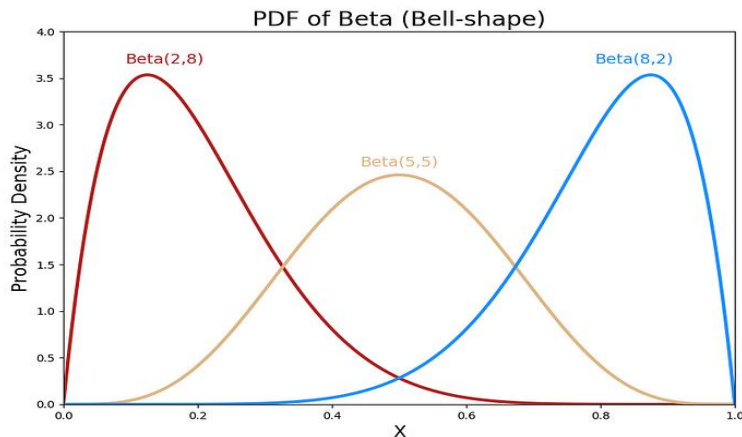
The beta distribution will be defined for the parameters bounded between zero and one, which include the shocks autoregressive parameters, wage and price indexation parameters, habit formation parameters, inflation, and bank interest rate stabilizer indices.

The beta PDF is as follows $P(x) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha, \beta)}$, where $B(\alpha, \beta) = \frac{\Gamma(\alpha)\Gamma(\beta)}{\Gamma(\alpha+\beta)}$ and Γ is the gamma function. The numerator of the beta PDF is a binomial distribution and the denominator is a normalizing constant that ensures that the function integrates to 1.

The difference between the binomial and the beta distribution is that the former models the number of successes (x), while the latter models the probability (p) of success. In other words, the probability is a parameter in the binomial distribution. In contrast, in the beta distribution, the probability is a random variable. The other reason why the beta distribution is popular is because it is the *conjugate prior* for the Bernoulli, binomial, negative binomial and geometric distributions (these are distributions that involve success and failure) in Bayesian inference. Using a conjugate prior, such as the beta distribution, in Bayesian inference gives us significant advantages. One of the main benefits is that computing a posterior using a conjugate prior is very easy and it reduces the number of computation times. It allows us to avoid the expensive numerical computations typically involved in Bayesian inference. When a conjugate prior is used, the posterior distribution belongs to the same family as the prior distribution, and that greatly simplifies the computations.

The other reason for choosing a beta distribution is that it takes many different shapes. Depending on the values of its parameters α and β , the probability density function (PDF) of a beta distribution can look like a bell-shape (when α and β are greater than 1), a U-shape with asymptotic ends (when α and β are smaller than 1), a strictly increasing or decreasing line, or even a straight horizontal line (when either α and β are 1 and 2).

Figure 2.17: Bell-shaped beta distribution



For instance, when $\alpha = 8$ and $\beta = 2$, the PDF of the beta distribution produces the bell-shaped curve represented by the blue colour, in contrast to the red one. The x-axis represents the probability of success. Moreover, when $\alpha + \beta$ is large enough and α and β are approximately equal, the beta PDF can approximate a normal distribution.

Figure 2.18: Straight lined beta distribution

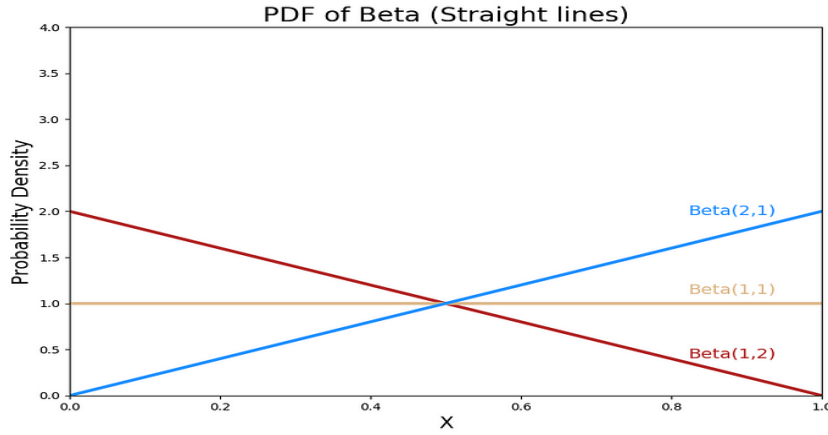
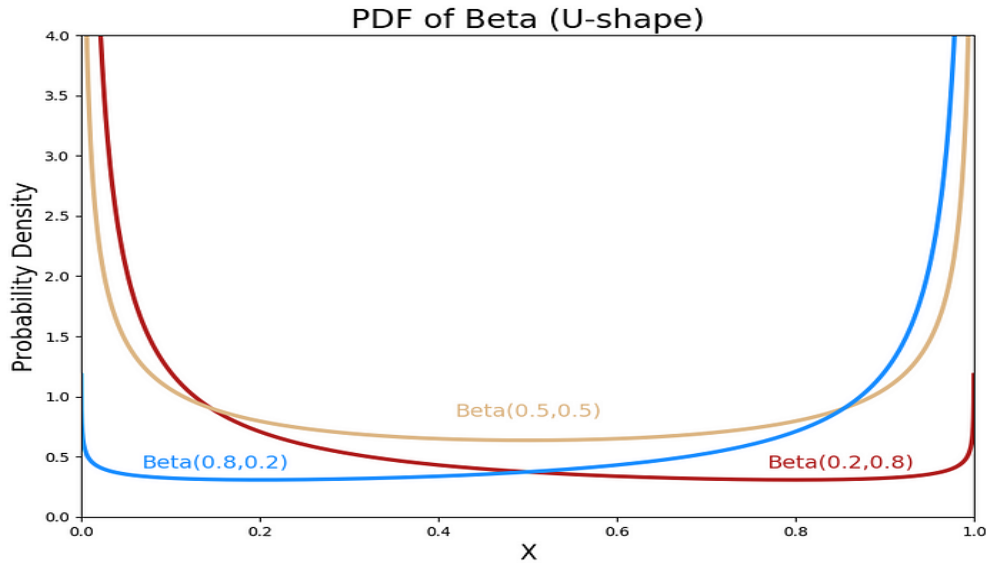


Figure 2.19: U-shaped beta distribution



There was no prior strong information related to the autoregressive parameters. Therefore, the priors were completely harmonized, with their means set at a range of 0.1 to 2 in line with the literature, and with a standard deviation of 0.1 to 0.5 for all the parameters.

$$\Theta \text{ with Beta Distribution} = \left[\begin{array}{c} \phi_{\pi}, \phi_R, l_p, l_w, a^h, \rho_z, \rho_a, \rho_j, \rho_{mE}, \rho_{mI}, \rho_d, \rho_{bH}, \rho_{bE}, \rho_{tn}, \rho_{tb}, \rho_{qk}, \\ \rho_G, \rho_y, \rho_l, \rho_{Kb} \end{array} \right]$$

The Inverse Gamma Distribution will be used for parameters that are assumed to be positive, Real Numbers, such as standard deviations of shocks. The mean will be set at 0.01 for all the shocks, which is the standard value in the macro literature.

To ensure the success of the numerical optimization of the posterior kernel, the prior mean will be set at the considerably low level of 0.01, for the remaining shocks. The standard deviations for all these priors were set at 0.05, which is usually used in the literature.

$$\Theta \text{ with Inverse Gamma Distribution} = \left[\sigma_z, \sigma_a, \sigma_j, \sigma_{mE}, \sigma_{mI}, \sigma_d, \sigma_{bH}, \sigma_{bE}, \sigma_{tn}, \sigma_{tb}, \sigma_{qk}, \sigma_R, \sigma_y, \sigma_l, \sigma_{Kb}, \sigma_G, \sigma_{IG}, \sigma_{CoT}, \sigma_{ET}, \sigma_{CT} \right]$$

Appendix A2.5.4: Technical Appendix - Setting the Model Equations – Selected Equations

Households Block of the Model

$$\max_{\{c_t^l, h_t^l, d_t^l\}} E_0 \sum_{t=0}^{\infty} \beta_p^t \left[(1 - a^p) \varepsilon_t^z \log(c_t^p(i) - a^p c_{t-1}^p) + \varepsilon_t^h \log h_t^p(i) - \frac{l_t^p(i)^{1+\phi}}{1+\phi} \right], \quad (\text{A2.2.1})$$

subject to

$$c_t^p(i) + q_t^h \left(h_t^p(i) - h_{t-1}^p(i) \right) + d_t^p(i) \leq w_t^p l_t^p(i) + \frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^p(i) + t_t^p(i) \quad (\text{A2.2.2})$$

Step 1 - Setting up a Lagrangian from the Objective function in 1 and budget constraint in 2

$$\text{Let } f(x, y) = \max_{\{c_t^l, h_t^l, d_t^l\}} E_0 \sum_{t=0}^{\infty} \beta_p^t \left[(1 - a^p) \varepsilon_t^z \log(c_t^p(i) - a^p c_{t-1}^p) + \varepsilon_t^h \log h_t^p(i) - \frac{l_t^p(i)^{1+\phi}}{1+\phi} \right] \text{ and}$$

$$\begin{aligned} g(x, y) = c &= c_t^p(i) + q_t^h \left(h_t^p(i) - h_{t-1}^p(i) \right) + d_t^p(i) \\ &\leq w_t^p l_t^p(i) + \frac{(1 + r_{t-1}^d)}{\pi_t} d_{t-1}^p(i) + t_t^p(i) \end{aligned}$$

Therefore, the Lagrangian function, after introducing the Lagrangian Multiplier λ shall be

$$\mathcal{L}(x, y, \lambda) = f(x, y) - \lambda(g(x, y) - c) \quad (\text{A2.2.3})$$

Which in full is presented in equation A2.2.4

$$\begin{aligned} \mathcal{L} \left(\beta_p^t (1 - a^p) \varepsilon_t^z \log(c_t^p(i) - a^p c_{t-1}^p) + \beta_p^t \varepsilon_t^h \log h_t^p(i) - \beta_p^t \frac{l_t^p(i)^{1+\phi}}{1+\phi}, \lambda \right) = \\ \left[\beta_p^t (1 - a^p) \varepsilon_t^z \log(c_t^p(i) - a^p c_{t-1}^p) + \beta_p^t \varepsilon_t^h \log h_t^p(i) - \beta_p^t \frac{l_t^p(i)^{1+\phi}}{1+\phi} \right] - \\ \lambda \left[c_t^p(i) + q_t^h (h_t^p(i) - h_{t-1}^p(i)) + d_t^p(i) - w_t^p l_t^p(i) + \frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^p(i) + t_t^p(i), \right] \end{aligned} \quad (\text{A2.2.4})$$

Step 2 – Obtain FOC from LF by differentiating the LF in 4 concerning c_t^p , h_t^p , and d_t^p

$$\frac{\partial \mathcal{L}(x, y, \lambda)}{\partial c_t^p} = f_1'(x, y) - \lambda g_1'(x, y) = 0 \quad (\text{A2.2.4a})$$

$$\frac{\partial \mathcal{L}(x, y, \lambda)}{\partial h_t^p} = f_2'(x, y) - \lambda g_2'(x, y) = 0 \quad (\text{A2.2.4b})$$

$$\frac{\partial \mathcal{L}(x, y, \lambda)}{\partial d_t^p} = f_3'(x, y) - \lambda g_3'(x, y) = 0 \quad (\text{A2.2.4c})$$

We will have four partial derivatives of the Lagrangian for our unconstrained consumption and housing functions presented in the objective function and our budget constraint equation, and at the optimal choices these will be as follows:

Taking the derivate of the: $(1 - a^p) \varepsilon_t^z \log(c_t^p(i) - a^p c_{t-1}^p) - \lambda_t^p c_t^p$ gives the FOC below:

Since the $\frac{\partial \ln(x, y, \lambda)}{\partial c_t^p} = \frac{1}{c_t^p}$ therefore:

$$\lambda_t^p = \varepsilon_t^z \frac{(1-a^p)}{c_t^p - a^p c_{t-1}^p} \quad (\text{A2.2.5})$$

Taking the derivate of the: $\varepsilon_t^h \log h_t^p(i) - \lambda_t^p \left[q_t^h (h_t^p(i) - h_{t-1}^p(i)) \right]$ gives the FOC below:

$$\lambda_t^p q_t^h = \frac{\varepsilon_t^h}{h_t^p} + \beta^P E_t[\lambda_{t+1}^p q_{t+1}^h] \quad (\text{A2.2.6})$$

Taking the derivate of the: $\lambda_t^p \left[\frac{(1+r_{t-1}^d)}{\pi_t} d_{t-1}^p(i) \right]$ gives the FOC below

$$\lambda_t^p = \beta^P E_t \left[\lambda_{t+1}^p \frac{(1+r_{t-1}^d)}{\pi_t} \right] \quad (\text{A2.2.7})$$

Repeating the above procedures for impatient households using their objective function and budget constraints, and drawing up the Lagrangian Function and taking FOC will yield:

$$\lambda_t^I = \varepsilon_t^z \frac{1-a^P}{c_t^I - a^I c_{t-1}^I} \quad (\text{A2.2.8})$$

$$\lambda_t^I q_t^h = \frac{\varepsilon_t^h}{h_t^I} + \beta^I E_t[\lambda_{t+1}^I q_{t+1}^h + s_t^I m_t^I q_t^I \pi_{t+1}] \quad (\text{A2.2.9})$$

$$\lambda_t^I = \beta^I E_t \left[\lambda_{t+1}^I \frac{(1+r_t^{bH})}{\pi_{t+1}} \right] \quad (\text{A2.2.10})$$

$$\pi_t^{w^S} = \frac{w_t^S}{w_{t-1}^S} \pi_t. \quad (\text{A2.2.11})$$

The MODEL block for households is made up of equations A2.2.5, A2.2.6, A2.2.7, A2.2.8, A2.2.9, A2.2.10 being FOC, household budget and borrowing constraints, and equation A.2.2.11 for wage determination.

Entrepreneurs Block of the Model

Repeating the above procedures for Entrepreneurs using their objective function and budget constraints, and drawing up the Lagrangian Function and taking FOC will yield:

$$\lambda_t^E = \frac{1-a^E}{c_t^E - a^E c_{t-1}^E} \quad (\text{A2.2.12})$$

$$\lambda_t^E q_t^k = E_t \left\{ s_t^E m_t^E q_{t+1}^k \pi_{t+1} (1 - \delta) + \beta_E \lambda_{t+1}^E [r_{t+1}^k u_{t+1} + q_{t+1}^k (1 - \delta) - \psi(u_{t+1})] \right\} \quad (\text{A2.2.13})$$

$$r_t^k = \xi_1 + \xi_2 (u_t - 1) \quad (\text{A2.2.14})$$

$$w_t^k = (1 - \alpha) \frac{y_t^E}{x_t} \frac{\mu}{l_{t,E}^P} \quad (\text{A2.2.15})$$

$$w_t^l = (1 - \alpha) \frac{y_t^E}{x_t} \frac{1-\mu}{l_t^{E,l}} \quad (\text{A2.2.16})$$

$$\lambda_t^E = s_t^E (1 + r_t^{bE}) \beta_E E_t \left[\lambda_{t+1}^E \frac{(1+r_t^{bE})}{\pi_{t+1}} \right] \quad (\text{A2.2.17})$$

The MODEL block for entrepreneurs is made up of equations A2.2.12 to A2.2.14 including entrepreneurs' budget constraints, and production technology equations.

Capital Producers Block of the Model

The problem of capital producers is:

$$\max E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^E \{q_t^k [k_t - (1 - \delta)k_{t-1}] - i_t\} \quad (\text{A2.2.18})$$

Subject to the capital accumulation equation below:

$$k_t = (1 - \delta)k_{t-1} + \beta_E E_t \left[1 - \frac{K_i}{2} \left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} \right)^2 \right] i_t \quad (\text{A2.2.19})$$

Setting a Lagrangian and solving for the price of capital, the FOC equation for the price of capital q_t^k , is given by:

$$1 = q_t^k \left[1 - \frac{K_i}{2} \left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1 \right)^2 - k_i \left(\frac{i_t \varepsilon_t^{qk}}{i_{t-1}} - 1 \right) \frac{i_t \varepsilon_t^{qk}}{i_{t-1}} \right] + \beta_E E_t \left[\frac{\lambda_{t+1}^E}{\lambda_t^E} q_{t+1}^k \varepsilon_{t+1}^{qk} k_i \left(\frac{i_{t+1} \varepsilon_{t+1}^{qk}}{i_t} \right) \left(\frac{i_{t+1}}{i_t} \right)^2 \right] \quad (\text{A2.2.20})$$

The MODEL block for capital producers is made up of equations A2.2.18 and A2.2.20.

Banks Block of the Model

We will use the derived Jacobians above to calculate the optimal interest rate structure for our banking system after disaggregating the overall bank profit function below with adjustment costs.

$$j_t^b = \left[r_t^{bH} b_t^H + r_t^{bE} b_t^E - mc_{t-1}^b [b_t^H + b_t^E] + r_t^{tn} t n_t^b + r_t^{tb} t b_t^b - mc_{t-1}^{tn} [t n_t^b + t b_t^b] - (r_t^{ib} - r_t^d) d_{t-1} - \frac{k_{kb}}{2} \left(\frac{K_t^d}{B_t} - v^b \right)^2 - \frac{k_d}{2} \left(\frac{r_{t-1}^d}{r_{t-2}^d} - 1 \right)^2 r_{t-1}^d d_{t-1} - \frac{k_{bh}}{2} \left(\frac{r_{t-1}^{bh}}{r_{t-2}^{bh}} - 1 \right)^2 r_{t-1}^{bh} d_{t-1} \right]$$

$$\begin{aligned} & 1)^2 r_{t-1}^{bh} b h_{t-1} - \frac{k_{be}}{2} \left(\frac{r_{t-1}^{be}}{r_{t-2}^{be}} - 1 \right)^2 r_{t-1}^{be} b e_{t-1} - \frac{k_{tn}}{2} \left(\frac{r_{t-1}^{tn}}{r_{t-2}^{tn}} - 1 \right)^2 r_{t-1}^{tn} t n_{t-1} - \\ & \left. \frac{k_{tb}}{2} \left(\frac{r_{t-1}^{tb}}{r_{t-2}^{tb}} - 1 \right)^2 r_{t-1}^{tb} t b_{t-1} \right] \end{aligned} \quad (\text{A2.2.21})$$

Thus, when choosing the optimal treasury bond rate:

$$\max_{\{r_t^{tn}, r_t^{tb}\}} E_0 \sum_{t=0}^{\infty} \Lambda_{0,t}^P \left[\begin{aligned} & r_t^{tn} t n_t^b + r_t^{tb} t b_t^b - m c_{t-1}^{tn} [t n_t^b + t b_t^b] \\ & - \frac{k_{tn}}{2} \left(\frac{r_{t-1}^{tn}}{r_{t-2}^{tn}} - 1 \right)^2 r_t^{tn} t n_t - \frac{k_{tb}}{2} \left(\frac{r_{t-1}^{tb}}{r_{t-2}^{tb}} - 1 \right)^2 r_t^{tb} t b_t \end{aligned} \right]$$

$$\text{Subject to } t n_{it}(i, j) = \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t \text{ and } t b_{it}(i, j) = \left[\frac{r_{it}^{tb}(i, j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} T B_t$$

In monopolistic market symmetric equilibrium where $r_{it}^{tn} = r_t^{tn}$, $t n_{it} = T N_t$ for all $t > 0$

$$\begin{aligned} \mathcal{L}_{r_{it}^{tn}} : & \left[\left(r_t^{tn} \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t - m c_t^{tn} \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t - \frac{k_{tn}}{2} \left(\frac{r_{it-1}^{tn}(i, j)}{r_{it-2}^{tn}(i, j)} - 1 \right)^2 r_t^{tn} T N_t \right) \right. \\ & \left. + \lambda \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t = 0 \right] \end{aligned}$$

$$r_t^{tn} \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t \text{ differentiating this term w.r.t } r_{it}^{tn}(i, j)$$

$$\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t - \varepsilon_t^{tn} \frac{r_t^{tn}}{r_t^{tn}} \left(\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}-1} T N_t \right)$$

$$- \varepsilon_t^{tn} \frac{r_t^{tn}}{r_t^{tn}} \left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}-1} T N_t = \varepsilon_t^{tn} \frac{r_t^{tn}}{r_t^{tn}} \left(\frac{\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}}}{\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^1} \right) T N_t, \text{ assuming a symmetric}$$

equilibrium the term $\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^1 = 1$ therefore

$$\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t - \varepsilon_t^{tn} \frac{r_t^{tn}}{r_t^{tn}} \left(\left[\frac{r_{it}^{tn}(i, j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} T N_t \right) = 0 \quad (\text{A2.2.21a})$$

$-mc_t^{tn} \left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} TN_t$ differentiating this term w.r.t $r_{it}^{tn}(i,j)$

$$-\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} mc_t^{tn} + \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} \left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}-1}, TN_t = \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} \left(\frac{\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}}}{\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^1} TN_t \right)$$

Assuming a symmetric equilibrium the term $\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^1 = 1$, therefore

$$\varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} \left(\frac{\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}}}{\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^1} TN_t \right) = \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} \left(\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} TN_t \right) = 0$$

$$\varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} \left(\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} TN_t \right) \quad (A2.2.21b)$$

$\left[-\frac{k_{tn}}{2} \left(\frac{r_{it}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} - 1 \right)^2 r_t^{tn} TN_t \right]$ differentiating this term w.r.t $r_{it}^{tn}(i,j)$ and solving expectations of $r_{it-1}^{tn}(i,j)$ forward, simplifies to the function below

$$-\left[\frac{2k_{tn}}{2} \left(\frac{r_{it}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} - 1 \right)^{2-1} r_t^{tn} \frac{1}{r_{it-1}^{tn}(i,j)} TN_t \right] + \beta_{tn} \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \frac{2k_{tn}}{2} \left(\frac{r_{it+1}^{tn}(i,j)}{r_{it-1+1}^{tn}(i,j)} - 1 \right)^{2-1} r_{t+1}^{tn} \frac{1}{r_{it-1+1}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\}$$

$$\left[-k_{tn} \left(\frac{r_{it}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} - 1 \right)^1 \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} TN_t \right] + \beta_{tn} \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tn} \left(\frac{r_{it+1}^{tn}(i,j)}{r_{it-1+1}^{tn}(i,j)} - 1 \right)^1 \frac{r_{t+1}^{tn}}{r_{it-1+1}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\}$$

$$\left[-k_{tn} \left(\frac{r_{it}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} - 1 \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} \left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^{\varepsilon_t^{tn}} TN_t \right] + \beta_{tn} E_0 \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tn} \left(\frac{r_{it+1}^{tn}(i,j)}{r_{it}^{tn}(i,j)} - 1 \right) \frac{r_{t+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\} = 0 \quad (A2.2.21c)$$

Combining equations A2.2.21a, A2.2.21b and A2.2.21c and eliminating the term $\left(\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}}\right]^{\varepsilon_t^{tn}} TN_t\right)$ in A2.2.21a, A2.2.21b and A2.2.21c reduces the combined part as a Jacobian term of optimal deposit interest rates.

$$\begin{aligned}
& 1 - \varepsilon_t^{tn} + \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} - k_{tn} \left(\frac{r_{it}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} - 1 \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} + \\
& + \beta_{tn} E_0 \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tn} \left(\frac{r_{it+1}^{tn}(i,j)}{r_{it}^{tn}(i,j)} - 1 \right) \frac{r_{it+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\} = 0 \\
& 1 - \varepsilon_t^{tn} + \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} - k_{tn} \left(\frac{r_{it}^{tn}(i,j) - r_{it-1}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} + \\
& + \left\{ \beta_{tn} E_0 k_{tn} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{tn}(i,j) - r_{it}^{tn}(i,j)}{r_{it}^{tn}(i,j)} \right) \frac{r_{it+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\} = 0 \tag{A2.2.22}
\end{aligned}$$

In monopolistic market symmetric equilibrium where $r_{it}^{tb} = r_t^{tb}$, $tb_{it} = TB_t$ for all $t > 0$

$$\begin{aligned}
\mathcal{L}_{r_{it}^{tb}} : & \left[(r_t^{tb} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t - mc_t^{tb} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t - \frac{k_{tb}}{2} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right)^2 r_t^{tb} TB_t \right] \\
& + \lambda \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t = 0
\end{aligned}$$

$$r_t^{tb} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \text{ differentiating this term w.r.t } r_{it}^{tb}(i,j)$$

$$\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t - \varepsilon_t^{tb} \frac{r_t^{tb}}{r_t^{tb}} \left(\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}-1} TB_t \right)$$

$$-\varepsilon_t^{tb} \frac{r_t^{tb}}{r_t^{tb}} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}-1} TB_t = \varepsilon_t^{tb} \frac{r_t^{tb}}{r_t^{tb}} \left(\frac{\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}}}{\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^1} \right) TB_t, \text{ assuming a symmetric equilibrium}$$

the term $\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^1 = 1$ therefore

$$\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t - \varepsilon_t^{tb} \frac{r_t^{tb}}{r_t^{tb}} \left(\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \right) = 0 \quad (\text{A2.2.22a})$$

$-mc_t^{tb} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t$ differentiating this term w.r.t $r_{it}^{tb}(i,j)$

$$-\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} mc_t^{tb} + \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}-1}, TB_t = \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} \left(\frac{\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tn}}}{\left[\frac{r_{it}^{tn}(i,j)}{r_t^{tn}} \right]^1} TN_t \right)$$

assuming a symmetric equilibrium the term $\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^1 = 1$, therefore

$$\varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} \left(\frac{\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}}}{\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^1} TB_t \right) = \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} \left(\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \right) = 0$$

$$\varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} \left(\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \right) \quad (\text{A2.2.22b})$$

$\left[-\frac{k_{tb}}{2} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right)^2 r_t^{tb} TB_t \right]$ differentiating this term w.r.t $r_{it}^{tb}(i,j)$ and solving expectations of $r_{it-1}^{tb}(i,j)$ forward, simplifies to the function below

$$-\left[\frac{2k_{tb}}{2} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right)^{2-1} r_t^{tb} \frac{1}{r_{it-1}^{tb}(i,j)} TB_t \right] + \beta_{tb} \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \frac{2k_{tb}}{2} \left(\frac{r_{it+1}^{tb}(i,j)}{r_{it-1+1}^{tb}(i,j)} - 1 \right)^{2-1} r_{t+1}^{tb} \frac{1}{r_{it-1+1}^{tb}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\}$$

$$\begin{aligned}
& \left[-k_{tb} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right)^1 \frac{r_t^{tb}}{r_{it-1}^{tb}(i,j)} TB_t \right] + \beta_{tb} \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tb} \left(\frac{r_{it+1}^{tb}(i,j)}{r_{it-1+1}^{tb}(i,j)} - 1 \right)^1 \right. \\
& \quad \left. \frac{r_{t+1}^{tb}}{r_{it-1+1}^{tn}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\} \\
& \left[-k_{tb} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right) \frac{r_t^{tb}}{r_{it-1}^{tb}(i,j)} \left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \right] + \beta_{tb} E_0 \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tb} \left(\frac{r_{it+1}^{tb}(i,j)}{r_{it}^{tb}(i,j)} - \right. \right. \\
& \quad \left. \left. 1 \right) \frac{r_{t+1}^{tb}}{r_{it}^{tb}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\} = 0 \tag{A2.2.22c}
\end{aligned}$$

Combining equations A2.2.22a, A2.2.22b and A2.2.22c and eliminating the term $\left(\left[\frac{r_{it}^{tb}(i,j)}{r_t^{tb}} \right]^{\varepsilon_t^{tb}} TB_t \right)$ in A2.2.22a, A2.2.22b and A2.2.22c reduces the combined part as a Jacobian term of optimal deposit interest rates.

$$\begin{aligned}
& 1 - \varepsilon_t^{tb} + \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} - k_{tb} \left(\frac{r_{it}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} - 1 \right) \frac{r_t^{tb}}{r_{it-1}^{tn}(i,j)} + \\
& + \beta_{tb} E_0 \left\{ \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} k_{tb} \left(\frac{r_{it+1}^{tb}(i,j)}{r_{it}^{tb}(i,j)} - 1 \right) \frac{r_{t+1}^{tb}}{r_{it}^{tb}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\} = 0 \\
& 1 - \varepsilon_t^{tb} + \varepsilon_t^{tb} \frac{mc_t^{tb}}{r_t^{tb}} - k_{tb} \left(\frac{r_{it}^{tb}(i,j) - r_{it-1}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} \right) \frac{r_t^{tb}}{r_{it-1}^{tb}(i,j)} + \\
& + \left\{ \beta_{tb} E_0 k_{tb} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{tb}(i,j) - r_{it}^{tb}(i,j)}{r_{it}^{tb}(i,j)} \right) \frac{r_{t+1}^{tb}}{r_{it}^{tb}(i,j)} \frac{TB_{t+1}(i,j)}{TB_t(i,j)} \right\} = 0 \tag{A2.2.23}
\end{aligned}$$

Repeating the above routine for loans, Treasury Note and Bills yields the optimal interest rates using equation A2.2.21 and constraints equation in Section 2.4.6.5, we get first order conditions for optimal interest setting as indicated below:

$$\begin{aligned}
& 1 - \varepsilon_t^{tn} + \varepsilon_t^{tn} \frac{mc_t^{tn}}{r_t^{tn}} - k_{tn} \left(\frac{r_{it}^{tn}(i,j) - r_{it-1}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} + \\
& + \left\{ \beta_{tn} E_0 k_{tn} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{tn}(i,j) - r_{it}^{tn}(i,j)}{r_{it}^{tn}(i,j)} \right) \frac{r_{t+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{TN_{t+1}(i,j)}{TN_t(i,j)} \right\} = 0 \tag{A2.2.24}
\end{aligned}$$

$$\begin{aligned}
& 1 - \frac{\varepsilon_t^{bh}}{r_t^{bh}} + \varepsilon_t^{bh} \frac{mc_t^b}{r_t^{bh}} - k_{bh} \left(\frac{r_{it}^{bh}(i,j) - r_{it-1}^{bh}(i,j)}{r_{it-1}^{bh}(i,j)} \right) \frac{r_t^{bh}}{r_{it-1}^{bh}(i,j)} + \\
& + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{bh}(i,j) - r_{it}^{bh}(i,j)}{r_{it}^{bh}(i,j)} \right) \frac{r_{t+1}^{bh}}{r_{it}^{bh}(i,j)} \frac{bh_{t+1}(i,j)}{bh_t(i,j)} \right\} = 0
\end{aligned} \tag{A2.2.25}$$

$$\begin{aligned}
& 1 - \frac{\varepsilon_t^{be}}{r_t^{be}} + \varepsilon_t^{bh} \frac{mc_t^b}{r_t^{be}} - k_{be} \left(\frac{r_{it}^{be}(i,j) - r_{it-1}^{be}(i,j)}{r_{it-1}^{be}(i,j)} \right) \frac{r_t^{be}}{r_{it-1}^{be}(i,j)} + \\
& + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^{be}(i,j) - r_{it}^{be}(i,j)}{r_{it}^{be}(i,j)} \right) \frac{r_{t+1}^{be}}{r_{it}^{be}(i,j)} \frac{be_{t+1}(i,j)}{be_t(i,j)} \right\} = 0
\end{aligned} \tag{A2.2.26}$$

$$\begin{aligned}
& -1 - \frac{\varepsilon_t^d}{r_t^d} + \varepsilon_t^{bh} \frac{mc_t^d}{r_t^d} - k_d \left(\frac{r_{it}^d(i,j) - r_{it-1}^d(i,j)}{r_{it-1}^{be}(i,j)} \right) \frac{r_t^d}{r_{it-1}^d(i,j)} + \\
& + \left\{ \beta_{bh} E_0 k_d \frac{\Lambda_{0,t+1}^P}{\Lambda_{0,t}^P} \left(\frac{r_{it+1}^d(i,j) - r_{it}^d(i,j)}{r_{it}^d(i,j)} \right) \frac{r_{t+1}^d}{r_{it}^d(i,j)} \frac{dt_{t+1}(i,j)}{dt_t(i,j)} \right\} = 0
\end{aligned} \tag{A2.2.27}$$

This optimal interest rate equation, A2.2.23 to A2.2.27, is very fundamental in the model, and specifically, equations A2.2.23 and A2.2.24 are the main interest rate channels through which domestic public debt interacts, and accumulation affects lending to the private sector in equations A2.2.25 and A2.2.26 above. These equations form part of the banking block equations in the model.

Appendix A2.6: Solving Linear Rational Expectation Difference Equations

Appendix A2.6.1: Solution to LRE difference equation when Matrix A_t is Invertible using Eigenvector-Eigenvalue Method – Blanchard Kahn (Jordan Decomposition Approach)

Consider the following model:

$$A_t \mathbb{E}_t Y_{t+1} = B_t Y_t + C_t \mathbb{E}_t X_t \tag{A2.3.1}$$

$$A_t^{-1} A_t \mathbb{E}_t y_{t+1} = A_t^{-1} B_t y_t + A_t^{-1} C_t \mathbb{E}_t x_t \tag{A2.3.2}$$

$$\mathbb{E}_t y_{t+1} = A_t^{-1} B_t y_t + A_t^{-1} C_t \mathbb{E}_t x_t \tag{A2.3.3}$$

$$\mathbb{E}_t y_{t+1} = A y_t + B \mathbb{E}_t x_{t+1} \tag{A2.3.4}$$

Partition y_{t+1} into k_{t+1} predetermined variables and y_{t+1} non-predetermined variables

$$\begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = A \begin{bmatrix} k_t \\ y_t \end{bmatrix} + \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.3.5})$$

Given that $A = P\Lambda P^{-1}$ (Jordan Decomposition) and that $PP^{-1} = I$, where Λ is a matrix of eigenvalues of matrix A

$$P^{-1} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = P^{-1} A \begin{bmatrix} k_t \\ y_t \end{bmatrix} + P^{-1} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.3.6})$$

$$P^{-1} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = P^{-1} P \Lambda P^{-1} \begin{bmatrix} k_t \\ y_t \end{bmatrix} + P^{-1} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.3.7})$$

$$P^{-1} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \Lambda P^{-1} \begin{bmatrix} k_t \\ y_t \end{bmatrix} + P^{-1} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_{t+1} \quad (\text{A2.3.8})$$

$$\text{Let } P^{-1} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix}, P^{-1} \begin{bmatrix} k_t \\ y_t \end{bmatrix} = \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix}, P^{-1} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} = \begin{bmatrix} R_{1t} \\ R_{2t} \end{bmatrix}$$

and let the matrix Λ and P^{-1} be partitioned as

$$\Lambda = \begin{bmatrix} \Lambda_{11} & 0 \\ 0 & \Lambda_{22} \end{bmatrix}, \quad P^{-1} = \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix}$$

Such that

$$\begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \Lambda \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_t \\ y_t \end{bmatrix} + \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.3.9})$$

$$\begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} \Lambda_{11} & 0 \\ 0 & \Lambda_{22} \end{bmatrix} \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_t \\ y_t \end{bmatrix} + \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.3.10})$$

There by:

$$\begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix} \text{ and } \begin{bmatrix} P_{11} & P_{12} \\ P_{21} & P_{22} \end{bmatrix} \begin{bmatrix} k_t \\ y_t \end{bmatrix} = \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix}$$

It follows as below that

$$P_{11}k_{t+1} + P_{12}y_{t+1} = \tilde{k}_{t+1} \quad (\text{A2.3.11})$$

$$P_{21}k_{t+1} + P_{22}y_{t+1} = \tilde{y}_{t+1} \quad (\text{A2.3.12})$$

$$P_{11}k_t + P_{12}y_t = \tilde{k}_t \quad (\text{A2.3.13})$$

$$P_{21}k_t + P_{22}y_t = \tilde{y}_t \quad (\text{A2.3.14})$$

$$\begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix} = \begin{bmatrix} \Lambda_{11} & 0 \\ 0 & \Lambda_{22} \end{bmatrix} \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix} + \begin{bmatrix} R_{1t} \\ R_{2t} \end{bmatrix} x_t \quad (\text{A2.3.15})$$

We then decouple equation A2.3.15 into two blocks of stable equation A2.3.16 and unstable system A2.3.17.

$$\tilde{k}_{t+1} = \Lambda_{11}\tilde{k}_t + R_{1t}x_t \quad (\text{A2.3.16})$$

$$\tilde{y}_{t+1} = \Lambda_{22}\tilde{y}_t + R_{2t}x_t \quad (\text{A2.3.17})$$

The decoupled equations are solved separately, starting with the unstable equation A2.3.17. The results obtained from equation A2.3.17 are used as input for equation A2.3.16. The unstable system is solved forward to time $t + j$ to yield:

$$\tilde{y}_{t+j} = (\Lambda_{22})^j \tilde{y}_t$$

As $|\Lambda_{22}| > 1$, the only stable solution is given by $\tilde{y}_{t+j} = 0$ for all t . From the partitioning of matrix P it follows from the transformed problem in equation A6.1.14 that $P_{21}k_t + P_{22}y_t = \tilde{y}_t = 0$

$$P_{21}k_t + P_{22}y_t = \tilde{y}_t = 0$$

$$P_{22}y_t = -P_{21}k_t$$

$$y_t = -P_{22}^{-1}P_{21}k_t \quad (\text{A2.3.18})$$

Equation A2.3.18 says that the forward-looking variables are a function of the predetermined (backward looking) variables

Secondly, we solve the stable equation A2.3.16 forward to time $t + j$ to yield

$$\tilde{k}_{t+j} = (\Lambda_{11})^j \tilde{k}_t$$

As $|\Lambda_{11}| < 1$, there are no instability problems. Insert equation A2.3.18 into equation A2.3.13 to get

$$\tilde{k}_t = P_{11}k_t + P_{12}(-P_{22}^{-1}P_{21}k_t) \quad \text{for all } t \quad (\text{A2.3.19})$$

$$\tilde{k}_t = (P_{11} - P_{12}P_{22}^{-1}P_{21})k_t \quad \text{for all } t \quad (\text{A2.3.20})$$

Using laws of expectations such that

$$\tilde{k}_{t+1} = \tilde{k}_t \quad (\text{A2.3.21})$$

Substituting equation A2.3.20 into equation A2.3.22, which is the same as the stable system equation A2.3.16, we get

$$\tilde{k}_{t+1} = \Lambda_{11}\tilde{k}_t + R_{1t}x_t \quad (\text{A2.3.22})$$

$$(P_{11} - P_{12}P_{22}^{-1}P_{21})k_{t+1} = \Lambda_{11}(P_{11} - P_{12}P_{22}^{-1}P_{21})k_t + R_{1t}x_t \quad (\text{A2.3.23})$$

$$\begin{aligned} k_{t+1} &= (P_{11} - P_{12}P_{22}^{-1}P_{21})^{-1}\Lambda_{11}(P_{11} - P_{12}P_{22}^{-1}P_{21})k_t \\ &\quad + (P_{11} - P_{12}P_{22}^{-1}P_{21})^{-1}R_{1t}x_t \end{aligned} \quad (\text{A2.3.23a})$$

As a result, future predetermined variables are a function of the current backward-looking variables. As a final step, the recursive formulation in A2.3.23 can be used to derive the solution for k_t and y_t for all t . Starting from the steady state value $k_0 = 0$, and drawing shocks from x_t from a normal distribution, the k_t are simulated from the shocks recursively with equation A2.3.23. Finally, y_t are calculated from k_t using equation A.2.3.18 above. This method works well when matrix A_t in equation A2.3.1 is invertible.

Appendix A2.6.2: Solution to LRE Difference Equations when Matrix A_t is Invertible using Eigenvector-Eigenvalue Method – Klein (Generalized Schur Decomposition Approach)

We consider the matrix pencil (A_t, B_t) defined in equation A2.4.1 and we introduce its real Generalized Schur decomposition. When A_t is invertible, generalized eigenvalues coincide with the standardized eigenvalues of matrix $A_t^{-1}B_t$.

Following Klein (2000) then, there exist unitary (orthogonal) matrices Q and Z , and quasi triangular (upper triangular) matrices T and S , such that:

$$A = QTZ \text{ and } B = QSZ, \text{ the Schur Decompositions}$$

Consider the following model:

$$A_t \mathbb{E}_t Y_{t+1} = B_t Y_t + C_t \mathbb{E}_t X_t \quad (\text{A2.4.1})$$

$$QTZ \mathbb{E}_t y_{t+1} = QSZ y_t + C_t \mathbb{E}_t x_t \quad (\text{A2.4.2})$$

$$Q^{-1}QTZ \mathbb{E}_t y_{t+1} = Q^{-1}QSZ y_t + Q^{-1}C_t \mathbb{E}_t x_t \quad (\text{A2.4.3})$$

$$TZ \mathbb{E}_t y_{t+1} = SZ y_t + Q^{-1}C_t \mathbb{E}_t x_t \quad (\text{A2.4.4})$$

Partition y_{t+1} into k_{t+1} predetermined variables and y_{t+1} non-predetermined variables

$$TZ \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = SZ \begin{bmatrix} k_t \\ y_t \end{bmatrix} + \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.4.5})$$

$$\begin{bmatrix} T_{11} & T_{12} \\ 0 & P_{22} \end{bmatrix} Z \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ 0 & S_{22} \end{bmatrix} Z \begin{bmatrix} k_t \\ y_t \end{bmatrix} + \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} x_t \quad (\text{A2.4.6})$$

$$\text{Let } Z \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix}, Z \begin{bmatrix} k_t \\ y_t \end{bmatrix} = \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix}, Q^{-1} \begin{bmatrix} B_{1t} \\ B_{2t} \end{bmatrix} = \begin{bmatrix} R_{1t} \\ R_{2t} \end{bmatrix}$$

$$\begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} k_{t+1} \\ \mathbb{E}_t y_{t+1} \end{bmatrix} = \begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix}, \begin{bmatrix} Z_{11} & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix} \begin{bmatrix} k_t \\ y_t \end{bmatrix} = \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix}$$

$$Z_{11} k_{t+1} + Z_{12} y_{t+1} = \tilde{k}_{t+1} \quad (\text{A2.4.7})$$

$$Z_{21} k_{t+1} + Z_{22} y_{t+1} = \tilde{y}_{t+1} \quad (\text{A2.4.8})$$

$$Z_{11} k_t + Z_{12} y_t = \tilde{k}_t \quad (\text{A2.4.9})$$

$$Z_{21} k_t + Z_{22} y_t = \tilde{y}_t \quad (\text{A2.4.10})$$

$$\begin{bmatrix} T_{11} & T_{12} \\ 0 & T_{22} \end{bmatrix} \begin{bmatrix} \tilde{k}_{t+1} \\ \mathbb{E}_t \tilde{y}_{t+1} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ 0 & S_{22} \end{bmatrix} \begin{bmatrix} \tilde{k}_t \\ \tilde{y}_t \end{bmatrix} + \begin{bmatrix} R_{1t} \\ R_{2t} \end{bmatrix} x_t \quad (\text{A2.4.11})$$

$$T_{11} \tilde{k}_{t+1} + T_{12} \tilde{y}_{t+1} = S_{11} \tilde{k}_t + S_{12} \tilde{y}_t + R_{1t} x_t \quad (\text{A2.4.12})$$

$$T_{22} \mathbb{E}_t \tilde{y}_{t+1} = S_{22} \tilde{y}_t + R_{2t} x_t \quad (\text{A2.4.13})$$

Solve for $\tilde{y}_t$ in equation A2.4.13 and plug in equation A2.4.8 and A2.4.10 in the new equation

$$\tilde{y}_t = S_{22}^{-1} \mathbb{E}_t T_{22} \tilde{y}_{t+1} - S_{22}^{-1} R_{2t} x_t \quad (\text{A2.4.14})$$

$$(Z_{21} k_t + Z_{22} y_t) = S_{22}^{-1} T_{22} \mathbb{E}_t (Z_{21} k_{t+1} + Z_{22} y_{t+1}) - S_{22}^{-1} R_{2t} x_t \quad (\text{A2.4.15})$$

We assume that Z_{22} is a full rank and thus invertible

$$Z_{22}y_t = -Z_{21}k_t + S_{22}^{-1}T_{22}\mathbb{E}_t(Z_{21}k_{t+1} + Z_{22}y_{t+1}) - S_{22}^{-1}R_{2t}x_t \quad (\text{A2.4.16})$$

$$y_t = -Z_{22}^{-1}Z_{21}k_t + Z_{22}^{-1}S_{22}^{-1}T_{22}\mathbb{E}_t(Z_{21}k_{t+1} + Z_{22}y_{t+1}) - Z_{22}^{-1}S_{22}^{-1}R_{2t}x_t \quad (\text{A2.4.17})$$

Looking for bounded solutions, we iterate equation A2.4.19, $Z_{22}^{-1}S_{22}^{-1}T_{22}\mathbb{E}_t(Z_{21}k_{t+1} + Z_{22}y_{t+1}) = 0$, to obtain:

$$y_t = -Z_{22}^{-1}Z_{21}k_t - Z_{22}^{-1}S_{22}^{-1}R_{2t}x_t \quad (\text{A2.4.18})$$

This shows, that when the Blanchard Kahn conditions are satisfied, there exists a unique bounded solution. Reciprocally, if the number of explosive eigenvalues is strictly smaller than n , there exist several solutions of the model equation A2.4.1. On the contrary, if the number of explosive eigenvalues is strictly higher than n , there is no solution. This strategy links explicitly the determinacy condition and the solution to a Schur decomposition. We notice in particular that the solution is linear and recursive.

The algorithm of solving used in Dynare relies on this Schur decomposition Juillard (1996) as shown below.

$$A_t\mathbb{E}_tY_{t+1} = B_tY_t + C_t\mathbb{E}_tX_t \quad (\text{A2.4.1})$$

These systems in equation A2.4.1 arise in many contexts. One such rich set of examples comes from the linearization of the individual optimization conditions and market clearing conditions in a (possibly distorted) dynamic equilibrium model. Notice that, unlike Blanchard and Kahn (1980), but like Sims (2002) and King and Watson (1998), I allow the matrix A to be singular. Roughly speaking, this generalization allows static (intertemporal) equilibrium conditions to be included among the dynamic relationships.

Technically, these singularities show up as zeroth-order equations in the triangularization of our system, reflecting that some equations in the original system state relationships among the variables in Y_t .

$$\begin{aligned}
& \text{exogenous processes should be taken as given} \\
& \text{first order condition for the wholesale branch where } r_{ib} \text{ is the policy rate} \\
& \text{bank balance sheet identity equation} \\
& -1 + \frac{\varepsilon_t^d}{r_t^d} - \varepsilon_t^d \frac{r_t^{ib}}{r_t^d} - k_d \left(\frac{r_{it}^d(i,j) - r_{it-1}^d(i,j)}{r_{it-1}^d(i,j)} \right) \frac{r_t^d}{r_{it-1}^d(i,j)} + \left\{ \beta_d E_0 k_d \frac{\Lambda_{0,t+1}^p}{\Lambda_{0,t}^p} \left(\frac{r_{it+1}^d(i,j) - r_{it}^d(i,j)}{r_{it}^d(i,j)} \right) \frac{r_{t+1}^d}{r_{it}^d(i,j)} \frac{d_{t+1}(i,j)}{d_t(i,j)} \right\} \\
& 1 - \frac{\varepsilon_t^{bh}}{r_t^{bh}} + \varepsilon_t^{bh} \frac{m_{ct}^b}{r_t^{bh}} - k_{bh} \left(\frac{r_{it}^{bh}(i,j) - r_{it-1}^{bh}(i,j)}{r_{it-1}^{bh}(i,j)} \right) \frac{r_t^{bh}}{r_{it-1}^{bh}(i,j)} + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^p}{\Lambda_{0,t}^p} \left(\frac{r_{it+1}^{bh}(i,j) - r_{it}^{bh}(i,j)}{r_{it}^{bh}(i,j)} \right) \frac{r_{t+1}^{bh}}{r_{it}^{bh}(i,j)} \frac{bh_{t+1}(i,j)}{bh_t(i,j)} \right\} \\
& 1 - \frac{\varepsilon_t^{be}}{r_t^{be}} + \varepsilon_t^{be} \frac{m_{ct}^b}{r_t^{be}} - k_{be} \left(\frac{r_{it}^{be}(i,j) - r_{it-1}^{be}(i,j)}{r_{it-1}^{be}(i,j)} \right) \frac{r_t^{be}}{r_{it-1}^{be}(i,j)} + \left\{ \beta_{bh} E_0 k_{bh} \frac{\Lambda_{0,t+1}^p}{\Lambda_{0,t}^p} \left(\frac{r_{it+1}^{be}(i,j) - r_{it}^{be}(i,j)}{r_{it}^{be}(i,j)} \right) \frac{r_{t+1}^{be}}{r_{it}^{be}(i,j)} \frac{be_{t+1}(i,j)}{be_t(i,j)} \right\} \\
& 1 - \frac{\varepsilon_t^{tn}}{r_t^{tn}} + \varepsilon_t^{tn} \frac{m_{ct}^{tn}}{r_t^{tn}} - k_{tn} \left(\frac{r_{it}^{tn}(i,j) - r_{it-1}^{tn}(i,j)}{r_{it-1}^{tn}(i,j)} \right) \frac{r_t^{tn}}{r_{it-1}^{tn}(i,j)} + \left\{ \beta_{tn} E_0 k_{tn} \frac{\Lambda_{0,t+1}^p}{\Lambda_{0,t}^p} \left(\frac{r_{it+1}^{tn}(i,j) - r_{it}^{tn}(i,j)}{r_{it}^{tn}(i,j)} \right) \frac{r_{t+1}^{tn}}{r_{it}^{tn}(i,j)} \frac{tn_{t+1}(i,j)}{tn_t(i,j)} \right\} \\
& 1 - \frac{\varepsilon_t^{tb}}{r_t^{tb}} + \varepsilon_t^{tn} \frac{m_{ct}^{tb}}{r_t^{tn}} - k_{tb} \left(\frac{r_{it}^{tb}(i,j) - r_{it-1}^{tb}(i,j)}{r_{it-1}^{tb}(i,j)} \right) \frac{r_t^{tb}}{r_{it-1}^{tb}(i,j)} + \left\{ \beta_{tb} E_0 k_{tb} \frac{\Lambda_{0,t+1}^p}{\Lambda_{0,t}^p} \left(\frac{r_{it+1}^{tb}(i,j) - r_{it}^{tb}(i,j)}{r_{it}^{tb}(i,j)} \right) \frac{r_{t+1}^{tb}}{r_{it}^{tb}(i,j)} \frac{tb_{t+1}(i,j)}{tb_t(i,j)} \right\} \\
& A_t \mathbb{E}_t Y_{t+1} = B_t \\
& r_t^{bh} b_t^H + r_t^{be} b_t^E - m_{ct-1}^b [b_t^H + b_t^E] + r_t^{tn} tn_t^b + r_t^{tb} tb_t^b - m_{ct-1}^{tn} [tn_t^b + tb_t^b] - (r_t^{ib} - r_t^d) d_{t-1} - \frac{k_{kb}}{2} \left(\frac{K_t^d}{B_t} - v^b \right)^2 - \frac{k_d}{2} \left(\frac{r_{t-1}^d}{r_{t-2}^d} - 1 \right)^2 r_{t-1}^d d_{t-1} - \frac{k_{bh}}{2} \left(\frac{r_{t-1}^{bh}}{r_{t-2}^{bh}} - 1 \right)^2 r_{t-1}^{bh} bh_{t-1} \\
& \frac{k_{be}}{2} \left(\frac{r_{t-1}^{be}}{r_{t-2}^{be}} - 1 \right)^2 r_{t-1}^{be} be_{t-1} - \frac{k_{tn}}{2} \left(\frac{r_{t-1}^{tn}}{r_{t-2}^{tn}} - 1 \right)^2 r_{t-1}^{tn} tn_{t-1} - \frac{k_{tb}}{2} \left(\frac{r_{t-1}^{tb}}{r_{t-2}^{tb}} - 1 \right)^2 r_{t-1}^{tb} tb_{t-1} \\
& \text{first order conditions for patient households and their budget constraints} \\
& \text{first order conditions for impatient households and their budhet constraints} \\
& \text{first order conditions for entrepreneurs and their resource constraints} \\
& \text{first order conditions for capital producers and their budget constraints} \\
& \text{first order conditions for retailers} \\
& \text{new keynesian phillips curve} \\
& \text{Taylor rule for Monetary Policy} \\
& \text{Aggregation conditions and General Equilibrium equation} \\
& \square
\end{aligned}$$

$$+ C_t \mathbb{E}_t \begin{bmatrix} \square \\ \varepsilon_{BH} \\ \varepsilon_{BE} \\ \varepsilon_{KBH} \\ \square \\ \square \\ \square \\ \varepsilon_{me} \\ \square \\ \varepsilon_j \\ \square \\ \varepsilon_y \\ \square \\ \varepsilon_{TN} \\ \varepsilon_{TB} \\ \square \\ \varepsilon_D \\ \varepsilon_{r_{ib}} \\ \square \\ \square \\ \varepsilon_{mi} \\ \square \\ \square \\ \varepsilon_y \\ \varepsilon_{e_{A,e}} \\ \square \\ \square \end{bmatrix}$$

Appendix A2.7: Solution to a Bayesian Maximum Likelihood DSGE model

We also demonstrate how the Dynare is used to solve a Bayesian Maximum Likelihood DSGE model using the system of equations derived in step below.

Bayesian DSGE Modelling

Appendix A2.7.1: Obtaining the Likelihood and Log-Likelihood

Function using Bayesian Theorem

$$p(\theta|Y) = \frac{p(\theta)p(Y|\theta)}{p(Y)} \quad (\text{A2.5.1})$$

$$p(\theta|Y) = \frac{p(\theta)p(Y|\theta)}{p(Y)} = \frac{f(Y|\theta)\pi(\theta)}{m(y)} \quad (\text{A2.5.2})$$

$m(y)$ is the marginal density of the data and does not depend on the model parameter θ . It is taken as a normalization constant in the denominator. Therefore equation A2.5.2 collapses to equation (A2.5.3).

$$m(y) \propto \int f(Y|\theta)\pi(\theta) dX \quad (\text{A2.5.3})$$

$$m(y) = \int f(Y|\theta)\pi(\theta) dX \quad (\text{A2.5.4})$$

$$\log m(y) = \log \int f(Y|\theta)\pi(\theta) dX \quad (\text{A2.5.5})$$

$$\log L(y) = \log f(Y|\theta) + \log \pi(\theta) \quad (\text{A2.5.6})$$

$$\log L(y) = \sum_{i=1}^m \log f(Y_i|\theta) + \sum_{i=1}^m \log \pi(\theta) \quad (\text{A2.5.7})$$

Equation A2.5.7 is the likelihood function of our data (Y) with respect to the model f.

Appendix A2.7.2: Maximizing the Log-Likelihood Function

R.A. Fischer's main contribution to statistics was to realize that the likelihood function is a vehicle for obtaining parameter estimates of a model. This later became what is popularly known as the maximum likelihood principle of model parameter estimation.

The Maximum Likelihood Principle postulates that a researcher must choose as estimates of the parameters those values that make obtaining the data that were obtained the most probable. In other words, we must choose the parameter values that maximize the value of the likelihood.

A few things to note:

- 1) Because the logarithm is a monotone increasing function, the likelihood and the log-likelihood will achieve their maximum at the same place. Therefore, nothing is lost in using the log-likelihood.
- 2) The log-likelihood is a lot to work with because it converts the products algebraically into sums (additive terms).
- 3) All the theoretical results concerning maximum likelihood estimators are based on the log-likelihood. And lastly;
- 4) Using the log-likelihood increases the numerical stability of the parameter estimates. Because the likelihood arises from joint probabilities (at least in the discrete setting) that, under independence, factor into product of marginal probabilities, the magnitude of the likelihood can be quite small, often very close to zero.

With a large number of observations this value can even approach the machine zero of the computing device being used, which often leads to numerical problems. Log-transformation converts these tiny probabilities into moderately large negative numbers, thus eliminating numerical instability.

Another argument in favour of maximum likelihood estimates (MLE) is that the maximum likelihood estimates of the model's parameters give that model the best chance of fitting the data. If after using these "best" estimates the model is deemed inadequate, we can then be sure that it is truly inadequate.

Maximizing the log-likelihood can be done in the following ways:

1. Graphically, by plotting the log-likelihood and estimating where the peak occurs.
2. Algebraically, by using calculus. This is a viable option only for simpler problems.
3. Numerically, using special optimization routines.

The derivative of the log-likelihood function is called the score or gradient function. For log-likelihoods that are functions of more than one parameter, obtaining the gradient means

taking the first partial derivatives with respect to each parameter in turn. The results are then organized in a vector as per below:

$$g(\theta) = g(\alpha, \beta) = \begin{bmatrix} \frac{\partial}{\partial \alpha} \log L(\alpha, \beta; x_1, x_2, \dots, x_n) \\ \frac{\partial}{\partial \beta} \log L(\alpha, \beta; x_1, x_2, \dots, x_n) \end{bmatrix} \quad (\text{A2.5.8})$$

where $\theta = \begin{bmatrix} \alpha \\ \beta \end{bmatrix}$ is a vector.

Using calculus, we know that all local maxima occur at the points where the Jacobian Matrix is equal to zero. These points are also called critical points. The common term used for first-order partial derivatives in mathematical applications such as Dynare and MATLAB is “Jacobian”. For simpler problems, it is easy to calculate the Jacobian at any given values of α, β . For more complicated models such as the ones we have used in our study, we cannot estimate by hand the Jacobian. Instead, we used numerical optimization routines. This is a well-developed, rich, and active area of research in computational mathematical sciences. There are many mathematical routines that have been developed in practice. Dynare uses the Newton-Raphson method for mathematical optimization problems to drive both the Jacobian and Hessian Matrices. To demonstrate how the Newton Optimization routine works in the software recursively, we often start with finding the roots of a function at a particular point called the initial point.

$$Y_{tangent} = f(\theta_0) + f'(\theta_0)(\theta - \theta_0) \quad (\text{A2.5.9})$$

$$f(\theta_0) + f'(\theta_0)(\theta - \theta_0) = 0 \quad (\text{A2.5.10})$$

$$(\theta - \theta_0) = -\frac{f(\theta_0)}{f'(\theta_0)} \quad (\text{A2.5.11})$$

$$\theta_1 = \theta_0 - \frac{f(\theta_0)}{f'(\theta_0)} \quad (\text{A2.5.12})$$

$$\theta_{k+1} = \theta_k - \frac{f'(\theta_k)}{f''(\theta_k)} \quad (\text{A2.5.12a})$$

This is the same routine Dynare uses to find steady states of the model, given the initialization. Once you have provided Dynare with initial values of the model parameters,

it invokes the Newton Optimization routine, as demonstrated above, and derives roots of the specified function.

For variables that are not initiated, Dynare assigns a value of zero when starting the optimization routine above until it derives both the necessary and sufficient conditions for maximization (where the necessary is the Jacobian and the sufficient is the Hessian).

In the maximum likelihood problem, we desire the roots of the score function, the first-order derivative of the log-likelihood. When there are multiple parameters to be estimated, θ becomes a vector of parameters such that $\theta \in \mathbb{R}^+$ and $f'(\theta_k)$ becomes the gradient or score vector (Jacobian) and the $f''(\theta_k)$ becomes a matrix of the second partials or the Hessian matrix H . The Hessian matrix when there are two parameters, α, β is the following.

$$Hessian(\alpha, \beta) = \begin{bmatrix} \frac{\partial^2}{\partial \alpha^2} \log(\alpha, \beta) & \frac{\partial^2}{\partial \alpha \partial \beta} \log(\alpha, \beta) \\ \frac{\partial^2}{\partial \alpha \partial \beta} \log(\alpha, \beta) & \frac{\partial^2}{\partial \beta^2} \log(\alpha, \beta) \end{bmatrix} \quad (A2.5.13)$$

In the Newton's optimization routine, the Hessian ($f''(\theta_k)$) occurs in the denominator. This is equivalent to multiplying by its reciprocal or matrix inversion. Thus, the Newton-Raphson method implemented for finding the MLE of the log-likelihood with multiple parameters is the following.

$$\theta_k = \theta_k - H^{-1}(\theta_k)g(\theta_k) \quad (A2.5.14)$$

Equation A2.5.14 is the same as equation A2.5.12; it says the MLE is the recursive result of point estimated parameters minus the product of its Hessian and Jacobian. These estimates will be necessary and sufficient parameters of the model.

Deriving Information Matrix

The information matrix $I(\theta_k)$ is an important quantity in likelihood theory. It is defined in terms of the Hessian and comes in two forms: the Observed Information and the Expected Information.

1. The observed information is just the negative of the Hessian evaluated at the Maximum Likelihood Estimate.

$$observed I(\theta_k) = -\frac{\partial^2}{\partial \theta_k^2} \log L(\alpha, \beta), \theta_k = \hat{\theta}_k \quad (A2.5.15)$$

2. The expected information is the expected value of the negative Hessian i.e., the mean of the sampling distribution of the negative Hessian.

$$expected I(\theta_k) = \left(-\frac{\partial^2}{\partial \theta_k^2} \log L(\alpha, \beta) \right), \theta_k = \hat{\theta}_k. \quad (A2.5.16)$$

Appendix A2.7.3: Use of Kalman Filter (Returns the Likelihood of a complex state space models).

In complicated state space models, the Kalman filter is used to optimally estimate the unobservable state vector and to update estimates when new observation becomes available. As a by-product, it also produces recursive forecasts of y_t , consistent with the information available at time t .

The Kalman filter is typically employed in state space models of the form:

$$y_t = x'_{1t} \alpha_t + x'_{2t} v_{1t} \quad (A2.5.17)$$

$$\alpha_t = \mathbb{D}_{0t} + \mathbb{D}_{1t} \alpha_{t-1} + \mathbb{D}_{2t} v_{2t} \quad (A2.5.18)$$

Where x'_{1t} is $m \times m_1$ matrix, x'_{2t} is $m \times m_2$ matrix, $\mathbb{D}_{0t}$ is $m_1 \times 1$ vector, $\mathbb{D}_{1t}$, $\mathbb{D}_{2t}$ are $m_1 \times m_1$ and $m_3 \times m_3$ matrices; v_{1t} is $m_2 \times 1$ vector of martingale difference sequences, $v_{1t} \sim \mathbb{N}(0, \Sigma_{v1})$; v_{2t} is $m_3 \times 1$ vector of martingale difference sequence, $v_{2t} \sim \mathbb{N}(0, \Sigma_{v2})$. We also assume that $E(v_{1t}, v'_{2t}) = 0$ and $E(v_{1t}, \alpha'_0) = 0$, for all time.

Typically, equation A2.5.17 is referred to as the measurement (observation) equation and equation A2.5.18 is referred to as the transition (state) equation. Note that in principle, α_t , is allowed to vary with time and that $x_{1t}, x_{2t}, \mathbb{D}_{0t}, \mathbb{D}_{1t}, \mathbb{D}_{2t}$ could be fixed (i.e., matrices of numbers) or realizations of random variables. For example, in time series context x_{1t} could contain lagged y_t 's and x_{2t} current and/or lagged stochastic volatility terms. Notice that it is possible to have m_2 shocks driving the m endogenous variables, $m_2 < m$.

Appendix A2.7.4: How the Kalman Filter Works

1. Select initial conditions. If all eigenvalues of $\mathbb{D}_1$ are less than one in absolute value, set $\alpha_1|0 = E(\alpha_1)$ and $\Omega_1|0 = \mathbb{D}_1 \Omega_1 \mathbb{D}'_1 + \mathbb{D}_2 \Sigma_{v2} \mathbb{D}'_2$ or $vec(\Omega_1|0) = (I - (\mathbb{D}_1 \otimes$

$\mathbb{D}_1')^{-1})\text{vec}(\mathbb{D}_2\Sigma_{v2}\mathbb{D}_2')$, in which case the initial conditional are mean and variances of the process. When some of the eigenvalues of $\mathbb{D}_1$ are greater than one, initial conditions cannot be drawn from the unconditional distribution and one needs a guess (say, $\alpha_1|0 = 0, \Omega_1|0 = k * I, k \text{ is large}$) to start the iteration. The Kalman filter will only work when the Blanchard Kahn conditions are satisfied.

2. Predict y_t and construct the mean square of the forecast using $t - 1$ information.

$$E(y_t|t-1) = x'_{1t}\alpha_t|t-1 \quad (\text{A2.5.19})$$

$$E(y_t - y_t|t-1)(y_t - y_t|t-1)' = E(x'_{1t}(\alpha_t - \alpha_t|t-1)(\alpha_t - \alpha_t|t-1)'x'_{1t}) + x'_{2t}\Sigma_{v1}x_2 \quad (\text{A2.5.20})$$

$$= x'_1\Omega_1|t-1x_1 + x'_{2t}\Sigma_{v1}x_2 \equiv \Sigma_t|t-1 \quad (\text{A2.5.21})$$

3. Update state equation estimates (after observing y_t):

$$\alpha_t|t = \alpha_t|t-1 + \Omega_1|t-1x_1\Sigma_{t|t-1}^{-1}(y_t - x'_1\alpha_t|t-1) \quad (\text{A2.5.22})$$

$$\Omega_t|t = \Omega_t|t-1 + \Omega_1|t-1x_1\Sigma_{t|t-1}^{-1}x'_1\Omega_1|t-1 \quad (\text{A2.5.23})$$

Where $\Sigma_{t|t-1}^{-1}$ is defined in equation (21)

4. Predict the state equation random variables next period:

$$\alpha_{t+1}|t = \mathbb{D}_1\alpha_t|t + \mathbb{D}_0 = \mathbb{D}_1\alpha_t|t-1 + \mathbb{D}_0 + K_t\epsilon_t \quad (\text{A6.3.24})$$

$$\Omega_{t+1}|t = \mathbb{D}_1\Omega_1\mathbb{D}_1' + \mathbb{D}_2\Sigma_{v2}\mathbb{D}_2' \quad (\text{A2.5.25})$$

Where $\epsilon_t = y_t - x'_1\alpha_t|t-1$ is the one step ahead forecast error in predicting y_t and

$K_t = \mathbb{D}_1\Omega_t|t-1x_1\Sigma_{t|t-1}^{-1}$ is the Kalman gain.

5. Repeat steps (2 to 4) until $t = T$.

Note that in step 3; $\Omega_1|t-1x_1 = E(\alpha_t - \alpha_t|t-1)(y_t - x'_1\alpha_t|t-1)'$. Hence the updated estimates of α_t are computed using the least square projection of $\alpha_t - \alpha_t|t-1$ on $(y_t - y_t|t-1)$ multiplied by the predictor error. Similarly, $\Omega_1|t-1x_1 = E(\alpha_t - \alpha_t|t-1)(\alpha_t - \alpha_t|t-1)'$ is updated using a quadratic form involving the covariance between

forecast errors in the two equations and the MSE of the forecasts. Note that equations A6.3.24 to A6.3.25 provide the inputs for the next step of the recursion.

Appendix A2.7.5: How the Metropolis Hastings Algorithm Works (MCMC)

The Metropolis-Hastings algorithm uses Bayes' Theorem to get the posterior distribution of a complex distribution, from which sampling directly is difficult.

$$p(\theta|Y) = \frac{p(\theta)p(Y|\theta)}{p(Y)} \quad (\text{A2.5.26})$$

$$p(\theta|Y) = \frac{p(\theta)p(Y|\theta)}{p(Y)} = \frac{f(Y|\theta)\pi(\theta)}{m(y)} \quad (\text{A2.5.27})$$

Essentially, it randomly selects different samples from a space and checks whether the new sample is more likely to come from the posterior than the previous sample. Since we are looking at the ratio of probabilities, $p(Y)$ in equation A2.5.26 gets cancelled out:

$$P(\text{Acceptance}) = \frac{P(\text{new Sample}) * \text{Likelihood of new sample}}{P(\text{old sample}) * \text{Likelihood of old sample}} \quad (\text{A2.5.28})$$

The likelihood of each new sample is decided by the function f . That is why f must be proportional to the posterior we want to sample from.

For the algorithm to decide whether to accept or reject, the following ratio must be computed for each new proposed θ .

$$\frac{P(\frac{\theta'}{D})}{P(\frac{\theta}{D})} = \frac{P(\frac{D}{\theta})P(\theta')}{P(\frac{D}{\theta})P(\theta)} \quad (\text{A2.5.29})$$

Where θ is the old sample, $P(\frac{D}{\theta})$ is the likelihood of sample θ .

The starting point of the algorithm is to define the prior mean and standard deviation. It draws the posterior using a proposal distribution. It is a normal distribution centred on the currently accepted sample.

It generates posterior means and standard deviations, which are point estimates of the model, using the likelihood functions generated with the help of the Kalman filter and given priors.

Appendix A2.7.6: Interpolation of Quarterly GDP, Household Consumption, Gross Capital Formation Data Series

The interpolation of annual data into quarterly data was done using the interpolator that we developed by borrowing the “Balance Sheet Approach” that was extracted from *The System of Macroeconomic Accounts Statistics: An Overview, IMF Pamphlet No.56*. If you have a continuous annual GDP series, it is then possible to generate quarterly GDP series in between the years using the “Balance Sheet Approach”. The starting point is the opening balance sheet which, in our case, will be the annual GDP of the preceding year. The closing GDP for the last quarter of the following year will then be the closing balance sheet for that year. The formula we have developed produces a “year-specific multiplier” that is then applied to the opening balance sheet to produce a monthly series that reconciles back to the closing balance sheet. Once the monthly series has been generated and reconciled, the data is organized into quarterly series. The key reconciliation point to note is that the 12th month or last quarterly series will always be equal to the closing balance sheet, which in our case is the following year’s annual GDP series.

The developed interpolator is presented below in mathematical forms:

$$\left(\left(\frac{\text{Closing } GDP_t}{\text{Opening } GDP_t} \right)^{\left(\frac{1}{12} \right)} \right) - 1 \quad (A2.5.30)$$

$$\begin{aligned} & (\text{December } 2004 \text{ } GDP_t) * \left(\left(\left(\frac{\text{December } 2005 \text{ } GDP_t}{\text{December } 2004 \text{ } GDP_t} \right)^{\left(\frac{1}{12} \right)} \right) - 1 \right) = \\ & \text{January } 2005 \text{ } GDP_t \end{aligned} \quad (A2.5.31)$$

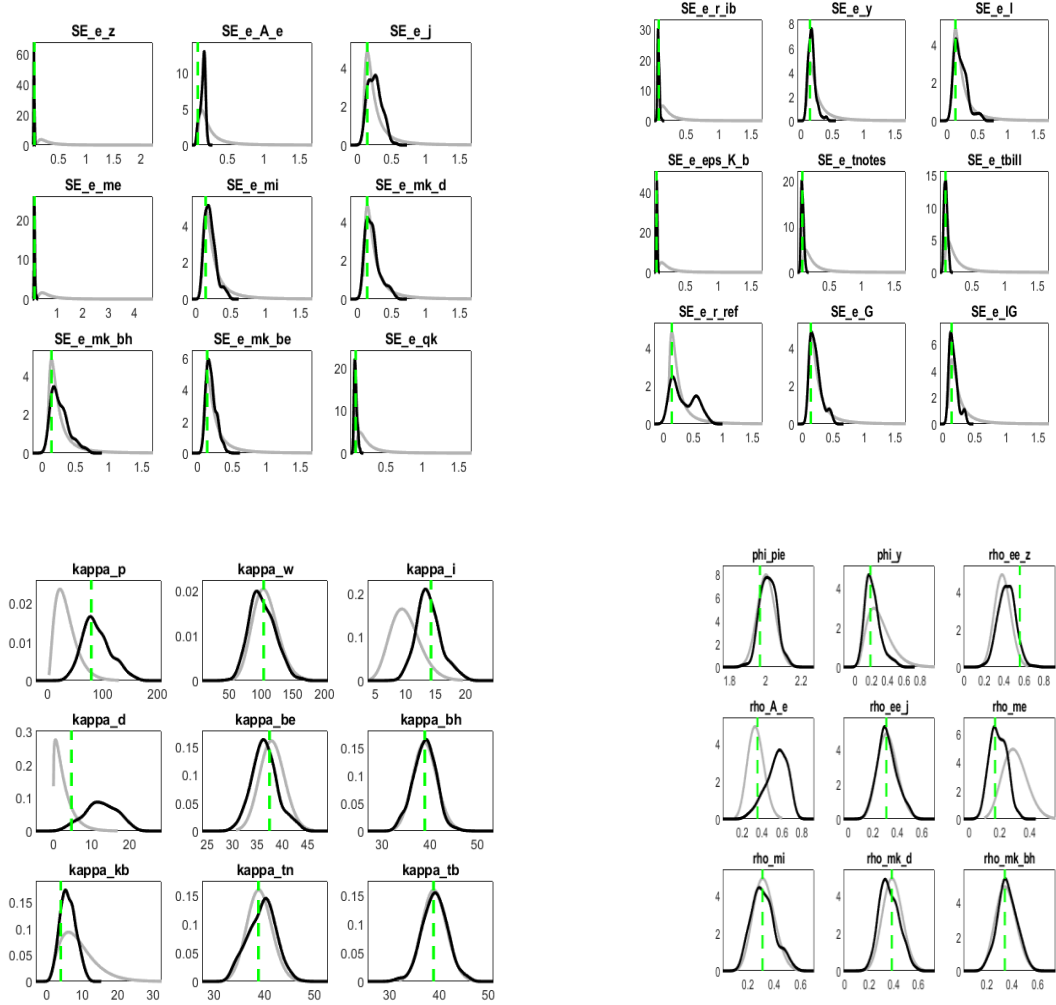
$$\begin{aligned} & (\text{January } 2005 \text{ } GDP_t) * \left(\left(\left(\frac{\text{December } 2005 \text{ } GDP_t}{\text{December } 2004 \text{ } GDP_t} \right)^{\left(\frac{1}{12} \right)} \right) - 1 \right) = \\ & \text{February } 2005 \text{ } GDP_t \end{aligned} \quad (A2.5.32)$$

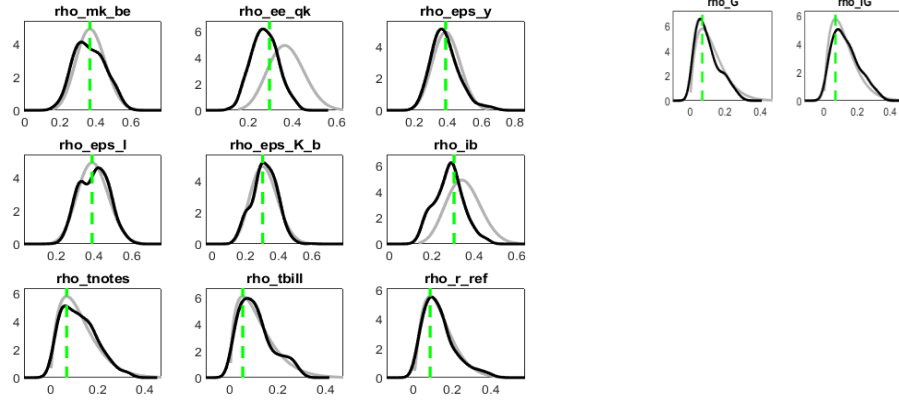
The process is repeated continuously up to the last balance sheet date, and thereafter the monthly generated series is organized in quarterly data. It is important to note that the interpolator generated above in equation A2.5.32 is already an additive or subtractive interpolator depending on the year-on-year GDP series progression. Therefore, the

quarterly GDP as per the balance sheet approach will be series extracted in March, June, September, and December of each series for a particular year of interest.

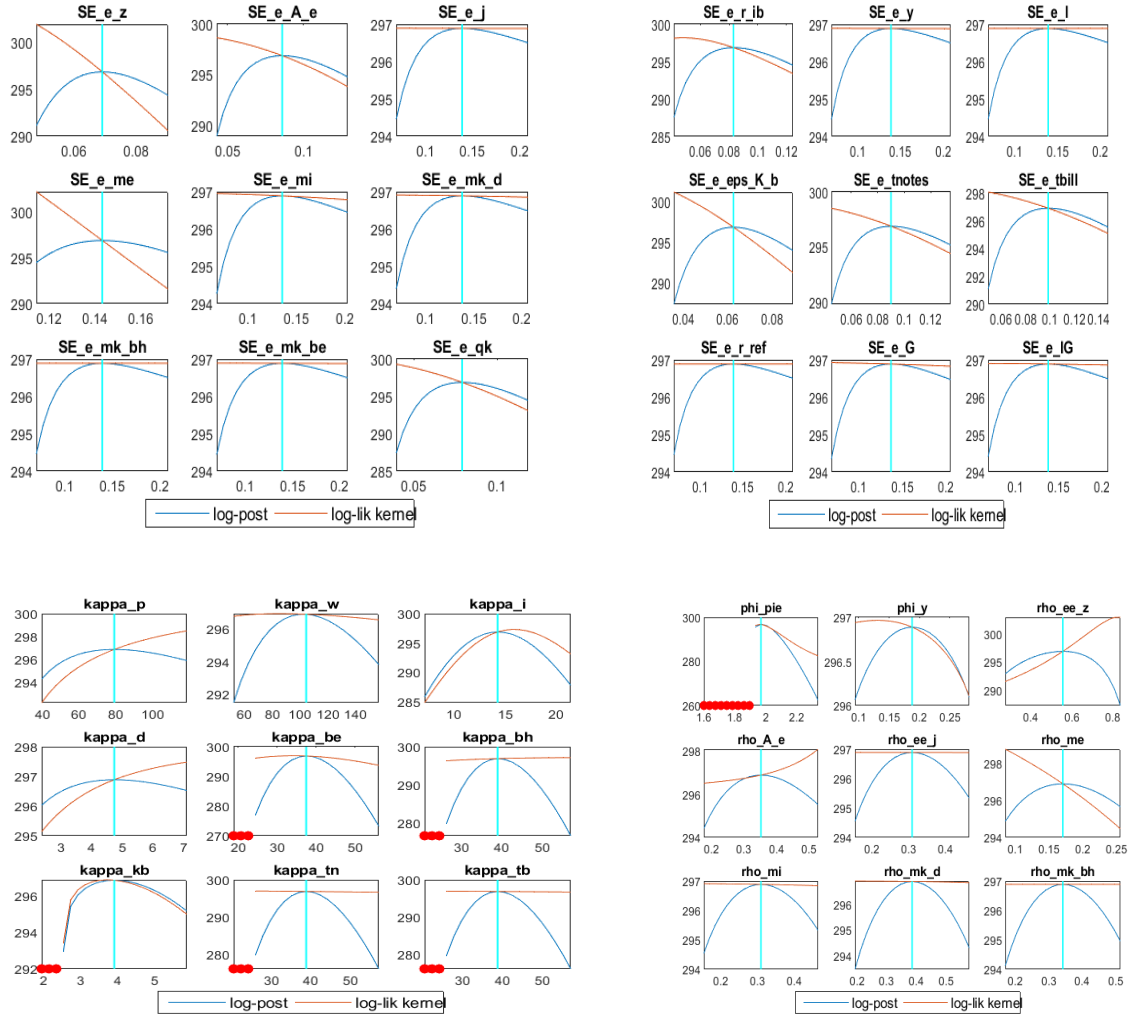
Appendix A2.8: Bayesian Estimation Results

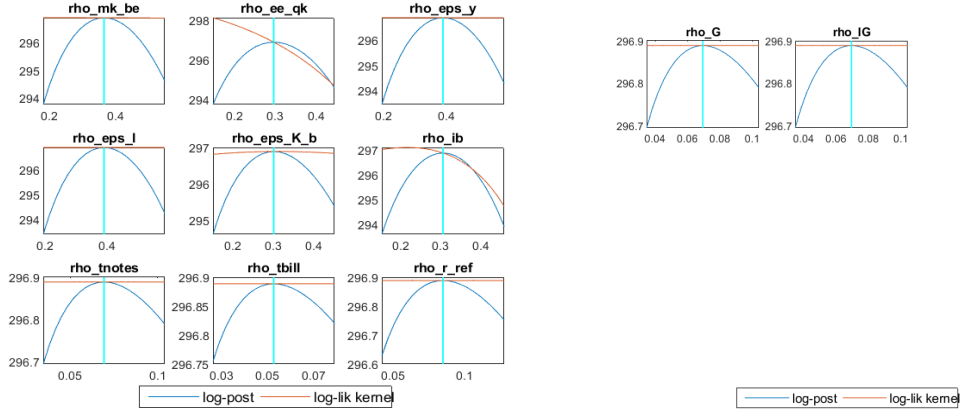
Appendix A2.8.1: Priors and Posteriors Graphs



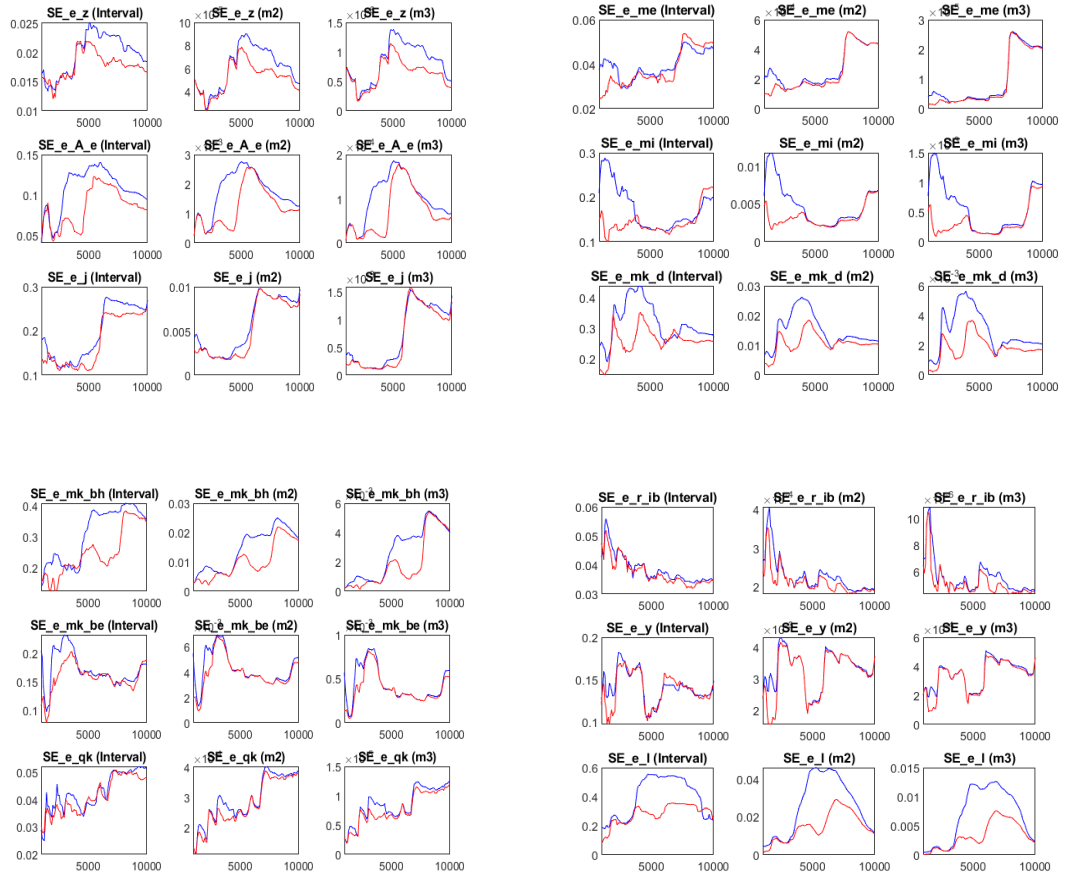


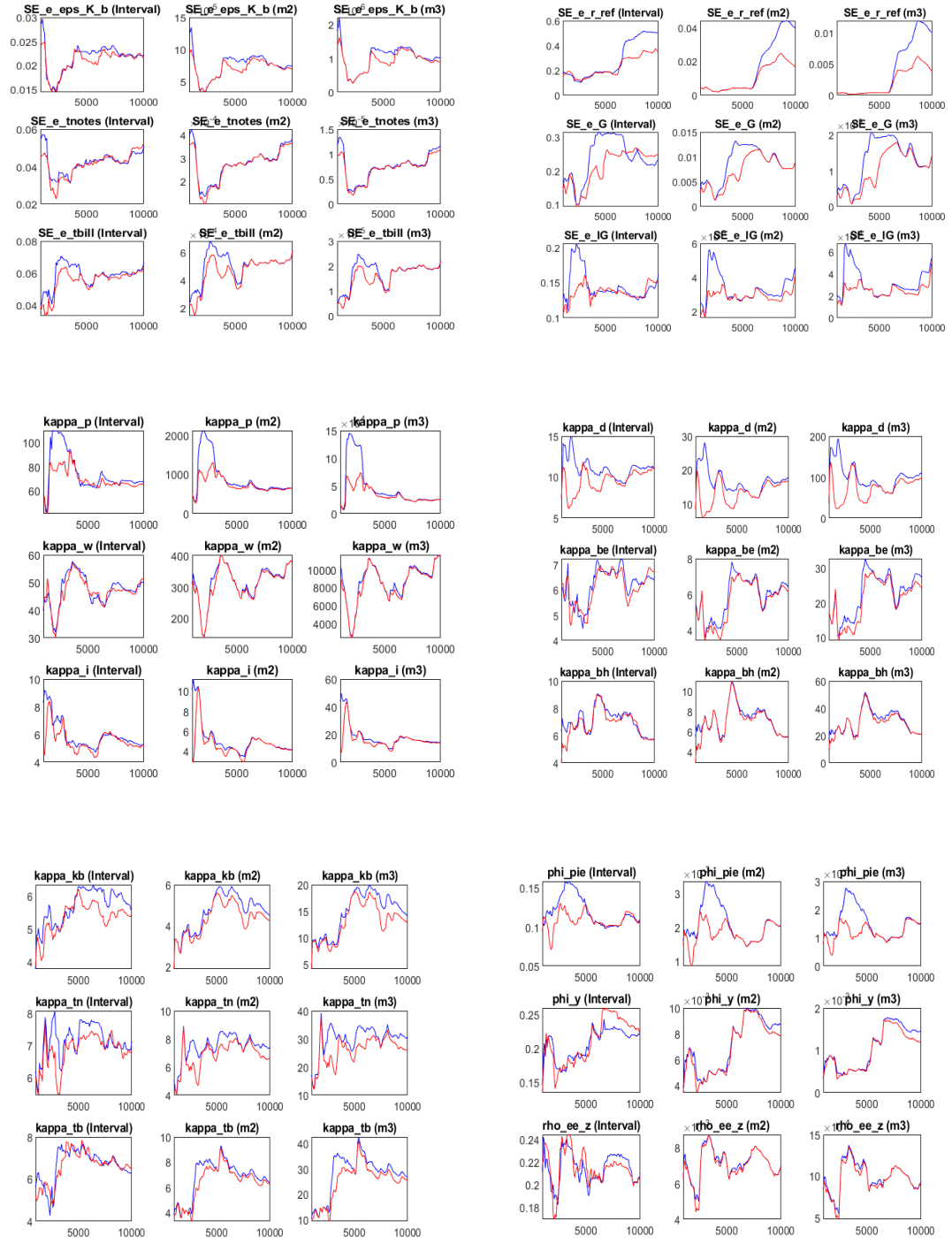
Appendix A2.8.2: Mode Check

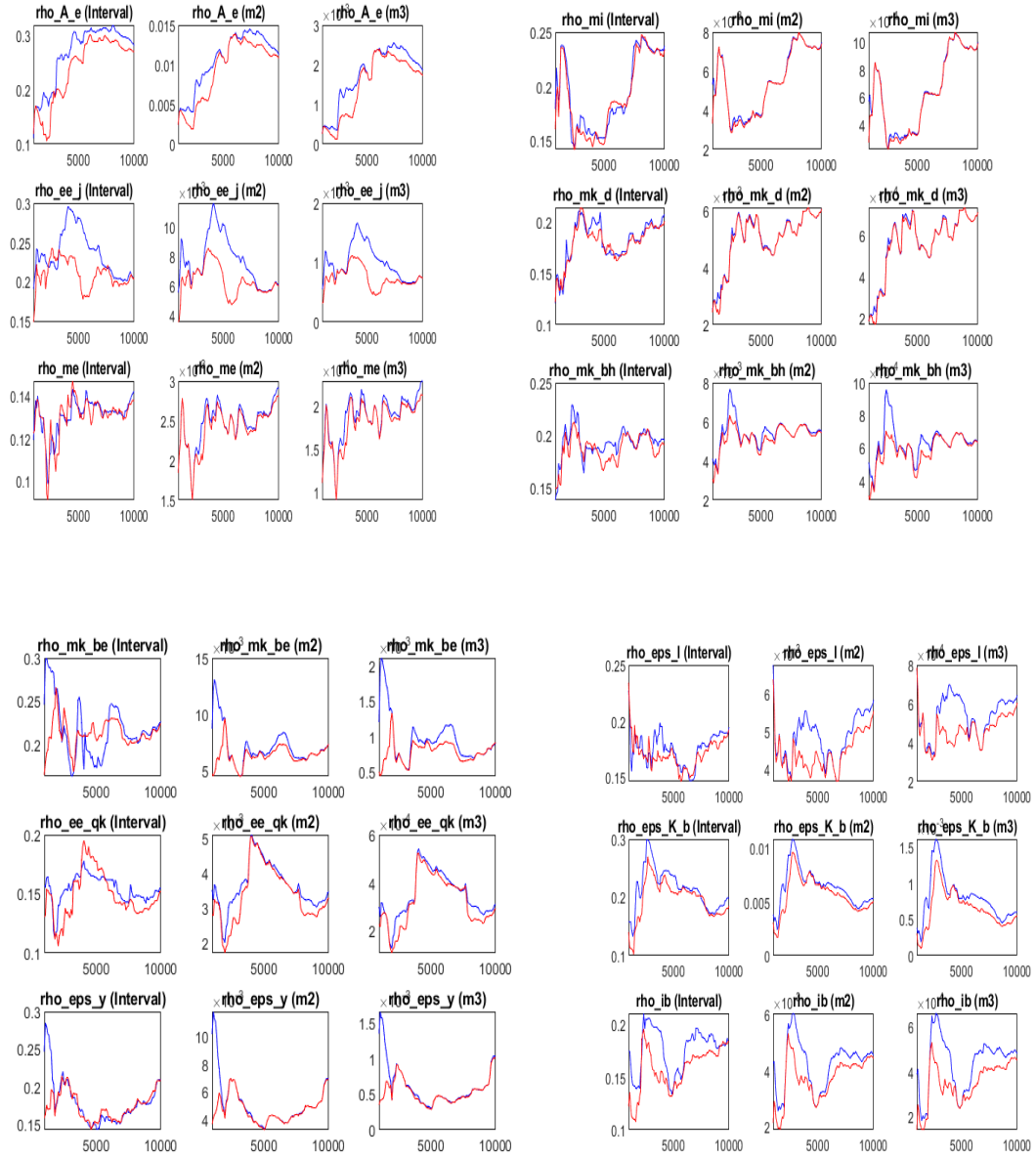


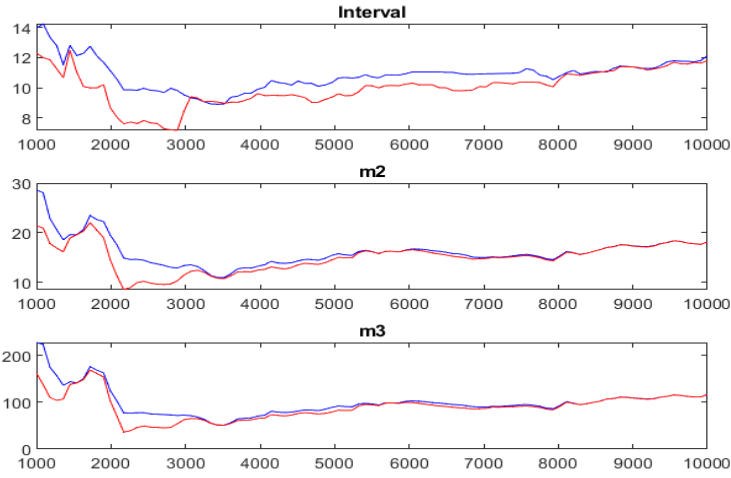
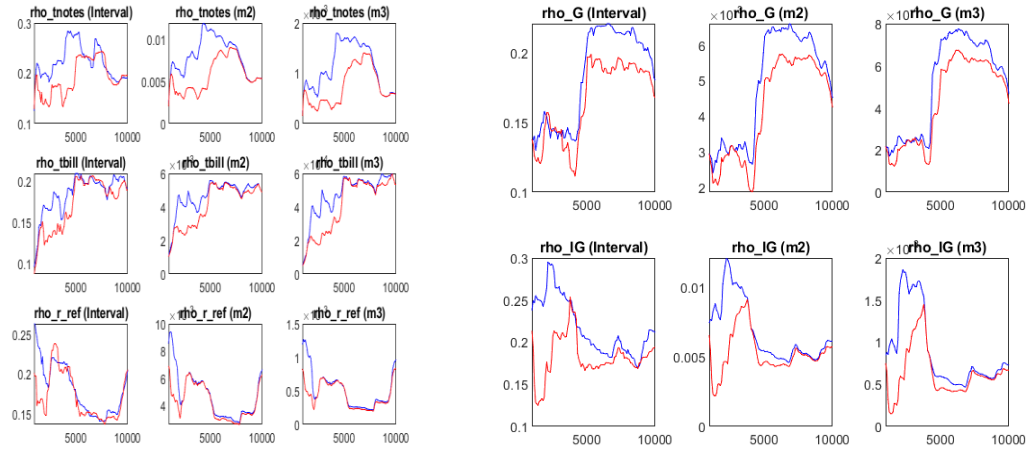


Appendix A2.8.3: MCMC univariate convergence diagnostic (Brooks and Gelman, 1998)

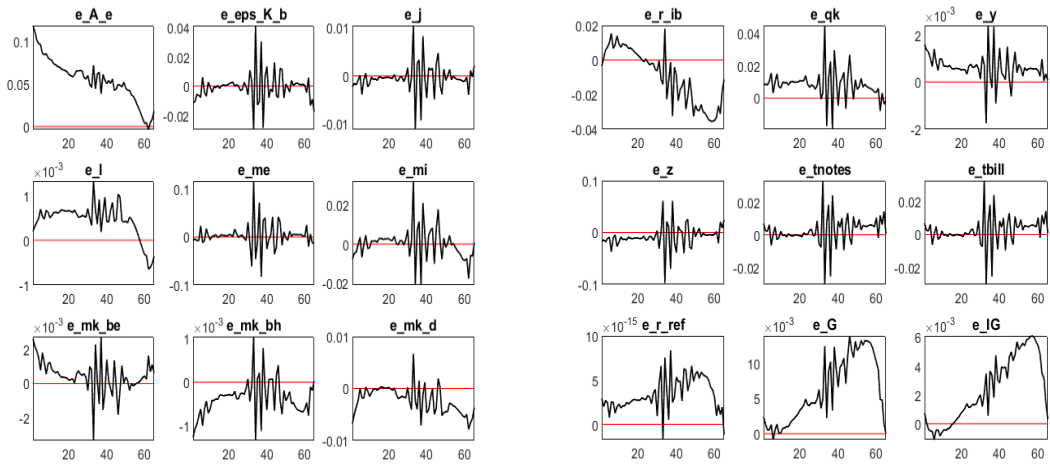








Appendix A2.8.4: Smoothed shocks



Appendix A2.8.5: Bayesian Estimation Results, Prior and Posterior Comparison

Table 2.4: Estimation results

Estimation Results						
parameters	prior mean	post. Mean	90% HPD interval		prior dist	pstdev
kappa_p	33.771	88.8571	49.0675	130.2529	gamm	20.0
kappa_w	107.352	102.1515	66.2152	129.3402	gamm	20.0
kappa_i	10.031	13.8778	10.6008	17.4245	gamm	2.5
kappa_d	2.775	12.4282	5.5163	19.4312	gamm	2.5
kappa_be	37.98	36.4525	31.9401	40.4143	gamm	2.5
kappa_bh	39.044	38.9009	35.4273	42.9974	gamm	2.5
kappa_kb	8.915	5.9874	2.6442	9.5804	gamm	5.0
kappa_tn	39.044	39.4785	34.4841	43.3879	gamm	2.5
kappa_tb	39.044	39.0943	34.9603	42.9481	gamm	2.5
phi_pie	2.004	2.0152	1.9348	2.0747	gamm	0.1
phi_y	0.303	0.2154	0.0657	0.3447	gamm	0.2
rho_ee_z	0.386	0.4255	0.2981	0.5655	beta	0.1
rho_A_e	0.338	0.5416	0.3795	0.7075	beta	0.1
rho_ee_j	0.322	0.3168	0.1904	0.4465	beta	0.1
rho_me	0.301	0.1912	0.1069	0.2748	beta	0.1
rho_mi	0.322	0.3153	0.1697	0.4556	beta	0.1
rho_mk_d	0.393	0.365	0.2449	0.4965	beta	0.1
rho_mk_bh	0.351	0.3608	0.2494	0.4952	beta	0.1
rho_mk_be	0.374	0.3641	0.2487	0.5211	beta	0.1
rho_ee_qk	0.372	0.2741	0.1712	0.3624	beta	0.1
rho_eps_y	0.394	0.385	0.258	0.5156	beta	0.1
rho_eps_l	0.396	0.4001	0.273	0.5125	beta	0.1
rho_eps_K_b	0.313	0.313	0.1909	0.4221	beta	0.1
rho_ib	0.35	0.2812	0.1548	0.3728	beta	0.1
rho_tnotes	0.123	0.1226	0.012	0.2261	beta	0.1
rho_tbill	0.113	0.1074	0.0064	0.2211	beta	0.1
rho_G	0.133	0.1302	0.0063	0.2462	beta	0.1
rho_IG	0.123	0.1006	0.0059	0.2043	beta	0.1

standard deviation of shocks						
	prior mean	post. Mean	90% HPD interval		prior dist	pstdev
e_z	0.400	0.0628	0.0522	0.0741	invg	2.0000
e_A_e	0.300	0.1542	0.0851	0.1979	invg	2.0000
e_j	0.300	0.2506	0.1031	0.4102	invg	2.0000
e_me	0.900	0.1464	0.1147	0.1711	invg	2.0000
e_mi	0.300	0.2015	0.0869	0.318	invg	2.0000
e_mk_d	0.300	0.2175	0.077	0.3842	invg	2.0000
e_mk_bh	0.300	0.2694	0.0928	0.4958	invg	2.0000
e_mk_be	0.300	0.1984	0.0968	0.3133	invg	2.0000
e_qk	0.300	0.0787	0.0515	0.1117	invg	2.0000
e_r_ib	0.300	0.0779	0.0592	0.1011	invg	2.0000
e_y	0.300	0.1701	0.0866	0.2628	invg	2.0000
e_l	0.300	0.2246	0.0869	0.3557	invg	2.0000
e_eps_K_b	0.300	0.0677	0.0528	0.0808	invg	2.0000
e_tnotes	0.300	0.0905	0.0585	0.1209	invg	2.0000
e_tbill	0.300	0.1021	0.0607	0.1395	invg	2.0000
e_G	0.300	0.2157	0.0856	0.3574	invg	2.0000
e_IG	0.300	0.1677	0.0654	0.2597	invg	2.0000
e_tbill	0.300	0.1021	0.0607	0.1395	invg	2.0000
e_G	0.300	0.2157	0.0856	0.3574	invg	2.0000
e_IG	0.300	0.1677	0.0654	0.2597	invg	2.0000

Appendix A2.9: Model Glossary Terms

$a^{p/I}$ – Degree of habit formation for Patient Households (P) , Impatient Households (I)

$c_t^{p/I}(i)$ – Current Consumption for Patient Households (P) , Impatient Households (I)

$c_{t-1}^{p/I}(i)$ – Past Consumption for Patient Households (P) , Impatient Households (I)

$\beta_{P/I}^t$ – Intertemporal discount factor for Patient Households (P) , Impatient Households (I)

β_P – Intertemporal discount factor for Patient Households (P)

β_I – Intertemporal discount factor for Impatient Households (I)

β_E – Intertemporal discount factor for Entrepreneurs (E)

ε_t^z – Shock to consumption

ε_t^h – Shock to demand for housing

ρ_z – autoregressive coefficient for consumption

ρ_j – autoregressive coefficient for bank profits

σ_z – standard deviation for a consumption shock

σ_j – standard deviation for bank profit shock

r_t^{bH} – loan interest rates to households

r_t^{bE} – loan interest rates to entrepreneurs

r_t^{tn} – loan interest rates to government for Treasury Notes

r_t^{tb} – loan interest rates to government for Treasury Bills

r_t^d – interest rate for deposits

r_t^{ib} – interbank interest rate

b_t^H – loans to households

b_t^E – loans to entrepreneurs

tn_t^b – loans to government in the form of Treasury Notes

tb_t^b – loans to government in the form of Treasury Bills

mc_t^b – bank marginal costs in lending to households

mc_t^{tn} – bank marginal costs in lending to government

d_t – bank deposits

ε_t^{bh} – elasticity of substitution faced by banks in lending to households

- ε_t^{be} – elasticity of substitution faced by banks in lending to entrepreneurs
- ε_t^{tn} – elasticity of substitution faced by banks in government lending in the form of Treasury Notes
- ε_t^{tb} – elasticity of substitution faced by banks in government lending in the form of Treasury Bills
- T_t – gross treasury investments on banks' balance sheet
- TN_t – gross Treasury Notes also presented as tn_t^b , TNOTES
- TB_t – gross Treasury Notes also presented as tb_t^b , TBILLS
- B_t – gross loans to households and entrepreneurs on banks' balance sheet
- BH_t – gross households' loans also presented as b_t^H
- BE_t – gross entrepreneur's' loans also presented as b_t^E
- D_t – gross bank deposits also presented as d_t
- K_t^b – bank capital

Quadratic Adjustment Costs Parameters

Quadratic adjustment costs parameters, inflation and output stabilizer weights take a gamma distribution because gamma distributions have rate and time parameters and are bounded between 1 and infinity. The quadratic adjustment costs parameters values are in excess of 1 and will not violate the Bayesian Model.

- | | |
|----------------------|--|
| κ_p (kappa_p) | – quadratic adjustment costs of retailers relative to changes in household consumption |
| κ_w (kappa_w) | – quadratic adjustment costs of labour unions relative to changes in household wages |

κ_i (kappa_i)	– quadratic adjustment costs of capital goods producers relative to changes in investments
κ_d (kappa_d)	– quadratic adjustment costs of deposit branch relative to changes in deposit rates of wholesale branches
κ_{bE} (kappa_be)	– quadratic adjustment costs of retail bank relative to changes in loan pricing to entrepreneurs
κ_{bH} (kappa_bh)	– quadratic adjustment costs of retail bank relative to changes in loan pricing to households
κ_{Kb} (kappa_kb)	– quadratic adjustment costs of retail bank relative to changes in bank capital
κ_{TN} (kappa_tn)	– quadratic adjustment costs of retail bank relative to changes in Treasury Notes pricing
κ_{TB} (kappa_tb)	– quadratic adjustment costs of retail bank relative to changes in Treasury Bill pricing
ϕ_π (phi_pie)	– inflation weight stabilizer
ϕ_y (phi_y)	– output stabilizer

Autoregressive Coefficients for Shock

The autoregressive coefficients (slope coefficients) for shocks take a beta distribution because the beta distribution takes various forms (it is a flexible distribution). The coefficients are capable of characterizing time-varying patterns and are bounded between 0 and 1. The autoregressive coefficients parameters values in excess of 1 will violate the Bayesian Model.

ρ_z (rho_ee_z)	– autoregressive coefficient for shock affecting household consumption
ρ_a (rho_A_e)	– autoregressive coefficient for shock affecting habit formation

ρ_j (rho_ee_j)	– autoregressive coefficient for shock affecting bank profit
ρ_{mE} (rho_me)	– autoregressive coefficient for shock affecting entrepreneurs loans to value ratio (LTV)
ρ_{mI} (rho_mi)	– autoregressive coefficient for shock affecting impatient household loans to value ratio (LTV)
ρ_d (rho_mk_d)	– autoregressive coefficient for shock affecting deposits
ρ_{bH} (rho_mk_bh)	– autoregressive coefficient for shock affecting loans to households
ρ_{bE} (rho_mk_be)	– autoregressive coefficient for shock affecting loans to entrepreneurs
ρ_{qk} (rho_ee_qk)	– autoregressive coefficient for shock affecting cost of capital
ρ_y (rho_eps_y)	– autoregressive coefficient for shock affecting output
ρ_l (rho_eps_l)	– autoregressive coefficient for shock affecting wages (labour hours)
ρ_{Kb} (rho_eps_K_b)	– autoregressive coefficient for shock affecting bank capital
ρ_R (e_r_ib)	– autoregressive coefficient for shock central bank policy rate
ρ_{TB} (rho_tbill)	– autoregressive coefficient for shock affecting Treasury Bills stock (public debt)
ρ_{TN} (rho_tnotes)	– autoregressive coefficient for shock affecting Treasury Notes stock (public debt)
ρ_G (rho_G)	– autoregressive coefficient for shock affecting government expenditure
ρ_{IG} (rho_IG)	– autoregressive coefficient for shock affecting public investments

Standard Deviation of Exogenous Shocks

The standard deviation of exogenous shocks follow an inverse (inverted) gamma distribution. The inverse gamma distribution is the reciprocal of the gamma distribution. It is also a conjugate prior for the rate parameter of an exponential or gamma distribution, or more generally, of the inverse of a scale parameter of an exponential family distribution. It has the shaper parameter that controls the height and the scale parameter that controls the spread.

σ_z (e_z)	– standard deviation for a consumption shock
σ_a (e_A_e)	– standard deviation for habit formation shock
σ_j (e_j)	– standard deviation for bank profits shock
σ_{mE} (e_me)	– standard deviation for entrepreneurs LTV shock
σ_{ml} (e_mi)	– standard deviation for impatient household LTV shock
σ_d (e_mk_d)	– standard deviation for a deposit shock
σ_{bH} (e_mk_bh)	– standard deviation for loans to household's shock
σ_{bE} (e_mk_be)	– standard deviation for loans to entrepreneur's shock
σ_{qk} (e_qk)	– standard deviation for cost of capital shock
σ_R (e_r_ib)	– standard deviation for interest rate shock
σ_y (e_y)	– standard deviation for output shock
σ_l (e_l)	– standard deviation for a wages/labour hours shock
σ_{Kb} (e_eps_K_b)	– standard deviation for a bank capital shock
σ_{TN} (e_tnotes)	– standard deviation for a Treasury Notes shock
σ_{TB} (e_tbill)	– standard deviation for a Treasury Bills shock
σ_G (e_G)	– standard deviation for a government expenditure shock
σ_{IG} (e_IG)	– standard deviation for a public investments shock

σ_{CoT} (e_tau_c) – standard deviation for a consumption tax shock

σ_{ET} (e_tau_l) – standard deviation for an employment tax shock

σ_{CT} (e_tau_k) – standard deviation for a capital tax shock

Appendix A2.10: Autoregressive processes

There is an assumption that the size of the shocks in the model is small enough so to remain in such a neighbourhood. Therefore, we can solve our model imposing the constraint that always binds. The shocks have corresponding steady state values.

The intertemporal shocks to preferences for consumption, housing, habit formation and labour supply are assumed to be stochastic *AR (1)* processes depicted below, respectively:

$$\varepsilon_t^z = (1 - \rho_z) * 1 + \rho_z \varepsilon_{t-1}^z + \eta_t^{\varepsilon^z}$$

$$\varepsilon_t^j = (1 - \rho_j) * 1 + \rho_j \varepsilon_{t-1}^j + \eta_t^{\varepsilon^j}$$

$$\varepsilon_t^a = (1 - \rho_a) * 1 + \rho_a \varepsilon_{t-1}^a + \eta_t^{\varepsilon^a}$$

$$\varepsilon_t^l = (1 - \rho_l) * 1 + \rho_l \varepsilon_{t-1}^l + \eta_t^{\varepsilon^l}$$

The loan-to-value ratios for impatient households are assumed to be stochastic *AR (1)* processes as below, respectively:

$$m_t^l = (1 - \rho_{mI}) \bar{m}^l + \rho_{mI} m_{t-1}^l + \eta_t^{mI}$$

$$m_t^E = (1 - \rho_{mE}) \bar{m}^E + \rho_{mE} m_{t-1}^E + \eta_t^{mE}$$

Following Smets & Wouters (2003), we assume that the elasticity of substitution in the banking industry is stochastic. The innovations to the elasticities of substitution can thus be interpreted as changes in banking interest spreads that arise independently of monetary policy and affect banking interest rates ($r_t^d, r_t^{bH}, r_t^{bE}, r_t^{tn}$, and r_t^{tb}). Elasticities of substitution to deposits, loans to households, loans to entrepreneurs, lending to the government in the form of Treasury Notes, Treasury Bills and bank capital follow *AR (1)* processes represented below, respectively:

$$\varepsilon_t^d = (1 - \rho_d) \bar{\varepsilon}^d + \rho_d \varepsilon_{t-1}^d + \eta_t^{\varepsilon^d}$$

$$\varepsilon_t^{bH} = (1 - \rho_d) \bar{\varepsilon}^{bH} + \rho_{bH} \varepsilon_{t-1}^{bH} + \eta_t^{\varepsilon^{bH}}$$

$$\varepsilon_t^{bE} = (1 - \rho_d) \bar{\varepsilon}^{bE} + \rho_{bE} \varepsilon_{t-1}^{bE} + \eta_t^{\varepsilon^{bE}}$$

$$\varepsilon_t^{tn} = (1 - \rho_{tn}) \bar{\varepsilon}^{tn} + \rho_{tn} \varepsilon_{t-1}^{tn} + \eta_t^{\varepsilon^{tn}}$$

$$\varepsilon_t^{tb} = (1 - \rho_{tb})\bar{\varepsilon}^{tb} + \rho_{tb}\varepsilon_{t-1}^{tb} + \eta_t^{\varepsilon^{tb}}$$

$$\varepsilon_t^{kb} = (1 - \rho_{kb}) * 1 + \rho_{kb}\varepsilon_{t-1}^{kb} + \eta_t^{\varepsilon^{kb}}$$

The shock to productivity of investment (capital) is a stochastic *AR (1)* process, represented below:

$$\varepsilon_t^{qk} = (1 - \rho_{qk}) + \rho_{qk}\varepsilon_{t-1}^{qk} + \eta_t^{\varepsilon^{qk}}$$

The elasticity of substitution faced by retailers in the goods and stickiness of prices (indexation) in the markets are stochastic *AR (1)* processes depicted below, respectively:

$$\varepsilon_t^y = (1 - \rho_y)\bar{\varepsilon}^y + \rho_y\varepsilon_{t-1}^y + \eta_t^{\varepsilon^y}$$

$$\varepsilon_t^l = (1 - \rho_l)\bar{\varepsilon}^l + \rho_l\varepsilon_{t-1}^l + \eta_t^{\varepsilon^l}$$

The shock to government expenditure and public sector investments are stochastic *AR (1)* processes indicated below, respectively:

$$\varepsilon_t^G = (1 - \rho_G)\bar{\varepsilon}^G + \rho_G\varepsilon_{t-1}^G + \eta_t^{\varepsilon^G}$$

$$\varepsilon_t^{IG} = (1 - \rho_{IG})\bar{\varepsilon}^{IG} + \rho_{IG}\varepsilon_{t-1}^{IG} + \eta_t^{\varepsilon^{IG}}$$

Assuming that we start the steady state at zero, these innovations become typical *AR (1)* processes, as below:

$$\varepsilon_t^z = \rho_z\varepsilon_{t-1}^z + \eta_t^{\varepsilon^z}$$

$$\varepsilon_t^j = \rho_j\varepsilon_{t-1}^j + \eta_t^{\varepsilon^j}$$

$$\varepsilon_t^a = \rho_a\varepsilon_{t-1}^a + \eta_t^{\varepsilon^a}$$

$$\varepsilon_t^l = \rho_l\varepsilon_{t-1}^l + \eta_t^{\varepsilon^l}$$

$$m_t^l = \rho_{ml}m_{t-1}^l + \eta_t^{m^l}$$

$$m_t^E = \rho_{mE}m_{t-1}^E + \eta_t^{m^E}$$

$$\varepsilon_t^d = \rho_d\varepsilon_{t-1}^d + \eta_t^{\varepsilon^d}$$

$$\varepsilon_t^{bH} = \rho_{bH}\varepsilon_{t-1}^{bH} + \eta_t^{\varepsilon^{bH}}$$

$$\varepsilon_t^{bE} = \rho_{bE}\varepsilon_{t-1}^{bE} + \eta_t^{\varepsilon^{bE}}$$

$$\varepsilon_t^{tn} = \rho_{tn}\varepsilon_{t-1}^{tn} + \eta_t^{\varepsilon_t^{tn}}$$

$$\varepsilon_t^{tb} = \rho_{tb}\varepsilon_{t-1}^{tb} + \eta_t^{\varepsilon_t^{tb}}$$

$$\varepsilon_t^{kb} = \rho_{kb}\varepsilon_{t-1}^{kb} + \eta_t^{\varepsilon_t^{kb}}$$

$$\varepsilon_t^{qk} = \rho_{qk}\varepsilon_{t-1}^{qk} + \eta_t^{\varepsilon_t^{qk}}$$

$$\varepsilon_t^y = \rho_y\varepsilon_{t-1}^y + \eta_t^{\varepsilon_t^y}$$

$$\varepsilon_t^l = \rho_l\varepsilon_{t-1}^l + \eta_t^{\varepsilon_t^l}$$

$$\varepsilon_t^G = \rho_G\varepsilon_{t-1}^G + \eta_t^{\varepsilon_t^G}$$

$$\varepsilon_t^{IG} = \rho_G\varepsilon_{t-1}^{IG} + \eta_t^{\varepsilon_t^{IG}}$$

CHAPTER THREE

IMPACT OF ADOPTING BASEL III LIQUIDITY COVERAGE RATIO, STABLE FUNDING RATIO ON LENDING IN MALAWI'S BANKING SECTOR

Abstract

This essay examines changes in banking regulations and how their adoption impacts bank lending activities. Malawi's banking industry regulators are planning to transition to Basel III from the current Basel II regime. This paper pioneers an assessment of the implications of this move for the banking industry. The study uses monthly data from January 2010 to December 2022 as well as the Feasible Generalised Least Square (FGLS) Panel Regression model with bank-specific variables (X) and macroeconomic controls (Z). The study finds that Tier 1 has a positive and significant impact on Malawi's banking sector lending growth whilst Tier 2 has a negative and insignificant impact on banking sector-wide lending growth effects. The non-risk weighted asset Basel III leverage ratios have significant and negative impacts on Malawi's bank sector lending growth, and the liquidity coverage ratio (LCR) has a positive and significant effect in explaining variability on lending in Malawi's banking overall and while the introduction of stable funding ratio (SFR) has a positive and significant impact on banking sector-wide lending growth effects. The study also found that the Basel III Capital and Liquidity rules have different effects on firm-level lending for the eight (8) banks in Malawi.

3.1 Introduction

Malawi adopted the Basel I Capital regulation in January 2000 and subsequently implemented Basel II in January 2014, as part of its efforts to achieve international harmonisation of financial systems. Presently, the country is preparing for the forthcoming adoption of Basel III, which is slated for formal implementation in January 2025. According to the Basel Committee on Banking Supervision (2010), the key features of Basel III have been the introduction of stricter liquidity standards, namely the Liquidity Coverage Ratio (LCR) and the Stable Funding Ratio (SFR). Basel III also further introduced a non-risk weighted asset capital ratio known as the Leverage Ratio (LR). This is in addition to compliance with the existing risk-weighted capital ratios of Tier 1 and Tier 2. In Basel III, the only modification to risk-weighted capital ratios has been to increase them from 8% to 10%. The introduction of Basel III will mean that financial institutions will have to increase the levels of capital they hold with the aim of strengthening the capacity of their balance sheets to absorb losses emanating from their own risk-taking behaviour or volatilities in business cycles. Additionally, financial institutions will be required to hold high quality liquid assets (HQLA) and a stable level of funding that will cushion the financial institutions' ability to withstand adverse liquidity shocks and funding withdrawals. However, the key question remains: how will these additional liquidity and capital regulatory frameworks for banks affect their ability to optimise their balance sheets for compliance, intermediation and profitability?

Much of the existing body of literature has heavily narrowed on the effects of capital ratios on lending, and presumably so because Basel I and II pillars placed heavy capital compliance on banks and very few studies have zoned in on the effects of Basel I, II and III liquidity measures on bank risk-taking behaviour. Hence empirical works that research on the impact of Basel III liquidity indicators on intermediation and bank performance are regarded as novel and for Malawi, to the best of our knowledge, this paper pioneers such a strand of empirical works. The main objective of this study is to analyse the potential implications associated with the adoption of an enhanced liquidity and capital framework, namely the liquidity coverage ratio, stable funding ratio, and leverage ratio as stipulated in Basel III within the financial system of a developing economy like Malawi.

This research has significant relevance in light of the general lack of depth in the capital and financial markets in Malawi, together with the constrained supply of liquidity. The study found that if Basel III will be adopted in Malawi's banking sector, the introduction of the Basel III Liquidity Coverage Ratio (LCR) will have a negative effect on lending practices within the country's banking sector. In contrast, the implementation of the Stable Funding Ratio (SFR) will have a notable and favourable impact on the overall expansion of lending activities within the banking industry. These findings were also consistent with those of Berger & Bouwman (2009). This study also found that the introduction of Basel III non-risk weighted asset capital ratio of leverage ratios is seen to have significant and negative implications for the lending progress within Malawi's banking sector. The study further found that Basel II risk-weighted capital ratio, namely Tier 1, has a statistically significant and positive impact on the lending expansion of the banking sector in Malawi. On the contrary, Tier 2 capital has a statistically negligible and adverse impact on the aggregate loan expansion within the banking industry. My study just like that of Gambacorta & Mistrulli (2004) found that prospective Basel III liquidity and capital rules affected banks differently in Malawi. We split the banks into two big banks, four middle banks and two smaller banks using the stress-testing criteria used by the Central Bank of Malawi, as discussed in Section 3.8.1 in Table 3.6. Our study, also like that of Bernanke & Lown (1991), deployed seven models to test varying effects of different model structures on bank lending. The detailed results are in Section 5. This research adds to the current scholarly understanding of the banking sector in Malawi with a special focus on the potential outcomes associated with the adoption of Basel standards—specifically Basel III—in Malawi. To the best of our current understanding, this study represents the first attempt to investigate this subject within the specific setting of Malawi in an empirical manner.

To this end, and to the best of our knowledge, we do not know any studies in Malawi that have taken this approach, studied this subject matter, and modelled the Malawian banking sector in the manner we have done in this paper. The rest of the paper is organized as follows: Section 3.2 discusses the context of the study, Section 3.3 reviews the relevant literature, Section 3.4 discusses the modelling framework used in the paper, Section 3.5

discusses the empirical modelling approach, Section 3.6 details the data and sources used, Section 3.7 presents the robustness checks, Section 3.8 discusses results from the modelling experiments, and Section 3.9 provides the conclusion.

3.2 Context of the Study and Basel Accords

The Government of Malawi (GoM) has regularly implemented a series of financial sector reforms from the early 1980s. The main aim of these reforms primarily centred on the reorganisation and privatisation of state-owned enterprises, together with the reduction of governmental interference in the economy. The measures were adopted in accordance with the structural adjustment policies (SAP) promoted by the International Monetary Fund (IMF) and the World Bank. The changes were especially targeted at the banking sector, aiming to modify the existing practices within this industry. Prominent changes included initiatives aimed at facilitating the entry and exit of players within the sector, the removal of constraints on interest and capital, and the total overhaul of supervisory and regulatory structures within the banking industry (Malawi Government, 2001).

The economic advantages associated with SAP have been a topic of continuous discussion among scholars and professionals. Nevertheless, a consensus exists, especially within the financial industry, that these regulations have led to the establishment of more effective private institutions engaged in deposit-taking activities. These institutions have a direct impact on the allocation of financial resources to sectors with higher productivity, therefore enabling risk mitigation and promoting the growth of the private sector. The decision to use a gradual approach in deregulating interest rates was taken by the Government of Malawi as part of the Structural Adjustment Programme (SAP). This was carried out in a sequential manner, in several phases. The granting of autonomy to commercial banks in July 1987 allowed them to use discretion in setting their lending interest rates. The liberalisation of deposit rates occurred in April 1988. The decision to discontinue preferential loan rates for the farm sector was taken in August 1988, and the complete deregulation of all rates was achieved by May 1990 (Malawi Government, 1987).

The Malawi Kwacha was fixed to a basket of seven currencies, including the US Dollar, Pound Sterling, Deutsche Mark, Rand, French Franc, and Dutch Guilder, during a period spanning from January 17, 1984, until February 18, 1994. On February 7th, 1994, the Malawi Kwacha transitioned to a floating exchange rate system. The first decision of the exchange rate took place at the fixing session on February 18th, 1994, whereby the value of USD1.00 was fixed at Mk6.51 (Malawi Government, 1999).

As stated earlier, there is an impending adoption of Basel III by the nation. Figure 1 in Appendix 1 presents a thorough depiction of the fluctuations seen in loans, liquidity, capital, and profitability in the Malawian setting, spanning the years 2015 to 2021, based on the author's calculations from various financial institutions' audited accounts from the respective periods. As of December 2022, the aggregate value of assets in the banking industry reached MK3.7 trillion, indicating a substantial growth compared to the MK981 billion recorded in 2015. As of December 2022, the aggregate deposits in the banking system reached MK2.6 trillion, indicating a substantial growth compared to the MK683 billion reported in 2015. The risk-weighted assets had significant growth, rising from MK829 million in 2015 to MK1.7 billion. As of December 2021, the Tier 1 ratio, which measures a bank's core capital in relation to its risk-weighted assets, was at 21%. The overall capital ratio, which reflects a bank's total capital in relation to its risk-weighted assets, was recorded at 17%. The leverage ratio for Malawian banks averages 10%, which is above the Basel III requirements of 3% for big banks. As of December 2021, the sector had strong liquidity ratios of 53%, 44%, and 39%. All these ratios were above minimum regulatory requirements, showing a healthy and sound banking system.

3.3 Contextual background of Basel Accords

The purpose of this section is to provide a comprehensive analysis of the development surrounding Basel Accords as obtained from the Bank of International Settlement (BIS) publications. The Basel Accords, a set of international banking regulations, have garnered significant attention and scholarly interest. This review aims to provide a solid foundation of knowledge on the background and context. The establishment of the Basel Committee on Banking Supervision occurred in 1974 under the Bank of International Settlements

(BIS), an institution that was founded as a forum for Central Bankers after the conclusion of the First World War. Until a recent point in time, the composition of the Committee included individuals from the Group of Ten (G10) in addition to Luxembourg and Spain. Each of these entities was represented by their own central bank and the governing body responsible for overseeing domestic banking activities.

The initial objective of the Committee was to address the regulatory difficulties arising from the growing globalization of the banking sector throughout the 1970s. The occurrence of the German Herstatt Bank and the Franklin National Bank of New York collapsing in 1974 demonstrated that financial crises were no longer limited to a single nation, thereby necessitating concerted international measures to mitigate the potential spillover effects of future crises. The first proposition put up by the Committee, known as the Basel Concordat of 1975, delineated regulations that outline the respective obligations of regulators in the home and host countries in relation to banks operating across national boundaries. Table 3.1 below shows the global financial sector events that triggered the introduction of Basel regulations.

Table 3.1: Summary Table of Basel Regime Implementation and Trigger Events

REGIME TYPE	TRIGGER EVENTS	ADOPTION DATES
BASEL I	LATIN AMERICA DEBT CRISIS (1982)	1988
BASEL II	CHALLENGES OF BASEL I	2004
BASEL III	AMERICAN SUB-PRIME CRISIS (2007-2008)	2023

Source: Author Compilations

3.3.1 Introduction to Basel I

During the 1980s, the Committee's scope expanded as American regulators sought a means to distribute the regulatory responsibilities placed on domestic banks after the occurrence of the Latin American Debt Crisis in 1982. To mitigate the need for future bailouts of

American banks, the United States Congress exerted pressure on its domestic regulatory agencies to implement a capital measurement system that mandated a predetermined ratio of capital to be maintained in relation to all liabilities recorded on a bank's balance sheets. American banks later raised concerns about experiencing a competitive disadvantage in comparison to overseas banks with less stringent regulations, particularly Japanese banks, which maintained far lower amounts of capital. In response, American authorities turned to the Basel Committee to create a unified framework for the capital regulation of banks with worldwide operations (Basel Committee on Banking Supervision, 1988). This led to the development of the 1988 Accord on Capital Adequacy, also known as Basel I.

The agreement that was introduced in December 1992, known as Basel I, established minimum capital requirements by using a ratio of capital to risk-weighted assets often referred to as Cook's ratio, and was set at 8%. The objective of Cook's ratio was to enable banks to effectively absorb unanticipated adverse shocks without causing detrimental effects to the overall economic systems. The risk-weighting of assets was determined based on the borrower's identification. Government bonds, as an example, were assigned a risk weighting of 0%, but conventional corporate loans were assigned a risk weighting of 100%. Consequently, capital equal to the whole 8% of the loan's value must be maintained as a safeguard. In contrast to subsequent iterations of the agreement, Basel I only addressed the issue of credit risk, which pertains to the inherent risk in banking associated with the potential default of a debtor on their loan.

3.3.2 Introduction of Basel II

During the latter part of the 1990s, it was seen by both Central Banks and International Active Banks that there were deficiencies in the operational execution of the 1988 agreement. Banks expressed their dissatisfaction with the disparity between the perceived level of economic capital that should be reserved for loan provisioning and the regulatory capital allocated to these loans as stipulated by the agreement. The crude risk weights used resulted in treating a loan to a secure blue-chip business the same as a retail customer's overdraft, or assigning the same fee to a loan for a major industrial nation as one to a fragile emerging market (Basel Committee on Banking Supervision, 1999). The circumstances

had resulted in the emergence of distorted motivations to engage in regulatory arbitrage, when individuals exploit the disparity between economic risk and regulatory risk to decrease capital levels without diminishing their exposure to risk. Banks engaged in arbitrage of Basel I's capital requirements using two distinct methods. Initially, the individuals proceeded to allocate their investments towards assets with a greater level of risk within a certain risk weight classification, resulting in a correspondingly increased rate of return. Furthermore, there was a strategic decision made to transfer assets off the balance sheet, often via the process of securitization. The assets in question were classified as "true sales" for regulatory reasons, even though the bank often kept a significant portion of the underlying risk via credit enhancements, such as liquidity facilities.

The outcome of these actions resulted in a decrease in the total capital levels within the banking sector. These levels had previously seen a significant increase with the implementation of Basel I in the early 1990s. The Basel Committee declared, in September 1998, its intention to conduct a formal evaluation of the 1988 agreement, with the aim of substituting it with a set of regulations that provide more adaptability. The first set of ideas for the new framework was issued by the organisation in June 1999. According to the Committee's statement, the newly established pact aimed to achieve the objective of ensuring that the Accord continued its efforts to maintain safety and stability within the financial system. Consequently, the newly established framework effectively preserved existing levels of capital inside the system. First, the Accord improved the level playing field in terms of competition; second, it introduced a more comprehensive strategy for mitigating risk. Following a protracted period of five years of talks, industry feedback, and comprehensive impact assessments, the Committee ultimately declared its consensus on a novel capital adequacy framework, known as the Basel II Accord. The Basel Committee introduced Basel II in June 2004. This framework is structured on three fundamental pillars: equity, risk management, and openness. Under the Basel II framework, banks can implement their own internal risk assessment, often referred to as the Internal Rating Based (IRB) model, to effectively monitor and manage risks. The ratio formerly known as Cook's ratio underwent a transformation and came to be known as McDonough's ratio. This revised ratio maintained the same threshold of 8% of total capital but included the

consideration of operational risk and market risk, in addition to credit risk. Furthermore, the definition of capital was refined to specifically include Tier 1 capital.

3.3.3 Introduction to Basel III

According to the Basel Committee on Banking Supervision (2010), the Basel III agreement was formulated in response to the lessons learnt from the global financial crisis, which originated with the subprime crisis in the United States in 2007 and rapidly disseminated around the globe. The Basel committee issued an interim report to address the most pressing issues arising from the crisis. That report formed the basis of Basel III.

Basel III encompasses three fundamental ideas. The first premise pertains to the establishment of minimum capital requirements. The publication of Basel III was intended to address the inherent limitations of Basel II. Basel III still maintains the risk-weight capital rules of Tier 1 and Tier 2 but enhances the ratios with an upward adjustment. These adjustments include raising the total capital ratio (Tier 2) from 8% to 10.5% in 2019, as well as increasing the Tier 1 capital ratio (now referred to as Core Tier 1 ratio) from 4.5% to 6% in 2019. The second premise pertains to the concept of the 'leverage ratio'. Basel III further introduces a non-risk weighted capital requirement known as a leverage ratio that requires banks to maintain a minimum leverage ratio of 3%. The leverage ratio is calculated by dividing the bank's Tier 1 capital by the average total consolidated assets. The third concept of Basel III pertains to the establishment of advanced and stricter liquidity ratios.

The Basel III framework introduces two liquidity measures, namely the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The Liquidity Coverage Ratio mandates that banks maintain a certain amount of high-quality liquid assets (HQLA) capable of withstanding a 30-day period of financial strain as determined by the regulatory authority overseeing the bank. In contrast, the Net Stable Funding Ratio mandates that banks maintain a level of stable financing that exceeds the prescribed threshold for a duration of one year during periods of heightened financial strain. The Net Stable Funding Ratio (NSFR) has the objective of mitigating liquidity mismatches within banking institutions. These ratios are expected to exceed 100%.

The significance of Basel III lies in its capacity to enhance regulatory frameworks, supervisory practices, and risk mitigation strategies within the banking sector. The implementation of Basel III regulations will serve as a preventive measure against banks engaging in excessive risk-taking behaviours that have the potential to negatively impact the whole economy. It will also enhance banks' capacity to absorb exceptional shocks. Basel III is expected to enhance the levels of openness and disclosure within the banking sector. According to the provisions of Basel III, the banking sector may anticipate improvements in the quality of capital, increased levels of capital, the implementation of minimum liquidity requirements for banks, a decrease in systemic risk, and variations in the transitional arrangements associated with Basel III.

3.4 Theories of Bank Regulation

Bank regulation refers to governmental interventions that restrict the economic decision-making and operations of banks. Banking products, like other goods and services, are purchased by customers in the financial markets. However, like the market for goods and services, financial markets may also experience market failures and generate negative externalities for consumers, markets, and the broader economy. Banking controls are necessary due to several negative externalities such as the monetary liquidity costs incurred by central banks, consumers and enterprises; the costs associated with bank failures; the social welfare costs of bank bailouts; and the costs resulting from inefficient banks, among other factors. There are two primary theoretical approaches to bank regulations: the normative approach and the positive approach. The normative approach includes several theoretical strands such as the public interest theory and the market failure theory. The positive approach encompasses private interest theory, which comprises the capture theory, the economic theory of regulation, and the public funding approach.

3.4.1 The Normative approach

The conventional normative theory of government has demonstrated its unique and analytically robust capacity to initiate discourse on the government's role in influencing the distribution of scarce resources in society, as well as assisting individuals in realising

their concept of a fair society. The unique aspect of normative public economics is in its focus on defining the economic function of the government based on its ability to produce Pareto improvements, which are benefits from trade that are not realised through free exchange. This distinguishes normative public economics from other disciplines in public policy. An inherent characteristic of the normative approach is the prioritisation of the government as emphasised by the market-failure paradigm. The classic normative approach is the most ancient method for assessing issues related to regulatory stances. The term “normative” is used to describe this method since it assumes that effective regulation is desired (Budäus, 1988; Hertog, 2010). The normative approach aims to provide justification for government involvement by highlighting instances of market failures within the banking industry.

Therefore, the government should only intervene in situations when there is a failure in the market (Musgrave, 1959; Blankart, 2006). The normative method analyses economic factors such as asymmetric information or externalities, to find instances of market failure. Its objective is to determine the most efficient or optimal style of regulation for banks (Hertog, 2010). The normative approach encompasses public interest theory and the market failure theory.

3.4.2 The Public Interest Theory – Market Failure Theory

Public interest theory has its foundation in microeconomics and was initially proposed by Pigou (1932 [1920]). Pigou further developed the works of Alfred Marshall, Leon Walras (general equilibrium framework) into what is known as Welfare Economics. Pigou provided the justifications of the presence of the state in markets. In his interpretation of regulation, he states:

state interference, designed to modify in any way the working of free competition, is bound to injure the national dividend; for this competition left to itself will continually push resources from points of lower productivity (in terms of economic satisfaction as measured in money) to points of higher productivity, thus tending always away from less

favourable, and towards more favourable, arrangements of the community's resources. (Pigou, 1932 [1920])

The literature of public interest theory is grounded on four assumptions: (a) perfect information, (b) benevolent regulators who aim to pursue the public interest, (c) separate markets that are extremely unstable and inefficient, and (d) relatively costless regulation. According to these assumptions, the 'government or state' interferes in markets when they are unable to regulate themselves. Thus, state interference is triggered when the neoclassical assumption of the Walrasian general equilibrium theory breaks down and resources are not allocated to their highest valued uses, defined as "market failure" (Posner, 1974). Therefore, general market regulation—including banking regulation—is administered as a response to protecting public interest from negative externalities from the actions of market players. Pigou and others held the view that unregulated markets encounter frequent failures ranging from externalities to monopoly power. A government that pursues social efficiency is one which controls these failures and protects the public through the administration of regulation.

Regulation therefore achieves allocative efficiency of resources from lower productivity to higher productivity. In other words, regulation's purpose is to achieve certain publicly desired results in circumstances where, for instance, the market would fail to yield these (Baldwin & Cave, 1999). The main drivers of market failure are market structure (such as natural monopoly), asymmetric information and externalities. In some markets, market structure, particularly natural monopoly, does play a decisive role in the justification of bank regulation because the banking industry consists of a small number of banks which exist with less competition. In developed markets, however, the presence of many banks naturally solves the problem of market structure (natural monopolies). In short, analysis of the aggregate effects of monopoly does not provide an argument for controls [in the banking sector] (Meltzer, 1967). Likewise, Goodhart (1988) indicated that market structure, with a few minor exceptions (for example, access to clearing houses), is not relevant in the banking system. Conversely, asymmetric information and externalities justify regulation in the banking industry.

3.4.3 The Market Failure Theory – Asymmetric Information

The concept of market driven economies thrives where information is readily and easily acquired with no transaction costs or frictions. In economics, frictions or transactional costs or quadratic adjustments exist because of unavailability of information or different market players possessing different sets of information.

This is often contrary to the assumption often represented in economic models of “perfect information” whereby modelling the real economy assumes quadratic adjustment costs, frictions and “asymmetric information” (Budäus, 1988; Tirole, 1988). Akerlof (1970), in his article titled “The Market for Lemons: Quality Uncertainty and the Market Mechanism”, became one of the first scholars to address the problem of asymmetric information in economics, modelled as quality uncertainty in the sale of goods. For this purpose, buyers and sellers do not have the same information regarding the cost and quality of goods and services. Bank regulation exists because the market players (banks, borrowers, lenders, and banking supervisors or regulators) possess different knowledge and information with regards to their motives of entering the financial transaction, actions, positions and expectations from each agent.

Banking, like any other market product, is devoid of perfect information and the players suffer from the problem of asymmetric information. In economics literature, there are three common phenomena of asymmetric information, namely, adverse selection, moral hazard and ruinous competition. The concepts of adverse selection and moral hazard are often discussed with reference to the economics of insurance and not banking (Tirole, 1988; Greenbaum & Thakor, 2007 [1995]; Burghof & Rudolph, 1996; Goodhart et al., 1998, Laffont & Martimort, 2002). To better understand the application of the asymmetric information problem in economics of banking regulation, the recommended starting point is to use the principal-agent paradigm. In this framework, the principal uses incentive-compatible contracts to align the agent’s interest to their own interest (Maskin & Tirole, 1990). When we assume utility maximisation in the banking market (the buying of deposits and selling of loans), banks by design have a dual principal-agent relationship; they are a principal (lender), agent I (on Inter-bank markets and when they receive deposits from

customers), and agent II (borrower). The dual principal-agent relationship manifests itself in the following manner: firstly, between the bank and the customer at the point of receiving the deposits; secondly, between the banks on the interbank market when they are lending to each other; and thirdly, between banks and borrowers at the time of creating loan contracts. In all these three scenarios a three-step asymmetric information problem is created.

Stiglitz & Weiss (1981) provided evidence of adverse selection and moral hazard in the credit market by means of an increase in interest rates. They used two assumptions. Firstly, they assumed a credit market with two types of borrowers: good and bad. Secondly, they introduced credit rationing—that is, the demand for loans is always greater than supply of the same and, conversely, good borrowers either do not receive loans at all or do not receive the optimal amount of loans. Stiglitz & Weiss (1981) also assumed that there are higher interest rates in the credit market, which consequently have two effects. Firstly, rationing of loans (credit) acts to exclude good borrowers from the credit market. They are crowded-out by bad borrowers because banks cannot distinguish between good and bad borrowers due to information asymmetry. This first effect is called adverse selection, a direct problem created by lack of better information (information asymmetry) before executing the loans contracts between banks and borrowers (Mishkin, 2013).

Adverse selection in the banking industry or market occurs when potential borrowers who have a high probability of default (producing an adverse credit outcome) are the ones who actively seek out loans and are thus most likely to be given the loans (selected) than good borrowers (Mishkin, 2013). Tirole (1988) noted that adverse selection in the theory and practice arises before the signing of the contract, in a situation where products or services of lower quality displace products and services of higher quality due to the cost of information. According to Arrow (1985) and Varian (2004), adverse selection refers to a situation where one side of the market cannot—without minimal costs or financial frictions—evaluate the quality of goods and services being offered by other players in the market. This is often referred to as hidden information. Stiglitz & Weiss (1981) theorized that in an environment of increasing interest rates or collateral requirements, these have a

potential of increasing the riskiness of the bank's loan portfolio, either by discouraging safer investors or by inducing borrowers to invest in riskier business projects. Laffont & Martimort (2002) describe this as a moral hazard.

Mishkin (2013) describes a moral hazard as a problem created by asymmetric information after the transaction has been concluded between the bank and the borrower. In other words, a moral hazard in banking "is the risk (hazard) that the borrower might engage in activities that are undesirable (immoral) from the lender's point of view". Whilst adverse selection problems arise before a contract is signed, the moral hazard problem arises after the contract has been concluded between the principal and the agent. The problem of a moral hazard is often reduced by signing insurance contracts such as deposit insurance, credit life and other forms of insurance on collaterals. Thus, because of risk insurance, the insured parties do not suffer if they behave carelessly, which is referred to as hidden action (Arrow, 1985; Tirole, 1988; Laffont & Martimort, 2002). In short, Stiglitz & Weiss (1981) posit that in the banking market, especially the market of credit (loans) and deposits, quality uncertainty leads to adverse selection because banks cannot observe borrowers' creditworthiness and, on the other hand, moral hazard arises due to behaviour uncertainty because banks have difficulty observing how loans are used.

The same applies to depositors; since they cannot with less costs evaluate which bank is safe, sound and solvent, they place deposits with any bank. However, they do not observe whether the banks safely invest these funds without exposing them to bank failures and portfolio fire sales due to liquidity problems. A third element in the market failure literature is *ruinous competition between banks*. This should often be seen in the light of interbank markets. In a free market, banks will enter price wars, especially in the market for deposits. As a result, it is purported that 'good' banks with good risk management frameworks (good services) are displaced by 'bad' banks with aggressive risk management frameworks (bad services). And coupled with lack of information and knowledge (buyer ignorance), depositors can only judge the quality of banking services with substantial difficulty or not at all. Llewellyn (1999) indicates that "the individual consumer has limited ability and opportunity to acquire the necessary skills to enter complex financial contracts".

Expanding on this point, Spong (1994) notes that an investigation of these factors is likely to be too complex and costly for most depositors. In other words, small “depositors are said to be unaware of—and unlikely to pay the cost of acquiring information about—the risk position accepted by the bank or the character of the banker” (Meltzer, 1967). In this case, adverse selection and ruinous competition exist at the same time as banks with a high risk of failing (bank fragility or bank run) will still appear too attractive to the general public, continue to amass deposits at higher interest rates (taking good business from financial solid banks) and continue giving out loans at attractive (competitive) interest rates when compared to good banks. In the process, good banks are affected by the existence of bad banks, and in extreme cases, good banks will exit, leaving the market with high risk or bad banks. This situation, in the end, will result in a sub-optimal allocation of resources in the form of loans and financial risk, hence the risk of a systematic banking crisis (bank run or fragility) (Baltensperger, 2005). Hence this is one of the justifications for having bank regulations such as the Basel Accords whose regulations protect the public from externalities of banking failures. Therefore, bank regulation could mitigate the problem of asymmetric information. In this sense, bank regulation provides minimal quality standards that reduce agency costs and serves as a substitute for the monitoring of the lender and borrower (Stillhart, 2002).

Consequently, there is a need for bank regulation to mitigate the asymmetric information problems that arise between the lender and the bank and between the bank and the borrower.

3.4.4 The Public Interest Theory – Externalities

Another justification for regulating the banking industry includes externalities. The concept of externalities (external effects) dates to the 1920s with earlier works of Marshall (1997 [1920]) and Pigou (1932 [1920]). In defining the concept, Marshall assumed internal effects. According to Marshall (1997 [1920]), all cost and benefit factors that influence decision makers directly in their decision-making functions can be understood by the term ‘internal effects’. In this case, for Marshall (1997 [1920]), externalities are the residual form of internal effects.

The concept of externalities was introduced into public finance by Pigou (1932 [1920]), who posited that externalities arise whenever there are either positive or negative side effects in the consumption or production of an economic agent. In this regard, Frey (1981) suggests that consumption or production is disturbed by the economic agent, leading to a Pareto inefficient situation. The concept of externalities from Marshall (1997 [1920]) and Pigou (1932 [1920]) can also be used in the bank regulation literature. With externalities in consumption, all economic interdependencies are considered, in which the benefits to a consumer (depositors and so on) are directly affected by the conduct of another economic agent. In simple terms, any market action taken by one player in a market is always likely to affect the economic position of all the other players in that market (Goodhart, 1988).

Risk-taking behaviour by banks that results in significant liquidity challenges—such that they even fail to meet both regulatory liquidity ratios and liquidity reserve requirements—pushes them to conduct “fire-sales”. This refers to the selling of fixed income securities, mostly Treasury Notes and Bills, at a discount, which in turn results in the incurring of losses on the asset side of the balance sheet. These losses not only result in reduction in the size of the banks’ balance sheets, but also lead to erosion of the regulatory capital of the banks, hence making them insolvent. This often leads to negative externalities from the banking sector, such as bank failures and systematic financial contagion, as was the case in the 2009 financial crisis (Kashyap et al., 2011).

Therefore, bank regulation enhances the liquidity position of banks through measures such as the introduction of Basel III, the Liquidity Coverage Ratio, Stable Funding Ratio and additional capital ratios, such as leverage ratio. These measures strengthen the banking industry and are important to circumvent and mitigate negative externalities from aggressive risk-taking behaviour by banks, which threatens the soundness of the global financial system due to interconnectedness. Baltensperger (1990) purported that when banks fail, it is the market that suffers, since credit in the revamped system becomes inherently expensive, as loans are often offered at unattractive terms, which results in underinvestment in the economy. The consequences of this are observable in low growth potential of economies (under-employment). Bank failures often have substantial social

costs in the real sector (real economy), especially when the failure involves financial institutions that were thought to be too big to fail. Therefore, it is for this cause that bank regulation is deemed necessary to mitigate the negative externalities of banking system failures on the real economy.

The failure of a bank affects the real sector (where you have consumers, entrepreneurs, and firms), the external sector, the monetary sector and the government sector (public financing). The real sector of the economy is where economic production happens. In this sector we have consumers, entrepreneurs, retailers, and capital good producers; this is the bedrock of economic activities. In the monetary sector, we have the monetary authorities who handle monetary policy, exchange rate policies, financial sector regulation (pension funds, insurance firms, microfinance, development banks), price stability, micro and macroprudential policies. In the external sector, we have the balance of payment administration and exchange rate management. In the government sector, we have fiscal policy administration and government borrowings (public finance management, which includes borrowing from the banking sector). All these sectors keep their deposits with the banking sector, as it is the engine of financial intermediation. All economic interdependencies are directly affected by the action of another economic agent (Marshall, 1997 [1920]; Pigou 1932 [1920]; Frey, 1981; Varian, 2001, 2004; Blankart, 2006).

3.4.5 The Public Financing Approach

Another economic justification for regulating the banking sector is the critical role banks play in augmenting public financing. Public financing, in this sense, means that a country's banking industry plays a pivotal role in bridging the resource envelop gap of the government. It involves funding fiscal deficits of the public sector (the government) in periods of inadequate tax revenue collections. In Malawi, as of December 2022, 42% of total consolidated assets of the banking sector consisted of Treasury Notes and Bills, which are loans from the domestic banking system provided to the government, while 28% were loans and advances given to firms and households. Other writers such as Bruni (1990) analysed the Italian banking industry as it was approaching 1992 and concluded that a large part of the activities of the banking sector were devoted to financing the public sector. It

is, therefore, in the government's interest to regulate the banking sector to ensure that it is financially sound and that it allocates capital efficiently, because government is an interested party to the existence of the banking sector.

3.4.6 The Positive Approach

The positive approach to banking regulation has its origin to the Chicago School of thought; with notable proponents in this school of thought such as Stigler (1971), Posner (1974), Peltzman (1976), and Frey (1981). The positive approach is a contrast to the normative approach that justifies the interventions of the government in industries by bringing in regulation to reduce the negative effects of market failures. Under the positive approach, the proponents underscore the fact that market players have good intentions and that naturally regulations work in their best interest. According to Friedman (1962), the positive approach focuses on objective facts and is not influenced by any specific ethical attitude or normative judgements. Hertog (2010), theorized that the positive approach entails providing the economic justifications for regulation and an analysis of the effects of regulation. In order to achieve this goal, the positive approach encompasses the political decision-making process and includes the development of the content and structure of banking regulation. According to Stigler (1971) and Peltzman (1976), the positive approach classifies regulation as a public good that is subjected to the market driven principles of supply and demand.

The positive approach encompasses private interest theory, which comprises the capture theory, the economic theory of regulation, the bureaucracy theory, and the public funding approach.

3.4.7 Private Interest Theory (Capture Theory)

The private interest hypothesis, commonly referred to as capture theory, describes the phenomenon where regulatory institutions come under the influence of the banking sector. As a result, banks manipulate and undermine the initial purpose of the rule, leading to modifications that ultimately benefit the banking industry. The introduction of Basel I across the world was because the American Banks, which can be termed as a special interest group, advocated for a world-wide application of the capital rules, because Japanese banks were making more profits and expanding faster than them on account of

weak capital requirements by their regulators. The private interest theory underpins the role of competing private interests of various groups in influencing public decisions and policy outcomes. The theory has its origins from an interplay of public interest theory and neoclassical theory. It is developed as a response to the self-serving interests of various groups, whose main objective is to maximize the financial gains or minimize financial losses of their members (Posner, 1974).

Therefore, regulation, according to this theory is an outcome of the demands of the various interest groups (Becker, 1983). These organized interest groups are actively engaged in the creation and implementation of regulations during the decision-making process, and they attempt to take advantage of supervisory agencies. Kane (1985, 1986) applied the private interest theory to the banking sector. His study pointed out that various interest groups such as depositors, investors, lawmakers advocate for implementation of banking regulation with the aim of mitigating the risk posed to their investments and private good (vested interest) in the banking industry. According to this theory, the demand side of the economy pushes for regulation (various interest groups) and on the supply side, the government and regulators supply regulation to the banking sector, hence treating bank regulation as a substitute good. This concept was well researched by Kane (1985, 1986), Hertog (2010), Stigler (1971), Posner (1974), Olson (1965), Stigler (1971), Niskanen (1975), and Peltzman (1976).

3.4.8 The Theory of Economic Regulation

The central point of the theory of economic regulation is that it explains who receives the benefits or burdens of regulation, the form of regulation and its effects on the optimal allocation of resources. Stigler (1971) enhanced and elaborated on the concepts initially established in private interest theory (capture theory), resulting in a revised theory of economic regulation. The theory posits that regulation is considered a public good that is subjected to the market driven principles of supply and demand, as outlined in Posner (1974). Stigler (1971) argues that the industry obtains and implements regulation largely for its own advantage. Regulation, which is considered a public good, is provided by policymakers on the supply side. In this particular case, the second perspective simply argues that the political process serves as the reasonable justification for regulating (Stigler,

1971). Unlike the public interest theory, government involvement does not aim to fix market inefficiencies. Instead, it aligns with the capture hypothesis, which suggests that regulation exists to serve the interests of politically influential organisations (Stigler, 1971).

Stigler (1971) states that in the banking business, big banks have advocated for changes to Basel II, Pillar 1: Capital Adequacy Requirements. Their focus is specifically on the Standardised Approach to determining Risk Weighted Assets (RWA). This would enable the banks to determine their own RWA using *internal ratings-based strategies (models)*. It can be deduced that this lobbying by big banks is not meant to address market failures. Rather, it serves the big banks' interest (both shareholders and management) for capital management purposes. According to the theory of economic regulation, the argument is that the banking sector adopts risk-weighted capital requirements for its own advantage, because, under the risk-weight method, big banks have the ability to manipulate the amount of capital they are obliged to hold for funding purposes.

3.5 Selected Empirical Literature Review

The adoption of Basel I and II in the early 90s and 2000s generated a lot of research interest among scholars. Much of the empirical work centred on examining the effects of introducing these capital rules on banks' lending in both domestic and international markets. The selected studies below used panel data analysis and summarise the effect of capital ratios and liquidity on bank lending.

Bernanke & Lown (1991) found that there was a positive association between Basel I and II risk adjusted capital ratios and growth in bank lending. They also found that there was a significant relationship between changes in employment and bank lending growth when they incorporated macroeconomic factors other than bank specific variables. Peek & Rosengren (1997) and Peek & Rosengren (2000) found that the implementation of risk-based capital requirements, specifically related to the Japanese stock market shortage, led to a notable reduction in lending activities by Japanese banks in the United States. This decline in lending was shown to have both economic and statistical significance. Gambacorta & Mistrulli (2004) concluded that banks that are well capitalized can

withstand monetary policy shocks that affect their available deposit pool for lending, mainly on account that well capitalized banks have a wider alternative in the form of non-deposit sources of financing such as bonds, and other capital augmenting financial instruments.

In conclusion, the authors emphasized the fact that the effect of Basel I and II Capital Accords affected banks differently, largely depending on their level of capitalization and appetite for risk. Berrospide & Edge (2010) found that bank capital ratios affected loans growth between six to ten times larger than the standard results they had found using panel data regressions. Kishan & Opiela (2000) found mixed results depending on the size of the banks' balance sheet, level of capitalization and effects on lending growth. Their study concluded that regulators should consider the distribution effects of monetary policy on different banks' ability to lend and when designing macroprudential policies.

Beatty & Liao (2011) found that when Basel risk-weighted Capital Accords were implemented, banks that had a greater time lag or delay in implementing the International Financial Reporting Standards (IFRS) 9 suffered credit losses which reduced their ability to advance credit during recessions, compared to banks that adopted the IFRS 9 promptly and recognised credit losses without delays. They also found that banks that had greater delays were more prone to capital shocks during recessions and that banks with less delays were less pro-cyclical for both well managed banks and poorly managed banks. They also concluded that bigger banks were more vulnerable to capital shocks when compared to smaller banks.

Carlson et al. (2013) found that irrespective of location, size and business characteristics, banks with higher capital ratios had a stronger loan growth in the 2008 and 2009 financial crisis and there was no relationship between the period before and after the financial crisis years. Their findings were like those of Berger & Bouwman (2009) and Demirguc-Kunt et al. (2010) who also found that there was a link between bank capital, and other items such as equity prices and market share, which were prominent during banking crises.

Bridges et al. (2014) found that changes in capital requirements for banks affected both capital and lending in the United Kingdom. With increasing capital requirements, banks in their model also gradually increased capital ratios and reduced loan origination in the year, following an increase in capital requirements. Labonne & Lame (2014) examined the different potential effects of bank capital ratios on loan growth using bank level analysis. They concluded that regulatory capital requirements induced non-linear reaction in proportion to the share of capital with which a bank is funded for French banks. They also showed that non-linearity is also prevalent in the ratio of non-performing loans to total loans. They concluded that the observed variation of the impact of both capital and non-performing loans exacerbated by regulatory capital constraints should be considered when regulators are designing macroprudential policy mix for the banking sector.

Olszak et al. (2014) concluded that for the European Union (EU) region, the impact of capital ratios on loan growth was stronger than was earlier reported in similar studies. They also investigated the extent to which different jurisdictions' bank regulation and supervision affected banks' ability to originate loans during economic recessions. They concluded that when the banking and supervisory regime is very restrictive, it reduces the restrictive effects of capital ratios on lending. The other component of their study was to investigate the procyclicality of loan loss provisions in income smoothing for banks in the EU. They concluded that income smoothing with loan loss provisions may encourage loan growth.

Košak et al. (2015) differentiated between Tier 1, Tier 2, customer and interbank deposits as sources of bank funding. They found significant and positive effects of Tier 1 on lending growth during the financial crisis. This effect was prominent among small banks and for banks in Brazil, Russia, India, China and South Africa (BRICs), as well as countries that are not affiliated with the Organisation for Economic Cooperation and Development (OECD). They also found that customer deposits positively influenced lending growth under banking crisis conditions. They also established a weak but positive influence of Tier 2, interbank deposits on lending growth in non-banking crisis conditions, as well as the converse truth that under banking crisis condition interbank deposits negatively affected

bank loan origination. They also found out that bank ownership had an influence on lending growth, and noted that commercial and foreign owned banks cut loan origination during crises, whereas government-owned financial institutions weathered the storm of banking crises and supported loan growth.

Alper et al. (2012) concluded that bank liquidity position was an important determinant of bank loan origination efforts. They also concluded that the interplay between interest rates and bank liquidity positions was insignificant, rejecting the findings of Kashyap & Stein (1995) about the existence of bank lending channels in Turkey as shown by the Turkish banking data. Allen & Paligorova (2015) found that Canadian public firms experienced a significant cut in availability of bank credit when compared with private firms, and that they were impacted by the costs of banks' wholesale funding from the pre-crisis times.

Berger & Bouwman (2009) constructed four measures of bank liquidity on all US Banks from 1993 to 2003 to measure the effects of bank liquidity and capital on bank lending. They concluded that bank liquidity positively correlated with an increase in bank value. They also found that bank liquidity and capital ratios had a positive significant relationship for big banks and a negative one for smaller banks.

3.6 Modelling Framework

3.6.1 Empirical Modelling Framework

The purpose of the empirical specification is to examine the influence of capital and liquidity on bank lending in Malawi. This analysis incorporates novel measures that draw inspiration from the Basel III regulatory framework, therefore expanding upon the factors previously explored in the available literature. Panel data estimation methods will be used to estimate a static regression model.

The underlying assumption of this model is that the current bank-lending behaviour may be elucidated by considering both bank-specific factors and macroeconomic variables. The technical analysis of the methodology is presented in Appendix B3.2. The model specification is presented in the following manner:

$$\Delta L_{i,t} = \alpha_i + \sum_{j=1}^j \beta_j X_{ji,t-1} + \sum_{k=1}^k \beta_{ki} X_{ki,t} + \varepsilon_{i,t} \quad (3.1)$$

The model framework in Equation 3.1, used in this study, is consistent with those used in the studies of Berrospide & Edge (2010), Bernanke & Lown (1991), Gambacorta & Mistrulli (2004), Kashyap & Stein (1995) and Kishan & Opiela (2000). The variable $\Delta L_{i,t}$ represents the loan origination growth of bank i at time t , which represents a month-on-month growth in loans denominated in Malawi Kwacha. The use of a growth rate model is justified due to the integration of variables in levels, which has been proved by conducting the Im-Pesaran-Shin test for cross-sectional variables and a conventional Dickey-Fuller test for the time series. Gambacorta & Mistrulli (2004) and Kashyap & Stein (1995), in their studies, adopted the use of loans growth rate to avoid spurious correlation among variables. The variables denoted as X_{ji} and X_{ki} represent the j th and k th factors, either particular to individual banks or related to macroeconomic conditions, that have been identified as predictors of bank lending in previous scholarly research. We use a Feasible Generalized Least Square (FGLS) panel estimator with bank-specific fixed effects in our analysis.

3.7 Variable definition

3.7.1 *The Dependent Variable*

The dependent variable used in our study is the monthly growth rate of private loans, encompassing aggregate lending to the household, entrepreneurs and firms. All values are expressed in Malawi Kwacha.

3.7.2 *Variables Specific to Banks*

This study uses all the capital ratios, from Basel II risk-weighted capital ratio measures to Basel II non-risk-weighted assets capital measures of Leverage Ratio, to assess their effects on lending growth in Malawi's banking sector.

The comprehensive measure of regulatory capital adequacy, known as the total regulatory capital ratio, is determined by dividing the sum of Tier 1 and Tier 2 capital by the total risk-weighted assets (RWAcpi). The Basel III regulatory framework has included supplementary capital criteria pertaining to the calibre of the capital base (Basel Committee

on Banking Supervision, 2010). The primary objective of Tier 1 capital is to enhance the overall quality of a bank's capital, therefore encouraging banks to adopt alternative strategies for managing the various elements of their regulatory capital. Tier 1 capital to risk-weighted assets is denoted as Tier1ratcpi, whereas Tier 2 capital to risk-weighted assets is represented as Tier2ratcpi. One notable finding during the 2008 financial crisis was that a majority of banks had favourable Tier 1 and Tier 2 ratios, but faced insolvency as a result of significant leverage present in their balance sheets. Consequently, the Basel Committee made the decision to implement additional capital conservation requirements in order to mitigate the risk of bank failures resulting from excessive borrowing. Therefore, the committee implemented the leverage ratio, which is calculated as the ratio of Tier 1 capital to total assets (Leveratcpi) in the banking sector. The implementation of the leverage ratio serves as a supplementary mechanism for overseeing a bank's capital adequacy, apart from risk-based approaches.

The group established a threshold of 3% for larger economies, while delegating the responsibility of determining the threshold for individual nations to national regulators. On average, banks in Malawi have a leverage ratio of around 10%. As elucidated in Section 3, the influence of capital ratio on the growth of bank lending is inconclusive. However, it is anticipated that banks with high leverage would experience a decline in lending, while banks with lesser leverage would witness an enhancement in lending. The calculation of Tier 1, Tier 2 and Leverage Ratio follows the formulas below.

$$Tier I = \frac{\sum_{t=0}^{\infty} Prudential Equity Capital}{\sum_{t=0}^{\infty} Risk Weighted Assets} \geq 10\% \quad (3.2)$$

$$\sum_{t=0}^{\infty} Risk Weighted Assets = \sum_{t=0}^{\infty} Credit Risk + \sum_{t=0}^{\infty} Market Risk + \sum_{t=0}^{\infty} Operational Risk \quad (3.3)$$

$$Tier II = \frac{\sum_{t=0}^{\infty} Adjusted Prudential Equity Capital}{\sum_{t=0}^{\infty} Risk Weighted Assets} \geq 15\% \quad (3.4)$$

$$Leverage ratio = \frac{\sum_{t=0}^{\infty} Tier I Capital}{\sum_{t=0}^{\infty} Exposure or Total Assets} \geq 3\% \quad (3.5)$$

The available research acknowledges liquidity as a significant factor influencing bank lending (Alper et al., 2012). In academic research, it is common to use asset and liability ratios, as opposed to Basel specific liquidity risk ratios. The main motivation is mainly due to the complexity of calculating and estimating Basel liquidity standards in linear models, hence there have not been many papers that have used Basel III specific liquidity measures or their proxies to examine the effects of liquidity standards on bank lending growth. According to the Basel Committee on Banking Supervision (2010), in the aftermath of the 2008 financial crisis, Basel III introduced two distinct liquidity ratios, namely the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The Liquidity Coverage Ratio (LCR), as discussed earlier on, requires banks to keep an adequate amount of High-Quality Liquid Assets (HQLA) to endure a period of heightened deposit withdrawals lasting one month. The Net Stable Funding Ratio (NSFR) requires banks to have a stable funding base and to finance long-term assets, to some extent, with longer-term liabilities such as bank bonds.

The Liquidity Coverage Ratio (LCR_{cp}) is calculated by dividing the High-Quality Liquid Asset (HQLA) by the Adjusted Available Stable financing (AASF) with consideration for financing run-off rates according to Basel Committee on Banking Supervision (2013). The AASF is a representation of the cash outflow that is expected to occur during a 30-day period, particularly under situations of heightened liquidity stress. The 30-day timeframe is deemed suitable in order to provide the financially strained bank with an opportunity to secure liquidity lines, such as the Central Bank Liquidity Bail Out Credit Lines. The stable funding measure is the ratio of the available amount of stable funding to the required amount of stable funding (GASF_{cp}). The measure of stable funding refers to the aggregate value of an organization's capital, market funding, and term deposits that have a duration of one year or more. Additionally, it includes a proportion of stable demand deposits, with durations of less than one year, which are anticipated to remain within the institution. The measurement of Available Stable Funding (ASF) is determined by assessing the overall stability of an institution's funding sources. This evaluation considers various factors such as the contractual maturity of the bank's liabilities and the varying likelihood of different funding providers withdrawing their funding. The determination of stable funding is

achieved by the allocation of an ASF Factor, ranging from 0% to 100%, to the capital and liabilities recorded on the bank's balance sheet (Basel Committee on Banking Supervision, 2013). This allocation is contingent upon many factors such as liquidity flight, convertibility, liquidity conversion, and the entity's accessibility to funds during periods of liquidity strain. The aforementioned parameters are shown in the table provided. Regulatory capital, as per the requirements of Basel I, II, and III, is allocated an ASF factor of 100% (1) prior to the application of capital deductions. Demand and savings deposits, on the other hand, are assigned an ASF factor of 70% (0.7), indicating their susceptibility to deposit flight during periods of significant liquidity stress. Term deposits and long-term borrowings, which include subordinated obligations such as Tier 2 loans, are allocated an ASF factor of 100% (1). The ASF Factor of 0% is allocated to short-term borrowings and other derivative obligations as a result of their lack of stability and susceptibility to significant liquidity outflows during times of crisis.

The determination of the necessary level of stable financing is conducted by evaluating the overall features of the liquidity risk profile associated with the bank's assets and off-balance sheet exposures. The calculation of the necessary stable funding is initiated by applying an RF factor, ranging from 0% to 100%, to the balance sheet carrying the value of the bank's assets based on the level of illiquidity. Illiquid assets, such as intangible assets, property plant and equipment, other assets, and commercial loans, are given a risk-free rate (RFR) of 0%. Assets with high liquidity such as cash and cash equivalents, unencumbered treasury assets, and trading assets, are designated with a Risk Factor (RF) of 100% (1). In the context of required funding calculations and the determination of High-Quality Liquidity Assets (HQLA), loans are often regarded as having low liquidity. Specifically, consumer loans are given a Risk Factor (RF) of 25% (0.25), whereas other loan types are allocated an RF of 0%. Stable Funding Ratio (SFR) refers to the proportion of Available Stable Funding (ASF) to Required Stable Funding (RSF), as previously discussed.

Table 3.2: Basel III Asset and Liability Liquidity Factors

Balance sheet asset class		Balance sheet liability class	
Required stable funding (High-Quality liquid assets (HQLA))	Factor	Available stable funding (ASF)	Factor
Cash and cash equivalents	1	Demand and savings deposits	0.7
Trading securities	1	Time deposits	1
Consumer loans	0.25	Short term borrowings	0
Commercial loans	0	Long term borrowings	1
Other loans	0	Derivative liabilities	0
Intangible assets	0	Other liabilities	1
Fixed assets	0	Subordinated debentures	1
Other assets	0	Total equity	1

Source: Basel Committee on Banking Supervision (2013)

As elucidated in Section 3, the influence of asset liquidity and financing stability on the expansion of bank lending remains inconclusive. The outcome is contingent upon the macroeconomic dynamics inside a particular country. In countries such as Malawi, where the government engages in significant domestic borrowing, banks may exhibit a preference for lending to the government via treasury assets rather than extending loans and advances to customers, even in the presence of heightened liquidity.

In this particular scenario, the implementation of the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR) might potentially provide either advantageous or disadvantageous outcomes for lending activities.

The calculation of LCR and SFR follows the formula below:

$$LCR = \frac{\sum_{t=0}^{\infty} \text{High Quality Liquid Assets}}{\sum_{t=0}^{\infty} \text{Total net cash outflows over the next 30 day calendar}} \geq 100\% \quad (3.6)$$

$$NSFR = \frac{\sum_{t=0}^{\infty} \text{Available amount of stable funding to 1 year}}{\sum_{t=0}^{\infty} \text{Required amount of stable funding to 1 year}} \geq 100\% \quad (3.7)$$

The bank's main risk is the management of its credit risk, the risk that is attached to customers who are unable to pay back what they have borrowed when it is due. The risk management systems for banks largely are designed to identify, prevent and mitigate the negative effects of credit risk on the bank's performance and capital management. Hence the developments in the credit risk of a bank largely shape how much credit the bank is able to offer to the market and at what price, despite the fact that a pricing jurisdiction like Malawi is to some extent controlled, and banks are not free to price the risk they assume. The increase in credit risk is expected to result in banks making increased expected credit losses (ECLs) that reduce their profitability, hence eroding their capital base. As such, banks will naturally reduce lending or shift portfolios to some safe assets.

Empirical studies such as those of Stiglitz & Weiss (1981), Berrospide & Edge (2010), Alhassan et al. (2013), and Cucinelli (2015) show that under periods of economic downturn and where credit risk is elevated, banks curtail lending growth. This study uses changes in impairments at the balance sheet level, namely *Impaircpi*, as a surrogate measure for assessing credit risk. Additionally, we have included an IFRS 9 impairment dummy variable. It is worth noting that banks in Malawi implemented the International Financial Reporting Standard 9 (IFRS 9) in the year 2018. This indicates that the methodology for determining credit losses has transitioned from the incurred loss approach mandated by IAS 39 to the anticipated credit loss approach as prescribed by IFRS 9. The dummy variable assumes a value of zero for the period spanning from 2010 to 2017, and afterwards takes on a value of one for the time frame including 2018 to 2022. Banks also largely grow their balance sheet in accordance with their risk appetite and this is seen as an important determinant that influences banks' ability to shift portfolios.

According to Peersman (2012), the developments in yield curves that affect the long-term path of interest rates serves as a motivation for banks to replace loans to the private sector on their balance sheets with government loans and securities. When interest rates on government papers are high in Malawi, banks shift much of their lending towards the accumulation of treasury instruments. Conversely, when these rates are low, banks increase lending to the private sector in search of higher margins. On the other hand, elevated

government bond rates give rise to heightened cost opportunities for banks in terms of loan issuance, leading to a reduction in the availability of new loans. Consequently, it is anticipated that there exists a positive correlation between the risk appetite of banks and the expansion of lending activities. The return on assets (ROA_{ratcpi}) is a proxy of banks' risk appetite, as seen in studies by Setiyono & Tarazi (2014). The relationship between profitability and bank loan growth is inconclusive in literature. Some studies have shown a positive relationship between profitability measures and bank lending whilst others have shown a negative relationship (Laidroo, 2014).

The prospect of greater profitability serves as a motivating factor for banks to expand their lending activities. In markets where the financial systems are well developed and where the banking sector is highly competitive, banks are able to increase margins in activities other than lending, such as generating substantial revenues in non-interest related incomes. This decreases their appetite for loan growth as an avenue to generate profits. In contrast, in developing and underdeveloped markets, banks have fewer avenues to increase margins, other than lending to the government and private sector. In these markets, banks' ability to increase lending is also dependent on how profitable they are.

The measurement of profitability in the banking industry is often assessed using the return on equity (ROE_{ratcpi}) metric, which signifies the bank's capacity to effectively use its capital to produce financial gains. The significance of bank size in influencing bank asset allocation choices has been well documented in empirical studies such as those of Berger and Udell (2006) and Uchida et al. (2008). For instance, Berger & Udell (2006) found that there is a negative correlation between the size and complexity of banks, on the one hand, and their lending activities towards small-scale enterprises, on the other. The bigger the banks, the more likely they are to switch lending to interbank accumulations of treasury instruments than lending to small scale firms.

According to Stein (2002), relatively small banks possess competitive advantages in the production of soft information. Therefore, it is anticipated that there would be a negative correlation between the size of a bank and its loan growth. Nevertheless, it has been

observed that the ability of big and intricate banks to analyse and interpret non-quantifiable information about small-scale enterprises, using their technical proficiency and benefiting from economies of scale, results in a favourable correlation between the size of the bank and the expansion of loan activities (Boyd & Runkhle, 1992). The measurement of bank size is represented by a log difference growth of total assets, denoted as TAcpi. According to Brei et al. (2013), it is crucial to consider the influence of mergers and acquisitions, as well as prospective alterations in financial statement reporting, that may cause disruptions in certain bank positions. By doing so, the analysis disregards an artificial increase in loan growth that is mostly attributed to mergers between banks or modifications in financial statement reporting practices. In accordance with the study conducted by Bouvatier & Lepetit (2012), a dummy variable (referred to as a merger dummy) is used to capture the aforementioned impacts. The merger dummy variable is assigned a value ranging from 0 to 1, representing the time period before and after a merger occurs in each bank.

3.7.3 Macroeconomic Variables and their influence on Bank Lending

When examining the factors that influence bank lending supply, it is crucial to consider not only the unique characteristics of individual banks, but also the broader macroeconomic conditions and the impact of credit demand. To achieve a comprehensive understanding, researchers have utilised country-level time series data in their studies on this topic (Ehrmann et al., 2003; Gambacorta, 2005; Carlson et al., 2013; Brei et al., 2013; Berrospide & Herrerias, 2015). One of the key determinants of the ability of banks to grow their balance sheet, thereby increasing their loan growth, is the level of economic activities. The optimal balance sheet investment choices or asset allocative efficiencies is often expected to be influenced by the macroeconomic environment (Chen et al., 2010; Pana et al., 2010). During periods of economic boom, there is a general increase in demand for financial products. The reverse is true during recessions, as businesses experience foreclosure and banks often scale down credit expansion.

This heightened demand might potentially enhance a bank's capacity to extend its loan portfolio at an accelerated pace. In the same vein, economic recessions are made worse by bank inability to extend credit when it is needed the most. This suggests the existence of a

procyclical association between economic growth and bank lending (Talavera et al., 2006; Dagher et al., 2016; Pruteanu-Podpiera, 2007; and Ladime et al., 2013). Bank lending is assessed in terms of the annual growth rate of nominal gross domestic product (GDPcpi). It is anticipated that this variable will have a favourable influence on the increase of bank lending. The study also examines the impact of monetary policy on bank lending behaviour, as shown in previous research conducted by Ehrmann et al. (2003), Abdkarim et al. (2007), Chami & Cosimano (2009), and Brei et al. (2013). The influence of monetary policy on bank lending is captured by the introduction of the interbank rate (IBRcpi). The choice of an interbank rate is motivated by the fact that the Reserve Bank of Malawi uses a corridor band that monitors the trajectory of the interbank rate and the policy rate and any fluctuations outside the band result in policy rates adjustments. It is expected that this variable will have a negative impact on bank lending. Ang et al. (2017) examined the effects of significant changes in the regulatory environment between 2008 and 2015, namely the phased implementation of Basel III. To measure these consequences, the researchers devised a country-specific index that quantifies the degree of implementation of Basel III across time. Some researchers have employed the strategy of introducing a switching dummy variable that takes the value between 0 and 1 to account for different Basel regimes. We also adopt a similar approach of introducing dummy variables to account for the switch between Basel I in the 2000s and Basel II in 2014.

3.8 Data and Sources

Table 3.3 presents the dependent and independent variables used in the study, their expected signs, and the sources of data used in the analysis. This research employs monthly panel data, which entails aggregating the data from commercial banks in Malawi from January 2010 to December 2022. The data used in this study was obtained from the Reserve Bank of Malawi Website Database, as well as the yearly financial statements of the banks operating in Malawi. These sources were selected to gather information on particular bank features. The research used Stata 15.0 software for doing econometric estimates.

Table 3.3: Variables, expected signs, and data sources.

Variable name	Variable description	Expected signs	Rationale	Source
Lndpcpi	Monthly growth rate of loans		The dependent variable	Banks AFS
Tier1ratcpi	Tier 1 ratio	+	An increase in capital levels should lead to increased lending	Banks AFS
Tier2ratcpi	Tier 2 ratio	+	An increase in capital levels should lead to increased lending	Banks AFS
Levcpi	Leverage ratio	-	An increase in leverage should lead to a decrease in lending	Calculated using banks AFS data
LCRratcpi	Liquidity coverage ratio	- /+	An increase in liquidity should lead to an increase in lending	Calculated using banks AFS data
SFRratcpi	Stable funding ratio	- /+	An increase in stable funding should lead to an increase in lending	Calculated using banks AFS data
ROAcpi	Return on assets	+	An increase in return on assets should lead to an increase in lending	Calculated using banks AFS data
ROEcpi	Return on equity	+	An increase in return on equity should lead to an increase in lending	Calculated using banks AFS data
TAcpi	Total bank size	+	The bigger the bank size should lead to more lending	Calculated using banks AFS data
GDPcpi	GDP	+	The higher the GDP, the higher should be the share of credit/Lending in the economy	NSO and generated series as discussed in Appendix A2.7.6

3.9 Robustness Check

The summary of model robustness checks is presented in Table 3.4. Our data had heteroscedasticity. Therefore, we utilized the generalized least squares estimator (GLS), which incorporates heteroscedasticity, cross-sectional, and serial correlations directly into the estimate process. Academic literature recognises the efficiency of Generalised Least Squares (GLS) above Ordinary Least Squares (OLS). To operationalize the GLS in our model, we analysed feasible generalized least squares (FGLS). Hansen (2007) used FGLS estimation to solve serial correlation and clustering difficulties in fixed effects panel and multilevel models. The first robustness check conducted on the variables of the model is that of stationarity. Our study employed several panel unit root or stationarity tests, such as the Levin–Lin–Chu (2002), Harris–Tzavalis (1999), Breitung (2000); Breitung & Das (2005), Im–Pesaran–Shin (2003), Fisher-type Choi (2001), and Hadri (2000) Lagrange multiplier (LM) tests. The null hypothesis of the Levin–Lin–Chu (2002), Harris–Tzavalis (1999), Breitung (2000); Breitung and Das (2005), Im–Pesaran–Shin (2003), and Fisher-type Choi (2001) tests posits that all the panels have a unit root. The null hypothesis of the Hadri (2000) Lagrange multiplier (LM) test states that all the panels exhibit (trend) stationarity. The inclusion of options enabled us to include fixed effects and temporal trends into the model of the data-generating process. Most of the tests in this context use the assumption that the panel datasets are balanced. However, there are two tests, namely the Im-Pesaran-Shin test and the Fisher-type test, that accommodate unbalanced panels.

The available information strongly contradicts the null hypothesis of a unit root, leading to the conclusion that all variables used in the model exhibit stationarity. The findings are shown in Appendix B3.2. The second robustness check that we conducted was the test for an appropriate model framework to be used in our study from several panel data options. The first step in our investigation was assessing the suitability of the Ordinary Least Square (OLS), Fixed Effects Panel Data (FE), and Random Effects Panel Data (RE) frameworks as potential models for estimating the observation equations. The first decision was to use a fixed-effects estimate method, since it was believed that the sample of banks was not selected randomly from the whole population of banks.

However, it should be noted that the data specifically pertains to the prominent financial entities in Malawi. Consequently, it might be argued that the random effects estimator may not be suitable in this context, since this decision is often made based on a general guideline rather than a rigorous model selection approach. However, the rule of thumb model selection approach must be supplemented with additional collaborative model choosing selection criteria. Therefore, prior to selecting the optimal regression technique, it was necessary to ascertain if the predictor variables in our model exhibit endogeneity. In this study, we conducted a test to identify the presence of endogenous regressors (predictor variables) in a regression model. Specifically, we employed the Hausman Test, which is also referred to as the Hausman specification test, the Durbin-Wu-Hausman (DWH) test, or the augmented regression test for endogeneity. The purpose of this test was to examine for panel endogeneity or model misspecification.

The linear regression model may be expressed as $y_t = z_t' \delta_0 + \varepsilon_t$, $t = 1, \dots, n$, where t represents the time period ranging from 1 to n . In the model above, z_t represents a $L \times 1$ vector of explanatory variables, δ_0 denotes the vector of unknown coefficients, and ε_t represents the random error term. The second equation's model incorporates the potential for correlation between the elements of z_t and the error term ε_t , implying that there exists a possibility where $E[z_{tk} \varepsilon_i] \neq 0$ for a certain k . An endogenous variable is defined as z_{tk} if $E[z_{tk} \varepsilon_i] \neq 0$. The presence of endogenous variables in z_{tk} has been widely acknowledged to result in bias and inconsistency of the least square estimator δ_0 in the second equation. Endogenous variables are characterized by their values being determined by other variables inside the system. The presence of endogenous regressors in a model may lead to the failure of ordinary least squares (OLS) estimators, since one of the underlying assumptions of OLS is the absence of correlation between predictor variables and the error term. In this scenario, instrumental variable estimators may serve as a viable option. The use of the Hausman test facilitated the selection process between a fixed effects model and a random effects model. The null hypothesis posits that the chosen model follows a random effects framework, whereas the alternative hypothesis suggests that the model adheres to a fixed effects framework. In essence, the tests aim to ascertain if there exists a link between the distinct mistakes and the regressors inside the model.

The null hypothesis posits that there is no statistically significant link between the two variables under investigation. The available data strongly contradicted the null hypothesis that the preferred model is based on random effects. Consequently, it is determined that the most suitable model is the fixed effects model. The null hypothesis was rejected due to the tiny p-value (less than 0.05). The findings are shown in Appendix B3.3. The third robustness check was the test for cross sectional dependence and contemporaneous correlation upon selecting the Fixed Effect Model based on the outcomes of the Hausman Test. Next, we conducted a test to examine the presence of contemporaneous correlation, specifically to see whether there is a lack of connection among the residuals across the various banks. Baltagi (2008) posits that the issue of cross-sectional dependency arises in macro panels characterised by lengthy time series spanning a duration beyond 20-30 years. The test that was performed was the Breusch-Pagan Lagrange Multiplier Test of Independence. The null hypothesis in the B-P/LM test of independence posits that there is no correlation among residuals across entities. Based on the test findings, it was determined that the null hypothesis could not be rejected due to the little p-value (less than 0.05). Consequently, it was established that there exists a correlation across the panels, indicating the presence of cross-sectional dependency. The findings are shown in Appendix B3.3.

As previously indicated, the presence of cross-sectional dependency is a more prominent concern in macro panels, characterised by lengthy time series spanning over 20 or more years, as opposed to micro panels. In our particular scenario, the duration of our panels is limited to a maximum of 13 years, which may be considered quite short. Consequently, we performed an alternate examination to assess the presence of contemporaneous association. The Pesaran CD (cross-sectional dependency) test was used to examine the presence of correlation among the residuals across entities in micro panels. Cross-sectional reliance has the potential to introduce bias in test outcomes, which is sometimes referred to as contemporaneous correlation. The null hypothesis posits that there is no correlation among the residuals. Based on the test findings, it was determined that the null hypothesis could be accepted. This conclusion was drawn due to the observation of a significant p-value beyond the threshold of 0.05. Consequently, it was inferred that there was no correlation

among the panels, indicating the absence of cross-sectional dependency. The findings are shown in Appendix B3.3.

Lastly, we conducted the robustness check for heteroscedasticity of the residuals. Heteroscedasticity testing was also conducted for the fixed-effects model. The null hypothesis posits that there exists homoscedasticity, which refers to the assumption of constant variance. Heteroscedasticity poses a challenge since it violates the assumption of homoscedasticity in ordinary least squares (OLS) regression, where it is assumed that all residuals are derived from a population with a consistent variance. To adhere to the regression assumptions and establish confidence in the findings, it is essential that the residuals exhibit consistent variance and adhere to the prescribed Ω form. The symbol Ω represents a matrix composed of three blocks, each containing the scalar σ multiplied by the identity matrix I , with zeros in the remaining entries.

$$\Omega = \begin{bmatrix} \sigma I & 0 & 0 \\ 0 & \sigma I & 0 \\ 0 & 0 & \sigma I \end{bmatrix} \quad (2.8)$$

Nevertheless, it is worth noting that in several cross-sectional datasets, there exists variation in the variance across different panels. It is a prevalent practice to collect data pertaining to banks or other entities that exhibit variances in scale as a result of distinct bank-specific features, such as disparities in loan book sizes and disparities in balance sheet sizes. The `xttest3` heteroscedasticity test was conducted using Stata software. The null hypothesis of the test posits the presence of homoscedasticity, indicating constant variance. Based on the test findings, it was determined that the null hypothesis could be rejected, as the p-value was discovered to be less than 0.05. Consequently, it was established that there is heteroscedasticity among the panels. The findings are shown in Appendix B3.3. Given the existence of heteroscedasticity, we made the decision to modify the model from panel data with fixed effects, as previously suggested by the Hausman test, to a model that incorporates heteroscedasticity. Heteroscedasticity, cross-sectional correlations, and serial correlations are significant issues that arise in the error terms of panel regression models. There are two distinct techniques for addressing these issues. One possible method is to employ the ordinary least squares (OLS) estimator, while incorporating robust standard errors that account for heteroscedasticity and correlations. This can be achieved through

various approaches, such as those proposed by White (1980), Newey & West (1987), Liang and Zeger (1986), Arellano (1987), Driscoll & Kraay (1998), Hansen (2007), Vogelsang (2012), and other relevant studies.

Clustered standard errors, such as those discussed by Petersen (2009), Wooldridge (2010), and Cameron & Miller (2015), are often used in statistical analysis. In their study, Bai et al. (2021) put forward a method for estimating resilient standard errors in the presence of unknown clusters. Abadie et al. (2017) advise against the indiscriminate use of clustered standard errors due to the potential for conservative confidence intervals. The alternative method involves using the Generalized Least Squares estimator (GLS), which incorporates heteroscedasticity, as well as cross-sectional and serial correlations, directly into the estimate process. The greater efficiency of the Generalised Least Squares (GLS) method in comparison to Ordinary Least Squares (OLS) is widely acknowledged in academic literature.

This study focuses its attention on the second method. In the context of panel models, the covariance matrix underpinning the analysis encompasses a substantial number of parameters. Ensuring the operationalization of the Generalised Least Squares (GLS) method has significant importance. Therefore, we proceed to examine the concept of Feasible Generalised Least Squares (FGLS). In a study conducted by Hansen (2007), the focus was on the use of FGLS estimation in addressing the challenges posed by serial correlation and clustering issues in fixed effects panel and multilevel models. The Feasible Generalised Least Squares (FGLS) estimator is more efficient than the Generalised Least Square (GLS) and Ordinary Least Squares (OLS) estimators in the presence of heteroskedasticity, serial and cross-sectional correlations. The technique that is employed requires prior knowledge of the cluster structure. The presence of an unknown cluster structure is assumed, and the issue of heteroscedasticity, as well as both serial and cross-sectional correlations, is addressed by consistently calculating the large error covariance matrix. Romano et al. (2019) successfully derived asymptotically correct inference for the FGLS estimator in a cross-sectional situation. They achieved this by including heteroscedasticity consistent standard errors, even in the absence of information about the

functional form of conditional heteroscedasticity. Furthermore, Miller & Startz (2018) have made modifications to machine learning techniques, specifically in support of vector regression, in order to include the presence of misspecified heteroscedasticity.

The current work examines three key aspects: (i) the utilisation of balanced panel data, (ii) the scenario including a high number of observations and time periods, and (iii) the presence of both serial and cross-sectional correlations, while acknowledging the uncertain structure of clusters. In this study, we provide a Feasible Generalised Least Squares (FGLS) estimator that effectively addresses the issues of cross-sectional and serial correlation bias. Our proposed approach involves the use of a high-dimensional error covariance matrix estimator. Furthermore, our suggested methodology is suitable in cases when information about clusters is not accessible.

Table 3.4: Model robustness check results.

Type of test	Method used	Null hypothesis	Result	Way forward
Panel unit root test	Levin-Lin-Chu (2002), Haris-Tzavalis (1999), Breitung (2000), Breitung and Das (2005), Im-Pesaran-Shin (2003), Fisher-type (Choi, 2001), and Hadri (2000) Lagrange multiplier (LM)	The null hypothesis is that all panels have a unit root.	The data strongly rejects the unit root null hypothesis, indicating stationarity for all model variables.	-
Model selection test	Hausman specification test, Durbin-Wu-Hausman (DWH)	The null hypothesis states that the model uses random effects, while the alternative hypothesis states that it uses fixed effects (FE)	The data substantially defied the null hypothesis that the preferred explanation is random effects. Thus, the fixed effects model is best. The low p-value (0.05) rejected the null hypothesis.	We carried further robustness checks to reaffirm whether the FE model was indeed appropriate, such as Heteroscedasticity and Contemporaneous Correlation
Endogeneity test	Hausman specification test, Durbin-Wu-Hausman (DWH)	The Hausman test helps to determine if an independent variable is correlated with the error terms, which in turn violates the assumption of exogeneity in regression analysis	The high p-value (>0.05) accepted the null hypothesis of no endogeneity, meaning the estimator is not biased and is consistent. The fixed effects model was a recommended and was not misspecified model	A further FE robustness test was done, to check for the presence of panel cross-dependence and contemporaneous tests as well as panel Heteroscedasticity test.
Cross-dependence and contemporaneous test	Breusch-Pagan Lagrange multiplier test of independence was done Pesaran CD (Cross-sectional dependence)	The B-P/LM test of independence null hypothesis states that residuals across entities are uncorrelated The null hypothesis states that residuals are uncorrelated.	The test results showed that the null hypothesis could not be rejected due to the low p-value (0.05). This conclusion was obtained due to a significant p-value over 0.05. Thus, there was no association between panels, showing no cross-sectional dependency.	-
Heteroscedasticity test	Stata performed the xttest3 heteroscedasticity test	The test null hypothesis is homoscedasticity, suggesting constant variance	It was found that panels are heteroscedastic.	Given heteroscedasticity, we changed the model to a Feasible Generalised Least Square (FGLS) model.

3.10 Empirical Results and Discussions

3.10.1 The Impact of Basel III Capital Ratios on the Banking Sector

The regression results are shown in Table 3.5. When examining capital ratios, it is seen that the risk-weighted capital ratio, namely Tier 1, has a positive influence on the growth of lending in the banking sector of Malawi. However, its impact on the overall loan growth is found to be significant. On the other hand, Tier 2 capital ratio has a negative effect on the growth of lending in the banking sector as a whole, although this effect is not statistically significant. The implementation of non-risk weighted asset Basel III leverage ratios has been shown to have substantial and adverse effects on the development of lending in the banking industry of Malawi. When examining liquidity ratios, it is observed that the implementation of the Liquidity Coverage Ratio (LCR) has a statistically significant negative impact on the variability of lending in the overall banking sector of Malawi. Conversely, the introduction of the Stable Funding Ratio (SFR) has a statistically significant positive effect on the growth of lending in the banking sector as a whole. The coefficients are reported in Appendix B3.1.

Table 3.5: Summary of effects of Basel III capital and liquidity regulations on banks' lending.

Bank name	Tier 1 ratio (Tierratcpi)	Tier 2 ratio (Tier2ratcpi)	Leverage ratio (Levratcpi)	Liquidity coverage ratio (LCR)	Stable funding ratio (SFR)
All banks	+ve *(Sig)	-ve (Insig)	-ve *** (Sig)	+ve *** (Sig)	+ve *** (Sig)

Note: *** p<0.01, * p<0.1.

When segmented banks are examined by asset size, the risk-weighted capital ratio, especially Tier 1, positively affects the lending growth of two major banks, four medium banks, and two small banks. However, Tier 2 significantly reduces loan growth for Malawi's two major and two small banks.

On the other hand, Tier 2 significantly boosts the loan growth of the four midsize banks. Basel III leverage ratios, which ignore asset risk weighting, have reduced loan growth in Malawi, affecting the two major banks, four medium-sized banks, and two small banks. Implementing the Liquidity Coverage Ratio (LCR) has a statistically significant negative impact on the lending variability of two large banks and a positive impact on the lending behaviour of four medium-sized banks and two small banks in Malawi. In contrast, the Stable Funding Ratio (SFR) has a statistically significant negative effect on the loan growth of two major banks and four medium-sized banks in Malawi, while it positively impacts two small banks. Table 3.6 presents the regression results of the study when banks are segmented by asset size as discussed above. The coefficients are reported in Appendix B3.1.

Table 3.6: Summary of effects of Basel III capital and liquidity regulations on banks' lending.

Bank name	Tier 1 ratio (Tier1ratcpi)	Tier 2 ratio (Tier2ratcpi)	Leverage ratio (Levratcpi)	Liquidity coverage ratio (LCR)	Stable funding ratio (SFR)
2 big banks	+ve *** (Sig)	-ve *** (Sig)	-ve *** (Sig)	-ve *** (Sig)	-ve ** (Sig)
4 Middle Banks	+ve *** (Sig)	+ve * (Sig)	-ve *** (Sig)	+ve *** (Sig)	-ve ** (Sig)
2 Small Banks	+ve ** (Sig)	-ve ** (Sig)	-ve *** (Sig)	+ve (Insig)	+ve * (Sig)

Note: *** p<0.01, ** p<0.05, * p<0.1.

3.10.2 The Impact of Additional Non-Basel III Factors on the Banking Industry

Various empirical studies have shown that credit risk, bank size, cost of financing, nominal GDP growth rate, mergers, bank size, return on equity, return on assets and equity, and loan to deposit ratio affect bank lending in various nations. Tables 3.7 and 3.8 summarise our results on these influences on Malawi's banking industry and fragmented banking sector. The coefficients are reported in Appendix B3.1.

Table 3.7: Summary of effects of other non- Basel III factors on banks' lending (all banks).

Bank name	Impairments (Impaircpi)	Bank size (TAcpi)	Return on equity (ROE)	Loan to deposit ratio (LDR)	Gross domestic product (GDP)	Merger dummy	Basel dummy
All banks	+ve *(Sig)	+ve *** (Sig)	-ve *** (Sig)	-ve ** (Sig)	+ve *** (Sig)	+ve ** (Sig)	+ve *** (Sig)

Note: *** p<0.01, ** p<0.05, * p<0.1

Table 3.8: Summary of effects of other non- Basel III factors on banks' lending (segmented).

Bank name	Impairments (Impaircpi)	Bank size (TAcpi)	Return on equity (ROE)	Return on assets (ROA)	Loan to deposit ratio (LDR)	Gross domestic product (GDP)	Merger dummy	Basel dummy
2 big banks	+ve *** (Sig)	+ve *** (Sig)	-ve *** (Sig)	+ve (Insig)	+ve *** (Sig)	+ve *** (Sig)	-ve *** (Sig)	+ve *** (Sig)
4 middle banks	+ve (Insig)	+ve *** (Sig)	-ve *** (Sig)	+ve *** (Sig)	+ve (Sig)	+ve *** (Sig)	-ve *** (Sig)	+ve (Insig)
2 small banks	+ve *** (Sig)	+ve *** (Sig)	-ve (Insig)	+ve *** (Sig)	-ve ** (Sig)	+ve *** (Sig)	-ve *** (Sig)	+ve *** (Sig)

Note: *** p<.01, ** p<.05,

The loan growth within Malawi's banking sector is significantly and positively influenced by the credit risk associated with banks. The findings of our study align with the empirical findings of Berrospide & Edge (2010), Alhassan et al. (2013) and Cucinelli (2015), which concluded that credit risk has a negative impact on banks' capital position. Hence, in order to preserve the capital position, banks oftentimes reduce lending. In all jurisdictions, credit risk assets form a bigger component of risk weighted assets. The impact of bank credit risk on bank lending varies across different categories of banks in Malawi. Specifically, the influence is found to be substantial and positive for the two major banks and two small banks in the country. However, for the four middle banks in Malawi, the effect is deemed minimal, no matter favourable it is.

The size of banks has a significant and positive influence on the expansion of lending within the banking sector of Malawi. This observation indicates that smaller banks in Malawi have a tendency to approve a higher number of loan applications. Stein (2002) found that smaller banks had inherent strengths in generating qualitative information due to their extensive client networks, hence facilitating the expansion of their lending operations. The results of this study indicate that major financial institutions possess a greater capacity to mitigate their loan operations in response to external demands to downsize their asset portfolios. Large banks in Malawi are predominantly lenders on the interbank market and tend to accumulate financial investments. They engage in securitized lending and market operations, compared to small banks for whom loan origination is not the primary business. The impact of bank size risk on bank lending is shown to be statistically significant and positively correlated for the sample of two large banks, four medium-sized banks, and two small banks operating in Malawi's banking sector.

The loan growth in Malawi's banking sector is significantly and adversely affected by the Return on Equity (ROE). The influence of Return on Assets (ROA) on loan growth in the Malawian banking sector is both considerable and favourable. The lending expansion of the sector is shown to be insignificantly and negatively affected by the loan-to-deposit ratio (LDR). The impact of Return on Equity (ROE) on bank lending is found to be noteworthy

and adverse for the two major banks and four mid-sized banks in Malawi. However, the effect is deemed statistically negligible and negative for the two small banks.

The impact of Return on Assets (ROA) on bank lending is shown to be statistically significant and positive for the four middle banks and two small banks in Malawi. However, for the two big banks, the effect of ROA on bank lending is found to be statistically insignificant but still positive. The loan to deposit ratio (LDR) exhibits a notable and favourable impact on bank lending for two prominent banks, as well as four intermediary banks, within the context of the country. However, it demonstrates a large and adverse influence on lending activities for two smaller banks in the same region.

Additionally, it is worth noting that the growth rate of the nominal GDP has a noteworthy and favourable influence on the loan growth within the banking sector of the country. In light of enhanced economic circumstances, financial institutions exhibit a preference for extending their credit operations, as they provide better rates of return in comparison to alternative asset classes that produce lesser profits. In contrast, during periods of economic decline, banks reduce their lending activities in order to mitigate the risk of non-performing loans. The presence of a low-interest rate environment and a fiercely competitive banking market may result in a reduction of banks' interest margins, hence diminishing their inclination to engage in credit expansion endeavours.

The impact of gross domestic product (GDP) on bank lending is shown to be statistically significant and positively correlated for the sample of two large banks, four medium-sized banks, and two small banks operating in Malawi's financial sector.

Lastly, it can be seen that the merger and Basel dummies have a noteworthy and favourable influence on the increase of lending in the country's banking sector. The merger dummy variable has a substantial and adverse impact on the lending activities of the two major banks, four intermediate banks, and two small banks. The Basel dummy variable has a statistically significant and positive impact on bank lending for the two large banks and

two small banks. However, its influence on lending for the four medium-sized banks is shown to be statistically negligible, albeit favourable.

3.10.3 Results from Model Comparisons

Table 3.9 below exhibits the results from nesting seven models and varying different variables. As discussed in Section 3.8.1 above, it is observed that the risk-weighted capital ratio, specifically Tier 1, still has a significant and positive influence on the lending growth of the banking sector in Malawi, even across all the seven nested models where the only difference was alteration of variables. Tier 2 exhibits a negative and significant impact on lending growth for the banking sector in Malawi in all the seven models as well. The Basel III leverage ratios, which do not consider the risk weighting of assets, is shown to have notable and adverse effects on loan growth in Malawi, across model 1 to 4, and insignificant but negative effects in models 5 to 7. It is observed that the implementation of the Liquidity Coverage Ratio (LCR) has a statistically significant negative impact on the lending variability for models 1 to 3, as well as 7. The robustness check above suggests that with the introduction of Basel III Liquidity Coverage Ratio (LCR), we will see a reduction in bank lending. This in addition to enhanced capital rules of Tier 1 and Tier 2 under Basel III.

Table 3.9: Model comparison results after varying variables composition.

	Effects on Bank Lending						
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Tier1ratcpi	0.0282*** (0.0037)	0.0283*** (0.0037)	0.0286*** (0.0037)	0.0277*** (0.0037)		0.0248*** (0.0035)	0.0297*** (0.0037)
Tier2ratcpi	-0.0221*** (0.0038)	-0.0221*** (0.0038)	-0.0223*** (0.0038)	-0.0214*** (0.0038)		-0.0189*** (0.0035)	-0.0239*** (0.0038)
Levcpi	-0.0013** (0.0006)	-0.0013** (0.0006)	-0.0011** (0.0006)	-0.001* (0.0005)		-0.0005 (0.0005)	-0.0008 (0.0005)
Lcrratcpi	-0.0002** (0.0001)	-0.0002** (0.0001)	-0.0002* (0.0001)	-0.0001 (0.0001)	-0.0001 (0.0001)		-0.0003*** (0.0001)
Sfrat2cpi	0.0003 (0.0002)	0.0003 (0.0002)	0.0002 (0.0002)	0.0003 (0.0002)	-0.0001 (0.0002)		0.0002 (0.0002)
Lmdlbpaircpi	0.0016*** (0.0005)	0.0016*** (0.0005)	0.0016*** (0.0005)	0.0016*** (0.0005)	0.0021*** (0.0006)	0.0017*** (0.0005)	0.0018*** (0.0005)

Lmdpatcpi	0.0061**	0.0061**	0.0061**	0.0061**	0.0063**	0.0055**	0.0059**
	(0.0024)	(0.0024)	(0.0024)	(0.0024)	(0.0025)	(0.0024)	(0.0024)
Roecpi	-0.0017***	-0.0017***	-0.0018***	-0.0019***	-0.0017***	-0.002***	
	(0.0005)	(0.0005)	(0.0005)	(0.0004)	(0.0005)	(0.0004)	
Roacpi	0.0015**	0.0015**	0.0014**	0.0014**	0.0019***	0.0012**	
	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)	
Ldrcpi	0.0005	0.0006	0.0005	0.0003	0.0014**		0.0004
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)		(0.0007)
Lmdgdpcpi	1.3851***	1.3847***	1.3793***	1.3834***	1.3859***	1.385***	1.3858***
	(0.0199)	(0.0195)	(0.0198)	(0.0195)	(0.0205)	(0.0201)	(0.02)
Ldinb	0	0	-0.0001	-0.0002	0	0	0
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0007)
Merger dummy	0.0006**	0.0006**			0.0007**	0.0002	0.0006**
	(0.0003)	(0.0002)			(0.0003)	(0.0003)	(0.0003)
Basel dummy	0		0.0003		-0.0004	-0.0003	0
	(0.0003)		(0.0002)		(0.0003)	(0.0003)	(0.0003)
_Cons	0.0002	0.0002	0.0002	0.0003	0.0004	0.0006**	0.0002
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0002)	(0.0003)
Observations	1248	1248	1248	1248	1248	1248	1248
Pseudo R ²	. z	. z	. z	. z	. z	. z	. z
Basel dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Merger dummy	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note: Standard errors are in parentheses*** p<.01, ** p<.05, * p<.1

3.11 Conclusion

The consequences of the results presented in this paper have significant relevance for the development of policies and the establishment of regulatory frameworks within the banking sector. The impact of new capital and liquidity regulatory frameworks on banks' intermediation activities largely depends on the prevailing economic conditions in each jurisdiction, as well as the size and depth of financial markets that serve as sources of bank liquidity. In certain cases, these frameworks may prove to be ineffective or even harmful to the general intermediation role that banks play in economies. Banks might also switch the allocation of assets to optimise compliance and profitability, hence denying credit to the sectors that need it to spur economic growth.

One of the most important principles of bank regulation and supervision is the cardinal principle of “proportionality”: regulation and supervision should be tailored to the size and complexity of an institution, and to the risks it poses. Where allowed under applicable laws

and regulations, supervisory requirements can be applied more or less stringently. While proportionality can make rules simpler and the supervision of smaller or less complex institutions more straightforward, it should not necessarily be less stringent. However, the potential consequences of establishing capital and liquidity regulatory frameworks that are universally applicable to all banks may result in unintended outcomes, such as restricting banks from lending to certain economic segments within the economy, precipitating bank failures and, in the long run, creating banking oligopolies. The study's primary finding suggests that regulators should consider the diverse characteristics and behaviours of banks when implementing these stricter Basel III Liquidity Standards, perhaps by applying segmentation criteria as a roadmap to the adoption of these standards and allowing banks with different sizes a compliance window or waiver. This approach is crucial for financial stability and serves both micro and macroprudential purposes, as it will allow many financial institutions to survive and avoid market consolidations that bring in unnecessary monopolistic tendencies in the industry.

As part of consolidated risk management practices, banks will maintain, or invest in, a significant portion of High-Quality Liquid Assets (HQLA), and maintain a sizeable portion of stable long-term funding to withstand liquidity shocks emanating from market or macroeconomic shocks. By actively managing these risks, Basel III implementation will affect lending to governments and other economic agents hence making the crowding-out effects of public debt shocks discussed in Chapter 2 of this thesis more pronounced. Banks will hold significant HQLA for both liquidity and optimal capital management purposes, as a major portion of HQLA in Malawi is in the form of sovereign lending, which attracts zero capital charge in the computation of both Tier 1 and Tier 2 ratios.

With these mixed effects of Basel III on lending, the following assertion can be made: Basel III could be “necessary” but not “sufficient” for a healthy banking system and economic growth in Malawi—a “Jacobian” and not a “Hessian”. It is further recommended that Basel III must be accompanied by other measures and reforms. This leads to need to highlight the importance of the determinants of banking sector reforms in Malawi, an exercise that is undertaken in the last chapter of this thesis.

Appendix B3.1: FGLS Regression model

Banking Sector Impact Cross-sectional time-series FGLS regression

Lmdglbcpi	Coef.	St. err.	T-value	P-value	[95 % Conf	Interval]	ig.
tier1ratcpi	0.005	0.003	1.72	0.086	-0.001	0.011	*
tier2ratcpi	-0.001	0.003	-0.20	0.84	-0.007	0.005	
Levcpi	-0.005	0	-11.50	0.000	-0.006	-0.004	***
Lcrratcpi	0.0001	0	-3.74	0.000	0.000	0	***
sfrat2cpi	0.001	0	5.89	0.000	0.000	0.001	***
Lmdlbimpaircpi	0.001	0	1.92	0.055	0	0.002	*
Lmdtacpi	0.577	0.021	27.75	0.000	0.536	0.618	***
Roecpi	-0.002	0	-6.75	0.000	-0.003	-0.002	***
Roacpi	0.005	0.001	9.82	0.000	0.004	0.006	***
Ldrcpi	-0.001	0.001	-2.42	0.015	-0.003	0	**
Lmdgdpcpi	0.615	0.032	19.17	0.000	0.552	0.678	***
Ldinb	0	0.001	0.30	0.766	-0.001	0.001	
Mergerdummy	0	0	0.51	0.613	0	0.001	
Baseldummy	0.001	0	3.76	0.001	0	0.001	***
Constant	0	0	-0.97	0.331	-0.001	0	
Mean dependent var		0.00					0.007
		1					
Number of obs		1248		Chi-square			9793.317
Prob > chi2		0.00		Akaike crit. (AIC)			-11440.612
		0					

Note: *** p<.01, ** p<.05, * p<.1

Banks by Asset Category Threshold

Cross-sectional time-series FGLS regression: compXX = 2Big Banks

Lmdglbcpi	Coef.	St. err.	T-value	P-value	[95% Conf.	Interval]	Sig.
Tier1ratcpi	0.044	0.011	3.94	0	0.022	0.066	***
Tier2ratcpi	-0.039	0.01	-3.87	0	-0.058	-0.019	***
Levcpi	-0.044	0.007	-6.24	0	-0.057	-0.03	***
Lcrratcpi	-0.002	0.001	-3.12	0.002	-0.003	-0.001	***
Sfrat2cpi	-0.002	0.001	-2.34	0.019	-0.004	0	**
Lmdlbbimpcpi	0.028	0.006	4.41	0	0.016	0.041	***
Lmdtacpi	0.237	0.042	5.60	0	0.154	0.319	***
Roecpi	-0.014	0.003	-5.67	0	-0.019	-0.009	***
Roacpi	0.022	0.013	1.61	0.107	-0.005	0.048	
Ldrcpi	0	0.001	0.29	0.773	-0.001	0.002	
Lmdgdpcpi	0.909	0.045	20.04	0	0.82	0.998	***
Ldinb	0	0	-1.63	0.103	0	0	
Mergerdummy	-0.001	0	-5.27	0	-0.001	-0.001	***
Baseldummy	0.001	0	6.27	0	0.001	0.001	***
Constant	0.017	0.003	4.88	0	0.01	0.023	***
Mean dependent var	0.000		SD dependent var			0.006	
Number of obs.	156		Chi-square			105043.236	
Prob > chi2	0.000		Akaike crit. (AIC)			-2146.532	

Note: *** p<.01, ** p<.05

Cross-sectional time-series FGLS regression: compXX = 2Small Banks

	Coef.	St. Err.	t-value	p-value	[95% Conf	Interval]	Sig
Lmdglbcpi							
tier1ratcpi	0.038	0.017	2.27	0.023	0.005	0.071	**
tier2ratcpi	-0.02	0.01	-2.07	0.039	-0.04	-0.001	**
Levcpi	-0.106	0.018	-5.92	0	-0.141	-0.071	***
Lcrratcpi	0	0.001	0.43	0.668	-0.001	0.001	
sfrat2cpi	0.002	0.001	1.79	0.074	0	0.004	*
lmdlbpaircpi	0.075	0.012	6.17	0	0.051	0.099	***
Lmdtacpi	0.312	0.066	4.70	0	0.182	0.441	***
Roecpi	-0.017	0.01	-1.61	0.108	-0.037	0.004	
Roacpi	0.336	0.112	3.00	0.003	0.116	0.555	***
Ldrcpi	-0.005	0.003	-2.04	0.041	-0.011	0	**
Lmdgdpcpi	0.96	0.091	10.57	0	0.782	1.138	***
Ldinb	0	0.001	0.04	0.971	-0.002	0.002	
mergerdummy	-0.004	0.001	-6.66	0	-0.005	-0.003	***
Baseldummy	0.007	0.001	10.50	0	0.006	0.008	***
Constant	0	0	-0.06	0.953	0	0	
Mean dependent var	0.002		SD dependent var		0.007		
Number of obs.	156		Chi-square		7230.813		
Prob > chi2	0.000		Akaike crit. (AIC)		-1678.909		

Note: *** p<.01, ** p<.05, * p<.1

Cross-sectional time-series FGLS regression: compXX = 4Middle Banks

Lmdglbcpi	Coef.	St.err.	T-value	P-value	[95% Conf.	Interval]	Sig.
Tier1ratcpi	0.039	0.007	5.26	0	0.024	0.053	***
Tier2ratcpi	0.012	0.007	1.79	0.074	-0.001	0.026	*
Levcpi	-0.041	0.009	-4.27	0	-0.059	-0.022	***
Lcrratcpi	0.001	0	3.16	0.002	0.001	0.002	***
Sfrat2cpi	-0.002	0.001	-2.52	0.012	-	0	**
					0.003		
Lmdlbpaircpi	-0.006	0.013	-0.47	0.64	-0.032	0.02	
Lmdtacpi	0.451	0.038	11.75	0	0.376	0.526	***
Roecpi	-0.008	0.002	-	0.001	-0.012	-0.003	***
			3.48				
Roacpi	0.003	0.007	0.41	0.684	-0.01	0.016	
Ldrcpi	0.016	0.002	10.17	0	0.013	0.019	***
Lmdgdpcpi	0.743	0.05	14.88	0	0.645	0.841	***
Ldinb	0	0	-1.09	0.278	-0.001	0	
Mergerdummy	-0.002	0	-8.29	0	-0.002	-0.001	***
Baseldummy	0.001	0	7.60	0	0.001	0.002	***
Constant	-0.012	0.003	-4.46	0	-0.018	-0.007	***
Mean dependent var		0.001	SD dependent var			0.006	
Number of obs.		156	Chi-square			70509.242	
Prob > chi2		0.000	Akaike crit. (AIC)			-2076.311	

Note: *** p<0.01, ** p<0.05, * p<0.1

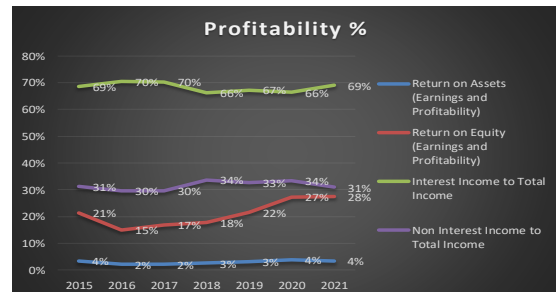
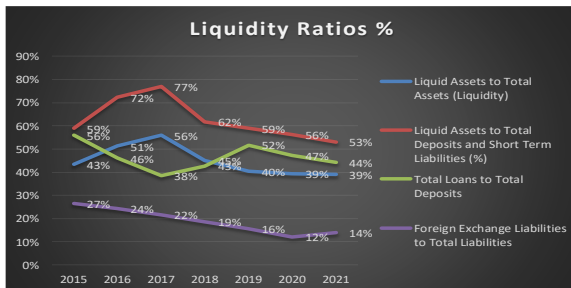
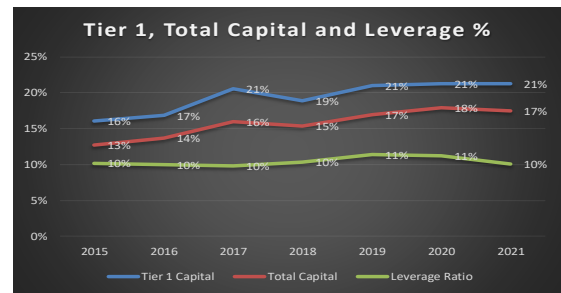
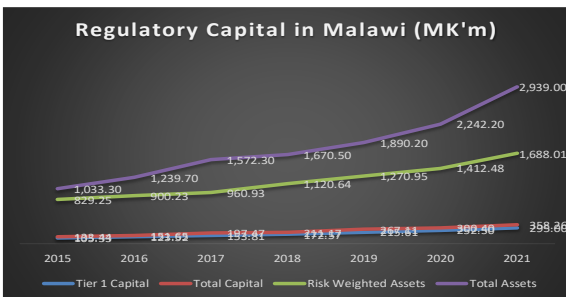
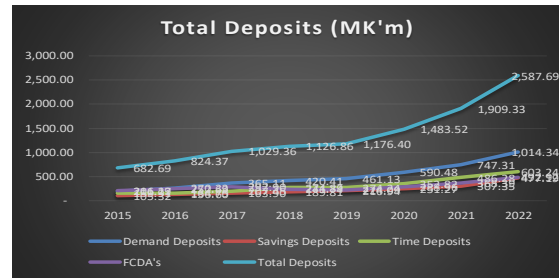
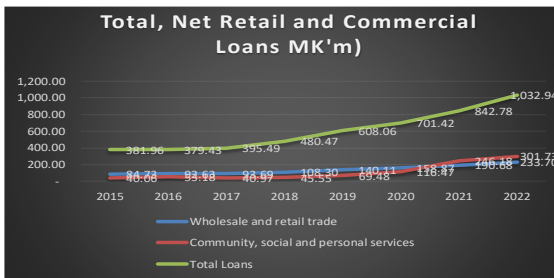
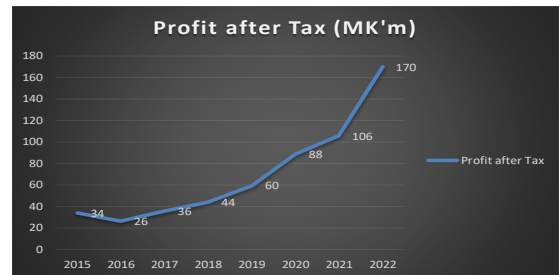
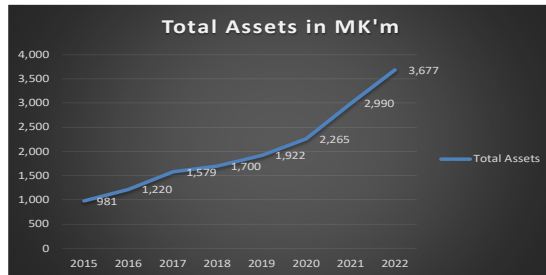


Figure 2.1- Lending growth, Capital ratios, Liquidity ratios, and Profitability in Malawi's Banking Sector

Appendix B3.2: Technical Analysis that leads to Model Selection of the FGLS Model

Appendix B3.2.1: Theoretical Modelling Framework

Various panel data estimation techniques, including Fixed Effect (FE), Random Effects (RE), Dynamic Panel Estimations (DPE), Generalised Least Square (GLS), and Feasible Generalised Least Square (FGLS), can be considered advancements of the Ordinary Least Squares (OLS) estimation technique. These techniques are built upon the theoretical framework of OLS. Hence, it is crucial that prior to justifying the selection of our modelling framework in Section 3.4.1, we start by examining the theoretical underpinnings of the modelling framework and proceed in a methodical way.

Appendix B3.2.2: Ordinary Least Square Panel Data

Typically, the primary aim of doing an Ordinary Least Squares (OLS) regression analysis is to minimise the sum of squared errors (residuals), denoted as ε . The Ordinary Least Squares (OLS) model may be represented in matrix notation as follows:

$$y = Xb + \varepsilon, \quad \text{where } \varepsilon = y - Xb \quad (\text{B3.1.1})$$

$$\sum \varepsilon_i^2 = [\varepsilon_1 \ \varepsilon_2 \ \dots \ \dots \ \varepsilon_n] \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \vdots \\ \varepsilon_n \end{bmatrix} = \varepsilon' \varepsilon \quad (\text{B3.1.2})$$

Therefore, we want to obtain the b that minimizes this function:

$$\begin{aligned} \varepsilon' \varepsilon &= (y - Xb)'(y - Xb) \\ &= y'y - b'X'y - y'Xb + b'X'Xb \\ &= y'y - 2b'X'y + b'X'Xb \end{aligned}$$

To complete the minimization procedure, we take the first-order derivative of the function $\varepsilon' \varepsilon$ with respect to b and set it to zero.

$$\frac{\partial \varepsilon' \varepsilon}{\partial b} = -2X'y + 2X'Xb = 0$$

To solve this, we subtract $2X'Xb$ from both sides:

$$-2X'y = -2X'Xb$$

This equation reduces to the below by further algebraic eliminations

$$(X'X)b = X'y$$

To solve for b the equation reduces to

$$b = \frac{X'y}{(X'X)} = (X'X)^{-1}X'y \quad (\text{B3.1.3})$$

The $X'X$ matrix is square, and therefore invertible (i.e., the inverse exists). However, the $X'X$ matrix can be non-invertible (i.e., singular) if $n < k$ – the number of k independent variables exceed the n – size – or if one or more of the independent variables is perfectly correlated with another independent variable. The $X'X$ matrix contains the basis for all the necessary means, variances, and covariances among the X 's.

$$X'X = \begin{bmatrix} n & \sum X_1 & \sum X_2 \\ \sum X_1 & \sum X_1^2 & \sum X_1X_2 \\ \sum X_2 & \sum X_2X_1 & \sum X_2^2 \end{bmatrix}$$

Appendix B3.2.3: Fixed Effects Panel Data

Equation B3.1.1, under OLS estimation techniques, as discussed above, can be transformed to equation B3.1.4. Given a panel data set of N cross-section units and T observations, the linear specification allowing for individual effects is:

$$y_{it} = x'_{it}\beta_i + e_{it},$$

$$i = 1, \dots, N, \quad t = 1, \dots, T \quad (\text{B3.1.4})$$

Where x_{it} is a $k \times 1$ and β_i is a parameter vector depending only on i but not on t . In this specification, individual effects are characterized by β_i and there is no time-specific effect. This may be reasonable when a short time series is observed for each unit.

Equation B3.1.1 above can be analogously expressed as:

$$y_i = X_i\beta_i + e_i \quad i = 1, 2, \dots, N \quad (\text{B3.1.5})$$

Where y_i is $T \times 1$, X_i is a $T \times k$, and e_i is a $T \times 1$. This is a system of equations with $k \times N$ parameters. Here, the dependent variable y and explanatory variables X are the same across individual units such that y_i and X_i are simply their observations for each individual i . For example, y in our case changes in bank lending, and each y_i contains specific bank i 's changes in lending. When T is small (i.e., observed time series are short), estimating equation B3.1.5 is not feasible. A simpler form of equation B3.1.5 is such that the intercept changes with i and the other parameters remain constant across i .

$$y_i = \ell_T a_i + Z_i b + e_i, \quad i = 1, 2, \dots, n \quad (\text{B3.1.6})$$

Where ℓ_T is the T -dimension vector of ones, $[\ell_T, Z_i] = X_i$, and $[a_i, b'] = \beta_i$. In the equation above, individual effects are completely captured by the intercept a_i . This specification simplifies equation B3.1.1 from kN to $N + k - 1$ parameters and is known as the fixed effects model. Staking N equations in equation B3.1.5 above together we obtain

$$(y) \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = (D) \underbrace{\begin{bmatrix} \ell_T & 0 & 0 \\ 0 & \ell_T & 0 \\ \vdots & \ddots & \vdots \\ 0 & 0 & \ell_T \end{bmatrix}}_{(D)} (a) \underbrace{\begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_N \end{bmatrix}}_{(a)} + (Z) \underbrace{\begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix}}_{(Z)} b + \underbrace{\begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{bmatrix}}_{(e)} \quad (\text{B3.1.7})$$

This is still a linear specification with $N + k - 1$ explanatory variables and TN observations. Note that each column D is in effect a dummy variable for the i th individual unit. In what follows, an individual unit will be referred to as a “group”. The following notations will be used in the sequel. Let $Z'_i((k - 1) \times T)$ be the i^{th} block of Z'_i and z_{it} be the t^{th} column. For z_{it} the i^{th} group average over time is

$$\bar{z}_i = \frac{1}{T} \sum_{t=1}^T z_{it} = \frac{1}{T} Z'_i \ell_T;$$

The i^{th} group average of y_{it} over time is

$$\bar{y}_i = \frac{1}{T} \sum_{t=1}^T y_{it} = \frac{1}{T} y'_i \ell_T;$$

The overall sample average of z_{it} (average over time and group) is

$$\bar{z} = \frac{1}{T} \sum_{i=1}^N \sum_{t=1}^T (z_{it}) = \frac{1}{T} Z'_i \ell_T$$

and the overall sample average of y_{it} is

$$\bar{y} = \frac{1}{TN} \sum_{i=1}^N \sum_{t=1}^T (y_{it}) = \frac{1}{T} y_i' \ell_T$$

Observe that the overall sample averages are

$$\bar{z} = \frac{1}{N} \sum_{i=1}^N \bar{z}_i, \quad \bar{y} = \frac{1}{N} \sum_{i=1}^N \bar{y}_i$$

The OLS estimator for b in the fixed effect model is

$$\hat{b}_{TN} = [Z'(I_{TN} - P_D)Z]^{-1} Z'(I_{TN} - P_D)y$$

Where $P_D = D(D'D)^{-1}D'$ is a projection matrix. Thus, $\hat{b}_{TN}$ can be obtained by regressing $(I_{TN} - P_D)y$ on $(I_{TN} - P_D)Z$. Let $\hat{a}_{TN}$ denote the OLS estimator of the vector a of individual effects. The fact that $D'\hat{y} = D'D\hat{a}_{TN} + D'Z\hat{b}_{TN}$

and that the OLS residual vector is orthogonal to D , $\hat{a}_{TN}$ can be computed as

$$\hat{a}_{TN} = (D'D)^{-1}D'(y - Z\hat{b}_{TN})$$

We will present alternative expressions for these estimators which yield more intuitive interpretations.

Writing $D = I_N \otimes \ell_T$, we have

$$\begin{aligned} P_D &= (I_N \otimes \ell_T)(I_N \otimes \ell_T' \ell_T)^{-1}(I_N \otimes \ell_T') \\ &= (I_N \otimes \ell_T)[I_N \otimes (\ell_T' \ell_T)^{-1}](I_N \otimes \ell_T') \\ &= I_N \otimes [\ell_T(\ell_T' \ell_T)^{-1} \ell_T'] \\ &= I_N \otimes \ell_T \ell_T' / T \end{aligned}$$

where $\ell_T \ell_T'$ is also a projection matrix. Thus,

$$I_{TN} - P_D = I_N \otimes (I_T - \ell_T \ell_T' / T),$$

and $(I_T - \ell_T \ell_T' / T)y_i = y_i - \ell_T \bar{y}_i$ with the t^{th} element being $y_{it} - \bar{y}_i$. It follows that

$$(I_{TN} - P_D)y = \begin{pmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{pmatrix} - \begin{pmatrix} \ell_T \bar{y}_1 \\ \ell_T \bar{y}_2 \\ \vdots \\ \ell_T \bar{y}_N \end{pmatrix},$$

which is the vector of all the deviations of y_{it} from the group averages $\bar{y}_i$. Similarly,

$$(I_{TN} - P_D)Z = \begin{pmatrix} z_1 \\ z_2 \\ \vdots \\ z_N \end{pmatrix} - \begin{pmatrix} \ell_T \bar{z}'_1 \\ \ell_T \bar{z}'_2 \\ \vdots \\ \ell_T \bar{z}'_N \end{pmatrix} \text{ with the } t^{th} \text{ observation in the } i^{th} \text{ block being}$$

$(z_T - \bar{z}_i)'$, the deviation of z_{it} from the group average $\bar{z}_i$. This shows that the OLS estimator can be obtained by regressing $y_T - \bar{y}_i$ on $z_T - \bar{z}_i$ for $i = 1, \dots, N$, and $t = 1, \dots, T$. That is,

$$\begin{aligned} \hat{b}_{TN} &= \left(\sum_{i=1}^N (z_T - \bar{z}_i \ell_T) (z_i - \ell_T \bar{z}'_i) \right)^{-1} \left(\sum_{i=1}^N (z'_i - \bar{z}_i \ell'_T) (y_i - \ell_T \bar{y}_i) \right) \\ &= \left(\sum_{i=1}^N \sum_{t=1}^T (z_{it} - \bar{z}'_i) (z_{it} - \bar{z}_i)' \right)^{-1} \left(\sum_{i=1}^N (z'_i - \bar{z}_i) (y_i - \bar{y}_i) \right) \end{aligned}$$

The estimator $\hat{b}_{TN}$ is referred to as the *within-groups estimator* because it is based on observations that are deviations from their group averages, as shown above. It is also easily seen that the i^{th} element of $\hat{a}_{TN}$ is

$$\hat{a}_{TN,i} = \frac{1}{T} (\ell'_T y_i - \ell'_T z_i \hat{b}_{TN}) = \bar{y}_i - \bar{z}_i \hat{b}_{TN},$$

which involves only group averages and the within-groups estimator. To distinguish $\hat{a}_{TN}$, $\hat{b}_{TN}$ from other estimators, we will suppress their subscript TN and denote them as $\hat{a}_w$ and $\hat{b}_w$. By the Gauss-Markov theorem, $\hat{a}_w$ and $\hat{b}_w$ are the BLUEs of a_0 and b_0 respectively. The variance-covariance matrix of the within-group estimator is

$$\begin{aligned} var(\hat{b}_w) &= \sigma_0^2 [Z'(I_{TN} - P_D)Z]^{-1} \\ &= \sigma_0^2 [\sum_{i=1}^N \sum_{t=1}^T (z_{it} - \bar{z}'_i) (z_{it} - \bar{z}_i)']^{-1} \end{aligned}$$

The variance of the i^{th} element of $\hat{a}_w$ is

$$var(\hat{a}_{w,i}) = \frac{1}{T} \sigma_0^2 + \bar{z}'_i [var(\hat{b}_w)] \bar{z}_i$$

The OLS estimator for the regression variance σ_0^2 in the case of the Fixed Effects Model is

$$\hat{\sigma}_w^2 = \frac{1}{TN - N - K + 1} \sum_{i=1}^N \sum_{t=1}^T (y_{it} - \hat{a}_{w,i} - z'_{it} \hat{b}_w)^2$$

which can be used to compute the estimators of $var(\hat{a}_w)$ and $var(\hat{b}_w)$.

It should be emphasized that the conditions $var(y_i) = \sigma_0^2 I_{TN}$ for all i and $cov(y_i, y_j) = 0$ for every $i \neq j$ may be much too strong in applications. When any one of these conditions fails, $var(y)$ may not be written as $\sigma_0^2 I_{TN}$ and $\hat{a}_w$ and $\hat{b}_w$ are no longer the BLUEs. Despite that $var(y)$ variation may not be a scalar variance-covariance matrix in practice, the fixed effects model is typically estimated by the OLS methods and hence also as the *least squares dummy variable model*.

For GLS and FGLS estimation:

$$y \sim \mathcal{N}(Da_0 + Zb_0, \sigma_0^2 I_{TN})$$

An interesting hypothesis for the fixed effects model is whether fixed (individual) effects indeed exist. This amounts to applying an F test to the hypothesis.

$$H_0: a_{1,0} = a_{2,0} = \dots = a_{N,0}$$

The null distribution of this F test is $F(N-1, TN-N-k+1)$. In practice, it may be more convenient to estimate the following specification for the fixed effects model.

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} = \begin{bmatrix} \ell_T & 0 & 0 \\ \ell_T & \ell_T & 0 \\ \vdots & \ddots & \vdots \\ \ell_T & 0 & \ell_T \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_N \end{bmatrix} + \begin{bmatrix} Z_1 \\ Z_2 \\ \vdots \\ Z_N \end{bmatrix} b + \begin{bmatrix} e_1 \\ e_2 \\ \vdots \\ e_N \end{bmatrix}$$

This specification is virtually the same as in equation B3.1.4, yet the parameters $a_1, i = 2, \dots, N$, now denote the difference between the i^{th} and the first group effects. Testing the existence of fixed effects is then equivalent to testing $H_0: a_{2,0} = \dots = a_{N,0} = 0$

Appendix B3.2.4: Generalized Least Square Panel Data

The GLS method focuses on the efficiency issue resulting from the failure of the classical OLS conditions.

Let G be a $T \times T$ non-stochastic matrix. Consider the transformed specification

$$Gy = GXb + G\varepsilon \quad (\text{B3.1.8})$$

where Gy denotes the transformed dependent variable and GX is the matrix of transformed explanatory variables. It can be seen that GX also has full column rank k provided that G is non-singular. Thus, the identification requirement for the specification carries over under non-singular transformations. It follows that b can still be estimated by the OLS method using these transformed variables. The resulting OLS estimator is

$$b(G) = (X'G'GX)^{-1}X'G'Gy$$

where the notation $b(G)$ indicates that this estimator is a function of G . If G is such that $G\Sigma_0G' = \sigma_0^2 I_T$ for some positive number σ_0^2 , the traditional OLS conditions will also hold for the transformed specification. Given this G , it is now readily seen that the OLS estimator in 3 is BLUE for b_0 . This shows that, as far as efficiency is concerned, one should choose G as a non-stochastic and non-singular matrix such that $G\Sigma_0G' = \sigma_0^2 I_T$. To find the desired transformation matrix G , note that Σ_0 is symmetric and positive definite so that it can be orthogonally diagonalized as $C'\Sigma_0C = \Lambda$, where C is a matrix of eigenvectors corresponding to the matrix of eigenvalues Λ . For $\Sigma_0^{-1/2} = C\Lambda^{-1/2}C'$ (or $\Sigma_0^{-\frac{1}{2}} = \Lambda^{-\frac{1}{2}}C'$), we have

$$\Sigma_0^{-1/2}\Sigma_0\Sigma_0^{-1/2'} = I_T$$

This result immediately suggests that G should be proportional to $\Sigma_0^{-1/2}$, i.e., $G = c\Sigma_0^{-1/2}$ for some constant c . Given this choice of G , we have $\text{var}(Gy) = G\Sigma_0G' = c^2 I_T$, a scalar covariance matrix. The estimator with $G = c\Sigma_0^{-1/2}$ is known as the GLS estimator and can be expressed as $\hat{\beta}_{GLS} = (c^2 X'\Sigma_0^{-1}X)^{-1}(c^2 X'\Sigma_0^{-1}y) = (X'\Sigma_0^{-1}X)^{-1}X'\Sigma_0^{-1}y$.

This estimator is by construction of the BLUE for β_0 . As the GLS estimator does not depend on c , it is without loss of generality to set $G = \Sigma_0^{-1/2}$. Given this choice of G let $y^* = Gy$, $X^* = GX$, and $e^* = Ge$. The transformed specification is

$$y^* = X^*\beta + e^*$$

The GLS estimator is a minimizer of the following GLS criterion function:

$$Q(\beta; \Sigma_0) = \frac{1}{T} (y^* - X^*\beta)'(y^* - X^*\beta) = \frac{1}{T} (y - X\beta)' \Sigma_0^{-1} (y - X\beta)$$

This criterion function is the weighted average of a weighted sum of squared errors and hence a generalized version of the standard OLS criterion function. Similarly, to the OLS method, define the vector of the GLS fitted values as

$$\hat{y}_{GLS} = X(X'\Sigma_0^{-1}X)^{-1}X'\Sigma_0^{-1}y$$

The vector of GLS residuals is $\hat{e}_{GLS} = y - \hat{y}_{GLS}$

The fact that $X(X'\Sigma_0^{-1}X)^{-1}X'\Sigma_0^{-1}$ is idempotent but not symmetric immediately implies that $\hat{y}_{GLS}$ is an oblique (but not orthogonal) projection of y onto $\text{span}(X)$. It can also be verified that the vector of GLS residuals is not orthogonal to X or any linear combination of the column vector of X ; i.e., $\hat{e}_{GLS}'X = y'[I_T - \Sigma_0^{-1}X(X'\Sigma_0^{-1}X)^{-1}X']X \neq 0$.

In fact, $\hat{e}_{GLS}$ is orthogonal to $\text{span}(\Sigma_0^{-1}X)$. It follows that $\hat{e}'\hat{e} \leq \hat{e}'_{GLS}\hat{e}_{GLS}$

That is, the OLS method still yields a better fit of original data.

Appendix B3.2.5: Feasible Generalized Least Square Panel Data

In practice, Σ_0 is typically unknown so the GLS estimator is not available. Substituting an estimator $\hat{\Sigma}_T$ for Σ_0 in the GLS estimator equation above yields the feasible generalized least squares (FGLS) estimator

$$\hat{\beta}_{FGLS} = (X'\hat{\Sigma}_T^{-1}X)^{-1}X'\hat{\Sigma}_T^{-1}y$$

which is readily computed from data. Note, however, that Σ_0 contains too many $(\frac{T(T+1)}{2})$ parameters. Proper estimation of Σ_0 would not be possible unless further restrictions on the elements of Σ_0 are imposed.

Under different assumptions on $\text{var}(y)$, Σ_0 has a simpler structure with much fewer (say $p \ll T$) unknown parameters and may be properly estimated. The properties of FGLS estimation depend on these assumptions. A clear disadvantage of the FGLS estimator is that its finite sample properties are usually unknown. Note that $\hat{\Sigma}_T$ is, in general, a function of y , so that $\hat{\beta}_{FGLS}$ is a complex function of the elements of y . It is therefore difficult, if not impossible, to derive the finite-sample properties, such as expectation and variance, of $\hat{\beta}_{FGLS}$.

Appendix B3.3: Diagnostic Test Results

Appendix B3.3.1: Panel Unit Root Tests: Fisher Type

Fisher-type unit-root test for logdglbcpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	1 lag	
		Statistic	p-value
Inverse chi-squared(16)	P	555.8999	0.0000
Inverse normal	Z	-22.53	0.0000
Inverse logit t(44)	L*	-54.8204	0.0000
Modified inv. chi-squared	Pm	95.4417	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Fisher-type unit-root test for tier1ratcpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	1 lag	
		Statistic	p-value
Inverse chi-squared(16)	P	458.0229	0.0000
Inverse normal	Z	-20.1391	0.0000
Inverse logit t(44)	L*	-45.1682	0.0000
Modified inv. chi-squared	Pm	78.1393	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Fisher-type unit-root test for tier2ratcpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 1 lag

		Statistic	p-value
Inverse chi-squared(16)	P	455.318	0.0000
Inverse normal	Z	-20.131	0.0000
Inverse logit t(44)	L*	-44.9014	0.0000
Modified inv. chi-squared	Pm	77.6612	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for levcp

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 1 lag

		Statistic	p-value
Inverse chi-squared(16)	P	381.0882	0.0000
Inverse normal	Z	-18.0176	0.0000
Inverse logit t(44)	L*	-37.5812	0.0000
Modified inv. chi-squared	Pm	64.5391	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for lccratcpi			
Based on augmented Dickey-Fuller tests			
Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	1 lag	
		Statistic	p-value
Inverse chi-squared(16)	P	358.3545	0.0000
Inverse normal	Z	-17.3137	0.0000
Inverse logit t(44)	L*	-35.3393	0.0000
Modified inv. chi-squared	Pm	60.5203	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			
Fisher-type unit-root test for sfrat2cpi			
Based on augmented Dickey-Fuller tests			
Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	1 lag	
		Statistic	p-value
Inverse chi-squared(16)	P	384.992	0.0000
Inverse normal	Z	-18	0.0000
Inverse logit t(44)	L*	-37.9662	0.0000
Modified inv. chi-squared	Pm	65.2292	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Fisher-type unit-root test for logdlbimpaircpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	576.6985	0.0000
Inverse normal	Z	-22.9835	0.0000
Inverse logit t(44)	L*	-56.8714	0.0000
Modified inv. chi-squared	Pm	99.1184	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for logdpatcpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	576.6985	0.0000
Inverse normal	Z	-22.9835	0.0000
Inverse logit t(44)	L*	-56.8714	0.0000
Modified inv. chi-squared	Pm	99.1184	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for roecpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	371.0047	0.0000
Inverse normal	Z	-17.6466	0.0000
Inverse logit t(44)	L*	-36.5868	0.0000
Modified inv. chi-squared	Pm	62.7566	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for roacpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	366.1964	0.0000
Inverse normal	Z	-17.5503	0.0000
Inverse logit t(44)	L*	-36.1127	0.0000
Modified inv. chi-squared	Pm	61.9066	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for ldrdpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	328.2667	0.0000
Inverse normal	Z	-16.3089	0.0000
Inverse logit t(44)	L*	-32.3721	0.0000
Modified inv. chi-squared	Pm	55.2015	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for logdgdpcpi

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	576.6985	0.0000
Inverse normal	Z	-22.9835	0.0000
Inverse logit t(44)	L*	-56.8714	0.0000
Modified inv. chi-squared	Pm	99.1184	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for ldinb

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	576.6985	0.0000
Inverse normal	Z	-22.9835	0.0000
Inverse logit t(44)	L*	-56.8714	0.0000
Modified inv. chi-squared	Pm	99.1184	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for mergerdummy

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: T -> Infinity

Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	186.1336	0.0000
Inverse normal	Z	-12.1388	0.0000
Inverse logit t(44)	L*	-18.3557	0.0000
Modified inv. chi-squared	Pm	30.0757	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for baseldummy

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	8
Ha: At least one panel is stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: $T \rightarrow \infty$

Asymptotics: $T \rightarrow \infty$

Panel means: Included

Time trend: Not included

Drift term: Not included

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(16)	P	231.8976	0.0000
Inverse normal	Z	-13.8273	0.0000
Inverse logit t(44)	L*	-22.8687	0.0000
Modified inv. chi-squared	Pm	38.1657	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Appendix B3.3.2: Panel Unit Root Tests: Levin-Lin-Chu Test

Levin-Lin-Chu unit-root test for logdglbcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 0 lags

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-33.486	
Adjusted t*	-35.2065	0.0000

Levin-Lin-Chu unit-root test for tier1ratcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-23.9111	
Adjusted t*	-20.2187	0.0000

Levin-Lin-Chu unit-root test for logdglbcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-27.8138	
Adjusted t*	-24.5618	0.0000

Levin-Lin-Chu unit-root test for tier2ratcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-23.409	
Adjusted t*	-19.3796	0.0000

Levin-Lin-Chu unit-root test for levcp1

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-22.1948	
Adjusted t*	-18.4406	0.0000

Levin-Lin-Chu unit-root test for lcratcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-20.0632	
Adjusted t*	-15.83	0.0000

Levin-Lin-Chu unit-root test for sfrat2cpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-21.3326	
Adjusted t*	-17.7088	0.0000

Levin-Lin-Chu unit-root test for logdlbimpaircpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-27.5208	
Adjusted t*	-23.7919	0.0000

Levin-Lin-Chu unit-root test for logdpatcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-29.9179	
Adjusted t*	-26.9754	0.0000

Levin-Lin-Chu unit-root test for roecpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-23.239	
Adjusted t*	-20.1756	0.0000

Levin-Lin-Chu unit-root test for roacpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-23.4058	
Adjusted t*	-20.5156	0.0000

Levin-Lin-Chu unit-root test for ldrcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
 Panel means: Included
 Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-20.7809	
Adjusted t*	-17.242	0.0000

Levin-Lin-Chu unit-root test for logdgdpcpi

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-26.632	
Adjusted t*	-23.1405	0.0000

Levin-Lin-Chu unit-root test for ldinb

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-25.1801	
Adjusted t*	-21.8375	0.0000

Levin-Lin-Chu unit-root test for mergerdummy

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-16.3213	
Adjusted t*	-10.8195	0.0000

Levin-Lin-Chu unit-root test for baseldummy

Ho: Panels contain unit roots	Number of panels	=	8
Ha: Panels are stationary	Number of periods	=	156

AR parameter: Common Asymptotics:

Asymptotics: $N/T \rightarrow 0$

Panel means: Included

Time trend: Not included

ADF regressions: 1 lag

LR variance: Bartlett kernel 17 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-18.6078	
Adjusted t*	-13.8267	0.0000

Appendix B3.3.3: Panel Unit Root Tests: Im-Pesaran-Shin Test

Im-Pesaran-Shin unit-root test for logdglbpci

Ho: All panels contain unit roots	Number of panels	=	8
Ha: Some panels are stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-11.8071		-2.15	-1.97	-1.8800
t-tilde-bar	-8.5453				
Z-t-tilde-bar	-24.036	0.0000			

Im-Pesaran-Shin unit-root test for tier1ratcpi

Ho: All panels contain unit roots	Number of panels	=	8
Ha: Some panels are stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-7.5682		-2.15	-1.97	-1.8800
t-tilde-bar	-6.4329				
Z-t-tilde-bar	-16.8223	0.0000			

Im-Pesaran-Shin unit-root test for tier2ratcpi

Ho: All panels contain unit roots	Number of panels	=	8
Ha: Some panels are stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included

ADF regressions: No lags included

		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-7.8202		-2.15	-1.97	-1.8800
t-tilde-bar	-6.582				
Z-t-tilde-bar	-17.3315	0.0000			

Im-Pesaran-Shin unit-root test for levcp1

Ho: All panels contain unit roots	Number of panels	=	8
Ha: Some panels are stationary	Number of periods	=	156

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
 Panel means: Included sequentially
 Time trend: Not included

ADF regressions: No lags included

		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-7.364		-2.15	-1.97	-1.8800
t-tilde-bar	-6.2853				
Z-t-tilde-bar	-16.318	0.0000			

Im-Pesaran-Shin unit-root test for lcrratcpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-6.1135		-2.15	-1.97	-1.8800
t-tilde-bar	-5.4753				
Z-t-tilde-bar	-13.5518	0.00000			
Im-Pesaran-Shin unit-root test for sfrat2cpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-6.6937		-2.15	-1.97	-1.8800
t-tilde-bar	-5.8379				
Z-t-tilde-bar	-14.7902	0.00000			
Im-Pesaran-Shin unit-root test for logdlbimpcpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-12.6875		-2.15	-1.97	-1.8800
t-tilde-bar	-8.8734				
Z-t-tilde-bar	-25.1568	0.00000			

Im-Pesaran-Shin unit-root test for logdpatcpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:		Asymptotics: T N -> Infinity			
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-14.3933		-2.15	-1.97	-1.8800
t-tilde-bar	-9.2711				
Z-t-tilde-bar	-26.5149	0.0000			
Im-Pesaran-Shin unit-root test for roecpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:		Asymptotics: T N -> Infinity			
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-7.3198		-2.15	-1.97	-1.8800
t-tilde-bar	-6.237				
Z-t-tilde-bar	-16.1531	0.0000			
Im-Pesaran-Shin unit-root test for roacpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:		Asymptotics: T N -> Infinity			
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
		Fixed-N exact critical values			
	Statistic	p-value	1%	5%	10%
t-bar	-7.3798		-2.15	-1.97	-1.8800
t-tilde-bar	-6.2637				
Z-t-tilde-bar	-16.2444	0.00000			

Im-Pesaran-Shin unit-root test for ldrdpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-6.9654		-2.15	-1.97	-1.8800
t-tilde-bar	-5.9576				
Z-t-tilde-bar	-15.1989	0.0000			
Im-Pesaran-Shin unit-root test for logdgdpcpi					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-11.8547		-2.15	-1.97	-1.8800
t-tilde-bar	-8.5866				
Z-t-tilde-bar	-24.1773	0.0000			
Im-Pesaran-Shin unit-root test for ldinb					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-11.7961		-2.15	-1.97	-1.8800
t-tilde-bar	-8.5644				
Z-t-tilde-bar	-24.1014	0.0000			

Im-Pesaran-Shin unit-root test for mergerdummy					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:		Asymptotics: T N -> Infinity			
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-5.1982		-2.15	-1.97	-1.8800
t-tilde-bar	-4.8079				
Z-t-tilde-bar	-11.2725	0.0000			

Im-Pesaran-Shin unit-root test for baseldummy					
Ho: All panels contain unit roots	Number of panels	=	8		
Ha: Some panels are stationary	Number of periods	=	156		
AR parameter: Panel-specific Asymptotics:	Asymptotics: T N -> Infinity				
Panel means: Included sequentially					
Time trend: Not included					
ADF regressions: No lags included					
			Fixed-N exact critical values		
	Statistic	p-value	1%	5%	10%
t-bar	-5.7829		-2.15	-1.97	-1.8800
t-tilde-bar	-5.2558				
Z-t-tilde-bar	-12.8021	0.0000			

Appendix B3.3.4: Panel Unit Root Tests: Breitung Test

Breitung unit-root test for logdglbcpi

Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-19.3509	0.0000

Breitung unit-root test for tier1ratcpi

Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-8.7851	0.0000

Breitung unit-root test for tier2ratcpi

Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-8.2496	0.0000

Breitung unit-root test for levcp

Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-8.5513	0.0000

Breitung unit-root test for lcratcpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-9.0049	0.0000

Breitung unit-root test for sfrat2cpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-9.8896	0.0000

Breitung unit-root test for logdlbimpcpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-20.9784	0.0000

Breitung unit-root test for logdpatcpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-25.1215	0.0000

Breitung unit-root test for roecpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-10.734	0.0000

Breitung unit-root test for roacpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-12.952	0.0000

Breitung unit-root test for ldrapi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-9.3726	0.0000

Breitung unit-root test for logdgdpcpi		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-22.3605	0.0000

Breitung unit-root test for ldinb		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-24.1356	0.0000
Breitung unit-root test for mergerdummy		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-8.8368	0.0000
Breitung unit-root test for baseldummy		
Ho: Panels contain unit	Number of panels	8
Ha: Panels are stationary	Number of periods	156
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity	
Panel means: Included	sequentially	
Time trend: Not included	Prewhitening: Not performed	
	Statistic	p-value
lambda	-7.7829	0.00000

Appendix B3.3.5: Model Selection Test – Hausman Test

	Coefficients			
	(b) fe	(B) re	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
tier1ratcpi	-0.0028332	0.0052539	-0.0080871	0.0018884
tier2ratcpi	0.0098028	-0.000624	0.0104267	0.0020127
levcpi	-0.0062202	-0.0053164	-0.0009039	0.0003058
lcrratcpi	-0.0008291	-0.0002878	-0.0005413	0.0000874
sfrat2cpi	0.001092	0.0009828	0.0001092	0.00015
logdlbimpa~i	0.0007193	0.0008167	-0.0000973	.
logdtacpi	0.5918286	0.5767854	0.0150432	0.0058646
roecpi	-0.0013977	-0.0024356	0.001038	0.0001713
roacpi	0.0057813	0.0049339	0.0008474	0.0000861
ldrcpi	-0.001671	-0.0014068	-0.0002642	0.0003411

logdgdpcpi	0.5972955	0.6147458	-0.0174503	0.0071841
ldinb	0.0001183	0.000156	-0.0000377	.
mergerdummy	0.0006953	0.0001105	0.0005849	0.000103
baseldummy	0.0011914	0.0008949	0.0002965	0.0000466

b= consistent under Ho and Ha; obtained from xtreg

B= inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(14) = (b-B)'[(V_b-V_B)^(-1)](b-B)

= 82.27

Prob>chi2 = 0.0000

(V_b-V_B is not positive definite)

Appendix B3.3.6: Breusch-Pagan Contemporaneous Correlation Test (Cross Sectional Dependency test)

Correlation matrix of residuals:

	__e1	__e2	__e3	__e4	__e5	__e6	__e7	__e8
__e1	0.000816							
__e2	0.000143	0.00043						
__e3	-8.60E-06	-0.00015	0.000346					
__e4	0.000083	1.09E-05	-3.14E-05	0.001136				
__e5	0.000115	-0.00012	-0.000234	-0.00019	0.001869			
__e6	4.78E-05	1.24E-05	5.05E-05	-3.6E-05	-0.000101	4.74E-05		
__e7	-0.00052	-0.00012	6.45E-05	0.000251	-0.000799	6.01E-05	0.002155	
__e8	0.000168	-4.9E-05	1.37E-05	0.000178	-8.99E-05	8.24E-06	0.000132	0.000189

	__e1	__e2	__e3	__e4	__e5	__e6	__e7	__e8
__e1	1.0000							
__e2	0.2406	1.0000						
__e3	-0.0162	-0.3817	1.0000					
__e4	0.0862	0.0156	-0.05	1.0000				
__e5	0.0932	-0.1335	-0.2906	-0.132	1.0000			
__e6	0.2428	0.0867	0.3944	-0.1547	-0.3391	1.0000		
__e7	-0.3923	-0.1245	0.0747	0.1604	-0.3983	0.188	1.0000	
__e8	0.4284	-0.1721	0.0537	0.3831	-0.1513	0.0871	0.2062	1.0000

Breusch-Pagan LM test of independence: chi2(28) = 239.294 Pr = 0

Based on 156 complete observations over panel units

Appendix B3.3.7: Heteroscedasticity Test in Fixed Effects Regression Model

Modified Wald test for groupwise heteroscedasticity
in fixed effect regression model

H0: $\sigma(i)^2 = \sigma^2$ for all i

chi2 -8 = 25739.15
Prob>chi2 = 0.0000

Appendix B3.3.8: Pesaran ABS Contemporaneous Correlation Test (Cross Sectional Dependency test)

Pesaran's test of cross sectional independence = 0.012 Pr = 0.9908

Average absolute value of the off-diagonal elements = 0.196

CHAPTER FOUR

MODELLING DETERMINANTS OF FINANCIAL SECTOR POLICY REFORMS IN THE MALAWIAN BANKING SECTOR: A LOGISTIC REGRESSION APPROACH

Abstract

Reforming the financial sector is widely viewed as beneficial for the economy, as it fosters financial innovation and enhances efficiency within the financial system, which could result in increased economic growth. This essay studies the determinants of financial sector policy reforms in the banking sector in Malawi. In this study, we modelled financial sector policy reform conditions in a developing country while applying a Logistic Regression model using data from Malawi from the period between 1980 and 2023. We embedded a financial sector policy reform dummy variable, as well as bank specific and macroeconomic drivers of reforms in the model. Our study finds that macroeconomic, monetary and fiscal drivers such as the ratio of external debt stock to gross national income ratio, debt service costs to primary revenue, short term debt to primary revenue ratio, short term debt to total external debt, growth in real GDP, broad money to GDP ratio, and domestic credit to GDP ratio have negative and significant impacts in accelerating financial sector reforms in Malawi.

4.1 Introduction

Reforms in the financial sector constitute a crucial element of the strategies employed by nations to overcome fragility. However, the specifics and emphasis of these reforms, as well as their prioritisation in relation to other policies, differ significantly across countries. Regardless of the initial factors contributing to fragility, effective exit strategies consistently incorporate reforms within the financial sector, which typically emphasise immediate objectives: halting bank losses, implementing monetary control, and revitalising the mechanisms of financial intermediation and credit flow to the

economy. Long-term financial development objectives, including financial deepening, are acknowledged as significant. However, the necessary policy measures are implemented subsequently once the financial sector has regained its stability and can fulfil its fundamental roles. It is essential that significant, practical, and sustained technical support and capacity development are provided in every instance to guarantee the enduring success of these reforms.

For nearly a hundred years, scholars have engaged in discussions regarding the significance of the financial sector in the context of economic development. Since Schumpeter (1911) presented arguments highlighting the productivity and growth enhancing effects of the services offered by a developed financial sector, a significant body of theoretical and empirical literature has subsequently developed. Initially, this literature examined whether the financial sector has a causal influence on economic development or if financial intermediaries simply emerge from swift industrialisation. Proposed by Robinson (1952), this perspective held significant influence until the mid-1960s. Gerschenkron (1962), Patrick (1966), and especially Goldsmith (1969), emphasised the dynamic influence that the financial sector can exert in the context of economic development. This ground-breaking work has significantly influenced the trajectory of thought, yet the question of causality continues to be a crucial topic in theoretical discussions to this day.

During the 1970s, the focus was on the phenomenon of financial repression, a strategy employed by numerous governments to stimulate growth and revenue by maintaining artificially low interest rates and implementing inflationary monetary policies. The theoretical foundations were laid by Keynes (1936) and Tobin (1965), who supported the notion of government intervention in the credit market. McKinnon & Shaw (1973) inadvertently presented critiques of financial repression policies.

The importance of the financial sector in enhancing savings volumes through the establishment of suitable incentives was highlighted. To achieve elevated savings and investment rates, it was suggested that governments eliminate interest rate ceilings and refrain from increasing seigniorage through inflationary monetary policies. Consequently, real interest rates ought to increase to levels that clear the market, thereby promoting higher savings. A significant aspect of the McKinnon Shaw models

is that they account for only temporarily elevated growth rates. A number of governments in developing nations adhered to the guidance provided and experienced notable increases in growth rates, though this was occasionally accompanied by excessively high and unstable real interest rates.

During the early 1980s, the Neo-structuralists offered critiques of the McKinnon-Shaw school, forecasting that financial liberalisation would impede growth. Their arguments reflect the ideas presented by Keynes (1936) and Tobin (1965). Stiglitz (1989) critiques financial liberalisation based on theoretical considerations regarding market failures within financial markets. A distinct aspect of the theory that establishes a positive connection between finance and growth surfaced in the early 1990s, evolving as a segment of the literature on endogenous growth. King and Levine (1993b) adhere to Schumpeter's perspective by highlighting the significance of innovation. Financial systems effectively direct savings towards their most efficient applications while also mitigating the risks linked to these endeavours. By accomplishing these tasks, they enhance the likelihood of successful innovation and accelerate the pace of technological advancement. The primary conclusion drawn from the literature on endogenous growth is that it is possible to maintain an increase in growth rates over time. Unlike the perspective that emphasises the accumulation of physical capital, the pace of technological advancement is determined from within the system. This prevents the marginal productivity of capital from decreasing. Levine (1997) outlines several fundamental roles of financial systems that promote capital accumulation and productivity growth: they enable the trading, hedging, diversifying, and pooling of risk; they allocate resources; they oversee managers and enforce corporate governance; they mobilise savings; and they facilitate the exchange of goods and services.

The reason why we must make efforts to study this topic is that financial sector challenges undermine the stability of the financial system and often induce economic crises or are a precursor of recessions. To this end, and to the best of our knowledge, we do not know any studies in Malawi that have taken this approach, studied this subject matter, and modelled Malawi's banking sector in the manner we have done in this paper. Our study also found that a number of factors that are important in the design and conduct of monetary policy, such as changes in inflation rates, domestic credit to private sector to GDP ratio, total reserves as a percentage of external debt, and broad money to GDP ratio have a significant influence in propagating financial sector reforms

in Malawi. The study also found that fiscal variables such as external debt stock to gross national income, short term debt as a percentage of export of goods, services and primary income, and short-term debt as percentage of external debt also have significant influence in propagating financial reforms in Malawi. Another finding was that domestic credit liquidity conditions, such as the ratio of domestic private credit to GDP, had negative and significant effects on accelerating financial sector reforms in Malawi. These findings are consistent with studies of Lindgren et al. (1996), Reinhart & Rogoff (2009), Brunnermeier (2001), Kindleberger (1978), Smith (2002), De Nicolo et al. (2010), Dell'Ariccia et al. (2010), Rochet (2008), Caprio & Honohan (2010), Calomiris (2010), Bhattacharya & Thakor (1993), Boot & Greenbaum (1993), Laeven (2002), Hovakimian et al. (2003), and Demirguc-Kunt et al. (2008).

The rest of the paper is organised as follows: Section 4.2 discusses the context of the study, Section 4.3 looks at the review of relevant literature, Section 4.4 discusses the modelling framework used in the paper, Section 4.5 presents the Financial Sector Policy Reforms Variable, followed by the explanatory variables, and the data and sources in Sections 4.6 and 4.7, respectively; the robustness check is presented in Section 4.8; Section 4.9 discusses results from the modelling experiments, and Section 4.10 concludes.

4.2 Context of the Study

4.2.1 History of Malawi's Banking Sector, Reforms and Consolidations

In 1964, when Malawi attained independence, the banking sector was largely dominated by two foreign commercial banks (Standard Bank and Barclays Bank), with the largely government owned financial institutions such as New Building Society (NBS), National Finance Company (NFC) and the Post Office Savings Bank (POSB) providing some level of competition.

In 1971, Standard Bank and Barclays Bank, with the approval of the Malawi Government, merged to form National Bank of Malawi (NBM). The Government owned entity, ADMARC, took additional equity into the newly formed bank. In 1969, the Commercial Bank of Malawi (CBM) was incorporated. It started operations in 1970, providing competition to National Bank of Malawi and offering similar

commercial banking facilities. In 1972, the Government of Malawi established the Investment and Development Bank (INDEBANK) as a development finance institution which was entrusted with the responsibility of promoting private sector investment and initiatives in Malawi. The late 1980s and 1990s witnessed moderate entry into commercial banking services by non-bank financial institutions. In 1987, Leasing and Finance Company of Malawi (LFC) was incorporated, offering financial leases. In the 1990s the financial system opened to entry. New banking institutions such as INDEFinance, Finance Company of Malawi (FINCOM), First Merchant Bank (FMB) and Malawi Finance Bank (MFB) were incorporated. The Post Office Savings Bank (POSB) that was established in 1911 was incorporated into Malawi Savings Bank in 1990. Despite the changes, however, the two established commercial banks continue to dominate the banking industry.

The financial sector, particularly the banking sector in Malawi, has gone through a lot of changes over the years. There have been mergers and acquisitions in the sector, even though there is very scanty literature on this. The Table 4.1 below summarizes the changes that have taken place in the banking sector since 1970s (the author compiled the information). The main driver of mergers and acquisitions in the banking sector has been to rescue financial institutions that have had solvency and liquidity problems. The other driver has been the Government of Malawi's need to disinvest its interest in the banking sector as part of financial sector reforms propagated by the International Development Association and International Monetary Fund.

Table 4.1: Malawi's historical banking sector restructurings

Name of the Institution	Year of Establishment	Year of Disposal	Buyer	Reasons of Sale
Standard Bank – 100%	1890	1971	National Bank of Malawi formed in 1971 with original shareholding as Standard Bank -25%, Barclays-25%, Private Sector Malawi Investment Company -29%, ADMARC – 20%	Solvency and Liquidity
Barclays Bank – 100%	1890	1971	Standard Bank – 25.5% Barclays – 25.5% Press Holdings – 29% Agricultural Development and Marketing Corporation (ADMARC) – 20%	Solvency and Liquidity
Post and Savings Bank of Malawi (POSBM)	1911	1990	Malawi Savings Bank	Solvency and Liquidity
New Building Society (NBS)	1964	-	Recapitalized in 2012	Solvency and Liquidity (Technical Depositors Run)
Commercial Bank of Malawi (Owned by Press – 40%, MDC-30% and	1969	2001	Standard Bank Plc (Standard Bank Group-54.7%, Public -18.85%, Nico Holdings – 18.20%, Old Mutual Life – 4.89%, Press Trust -2.11%, Magetsi Pension Fund – 1.25%	Solvency and Liquidity

Malawi Government -30%)				
National Bank of Malawi	1971	2000	Standard Bank – 25.5% Barclays – 25.5% Press Holdings – 29% Agricultural Development and Marketing Corporation (ADMARC) – 20%	
Investment and Development Bank of Malawi (INDEBANK)	1972	2015	National Bank of Malawi	Solvency and Liquidity (Technical Depositors Run)
Finance Company of Malawi (Fincom) formerly owned 100% by ADMARC	1976	2002	Nedbank	Solvency and Liquidity
Malawi Savings Bank	1990	2015	FDH BANK	Solvency and Liquidity (Technical Depositors Run)
First Capital Bank	1995	-	Anadkat Family Prime Bank of Kenya	
Finance Bank	1999	2005	Reserve Bank of Malawi	Regulatory Disposal (Technical Depositors Run)
National Bank	2000	-	Press Corporation – 51.5%, Old Mutual Group -25.1%,	

of Malawi Plc			Members of the Public – 21.6%, ESOP – 1.8%	
FDH Bank	2000		Mpinganjira Family Press Corporation Ltd Old Mutual Life Assurance (MW) Limited Kingdom Financial Holdings Limited (Zimbabwe)	
Nedbank Malawi	2002	2019	MyBucks Banking Corporation (MBC)	Solvency and Liquidity (Technical Depositors Run)
Opportunity International Bank of Malawi	2003	2017	First Capital Bank	Solvency and Liquidity
International Commercial Bank	2008	2013	First Capital Bank	Solvency and Liquidity
New Finance Bank	2014	2019	MyBucks Banking Corporation (MBC)	Regulatory Disposal (Technical Depositors Run)
MyBucks Banking Corporation	2019	2023	CENTENARY RURAL BANK	Solvency and Liquidity (Technical Depositors Run)

Source: Author's compilation from reports and accounts (various banks)

4.2.1 Identification of Financial Sector Reforms Periods and Dummy

Financial sector reforms are policy measures designed to deregulate the financial system and transform its structure with the view to achieving a liberalized market-oriented system within an appropriate regulatory framework. The main forms of financial sector policy reforms that have happened in Malawi between 1980 and 2023 have been summarized in Table 4.2. These have predominantly taken the form of devaluation of the local currency against the US dollar, and has been done since 1980s. The main rationale has been to correct the overvaluation in the fixed exchange rate regime Malawi was maintaining until the Kwacha was floated in 1993. From 1993, Malawi still maintained a managed or pegged exchange rate regime that has also been susceptible to currency overvaluation. As a result, the currency has constantly been devalued. For the purposes of modelling financial sector reforms, we consider devaluation of the Kwacha of between 1%-5% to be a normal market correction mechanism from the forces of demand and supply; and any devaluations in excess of 5% to be policy corrections of currency overvaluations as a financial sector policy reform.

The other main forms of financial sector reforms in Malawi have been deregulation of interest rates, removal of interest rates ceilings, removal of preferential lending to certain sectors, changes in the bank rate (policy rates), changes in liquidity reserve requirements (LRR), introduction of new financial instruments by regulators in the market (such as RBM bills), Treasury Bills and Notes, admission of new players in the financial sector (market deepening), winding up of financial intermediaries, and introduction of the reference rate as a benchmark interest rate for all commercial banks in Malawi in 2019. For the purposes of modelling financial sector reforms, we consider bank rate and saving rate changes of between 1%-20% to be a normal central bank monetary policy instrument deployment and market response to monetary conditions; and any bank rate and savings rate changes in excess of 20% to be policy response to challenges in the financial sector. For the purposes of Liquidity Reserve Requirement, changes in excess of 10% are considered as response to challenges in the financial sector and will qualify as reform, and those less than 10% are purely liquidity management and will not be considered as reforms.

Once we have identified a set of financial sector reforms in each year, we will assign them a “Yes” or “No”, to our identification criterion. The financial sector reform dummy, which is our dependent variable, takes the value zero (0), where there is a “No”, meaning there are

no major reforms, and takes the value one (1), where there is a “Yes”, meaning there are major reforms.

Table 4.2: Policy reforms and deregulation in the financial and banking sector in Malawi, 1982-2000

Year	Policy Actions	Financial Sector Reforms Indicator	Financial Sector Reforms Dummy
1982	Devaluation of Malawi Kwacha by 15% in April. Adjustment of interest rates.	Yes	1
1983	Devaluation of Malawi Kwacha by 12% in September. Adjustment of interest rates. Savings rate moved by 21% in December	Yes	1
1984	Devaluation of Malawi Kwacha by 3% in January. Adjustment of interest rates.	No	0
1985	Devaluation of Malawi Kwacha by 15% in April. Adjustment of interest rates.	Yes	1
1986	Devaluation of Malawi Kwacha by 9.5% in January and 10% in August. Adjustment of interest rates. Entry and Establishment of Leasing and Finance Company in 1986 as a lease finance company.	Yes	1
1987	Devaluation of Malawi Kwacha by 20% in February. Liberalization of lending rates Bank rate moved upwards by 27% in July Savings rate moved by 24% in July	Yes	1
1988	Devaluation of Malawi Kwacha by 15% in January. Deregulation of deposit rates	Yes	1
1989	Review of the legal framework for the financial sector leading into new and revised legislation: Reserve Bank Act of 1989, Banking Act 1989 leading to deregulation of entry into the banking sector. Liquidity Reserve Requirement (LRR) was enforced at 10% of commercial	Yes	1

	bank liabilities effective June 1, with commercial banks earning interest on reserves.		
1990	Devaluation of Malawi Kwacha by 7% in March Restructuring of Post Office Savings Bank into Malawi Savings Bank. Incorporation of Leasing and Finance Company as a Leasing Finance Bank on September 14. Preferential lending to agricultural sector was abandoned. Reserve Bank of Malawi introduced the marketing of its own bills. LRR adjusted four times (January 2: 25%, May 15: 15%, June 1: 10%, September 1: 20%.) LRR ceased to earn interest with effect from December 1. Bank rate moved by 27% in May	Yes	1
1991	Incorporation of National Finance Company as a lease finance bank on April 17. Entry and incorporation of CBM Financial Services as a subsidiary of Commercial Bank of Malawi, as a lease finance company on June 28. Incorporation of the Finance Corporation of Malawi as a corporate bank (trade financing) on August 1. Incorporation of Indebank Financial Services as a corporate bank (trade financing) on September 6. LRR decreased to 15% with effect from August 1. Complete liberalization of foreign exchange allocation. Savings rate moved by 308% in January	Yes	1
1992	Devaluation of Malawi Kwacha by 15% in June and 22% in June. LRR increased to 20% with effect from December 23.	Yes	1

	Penalty for non-compliance of LRR was introduced at 18%. Bank rate moved by 43% in June Savings rate moved by 45% in June		
1993	LRR increased to 30% with effect from October 29. Bank rate moved by 25% in July Savings rate moved by 26%	Yes	1
1994	Flotation of Malawi Kwacha in the foreign exchange market in February. Entry and incorporation of the First Merchant Bank as a commercial bank on July 5. LRR increased to 35% with effect from December. Bank rate moved by 33% in December	Yes	1
1995	Penalty for non-compliance with LRR was increased to 45% at the beginning of the year to 55% in April to 60% in June. Entry and incorporation of Finance Bank as a commercial bank on March 29. Incorporation of Malawi Savings rate moved by 35% in February	Yes	1
1996	Bank rate reduced from 45% on June 12 to 35% on September 9 to 27% from November 13 and the LRR was reduced 55% to 47%.	Yes	1
1997	Bank rate was reduced from 27% to 23% on August 1. Penalty for non-compliance of LRR was reduced to 43% and calculation of LRR was changed from daily to monthly average and RBM started paying interest on reserves.	Yes	1
1998	Entry and incorporation of Continental Discount House in March and the introduction of inter-bank market lending among banks. Introduction of daily basis LRR observance by commercial banks with effect from August 1	Yes	1

	and RBM ceased paying interest on reserves. Commercial banks discretion to put reserves with either RBM or Discount House or in their vault was introduced. Bank rate was decreased from 32.5% to 30% with effect from September 14. Incorporation of Loita Investment Bank as a merchant bank on November 28. Sharp depreciation of the Malawi Kwacha in August 1998. Savings rate moved to 43% in February, 28% in September, and 39% in October		
1999	Bank rate increased from 43% to 47% on January 11.	Yes	1
2000	The LRR was lowered to 30% in June and the penalty on shortfalls on the LRR account set at ¼% per day. RBM reintroduced own bills and bank rate decreased to 44.5% in August and increased to 53.2% in December. 8% devaluation in May, 7% in June, 22% in September and 7% in October Adoption of Basel I, banking regulations	Yes	1
2001	7% devaluation in November Bank rate moved by 22% in January, and 23% in February	Yes	1
2002	7% devaluation in February	Yes	1
2003	8% devaluation in July, 12% in August	Yes	1
2004	No major financial policy reform	No	0
2005	No major financial policy reform	No	0
2006	No major financial policy reform	No	0
2007	No major financial policy reform	No	0
2008	No major financial policy reform	No	0
2009	No major financial policy reform	No	0
2010	No major financial policy reform	No	0
2011	10% devaluation in August	Yes	1

2012	61% devaluation in May, 6% in September Bank rate moved by 23% in May and 31% in July Savings rate moved by 38% in May and 42% in July	Yes	1
2013	6% devaluation in January, 7% in February, 7% in March, 10% in Sept, and 7% in October	Yes	1
2014	14% devaluation in October Adoption of Basel II, banking regulations	Yes	1
2015	16% devaluation in July, 10% in August, 9% in Nov and 10% in Dec	Yes	1
2016	8% devaluation in January	Yes	1
2017	No major financial policy reform	No	0
2018	No major financial policy reform	No	0
2019	Introduction of the Reference Rate	Yes	1
2020	No major financial policy reform	No	0
2021	No major financial policy reform	No	0
2022	25% devaluation in May Bank rate moved by 29% in October	Yes	1
2023	44% devaluation in November Bank rate moved by 22% in April	Yes	1

Source: Chirwa & Mlachila (2004), with current author additions.

Figure 4.20: Historical exchange rate movements between 1997 - 2024

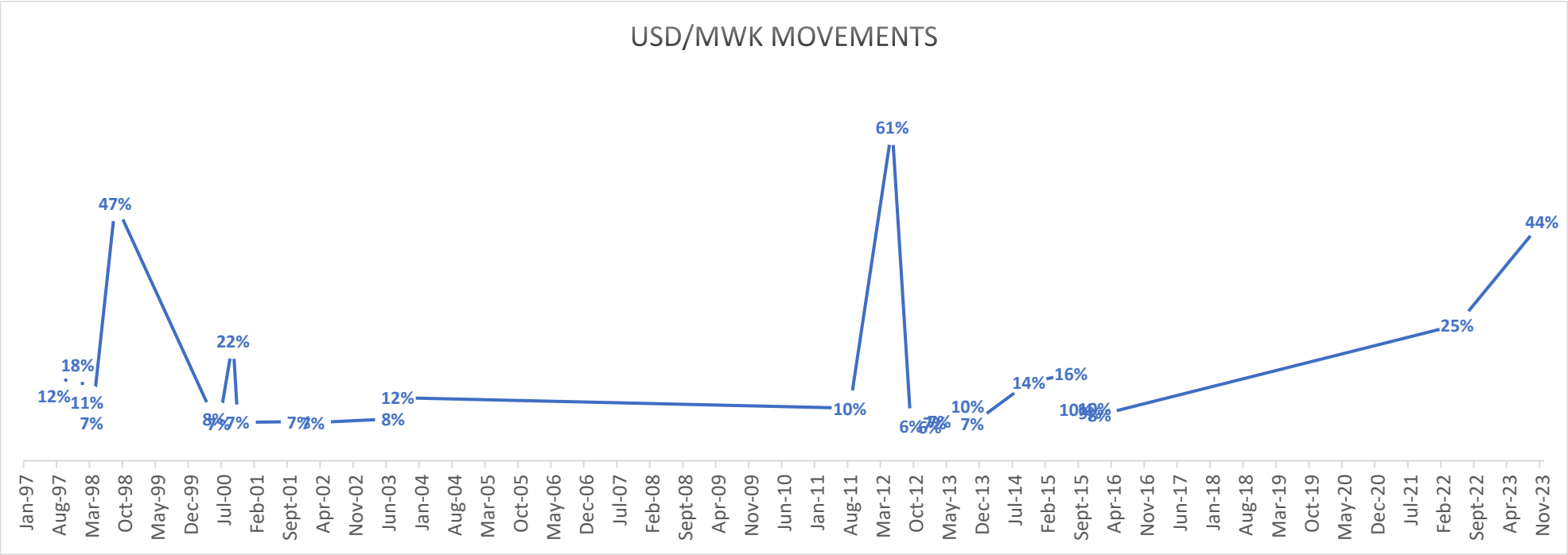
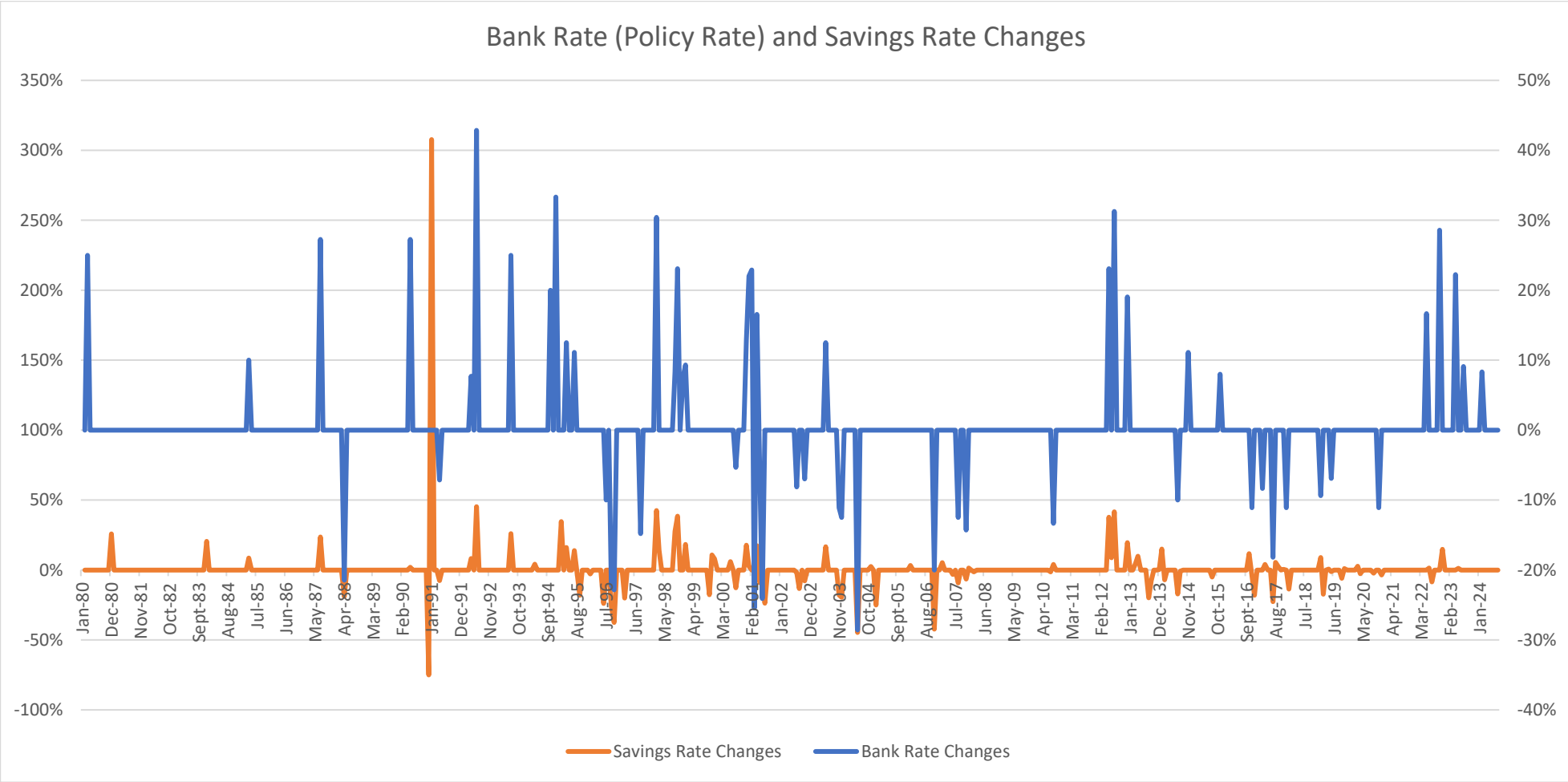


Figure 4.21: Historical bank rate (policy rates) and savings rate movements between 1980 - 2023



4.3 Theoretical & Empirical Literature Review: Financial Sector Reforms

4.3.1 The 1960s: Pioneers in Finance Sector Reforms and Growth

In the scholarly discussion regarding the connection between finance sector reforms and growth, arguments supporting financial repression from a Keynesian perspective have held sway for a considerable period. Prior to the 1960s, the prevailing theory supported the notion that financial development was a consequence of growth, rather than the other way around. Gerschenkron (1962) framed the significance of the banking sector within the concept he termed “economic backwardness”. His hypothesis posits that the level of economic development a nation possesses at the onset of industrialisation plays a crucial role in shaping the function of its banking sector. In England, industrialisation thrived without a robust financial sector, as investments were modest and required minimal capital along with specialised entrepreneurial skills. Germany, a country with some developmental challenges, embarked on its industrialisation journey at a time when technology had progressed significantly and investments were substantial. The banking sector played a crucial role in supplying both capital and fostering entrepreneurship to propel the industrialisation process forward. Russia required a robust financial sector and decisive government leadership to effectively guide large-scale, capital-intensive industries towards progress. Patrick (1966) delved even deeper than Gerschenkron (1962) into the inquiry regarding the causal connections between financial sector and growth. He recognised two distinct patterns, which he referred to as “demand following” and “supply leading,” and linked them to particular phases of the development process. In the initial of the two patterns, economic development creates a demand for financial services, and is passively met by an expanding financial sector. The swift expansion of aggregates heightens the need for external financing. When there is significant variation in growth among different sectors or industries, the demand for financial services to allocate savings to the more prosperous sectors will increase. In the second pattern, financial intermediation promotes economic growth by directing the savings of primarily small savers towards larger investors. The financial sector facilitates the flow of resources from traditional industries to modern enterprises, thereby fostering entrepreneurship in the latter. According to Patrick (1966), the second pattern, which is supply-leading, prevails in the initial phases of economic development and then progressively transitions its leading role to the demand-following pattern.

Initially, the direction of causality flows from finance to growth, a situation that one would anticipate in developing nations. The anticipated pattern of demand should lead us to expect a causal relationship flowing from growth to finance. It can be anticipated that more developed economies will demonstrate this particular direction of causality. Rondo & Olga (1967) posit that financial systems can serve as both catalysts for growth and products of growth, while underscoring the essential importance of service quality and the efficiency of their delivery. They then provide a concise overview of the key characteristics of the financial system, especially regarding banks: financial intermediation acts as a mechanism for directing small amounts of capital from cautious savers to individuals with entrepreneurial abilities who are more willing to take risks, thereby enhancing the availability of resources for the latter group. Furthermore, financial intermediation offers motivation for investors. The reduction in borrowing costs motivates entrepreneurs to pursue more substantial investments. An expanding financial sector is expected to diminish the variability of interest rates across different users, regions, and during seasonal fluctuations. Thirdly, financial institutions facilitate a more effective distribution of the frequently unproductive initial wealth during the early phases of industrialisation. Ultimately, they underscore the importance of the financial sector in fostering advancements in technology. Cameron (1972) posits that most technical innovations are brought forth by established companies that have access to bank financing. His main argument, however, does not reside in his theoretical considerations. He presents comprehensive case studies on the interplay between finance and growth during the successful industrialisation processes in England, Scotland, France, Belgium, Germany, Russia, and Japan throughout the 19th century. The analysis of these case studies reveals notable similarities and distinctions.

In England, the authorities exercised considerable caution in permitting the financial sector to engage in activities that would foster growth. However, a relaxed approach to governance and a sufficiently flexible legal framework rendered financial innovation feasible. These financial innovations played a crucial role in accelerating industrialisation. The role of finance in the industrialisation of Scotland was particularly remarkable. In light of policies that promote freedom and competition, financial institutions have pioneered innovations such as the cash credit system and have taken an active role in industry. The banking sector in Scotland, along with a robust

educational framework, played a significant role in driving industrial development and maintaining exceptionally high growth rates over an extended period.

The underdeveloped banking system in France hindered the pace of industrialisation during the early part of the 19th century. The limitations on credit volumes, the insufficient number of bank branches, and the lack of diversity and specialisation among financial institutions were the primary factors hindering economic development, largely attributable to the monopolistic stance of the Banque de France. During the latter part of the century, several financial reforms were initiated. However, numerous restrictions persisted. The financial system in Belgium during that period showcased significant innovations, including the establishment of the first joint-stock bank, aimed at facilitating industrial development. Although there were certain limitations, such as the oversight of short-term commercial credit prior to 1851, the Belgian financial system facilitated growth in a manner akin to the Scottish model, despite exhibiting considerably less competition than its counterpart. Prior to 1870 in Germany, private banks played a crucial role as the primary financial institutions that facilitated the mobilisation of capital for industrial advancement. They frequently formed strong connections with industrial enterprises, simultaneously demanding and supplying credit, thereby playing a crucial role in driving economic development. The growth of the Prussian Bank, nonetheless, hindered advancement due to its limiting policies. The German experience illustrates the critical role that competition plays in the banking sector, which was notably deficient during that time.

In Russia, the banking sector has played a more significant role in driving economic development compared to numerous other nations. Financial institutions harnessed substantial assets that might have otherwise stayed unutilised. Different categories of financial institutions, both public and private, collaborated to mobilise capital for industry, while the money supply adhered to a stringent system of note issuance. From 1868 until the onset of World War I, Japan developed a financial system that effectively fostered economic growth. Financial institutions maintained strong connections with the sector and focused mainly on financing long-term fixed investments and operational capital. In Patrick's (1966) terminology, the Japanese banking system during that period was characterised as "supply-leading." The analysis reveals the emergence of two distinct groups of countries: in Scotland, Belgium, Russia, and Japan, the financial

sector played a crucial role in advancing industrialisation, whereas in Germany (prior to 1870) and France, misguided policies hindered financial development. In England, misguided policies were unable to halt the swift pace of financial growth and innovation. In this collection of nations, finance displayed a distinctly “demand-following” trend.

Cameron (1972) presents additional case studies of nations that either failed to reach a notable degree of industrialisation prior to 1914 (Serbia, Spain), or those that experienced incomplete and postponed industrialisation (Austria, Italy), as well as countries that underwent a swift economic development (USA, Japan). The financial system of Austria has been identified as having a detrimental impact on the industrialisation process, primarily due to the reluctance of bankers to engage in necessary risk-taking. Moreover, the implementation of protectionist trade policies resulted in a more cautious approach from banks and entrepreneurs. Given that various misguided policies had compromised the effectiveness of the financial system, it is reasonable to conclude that financial conditions had impeded growth.

In Serbia, the slow pace of industrialisation stemmed more from a general deficiency in managerial and entrepreneurial skills than from an underdeveloped financial system. The latter had developed an unexpectedly intricate structure after just a few years of autonomy. The financial instability in Italy, driven by excessive government borrowing, appears to have notably impeded the accumulation of private domestic capital. In Spain’s situation, the financial system was unable to support industrialisation as the political authorities prioritised public finance and railway construction. This second set of case studies illustrates how misguided financial sector policies hindered the industrialisation process in various countries, while also demonstrating that finance alone cannot address bottlenecks present in other sectors. Goldsmith (1969) argues that the beneficial impact of financial intermediation on growth may stem from enhancements in both the efficiency and the volume of investment, although he attributes a lesser significance to the latter. He was the pioneer in presenting substantial empirical evidence regarding the relationship between finance and growth across various countries. Through the establishment of a metric for financial development, characterised by the value of all financial assets relative to GNP (referred to as FIR or financial interrelations ratio), Goldsmith paved the way for subsequent empirical

investigations in this domain. In a study involving a sample of 35 countries across various economic systems, a preliminary positive correlation is observed between the financial development variable and GNP per capita, with both metrics assessed for the early 1960s. The outcome is somewhat diminished by the presence of several outliers: Japan, Italy, and the UK exhibited significantly higher values of FIR, while the Soviet Union showed a considerably lower value than what their respective levels of national wealth would suggest.

Goldsmith provides further evidence for four nations: Germany, Japan, the US, and the UK. Throughout a century-long span from 1860 to 1963, the correlation between FIR and output exhibited considerable variability not only among different nations but also within individual countries, where long-term relationships appeared to be influenced by various unforeseen factors. The research conducted by Gerschenkron (1962), Patrick (1966), Cameron (1972), and Goldsmith (1969) initiated a continuous scholarly discussion that influenced decision-makers in both developing and developed nations.

4.2.1 The 1970s: The McKinnon-Shaw School

4.2.1.1 Characteristics and Rationale of Financial Repression

The primary emphasis of the McKinnon-Shaw school is on financial repression. They argue that this policy is detrimental to long-term growth as it diminishes the amount of capital accessible for investment. Prior to delving into a more comprehensive analysis of the McKinnon-Shaw school, it is essential to succinctly outline the key features of this policy and elucidate the reasons for its implementation in numerous developing nations. Financial repression refers to the imposition of broad nominal interest rate caps alongside rising and accelerating inflation rates. Elevated reserve requirements could potentially influence the situation as well. The foundation of this discussion rests on the theoretical principles of the liquidity preference theory as articulated by Keynes (1936). The equilibrium level of real interest rates at full employment, he contended, was generally lower than that produced by liquidity preference. Consequently, it became necessary to reduce interest rates to prevent a decline in income. Tobin (1965) presents a model of small household producers who distribute their wealth between money and productive capital. Financial repression diminishes the demand for money, favouring productive capital, which in turn increases the capital/labour ratio and propels economic

growth. Neo-structuralists contend that elevated interest rates lead to a rise in inflation in the short term due to cost-push effects and hinder economic growth due to a diminished real credit volume. These theoretical considerations are, nonetheless, enhanced by the policy requirements that prevailed in developing nations. When the government struggles to gather adequate tax revenue, it resorts to financial repression measures, effectively acting as an implicit tax on the financial sector.

Fry (1995) argues that financial repression represents a significant and unintended type of financial limitation, which he views as a suboptimal strategy for governments that struggle with tax collection capabilities. In situations of financial constraint, priority is afforded to financial institutions and instruments when the government can readily obtain seigniorage from them. Reserve requirements, mandatory holdings of government bonds, or interest rate ceilings assist the authorities in channelling savings to the public sector at minimal or no cost. The banking and credit sector is particularly suitable for this purpose, as it presents greater challenges in extracting seigniorage from the private equity and bond markets.

4.2.1.2 Financial Liberalization (Reforms) in McKinnon-Shaw

McKinnon & Shaw (1973) initiated a critique of the prevailing theoretical frameworks supporting financial repression. Challenging the views of Keynes (1936) and Tobin (1956), they advocated for financial reforms in the form of liberalisation of interest rates and the elimination of various financial repression policies. The fundamental framework includes financial intermediaries, savers, and investors. This model operates on the principle of inside money, as it involves loans to the private sector that are supported by the internal debt generated within that sector. The stated interest rate remains constant, keeping the real rate beneath its equilibrium point. Saving is an advantageous aspect, while investment is a disadvantageous aspect of the real interest rate. When the latter is influenced by either rising inflation or a reduction in the fixed nominal interest rate, the tendency for saving will diminish. The sustained effect of inflation can be attributed to another perspective: when inflation is mitigated through land ownership, the decline in real interest rates will encourage demand for land, as deposits lose their appeal. The transition of savings from bank accounts to land ownership accelerates the increase in land prices beyond the overall price level. The

induced wealth effect leads to a rise in consumption, which consequently results in a decrease in investment. In the context of financial repression, where the nominal interest rate is set below the market clearing value, we can anticipate two potential scenarios. Should the deposit rate remain constant, a significant gap will emerge between the rates for lending and deposits. In the context of loan and deposit rate ceilings, particularly relevant for developing nations, it is essential that non-price rationing of funds occurs.

The determination of credit allocation hinges on various criteria, including transaction costs, perceived default risks, collateral quality, political influence, reputation, loan size, and hidden benefits for loan officers, rather than solely on anticipated investment productivity. The overall effectiveness of investment diminishes as those with lesser returns start to yield profits once the ceiling on loan rates is established at a notably low threshold. Adverse selection occurs when entrepreneurs enter the market without having sought credit prior to the establishment of the ceiling. The behaviour of banks regarding risk-taking is adversely impacted, as they are unable to impose risk premia, when ceilings are in place. The allocation of credit is, to a certain degree, influenced by randomness, which serves as an additional factor of distortion. The recommendation put forth by McKinnon & Shaw (1973) is to eliminate institutional limitations on nominal interest rates and to lower inflation. Although McKinnon & Shaw (1973) arrive at similar conclusions, their theoretical frameworks exhibit notable distinctions. McKinnon's model is founded on the premise that all economic units are constrained to self-financing and that significant indivisibilities exist in investment. He treats savers and firms as if they are one and the same, without any differentiation. An individual looking to invest should first gather deposits or various financial assets beforehand to facilitate future investments. There exists a relationship between deposits and physical capital that spans across different time periods. Given that investors are unable to borrow for investment purposes, McKinnon's model is occasionally viewed through the lens of an outside money framework. In Shaw's model, complementarity is not required, as investors are not limited to self-financing. He offers a clear and detailed perspective on the inside money approach. Financial intermediaries enhance the accumulation of deposits by increasing the real returns available to savers, thereby broadening their capacity to lend. Simultaneously, they reduce actual expenses for investors by means of risk diversification, leveraging economies of scale in lending,

enhancing operational efficiency, decreasing information costs for savers and investors, and catering to liquidity preferences. The complementarity hypothesis proposed by McKinnon and Shaw's perspective on debt intermediation are not inherently in opposition, as investment can be supported through both external and internal financing methods. McKinnon focuses on the context of developing nations, while Shaw's examination pertains to the circumstances of more advanced economies with intricate financial frameworks.

Following the McKinnon-Shaw debate, several studies have surfaced that build upon the original framework. Kapur (1976), Galbis (1977), Mathieson (1980), and Fry (1988) construct formal macroeconomic models that illustrate how national authorities impose financial repression by setting the deposit rate of interest below its market clearing value, rather than the loan rate. The demand for money is influenced by the fixed nominal interest rate as well as inflationary pressures. Rising inflation diminishes the demand for real money. The liabilities of banks diminish in real terms, leading to a corresponding decrease in their assets, which in turn constrains the availability of credit for investment purposes. In terms of portfolio dynamics, inflation hampers growth as it prompts households to prioritise unproductive inflation hedges rather than channelling funds into productive investments via deposits.

Kapur (1976) and Mathieson (1980) present a particular form of financial repression: even in the absence of ceilings on interest rates, reserve requirements can achieve a similar outcome. Under the assumption of zero inflation, a constant required reserve ratio establishes an upper limit on the deposit rate. The rise in inflation exacerbates the disparity between loan and deposit rates. The implication of this policy in this context is that lowering reserve requirements at a specific inflation rate expands the capacity of the banking system for lending activities. Furthermore, a reduced reserve requirement increases the deposit rate ceiling at any specified loan rate. The demand for deposits rises, leading to an expansion in the financial sector. Within the Kapur-Mathieson framework, one encounters a developing economy characterised by a surplus of labour and a production technology that aligns with the Harrod-Domar model. The financial sector influences solely the quantity of investment in the Harrod-Domar model, leaving the quality unaffected. Fry (1988) and Galbis (1977) broaden the framework firstly by enabling the real deposit rate of interest to also impact it by enhancing the average

efficiency of investment. In Galbis's two-sector model, financial repression results in a lasting coexistence of a traditional sector characterised by a low, constant rate of return to capital, alongside a modern sector that offers a higher rate of return. A reduced deposit rate results in increased self-financed investment within the traditional sector. Raising the deposit rate enhances the demand for money in this sector, thereby facilitating greater investment in the modern sector through bank loans. The alteration in the investment composition enhances the overall efficiency of investment. In Fry's model, the deposit rate significantly influences the level of investment.

In every model of the McKinnon-Shaw variety, the deposit rate that optimises growth is the one that emerges from a free-market equilibrium. The authors suggest eliminating interest rate ceilings, discontinuing selective or directed credit programs, lowering reserve requirements, and, crucially, fostering competitive conditions within the financial sector. Kapur, Mathieson, and Fry further advance dynamic models that effectively demonstrate the impacts of interest rate liberalisation as a strategy for stabilisation policy. The analysis leads to the conclusion that, beginning from a context of financial repression, the liberalisation of interest rates presents a dual benefit. In addition to fostering long-term growth, financial liberalisation mitigates the negative impacts associated with monetary stabilisation programs.

4.2.1.3 Extensions and Criticisms of the McKinnon-Shaw Approach

The extensions of the McKinnon-Shaw approach by Kapur (1976), Galbis (1977), Mathieson (1980), and Fry (1988) contribute minimally to the foundational concepts, instead serving to formalise the existing McKinnon-Shaw models. Kapur and Mathieson restrict their analysis by presuming that investment efficiency remains constant after financial liberalisation, whereas Galbis (1977) and Fry (1998) explore the scenario in which efficiency improves. Kapur's model suggests that when the deposit rate of interest increases, it leads to a rise in real money demand, which in turn boosts the real supply of bank credit, ultimately accelerating economic growth. Mathieson's model arrives at comparable conclusions, differing from Kapur (1976) primarily by positing that fixed capital is fully utilised, whereas Kapur's assumption was that it was under-utilized. Galbis (1977) develops a two-sector model to examine the impact of financial repression on the average efficiency of investment. This model

suggests that financial liberalisation enhances efficiency by reallocating savings from self-investment to opportunities that offer higher rates of return. Fry additionally highlights the enhancements in investment efficiency that occur after financial liberalisation (reforms).

The main critics of the McKinnon-Shaw approach include Wijnbergen (1983) and Taylor & O'Connell (1985). Wijnbergen (1983), presents a comparison of his model with those developed by McKinnon and Kapur. According to him,

the findings presented by McKinnon/Kapur hinge significantly on a concealed presumption regarding asset market structure, a presumption that remains unstated: all these authors operate under the assumption that the portfolio transition into time deposits is derived from a 'unproductive' asset such as gold, cash, commodity stocks, etc. (Wijnbergen, 1983)

He further states that "it is not at all clear that time deposits' serve as closer substitutes to cash, gold, etc., rather than to loans provided in the curb markets". Taylor & O'Connell (1985) anticipate that the latter outcome will prevail. In a study conducted in Korea, Wijnbergen (1983), reached the conclusion that "substitution between the curb market and time deposits is of more importance than substitution between currency and time deposits". In this scenario, the overall availability of funds for the business sector is expected to decrease as resources are redirected from the curb market, which offers direct intermediation without reserve requirements, into the banking system, which only facilitates partial intermediation. This partiality arises because a portion of the funds is allocated to required and free reserves instead of being fully transferred to businesses. In other terms, Wijnbergen (1983) and Taylor & O'Connell (1985) incorporate a distortion into their model through the implementation of reserve requirements within the banking sector. Consequently, they presume that the efficiency of investments remains constant, regardless of whether the financing comes from the banking sector or the curb market. As previously mentioned, McKinnon and Shaw held a different perspective, acknowledging the curb market but believing it resulted in diminished investment efficiency.

4.2.2 The 1980s: Critiques of Financial Liberalisation Policies

4.2.2.1 Neo-structuralists

The emergence of the Neo-structuralist school can be attributed to varied experiences with financial liberalisation policies, which critiqued financial deregulation through a macroeconomic lens. Taylor & O'Connell (1985) and Wijnbergen (1983) notably presented two arguments, with one being particularly relevant to developing economies. The model highlights the significant impact of curb or unorganised money markets in assessing the potential of financial liberalisation to foster growth.

An increase in the real deposit interest rate resulting in a shift of assets from the unorganised to the formal credit market will cause a decline in financial intermediation due to the existence of reserve requirements. In the unregulated money market, there are no reserve requirements in place. The magnitude of the contractionary impact on credit supply is influenced by how significantly assets are shifted away from inflation hedges or the curb market. The second argument centres on cost-push inflation stemming from rising interest rates, which could potentially result in a decline of effective demand. Even if financial intermediation does not diminish, the second argument remains valid, especially since a heightened tendency to save could further undermine effective demand. The Neo-structuralist models, however, are based on the premise that unorganised money markets operate competitively, which may not necessarily hold true. Another concerning aspect of these models is their focus on the total credit and investment volume rather than the efficiency of the investments made. The latter could potentially be improved through a rise in credit expenses.

4.2.2.2 Market Imperfections

A different set of authors directed their focus towards the microeconomic foundations of macroeconomic policies. Stiglitz & Weiss (1981) illustrate that imbalances in the credit market can arise from factors beyond government intervention. The authors demonstrate that the cost of credit can influence the characteristics of the transaction, potentially leading to market inefficiencies. The outcome stems from a negative selection influence and a motivational influence. Elevated and market-clearing interest rates could potentially draw in fewer desirable borrowers or encourage borrowers to engage in more speculative investment ventures. As a result, the likelihood of

borrowers defaulting increases. This could result in banks refraining from increasing the interest rate to its appropriate market clearing level. Consequently, there may be a situation where only substantial loans are distributed. In a similar vein, it is conceivable to have equilibria characterised by excess supply. The negative consequences stem from the microeconomic deficiencies inherent in a free credit market.

Adverse selection can indeed present a significant challenge on its own. Mankiw & Whinston (1986) examine the issue of financial collapse within this framework. The model they present illustrates how minor fluctuations in the interest rate can impact the risk profile of the borrower pool. This situation could potentially result in a breakdown of the credit market if the pool of loan applicants presents too much risk for banks to achieve their necessary returns. Furthermore, a restrictive monetary policy could have effects that extend beyond merely influencing the economy along the marginal efficiency of capital schedule. It may also lead to a severe financial crisis in extreme cases. The examination of principal-agent problems is conducted by Shleifer & Vishny (1986) as well as Stiglitz (1985). In a corporate setting characterised by numerous minor stakeholders, it is posited that it may not be beneficial for any individual owner to oversee the management activities. The issue of free-riding emerges from the public good nature of the expensive information gathering undertaken by a single stockholder, who can readily divest his financial stake. Another aspect of the literature concerning market failure examines the problem of asymmetric information within credit markets. Financial institutions arise due to the disparities in information between those providing loans and those seeking them. In the costly state verification approach, financial intermediaries can ascertain the success of an investment solely at a monitoring cost, which they endeavour to minimise. Information asymmetries present a significant challenge as they can result in the misallocation of capital and increased monitoring costs. As demonstrated by Williamson (1987), this can lead to equilibrium credit rationing even when other market failures are not present.

The concept of moral hazard frequently arises in discussions surrounding deposit insurance schemes. Initially intended to address the adverse externalities stemming from the operations of banks towards their clientele, deposit insurance might inadvertently lead to a different form of market failure. This could potentially foster a propensity for risk-taking among bank managers. Gennotte & Pyle (1991) illustrate that

the introduction of stricter capital requirements alongside deposit insurance can result in a heightened level of asset risk. The oversight and management of asset risk by regulatory bodies must address this issue effectively.

4.2.3 The 1990s: Finance and Endogenous Growth

During the 1990s, investigations into the connection between financial development and sustained growth were invigorated by insights from the literature on endogenous growth. A segment of this stream began to concentrate on the inquiry of whether financial conditions could account for sustained growth in per capita GDP. The main point is that finance creates an external impact on the overall efficiency of investment, counterbalancing the reduction in the marginal product of capital. Certain research examines the function of stock markets in isolation. In numerous studies, the model structure aligns with the AK type (Romer, 1986), indicating that there are constant returns to a sufficiently expansive notion of capital. Bencivenga & Smith (1993) illustrate a model in which savings are directed towards more productive activities by enabling investors to modify the composition of their assets in favour of illiquid, growth-enhancing options. Individuals encounter ambiguity regarding their future liquidity requirements and consequently possess two categories of assets: one that is liquid, offering safety but lacking productivity, and another that is illiquid, characterised by high productivity and associated risks.

The presence of financial intermediaries alters the asset composition, leaning towards riskier options, which consequently enhances growth. Financial institutions enable individuals to mitigate the risks linked to their liquidity requirements. Despite the unpredictability individuals encounter regarding their future liquidity requirements, financial institutions experience a consistent demand for liquidity from their clients, attributable to the law of large numbers. Consequently, financial institutions are empowered to distribute investment resources with greater efficiency. Moreover, the reduction of socially unnecessary capital liquidation is achievable as individuals are not compelled to divest their investments when financial intermediaries are present. In a similar vein, Bencivenga et. al (1995) demonstrate that financial institutions mitigate the liquidity risk faced by savers by making financial assets tradable through stock markets or by allowing depositors to withdraw cash prior to a project's maturity through

banks. This diminishes the deterrent to investing in long-term projects. The reduction of transaction costs in financial markets is essential for their examination. A variety of studies explore the potential for reciprocal externalities between finance and growth, which facilitates the existence of multiple equilibria and poverty traps. Greenwood & Jovanovic (1990) present a model where both financial intermediation and growth are determined within the system.

The authors posit a constructive two-way causal relationship between financial development and growth. On one side, financial institutions gather and scrutinise data to identify investment opportunities that promise the greatest returns. They direct resources towards the most effective applications, thus enhancing the efficiency of investment and fostering growth. However, the impact of financial institutions is twofold: the returns that individuals receive are not only elevated but are also more secure, as the financial system provides insurance for investors against unique risks. Conversely, expansion offers the necessary resources to establish and enhance an expensive financial framework. Saint-Paul (1992) examines the impact of financial markets on technological selection and the distribution of labour. In this framework, agents have the option to select from two distinct technologies: the first offers flexibility and enables productive diversification, yet it is characterised by low productivity. The second is structured, more focused, and efficient. When faced with shifts in consumer preferences that could result in diminished demand for specific products, and in the absence of financial institutions, individuals who are risk-averse might lean towards technological flexibility rather than prioritising high productivity. Financial markets enable individuals to maintain a diversified portfolio to protect themselves from adverse demand shocks and to choose the more efficient technology. This encourages a more extensive division of labour. The framework accommodates various equilibria: in the state of low equilibrium, financial markets exhibit underdevelopment, leading individuals to opt for technologies that, while less productive, offer greater flexibility. The implementation of these technologies presents minimal risk exposure, and the motivation to advance financial markets appears to be constrained. The economy finds itself ensnared in a condition of underdevelopment. In the advanced equilibrium financial markets, there are 11 developed entities, and technology is both specialised and carries inherent risks. This establishes a necessity for financial markets. The model

is subsequently expanded to examine various growth trajectories and the divergence observed among similar nations.

Berthélemy & Varoudakis (1996) present reciprocal externalities between the financial sector and the real sector within a learning-by-doing endogenous growth framework. It is presumed that the financial sector positively impacts capital efficiency, which in turn fosters growth, while also exerting an external influence on the financial sector through the volume of savings generated by the real sector.

The mechanisms operate in the following manner: the financial sector initially directs savings towards more productive applications by gathering and evaluating information regarding investment prospects. The growth of the real sector leads to a heightened volume of savings. The expansion of the financial market fosters heightened competition and enhances technical efficiency via experiential learning within the financial sector. This reciprocal relationship leads to a progressive process, resulting in various equilibria. A lack of adequate financial development could potentially contribute to the formation of poverty traps. King & Levine (1993) present a Schumpeterian model of technological advancement akin to the work of Romer (1990) and Grossman & Helpman (1991), focusing on cost-reducing innovations related to an intermediate product. Financial intermediaries and securities markets empower specific entrepreneurs to engage in innovative endeavours, influencing growth by enhancing productivity. Financial systems influence entrepreneurial endeavours in four significant ways: they assess entrepreneurs, aggregate resources, mitigate risk, and appraise the anticipated returns from innovative pursuits. Enhanced financial systems elevate the likelihood of achieving successful innovation. Impediments such as deposit rate ceilings or elevated reserve requirements hinder the pace of innovation. A further collection of research focuses on topics such as governmental actions in the credit market or instances of market failure. The respective authors have recontextualized these longstanding issues within the contemporary framework of endogenous growth. Roubini & Sala-i-Martin (1992) critically analyse financial repression within the framework of an AK model of endogenous growth characterised by non-decreasing returns to capital. In their framework, authorities may choose to implement strategies of financial repression to create straightforward inflationary income. Financial repression compels individuals to maintain a greater quantity of nominal money,

serving as the foundation for the inflation tax. In the context of a high-income tax susceptible to evasion, it is observed that governments may opt to restrict the financial sector while simultaneously hastening inflationary pressures. The reduction in growth can be attributed to the adverse impact of financial repression on capital productivity and the overall level of savings. Mattesini (1996) presents an alternative perspective on the relationship between financial development and economic growth. He constructs a straightforward overlapping generations model in which the credit market exhibits asymmetric information.

Similar to the work of Roubini & Sala-i-Martin (1992), the production framework relies on a constant return to scale technology as proposed by Romer (1986). The level of monitoring costs of financial institutions serves as a key determinant of growth, reflecting the efficiency of the intermediation system. This parameter is estimated by examining the difference between lending and borrowing rates to facilitate empirical analysis. It is posited that elevated monitoring expenses may hinder economic growth, suggesting a negative correlation between spreads and growth rates. Bencivenga & Smith (1993) introduce an alternative endogenous growth model of the AK variety that pertains to market failure. This model illustrates that credit rationing and growth are interlinked, resulting in lasting negative impacts on economic development. A considerable volume of research has been conducted on the critical role of stock markets in the development process. We will examine these studies individually as they produce varying outcomes for banking and stock market activities, highlighting the distinct services offered by banks and securities markets. For example, Atje & Jovanovich (1993) did not create an endogenous growth model. Instead, they adopt the methodology of Greenwood & Jovanovic (1990) and apply it to stock markets. The stock market provides a safeguard for investors against unique risks and enhances the availability of information regarding investment opportunities. The reciprocal relationship between growth and the advancement of stock markets is evident. The framework established by Greenwood and Jovanovic represents a true endogenous growth model, indicating that there are no diminishing returns to capital due to the process of financial intermediation.

Levine (1991) develops an endogenous growth model where a stock market consistently enhances growth by incorporating two functions: it mitigates liquidity risk

and productivity risk. In the absence of stock markets, investors who are cautious about risk may be discouraged from putting their money into a company due to productivity shocks that are unique to that firm. Stock markets provide a safeguard for investors against this unique risk by enabling them to maintain diversified portfolios. This situation increases the portion of resources designated for the company. Secondly, liquidity shocks may compel individuals to hastily divest assets at a diminished liquidation return. The stock market mitigates that risk, as ownership can be transferred with greater ease and under more favourable conditions. The decrease in liquidity risk promotes corporate investment, thereby indirectly fostering growth.

The untimely withdrawal of stable capital can be prevented, thereby ensuring that unwarranted disruptions to technological advancement do not occur. This enhances organisational efficiency and directly fosters expansion. The model further illustrates that hindering or imposing taxes on financial market activities adversely affects long-term growth.

4.4 Modelling Framework

4.4.1 Empirical Modelling Framework

We estimate the probability of the determinants of financial sector reforms using a multivariate logit model. In each period, the country is either experiencing a reform condition, or it is not. Accordingly, our dependent variable, the reforms dummy, takes the value zero if there are no reforms, and takes the value one if there are reforms. The probability that reforms will occur at a particular time is hypothesized to be a function of a vector of n explanatory variables $X(i, t)$. The choice of the explanatory variables is discussed below. Let $P(i, t)$ denote a dummy variable that takes the value of one when financial sector policy reforms occur at time t and a value zero otherwise. β is a vector of n unknown coefficients and $F(\beta'X(i, t))$ is the cumulative probability distribution function evaluated at $\beta'X(i, t)$. The log-likelihood function model becomes:

$$\begin{aligned} \ln L = & \sum_{t=\dots\dots\dots T} \sum_{i=1\dots\dots\dots n} P(i, t) \ln \{F(\beta'X(i, t))\} \\ & + [1 - P(i, t)] \ln \{1 - F(\beta'X(i, t))\} \end{aligned} \quad (4.1)$$

In modelling the probability distribution, we use the logistic functional form. Thus, when interpreting the regression results, it is important to remember that the estimated coefficients do not indicate the increase in the probability of reforms, given a one-unit increase in the corresponding explanatory variables. Instead, in the above specification, the coefficients reflect the effect of a change in an explanatory variable on $\ln\{P(i, t)/(1 - P(i, t))\}$. Therefore, the increase in the probability depends upon the original probability and thus upon the initial values of all the independent variables and their coefficients. While the sign of the coefficient does indicate the direction of change, the magnitude depends on the slope of the cumulative distribution function $\beta'X(i, t)$.

In other words, a change in the explanatory variable will have different effects on the probability of reforms depending on the country's initial reforms probability. Under the logistic specification, if a country has an extreme high (or low) initial probability of financial sector policy reforms, a marginal change in the independent variables has little effect on its prospects, while the same marginal change has a greater effect if the country's probability of reforms is in an intermediate range. After the onset of financial sector policy reforms, the behaviour of some of the explanatory variables is likely to be affected by the reforms themselves. For instance, as described below, one explanatory variable used in the regression is the credit-to-GDP ratio. This ratio is likely to increase or decrease as a result of the banking sector reforms, and the reduction or increase in credit may, in turn, affect another explanatory variable: GDP growth. Another regressor that may be affected by the financial sector policy reforms is the real interest rate, which is likely to fall owing to loosening of the monetary policy that often accompanies banking sector restructurings and reforms.

The logistic distribution model framework in equation 4.1, used in this study, is commonly used in banking sector reforms studies such as those by Cole & Gunther (1993) and Gonzalez-Hermosillo et al. (1997). The detailed theoretical logistical regression discussions have been summarised in Appendix C3.2.

4.5 Financial Sector Policy Reforms Variable (Dependent Variable)

An essential component of our investigation involves creating the financial sector policy reforms dummy variable. To achieve this objective, we have utilised the

indicators presented in Table 4.2 of Section 4.2 to detect instances of financial sector policy reforms. Subsequently, we have assigned a financial sector reform dummy variable to each identified period. Our dependent variable, the reforms dummy, takes the value zero if there are no reforms, and takes the value one if there are reforms.

To do this, we have determined and established the episodes of financial sector policy reforms in the financial sector between the years 1980 and 2023, using the indicators provided in Table 4.2 of Section 4.2. We adopt a similar methodological approach that was used in the research on banking sector reforms which rely on five recent studies as their main sources: Caprio & Klingebiel (1996), Drees & Pazarbasioglu (1998), Kaminsky & Reinhart (1999), Lindgren et al. (1996), and Sheng (1995).

4.6 Explanatory Variables

Our choice of explanatory variables reflects the theory of the determinants of financial sector policy reforms summarized in Section 4. A list of the variables and their sources are in Table 4.3 below.

Table 4.3: Variables, expected signs, and data sources.

Variable name	Variable description	Expected signs	Rationale	Source
Inflation	Rate of change of the GDP deflator	-/+	Lower inflation signals a strong economy and healthy financial sector and higher inflation should lead to financial sector fragility and crises	World Bank Database
Growth	Rate of growth of real GDP	+/-	An increase in rate of GDP growth should lead to strong economy and healthy financial sector and a decrease in economic growth should	World Bank Database

			lead to financial sector fragility and crises	
Private Credit/GDP	Ratio of domestic credit to private sector GDP	+/-	The higher ratio signals a strong economy and healthy financial sector and lower ratio signals financial sector fragility and crises	World Bank Database
Broad Money/Total Reserves	Ratio of broad money to total reserves of the central bank	+/-	The lower ratio signals a strong economy and healthy financial sector and higher ratio signals financial sector fragility and crises	World Bank Database
	Rate of growth of broad money	+/-	From a medium to longer-term perspective, inflation moves in line with broad monetary aggregates. This relationship holds through time, as well as across countries and monetary policy regimes: it is “hardwired” into the deep structure of the economy. The higher the ratio, it is indicative of a looming financial sector or currency crisis.	World Bank Database
Short Term Debt/Export Revenue	Ratio of Government Short term debt	+/-	The lower the ratio signals a strong economy and healthy	World Bank Database

	to Export Revenues		financial sector as it reduces Government excessive appetite from domestic borrowing (crowding-out effects) and also reduction in banks' balance sheet exposure to sovereign risks.	
Debt Service Cost/Export Revenue	Ratio of Government Debt service costs to Export Revenues	+/-	The lower the ratio signals a strong economy and healthy financial sector as it reduces Government excessive appetite from domestic borrowing (crowding-out effects) and also reduction in banks' balance sheet exposure to sovereign risks.	World Bank Database
External Debt/Gross National Income	Ratio of Government External Debt to Gross National Income	+/-	The lower the ratio signals a strong economy and healthy financial/banking sector as it reduces Government excessive appetite from domestic borrowing (crowding-out effects) and also reduction in banks' balance sheet exposure to sovereign risks.	World Bank Database

Broad Money/GDP	The ratio of Broad Money to GDP		This is a proxy measure of financial development. The higher the ratio signals a strong economy and might spur banks to assume more risks by excessively expanding their balance sheets.	World Bank Database
Cash/Bank	Ratio of bank liquid reserves to bank assets	+/-	The higher ratio signals a strong economy and healthy financial/banking sector and lower ratio signals banking sector fragility and crises	World Bank Database

These variables include, the rate of growth of real GDP, the rate of inflation change, liquid assets to banking assets, broad money annual growth rates, broad money to GDP ratio, external debt to gross national income ratio, debt service costs to export revenue, short-term debt to external debt, short-term debt to revenue, and domestic credit to GDP ratio. The rationale for inclusion of financial liberalisation variables such as domestic credit to GDP ratio is because financial liberalisation might potentially lead to a rise in financial fragility due to the heightened possibilities for excessive risk-taking and fraudulent activities by the financial sector. Kaminsky & Reinhart (1999) discovered that the presence of a financial liberalisation variable is a reliable indicator for predicting the likelihood of reforms in their study of 20 nations. Pill and Pradhan (1995) determine that the most effective measure of the development of financial liberalisation is the ratio of credit allocated to the private sector in relation to the gross domestic product (GDP). Hence, we incorporate this variable as an independent variable in our calculations. Inflation is included as an explanatory factor due to its probable correlation with elevated nominal interest rates and its potential to represent macroeconomic mismanagement, which has negative repercussions on the economy

and the financial sector through several channels. We also included indicators such as the broad money to total reserves ratio, domestic credit to private sector as a percentage of GDP, broad money annual growth rate, broad money as a percentage of GDP, and liquid assets as a percentage of total monetary assets. These measurements signify the depth of the financial sector in a country and the extent of financial expansion and advancement to support economic activities, specifically the magnitude of the banking industry. These variables impact the risk appetite of banks and affect many aspects of their financial stability and depth of intermediation. If left unchecked, they can make the financial sector susceptible to crises, necessitating financial sector reforms.

We also included fiscal variables that examined the effect of central government funding tools on the financial sector. These include examples such as government short term debt as a proportion of export revenue, debt service expenses as a percentage of export revenue, short term debt as a percentage of total external debt and external debts as a percentage of gross national income. These capture the financial requirements of the central government and the effect of each financing option on the financial sector. These factors are significant because they impact available fiscal space due to challenging revenue collections (tax base). The central government frequently fails to implement stringent prudential rules that would typically enhance the financial sector or banking industry and banks' financial position, in order to facilitate their borrowing during periods of poor tax revenue collections. This inclination frequently leads to prudential authorities refraining from implementing financial reforms in good time. Lindgren, Garcia, and Saal (1996) state that supervisors frequently face obstacles when attempting to address issues in banks that are publicly known. This results in government spending. Common rationales for not acting include claims of insufficient budgetary capacity or a precarious economic condition that precludes addressing banking issues. Even if government authorities are willing to act despite financial constraints, the public may perceive otherwise, leading to bank runs that exacerbate the initial issues and escalate them into a full-blown crisis. Another rationale for considering the government's fiscal condition is that the inability to manage the budget deficit might provide a significant hindrance to the achievement of effective financial deregulation (McKinnon, 1973). Failed endeavours to implement financial deregulation might subsequently lead to complications for the banking sector.

4.7 Data and Sources

Table 4.3 presents the dependent variables used in the study, their expected signs, and the sources of data used in the analysis. This research employs annual panel data, which entails aggregating the data from commercial banks in Malawi from 1980 to 2022. The data used in this study was obtained from the IMF World Economic Outlook database, World Bank Data Bank and Reserve Bank of Malawi Website Database. The research used Stata 15.0 software for doing econometric estimates.

4.8 Robustness Check

We employed various Lagrange multiplier (LM) tests, including the Levin-Lin-Chu (2002), Haris-Tzavalis (1999), Breitung (2000), Breitung & Das (2005), Im-Pesaran-Shin (2003), Fisher-type (Choi, 2001), and Hadri (2000) tests, to assess the presence of unit root issues in our variables. The null hypothesis in all of these tests assumes the presence of a unit root. The findings of our analysis refuted the null hypothesis and established that there was no presence of a unit root in our data.

The outcomes are displayed in Appendix C3.2, and summarised in Table 4.4 below. Subsequently, we may utilise the variables in their present state to do our logistic regression analysis. Furthermore, we conducted an assessment to determine if the logistic model is an appropriate form to employ in our investigation. In logistic regression modelling, it is assumed that the logarithm of the odds of the outcome variable is a linear combination of the independent variables. This entails two facets, as we are addressing the two components of our logistic regression equation. Firstly, examine the link function of the dependent variable on the left side of the equation. It is presumed that the logit function is the appropriate function to utilise in logistic regression. Furthermore, on the right-hand side of the equation, we assume that we have included all the pertinent variables, excluded any variables that should not be part of the model, and that the logit function is a linear amalgamation of the predictors. There is a possibility that the logit function may not be the appropriate option as the link function, or that the connection between the logit of the outcome variable and the independent variables is not linear. Regardless of the scenario, we are faced with a specification error. The misapplication of the link function is often less significant as compared to employing alternative link functions such as probit, which is based on the normal distribution. In practical terms, our primary concern is whether our model

includes all the pertinent variables and if the linear combination of these predictors is satisfactory. We employed the Stata command "linktest" to identify a specification mistake, which is executed subsequent to the "logit" or "logistic" function. The underlying concept of linktest is that if the model is well described, any extra variables that are statistically significant should not be discoverable, unless by random accident. Following the regression command (namely, logit or logistic), the linktest uses the linear predicted value (`_hat`) and linear predicted value squared (`_hatsq`) as the predictors for reconstructing the model.

Given that the variable `_hat` represents the expected value from the model, it should serve as a statistically significant predictor. This will only occur if the model is entirely mischaracterized. However, if our model is well defined, the variable `_hatsq` should not have significant predictive ability except via random accident. Consequently, if the value of `_hatsq` is meaningful, then the linktest is also meaningful. This often indicates that we have either excluded pertinent variable(s) or inaccurately stated our connection function. The findings indicated that our logistic regression model was accurately described. The findings are displayed in Appendix C3.2. We further performed a goodness-of-fit model test. Hosmer and Lemeshow's goodness-of-fit test is a widely used measure of model fit. The concept underlying Hosmer and Lemeshow's goodness-of-fit test is that there should be a tight correspondence between the anticipated frequency and the actual frequency, and that a higher degree of correspondence indicates a better fit. Hosmer-Lemeshow's goodness-of-fit statistic is calculated by using the Pearson chi-square value derived from the contingency table that contains the observed frequencies and anticipated frequencies. A test of association for a two-way table, such as Hosmer and Lemeshow's test, will result in a significant p-value if there is a good match. When there are continuous predictors in the model, the presence of several cells defined by the predictor variables leads to the creation of a very large contingency table. Consequently, this often results in a significant outcome. A conventional approach involves consolidating the patterns created by the predictor variables into 10 groups and constructing a contingency table with dimensions of 2 by 10. Based on a p-value of 0.23, we may conclude that Hosmer and Lemeshow's goodness-of-fit test suggests that our model is an excellent fit for the data.

Table 4.4: Model robustness check results.

Type of test	Method used	Null hypothesis	Result
Panel unit root test	Levin-Lin-Chu (2002), Haris-Tzavalis (1999), Breitung (2000), Breitung and Das (2005), Im-Pesaran-Shin (2003), Fisher-type (Choi, 2001), and Hadri (2000) Lagrange multiplier (LM)	The null hypothesis tests are that all panels have a unit root.	The data strongly rejects the unit root null hypothesis, indicating stationarity for all model variables. The results are displayed in Appendix C4.2.2.
Model selection test	Linktest	The null hypothesis states that there are no misspecification errors and therefore no need to include or omit variables and that the predicated $\hat{Y}$ is very identical to the real Y dependent variable values; hence the selected logistic model is correct.	The data substantially accepted the null hypothesis that there are no specification errors and that the logistic regression was the preferred model. The variable $\hat{Y}$ is statistically significant predictor with p-value (0.008), and variable $\hat{Y}^2$ is statistically insignificant with a p-value of 0.262 (insignificant). Therefore, the linktest is insignificant. The results showed that our logistic regression model was correctly specified. The results are shown in Appendix C4.2.2.
Model goodness-of-fit test	Hosmer and Lemeshow's test	The null hypothesis states that there are is goodness of fit.	The test statistic follows a Chi-squared distribution with G-2 degrees of freedom. A large value of Chi-squared (with small p-value < 0.05) indicates poor fit and small Chi-squared values (with larger p-value closer to 1) indicate a good logistic regression model fit. The test result is a small Chi-squared of 10.49.30 with p-value of 0.2321 as shown in Appendix C4.2.2, indicating that the selected logistic model has goodness of fit and we accept the null hypothesis.

4.9 Empirical Results and Discussions

Table 4.5 below exhibits the results from the benchmark model and nesting seven models together and varying various variables. It is observed that the changes in GDP growth rates, changes in inflation rates, domestic credit to private sector to GDP ratio, total reserves as a percentage of external debt, short term debt as a percentage of export of goods, services and primary income, debt service costs as a percentage of primary export revenue, short term debt as a percentage of external debt, external debt to gross national income ratio and broad money to GDP ratio have a significant impact on the log-odds of financial sector policy reforms in Malawi.

Table 4.5: Model results and comparison.

	(1) equation1	(2) equation2	(3) equation3	(4) equation4	(5) equation5	(6) equation6	(7) equation7
gdpgrowthannual	-7.5725** (3.6002)	-7.5725** (3.6002)	-7.5725** (3.6002)		-2.5305*** (.9559)	-4.9718** (2.146)	
inflationexpect~n	1.1** (.5325)	1.1** (.5325)	1.1** (.5325)	.3496 (.3843)	.3526** (.1739)	.6881** (.3156)	
broadmoneytotot~i	-1.8249 (3.4334)	-1.8249 (3.4334)	-1.8249 (3.4334)	3.2901* (1.956)			2.7104 (1.7734)
domesticcreditt~r	-17.4428 (11.2149)	-17.4428 (11.2149)	-17.4428 (11.2149)	-6.1177* (3.2969)			-4.9479 (3.0227)
broadmoneygrowt~l	.0105 (.188)	.0105 (.188)	.0105 (.188)	.0467 (.074)			.0376 (.0719)
totalreservesof~d	2.3623 (2.7076)	2.3623 (2.7076)	2.3623 (2.7076)	2.7572 (1.8183)		2.9757* (1.6079)	2.1688 (1.7897)
shorttermdebtto~s	-12.4576** (5.9599)	-12.4576** (5.9599)	-12.4576** (5.9599)	-2.1594* (1.299)	-5.2192** (2.4839)	-7.42* (4.3259)	-2.1908* (1.2288)
debtseviceppga~p	-10.5708* (5.7873)	-10.5708* (5.7873)	-10.5708* (5.7873)	-.2203 (1.9231)	-4.6725* (2.7389)	-7.0361* (3.8442)	-.4393 (1.8584)
shorttermdebtto~d	5.6321** (2.8485)	5.6321** (2.8485)	5.6321** (2.8485)	.8929 (1.2568)	2.7475 (2.0962)	3.9277 (3.6197)	.9958 (1.2089)
externaldebtsto~i	33.4242** (13.5882)	33.4242** (13.5882)	33.4242** (13.5882)	7.9341** (3.3376)	13.9189** (6.2563)	27.6289** (12.9861)	7.7965** (3.2678)
broadmoneyofgdp	-26.0833* (13.3615)	-26.0833* (13.3615)	-26.0833* (13.3615)	-6.7644 (5.6149)	-16.6457** (7.5854)	-27.977** (12.8394)	-6.2681 (5.0958)
liquidassetsaso~y	-1.416 (11.7222)	-1.416 (11.7222)	-1.416 (11.7222)	-1.9397 (2.5501)		-2.4414 (3.7167)	-2.0987 (2.4934)
_cons	2.8156 (1.7719)	2.8156 (1.7719)	2.8156 (1.7719)	.2261 (.5732)	1.5007** (.677)	1.2644 (.7806)	.2844 (.5347)
Observations	43	43	43	43	43	43	43
Pseudo R ²	.7344	.7344	.7344	.3218	.504	.608	.2802

Standard errors are in parentheses

*** $p < .01$, ** $p < .05$, * $p < .1$

4.9.1 The Impact of Monetary, Fiscal and Macroeconomic Variables in Influencing Financial Sector Policy Reforms in Malawi

Our study has shown that a number of macroeconomic factors that measure the indebtedness of a country and its ability to service the debts, mobilise both internal and external domestic revenues have significant effects on the log-odds of influencing financial sector reforms in Malawi. A number of channels have been identified in the literature for the negative impact on private investment and saving of large ratios of external public debt to gross national incomes, debt service costs to countries revenues, and significant amount of short-term debts to overall external debt positions. In economic literature there are three channels are that are particularly relevant for the countries of sub-Saharan Africa, such as Malawi. First, the resources used for servicing the debt crowd out public investment, which in turn discourages private investment, given the complementarity between these two types of investments. Second, the external debt ratio could be indicative of a “debt overhang,” as discussed in Chapter Two of this thesis, whereby high debt ratios lead economic agents to anticipate increased future tax liabilities to enhance government capacity to service the increased debt levels. An increasing external debt ratio could also induce these agents to transfer funds abroad, thus raising the implicit domestic cost of capital. Finally, uncertainty as regards the future stance on economic policies in response to an uncertain debt-service profile could also have deleterious effects on private capital formation. These in turn usually have an impact on economic growth, and as supported by our study findings, GDP growth rates have indeed a negative log-odd on financial sector reforms. Hence to address these risks that comes with deteriorating debt levels, usually countries embark on financial and economic reforms.

The extent to which public debt dynamics change when market-oriented reforms are implemented in emerging markets and developing economies remains an open empirical question. The channels through which reforms affect fiscal outcomes, directly or indirectly and in either direction, may vary with countries’ structural characteristics and cyclical conditions. The existing literature examining the budgetary effects of structural reforms includes works by Hughes-Hallett, Jensen, and Richter (2005); International Monetary Fund (2016); Banerji et.al (2017); and Furceri and Jalles (2020). The majority of these

studies focused on advanced economies and, therefore, give rise to closer inspection of the fiscal implications of such reforms in emerging markets and developing economies, which remain greatly understudied. The sign and magnitude of the fiscal funding dynamics ultimately depend on reforms' credibility and design (Heinemann 2005; Tavares 2004; Deroose and Turrini 2005) as well as on the political economy aspects of structural reforms (Eichengreen and Wyplosz 1998; Saint-Paul 1996; Blanchard and Giavazzi 2003; Boeri 2005; Ciminelli et.al 2019; Alesina et.al 2020). The empirical analysis indicates that, on average, market reforms in emerging markets and developing economies have historically been associated with a reduction in the public-debt-to-GDP ratio over the medium term.

Our study also found that a number of factors that are important in the design and conduct of monetary policy such as changes in inflation rates, domestic credit to private sector to GDP ratio, total reserves as a percentage of external debt and broad money to GDP ratio have a significant effect on the log-odds of financial sector reforms in Malawi. It should be noted that it is one of monetary policy priorities to ensure that liquidity conditions remain consistent with achievement of the agreed targets for reserve money through open market operations. Hence broad money stock remains the nominal anchor and the primary tool for reducing inflation. Reserve money targets provide the framework for the central bank's monetary policy operations. Therefore, when broad money to GDP ratio targets departs from the monetary policy framework targets over a protracted period of time, authorities usually embark on reforms that address the risks on the financial sector. A stable macroeconomic environment usually is associated, among others, with low inflation and limited government recourse to funds from the banking system. As such, macroeconomic stabilization is indispensable to raising levels of private saving and capital formation and to thereby fostering private sector led development through increased supply of domestic credit to the private sector. A deterioration of the ratio of domestic credit to the private sector to GDP will therefore signal countries to embark on financial sector reforms.

4.9.2 Persistence of Financial Repression in Malawi and Implication for Future Reforms, and Policy Interventions

Financial repression in recent years in Malawi, particularly after the Covid-19 pandemic, has usually been in the form of a general rise in public debt, with high debt to GDP ratios. It also involves pursuing economic policies that artificially keep interest rates low to manage debt. Examples include the introduction of the reference rate in Malawi in 2019; banking regulators softening liquidity reserve requirement (LRR) ratios on both domestic and foreign deposits, thereby creating a significant pool of resources that banks can continue to use for lending—resources that end up being taken up by government debt; moral suasion regulations that request banks to give moratoriums and lower interest rates to customers in the wake of the pandemic; and in some cases, through regulations requiring banks to hold a specific amount of government bonds, effectively reducing the yield on those bonds.

While financial repressive policies might initially help governments to deleverage, financial repression can have unintended consequences, impacting private investment and saving decisions, potentially leading to a net increase in the debt-to-GDP ratio. Because of globally and nationally induced low interest rates, governments borrowed heavily but the majority of the borrowings went towards social services and not in public investments that enhance the GDP growth. Inadvertently, the huge government debts resulted in increased spending towards debt servicing costs at the expense of growth enhancing investments, thereby reducing the fiscal space and compounding fiscal dominance problems and resulting in stagflation (low growth and high inflation).

Among the solutions to solve the side effects of prolonged financial repressive policies is the implementation of fiscal consolidation policies, which address the growing public debt, both external and domestic; and policies that reduce or contain the fiscal deficits. These are mainly revenue enhancing policies and expenditure control policies. Governments should reduce the levels of general subsidies that they offer in the economy, control the size of the government (addressing employment cost to GDP ratio), and implementing reforms that

bring about efficiency in service delivery and revenue collection. These could also form part of future research on the same question.

4.10 Conclusion and Policy Recommendations

The results of our analysis indicate that financial sector reforms in Malawi are primarily influenced by macroeconomic (fiscal) and monetary factors. These findings are indicative that there are still some elements of financial repression in the financial sector in Malawi. This necessitates implementation of financial sector reforms. Fry (1995) argues that financial repression represents a significant and unintended type of financial limitation, which he views as a suboptimal strategy for governments that struggle with fiscal space issues (tax collection capabilities). In such situations of fiscal space constraint, most governments in developing countries resort to seigniorage revenue, increased reserve requirements, and obtaining significant government bonds from the domestic financial sector, thereby increasing the cost of borrowing in domestic markets. This serves as an implicit interest rate ceiling and discourages the financial sector from efficiently allocating capital to sectors that usually generate economic growth. It is therefore recommended that government implement strategies that ensure a widening and deepening of the tax base so as to improve revenue collection. This is because our findings have shown that debt sustainability indicators are mostly the ones that determine the extent of financial sector reforms in Malawi.

Studies on determinants of banking reforms, banking crises and fragility have extensively used the probit/logit framework. However, the disadvantage of this approach is that it is static, thereby not able to capture dynamics of banking reforms in terms of timing and likelihood over time. To overcome these shortcomings of the probit/logit model, future studies may consider using the duration model with time-varying covariates. This approach provides the conditional probability of observing banking reforms at period t , assuming no such bank reform has occurred in the economy until period t . The main advantages of using the duration model compared to the conventional probit/logit approach is that the duration model recognizes that the probability of a bank reform may vary over time depending on bank-specific, country-specific and macroeconomic conditions. Further, duration model

does not require strong distributional assumptions associated with probit/logit models. These could form the basis of future research on the same topic.

Appendix C4.1: Modelling Conditional Probabilities

There are several research questions where we focus on input-output interactions, similar to regression analysis, but with a discrete output variable instead of a continuous one. There are several instances where we encounter binary results, such as whether a loan will be repaid or not, or if a bank will fail or not. Aside from the binary result, we have some input variables that may exhibit continuity or discontinuity. What methods may we use to create a representation and examine this data? The examination of logistic models provides the solution to this question. We might attempt to formulate a rule that predicts the binary output based on the input variables. The process is referred to as classification, and it has significance in the fields of statistics and machine learning. However, employing a binary approach of guessing either “yes” or “no” is somewhat rudimentary, particularly in the absence of an infallible principle. (What is the justification for its existence?) An approach that considers noise and provides a nuanced response is frequently advantageous. Essentially, we require probabilities, necessitating the fitting of a stochastic model.

It would be desirable to know the conditional distribution of the response variable Y , given the input variables X , denoted as $\Pr(Y \mid X)$. This would provide us with information on the accuracy of our forecasts. If our model predicts a 51% probability of snow and it fails to snow, it is preferable to a scenario where the model predicts a 99% probability of snow (although even a 99% probability does not guarantee snowfall). We have seen the method of estimating conditional probabilities in a non-parametric manner, which may be accomplished by using the kernels designed for discrete variables. Although this strategy has many advantages, it requires the development of a model for the simultaneous distribution of outputs Y and inputs X , which can be a time-consuming task.

Let us designate one of the classes as “1” and the other as “0”. Then Y becomes an indicator variable, and you can convince yourself that $\Pr(Y = 1) = E[Y]$. Similarly, $\Pr(Y = 1 \mid X = x) = E\{Y \mid X = x\}$. (In a phrase, “conditional probability is the conditional

expectation of the indicator”. This is advantageous for us since we have acquired comprehensive knowledge regarding the estimation of conditional expectations. To proceed efficiently, we should select our preferred smoothing method and calculate the regression function for the indicator variable.

This will provide an estimate of the conditional probability function. There are two reasons not to just plunge ahead with that idea. One is that probabilities must be between 0 and 1, but our smoothers will not necessarily respect that, even if all the observed y_i they get are either 0 or 1. The other is that we might be better off making more use of the fact that we are trying to estimate probabilities, by more explicitly modeling the probability. Assume that $Pr(Y = 1|X = x) = p(x; \theta)$, for some function p parameterized by θ . parameterized function θ , and further assume that observations are independent of each other. The (conditional) likelihood function is

$$\prod_{i=1}^n Pr(Y = y_i|X = x_i) = \prod_{i=1}^n p(x_i; \theta)^{y_i} (1 - p(x_i; \theta))^{1-y_i} \quad (C4.1.1)$$

In a sequence of Bernoulli trials $y_1 \dots \dots \dots y_n$, where there is a constant probability of success p , the likelihood is

$$\prod_{i=1}^n p^{y_i} (1 - p)^{1-y_i} \quad (C4.1.2)$$

This likelihood is maximized when $p = \hat{p} = n^{-1} \sum_i^n y_i$. If each trial had its own success probability p_i , this likelihood becomes

$$\prod_{i=1}^n p_i^{y_i} (1 - p_i)^{1-y_i} \quad (C4.1.3)$$

Without some constraints, estimating the “inhomogeneous Bernoulli” model by maximum likelihood does not work; we would get $\hat{p}_i = 1$ when $y_i = 1$, $\hat{p}_i = 0$ when $y_i = 0$, and learn nothing. If, on the other hand, we assume that the p_i is not just arbitrary numbers but are linked together, those constraints give non-trivial parameter estimates, and let us generalize. In the kind of model we are talking about, the constraint, $p_i = p(x_i; \theta)$, tells us that p_i must be the same whenever x_i is the same, and if p is a continuous function, then similar values of x_i must lead to similar values of p_i . Assuming p is known (up to

parameters), the likelihood is a function of θ , and we can estimate θ by maximizing the likelihood.

Appendix C4.1.1: Logistic Regression

To sum up: we have a binary output variable Y , and we want to model the conditional probability $\Pr(Y = 1|X = x)$ as a function of x ; any unknown parameters in the function are to be estimated by maximum likelihood. Using linear regression to solve the likelihood function, we follow the steps below:

- 1) The most obvious idea is to let $p(x)$ be a linear function of x . Every increment of a component of x would add or subtract so much to the probability. The conceptual problem here is that p must be between 0 and 1, and linear functions are unbounded. Moreover, in many situations we empirically see “diminishing returns” — changing p by the same amount requires a bigger change in x when p is already large (or small) than when p is close to 1/2. Linear models cannot do this.
- 2) The next most obvious idea is to let $\log p(x)$ be a linear function of x , so that changing an input variable multiplies the probability by a fixed amount. The problem is that logarithms are unbounded in only one direction, and linear functions are not.
- 3) Finally, the easiest modification of $\log p$ which has an unbounded range is the logistic (or logit) transformation, $\log \frac{p}{1-p}$. We can make this a linear function of x without fear of nonsensical results. (Of course, the results could still happen to be wrong, but they are not guaranteed to be wrong.)

This last alternative is logistic regression. Formally, the model logistic regression model is that

$$\log \frac{p(x)}{1-p(x)} = \beta_0 + x \cdot \beta \quad (\text{C4.1.4})$$

Solving for p , this gives

$$p(x; b, w) = \frac{e^{\beta_0 + x \cdot \beta}}{1 + e^{\beta_0 + x \cdot \beta}} = \frac{1}{1 + e^{-(\beta_0 + x \cdot \beta)}} \quad (\text{C4.1.5})$$

Notice that the overall specification is a lot easier to grasp in terms of the transformed probability than in terms of the untransformed probability.

To minimize the misclassification rate, we should predict $Y = 1$ when $p \geq 0.5$ and $Y = 0$ when $p < 0.5$. This means guessing 1 whenever $\beta_0 + x \cdot \beta$ is non-negative, and 0 otherwise. So logistic regression gives us a linear classifier. The decision boundary separating the two predicted classes is the solution of $\beta_0 + x \cdot \beta = 0$, which is a point if x is one dimensional, a line if it is two dimensional, etc. One can show (exercise!) that the distance from the decision boundary is $\frac{\beta_0}{\|\beta\|} + x \cdot \beta / \|\beta\|$. Logistic regression not only says where the boundary between the classes is, but also says (via equation C4.1.5) that the class probabilities depend on distance from the boundary, in a particular way, and that they go towards the extremes (0 and 1) more rapidly when $\|\beta\|$ is larger. It is these statements about probabilities which make logistic regression more than just a classifier. It makes stronger, more detailed predictions, and can be fit in a different way; but those strong predictions could be wrong. Using logistic regression to predict class probabilities is a modelling choice, just like it is a modelling choice to predict quantitative variables with linear regression.

Logistic regression is one of the most commonly used tools for applied statistics and discrete data analysis. There are basically four reasons for this.

- 1) Tradition.
- 2) In addition to the heuristic approach above, the quantity $\log \frac{p}{1-p}$ plays an important role in the analysis of contingency tables (the “log odds”). Classification is a bit like having a contingency table with two columns (classes) and infinitely many rows (values of x). With a finite contingency table, we can estimate the log-odds for each row empirically, by just taking counts in the table.
With infinitely many rows, we need some sort of interpolation scheme; logistic regression is linear interpolation for the log-odds.
- 3) It is closely related to “exponential family” distributions, where the probability of some vector v is proportional to $\exp \beta_0 + \sum_{j=1}^m f_j(v) \beta_j$. If one of the components of v is binary, and the functions f_j are all the identity function, then we get a logistic

- regression. Exponential families arise in many contexts in statistical theory (and in physics!), so there are lots of problems which can be turned into logistic regression.
- 4) It often works surprisingly well as a classifier. But many simple techniques often work surprisingly well as classifiers, and this does not really testify to logistic regression getting the probabilities right.

Appendix C4.1.2: Likelihood Function for Logistic Regression

Because logistic regression predicts probabilities, rather than just classes, we can fit it using likelihood. We have a vector of features, x_i , and an observed class, y_i . The probability of that class was either p , if $y_i = 1$, or $1 - p$, if $y_i = 0$. The likelihood is then

$$L(\beta_0, \beta) = \prod_{i=1}^n p(x_i)^{y_i} (1 - p(x_i))^{1-y_i} \quad (\text{C4.1.6})$$

The log-likelihood turns products into sums:

$$l(\beta_0, \beta) = \sum_{i=1}^n y_i \log p(x_i) + (1 - y_i) \log 1 - p(x_i) \quad (\text{C4.1.7})$$

$$= \sum_{i=1}^n \log 1 - p(x_i) + \sum_{i=1}^n y_i \log \frac{p(x_i)}{1 - p(x_i)} \quad (\text{C4.1.8})$$

$$= \sum_{i=1}^n \log 1 - p(x_i) + \sum_{i=1}^n y_i (\beta_0 + x_i \cdot \beta) \quad (\text{C4.1.9})$$

$$= \sum_{i=1}^n -\log 1 + e^{\beta_0 + x_i \cdot \beta} + \sum_{i=1}^n y_i (\beta_0 + x_i \cdot \beta) \quad (\text{C4.1.10})$$

Where in the next-to-last step we finally use equation C4.1.4. Typically, to find the maximum likelihood estimates would differentiate the log likelihood with respect to the parameters, set the derivatives equal to zero, and solve. To start that, take the derivative with respect to one component of β , say β_j .

$$\frac{\partial l}{\partial \beta_j} = - \sum_{i=1}^n \frac{1}{1 + e^{\beta_0 + x_i \cdot \beta}} e^{\beta_0 + x_i \cdot \beta} x_{ij} + \sum_{i=1}^n y_i x_{ij} \quad (\text{C4.1.11})$$

$$= \sum_{i=1}^n (y_i - p(x_i; \beta_0, \beta)) x_{ij} \quad (\text{C4.1.12})$$

We are not going to be able to set this to zero and solve exactly. (That is a transcendental equation, and there is no closed-form solution.) We can, however, approximately solve it numerically.

Appendix C4.1.3: Logistic Regression with More Than Two Classes

If Y can take on more than two values, say k of them, we can still use logistic regression. Instead of having one set of parameters β_0, β , each class c in $0: (k - 1)$ will have its own offset $\beta_0^{(c)}$ and vector $\beta^{(c)}$, and the predicted conditional probabilities will be

$$\Pr(Y = c | \vec{X} = x) = \frac{e^{\beta_0^{(c)} + x \cdot \beta^{(c)}}}{\sum_c e^{\beta_0^{(c)} + x \cdot \beta^{(c)}}} \quad (\text{C4.1.13})$$

You can check that when there are only two classes (say, 0 and 1), equation C4.1.13 reduces to equation C3.1.12, with $\beta_0 = \beta_0^{(1)} - \beta_0^{(0)}$ and $\beta = \beta^{(1)} - \beta^{(0)}$. In fact, no matter how many classes there are, we can always pick one of them, say $c = 0$, and fix its parameters at exactly zero, without any loss of generality. Calculation of the likelihood now proceeds as before, and so does maximum likelihood estimation.

Appendix C4.1.4: Newton's Method for Numerical Optimization

There are a huge number of methods for numerical optimization; we cannot cover all bases, and there is no magical method which will always work better than anything else. However, there are some methods which work very well on difficult problems which keep coming up. One of the most ancient yet important of them is Newton's method ("Newton-Raphson"). Let us start with the simplest case of minimizing a function of one scalar variable, say $f(\beta)$. We want to find the location of the global minimum, β^* . We suppose that f is smooth, and that β^* is a regular interior minimum, meaning that the derivative at β^* is zero and the second derivative is positive. Near the minimum we could make a Taylor expansion:

$$f(\beta) \approx f(\beta^*) + \frac{1}{2}(\beta - \beta^*)^2 \left. \frac{d^2 f}{d\beta^2} \right|_{\beta = \beta^*} \quad (\text{C4.1.14})$$

We can see here that the second derivative has to be positive to ensure that $f(\beta) > f(\beta^*)$. In words, $f(\beta)$ is close to quadratic near the minimum. Newton's method uses this fact, and minimizes a quadratic approximation to the function we are really interested in. (In other words, Newton's method is to replace the problem we want to solve, with a problem which we can solve.) Guess an initial point $\beta(0)$.

If this is close to the minimum, we can take a second order Taylor expansion around $\beta(0)$ and it will still be accurate:

$$f(\beta) \approx f(\beta^{(0)}) + (\beta - \beta^{(0)}) \left. \frac{df}{dw} \right|_{\beta = \beta^{(0)}} + \frac{1}{2} (\beta - \beta^{(0)})^2 \left. \frac{d^2f}{dw^2} \right|_{\beta = \beta^{(0)}} \quad (\text{C4.1.15})$$

Now it is easy to minimize the right-hand side of equation C4.1.15. Let us abbreviate the

derivatives, because they get tiresome to keep writing out: $\left. \frac{df}{dw} \right|_{\beta = \beta^{(0)}} = f'(\beta^{(0)})$,

$\left. \frac{d^2f}{dw^2} \right|_{\beta = \beta^{(0)}} = f''(\beta^{(0)})$. We just take the derivative with respect to β , and set it equal

to zero at a point we shall call β^1 :

$$0 = f'(\beta^{(0)}) + \frac{1}{2} f''(\beta^{(0)}) 2(\beta^{(1)} - \beta^{(0)}) \quad (\text{C4.1.16})$$

$$\beta^{(1)} = \beta^{(0)} - \frac{f'(\beta^{(0)})}{f''(\beta^{(0)})} \quad (\text{C4.1.17})$$

The value $\beta(1)$ should be a better guess at the minimum β^* than the initial one $\beta(0)$ was. So, if we use it to make a quadratic approximation to f , we shall get a better approximation, and so we can iterate this procedure, minimizing one approximation and then using that to get a new approximation:

$$\beta^{(n+1)} = \beta^{(n)} - \frac{f'(\beta^{(n)})}{f''(\beta^{(n)})} \quad (\text{C4.1.18})$$

Notice that the true minimum β^* is a fixed point of equation C4.1.18: if we happen to land on it, we shall stay there (since $f'(\beta^*) = 0$). We will not show it, but it can be proved that if $\beta^{(0)}$ is close enough to β^* , then $\beta^{(n)} \rightarrow \beta^*$, and that in general $|\beta^{(n)} - \beta^*| = O(n^{-2})$, a very rapid rate of convergence. (Doubling the number of iterations we use does not reduce the error by a factor of two, but by a factor of four).

Appendix C4.1.5: Newton's Method in More than One Dimension

Suppose that the objective f is a function of multiple arguments, $f(\beta_1, \beta_2, \dots, \beta_p)$. Let's bundle the parameters into a single vector, w . Then the Newton update is

$$\beta^{(n+1)} = \beta^{(n)} - H^{-1}(\beta^{(n)}) \nabla f(\beta^{(n)}) \quad (\text{C4.1.19})$$

where ∇f is the gradient of f , its vector of partial derivatives $[\frac{\partial f}{\partial \beta_1}, \partial f / \partial \beta_2, \dots, \partial f / \partial \beta_p]$, and H is the Hessian of f , its matrix of second partial derivatives, $H_{ij} = \frac{\partial^2 f}{\partial \beta_i \partial \beta_j}$. Calculating H and ∇f is not usually very time-consuming, but taking the inverse of H is, unless it happens to be a diagonal matrix. This leads to various quasi-Newton methods, which either approximate H by a diagonal matrix, or take a proper inverse of H only rarely (maybe just once), and then try to update an estimate of $H^{-1}(\beta^{(n)})$ as $\beta^{(n)}$ changes.

Appendix C4.1.6: Iteratively Re-Weighted Least Squares

Logistic regression, after all, is a linear model for a transformation of the probability. Let us call this transformation g :

$$g(p) \equiv \log \frac{p}{1-p} \quad (\text{C4.1.20})$$

So, the model is

$$g(p) = \beta_0 + x \cdot \beta \quad (\text{C4.1.21})$$

and $Y|X = x \sim \text{Binom}(1, g^{-1}(\beta_0 + x \cdot \beta))$.

It seems that what we should want to do is take $g(y)$ and regress it linearly on x . Of course, the variance of Y , according to the model, is going to change depending on x — it will be $(g^{-1}(\beta_0 + x \cdot \beta))(1 - g^{-1}(\beta_0 + x \cdot \beta))$ - so we really ought to do a weighted linear regression, with weights inversely proportional to that variance. Since writing $\beta_0 + x \cdot \beta$ is getting annoying, let us abbreviate it by μ (for “mean”), and let's abbreviate that variance as $V(\mu)$. The problem is that y is either 0 or 1, so $g(y)$ is either $-\infty$ or $+\infty$. We will evade this by using Taylor expansion.

$$g(y) \approx g(\mu) + (y - \mu)g'(\mu) \equiv z \quad (\text{C4.1.22})$$

The right-hand side, z will be our effective response variable. To regress it, we need its variance, which by propagation of error will be $(g'(\mu))^2 V(\mu)$. Notice that both the weights

and z depend on the parameters of our logistic regression, through μ . So having done this once, we should really use the new parameters to update z and the weights, and do it again. Eventually, we come to a fixed point, where the parameter estimates no longer change. The treatment above is rather heuristic, but it turns out to be equivalent to using Newton's method, with the expected second derivative of the log likelihood, instead of its actual value. Since, with a large number of observations, the observed second derivative should be close to the expected second derivative, this is only a small approximation.

Appendix C4.1.7: Generalized Linear Models and Generalized Additive Models

Logistic regression is a type of generalised linear model (GLM) that belongs to a larger family of models. In logistic regression, the response variable is assumed to follow a certain parametric distribution, and the parameters of this distribution are determined by a linear predictor. Ordinary least-squares regression refers to a scenario where the response variable follows a Gaussian distribution, with a mean that is equal to the linear predictor, and a constant variance. Logistic regression refers to a scenario in which the response variable follows a binomial distribution. The number of data points with a certain value of x (usually 1, but not necessarily) is denoted by n . The probability, p , is determined by equation C4.1.5. Altering the connection between the parameters and the linear predictor is referred to as modifying the link function. The link function is used on the mean response in order to obtain the linear predictor, rather than the reverse process. This is due to computational considerations, as stated in section C4.1.4 rather than C4.1.5. In addition to logistic regression, there are several types of binomial regression. Additionally, there is the option of utilising Poisson regression, which is suitable for datasets consisting of counts that do not have an upper limit. Another alternative is gamma regression. One caveat regarding the use of maximum likelihood for fitting logistic regression is that it may exhibit poor performance when the data can be linearly segregated. In order to maximise the probability, $p(x_i)$ should have a high value when $y_i = 1$, and a low value when $y_i = 0$. If β_0, β_0 is a set of parameters that perfectly classifies the data, then any scaled version of β_0 , denoted as $c\beta$ where $c > 1$, will also perfectly classify the data.

However, in logistic regression, the scaled set of parameters will yield more extreme probabilities and therefore a higher likelihood. In the case of linearly separable data, there

is no parameter vector that maximises the likelihood, as the likelihood can always be increased by scaling the vector while maintaining its direction.

Appendix C4.1.8: Generalized Additive Models

Generalised additive models (GAMs) are a logical progression from generalised linear models. In GAMs, rather than representing the transformed mean response as a linear function of the inputs, we represent it as an additive function of the inputs. This entails integrating a procedure for optimising additive models with the maximisation of likelihood. Generalised Additive Models (GAMs) can be employed to assess Generalised Linear Models (GLMs) in a similar manner that smoothers can be used to evaluate parametric regressions. The procedure involves fitting a GAM and a GLM to the same dataset, simulating data from the GLM, and subsequently re-fitting both models to the simulated data. When performed several times, this yields a distribution that quantifies the extent to which the Generalised Additive Model (GAM) seems to provide a superior fit compared to the Generalised Linear Model (GLM), even when the GLM is accurate. Subsequently, you may extract a p-value from this distribution.

Appendix C4.2: Model Diagnostic results

Appendix C4.2.1: Model Specification Test

Iteration 0: log likelihood = -28.38259						
Iteration 1: log likelihood = -20.180477						
Iteration 2: log likelihood = -19.815672						
Iteration 3: log likelihood = -19.811793						
Iteration 4: log likelihood = -19.811792						
Logistic regression					Number of obs	43
					LR chi2(2)	17.14
					Prob > chi2	0.0002
Log likelihood = -19.811792					Pseudo R2	0.302
financialreformdummy	Coef. Std. Err.	Coef.	z	P> z	[95% Conf. Interval]	
_hat	1.350618	0.510436	2.65	0.008	0.350182	2.351054
_hatsq	-0.2138164	0.1906749	-1.12	0.262	-0.5875324	0.1598996
_cons	0.1930913	0.4586444	0.42	0.674	-0.7058352	1.092018

Appendix C4.2.2: Hosmer and Lemeshow's goodness-of-fit test

Group	Prob	Obs_1	Exp_1	Obs_0	Exp_0	Total
1	0.2313	1	0.7	4	4.3	5
2	0.3031	0	1.2	4	2.8	4
3	0.4727	1	1.6	3	2.4	4
4	0.5905	4	2.7	1	2.3	5
5	0.6653	4	2.6	0	1.4	4
6	0.7562	3	2.9	1	1.1	4
7	0.8488	3	4	2	1	5
8	0.9356	4	3.7	0	0.3	4
9	0.9559	3	3.8	1	0.2	4
10	0.9858	4	3.9	0	0.1	4

number of observations	=	43
number of groups	=	10
Hosmer-Lemeshow chi2(8)	=	10.49
Prob > chi2	=	0.2321

Unit Root Test for the Variables

Appendix C4.2.3: Fisher Type Unit Root Test

Fisher-type unit-root test for gdpgrowthannual

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	0 lags	
		Statistic	p-value
Inverse chi-squared(2)	P	32.0243	0.0000
Inverse normal	Z	-5.1796	0.0000
Inverse logit t(9)	L*	-9.4375	0.0000
Modified inv. chi-squared	Pm	15.0121	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Fisher-type unit-root test for inflationexpectation

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43
AR parameter: Panel-specific Asymptotics: T -> Infinity	Asymptotics: T -> Infinity		
Panel means: Included			
Time trend: Not included			
Drift term: Not included	ADF regressions:	0 lags	
		Statistic	p-value
Inverse chi-squared(2)	P	39.02	0.0000
Inverse normal	Z	-5.7976	0.0000
Inverse logit t(9)	L*	-11.4991	0.0000
Modified inv. chi-squared	Pm	18.51	0.0000
P statistic requires number of panels to be finite.			
Other statistics are suitable for finite or infinite number of panels.			

Fisher-type unit-root test for broadmoneytototalreservesratio

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots

Ha: At least one panel is stationary

Number of panels = 1

Number of periods = 43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	39.8334	0.0000
Inverse normal	Z	-5.8654	0.0000
Inverse logit t(9)	L*	-11.7388	0.0000
Modified inv. chi-squared	Pm	18.9167	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for domesticcredittoprivatesectorofg

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots

Ha: At least one panel is stationary

Number of panels = 1

Number of periods = 43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	40.1496	0.0000
Inverse normal	Z	-5.8916	0.0000
Inverse logit t(9)	L*	-11.832	0.0000
Modified inv. chi-squared	Pm	19.0748	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for broadmoneygrowthannual

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	36.1699	0.0000
Inverse normal	Z	-5.5536	0.0000
Inverse logit t(9)	L*	-10.6592	0.0000
Modified inv. chi-squared	Pm	17.085	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for totalreservesoftotalexternaldebt

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	37.9228	0.0000
Inverse normal	Z	-5.7048	0.0000
Inverse logit t(9)	L*	-11.1758	0.0000
Modified inv. chi-squared	Pm	17.9614	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for shorttermdebttoexportsgoodsser

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity
 Panel means: Included
 Time trend: Not included
 Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	45.9746	0.0000
Inverse normal	Z	-6.3554	0.0000
Inverse logit t(9)	L*	-13.5486	0.0000
Modified inv. chi-squared	Pm	21.9873	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for debtserviceppgandimfonlyofexport

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity
 Panel means: Included
 Time trend: Not included
 Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	15.532	0.0004
Inverse normal	Z	-3.3367	0.0004
Inverse logit t(9)	L*	-4.577	0.0007
Modified inv. chi-squared	Pm	6.766	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for shorttermdebtoftotalexternaldebt

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity
 Panel means: Included
 Time trend: Not included
 Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	40.6884	0.0000
Inverse normal	Z	-5.9359	0.0000
Inverse logit t(9)	L*	-11.9908	0.0000
Modified inv. chi-squared	Pm	19.3442	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for externaldebtstocksofgni

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity
 Panel means: Included
 Time trend: Not included
 Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	32.5262	0.0000
Inverse normal	Z	-5.2262	0.0000
Inverse logit t(9)	L*	-9.5854	0.0000
Modified inv. chi-squared	Pm	15.2631	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for broadmoneyofgdp

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	39.0264	0.0000
Inverse normal	Z	-5.7981	0.0000
Inverse logit t(9)	L*	-11.501	0.0000
Modified inv. chi-squared	Pm	18.5132	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Fisher-type unit-root test for liquidassetsasoftotalmonetaryass

Based on augmented Dickey-Fuller tests

Ho: All panels contain unit roots	Number of panels	=	1
Ha: At least one panel is stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: T -> Infinity

Panel means: Included

Time trend: Not included

Drift term: Not included

Asymptotics: T -> Infinity

ADF regressions: 0 lags

		Statistic	p-value
Inverse chi-squared(2)	P	25.0697	0.0000
Inverse normal	Z	-4.4877	0.0000
Inverse logit t(9)	L*	-7.388	0.0000
Modified inv. chi-squared	Pm	11.5348	0.0000

P statistic requires number of panels to be finite.

Other statistics are suitable for finite or infinite number of panels.

Appendix C4.2.4: Levin-Lin-Chu Test

Levin-Lin-Chu unit-root test for *gdpgrowthannual*

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
	Statistic		p-value
Unadjusted t	-6.9092		
Adjusted t*	-5.8486		0.0000

Levin-Lin-Chu unit-root test for *inflationexpectation*

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
	Statistic		p-value
Unadjusted t	-5.3371		
Adjusted t*	-3.7886		0.0001

Levin-Lin-Chu unit-root test for broadmoneytototalreservesratio

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
Panel means: Included
Time trend: Not included

ADF regressions: 1 lag
LR variance: Bartlett kernel 11 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-5.6515	
Adjusted t*	-4.2261	0.0000

Levin-Lin-Chu unit-root test for domesticcredittoprivatesectorofg

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
Panel means: Included
Time trend: Not included

ADF regressions: 1 lag
LR variance: Bartlett kernel 11 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-4.0243	
Adjusted t*	-2.4378	0.0074

Levin-Lin-Chu unit-root test for broadmoneygrowthannual

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43

AR parameter: Common Asymptotics: Asymptotics: N/T $\rightarrow$ 0
Panel means: Included
Time trend: Not included

ADF regressions: 1 lag
LR variance: Bartlett kernel 11 lags average (chosen by LLC)

	Statistic	p-value
Unadjusted t	-4.8604	
Adjusted t*	-2.8897	0.0019

Levin-Lin-Chu unit-root test for totalreservesoftotalexternaldebt

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-5.7622	
Adjusted t*		-4.4938	0.0000

Levin-Lin-Chu unit-root test for shorttermdebttoexportsogoodsser

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-6.8107	
Adjusted t*		-5.3231	0.0000

Levin-Lin-Chu unit-root test for debtserviceppgandimfonlyofexport

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-5.1087	
Adjusted t*		-3.9485	0.0000

Levin-Lin-Chu unit-root test for shorttermdebtoftotalexternaldebt

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-5.9934	
Adjusted t*		-4.4799	0.0000

Levin-Lin-Chu unit-root test for externaldebtstocksofgni

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-5.2193	
Adjusted t*		-3.6777	0.0001

Levin-Lin-Chu unit-root test for broadmoneyofgdp

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-4.9009	
Adjusted t*		-3.3179	0.0005

Levin-Lin-Chu unit-root test for liquidassetsasoftotalmonetaryass

Ho: Panels contain unit roots	Number of panels	=	1
Ha: Panels are stationary	Number of periods	=	43
AR parameter: Common Asymptotics:	Asymptotics: N/T -> 0		
Panel means: Included			
Time trend: Not included			
ADF regressions: 1 lag			
LR variance: Bartlett kernel 11 lags average (chosen by LLC)			
		Statistic	p-value
Unadjusted t		-5.0021	
Adjusted t*		-3.5255	0.0002

Appendix C4.2.5: Im-Pesaran-Shin Unit Root Test

Im-Pesaran-Shin unit-root test for
gdpgrowthannual

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.0776		-2.42	-2.15	-2.0200
t-tilde-bar	-4.4367				
Z-t-tilde-bar	-3.7	0.0001			

Im-Pesaran-Shin unit-root test for
inflationexpectation

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.7273		-2.42	-2.15	-2.0200
t-tilde-bar	-4.6652				
Z-t-tilde-bar	-3.9847	0.0000			

Im-Pesaran-Shin unit-root test for broadmoneytototalreservesratio

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific

Asymptotics:

Asymptotics: T N -> Infinity

Panel means: Included sequentially

Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.8008		-2.42	-2.15	-2.0200
t-tilde-bar	-4.6889				
Z-t-tilde-bar	-4.0143	0.0000			

Im-Pesaran-Shin unit-root test for domesticcredittoprivatesectorofg

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific

Asymptotics:

Asymptotics: T N -> Infinity

Panel means: Included sequentially

Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.8292		-2.42	-2.15	-2.0200
t-tilde-bar	-4.698				
Z-t-tilde-bar	-4.0256	0.000			

Im-Pesaran-Shin unit-root test for
broadmoneygrowthannual

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.4668		-2.42	-2.15	-2.0200
t-tilde-bar	-4.5777				
Z-t-tilde-bar	-3.8758	0.00010			

Im-Pesaran-Shin unit-root test for
totalreservesoftotalexternaldebt

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.6276		-2.42	-2.15	-2.0200
t-tilde-bar	-4.6324				
Z-t-tilde-bar	-3.9438	0.00000			

Im-Pesaran-Shin unit-root test for
shorttermdebttoexportsgoodsser

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific

Asymptotics:

Asymptotics: T N -> Infinity

Panel means: Included
sequentially

Time trend: Not included

ADF regressions: No lags
included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-7.3453		-2.42	-2.15	-2.0200
t-tilde-bar	-4.8523				
Z-t-tilde-bar	-4.2179	0.0000			

Im-Pesaran-Shin unit-root test for
debtseviceppgandimonlyofexport

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific

Asymptotics:

Asymptotics: T N -> Infinity

Panel means: Included sequentially

Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-4.3117		-2.42	-2.15	-2.0200
t-tilde-bar	-3.6068				
Z-t-tilde-bar	-2.666	0.0038			

Im-Pesaran-Shin unit-root test for
shorttermdebtoftotalexternaldebt

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.8776		-2.42	-2.15	-2.0200
t-tilde-bar	-4.7132				
Z-t-tilde-bar	-4.0446	0.00000			

Im-Pesaran-Shin unit-root test for
externaldebtstocksofgni

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.1255		-2.42	-2.15	-2.0200
t-tilde-bar	-4.4547				
Z-t-tilde-bar	-3.7225	0.0001			

Im-Pesaran-Shin unit-root test for
broadmoneyofgdp

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-6.7279		-2.42	-2.15	-2.0200
t-tilde-bar	-4.6654				
Z-t-tilde-bar	-3.985	0.00000			

Im-Pesaran-Shin unit-root test for liquidassetsasoftotalmonetaryass

Ho: All panels contain unit roots	Number of panels	=	1
Ha: Some panels are stationary	Number of periods	=	43

AR parameter: Panel-specific
Asymptotics: Asymptotics: T N -> Infinity
Panel means: Included sequentially
Time trend: Not included

ADF regressions: No lags included

	Statistic	p-value	Fixed-N exact critical values		
			1%	5%	10%
t-bar	-5.3874		-2.42	-2.15	-2.0200
t-tilde-bar	-4.1521				
Z-t-tilde-bar	-3.3455	0.0004			

Appendix C4.2.6: Breitung Unit Root Test

Breitung unit-root test for gdpgrowthannual

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.2871	0.00000	

Breitung unit-root test for inflationexpectation

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.6526	0.00000	

Breitung unit-root test for broadmoneytototalreservesratio

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.5848	0.00000	

Breitung unit-root test for
domesticcreditoprivatesectorofg

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.6822	0.00000	

Breitung unit-root test for
broadmoneygrowthannual

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.5743	0.00000	

Breitung unit-root test for
totalreservesoftotalexternaldebt

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.4914	0.00000	

Breitung unit-root test for
shorttermdebttoexportsofgoodsser

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.7084	0.00000	

Breitung unit-root test for
debt service ppg and imfonly of export

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-3.606	0.0002	

Breitung unit-root test for
shorttermdebt to total external debt

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.5804	0.00000	

Breitung unit-root test for
externaldebtstocksofgni

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.4469	0.00000	

Breitung unit-root test for broadmoneyofgdp

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.6036	0.00000	

Breitung unit-root test for
liquidassetsasoftotalmonetaryass

Ho: Panels contain unit	Number of panels	1	0
Ha: Panels are stationary	Number of periods	43	0
AR parameter: Common Asymptotics:	Asymptotics: T N -> Infinity		
Panel means: Included	sequentially		
Time trend: Not included	Prewhitening: Not performed		
	Statistic	p-value	
lambda	-4.0171	0.00000	

Appendix C4.2.7: Multi-Collinearity Test

	gdpgro~l	inflat~n	broadm~o	domest~g	broadm~l	totalr~t	shortt~r	debtse~t	shortt~t	extern~i	broadm~p	liquid~s
gdpgrowtha~l	1											
inflatione~n	0.1998	1										
broadmoney~o	-0.1498	-0.0115	1									
domesticcr~g	0.2084	0.2338	0.2251	1								
broadmoney~l	0.037	0.0672	-0.3282	0.3371	1							
totalreser~t	0.1102	-0.1127	-0.6511	-0.1076	0.2385	1						
shorttermd~r	0.008	-0.0741	0.0949	-0.2394	0.0137	-0.1425	1					
debtse~t	-0.095	0.0227	-0.0022	-0.0245	-0.122	-0.2611	0.0223	1				
shorttermd~t	0.059	-0.0725	0.0117	-0.0915	0.0135	0.3092	0.6919	-0.1754	1			
externalde~i	-0.0725	0.1224	-0.0215	0.3128	0.2414	-0.3604	0.0179	0.3825	-0.3454	1		
broadmoney~p	-0.1037	0.1125	0.0852	0.6765	0.233	-0.048	-0.3998	0.0017	-0.3807	0.4799	1	
liquidasse~s	0.0267	-0.0658	-0.0736	-0.0504	-0.1105	0.0904	-0.1925	0.164	-0.0607	0.0932	-0.0282	1

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