Contents

Table of Contents ................................. 2
List of Tables .................................... 5
List of Figures .................................... 6
Abstract .......................................... 8
Declaration ........................................ 9
Copyright Statement ............................. 10
Acknowledgement ................................. 11

Introduction ..................................... 12

1 Excess Reserves, Monetary Policy and Financial Volatility: The Case of Trinidad and Tobago 20
  1.1 Introduction ................................. 20
  1.2 Background ................................... 26
    1.2.1 Monetary Policy and Excess Reserves .......... 26
    1.2.2 Consequences of Excess Liquidity for Monetary Policy .... 27
    1.2.3 Policy Measures Undertaken by the Central Bank to Reduce Excess Liquidity .......... 28
  1.3 The Model ................................... 29
    1.3.1 Households ............................... 32
    1.3.2 Final Good-Producing Firm .................. 34
    1.3.3 Intermediate Good-Producing Firms .......... 35
    1.3.4 Capital Good Producer ...................... 38
    1.3.5 Commercial Bank ........................... 40
    1.3.6 Central Bank .............................. 45
    1.3.7 Government ............................... 46
  1.4 Symmetric Equilibrium ....................... 47
  1.5 Steady State and Log-Linearization .......... 48
  1.6 Calibration ................................. 50
  1.7 Policy Analysis ............................. 53
1.7.1 Negative Supply Shock ........................................ 53
1.7.2 Monetary Policy Shocks .................................... 55
1.7.3 Liquidity Shock: Increase in Bank Deposits ............ 58
1.7.4 Simultaneous Shocks to Deposits and Reserve Requirements . 59
1.8 Policy Rules for Managing Excess Reserves .................. 60
1.8.1 An Augmented Taylor Rule ................................. 60
1.8.2 A Countercyclical Reserve Requirement Rule ............ 61
1.9 Sensitivity Analysis ........................................... 62
1.9.1 Higher Cost Channel Effect ................................. 62
1.9.2 Increase in the Reserve Requirement Ratio .............. 63
1.9.3 Increase in the Excess Reserve Ratio ..................... 63
1.10 Concluding Remarks ........................................... 64
1.A Appendix ......................................................... 85
1.A.1 Solution to Optimization Problems ........................ 85
1.A.2 Steady-State Equations ...................................... 90
1.A.3 Log-Linearized Equations .................................. 95

2 Fiscal Rules for Resource Windfall Allocation: The Case of Trinidad and Tobago 99
2.1 Introduction ...................................................... 99
2.2 Background ..................................................... 103
  2.2.1 The Importance of the Energy Sector .................... 104
  2.2.2 Characteristics of the Energy Sector ...................... 106
  2.2.3 The Heritage and Stabilisation Fund (HSF) .............. 108
2.3 The Model ...................................................... 110
  2.3.1 Total Output .............................................. 111
  2.3.2 Tradable Production ...................................... 111
  2.3.3 Nontradable Production ................................... 111
  2.3.4 Resource Production and Prices ......................... 112
  2.3.5 Households ............................................... 113
  2.3.6 Government ............................................... 115
  2.3.7 World Interest Rate and Risk Premium .................. 118
  2.3.8 Market-Clearing Conditions ............................. 118
2.4 Steady State and Log-Linearization .......................... 120
2.5 Calibration ..................................................... 121
2.6 Dynamics of Resource Price Shocks .......................... 125
  2.6.1 Full Spending of Resource Windfall .................... 125
  2.6.2 Full Saving of Resource Windfall in Sovereign Wealth Fund . 127
List of Tables

1.1 Reserve Requirement Levels in Various Countries .................. 68
1.2 Calibrated Parameter Values: Benchmark Case .................... 69
1.3 Standard Deviations under Standard Taylor Rule and Augmented Taylor Rule with Increase in Bank Deposits .................... 70
1.4 Standard Deviations when the Reserve Requirement Ratio is Exog- enous and Endogenous ........................................... 71

2.1 Economic Contribution of the Energy Sector (percent, 2000-2012) 142
2.2 Infrastructure Indicators in Trinidad and Tobago compared to the Upper Middle-Income and High-Income Groups ..................... 143
2.3 Calibrated Parameter Values: Benchmark Case .................... 144
2.4 Trinidad and Tobago: Initial Steady-State Values (in percent of total output, unless otherwise indicated) .......................... 145
2.5 Optimal Allocation of Resource Windfalls under Social Loss Function 146
2.6 Optimal Allocation of Resource Windfalls under Generalized Loss Function ....................................................... 147
2.7 Social Loss Function: Higher Degree of Capital Mobility ........ 148
2.8 Social Loss Function: Lower Share of Management Fee to Residents 149
2.9 Social Loss Function: Alternative Specification of the Risk Premium 150
2.10 Social Loss Function: Public Investment of Resource Windfalls .... 151
2.11 Social Loss Function: Resource Production Shock ................. 152
List of Figures

1.1 The Percent of Excess Reserves to Total Reserves in Trinidad and Tobago ........................................... 72
1.2 Total Financial System Assets in Trinidad and Tobago .............. 73
1.3 Net Domestic Fiscal Injections (NDFI) as a percent of GDP, Excess Reserves to Total Reserves (ER-TR) and Government Expenditure (GOV’T EXP) to GDP ........................................ 74
1.4 Liquidity Absorption Measures ................................................. 75
1.5 Negative Supply Shock ......................................................... 76
1.6 Increase in Refinance Rate ..................................................... 77
1.7 Increase in Reserve Requirement Ratio ...................................... 78
1.8 Increase in Bank Deposits ...................................................... 79
1.9 Increase in Bank Deposits and Simultaneous Shocks to Deposits and Reserve Requirements .............................. 80
1.10 Increase in Bank Deposits under Standard Taylor Rule and Augmented Taylor Rule .................................. 81
1.11 Increase in Bank Deposits when the Reserve Requirement Ratio is Exogenous and Endogenous ................. 82
1.12 Increase in the Required Reserve Ratio under a Contractionary Monetary Policy Shock ............................. 83
1.13 Increase in the Excess Reserve Ratio under a Contractionary Monetary Policy Shock .............................. 84
2.1 Trinidad and Tobago: Overall Primary Balance and Non-Energy Primary Balance (as a percent of GDP) ............. 153
2.2 Real GDP Growth in Trinidad and Tobago ............................... 154
2.3 Trinidad and Tobago’s Terms of Trade Index .......................... 155
2.4 Production Structure in Trinidad and Tobago ........................... 156
2.5 Trinidad and Tobago’s Real Effective Exchange Rate (2005=100; increase in index represents an appreciation) .......... 157
2.6 Trinidad and Tobago’s Global Competitiveness Index (GCI) ...... 158
2.7 Sectoral Distribution of Employment in Trinidad and Tobago (percent of Total Employment) ............................................ 159
2.8 Crude Oil Production in Trinidad and Tobago .................................. 160
2.9 Natural Gas Production in Trinidad and Tobago .................................. 161
2.10 Assets of the Heritage and Stabilisation Fund (HSF) as a percent of GDP ................................................................. 162
2.11 Full Spending of Resource Windfall .................................................. 163
2.12 Full Saving Experiment versus Full Spending Experiment ................. 164
2.13 Volatility of Consumption, the Real Exchange Rate and the Overall Primary Balance to Output Ratio as a Fraction of the Resource Windfall Saved ........................................ 165
2.14 Full Spending Experiment: Resource Price Shock versus Resource Production Shock .................................................. 166
2.15 Full Saving Experiment: Resource Price Shock versus Resource Production Shock .................................................. 167
Abstract

Trinidad and Tobago is a small open economy that faces macroeconomic policy challenges which are related to imperfections in the financial sector and volatility of energy sector revenues. Specifically, two of the key issues policymakers are grappling with are high levels of excess reserves and the optimal management of the economy’s resource revenues—in the face of domestic and external shocks to the energy sector. This thesis uses a general equilibrium modeling approach to examine the dynamic effects of these policy challenges on the Trinidad and Tobago economy.

Chapter 1 examines the financial and real effects of excess reserves in a New Keynesian Dynamic Stochastic General Equilibrium model with monopoly banking, credit market imperfections and a cost channel. The model explicitly accounts for the fact that banks in Trinidad and Tobago hold excess reserves and they incur costs in holding these assets. Simulations of a shock to required reserves show that although raising reserve requirements is successful in sterilizing excess reserves, it creates a procyclical effect for real economic activity. This result implies that financial stability may come at a cost of macroeconomic stability. The findings also indicate that using an augmented Taylor rule in which the policy interest rate is adjusted in response to changes in excess reserves reduces volatility in output and inflation but increases fluctuations in financial variables. To the contrary, using a countercyclical reserve requirement rule helps to mitigate fluctuations in excess reserves, but increases volatility in real variables.

Chapter 2 uses an open economy Dynamic Stochastic General Equilibrium model to analyze the transmission of resource price shocks and a shock to resource production in the Trinidad and Tobago economy. It also applies alternative fiscal rules to determine the optimal allocation of resource windfalls between spending today and saving in a sovereign wealth fund. The results show that spending all the resource windfall on consumption and investment creates more volatility and amplifies Dutch disease effects, when compared to the case where all the excess revenues are saved. Also, neither a policy of full spending nor full saving of the surplus revenue inflows is optimal if the government is concerned about both household welfare and fiscal stability. In order to minimize deviations from both objectives, the optimal fiscal response suggests that a larger fraction of the resource windfalls should be saved, than what the government is presently saving.
Declaration

I declare that no portion of the work referred to in the thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.
Copyright Statement

i. The author of this thesis (including any appendices and/or schedules to this thesis) owns certain copyright or related rights in it (the “Copyright”) and he has given The University of Manchester certain rights to use such Copyright, including for administrative purposes.

ii. Copies of this thesis, either in full or in extracts and whether in hard or electronic copy, may be made only in accordance with the Copyright, Designs and Patents Act 1988 (as amended) and regulations issued under it or, where appropriate, in accordance with licensing agreements which the University has from time to time. This page must form part of any such copies made.

iii. The ownership of certain Copyright, patents, designs, trade marks and other intellectual property (the “Intellectual Property”) and any reproductions of copyright works in the thesis, for example graphs and tables (“Reproduc-tions”), which may be described in this thesis, may not be owned by the author and may be owned by third parties. Such Intellectual Property and Reproductions cannot and must not be made available for use without the prior written permission of the owner(s) of the relevant Intellectual Property and/or Reproductions.

iv. Further information on the conditions under which disclosure, publication and commercialisation of this thesis, the Copyright and any Intellectual Property and/or Reproductions described in it may take place is available in the University IP Policy

see http://www.campus.manchester.ac.uk/medialibrary/policies/intellectualproperty.pdf

in any relevant Thesis restriction declarations deposited in the University Library, The University Library’s regulations

see http://www.manchester.ac.uk/library/aboutus/regulations

and in The University’s policy on presentation of Theses.
Acknowledgement

The completion of this thesis could not have been possible without the support and assistance from several persons.

I must first say thanks to the Almighty God for his divine guidance which he has bestowed upon me during this programme. This thesis could not have been completed without God’s abundant blessings.

I wish to sincerely extend my deepest gratitude to my family—specifically my mother, father and sisters—for their overwhelming support, encouragement and prayers over the past three years.

Furthermore, I am indebted to my supervisor, Professor Pierre-Richard Agénor, for his useful guidance and support throughout my Ph.D. I am very thankful to him for the time he took to actively supervise my research and for the invaluable knowledge he imparted on me.

In addition, I am thankful to Dr. George Chouliarakis and Dr. Issouf Samake for being part of my Ph.D. evaluation committee and for their valuable comments and suggestions on my research.

Additionally, I wish to express thanks to my friends and colleagues who provided support and helpful comments on my research. Specifically, I am very grateful to my friend Emile Williams who has been supportive throughout my studies. Also, I would like to thank my friend Dr. Roy Zilberman for helpful suggestions and advice on Dynare/Matlab, and Dr. DeLisle Worrell for reading my Ph.D. chapters and providing useful comments.

Further, I would like to extend my gratitude to the members of the Economics DA, specifically Professor Anne Villamil and Dr. George Bratsiotis for helpful discussions and comments, as well as Dr. Kyriakos Neanidis for helpful advice in general. I am also very thankful to Professor Horst Zank and the Economics DA for providing funding support for me to present my research at international conferences including the 9th Dynare Conference at the Shanghai University of Finance and Economics (Shanghai, China) and The Central Bank of Barbados Annual Review Seminar (Bridgetown, Barbados).

Finally, I am thankful to the Economic and Social Research Council (ESRC) and the School of Social Sciences, University of Manchester, for funding my research, and the Economics Department for providing the necessary facilities for me to conduct my research.
Introduction

Small open economies typically face a range of macroeconomic policy challenges—owing to the fact that they are exposed to a range of external shocks. The external volatility that these countries face can translate into macroeconomic instability in the domestic economy. Also, because small open economies have highly distorted financial systems with significant market imperfections, domestic and external shocks to these economies tend to be magnified. Trinidad and Tobago is a small open economy, and like similar types of economies, faces macroeconomic policy challenges related to external shocks and imperfections in the financial sector. Specifically, two of the key issues that policymakers in Trinidad and Tobago are grappling with at the moment are excess reserves in the banking system and the volatility of energy prices—which creates uncertainty of resource revenues.

Owing to the fact that Trinidad and Tobago is an energy producer, an increase in energy prices creates fiscal outlays that are greater than the absorptive capacity of the economy (Primus et al. (2014)). Thus, the key source of liquidity creation is the government’s fiscal injections in the economy—as discussed in Section 1.2.1. Furthermore, although the problem of excess reserves is a challenge for monetary policy, it is important to note that in the context of a resource-rich developing country, it is a fiscal policy issue. Therefore, because the government’s monetization of energy sector revenues is the key source of the problem, it is necessary to determine the optimal proportion of the excess resource revenues that should be spent. This study therefore analyzes two key issues, which are directly related and determined by the government’s fiscal operations.

To analyze how excess reserves and the volatility of energy prices shape macroeconomic outcomes, and the quantitative effects of policy responses to them, a general equilibrium setting is required. Therefore, the Dynamic Stochastic General Equi-
librium (DSGE) methodology is used to examine these issues. In light of this, the overall contribution of this thesis is that it is the first application of the DSGE methodology to the Trinidad and Tobago economy to quantify the effects of excess reserves and energy price and production shocks, as well as the appropriate monetary and fiscal response to these shocks, on the economy.

DSGE models have become the workhorse for the conduct of quantitative policy analysis in both industrial and developing countries, and they have proven to be useful to gain insight into the appropriate policy responses to shocks. Because these models are built on microeconomic foundations, they provide a fully integrated framework to address important policy questions. Furthermore, the stochastic and general equilibrium nature of DSGE models allow them to capture the dynamic interaction between policy actions and agents’ behaviour (Sbordone et al. (2010)). In addition, the features of DSGE models allow one to examine the real and financial effects of various shocks on the economy, and the transmission process of macroeconomic policy (Christiano et al. (2010b)).

In Trinidad and Tobago, the commercial banking sector is the largest segment of the financial market, as it accounts for the majority of the financial system assets. The main challenge facing the banking sector of Trinidad and Tobago is high persistent excess reserves—which have risen to record levels in recent years. Excess liquidity impairs the transmission mechanism of monetary policy, so its presence hinders monetary policy operation. An examination of the data for Trinidad and Tobago shows that the abundance of liquidity has put downward pressure on short-term interest rates. Intuitively, the high levels of excess liquidity have obviated the need for commercial banks to compete for deposits. Also, any attempt by the monetary authority to increase liquidity in order to stimulate demand is ineffective. By contrast, if the Central Bank wishes to pursue monetary tightening, commercial banks may not raise their interest rates in response to an increase in the policy interest rate. It has been observed that over 50 percent of the loans issued in Trinidad
and Tobago in 2008 were contracted below the prime lending rate—despite the fact that over the same period the Central Bank increased the policy rate three times in an attempt to pursue monetary tightening.

Given the implications excess reserves can have for monetary policy, this phenomenon warrants further investigation. Chapter 1 of this thesis develops and calibrates a New Keynesian DSGE framework with monopoly banking, credit market imperfections and a cost channel to examine the effects of excess liquidity on monetary policy in Trinidad and Tobago. The model extends and modifies the framework in Agénor and Alper (2012), and integrates aspects of Glocker and Towbin (2012) and Agénor et al. (2013) to capture the fact that banks hold excess reserves and there are costs associated with holding these assets. In the model, the commercial bank has an explicit demand for excess reserves and total reserves held at the central bank are remunerated at a rate below the refinance rate.

The framework is used to examine the financial and real effects of a negative productivity shock, an increase in the policy interest rate, a shock to the reserve requirement ratio and an exogenous increase in bank liquidity. Furthermore, simultaneous shocks are applied to deposits and reserve requirements to investigate whether raising the required reserve ratio can dampen the effects of an increase in bank liquidity. In addition, the dynamic effects of a liquidity shock are investigated under two alternative policy rules: an augmented Taylor rule in which the central bank adjusts its policy rate in response to changes in excess reserves, and a counter-cyclical rule in which the reserve requirement ratio reacts to deviations in excess reserves.

The contributions of this research are threefold: firstly, this study is the first application of a general equilibrium model, that explicitly accounts for the costs banks incur in holding excess reserves, to the Trinidad and Tobago economy; secondly, this research is the first attempt to examine (using a New Keynesian framework) whether a simultaneous increase in the required reserve ratio, in response to a posi-
tive liquidity shock, is an effective measure to withdraw liquidity from the financial system—as practised in central bank policymaking; and thirdly, in addition to the standard interest rate rule, this study incorporates two alternative policy rules in a general equilibrium model with endogenous excess reserves, to examine the real and financial effects of a liquidity shock.

The results show that a negative supply shock leads to an increase in prices and a drop in output, whereas a contractionary monetary shock causes both prices and output to fall. In addition, because the refinance rate rises following both types of shocks, the opportunity cost of holding excess reserves increases. The findings also indicate that although a positive shock to required reserves is successful in reducing excess reserves, the effect is expansionary for real economic activity. Furthermore, under a liquidity shock, a simultaneous increase in reserve requirements can help to reduce the quantity of excess reserves in the banking system. In the case of the augmented Taylor rule, a liquidity shock has a less dampening effect on real variables but increases volatility in financial variables. By contrast, using a counter-cyclical reserve requirement rule increases volatility in real variables but mitigates fluctuations in financial variables.

The second challenge facing policymakers in Trinidad and Tobago is the volatility of resource revenue, which is due mainly to international energy price shocks, as well as domestic energy production shocks. The uncertainty of resource revenue brings the question of how to manage the windfall gains from the country’s energy resources. This is a critical issue because the energy sector accounts for a substantial share of exports and government revenue. Furthermore, evidence of the economy’s macroeconomic cycle has shown that the heavy dependence on the economic rents from the energy sector makes the economy vulnerable to commodity price and production shocks and has led to procyclical government spending and boom-bust cycles.

Over the period 1973-1982, Trinidad and Tobago benefited tremendously from
oil price and production booms. In 1983, oil prices began to decline and collapsed in 1985-1986, causing a severe decrease in government revenues, thereby leading the economy into a severe recession (Theodore (1992)). As a consequence, for most of the period during 1985-1993, the economy experienced negative growth and high levels of unemployment. In light of the economic hardship, over the period 1989-1991, Trinidad and Tobago entered into structural adjustment programmes with the International Monetary Fund and the World Bank (see The World Bank (1989) and Hilaire (2000)). By 1994, the situation changed and the economy experienced positive GDP growth up to 2008. Specifically, during the period 2000-2008 the economy experienced another boom episode. However, economic activity contracted in 2009 because of a plunge in energy prices and resource revenue, during the global financial crisis. Although international commodity prices have improved since 2009, the economy still has not fully recovered. Therefore, the economic history of Trinidad and Tobago shows the importance of the fortunes of the energy sector to achieve and maintain macroeconomic stability. This also underscores the importance of determining the optimal balance between spending and saving of resource revenues.

Two common views in the literature on how resource revenues should be managed are the Permanent Income Hypothesis (PIH) and the Bird-in-Hand policy (which are discussed in Section 2.1). The PIH and Bird-in-Hand approaches have been criticized because they fail to take into account the capital scarcity and infrastructure gaps of many developing countries (see van der Ploeg and Venables (2011) and van der Ploeg (2012)). Therefore, because in both policies consumption is skewed towards future generations, they are not considered to be optimal to address the current development needs of developing countries. In response to the limitations of the PIH and Bird-in-Hand approaches, there have been discussions on how resource income should be used and attempts to determine the optimal share of a resource windfall between consumption and saving (see for instance, Collier et al. (2010), Venables

---

1Gelb (1988) noted that if a larger share of the windfall was saved during the boom, the impact of the recession on the Trinidad and Tobago economy would have been less severe.
One shortcoming of these studies is that they use arbitrary allocation rules—which are not based on any measure of volatility—to determine how much of the windfall should be saved. In light of this, Agénor (2014) closes the gap in the literature by providing a methodological contribution on the issue of optimal allocation of resource windfalls in a DSGE model using a loss function defined in terms of consumption volatility and fiscal or macroeconomic stability.

Moreover, acknowledging the importance of having a formal mechanism to manage the proceeds from natural resources, in 2000 the government of Trinidad and Tobago established an interim sovereign wealth fund, which was later formalized in 2007 as the Heritage and Stabilisation Fund (HSF). Although the HSF specifies rules regarding deposits into the Fund, these guidelines are not based on any rigorous framework but rather on adhoc rules which may not have considered key macroeconomic variables. In the face of depleting energy reserves, along with external shocks to energy prices, there have been recent calls from academics and policymakers for the HSF to develop a clearer focus on saving, and a strategy that clearly outlines how much of the windfall to save and consume (see International Monetary Fund (2012b)). Given the economic costs that can arise from sharp and unexpected declines in resource revenue, it is important to save some of the windfall from a resource price boom to smooth consumption overtime (Collier et al. (2010)). Thus, a critical issue for policymakers in Trinidad and Tobago is to determine the optimal allocation of the economy’s resource windfalls between spending and saving.

Chapter 2 modifies the framework in Agénor (2014) and applies it to the Trinidad and Tobago economy. Some of the key features of this model are that there is domestic consumption of energy products, both households and the government have imperfect access to world capital markets, and there is imperfect intersectoral capital mobility. Also, public capital is subject to absorption constraints, which affects
investment efficiency. The model is used to determine the transmission of a temporary resource price shock and a resource production shock under two alternative fiscal rules—a full spending rule and a full saving rule. Under the full spending rule, the government spends all the windfall on consumption and investment so there is no asset accumulation in the sovereign wealth fund. In the full saving experiment all the resource revenue is accumulated in a sovereign wealth fund and only the interest income generated from the fund is used to finance government spending on consumption and investment, in proportion of initial spending allocations. Furthermore, the framework examines the optimal allocation of the resource windfall between spending today and saving in a sovereign wealth fund, in terms of consumption volatility and fiscal stability.

The contribution of this research is that it represents the first application of the Agénor framework to a mature energy producing economy. It is also the first attempt to provide a rigorous assessment of how much of the resource windfall should be used for consumption and savings in a general equilibrium framework, which takes some of the features of the Trinidad and Tobago economy into account. The results show that spending all the resource windfall on consumption and investment creates a lot of volatility, and amplifies Dutch disease effects. By contrast, when all the windfall is saved, the contraction in the nonresource tradable sector and the real appreciation is mitigated. These findings therefore provide evidence that fiscal policy can help to minimize the impact of resource price and production shocks.

Moreover, the findings from the optimal rule suggest that if the government is equally concerned about household welfare and fiscal stability, they should save a larger fraction of the resource windfalls, than what is currently being saved. In a recent study by Dabla-Norris et al. (2012), the efficiency of public investment for Trinidad and Tobago was estimated to be 27.5 percent. It is therefore important to note that, against the backdrop of very poor efficiency of investment spending, it can be optimal for the government to save a larger proportion of the resource
windfalls. Governance reforms are also critical to improve the efficiency of public investment spending, before more of the windfall gains can be spent.
Chapter 1

Excess Reserves, Monetary Policy and Financial Volatility: The Case of Trinidad and Tobago

1.1 Introduction

Excess reserves have been a common feature of the banking system of many countries across the world.\(^1\) In developed countries, the phenomenon of excess reserves has become more apparent since the global financial crisis. For instance, in the case of the U.S., the sharp increase in excess reserves since 2008 occurred because risk averse banks stopped lending to each other and engaged in liquidity hoarding (see Ashcraft et al. (2009), Hilton and McAndrews (2010) and Jenkins (2010)). Others argued that the policy initiatives undertaken by the Federal Reserve in response to the crisis caused the quantity of bank reserves to surge (see Keister and McAndrews (2009) and Ennis and Wolman (2012)). Similarly, excess reserves have been growing rapidly in commercial banks in the Euro Area since the onset of the global economic crisis (see European Central Bank (2008) and Sol Murta and Garcia (2010)).

In developing economies, the problem of excess reserves is more prevalent. For several years, the banking system of some developing countries has recorded high

\(^1\)In most financial systems, excess liquidity refers to the maintenance by banks of a higher level of funds than is normally required to meet their statutory reserve requirements and settlement balances. Excess liquidity (or excess reserves) is measured as the difference between total bank reserves and required bank reserves. For this reason, the terms excess liquidity and excess reserves are used interchangeably in the literature.
persistent liquidity—for instance, inspection of the data over the last decade reveals that the ratio of excess reserves to total reserves has been greater than 15 percent for most of the period in Belize and above 25 percent in Jamaica. Given its importance to the monetary transmission process, several researchers have empirically examined the determinants of excess liquidity in developing economies. Contributions along these lines include Maynard and Moore (2005) for Barbados, Saxegaard (2006) for Sub-Saharan Africa, Khemraj (2007, 2009) for Guyana, Anderson-Reid (2011) for Jamaica, Pontes and Sol Murta (2012) for Cape Verde, Jordan et al. (2012) for The Bahamas and Primus et al. (2014) for Trinidad and Tobago. In most cases, these studies show that excess reserves appear to be a structural phenomenon.2

As highlighted in Agénor and El Aynaoui (2010), the reasons for excess liquidity can be categorized into structural and cyclical factors. One structural factor is a low degree of financial development. Therefore, excess liquidity tends to be more persistent in countries with underdeveloped financial markets, such as inefficient payment systems, or an underdeveloped market for government securities (see Saxegaard (2006)). Another structural factor is a high degree of risk aversion. In an environment of increased uncertainty, risk averse banks charge a high risk premia to reduce demand for loans and to safeguard their loan portfolio. This leads to a voluntary build-up of excess liquid assets.3

Regarding the cyclical factors, one of the main sources of excess reserves is foreign currency inflows (Ganley (2004) and Heenan (2005)). Current account inflows arise mainly through revenues received from commodity exports. Therefore, exporters

---

2Excess bank liquidity is also a problem for large developing countries, such as Brazil, Russia, India, China and Nigeria. Some of the other developing countries with the problem of excess reserves include Botswana (see Akinboade and Zachariah (1997)), Egypt (see Fielding and Shortland (2005)), Mexico (see Jallath-Coria et al. (2005)), Tanzania (see Aikaeli (2006)), Turkey (see Tabak and Bankasi (2006)), Fiji (see Jayaraman and Choong (2012)), Indonesia (see Bathaluddin et al. (2012)), Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and the Dominican Republic (see Deléchat et al. (2012)), and Morocco (see El Hamma and Ejbari (2013)).

3Similarly, in a crisis environment where banks perceive an increase in the risk of default on loans, they may be unwilling to lend. For instance, Agénor et al. (2004) found that the contraction in bank credit and the associated increase in excess reserves in Thailand following the Asian financial crisis in the late 1990s resulted from supply related factors, which emanated from the banks.
of minerals, such as Botswana, and oil exporting economies, such as Nigeria and Trinidad and Tobago, observe huge surpluses in their current account when commodity prices are high on world markets. Particularly in oil-producing countries, a rise in oil prices results in an increase in government revenues. In many cases, these energy windfalls are used to finance an increase in government spending. As a result, the banking system of these economies holds large quantities of involuntary excess liquidity.\textsuperscript{4} Capital account inflows may arise from aid-related transfers, foreign direct investment and portfolio inflows. Another cyclical cause of excess liquidity is inflation. Because inflation leads to higher volatility in relative prices and an increase in riskiness of investment projects, it raises uncertainty about the value of collateral. This causes banks to demand a higher risk premium, which increases the lending rate. The higher loan rate can lead to a contraction in credit demand and increase excess reserves.

In an attempt to withdraw excess liquidity from the financial system, central banks have used open market operations, and issued central bank bills.\textsuperscript{5} Central banks have also issued long-term securities (bonds) and implemented special deposit facilities. In addition, reserve requirements have been used frequently to manage liquidity.\textsuperscript{6,7} For instance, between 2006 and 2009, the central banks of China, India and Trinidad and Tobago have all increased reserve requirements to mop up excess liquidity. Using reserve requirements can help the central bank or the government to reduce the quantity of excess reserves in the financial system without incurring interest costs, which are associated with the issuance of securities (Gray (2011)).

\textsuperscript{4}According to Agénor and El Aynaoui (2010, p. 923), involuntary excess liquidity is "the involuntary accumulation of liquid reserves by commercial banks". Several researchers have examined the issue of involuntary excess liquidity. See for instance, Saxegaard (2006), Bathaluddin et al. (2012) and Primus et al. (2014).

\textsuperscript{5}See Nyawata (2012) for a discussion of the pros and cons of using Treasury bills and central bank bills to absorb liquidity.

\textsuperscript{6}Reserve requirement levels vary greatly across countries. It has been observed that these ratios are generally higher in developing countries, when compared to developed countries (see Table 1.1).

\textsuperscript{7}In recent years, a number of central banks have used reserve requirements as a liquidity management tool. See Montoro and Moreno (2011), Robitaille (2011) and Tovar et al. (2012) for further discussions.
Also, reserve requirements can be more effective because selling securities to sterilize excess liquidity can in fact be self-defeating as it can cause market interest rates to increase and stimulate capital inflows, thereby making the excess liquidity problem worse, if to begin with it resulted from large inflows (Lee (1997)). One disadvantage to note however is reserve requirements act as a tax on the financial sector (Central Bank of Trinidad and Tobago (2005) and Montoro and Moreno (2011)).

Excess liquidity impedes the transmission of monetary policy and undermines the ability of monetary policy to stabilize the economy. It is important for excess bank reserves to be managed because tight liquidity conditions are necessary for the central bank to have leverage over the commercial banks to achieve its monetary objectives. Changes in the policy interest rate can be reflected in the interest rates in the banking sector if commercial banks do not hold substantial liquidity above the legal requirement—in this case, the central bank can effectively perform the function of monopoly supplier of domestic currency (Ganley (2004)). Furthermore, in the presence of excess liquidity, the effectiveness of monetary policy can be asymmetric. As empirically documented in Lebedinski (2007) for Morocco, when banks hold excess reserves they are more likely to respond in an asymmetric manner when adjusting deposit rates.

Moreover, excess reserves represent a challenge to monetary policy. When banks hold excess reserves, attempts by the monetary authorities to increase liquidity to stimulate demand will be ineffective.\footnote{This is particularly important when banks hold excess reserves for precautionary purposes. In this case, an expansionary monetary policy will only raise the amount of excess reserves further, and will not help to expand credit.} By contrast, if a central bank wants to pursue monetary tightening, an increase in the policy interest rate may not be transmitted to deposit and loan rates as banks holding excess reserves may not raise their interest rates. A lower deposit rate discourages savings and encourages consumption, whereas a lower loan rate stimulates demand for credit. These can therefore have inflationary consequences. Furthermore, when banks hold excess
reserves, they are more inclined to lower credit standards and reduce loan rates to expand lending. This can lead to a rise in the risk of loan default and make the financial system more susceptible to crisis.

Despite the impact excess reserves can have on the transmission mechanism of monetary policy, there have been few attempts to examine the role of reserves in a New Keynesian general equilibrium framework. Two of the analytical contributions in this area are Christiano et al. (2010a) and Samake (2010). Although both studies incorporated excess reserves into a general equilibrium model with banking, they did not model the fact that banks incur costs in holding these assets. It is important to have a well-defined demand for excess reserves to explicitly account for the rate of return on reserves and any opportunity cost of holding reserves.

This chapter therefore explicitly models excess reserves in a Dynamic Stochastic General Equilibrium (DSGE) framework with monopoly banking, credit market imperfections and a cost channel. The model extends and modifies the framework in Agénor and Alper (2012), and integrates aspects of Glocker and Towbin (2012) and Agénor et al. (2013). In this framework, excess reserves are endogenous—as banks voluntarily demand this asset—and there are convex costs associated with holding these reserves as in Glocker and Towbin (2012). The model is calibrated based on Trinidad and Tobago data due to the fact that excess reserves have been growing very rapidly in that country. This research represents an essential contribution as it is the first attempt to apply a general equilibrium model with banking, to the Trinidad and Tobago economy, to examine the macroeconomic effects of excess reserves.

The model is used to examine the financial and real effects of a productivity shock, an increase in the policy interest rate, a shock to the reserve requirement ratio and an exogenous increase in bank liquidity. Also, simultaneous shocks are applied to deposits and reserve requirements to examine whether increasing required reserves in response to a surge in liquidity is an effective measure. This experiment is another
key contribution to this chapter. Although it has been often observed in practice that raising reserve requirements can indeed offset an increase in liquidity, this is the first attempt to model this in a New Keynesian general equilibrium framework. In addition, the model is used to investigate the responses of the key variables following a liquidity shock when two alternative policy rules are used: an augmented Taylor rule in which the central bank adjusts its policy rate in response to changes in excess reserves, and a countercyclical rule in which the reserve requirement ratio reacts to deviations in excess reserves.

The results show that a negative supply shock and a contractionary monetary shock have the traditional effects. In the former case prices increase and output declines, while in the latter both prices and output fall. As the refinance rate rises following both types of shocks, the opportunity cost of holding excess reserves increases. The findings also indicate that although a positive shock to required reserves is successful in reducing excess reserves, the effect is expansionary for real economic activity. In the case of a liquidity shock, a simultaneous increase in reserve requirements can assist in reducing the quantity of excess reserves in the financial system. Furthermore, when an augmented Taylor rule which includes excess reserves is used, a liquidity shock has a less dampening effect on real variables but increases fluctuations in financial variables. To the contrary, using a countercyclical reserve requirement rule has the opposite effect for both real and financial variables.

The rest of this chapter is organized as follows. Section 1.2 provides a review of the problem of excess reserves and its implications for monetary policy. Section 1.3 presents the model and Section 1.4 outlines the symmetric equilibrium. The key steady-state and log-linearized equations of the model are presented in Section 1.5. Section 1.6 provides a discussion of the calibration for Trinidad and Tobago. In Section 1.7, impulse response functions are used to discuss the findings from the policy experiments and other shocks to the model. Section 1.8 examines the dynamic effects of an increase in excess reserves under alternative policy rules, whereas Section
1.9 presents some sensitivity analysis to gauge the robustness of the results. The final section provides a summary of the main results.

### 1.2 Background

This section discusses the problem of excess reserves and its consequences for the effectiveness of monetary policy. It also highlights the measures undertaken to absorb some of the liquidity from the financial system.

#### 1.2.1 Monetary Policy and Excess Reserves

Managing excess liquidity in a small open economy with a fragmented market has been a challenge for the Central Bank of Trinidad and Tobago. The banking system of Trinidad and Tobago has been plagued with persistent high liquidity, which has risen to record levels in recent years. Figure 1.1 shows that commercial banks’ excess reserves as a percent of total reserves increased exponentially from an average of 7.0 percent in 2000 to 35.7 percent in 2013. In Trinidad and Tobago, commercial banks are the key intermediaries in the financial system and they hold the majority of total financial system assets. An inspection of the data shows that commercial banks’ assets to total financial system assets have increased over the period 2007 to 2013 from 29.4 percent to 34.7 percent, respectively (Figure 1.2). Because commercial banks are the core of the financial system, excess liquidity is measured as commercial banks’ total reserves minus required reserves.

In Trinidad and Tobago, the repo rate is the official policy instrument used by the Central Bank to effect monetary policy. In light of the high financial system liquidity, changes in the repo rate have little effect on liquidity and adjustments in the rate are not fully transmitted to money and credit market rates. As a result of this, in recent years, the Central Bank had to increase reliance on the use of direct policy instruments to effect monetary policy. The current monetary policy framework
therefore uses a combination of both direct and indirect instruments, where the repo rate is the main indirect policy tool, and the statutory reserve requirement is the principal direct instrument employed by the Central Bank to influence monetary conditions (Central Bank of Trinidad and Tobago (2004)).

The build-up of excess liquidity in the banking system stems from the fact that Trinidad and Tobago is an energy producer, so high energy prices have significantly increased government revenues and expenditure. The limited capacity of the country to absorb the increased fiscal outlays has led to chronic excess liquidity in the banking system. Thus, the main source of liquidity is the government’s fiscal injections into the economy, which are financed by tax payments received from energy sector companies (Central Bank of Trinidad and Tobago (2005)). Inspection of the data reveals that over the period 2000 to 2006, the government’s domestic fiscal operations injected an equivalent of 5.5 percent of GDP in the economy, and 9.8 percent of GDP during 2007-2012. Figure 1.3 shows that these fiscal injections are positively correlated with the proportion of excess reserves to total reserves, and the ratio of government expenditure to GDP.

1.2.2 Consequences of Excess Liquidity for Monetary Policy

Due to the high levels of liquidity in the banking system, commercial banks in Trinidad and Tobago do not need to borrow from the Central Bank. As a result, the monetary authority loses its ability to influence short-term interest rates. Indeed, an inspection of the data reveals that commercial banks’ use of the interbank market declined substantially between 2008 and 2012, and during the period 2009-2012 there were no repo transactions. Hence, changes in the repo policy rate were not important in determining how commercial banks price their funds; so the monetary authority loses its ability to implement monetary policy through market-based instruments.

9In 2012, the energy sector accounted for 44 percent of GDP, 54 percent of government revenue, and 81 percent of merchandise exports. Also, for the same period, the non-energy tradable sector and the nontradable sector accounted for 6 percent and 50 percent of GDP, respectively.
In order to withdraw some of the excess liquidity from the banking system, the Central Bank is consistently selling Treasury bills and notes, as well as issuing bonds. Because the government has to pay interest on these instruments, this adds pressure to the fiscal deficit. Furthermore, the surge in excess liquidity in recent years has intensified pressures in the foreign exchange market and has caused the Central Bank to increase the supply of foreign currency, to ensure the stability of the exchange rate. One of the reasons attributed for the increase in demand for foreign exchange is investment by commercial banks in foreign assets. An examination of the balance of payments data shows evidence of this as the net capital and financial movements for commercial banks have been negative for most of the last decade. Therefore, to meet the increased demand and to manage the exchange rate, the Central Bank intensified sales of foreign exchange (mainly U.S. dollars) to authorized dealers.

1.2.3 Policy Measures Undertaken by the Central Bank to Reduce Excess Liquidity

One of the direct policy instruments used to contain the liquidity overhang is the primary required reserve ratio applicable to commercial banks. In 2008, this ratio was raised on three separate occasions by a total of 6 percentage points, bringing it to 17 percent of prescribed liabilities—which still is the current rate. Against the backdrop of high financial system liquidity, in 2006 the Bank re-introduced a secondary reserve requirement whereby commercial banks are required to hold an equivalent amount of 2 percent of their prescribed liabilities at the Central Bank.

---

10 Although most of the banks in Trinidad and Tobago are foreign-owned, inspection of the data shows that they do not borrow substantial funds from abroad. Actually, because the banks hold a lot of idle funds as excess reserves, and given the limited investment opportunities in the economy, they invest abroad.

11 Previously, the secondary reserve requirement mandated financial institutions to keep a proportion of deposits in the form of Treasury bills. This helped to reduce bank loans to the government.

12 Prescribed liabilities represent total demand, savings and time deposits, short term credit instruments with a maturity up to and including one year and all fund raising instruments maturing within or beyond one year of the reporting date.

28
These secondary reserves balances are remunerated at 350 basis points below the repo rate. Another direct measure implemented since 2005 is a special deposit facility, whereby commercial banks are required to deposit specific amounts in interest bearing accounts. Although these deposits cause an immediate precipitous decline in excess reserves, this measure only temporarily removes some of the surplus liquidity from the banking system.

Regarding the indirect measures, the Central Bank intensified the level of open market operations to reduce the amount of liquidity in the banking system. In doing so, it increased the sales of three and six-month Treasury bills and one-year Treasury notes to commercial banks. The Central Bank also issued special liquidity absorption bonds to complement the impact of regular open market operations. It has been observed that the increase in foreign exchange sales (mainly U.S. dollars) helped to remove local currency from the financial system and in so doing, absorb liquidity.\textsuperscript{13}

It has however been recognized that the high levels of liquidity in the financial system have outpaced the liquidity absorption measures undertaken by the Central Bank. Figure 1.4 provides a summary of the liquidity absorption measures. An inspection of the data shows that the sale of foreign exchange, which is an indirect liquidity absorption measure, withdrew the most liquidity from the financial system since 2005.

1.3 The Model

Consider an economy which contains seven classes of agents: identical infinitely-lived households indexed by $h \in [0,1]$, a final good-producing firm, a continuum of intermediate good-producing firms indexed by $j \in [0,1]$, a capital good producer, a commercial bank (a bank, for short), the central bank (whose responsibility is to

\textsuperscript{13}The Central Bank is the main supplier of foreign currency in the Trinidad and Tobago economy. In order to ensure the stability of the exchange rate, the Bank intervenes in the foreign exchange market whenever necessary.
regulate the commercial bank) and the government.\textsuperscript{14}

Households consume and supply labour to intermediate good-producing firms. Households also choose the real levels of cash, deposits and government bonds to hold at the beginning of the period. Each household supplies labour to the intermediate good-producing firm which it owns. Intermediate good-producing firms use the labour provided by households and capital (which is rented from the capital good producer) to produce a unique good that is sold on the monopolistically competitive market. The pricing mechanism of Rotemberg (1982) is used to account for the fact that intermediate good-producing firms incur a cost in adjusting prices. The final good-producing firm aggregates imperfectly substitutable intermediate goods into a single final good which is used for consumption, investment or government spending. The final good is sold at a perfectly competitive price. The capital good producer purchases the final good for investment and combines it with existing capital stock to produce new capital goods. In this model, wages are fully flexible and adjust to clear the market.

The commercial bank, which is owned by households, supplies credit in advance to intermediate good-producing firms to finance their short-term working capital needs. Owing to the fact that these loans are short-term in nature, it is assumed that they do not carry any risk. The bank also supplies credit to the capital good producer for investment financing. The bank’s supply of loans is perfectly elastic at the prevailing lending rate. These loans are extended prior to production or investment and are repaid at the end of the period. The bank pays interest on household deposits and central bank loans. In addition, the bank is required to hold minimum reserves against deposits at the central bank, and it has an explicit demand for excess reserves—the bank therefore holds excess reserves voluntarily. Because the bank does not hold involuntary reserves, the model does not account

\textsuperscript{14}In effect, the household and capital good producer can be thought of as one unit in this model, and this unit ignores the potential benefit of housing as collateral in capital good production while making housing choices. This point is further discussed later.
for any asymmetric effect on bank pricing behaviour. Total reserves at the central bank are remunerated at the reserve rate denoted by $M$, which is constant. The bank determines the total reserve ratio, the deposit rate and the lending rate, and borrows from the central bank to finance any shortfall in funding. The central bank sets its policy interest rate using a Taylor-type rule and supplies all the credit demanded by the bank at the prevailing refinance rate. It is important to note that because there is a perfectly elastic supply of liquidity, the bank is not subject to (random) withdrawal risk which has been a key factor in reserve management models. Therefore, increased uncertainty about the size of cash withdrawals does not influence the quantity of excess bank reserves in this model.

The financial sector of the model incorporates features that are relevant to the structure of the Trinidad and Tobago economy. First, commercial banks in the economy have a voluntary demand for excess reserves (see Primus et al. (2014)), which the model accounts for given the bank’s explicit demand for excess reserves. Second, commercial banks in Trinidad and Tobago are required to hold primary and secondary reserves at the Central Bank—as highlighted in Section 1.2.3. Given that the secondary reserves are remunerated, the model extends this to consider the case of interest being paid on the bank’s total reserve holding at the central bank—which is the case in a few countries. Third, as noted in Section 1.2.1, the Central Bank of Trinidad and Tobago conducts monetary policy by using a short-term interest rate—which commercial banks consider when determining their lending and deposit rates. The Central Bank sets the policy interest rate taking inflation and output growth into account. A study by Primus (2012) found that the policy interest rate set by the Central Bank of Trinidad and Tobago closely follows a Taylor rule; therefore, in the model, the central bank conducts monetary policy using a Taylor-type rule. Finally, the banking system (as in most developing countries) has credit market imperfections.

\[15\] In reserve management models, the optimal level of reserves demanded by commercial banks is a function of deposit fluctuations (see Morrison (1966), Poole (1968) and Baltensperger (1980) for further discussions).
and due to asymmetric information problems, lending to firms is collateralized. The other sectors of the model are standard for developing economies.

Moreover, as mentioned in Section 1.1, high levels of excess reserves is a common feature of the banking system of several developing countries. Therefore, although this research uses Trinidad and Tobago as a case study, this framework can be applied to other high- and middle-income countries that have a similar financial structure. For instance, the model is applicable to other developing countries where commercial banks have a voluntary demand for excess reserves, there are credit market imperfections, and the financial system is sufficiently developed so monetary policy can operate through the manipulation of a short-term interest rate. It is however important to note that a build up in excess reserves may also result from involuntary factors. To capture this, the framework will need to be modified as the model specifically accounts only for the case where banks have an explicit demand for excess reserves and therefore hold these assets voluntarily.

1.3.1 Households

Each household, \( h \), chooses consumption, labour supply to intermediate good-producing firms and real monetary assets. The objective of a representative household is to maximize the following utility function,

\[
U = E_t \sum_{t=0}^{\infty} \beta^t \left[ \frac{C_{ht}}{1 - \sigma^{-1}} \right] + \eta_N \ln(1 - N_{ht}) + \eta_X \ln X_{ht},
\]

where \( C_{ht} \) is household consumption, \( N_{ht} \) is the share of total time endowment (normalized to unity) household \( h \) spent working, \( X_{ht} \) is a composite index of real monetary assets, \( \sigma > 0 \) gives the intertemporal elasticity of substitution in consumption, \( \eta_N, \eta_X > 0 \) are preference parameters with respect to leisure and money holdings respectively, \( \beta \in (0,1) \) is the discount factor and \( E_t \) is the expectation operator conditional on the information available at the beginning of period \( t \).
The composite monetary asset is a combination of real cash balances $M_{ht}$ and real bank deposits $D_{ht}$, which can be represented by the following Cobb-Douglas function,

$$X_{ht} = (M_{ht}^H)^{\nu} D_{ht}^{1-\nu}, \quad (1.2)$$

where $\nu \in (0, 1)$.

Real wealth of household $h$ at the end of period $t$, $A_{ht}$, is given by,

$$A_{ht} = M_{ht}^H + D_{ht} + B_{ht}^H, \quad (1.3)$$

where $B_{ht}^H$ denotes holdings of one-period real government bonds.

At the beginning of period $t$, each household enters with $M_{ht-1}^H$ level of cash. Holding money balances yield no return, while deposits and government bonds yield gross returns of $(1 + i_{t}^D)$ and $(1 + i_{t}^B)$, respectively. Therefore, the total real returns from holding deposits and government bonds from period $t-1$, adjusted for the rate of inflation, are denoted respectively by $(1 + i_{t-1}^D) D_{ht-1} \frac{P_{t-1}}{P_t}$ and $(1 + i_{t-1}^B) B_{ht-1}^H \frac{P_{t-1}}{P_t}$, where $P_t$ represents the price of the final good.

In addition, households supply labour to intermediate good-producing firms, for which they receive a total real factor payment $\omega_t N_{ht}$, where $\omega_t$ denotes the economy-wide real wage. Each household owns an intermediate good-producing firm so all the profits made by that firm, $J_{ht}^I$, are paid to the respective household. Also, each household receives a fixed fraction $\varphi_h \in (0, 1)$ of the bank’s profits, $J_t^B$, and the capital good producer’s profits, $J_t^K$, with $\int_0^1 \varphi_h dh = 1$. Each household is also required to pay a lump-sum tax, whose real value is $T_{ht}$.

The real budget constraint of household $h$ is,

$$M_{ht}^H + D_{ht} + B_{ht}^H \leq \omega_t N_{ht} - T_{ht} + M_{ht-1}^H \left( \frac{P_{t-1}}{P_t} \right) + (1 + i_{t-1}^D) D_{ht-1} \left( \frac{P_{t-1}}{P_t} \right)$$

$$+(1 + i_{t-1}^B) B_{ht-1}^H \left( \frac{P_{t-1}}{P_t} \right) + J_{ht}^I + \varphi_h J_t^B + J_t^K - C_{ht}, \quad (1.4)$$
Each household maximizes lifetime utility with respect to $C_{ht}$, $N_{ht}$, $M_{ht}^H$, $D_{ht}$ and $B_{ht}^H$, taking $i_t^D$, $i_t^B$, $P_t$, and $T_{ht}$ as given. Maximizing (1.1) subject to (1.4) yields the following first order conditions,\footnote{Details of the derivations are shown in Appendix 1.A.1.}

\begin{align*}
C_{ht}^{-1/\sigma} &= \beta E_t \left[ (C_{ht+1})^{-1/\sigma} \left( \frac{1 + i_t^B}{1 + \pi_{t+1}} \right) \right], \quad (1.5) \\
N_{ht} &= 1 - \frac{\eta_X (C_{ht})^{1/\sigma}}{\omega_t}, \quad (1.6) \\
M_{ht}^H &= \frac{\eta_X \nu (C_{ht})^{1/\sigma} (1 + i_t^B)}{i_t^B}, \quad (1.7) \\
D_{ht} &= \frac{\eta_X (1 - \nu) (C_{ht})^{1/\sigma} (1 + i_t^B)}{i_t^B - i_t^D}, \quad (1.8)
\end{align*}

where $\pi_{t+1} = (P_{t+1} - P_t) / P_t$ is the inflation rate. The transversality condition is determined by the following equation,

\begin{equation}
\lim_{s \to \infty} E_{t+s} \Lambda_{t+s}^{\beta s} (M_{t+s}^H) = 0.
\end{equation}

Equation (1.5) is the standard Euler equation which describes the optimal consumption path. Equation (1.6) represents the optimal labour supply which is positively related to the real wage and negatively related to consumption. Equation (1.7) shows that the demand for real cash balances depends positively on consumption and negatively on the opportunity cost of holding cash (measured by the rate of return on government bonds). Equation (1.8) denotes the real demand for deposits which is positively related to consumption and the deposit rate, and negatively related to the bond rate.

### 1.3.2 Final Good-Producing Firm

The final good producer assembles a continuum of imperfectly substitutable intermediate goods $Y_{jt}$, indexed by $j \in (0, 1)$, to produce the final good $Y_t$, which is used
for private consumption, government consumption and investment. The production
technology for combining intermediate goods to produce the final good is given by
the standard Dixit-Stiglitz (1977) technology,

$$Y_t = \left\{ \int_0^1 [Y_{jt}]^{(\theta-1)/\theta} d_j \right\}^{\theta/(\theta-1)},$$

(1.10)

where $\theta > 1$ represents the elasticity of demand for each intermediate good.

Given the prices of intermediate goods, $P_{jt}$, and the final good price, $P_t$, the final
good-producing firm chooses the quantities of intermediate goods to maximize its
profits. The profit maximization problem of the final good producer is given by,

$$\max_{Y_{jt}} P_t \left\{ \int_0^1 [Y_{jt}]^{(\theta-1)/\theta} d_j \right\}^{\theta/(\theta-1)} - \int_0^1 P_{jt} Y_{jt} d_j.$$

(1.11)

The first-order condition with respect to $Y_{jt}$ is,

$$Y_{jt} = \left( \frac{P_{jt}}{P_t} \right)^{\theta} Y_t.$$

(1.12)

Equation (1.12) gives the demand for each intermediate good $j$. Substituting
(1.12) in (1.10) and imposing a zero-profit condition, the final good price is repre-
sented by,

$$P_t = \left[ \int_0^1 (P_{jt})^{1-\theta} d_j \right]^{1/(1-\theta)}.$$

(1.13)

### 1.3.3 Intermediate Good-Producing Firms

Each intermediate good-producing firm, $j$, produces a perishable good which is sold
on a monopolistically competitive market. To produce these goods, each firm rents
capital at the price $r^K_t$ from the capital good producer and combines it with labour.
The technology faced by each intermediate good-producing firm is given by the
Cobb-Douglas production function,

\[ Y_{jt} = A_t K_{jt}^\alpha N_{jt}^{1-\alpha}, \quad (1.14) \]

where \( N_{jt} \) is household \( h = j \) labour hours, \( K_{jt} \) is the amount of capital rented by the firm, \( \alpha \in (0, 1) \) is the elasticity of output with respect to capital and \( A_t \) is a serially uncorrelated technology shock which follows a first-order autoregressive process, \( A_t = A_{t-1}^\rho \exp (\xi_t^A) \), where \( \rho \in (0, 1) \) and \( \xi_t^A \sim N(0, \sigma_\xi^A) \).

In order to pay wages in advance, firm \( j \) takes a loan from the bank at the beginning of the period. The amount borrowed is,

\[ L_{jt}^{FW} = \kappa^W \omega_t N_{jt}, \quad (1.15) \]

where \( L_{jt}^{FW} \) represents the real value of loans demanded by intermediate good producers for all \( t \geq 0 \) and \( \kappa^W \in (0, 1) \). Similar to Agénor et al. (2013), it is assumed that short-term loans for working capital do not carry any risk and are therefore contracted at a rate that reflects only the marginal cost of borrowing from the central bank, \( i^R_t \), which is the refinance rate. The wage bill, inclusive of interest payments is \((1 + i^R_t)\kappa^W \omega_t N_{jt} + (1 - \kappa^W)\omega_t N_{jt}\). Rearranging this gives \((1 + \kappa^W i^R_t)\omega_t N_{jt}\), which shows the firm’s wage bill includes a constant share of financing of working capital needs. Thus, \( \kappa^W \) indicates the strength of the cost channel; if \( \kappa^W = 0 \), no cost channel exists.

Intermediate good producers solve a two stage problem. In the first stage, given input prices, firms integrate capital and labour in a perfectly competitive market in order to minimize their total costs. The cost minimization problem for firm \( j \) is,

\[ \min_{N_{jt}, K_{jt}} \left[ (1 + \kappa^W i^R_t)\omega_t N_{jt} + r^K_t K_{jt} \right]. \quad (1.16) \]

Minimizing (1.16) subject to (1.14), the first-order conditions with respect to \( N_{jt} \)
and \( K_{jt} \) equate the marginal products of capital and labour to their relative prices, from which the capital-labour ratio is obtained,

\[
\frac{K_{jt}}{N_{jt}} = \left( \frac{\alpha}{1-\alpha} \right) \left( \frac{1 + \kappa^W_i R_t}{r^K_t} \right)^{\alpha}. \tag{1.17}
\]

The unit real marginal cost is,

\[
m_{c_{jt}} = \left[ (1 + \kappa^W_i R_t)^{1-\alpha} (r^K_t)^{\alpha} \right] \frac{1}{\alpha^\alpha (1 - \alpha)^{1-\alpha}}. \tag{1.18}
\]

In the second stage, each firm chooses prices, \( P_{jt} \), to maximize the discounted real value of current and future profits. Nominal price stickiness is introduced along the lines of Rotemberg (1982), by assuming that intermediate good-producing firms incur a cost in adjusting prices. These price adjustment costs, \( PAC_{jt} \), which are measured in terms of aggregate output, \( Y_t \), take the form,

\[
PAC_{jt} = \frac{\phi_F}{2} \left( \frac{P_{jt}}{P_{jt-1}} - 1 \right)^2 Y_t, \tag{1.19}
\]

where \( \phi_F \geq 0 \) is the degree of price stickiness.

Thus, the profit maximization problem for the intermediate good producer is,

\[
\max_{P_{jt}} E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t J^I_{jt}, \tag{1.20}
\]

where \( \beta^t \Lambda_t \) is the firm’s discount factor for period \( t \), with \( \Lambda_t \) representing the marginal utility gained from consuming an additional unit of profit. Real profits, \( J^I_{jt} \), are defined as,

\[
J^I_{jt} = Y_{jt} - m_{c_{jt}} Y_{jt} - PAC_{jt}. \tag{1.21}
\]

Substituting (1.12) and (1.19) in (1.21) and taking \( m_{c_{jt}} \), \( P_t \) and \( Y_t \) as given, the
first-order condition with respect to $P_{jt}$ is,

$$(1-\theta)\Lambda_t \left( \frac{P_{jt}}{P_t} \right)^{-\theta} Y_t \Lambda_t \left( \frac{P_{jt}}{P_t} \right)^{-\theta-1} \left( \frac{P_{jt}}{P_{jt-1}} - 1 \right) \frac{Y_t}{P_{jt-1}} + \beta\phi E_t \left\{ \Lambda_{t+1} \left( \frac{P_{jt+1}}{P_{jt}} - 1 \right) \left( \frac{P_{jt+1}}{P_{jt}} \right) Y_{t+1} \right\} = 0.$$

Equation (1.22) gives the adjustment process of the nominal price $P_{jt}$. When there is no price adjustment cost ($\phi = 0$), the price equals a mark-up over the real marginal cost,

$$P_{jt} = \left( \frac{\theta}{\theta - 1} \right) mc_{jt} P_t.$$ 

(1.23)

In a symmetric equilibrium $P_{jt} = P_t$ for all $j$; hence the real marginal cost equals the reciprocal of the mark-up, $mc_t = \frac{(\theta - 1)}{\theta}$.

### 1.3.4 Capital Good Producer

In the economy, all the capital is owned by the capital good producer who employs a linear production function to produce capital goods. As in Agénor et al. (2013), at the beginning of each period, the capital good producer purchases $I_t$ of the final good from the final good producer. Because payments for these final goods must be made in advance, the capital good producer borrows from the bank,

$$L_t^{F,I} = I_t,$$

(1.24)

where $L_t^{F,I}$ denotes real loans made to the capital good producer for investment purposes. The total costs faced by the capital good producer at the end of period $t$ for buying an amount $I_t$ of the final good is $(1 + i_t^{L}) I_t$, where $i_t^{L}$ is the lending rate.

The capital good producer combines undepreciated capital from the previous period, with investment to produce new capital goods. New capital goods, denoted
as $K_{t+1}$, are given by,

$$K_{t+1} = I_t + (1 - \delta)K_t - \frac{\Theta_K}{2} \left( \frac{K_{t+1}}{K_t} - 1 \right)^2 K_t,$$  \hspace{1cm} (1.25)

where $K_t = \int_0^1 K_j dJ$, $\delta \in (0, 1)$ gives the constant rate of depreciation and $\Theta_K > 0$ measures the magnitude of adjustment costs. The capital good producer rents the new capital stock to intermediate good-producing firms at the rate $r^K_t$.

The capital good producer chooses the amount of capital stock in order to maximize the value of the discounted stream of dividend payments to the household. The optimization problem of the capital good producer is given by,$^{17}$

$$\max_{K_{t+1}} E_t \sum_{t=0}^{\infty} \beta^t \Lambda_t J^K_t,$$  \hspace{1cm} (1.26)

where real profits, $J^K_t$, can be denoted as,

$$J^K_t = r^K_t K_t - (1 + i^K_t)I_t.$$  \hspace{1cm} (1.27)

Maximizing (1.26) subject to (1.25), the first-order condition is,

$$E_t r^K_{t+1} = (1 + i^K_t)E_t \left\{ 1 + \Theta_K \left( \frac{K_{t+1}}{K_t} - 1 \right) \left( \frac{1 + i^K_t}{1 + i^{L_t}_t} \right) \right\}$$  \hspace{1cm} (1.28)

$$-E_t \left\{ (1 + i^K_{t+1}) \left( 1 - \delta \right) + \frac{\Theta_K}{2} \left( \frac{K_{t+2}}{K_t+1} \right)^2 - 1 \right\}.$$

Equation (1.28) shows the expected rental rate of capital is a function of the current and expected loan rates, the cost of adjusting capital across periods, the bond rate, the depreciation rate and the inflation rate. The opportunity cost of

$^{17}$As noted earlier, the household and capital good producer in this model can be thought of as a single unit with respect to housing choices. Agénor et al. (2013) assume further that in case of default the capital seized by the bank is returned immediately and in its entirety to the household, who turns it back instantly to the capital good-producing firm. As a result, and as implicitly assumed in (1.27), the capital good producer does not internalize the risk of default, that is, the possibility that it could lose the fraction of the housing stock that it used to secure bank loans. See Agénor et al. (2014) for an alternative treatment.
investing in physical capital is measured by the real rate of return on government bonds. If the capital good producer does not borrow at the beginning of the period, and there are no adjustment costs \( \Theta_K = 0 \),

\[
E_t t^{K}_{t+1} = E_t \left( \frac{1 + i^B_t}{1 + \pi_{t+1}} \right) - 1 + \delta.
\]  

(1.29)

Equation (1.29) is the standard arbitrage condition which implies that capital is produced up to the point where the (expected) rental rate of capital is equal to the (expected) real interest rate on government bonds, plus depreciation.

### 1.3.5 Commercial Bank

The bank receives deposits \( D_t \) from households at the start of each period. These deposits are used to finance loans to intermediate good-producing firms to cover wage payments and to the capital good producer for investment. Therefore, combining (1.15) and (1.24), total lending, \( L_t^F \), in real terms is,

\[
L_t^F = \kappa^W \omega_t N_t + I_t.
\]  

(1.30)

Given households’ deposits and total loans to firms, to finance any shortfall in funding, the bank borrows from the central bank, \( L_t^B \), for which it pays a net interest rate \( i_t^R \).

Assets of the commercial bank at the beginning of period \( t \) consist of real loans to firms and real total reserve holdings, \( TR_t \), whereas its liabilities comprise of real loans from the central bank and real deposits. The bank’s balance sheet is thus,

\[
L_t^F + TR_t = L_t^B + D_t.
\]  

(1.31)

Total reserves comprise of excess reserves, \( ER_t \), and required reserves, \( RR_t \), which are the compulsory minimum amount of reserves the bank must hold at the
central bank. Thus,

\[ TR_t = ER_t + RR_t, \quad (1.32) \]

where total reserves are a portion \( \mu_t^{TR} \) of deposits and required reserves are a percent \( \mu_t \) of deposits. Therefore, \( TR_t = \mu_t^{TR}D_t \) and \( RR_t = \mu_t D_t; \) where \( \mu_t^{TR}, \mu_t \in (0,1). \) Using these in (1.32), excess reserves are therefore determined residually,\(^\text{18}\)

\[ ER_t = (\mu_t^{TR} - \mu_t)D_t. \quad (1.33) \]

Reserves held at the central bank are remunerated at the rate \( i_M, \)\(^\text{19}\) where \( i_M < i_t^R. \) The bank therefore chooses the total reserve ratio, the deposit rate and the lending rate to maximize its present discounted value of real profits. Hence, the bank’s profit maximization problem is,

\[ \max_{\{\mu_t^{TR},1+i_t^D,1+i_t^L\}} E_t - \sum_{t=0}^{\infty} \beta^t \Lambda_t J_t^B, \quad (1.34) \]

where, \( E_t - \) is the expectations operator based on information available at the beginning of period \( t \) and \( J_t^B \) represents real bank profits at the end of period \( t. \)

Therefore, expected real bank profits can be defined as,

\[ E_t - J_t^B = (1 + \kappa^W i_t^R)L_t^{FW} + Q_t^F(1 + i_t^L)L_t^{FI} + (1 - Q_t^F)\kappa^C K_t \]

\[ + (1 + i_t^M)TR_t - (1 + i_t^D)D_t - (1 + i_t^R)L_t^B - \Phi(\mu_t^{TR} - \mu_t)D_t, \quad (1.35) \]

where \( \kappa^C \in (0,1) \) and \( Q_t^F \in (0,1) \) is the repayment probability.

From equation (1.35), the first term on the right-hand side, \( (1 + \kappa^W i_t^R)L_t^{FW}, \) shows repayment on loans to intermediate good-producing firms. The second term,\(^\text{18}\)In principle, the bank should determine directly excess reserves; however, it is more convenient to solve for total reserves first, and use this solution to determine excess reserves.\(^\text{19}\)A few studies have discussed how interest on reserves can be used as a policy instrument (see Goodfriend (2002), Ennis and Weinberg (2007), Keister et al. (2008), Keister and McAndrews (2009), and Kashyap and Stein (2012)).
$Q^F_t(1+i_t^L)L^F_t$, represents expected repayment on loans to the capital good producer, providing that there is no default. The third term, $(1-Q^F_t)\kappa^C K_t$, denotes the bank’s earnings in case of default, where $1-Q^F_t$ represents the probability of default. This term therefore shows real effective collateral, given by a fraction $(\kappa^C)$ of the real capital stock. The expression $(1+i^M)TR_t$ denotes the principal plus interest gained from total reserves, whereas $(1+i^D_t)D_t$ represents the principal and interest paid on real deposits, and $(1+i^R_L)L^B_t$ reflects the gross repayments to the central bank. Similar to Glocker and Towbin (2012), the final term, $\Phi(\mu_t^{TR} - \mu_t)D_t$, is included to represent the convex costs of holding reserves, which are proportional to the amount of real deposits. Thus,

$$\Phi(\mu_t^{TR} - \mu_t) = -\Phi_{C1}(\mu_t^{TR} - \mu_t) + \frac{\Phi_{C2}}{2}(\mu_t^{TR} - \mu_t)^2 + \varepsilon_t^R.$$ (1.36)

From equation (1.36), $\Phi_{C1}$ and $\Phi_{C2}$ are cost function parameters. The linear term, $\Phi_{C1}(\mu_t^{TR} - \mu_t)$, determines steady-state deviations from the required reserve ratio. A positive deviation from the ratio may generate small benefits because holding excess reserves reduces the costs of liquidity management. Intuitively, if the bank fails to meet the reserve requirement it has to face the penalty rate for funds borrowed from the central bank. The quadratic term, $\frac{\Phi_{C2}}{2}(\mu_t^{TR} - \mu_t)^2$, indicates that negative deviations from the required ratio may generate large costs. For instance, the central bank may impose a higher penalty rate in cases where there are large negative deviations from its target, and at the same time, cease remuneration of excess reserves.\(^{20}\) The last term, $\varepsilon_t^R$, represents a cost shock.

From the balance sheet constraint (1.31), and given that $L^F_t$ and $D_t$ are determined by the private agents’ behaviour, borrowing from the central bank can be solved for residually. Therefore, using $TR_t = \mu_t^{TR}D_t$ in (1.31) yields,

$$L^B_t = L^F_t - (1 - \mu_t^{TR})D_t.$$ (1.37)

\(^{20}\)These responses, however, are not explicitly accounted for in the model.
Using $TR_t = \mu_t^{TR}D_t$ and substituting (1.36) and (1.37) in (1.35) gives the bank’s static optimization problem,

$$\max_{\{\mu_t^{TR},1+i_t^{D},1+i_t^{R}\}} \left\{ (1 + \kappa^W_i R_t^W) L_t^{F, W} + Q_t^F (1 + i_t^{L}) L_t^{F, L} + (1 - Q_t^R) \kappa^C K_t \right\} \quad (1.38)$$

$$+ (1 + i^M_t) \mu_t^{TR} D_t - (1 + i_t^{D}) D_t - (1 + i_t^{R}) [L_t^F - (1 - \mu_t^{TR}) D_t] -$$

$$\left[ -\Phi_{C1}(\mu_t^{TR} - \mu_t) + \frac{\Phi_{C2}}{2} (\mu_t^{TR} - \mu_t)^2 + \varepsilon_t^R \right] D_t \right\}. \quad (1.39)$$

The first-order condition with respect to $\mu_t^{TR}$ is,

$$\mu_t^{TR} = \mu_t + \frac{(1 + i^M) + \Phi_{C1} - (1 + i_t^{R})}{\Phi_{C2}}. \quad (1.40)$$

The difference between the total reserve ratio and the required reserve ratio $\mu_t^{TR} - \mu_t$, represents the excess reserve ratio, $\mu_t^{ER}$, which is given by,

$$\mu_t^{ER} = \frac{(1 + i^M) + \Phi_{C1} - (1 + i_t^{R})}{\Phi_{C2}}. \quad (1.41)$$

The first-order condition with respect to $1 + i_t^{D}$ is,

$$(1 + i^M) \mu_t^{TR} \left( \frac{\partial D_t}{\partial (1 + i_t^{D})} \right) - (1 + i_t^{D}) \left( \frac{\partial D_t}{\partial (1 + i_t^{D})} \right) - D_t$$

$$+ (1 + i_t^{R}) \left( 1 - \mu_t^{TR} \right) \left( \frac{\partial D_t}{\partial (1 + i_t^{D})} \right) - \Phi(\cdot) \left( \frac{\partial D_t}{\partial (1 + i_t^{D})} \right) = 0,$$

using $\eta_D = \left( \frac{\partial D_t}{\partial (1 + i_t^{D})} \right) \left( \frac{(1+i_t^{D})}{D_t} \right)$ to represent the constant interest elasticity of the supply of deposits by the household results in,

$$(1 + i_t^{D}) = (1 + \frac{1}{\eta_D})^{-1} \left[ (1 + i^M) \mu_t^{TR} + (1 - \mu_t^{TR})(1 + i_t^{R}) - \Phi(\mu_t^{TR} - \mu_t) \right],$$

or,
\[ 1 + i_t^D = (1 + \frac{1}{\eta_D})^{-1}[(1 + i_t^R) - \mu_t^{TR}(i_t^R - i_t^M)] \quad (1.41) \]

\[ + \Phi_{C1}(\mu_t^{TR} - \mu_t) - \frac{\Phi_{C2}}{2}(\mu_t^{TR} - \mu_t)^2]. \]

The first-order condition with respect to \(1 + i_t^L\) is,

\[ Q_t^F L_t^{FL} + Q_t^F (1 + i_t^L) \frac{\partial L_t^{FL}}{\partial (1 + i_t^L)} - (1 + i_t^R) \frac{\partial L_t^{FL}}{\partial (1 + i_t^R)} = 0, \]

using \(\eta_L = \frac{\partial L_t^{FL}}{\partial (1 + i_t^L)}(1 + i_t^L) L_t^{FL}\) to denote the interest elasticity of demand for loans for investment yields,

\[ Q_t^F + Q_t^F (1 + i_t^L) \frac{\eta_L}{(1 + i_t^L)} - (1 + i_t^R) \frac{\eta_L}{(1 + i_t^R)} = 0, \]

or,

\[ 1 + i_t^L = \frac{1 + i_t^R}{Q_t^F \eta_L^{-1} + 1}. \quad (1.42) \]

Equation (1.40) represents the bank’s excess reserve ratio. This shows that \(\mu_t^{ER}\) increases with \(i_t^M\) but falls with \(i_t^R\). Therefore, the excess reserve ratio is decreasing in the spread between the interest rate on reserves and the refinance rate. By holding an additional unit of excess reserves at the central bank, the bank benefits by gaining \(1 + i_t^M\); at the same time, it saves because it does not have to borrow from the central bank to meet reserve requirements. By contrast, the bank also incurs costs for holding the extra unit of excess reserves. Therefore, equation (1.40) balances the costs and the benefits of holding excess reserves. From equation (1.41), the (gross) interest rate on deposits depends on the marginal cost of borrowing from the central bank, which is lowered in the presence of remunerated reserves by the difference between the refinance rate and the interest rate on reserves. The deposit rate also depends on the costs associated with holding excess reserves. Equation (1.42) shows that the (gross) lending rate depends positively on the marginal cost of
borrowing from the central bank and negatively on the repayment probability, $Q_F^t$.

As in Agénor and Alper (2012), the repayment probability is taken to depend positively on "micro" and "macro" factors, namely, the real effective collateral-loan ratio and economic activity. Therefore, $Q_F^t$ increases with the collateral provided by firms and falls with the amount borrowed. Hence,

$$Q_F^t = \phi_0 \left( \frac{\kappa C K_t}{L_t F} \right)^{\phi_1} \left( \frac{Y_t}{Y} \right)^{\phi_2}, \quad (1.43)$$

where $\phi_0, \phi_1, \phi_2 > 0$ and $(Y_t/Y)$ represents the output gap, with $Y$ denoting the steady-state value of output\(^{21}\) under fully flexible prices.

### 1.3.6 Central Bank

The central bank’s assets consist of government bonds, $B_C^t$, and loans to the commercial bank, $L_B^t$, whereas its liabilities consist of total reserves, $TR_t$, and currency supplied to households and firms, $M^*_t$. Therefore, the central bank’s balance sheet is given by,

$$B_C^t + L_B^t = TR_t + M^*_t. \quad (1.44)$$

Using $TR_t = \mu^T R D_t$ and rearranging, equation (1.44) becomes,

$$M^*_t = B_C^t + L_B^t - \mu^T R D_t. \quad (1.45)$$

Equation (1.45) shows the supply of currency is matched by government bonds and central bank loans extended to the commercial bank, less the fraction of deposits held at the central bank.

In this economy, the central bank sets the policy interest rate using a Taylor-type rule (see Taylor (1993)), and supplies all the liquidity the bank needs through

---

\(^{21}\)Similar to other studies (see, for instance, Meh and Moran (2010)), the output gap is measured in terms of deviations from its steady-state value.
a standing facility. The policy rule is of the form,

\[ i_t^R = \chi i_{t-1}^R + (1 - \chi)[r + \pi_t + \varepsilon_1(\pi_t - \pi^T) + \varepsilon_2 \ln \left( \frac{Y_t}{Y} \right)] + \varepsilon, \tag{1.46} \]

where \( \chi \in (0, 1) \) measures the degree of interest rate smoothing, \( r \) is the steady-state value of the real interest rate on bonds, \( \pi_t \) represents current inflation, \( \pi^T \geq 0 \) is the central bank’s inflation target, \( \varepsilon_1, \varepsilon_2 > 0 \) measure the relative weights on inflation deviations from its target and the output gap, respectively and \( \varepsilon \) is a serially correlated shock with constant variance, which follows a first order autoregressive process of the form,

\[ \varepsilon_t = \rho_{\varepsilon} \varepsilon_{t-1} \exp (\xi'_t), \tag{1.47} \]

where \( \rho_{\varepsilon} \in (0, 1) \) and \( \xi'_t \sim N(0, \sigma_\xi) \) is a serially correlated random shock with zero mean. The standard specification (1.46) will be extended later in the text to include a measure of excess reserves, in order to examine the dynamic effects of an increase in bank reserves under an interest rate rule which reacts directly to changes in liquidity.

### 1.3.7 Government

The government purchases the final good, collects taxes, and issues one-period risk-free bonds, \( B_t \), which are held by the central bank, \( B^C_t \), and households, \( B^H_t \). Total bonds can be denoted by, \( B_t = B^C_t + B^H_t \). The government’s real budget constraint is given by,

\[ B_t + T_t + i_{t-1}^R \frac{P_{t-1}}{P_t} + i^B_{t-1} P_{t-1}^C - i^M T R_{t-1} \frac{P_{t-1}}{P_t} = \tag{1.48} \]

\[ G_t + (1 + i^B_{t-1}) B_{t-1} \frac{P_{t-1}}{P_t}, \]

where \( G_t \) denotes real government spending and \( T_t \) represents real lump-sum tax revenues. The sum of the terms \( i_{t-1}^R \frac{P_{t-1}}{P_t}, i^B_{t-1} P_{t-1}^C \) and \( i^M T R_{t-1} \frac{P_{t-1}}{P_t} \) (adjusted
for the rate of inflation) comes from the assumption that the net income earned by 
the central bank from lending to the commercial bank, holding government bonds 
and holding reserves from the commercial bank, respectively, is transferred to the 
government at the end of each period.

Government purchases represent a constant fraction, \( \psi \in (0, 1) \), of output of the 
final good,

\[
G_t = \psi Y_t. 
\] (1.49)

### 1.4 Symmetric Equilibrium

In a symmetric equilibrium, all firms producing intermediate goods are identical 
so they produce the same output, and prices are the same across firms. Also, all 
households supply the same number of labour hours. Therefore, \( K_{jt} = K_t \), \( N_{jt} = N_t \), 
\( Y_{jt} = Y_t \), \( P_{jt} = P_t \), for all \( j \in (0, 1) \).

It is necessary for equilibrium conditions in the credit, deposit, goods and cash 
markets to be satisfied.\(^{22}\) The supply of loans by the commercial bank and supply 
of deposits by households are perfectly elastic at the prevailing interest rates; as a 
result, the markets for loans and deposits always clear. To satisfy equilibrium in the 
goods markets, production must be equal to aggregate demand. Thus, using (1.19),

\[
Y_t = C_t + G_t + I_t + \frac{\phi_F}{2} \left( \frac{1 + \pi_t}{1 + \pi} - 1 \right)^2 Y_t. 
\] (1.50)

The equilibrium condition of the market for cash is,

\[
M_t^s = M_t^H + M_t^F, \tag{1.51}
\]

where \( M_t^F = \int_0^1 M^F_{jt} \, dj \) represents the total cash holdings of intermediate good-
producing firms and the capital good producer. It is assumed that bank loans to all 

\(^{22}\) The equilibrium condition of the market for government bonds is eliminated by Walras’ Law.
firms are extended in the form of cash such that, $L^F_t = M^F_t$. Substituting this in (1.51), $M^*_t = M^H_t + L^F_t$. Replacing $M^*_t$ from (1.45) gives,

$$B^C_t + L^B_t - \mu^{TR} D_t = M^H_t + L^F_t. \hspace{1cm} (1.52)$$

Using $L^B_t$ from (1.37) into (1.52) gives,

$$B^C_t + (L^F_t + \mu^{TR} D_t - D_t) - \mu^{TR} D_t = M^H_t + L^F_t,$$

or,

$$\bar{B}^C = M^H_t + D_t. \hspace{1cm} (1.53)$$

Given that the total stock of bonds held by the central bank is constant, equation (1.53) implies that real cash balances are inversely related to real bank deposits. This equation also represents the money market equilibrium condition, from which the equilibrium bond rate is obtained.

### 1.5 Steady State and Log-Linearization

This section presents some of the key steady-state and log-linearized equations of the model. Further details on all the steady-state equations are shown in Appendix 1.A.2, whereas the log-linearized equations are outlined in Appendix 1.A.3.

Given that the steady state is characterized by zero inflation, from equation (1.5), the steady-state value of the bond rate (which is equal to the refinance rate) is given by,

$$1 + i^B = 1 + i^R = 1 + r = \frac{1}{\beta}.$$

The equality between $i^B$ and $i^R$ implies that the commercial bank has no incentive to borrow from the central bank in order to buy government bonds.
The steady-state deposit and lending rates are given by,

\[ 1 + i^D = (1 + \frac{1}{\eta_D})^{-1}[(1 + i^R) - \mu^{TR}(i^R - i^M)] + \Phi_{C1}(\mu^{TR} - \mu) - \frac{\Phi_{C2}}{2}(\mu^{TR} - \mu)^2, \]

\[ 1 + i^L = \frac{1 + i^R}{Q^F[\eta_L^{-1} + 1]} . \]

In the steady state, the repayment probability is inversely related to the firm’s assets over its liabilities,

\[ Q^F = \phi_0 \left( \frac{\kappa C}{L^{F,t}} \right)^{\phi_1} . \]

The steady-state value of the excess reserve ratio is given by,

\[ \mu^{ER} = \frac{(1 + i^M) + \Phi_{C1} - (1 + i^R)}{\Phi_{C2}} . \]

In order to solve the model, each variable is log-linearized around a non-stochastic, zero-inflation steady state. The log-linearized deposit rate is denoted by,\(^{23}\)

\[ \dot{i}_t^D = \frac{1}{(1 + i^D)(1 + \frac{1}{\eta_D})^{-1}} \left\{ (1 - \mu^{TR})(1 + i^R)i^R_t - \mu^{TR}\hat{\mu}_t^{TR}(i^R - i^M) \right. \]

\[ + \left. \left[ \Phi_{C1} - \Phi_{C2}(\mu^{TR} - \mu) \right] \left( \mu^{TR}\hat{\mu}_t^{TR} - \mu\hat{\mu}_t \right) \right\} . \]

Log-linearizing the lending rate yields,

\[ \dot{i}_t^L = \dot{i}_t^R - \hat{Q}_t^F , \]

where, a linear approximation of the repayment probability gives,

\[ \hat{Q}_t^F = \phi_2 \tilde{Y}_t + \phi_1 \left( \tilde{K}_t - \tilde{L}_t^{F,1} \right) . \]

\(^{23}\)The reserve requirement ratio is exogenous in this model. Therefore, \( \hat{\mu}_t = 0 \) except for the case when there is a shock to the variable.
From (1.40), the log-linearized excess reserve ratio is,

\[ \mu_{t}^{ER} = \frac{-(1 + i^R)\hat{R}_t}{\Phi C_2 \mu^{ER}}. \]

Log-linearizing (1.22) gives the New Keynesian Phillips Curve (see Galí (2008) and Walsh (2010)), which states that current inflation depends on firms’ marginal costs and expected inflation,

\[ \hat{\pi}_t = \frac{(\theta - 1)}{\phi_F} \hat{m}c_t + \beta E_t \hat{\pi}_{t+1}. \]

Log-linearizing equation (1.18), marginal costs are given by,

\[ \hat{m}c_t = (1 - \alpha)(\kappa^W i_t^R + \hat{\omega}_t) + \alpha \left( \frac{1 + r^K}{r^K} \right) \hat{r}^K - \hat{A}_t. \]

This equation shows that marginal costs depend positively on the real wage and the rental rate of capital, and negatively on aggregate supply shocks. Also, because \( \kappa^W > 0 \) based on the calibration, marginal costs are directly affected by changes in \( i_t^R \) (which represents the interest rate on short-term loans for working capital).

### 1.6 Calibration

The model is calibrated for Trinidad and Tobago due to the fact that the banking system in that country has recorded high persistent liquidity. The main data sources are The Central Bank of Trinidad and Tobago and The Ministry of Finance of Trinidad and Tobago. Because Trinidad and Tobago is a high-income developing economy (see The World Bank (2014)), it can be difficult to get estimates for some of the parameters. Hence, in cases where country-specific parameters are not readily available, estimates based on other studies for high- and middle-income countries are used. The calibration can therefore be applied to other developing countries.
that have the problem of excess bank reserves.

A summary of the parameter values is provided in Table 1.2. Regarding the parameters for the household, the steady-state value of beta (quarterly) for Trinidad and Tobago is calculated using, \( \beta = 1 / (1 + r) \).\(^{24}\) This gives a value of beta equal to 0.985. The intertemporal elasticity of substitution, \( \sigma \), is taken to be 0.5, which is in line with estimates for middle-income countries (see Agénor and Montiel (2015)).

Similar to Agénor and Alper (2012), the preference parameter for leisure, \( \eta_N \), is calibrated at 1.8. The preference parameter for composite monetary assets, \( \eta_X \), is set at 0.02, which is consistent with the values used in existing studies for other developing countries. Furthermore, the relative share of cash in narrow money, \( \nu \), is calibrated to be 0.2, consistent with the available data for Trinidad and Tobago for the period 2007-2011.

For the production side, the elasticity of demand for intermediate goods, \( \theta \), is 10.0, which corresponds to a steady-state mark-up rate of 11.1 percent. The share of capital in output of intermediate goods, \( \alpha \), is 0.3 and is consistent with estimates for developing countries. The cost channel parameter, \( \kappa^W \), is set at 0.45. Using the method proposed in Keen and Wang (2007), the value of the adjustment cost parameter for prices, \( \phi_F \), is calculated as 65. As is standard in the literature, the depreciation rate for capital is set equal to 0.034. Also, the adjustment cost parameter for investment, \( \Theta_K \), is set at 18.

In considering the parameters characterizing bank behaviour, the effective collateral-loan ratio, \( \kappa^C \), is set at a value of 0.05 which is consistent with the evidence in Trinidad and Tobago. There is little information on the values for the cost function parameters, \( \Phi_{C1} \), and \( \Phi_{C2} \). Hence, these coefficients are calibrated such that the differential between the steady-state total reserve ratio and the required reserve ratio is 4.5 percent, which is close to the actual spread observed in the recent data for Trinidad and Tobago. Using this approach gives a value of 0.35 for \( \Phi_{C1} \) and 7.5 for

\(^{24}\)The average real bond rate, \( r \), for the period 2007-2011 is 1.52 percent. Using this value, \( \beta \) is equal to 0.985.
The elasticity of the repayment probability with respect to collateral, $\phi_1$, is set at a relatively low value, 0.02; whereas the elasticity of the repayment probability with respect to cyclical output, $\phi_2$, is 0.2, as in Agénor et al. (2012).

On the central bank side, the required reserve ratio, $\mu$, is set at 0.17, as imposed by the Central Bank of Trinidad and Tobago according to legislation. Similar to Agénor and Alper (2012), the lagged value of the policy rate in the interest rate rule, $\chi$, is set to 0. The calibration therefore implies that there is direct interest rate smoothing from the central bank’s policy response. The parameters for the response of the refinance rate to inflation deviations from its target and to output growth, $\varepsilon_1$ and $\varepsilon_2$, are set to 1.5 and 0.1, respectively, which are standard values estimated for Taylor-type rules in middle-income countries. The degree of persistence in the supply shock, $\rho_A$, and the shock to the refinance rate, $\rho_a$, are both set to 0.4. Finally, the share of government spending in output is estimated as 0.15, which is in line with the actual value observed for the period 2007-2011 in Trinidad and Tobago.

The steady-state deposit rate is calibrated at 1.05 percent, which is the actual value on average for the period 2007-2011. It is important to note that the low deposit rate is due to the high liquidity environment, which depresses the short-term interest rate. Further, the data show that the prime lending rate for Trinidad and Tobago is 10.7 percent on average during 2007-2011. This value is therefore used for the steady-state loan rate. Banks in Trinidad and Tobago earn no interest on primary reserve requirements. However, the Central Bank pays interest on secondary reserve requirements, as discussed in Section 1.2.3. The interest rate paid on reserves is set at a low value of 0.25 percent, which satisfies the condition that the interest rate on total reserves is less than the refinance rate. The ratio of excess reserves to total reserves in the steady state is 20.9 percent, which is close to the value observed in the recent data for Trinidad and Tobago. Further, in the steady state,

\footnote{This represents the deposit rate announced by commercial banks for ordinary savings.}

\footnote{Similarly, inspection of the data shows that the rise in excess reserves in the U.S. and Euro Area in recent years was associated with a sharp fall in the short-term interest rate.}
the proportion of deposits held as total reserves is 21.5 percent. The steady-state value of the repayment probability is 97 percent; this implies the default probability is around 3 percent. The steady-state ratio of consumption to output is 68.1 percent, which is close to the value observed for the period 2007-2011. The cash plus deposit to output ratio in the steady state is set at 45.2 percent, which is in line with the actual value for the period 2007-2011. Also, in the steady state the ratio of investment to output is set at 16.8 percent, while the collateral-to-loan ratio is 1.47.

1.7 Policy Analysis

This section uses impulse response functions to study the dynamic effects of four shocks to the model. All the figures show the percent deviation of the variables from their steady-state values, with the exception of the total reserve ratio, the ratio of excess reserves to total reserves, inflation and the interest rate variables which are expressed in percentage points. The first case examines the impact of a negative supply shock; then the transmission of monetary policy following an increase in the central bank’s refinance rate is analyzed. The next experiment investigates the impact of a shock to reserve requirements. Following this, I examine the response of the model to a liquidity shock, taking the form of an increase in bank deposits. Finally, simultaneous shocks are administered to deposits and the required reserve ratio.

1.7.1 Negative Supply Shock

Figure 1.5 shows the impulse response functions of some of the main variables of the model following a one percent negative productivity shock. The direct effect of the shock is an immediate decline in output, and a rise in the marginal production costs, which in turn exerts an upward pressure on prices. As the rise in inflation dominates the fall in output, the policy rate, which is determined by the Taylor
rule, rises as a result. The higher policy rate leads to a direct increase in the deposit rate, which in turn raises the demand for bank deposits, and reduces borrowing from the central bank. From the central bank’s balance sheet, a fall in loans to the commercial bank reduces the supply of currency, and therefore to restore equilibrium in the money market, the demand for cash must fall. Because the central bank’s real bond holdings, which determine the total monetary assets, are fixed, the bond rate adjusts to clear the money market. Therefore, to reduce the demand for cash, the bond rate increases, which, through intertemporal substitution, leads to a fall in the level of current consumption. Overall, the higher rate of return on deposits and bonds increases households’ demand for these financial assets, and lowers their consumption.

A key point to note is that based on the calibration, the cost channel exists ($\kappa_W > 0$). Thus, owing to the fact that marginal costs depend directly on the policy interest rate, an increase in this rate tends to further raise firms’ marginal costs as it increases the labour costs of production. Furthermore, the increase in the refinance rate also translates to an immediate rise in the loan rate, which lowers the demand for investment and the level of physical capital over time. The collateral-to-loan ratio increases on impact as loans for investment fall by more than the value of collateral. Because the collateral effect is dominated by the cyclical output effect, the repayment probability falls, causing the loan rate to increase further, which in turn exerts an upward pressure on the rental rate of capital. Based on the calibration, the higher rental rate of capital offsets the fall in the level of physical capital, the rise in both labour supply and the refinance rate, causing real wages to increase upon the impact of the shock.\footnote{The value of capital, labour supply, the refinance rate and the rental rate of capital were calculated. The results showed that the increase in the rental rate of capital offsets the total (negative) value of all the other variables, bringing about an increase in real wages.}

In this model, excess reserves are positively related to their rate of return, but
depend negatively on the refinance rate. Therefore, because the interest rate paid on reserves is fixed by the central bank, an increase in the marginal cost of borrowing from the central bank lowers the level of excess reserves. As the refinance rate and the other interest rates in the banking sector increase, the costs of holding excess reserves are higher. Put differently, there is a higher opportunity cost of holding excess reserves when the marginal cost of borrowing from the central bank increases. Thus, provided that the interest rate on reserves remains unchanged, the rise in other short-term interest rates indicates that banks can earn a higher return from investing in other assets, so they reduce demand for excess reserves. Given that the excess reserve ratio decreases, and that the required reserve ratio remains constant, the total reserve ratio also falls.

1.7.2 Monetary Policy Shocks

This section examines the transmission of two monetary policy shocks: an increase in the refinance rate and an increase in the reserve requirement ratio.

Figure 1.6 illustrates the general equilibrium effects of a one percent increase in the refinance rate. A rise in the policy interest rate raises the deposit and loan rates immediately. As in the previous case, the rise in the deposit rate increases households’ demand for bank deposits, and reduces their incentive to hold cash. The higher level of bank deposits lowers both central bank borrowing and the money supply. Consequently, the government bond rate increases to reduce demand for cash and to restore equilibrium in the money market. In response to the rise in the bond rate, current consumption and output fall. At the same time, a higher loan rate leads to a reduction in loans for investment, which in turn causes the collateral-to-loan ratio to increase. However, as the drop in output dominates the rise in the collateral-to-loan ratio, the repayment probability falls. In this case, real wages fall by more than the value of physical capital, placing downward pressure on the rental rate of capital. The decline in marginal costs, which results from the drop in the
rental rate of capital and real wages, creates a downward pressure on inflation.

Similar to the case of the negative productivity shock, the higher refinance rate increases the opportunity cost of holding excess reserves. As a consequence, the bank demands less excess reserves. The reduction in the quantity of excess reserves leads to an immediate fall in the level of total bank reserves.

Figure 1.7 illustrates the effects of a one percent increase in the minimum reserve requirement ratio, $\mu_t$. Given that the required reserve rate is exogenous in this model, to assess the impact of an increase, it is assumed that $\mu_t$ is stochastic and follows a first-order autoregressive process of the form: $\mu_t = \mu_{t-1}^\rho \exp (\xi_t^\rho)$. The impulse response functions show that an increase in reserve requirements does indeed lead to a reduction in the excess reserve ratio. In general, because the required reserve ratio goes up and the excess reserve ratio falls, the net effect on the total reserve ratio is a priori ambiguous; given our calibration, the net effect is positive, as shown in the simulations. Because the deposit rate is set as a mark-down on the total reserve ratio, a rise in total reserves leads to a fall in the interest rate on deposits. Consequently, household deposits fall, while borrowing from the central bank and the money supply increase. Equilibrium in the money market requires an increase in the demand for cash, which is brought about through a reduction in the bond rate, which in turn leads to a higher level of current consumption and output. The policy rate increases in response to the rise in output.

Furthermore, an increase in the marginal cost of borrowing from the central bank leads to a rise in the loan rate, which results in a higher rental rate of capital, a decline in investment and a lower capital stock over time. Primarily owing to the higher rental rate of capital, real wages increase. As observed previously, a higher lending rate leads to a reduction in investment loans, and a rise in the collateral-to-loan ratio. The higher output, along with the increase in the collateral-to-loan ratio,

---

28 Agénor and El Aynaoui (2010), using a simple (static) model with credit market imperfections, also found that raising reserve requirements can help to sterilize excess liquidity. Therefore, central banks use the required reserve ratio as a liquidity management tool (see Montoro and Moreno (2011), Robitaille (2011) and Tovar et al. (2012) for further discussions).
causes the repayment probability to rise. Nevertheless, the increase in the refinance rate dominates the response of the repayment probability, such that the loan rate rises although mitigated due to the fall in the perception of risk. Marginal costs increase because of three simultaneous effects: the increase in the refinance rate, higher real wages and the rise in the rental rate of capital. The increase in firms’ production costs creates an upward pressure on prices, which ultimately leads to an amplified rise in the refinance rate.

In a related study, Glocker and Towbin (2012) used an open economy model with competitive banking to examine whether reserve requirements are effective as a monetary policy tool. Although the focus of the Glocker-Towbin study was principally on reserve requirements and some of the features of the model were different to the one used in this study, the simulations for an increase in reserve requirements reveal similar findings. In both studies the results show that under an interest rate rule an increase in reserve requirements widens the spread between lending and deposit rates.\(^\text{29}\) The higher lending rate reduces investment and can lead to a fall in output. Owing to the fact that the bank holds excess reserves, it is fully responsive to the increase in reserve requirements and therefore cuts the deposit rate to induce households to reduce their demand for deposits. The lower level of deposits, in turn, leads to a lower ratio of excess reserves, while the fall in the deposit rate stimulates consumption. The total net effect of the shock on output depends on the relative changes in consumption and investment. Based on the calibration, the effect of the increase in consumption dominates the fall in investment, causing output to rise. This implies that changes in reserve requirements are procyclical, with respect to economic activity.\(^\text{30}\)

\(^{29}\) Montoro and Moreno (2011) and Tovar et al. (2012) also pointed out that an increase in required reserves acts as a tax on banks, so the spread between deposit and lending rates widens.

\(^{30}\) See Baltensperger (1982) and Horrigan (1988) for further discussions on the impact of changes in reserve requirements on economic stability.
ratio on economic activity depend—to a great extent—on the use of other monetary policy instruments. In the case where mainly direct policy tools are used to effect monetary policy, a higher required reserve ratio can lead to an increase in demand for deposits by banks, which will cause the deposit rate to increase, and inflation and output to fall. However, under an interest rate rule, the effect of a higher level of reserve requirements acting as a tax on bank dominates, so the central bank accommodates the increase in required reserves, and the spread between the lending and deposit rates increases.

In the case of a decrease in reserve requirements, the deposit rate rises and the loan rate falls. The fall in the loan rate increases investment, while the rise in the deposit rate reduces consumption. Usually, the overall effect brings about a fall in output because the drop in consumption dominates the increase in investment. This is contrary to the conventional view of monetary policy whereby a fall in required reserves brings about an expansionary effect. In keeping with the conventional view, the findings from a study by Areosa and Coelho (2013) showed that a decrease in reserve requirements caused output to increase. It must however be noted that in their study, the condition specified for the loan rate, which was not derived optimally, ensured that a lower reserve requirement ratio generated an overall countercyclical effect.

1.7.3 Liquidity Shock: Increase in Bank Deposits

As illustrated in Figure 1.8, the direct effect of an exogenous one percent increase in bank deposits is an immediate rise in the ratio of excess reserves to total reserves. Given that required reserves remain constant, the increase in excess reserves leads to a rise in total reserves. The higher level of bank deposits also reduces borrowing from the central bank, thereby lowering money supply. Similar to the cases of the supply shock and the monetary shock, to restore equilibrium in the money market, the bond rate rises, which, through intertemporal substitution, results in a reduction
in current consumption and a fall in output. In response to the drop in output, the policy interest rate falls, leading to a downward pressure on the loan rate, which in turn reduces the rental rate of capital. A lower rental rate of capital increases the demand for physical capital and investment. As observed previously, the fall in the rental rate of capital reduces real wages; in turn, the fall in both variables results in a drop in the firms’ marginal costs and thus inflation. The decrease in prices leads to an amplified drop in the policy rate. Also, the lower loan rate stimulates investment, leading to a fall in the collateral-to-loan ratio, which combined with the contraction in output, causes the repayment probability to fall. The lower refinance rate attenuates the response of the repayment probability to the shock, leading to an amplified decline in the lending rate.

1.7.4 Simultaneous Shocks to Deposits and Reserve Requirements

The results from the previous sections show that a shock to deposits increases excess reserves, but a shock to the reserve requirement ratio reduces the amount of excess liquidity in the banking system. Therefore, this section investigates the impact of simultaneous one percent shocks to deposits and required reserves. The premise for this experiment is to examine if there is an increase in excess liquidity, and at the same time the central bank responds in a non-systematic manner by raising reserve requirements, whether fluctuations in excess reserves can be reduced. Figure 1.9 shows the impulse response functions of the shock to deposits alone, and the joint shocks. The results show indeed that when there is a positive shock to liquidity, and there is a simultaneous increase in reserve requirements, the volatility in excess reserves is reduced. Therefore, this finding provides formal evidence (in line with the practical evidence on central bank policymaking), that raising reserve requirements, when there is an exogenous increase in liquidity, helps to sterilize excess reserves. It should also be noted that under the combined shock, there is lower volatility for
the interest rate variables. Notably, fluctuations in inflation and output are also reduced.

1.8 Policy Rules for Managing Excess Reserves

This section examines the macroeconomic effects of a one percent liquidity shock when two alternative policy rules are used—an augmented Taylor rule and a counter-cyclical rule for the required reserve ratio.

1.8.1 An Augmented Taylor Rule

First, I consider the case where the central bank adjusts its policy rate directly in response to changes in excess reserves. The rationale for this is to examine how effective a policy rule which responds to fluctuations in excess reserves may be in mitigating the volatility in the main variables of the model, under a shock to deposits. The augmented interest rate rule in its log-linear form is given by,

\[
i_t^R = \chi i_{t-1}^R + (1 - \chi) [\varepsilon_1(\hat{\pi}_t) + \varepsilon_2(\hat{Y}_t) + \varepsilon_3(\hat{ER TR}_t)] + \epsilon_t,
\]

(1.54)

where \( \hat{ER_{TR}}_t \) denotes the ratio of excess reserves to total reserves. Primus (2012) estimated an augmented Taylor rule for Trinidad and Tobago which included a measure of excess reserves. The results from her study showed the relative weight corresponding to deviations in excess reserves from steady state, \( \varepsilon_3 \), is \( -0.03 \). The negative coefficient indicates that in response to an increase in excess reserves, the central bank lowers the policy rate to reduce incentive for banks to hold excess liquidity. Intuitively, if the penalty rate for not meeting the reserve requirement is low, commercial banks would tend to reduce their holdings of excess reserves. By contrast, if the penalty rate is high, banks would voluntarily hold excess reverses as a measure of precaution to avoid any shortfall in liquidity. A reduction in the policy rate is also expected to lower the deposit rate, which in turn discourages household
deposits.

The estimated value of $-0.03$ was quite low and had only a marginal effect on the policy rule and the model by extension. As a result of this, alternative values of $-0.05$ and $-0.2$ are considered for $\varepsilon_3$. To assess the impact of an augmented policy rule on volatility, I compare the asymptotic standard deviations and the relative standard deviations of the main variables in the model under a liquidity shock with the augmented Taylor rule and the standard Taylor rule (see Table 1.3). Figure 1.10 compares the simulations of a shock to deposits under both rules when $\varepsilon_3$ is set at $-0.2$. The results from Figure 1.10 and Table 1.3 indicate that the augmented Taylor rule is effective in reducing the volatility of key macroeconomic variables such as inflation, consumption and output (among other variables), following an exogenous increase in deposits. In addition, the refinance rate, the loan rate, the deposit rate, the total reserve ratio and the ratio of excess reserves to total reserves are slightly more volatile. Further, under the augmented rule, the more volatile negative reaction of the loan rate stimulates investment; as a result, fluctuations in investment rise.

### 1.8.2 A Countercyclical Reserve Requirement Rule

In the second case I investigate the macroeconomic effects of a policy rule in which the required reserve ratio is determined by its previous value, a fraction of its steady-state value, and deviations in excess reserves. Therefore, in this approach, the required reserve ratio is endogenous and serves a countercyclical role for managing changes in excess reserves. The central bank is assumed to set the reserve requirement rule according to the following,

\[
\hat{\mu}_t = (1 - \tau)\mu + \zeta (ER + TR_t) + \tau \hat{\mu}_{t-1},
\]

(1.55)
where \( \tau \) denotes the degree of persistence in the policy rule and \( \zeta \), which measures deviations in the ratio of excess reserves to total reserves from its steady state, is an indicator of cyclical conditions. There is little information on the values for \( \tau \) and \( \zeta \); hence, for illustrative purposes a value of 0.12 is used for \( \tau \), and \( \zeta \) is set at 0.85. Thus, there is a relatively low degree of persistence in changes of the required reserve ratio. Also, the positive value for \( \zeta \) means that the central bank increases required reserves when there is a rise in excess bank liquidity.

To assess whether the countercyclical rule can help to reduce volatility, I compare the asymptotic standard deviations and the relative standard deviations of the main variables when the reserve requirement ratio is endogenous and exogenous to the model. The results from Table 1.4 and the impulse response functions in Figure 1.11 show that the countercyclical reserve requirement rule is successful in reducing fluctuations in excess reserves and total reserves, but at the expense of inflation and output being more volatile. The results also indicate that the reserve requirement rule has no effect on the other macroeconomic variables in the model.

1.9 Sensitivity Analysis

To test the robustness of the results, this section examines the responses of the key variables in the model under alternative parameter configurations. Specifically, I examine the case where there is a stronger cost channel effect, an increase in the reserve requirement ratio and a higher level of excess reserves.

1.9.1 Higher Cost Channel Effect

This experiment examines the case where firms finance all their working capital needs from bank loans, that is, from (1.15) an increase in \( \kappa^W \) from 0.45 to 1, under a one percent shock to the policy interest rate. In general, the results (which are not
reported here) are similar to the benchmark case (Figure 1.6). The main difference is that there is a slight increase in volatility of the financial variables—that is, the excess to total reserve ratio, the total reserve ratio, the deposit rate, the loan rate and the bond rate. Intuitively, if firms use bank loans to finance all their working capital needs, there is a stronger (direct) cost channel effect; so the higher refinance rate is reflected in the financial variables.

1.9.2 Increase in the Reserve Requirement Ratio

This experiment evaluates the impact of a more aggressive use of reserve requirements under a one percent increase in the policy rate. Thus, the reserve requirement ratio was raised by 3 percent, which implies that $\mu$ increases from 17 percent to 20 percent. The results, which are presented in Figure 1.12, show that on impact of the shock, the excess reserve ratio falls by more when the reserve requirement ratio is higher. Therefore, a contractionary monetary policy is more successful in reducing excess reserves, if reserve requirements are used more aggressively. In addition, the financial variables are slightly more volatile when the reserve requirement ratio is higher.

1.9.3 Increase in the Excess Reserve Ratio

This experiment examines the impact of a higher excess reserve ratio, under a monetary policy shock and a shock to the reserve requirement ratio. To quantify these effects, the cost function parameters, $\Phi_{C1}$ and $\Phi_{C2}$, are changed from 0.35 and 7.5 to 0.2 and 2.2 respectively, so the excess reserve ratio, $\mu^{ER}$, is increased by 4 percent.

Figure 1.13 shows the results of a higher excess reserve ratio under a one percent increase in the policy interest rate. The findings reveal that when there is a

\[31\] Given that the results are not significantly different, further empirical testing can be conducted to determine whether the cost channel parameter—which is positive—is also significant for Trinidad and Tobago (see, for instance, Malikane (2012)).
higher level of excess reserves (that is the case where $\Phi_{C1} = 0.2$ and $\Phi_{C2} = 2.2$), the interest rate variables are slightly more volatile but the real variables remain unchanged. Also, given that the bank holds more excess reserves, on impact of the shock volatility in the excess reserve ratio and the total reserve ratio is amplified, and both variables fall by substantially more compared to the case where the proportion of excess reserves is lower.

Furthermore, the case of an increase in the excess reserve ratio under a one percent positive shock to the reserve requirement ratio was considered. The results (which are not reported) show that the ratio of excess reserves to total reserves is highly more volatile on impact of the shock—as compared to the benchmark case (Figure 1.7). However, fluctuations in the total reserve ratio are mitigated because of the higher reserve requirement ratio.

1.10 Concluding Remarks

The purpose of this chapter was to examine the dynamic effects of excess reserves in a New Keynesian general equilibrium model with banking. For this purpose, I extend and modify the framework presented in Agénor and Alper (2012) and Agénor et al. (2013), by allowing the monopoly bank to hold excess reserves. As in Glocker and Towbin (2012), the model explicitly accounts for the fact that banks incur convex costs in holding excess reserves, which are proportional to their deposit holdings. Similar to the practice in a few countries, the bank receives interest payments on reserves from the central bank. Other notable features of the model are that it accounts for credit market imperfections and it incorporates a cost channel because intermediate good-producing firms must borrow in advance to finance their working capital needs. Also, the supply of bank loans to firms is perfectly elastic at the prevailing lending rate, and the central bank’s supply of liquidity is perfectly elastic at the policy interest rate.
The model, which was calibrated for Trinidad and Tobago, was used to explain the main macroeconomic variables responses to a negative supply shock, a shock to the refinance rate, a shock to reserve requirements and a liquidity shock. I also examined the case where there were simultaneous shocks to reserve requirements and liquidity. The simulations show that under both a negative supply shock and a contractionary monetary shock, the refinance rate increases, leading to a rise in demand for financial assets such as deposits and bonds. The higher policy rate also increases the opportunity cost of holding excess reserves, leading the bank to reduce demand for these assets; as a result, excess reserves fall. The simulations of the positive shock to the required reserve ratio show that an increase in reserve requirements leads to an immediate fall in excess reserves. However, although a higher level of required reserves mitigates the volatility in excess reserves, there is an expansionary effect on inflation and output. This result is similar to a study by Glocker and Towbin (2012) that found an increase in reserve requirements reduces the deposit rate, which in turn stimulates economic activity. Thus, although raising reserve requirements helps to mitigate fluctuations in reserves, it creates a procyclical effect. This implies that financial stability may come at a cost of macroeconomic stability. This therefore raises the question of the optimal combination of instruments which will ensure that the objectives of macroeconomic stability and financial stability are achieved.

Furthermore, the results from the joint shocks indicate that the impact of an exogenous rise in bank deposits can be less dampening on macroeconomic variables if the required reserve ratio increases simultaneously. This experiment therefore supports the decision—which has indeed been practiced by many central banks—to raise reserve requirements in order to sterilize excess reserves. This finding is also in line with many other contributions in the literature, which suggest that central banks should raise reserve requirements to reduce excess reserves (see for instance Agénor and El Aynaoui (2010), Gray (2011), Montoro and Moreno (2011), Robitaille
In addition, I examine two policy rules aimed at reducing macroeconomic fluctuations under a liquidity shock: an augmented interest rate rule which includes a measure of excess liquidity and an endogenous countercyclical reserve requirement rule. Given that banks have a voluntary demand for excess reserves, the rationale for the first rule is to investigate whether the volatility of key macroeconomic and financial variables can be reduced when the policy interest rate responds to changes in excess reserves. Therefore, in the case where there is a positive deviation in excess reserves, the central bank is likely to respond by reducing the policy interest rate. A lower refinance rate makes borrowing from the central bank less costly and discourages banks from holding excess reserves. In the second policy experiment I examine whether a countercyclical reserve requirement rule can reduce fluctuations in excess reserves. The findings show that although the augmented Taylor rule is successful in reducing volatility in real variables, the financial variables of the model become more volatile. The results from the countercyclical rule indicate that if the reserve requirement ratio is used in a countercyclical fashion, it can help to stabilize fluctuations in excess reserves, but at the expense of inflation and output being slightly more volatile.

The Central Bank of Trinidad and Tobago has been using reserve requirements to reduce excess reserves as mentioned in Section 1.2.3. This research suggests that the Central Bank can use a countercyclical reserve requirement rule—as specified in equation (1.55)—to adjust the required reserve ratio. One advantage of using this rule is that it can help to reduce the adverse effects associated with sharp increases (or decreases) in reserve requirements. Also, the Central Bank should continue to use Treasury bills and Treasury notes as these can help to reduce excess reserves and influence market interest rates. Thus, the use of short-term instruments can help to reduce the effects of an increase in reserve requirements on the deposit rate. Furthermore, owing to the fact that changes in the policy rate are weakly
transmitted to real variables because of high financial system liquidity, using an augmented interest rate rule which is adjusted in response to deviations in excess reserves can help to mitigate the effects of an increase in liquidity on real variables.
Table 1.1: Reserve Requirement Levels in Various Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Required Reserve Ratios (%) (2012)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>None</td>
</tr>
<tr>
<td>Belize</td>
<td>8.5</td>
</tr>
<tr>
<td>Brazil</td>
<td>44*</td>
</tr>
<tr>
<td>Canada</td>
<td>None</td>
</tr>
<tr>
<td>Cape Verde</td>
<td>18</td>
</tr>
<tr>
<td>China</td>
<td>20**</td>
</tr>
<tr>
<td>Croatia</td>
<td>13.5</td>
</tr>
<tr>
<td>Euro Area</td>
<td>1</td>
</tr>
<tr>
<td>Guyana</td>
<td>12</td>
</tr>
<tr>
<td>India</td>
<td>4.25</td>
</tr>
<tr>
<td>Jamaica</td>
<td>12</td>
</tr>
<tr>
<td>Malawi</td>
<td>15.5</td>
</tr>
<tr>
<td>New Zealand</td>
<td>None</td>
</tr>
<tr>
<td>Nigeria</td>
<td>12</td>
</tr>
<tr>
<td>South Africa</td>
<td>2.5</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2.5</td>
</tr>
<tr>
<td>The Bahamas</td>
<td>5</td>
</tr>
<tr>
<td>Trinidad and Tobago</td>
<td>17***</td>
</tr>
<tr>
<td>Turkey</td>
<td>11</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>None</td>
</tr>
<tr>
<td>United States</td>
<td>0-10</td>
</tr>
</tbody>
</table>

Notes: The reserve requirement ratio refers to holdings of domestic currency liabilities; *Reserve requirements on demand deposits; **For large financial institutions; ***Primary reserve requirements.

Source: Author’s survey.
### Table 1.2: Calibrated Parameter Values: Benchmark Case

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Households</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.985</td>
<td>Discount factor</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>0.5</td>
<td>Elasticity of intertemporal substitution</td>
</tr>
<tr>
<td>$\eta_N$</td>
<td>1.8</td>
<td>Relative preference for leisure</td>
</tr>
<tr>
<td>$\eta_X$</td>
<td>0.02</td>
<td>Relative preference for money holdings</td>
</tr>
<tr>
<td>$\nu$</td>
<td>0.2</td>
<td>Share parameter in index of money holdings</td>
</tr>
<tr>
<td><strong>Production</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\theta$</td>
<td>10.0</td>
<td>Elasticity of demand, intermediate goods</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>0.3</td>
<td>Share of capital in output, intermediate good</td>
</tr>
<tr>
<td>$\phi_F$</td>
<td>65</td>
<td>Adjustment cost parameter, prices</td>
</tr>
<tr>
<td>$\Theta_K$</td>
<td>18</td>
<td>Adjustment cost parameter, investment</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.034</td>
<td>Depreciation rate of capital</td>
</tr>
<tr>
<td><strong>Bank</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa^C$</td>
<td>0.05</td>
<td>Effective collateral-loan ratio</td>
</tr>
<tr>
<td>$\Phi_{C1}$</td>
<td>0.35</td>
<td>Linear cost function parameter</td>
</tr>
<tr>
<td>$\Phi_{C2}$</td>
<td>7.5</td>
<td>Quadratic cost function parameter</td>
</tr>
<tr>
<td>$\phi_1$</td>
<td>0.02</td>
<td>Elasticity of risk premium with respect to collateral</td>
</tr>
<tr>
<td>$\phi_2$</td>
<td>0.2</td>
<td>Elasticity of risk premium with respect to cyclical output</td>
</tr>
<tr>
<td>$\kappa^W$</td>
<td>0.45</td>
<td>Share of financing working capital</td>
</tr>
<tr>
<td><strong>Central Bank</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu$</td>
<td>0.17</td>
<td>Reserve requirement ratio</td>
</tr>
<tr>
<td>$\chi$</td>
<td>0</td>
<td>Degree of persistence in interest rate rule</td>
</tr>
<tr>
<td>$\varepsilon_1$</td>
<td>1.5</td>
<td>Response of refinance rate to inflation deviations</td>
</tr>
<tr>
<td>$\varepsilon_2$</td>
<td>0.1</td>
<td>Response of refinance rate to output growth</td>
</tr>
<tr>
<td><strong>Government</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\psi$</td>
<td>0.15</td>
<td>Share of government spending in output</td>
</tr>
<tr>
<td><strong>Shock</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\rho_A$ ($\rho_\gamma$)</td>
<td>0.4</td>
<td>Degree of persistence, supply shock (shock to refinance rate)</td>
</tr>
</tbody>
</table>
Table 1.3: Standard Deviations under Standard Taylor Rule and Augmented Taylor Rule with Increase in Bank Deposits

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\varepsilon_3 = 0$</th>
<th>$\varepsilon_3 = -0.03$</th>
<th>$\varepsilon_3 = -0.05$</th>
<th>$\varepsilon_3 = -0.2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinance rate</td>
<td>0.0049</td>
<td>0.0049 1.0000</td>
<td>0.0050 1.0204</td>
<td>0.0051 1.0408</td>
</tr>
<tr>
<td>Loan rate</td>
<td>0.0046</td>
<td>0.0046 1.0000</td>
<td>0.0047 1.0217</td>
<td>0.0050 1.0870</td>
</tr>
<tr>
<td>Bond rate</td>
<td>0.0012</td>
<td>0.0012 1.0000</td>
<td>0.0012 1.0000</td>
<td>0.0011 0.9167</td>
</tr>
<tr>
<td>Deposit rate</td>
<td>0.0038</td>
<td>0.0038 1.0000</td>
<td>0.0039 1.0263</td>
<td>0.0040 1.0526</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.0031</td>
<td>0.0030 0.9677</td>
<td>0.0028 0.9032</td>
<td>0.0018 0.5806</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.0021</td>
<td>0.0020 0.9524</td>
<td>0.0019 0.9048</td>
<td>0.0014 0.6667</td>
</tr>
<tr>
<td>Total reserve ratio</td>
<td>0.0031</td>
<td>0.0031 1.0000</td>
<td>0.0031 1.0000</td>
<td>0.0032 1.0323</td>
</tr>
<tr>
<td>Excess-total reserves</td>
<td>0.0116</td>
<td>0.0117 1.0086</td>
<td>0.0118 1.0172</td>
<td>0.0122 1.0517</td>
</tr>
<tr>
<td>Output</td>
<td>0.0016</td>
<td>0.0015 0.9375</td>
<td>0.0014 0.8750</td>
<td>0.0006 0.3750</td>
</tr>
<tr>
<td>Investment</td>
<td>0.0001</td>
<td>0.0005 5.0000</td>
<td>0.0008 8.0000</td>
<td>0.0003 30.0000</td>
</tr>
<tr>
<td>Rental rate capital</td>
<td>0.0008</td>
<td>0.0007 0.8750</td>
<td>0.0007 0.8750</td>
<td>0.0004 0.5000</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.0109</td>
<td>0.0100 0.9174</td>
<td>0.0095 0.8716</td>
<td>0.0051 0.4679</td>
</tr>
<tr>
<td>Marginal cost</td>
<td>0.0138</td>
<td>0.0129 0.9348</td>
<td>0.0123 0.8913</td>
<td>0.0077 0.5580</td>
</tr>
<tr>
<td>Repayment prob.</td>
<td>0.0003</td>
<td>0.0003 1.0000</td>
<td>0.0003 1.0000</td>
<td>0.0002 0.6667</td>
</tr>
<tr>
<td>Collateral-loan ratio</td>
<td>0.0001</td>
<td>0.0005 5.0000</td>
<td>0.0008 8.0000</td>
<td>0.0029 29.0000</td>
</tr>
</tbody>
</table>

Notes: *Sd. Dev. is the standard deviation; ** Rel. S.D. denotes the relative standard deviation.
Table 1.4: Standard Deviations when the Reserve Requirement Ratio is Exogenous and Endogenous

<table>
<thead>
<tr>
<th>Variable</th>
<th>$\hat{\mu}_t = 0$ Sd. Dev.</th>
<th>$\hat{\mu}<em>t = (1 - \tau)\mu + \zeta(ER</em>{TR_t}) + \tau\hat{\mu}_{t-1}$ Sd. Dev.*</th>
<th>Rel. S.D.**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refinance rate</td>
<td>0.0049</td>
<td>0.0049</td>
<td>1.0000</td>
</tr>
<tr>
<td>Loan rate</td>
<td>0.0046</td>
<td>0.0046</td>
<td>1.0000</td>
</tr>
<tr>
<td>Bond rate</td>
<td>0.0012</td>
<td>0.0012</td>
<td>1.0000</td>
</tr>
<tr>
<td>Deposit rate</td>
<td>0.0038</td>
<td>0.0038</td>
<td>1.0000</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.0031</td>
<td>0.0032</td>
<td>1.0323</td>
</tr>
<tr>
<td>Consumption</td>
<td>0.0021</td>
<td>0.0021</td>
<td>1.0000</td>
</tr>
<tr>
<td>Total reserve ratio</td>
<td>0.0031</td>
<td>0.0024</td>
<td>0.7742</td>
</tr>
<tr>
<td>Excess-total reserves</td>
<td>0.0116</td>
<td>0.0078</td>
<td>0.6724</td>
</tr>
<tr>
<td>Output</td>
<td>0.0016</td>
<td>0.0017</td>
<td>1.0625</td>
</tr>
<tr>
<td>Investment</td>
<td>0.0001</td>
<td>0.0001</td>
<td>1.0000</td>
</tr>
<tr>
<td>Rental rate capital</td>
<td>0.0008</td>
<td>0.0008</td>
<td>1.0000</td>
</tr>
<tr>
<td>Real wage</td>
<td>0.0109</td>
<td>0.0109</td>
<td>1.0000</td>
</tr>
<tr>
<td>Marginal cost</td>
<td>0.0138</td>
<td>0.0138</td>
<td>1.0000</td>
</tr>
<tr>
<td>Repayment prob.</td>
<td>0.0003</td>
<td>0.0003</td>
<td>1.0000</td>
</tr>
<tr>
<td>Collateral-loan ratio</td>
<td>0.0001</td>
<td>0.0001</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

Notes: *Sd. Dev. is the standard deviation; ** Rel. S.D. denotes the relative standard deviation.
Figure 1.1: The Percent of Excess Reserves to Total Reserves in Trinidad and Tobago

Note: In Trinidad and Tobago, prior to January 2006 excess liquidity is measured by commercial banks’ holdings of special deposits. This is therefore taken into account in computing excess reserves before 2006 (see Central Bank of Trinidad and Tobago, Monetary Policy Report (2007)).

Source: Central Bank of Trinidad and Tobago Database.
Figure 1.2: Total Financial System Assets in Trinidad and Tobago

Note: NFIs denotes Non-Bank Financial Institutions.
Source: Central Bank of Trinidad and Tobago Database.
Figure 1.3: Net Domestic Fiscal Injections (NDFI) as a percent of GDP, Excess Reserves to Total Reserves (ER-TR) and Government Expenditure (GOV’T EXP) to GDP

Source: Central Bank of Trinidad and Tobago Database.
Figure 1.4: Liquidity Absorption Measures

Notes: A positive (+) sign means a net withdrawal from the financial system while a negative (-) sign means a net injection; Data for Special Deposit Facility represent the cumulative total deposits; OMO denotes Open Market Operations.

Source: Central Bank of Trinidad and Tobago Database.
Figure 1.5: Negative Supply Shock

Absolute deviations from baseline, unless otherwise indicated.
Absolute deviations from baseline, unless otherwise indicated.
Figure 1.7: Increase in Reserve Requirement Ratio

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.8: Increase in Bank Deposits

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.9: Increase in Bank Deposits and Simultaneous Shocks to Deposits and Reserve Requirements

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.10: Increase in Bank Deposits under Standard Taylor Rule and Augmented Taylor Rule

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.11: Increase in Bank Deposits when the Reserve Requirement Ratio is Exogenous and Endogenous

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.12: Increase in the Required Reserve Ratio under a Contractionary Monetary Policy Shock

Absolute deviations from baseline, unless otherwise indicated.
Figure 1.13: Increase in the Excess Reserve Ratio under a Contractionary Monetary Policy Shock

Absolute deviations from baseline, unless otherwise indicated.
1.A Appendix

1.A.1 Solution to Optimization Problems

Solutions to the optimization problems of the household:

Substituting (1.2) in (1.1) subject to (1.4), the Lagrangian function for the household problem can be written as,

\[
L^H = E_t \sum_{t=0}^{\infty} \beta^t \left[ C_{ht} \right]^{1-\sigma-1} + \eta_N \ln(1 - N_{ht}) + \eta_X \ln[(M_{ht}^H)^\nu D_{ht}^{1-\nu}] 
\]  

(1.56)

\[
+ \Lambda_t \{ \omega_t N_{ht} - T_{ht} + M_{ht-1}^H \frac{P_{t-1}}{P_t} + (1 + i_{t-1}^D) D_{ht-1} \frac{P_{t-1}}{P_t} 
\]

\[
+ (1 + i_{t-1}^B) B_{ht-1}^H \frac{P_{t-1}}{P_t} + J_{ht}^I + \varphi_h J_t^B + J_t^K - C_{ht} - M_{ht}^H - D_{ht} - B_{ht}^H \},
\]

where \( \Lambda_t \) denotes the Lagrange multiplier. Let \( \pi_{t+1} = (P_{t+1} - P_t) / P_t \) denote the inflation rate; maximizing (1.56) with respect to \( C_{ht}, N_{ht}, M_{ht}^H, D_{ht} \) and \( B_{ht}^H \), taking \( i_t^D, i_t^B, P_t \), and \( T_{ht} \) as given yields the following first order conditions,

\[
C_{ht}^{-1/\sigma} = \Lambda_t,
\]

(1.57)

\[
\eta_N \frac{1}{1 - N_{ht}} - \Lambda_t \omega_t = 0,
\]

(1.58)

\[
\frac{\eta_X \nu}{M_{ht}^H} - \Lambda_t + \beta E_t \left( \frac{\Lambda_{t+1}}{1 + \pi_{t+1}} \right) = 0,
\]

(1.59)

\[
\frac{\eta_X (1 - \nu)}{D_{ht}} - \Lambda_t + \beta E_t \left\{ \Lambda_{t+1} \left( \frac{1 + i_t^D}{1 + \pi_{t+1}} \right) \right\} = 0,
\]

(1.60)

\[
\beta E_t \left( \frac{\Lambda_{t+1}}{1 + \pi_{t+1}} \right) = \frac{\Lambda_t}{1 + i_t^B}.
\]

(1.61)

The transversality condition is given by,

\[
\lim_{s \to \infty} E_{t+s} \Lambda_{t+s}^s \beta^s (M_{t+s}^H) = 0.
\]

(1.62)
Combining (1.57) and (1.61), the Euler equation is,

\[ C_{ht}^{-1/\sigma} = \beta E_t \left[ (C_{ht+1})^{-1/\sigma} \left( \frac{1 + i^B_t}{1 + \pi_{t+1}} \right) \right]. \tag{1.63} \]

Using (1.57) in (1.58) and rearranging yields the supply of labour equation,

\[ N_{ht} = 1 - \frac{\eta_X(C_{ht})^{1/\sigma}}{\omega_t}. \tag{1.64} \]

Substituting (1.61) in (1.59) and using (1.57) gives the demand for real cash balances,

\[ M^H_{ht} = \frac{\eta_X \nu(C_{ht})^{1/\sigma}(1 + i^B_t)}{i^B_t - i^D_t}. \tag{1.65} \]

Combining (1.57), (1.60) and (1.61), the real demand for bank deposits is,

\[ D_{ht} = \eta_X(1 - \nu)(C_{ht})^{1/\sigma}(1 + i^B_t). \tag{1.66} \]

Solutions to the optimization problems of the final good-producing firm:
The profit maximization problem of the final good producer is given by,

\[ \max_{Y_{jt}} P_t \left\{ \int_0^1 [Y_{jt}]^{(\theta - 1)/\theta} dj \right\}^{\theta/(\theta - 1)} - \int_0^1 P_{jt} Y_{jt} dj. \tag{1.67} \]

The first-order condition with respect to \( Y_{jt} \) gives,

\[ P_t \left( \int_0^1 Y_{jt}^{\theta - 1/\theta} dj \right)^{-1/\theta} Y_{jt}^{1/\theta} - P_{jt} = 0. \]

Given that \( Y_t^{1/\theta} = \left\{ \int_0^1 [Y_{jt}]^{(\theta - 1)/\theta} dj \right\}^{1/(\theta - 1)} \), this can be written as,

\[ Y_{jt} = \left( \frac{P_{jt}}{P_t} \right)^{-\theta} Y_t. \tag{1.68} \]

Equation (1.68) gives the demand for each intermediate good \( j \).
Using (1.68) in the final good production function (1.10), then making \( P_t \) the subject, the final good price can be denoted as,

\[
P_t = \left[ \int_0^1 (P_{jt})^{1-\theta} dj \right]^{1/(1-\theta)}.
\] (1.69)

Solutions to the optimization problems of intermediate good-producing firms:

The first-stage minimization problem for firm \( j \) is,

\[
\min_{N_{jt},K_{jt}} \left[ (1 + \kappa W_i t^R) \omega_t N_{jt} + r^K_t K_{jt} \right].
\] (1.70)

Minimizing (1.70) subject to (1.14), the Lagrangian function for this problem is,

\[
\mathcal{L}^{IG} = (1 + \kappa W_i t^R) \omega_t N_{jt} + r^K_t K_{jt} + \lambda_t \left[ Y_{jt} - A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha} \right],
\] (1.71)

where \( \lambda_t \) denotes the Lagrange multiplier. The first-order condition with respect to \( N_{jt} \) yields,

\[
(1 + \kappa W_i t^R) \omega_t = \lambda_t (1 - \alpha) \frac{Y_{jt}}{N_{jt}};
\] (1.72)

The first-order condition with respect to \( K_{jt} \) gives,

\[
r^K_t = \frac{\alpha Y_{jt}}{K_{jt}} \lambda_t.
\] (1.73)

Combining (1.72) and (1.73) gives,

\[
N_{jt} = \frac{(1 - \alpha)}{\alpha} \frac{r^K_t}{(1 + \kappa W_i t^R) \omega_t} K_{jt}.
\] (1.74)

With \( Y_{jt} = 1 \), the constraint (1.14) can be rewritten as \( 1 - A_t K_{jt}^{\alpha} N_{jt}^{1-\alpha} = 0 \).

Using (1.74) in this gives,

\[
K_{jt} = A_t^{-1} \left[ \frac{\alpha}{(1 - \alpha)} \frac{(1 + \kappa W_i t^R) \omega_t}{r^K_t} \right]^{1-\alpha}.
\] (1.75)
From (1.74) and (1.75), $N_{jt}$ is,

$$N_{jt} = A_t^{-1} \left( \frac{\alpha}{1 - \alpha} \right)^{-\alpha} \left( \frac{(1 + \kappa^W_i t R)\omega_t}{r^K_t} \right)^{-\alpha}.$$  \hspace{1cm} (1.76)

Combining (1.75) and (1.76) the capital-labour ratio is,

$$\frac{K_{jt}}{N_{jt}} = \left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{(1 + \kappa^W_i t R)\omega_t}{r^K_t} \right).$$  \hspace{1cm} (1.77)

Combining (1.72) and (1.73) yields,

$$[1 - \alpha + \alpha] \lambda_t = \lambda_t = \frac{[(1 + \kappa^W_i t R)\omega_t N_{jt} + r^K_t K_{jt}]}{Y_{jt}}.$$

This implies that $\lambda_t$ is also equal to the unit real marginal cost, $mc_{jt}$. Using (1.14) and (1.77) in this gives the unit real marginal cost as,

$$mc_{jt} = \frac{[(1 + \kappa^W_i t R)\omega_t]^{1 - \alpha} (r^K_t)^{\alpha}}{\alpha^\alpha (1 - \alpha)^{1 - \alpha} A_t}.$$  \hspace{1cm} (1.78)

The second-stage optimization problem for the intermediate good producer is,

$$\max_{P_{jt}} \sum_{t=0}^{\infty} r^t \Lambda_t \left\{ \left[ \frac{P_{jt}}{P_t} \right]^{-\theta} Y_t - mc_{jt} \left[ \left( \frac{P_{jt}}{P_t} \right)^{-\theta} Y_t \right] - \frac{\phi_F}{2} \left( \frac{P_{jt}}{P_{jt-1}} - 1 \right)^2 Y_t \right\}.$$  \hspace{1cm} (1.79)

Taking $mc_{jt}$, $P_t$ and $Y_t$ as given, the first-order condition with respect to $P_{jt}$ is,

$$(1 - \theta) \Lambda_t \left( \frac{P_{jt}}{P_t} \right)^{-\theta} Y_t \frac{P_t}{P_{jt}} + \theta \Lambda_t mc_{jt} \left( \frac{P_{jt}}{P_t} \right)^{-\theta-1} Y_t \frac{P_t}{P_{jt-1}} - \Lambda_t \phi_F \left( \frac{P_{jt}}{P_{jt-1}} - 1 \right) \frac{Y_t}{P_{jt-1}} \right) - \beta \phi_F E_t \left\{ \Lambda_{t+1} \left( \frac{P_{jt+1}}{P_{jt}} - 1 \right) \left( \frac{P_{jt+1}}{P_{jt}} \right) Y_{t+1} \right\} = 0.$$  \hspace{1cm} (1.80)
Solutions to optimization problems of the capital good producer:

The optimization problem of the capital good producer is given by,

\[
\max_{K_{t+1}} \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ r^K_t K_t - (1 + i_t^L) \left[ K_{t+1} - (1 - \delta) K_t + \frac{\Theta_K}{2} \left( \frac{K_{t+1}}{K_t} - 1 \right)^2 K_t \right] \right\}.
\]

(1.81)

The first-order condition with respect to \( K_{t+1} \) is,

\[
\beta \Lambda_{t+1} r^K_{t+1} - \Lambda_t (1 + i_t^L) + \beta \Lambda_{t+1} (1 + i_{t+1}^L) (1 - \delta)
\]

\[
-(1 + i_t^L) \Lambda_t \Theta_K \left( \frac{K_{t+1}}{K_t} - 1 \right) \frac{K_t}{K_t} - (1 + i_{t+1}^L) \beta \Lambda_{t+1} \frac{\Theta_K}{2} \left( \frac{K_{t+2}}{K_{t+1}} - 1 \right)^2
\]

\[
+(1 + i_{t+1}^L) \beta \Lambda_{t+1} \Theta_K \left( \frac{K_{t+2}}{K_{t+1}} - 1 \right) \frac{K_{t+2}}{K_{t+1}} = 0.
\]

Using some algebraic manipulations and substituting equation (1.61) in this gives,

\[
E_t r^K_{t+1} = (1 + i_t^L) E_t \left\{ 1 + \Theta_K \left( \frac{K_{t+1}}{K_t} - 1 \right) \left( \frac{1 + i_t^B}{1 + \pi_{t+1}} \right) \right\}
\]

(1.82)

\[
-E_t \left\{ (1 + i_{t+1}^L) \left[ (1 - \delta) + \frac{\Theta_K}{2} \left( \frac{K_{t+2}}{K_{t+1}} \right)^2 - 1 \right] \right\}.
\]
1.A.2 **Steady-State Equations**

This section presents the steady-state values of the variables in the model. These values are computed by dropping the time subscripts from the variables.

From (1.46), the policy rate in the steady state is,

$$i^R = r + \pi + \varepsilon_1(\pi - \pi^T). \quad (1.83)$$

In the steady state, inflation is equal to its target value. Thus,

$$\pi = \pi^T. \quad (1.84)$$

Using this result in (1.83) gives the steady-state value of the refinance rate,

$$i^R = r + \pi. \quad (1.85)$$

From equation (1.5), the steady-state value of the bond rate (which is equal to the real interest rate) is,

$$\frac{1 + i^B}{1 + \pi} = 1 + r = \frac{1}{\beta}. \quad (1.86)$$

In the case where the inflation target is equal to zero, there is zero inflation in the steady state, $\pi = \pi^T = 0$. Thus,

$$1 + i^B = 1 + i^R = 1 + r = \frac{1}{\beta}. \quad (1.86)$$

In the steady state, capital adjustment costs are zero,

$$\frac{\Theta_K}{2} \left( \frac{K}{K} - 1 \right)^2 K = 0. \quad (1.87)$$
Using (1.87) in (1.25), total investment in the steady state is,

\[ I = \delta K. \]  \quad (1.88)

From equation (1.50), the steady-state equilibrium condition of the goods market yields \( Y = C + G + I \). Using \( G = \psi Y \) from (1.49) and (1.88) in this, the steady-state value of consumption is given by,

\[ C = (1 - \psi)Y - \delta K. \]  \quad (1.89)

Using (1.87) in (1.28) gives the steady-state value of the rental rate of capital,

\[ r^K = [(1 + i^B) - (1 - \delta)](1 + i^L) > r. \]  \quad (1.90)

In the steady state, the total reserve ratio and excess reserve ratio from (1.39) and (1.40) respectively are,

\[ \mu^{TR} = \mu + \frac{[(1 + i^M) + \Phi_{C1} - (1 + i^R)]}{\Phi_{C2}}, \]  \quad (1.91)

\[ \mu^{ER} = \frac{(1 + i^M) + \Phi_{C1} - (1 + i^R)}{\Phi_{C2}}. \]  \quad (1.92)

The ratio of excess reserves to total reserves is,

\[ \text{ER}_{TR} = \frac{(\mu^{TR} - \mu)}{\mu^{TR}}, \]

or,

\[ \text{ER}_{TR} = \frac{\mu^{ER}}{\mu^{TR}}. \]  \quad (1.93)

Total reserves in the steady state are,

\[ TR = (\mu + \mu^{ER})D. \]  \quad (1.94)
From (1.41), the steady-state value of the deposit rate is,

$$1 + i^D = (1 + \frac{1}{\eta_D})^{-1}[(1 + i^R) - \mu^{TR}(i^R - i^M)]$$

(1.95)

$$+ \Phi C_1(\mu^{TR} - \mu) - \frac{\Phi C_2}{2}(\mu^{TR} - \mu)^2].$$

Using (1.42), the steady-state value of the lending rate is given by,

$$1 + i^L = \frac{1 + i^R}{Q^F[\eta_L^{-1} + 1]}.$$  

(1.96)

The steady-state value of the repayment probability from (1.43) is,

$$Q^F = \phi_0(\frac{K^C}{L_{F,I}})^{\phi_1}.$$ 

(1.97)

In the steady state, the collateral-to-loan ratio, $CL$, is,

$$CL = \frac{\kappa^C K}{L_{F,I}}.$$  

(1.98)

Using (1.86) in (1.7), the steady-state value for real cash balances is,

$$M^H = \frac{\eta_X (1 - \nu)C^{1/\sigma} (1 + i^B)}{1 - \beta}.$$  

(1.99)

From (1.8), the steady-state value of real bank deposits is,

$$D = \frac{\eta_X (1 - \nu)C^{1/\sigma} (1 + i^B)}{i^B - i^D}.$$  

(1.100)

The steady-state value of labour supply from equation (1.6) is given by,

$$N = 1 - \frac{\eta NC^{1/\sigma}}{\omega}.$$  

(1.101)
From (1.14), output of intermediate goods is,

\[ Y = AK^\alpha N^{1-\alpha}. \tag{1.102} \]

The capital-labour ratio in the steady state from (1.17) is,

\[ \frac{K}{N} = \left( \frac{\alpha}{1 - \alpha} \right) \left( \frac{1 + \kappa_W^R \omega}{r^K} \right). \tag{1.103} \]

Using (1.86) and (1.90) in (1.103), the steady-state real wage is,

\[ \omega = \left( \frac{1 - \alpha}{\alpha} \right) \frac{K \left[ \beta^{-1} - (1 - \delta) \right] (1 + i^L)}{N \left( 1 + \kappa_W^R \right)}. \tag{1.104} \]

In the steady state, the price adjustment equation (1.80) is,

\[ (1 - \theta) + \theta mc = 0, \]

whereas, the steady-state value of the marginal cost is,

\[ mc = \frac{\theta - 1}{\theta}. \tag{1.105} \]

From (1.15), the steady-state level of loans demanded by intermediate good producers is,

\[ L^{FW} = \kappa_W^W \omega N, \tag{1.106} \]

whereas, using (1.24), loans demanded by the capital good producer is,

\[ L^{FI} = I. \tag{1.107} \]

Combining (1.106) and (1.107) total loans are,

\[ L^F = \kappa_W^W \omega N + I. \tag{1.108} \]
From (1.37), the steady-state level of borrowing from the central bank is,

\[ L^B = L^F - (1 - \mu^T R)D. \]  \hfill (1.109)

The money market equilibrium condition in the steady state is,

\[ B^C = M^H + D. \]  \hfill (1.110)

From (1.48), taxes in the steady state are,

\[ T = G + i^M TR + i^B B^H - i^B L^B. \]  \hfill (1.111)
1.A.3  Log-Linearized Equations

The log-linearized equations of the model are presented in this section. Variables with a hat represent percentage point deviations for interest rate variables, inflation, the total reserve ratio and the excess reserve ratio from the steady state, and log-deviations around a non-stochastic steady state for the other variables.

Log-linearizing private consumption (equation (1.5)) gives,

\[ E_t \hat{C}_{t+1} = \hat{C}_t + \sigma (\hat{i}_t^B - E_t \hat{\pi}_{t+1}) , \tag{1.112} \]

where \( \hat{\pi}_{t+1} \) is defined as,

\[ E_t \hat{\pi}_{t+1} = E_t \hat{P}_{t+1} - \hat{P}_t. \tag{1.113} \]

Log-linearizing the demand for cash (equation (1.7)) gives,

\[ \hat{M}_t^H = \frac{1}{\sigma} \hat{C}_t - \left[ \frac{\beta}{1 - \beta} \right] \hat{i}_t^B. \tag{1.114} \]

The demand for deposits from (1.8) is,

\[ \hat{D}_t = \frac{1}{\sigma} \hat{C}_t + \frac{1 + \hat{i}_t^D}{\hat{i}_t^B - \hat{i}_t^D} \left[ \hat{i}_t^D - \hat{i}_t^B \right]. \tag{1.115} \]

From (1.6), labour supply in its log-linear form is,

\[ \hat{N}_t = \frac{\eta N(C)^{1/\sigma}}{\omega - \eta N(C)^{1/\sigma}} \left\{ \hat{\omega}_t - \frac{\hat{C}_t}{\sigma} \right\} . \tag{1.116} \]

From (1.17), labour demand can be derived as,

\[ \hat{N}_t = \hat{K}_t - \kappa^W \hat{i}_t^R - \hat{\omega}_t + \left( \frac{1 + r^K}{r^K} \right) \hat{i}_t^R. \tag{1.117} \]
Log-linearizing the rental rate of capital from (1.28) gives,

\[
\hat{\pi}_t^K = \frac{(1 + i^L)(1 + i^B)}{1 + r^K} \left\{ i^B_t + \hat{\pi}_t + \Theta_K \left( E_t \hat{K}_t + \hat{K}_t \right) \right\} - \frac{(1 + i^L)}{1 + r^K} \left\{ (1 - \delta) i^L_{t+1} + \Theta_K E_t \left( \hat{K}_{t+2} - \hat{K}_{t+1} \right) \right\}. \tag{1.118}
\]

Log-linearizing equation (1.80) gives the New Keynesian Phillips Curve,

\[
\hat{\pi}_t = \frac{(\theta - 1)}{\phi_F} \hat{m}c_t + \beta E_t \hat{\pi}_{t+1}. \tag{1.119}
\]

A log-linear approximation of the marginal cost, equation (1.18), yields,

\[
\hat{m}c_t = (1 - \alpha)(\kappa^W i^R_t + \hat{\omega}_t) + \alpha\left( \frac{1 + r^K}{r^K} \right) i^K_t - \hat{A}_t. \tag{1.120}
\]

From (1.14), output of intermediate goods in its log-linear form is,

\[
\hat{Y}_t = \hat{A}_t + (1 - \alpha) \hat{N}_t + \alpha \hat{K}_t. \tag{1.121}
\]

From (1.39) and (1.40) the log-linearized total reserve ratio and excess reserve ratio are given by,

\[
\hat{\mu}_t^{TR} = \frac{\mu^{\hat{\mu}_t} \mu^{ER}}{\mu^{\hat{\mu}_t} \mu^{ER}} - \frac{(1 + i^R)(\hat{i}_t^R)}{\phi_{C_2} \mu^{ER}}, \tag{1.122}
\]

\[
\hat{\mu}_t^{ER} = \frac{-(1 + i^R)\hat{i}_t^R}{\phi_{C_2} \mu^{ER}}. \tag{1.123}
\]

The ratio of excess reserves to total reserves in its log-linear form is,

\[
\hat{E}R_{TR} = \frac{\hat{\mu}_t^{TR}}{E_R_{TR}} - \frac{\mu^{\hat{\mu}_t}}{\mu^{TR} E_R_{TR}} - \hat{\mu}_t^{TR}. \tag{1.124}
\]

Total reserves are,

\[
\hat{TR}_t = \frac{1}{TR} \left\{ \left( \hat{\mu}_t + \hat{D}_t \right) \mu D + \left( \hat{\mu}_t^{ER} + \hat{D}_t \right) \mu^{ER} D \right\}. \tag{1.125}
\]
From (1.41), the deposit rate is given by,

$$i_t^D = \frac{1}{(1 + i_t)} \left( 1 + \frac{1}{\eta_D} \right)^{-1} \{(1 - \mu^{TR}) (1 + i^R) i_t^R - \mu^{TR} \mu^{TR} (i^R - i^M) \} + \{\Phi_{C1} - \Phi_{C2} (\mu^{TR} - \mu) \} \left( \mu^{TR} \mu^{TR} - \mu^{TR} \right) \}.$$  (1.126)

Log-linearizing the lending rate, equation (1.42), gives,

$$i_t^L = \hat{i}_t^R - \hat{Q}_t^F. \quad (1.127)$$

From (1.43), the repayment probability in its log-linear form is,

$$\hat{Q}_t^F = \phi_2 \hat{Y}_t + \phi_1 \left( \hat{K}_t - \hat{L}_t^{FI} \right). \quad (1.128)$$

The linearized equation for the collateral-to-loan ratio is given by,

$$\bar{C}L_t = \hat{K}_t - \hat{L}_t^{FI}. \quad (1.129)$$

From (1.46), the central bank policy rate is determined by,

$$i_t^R = \chi i_{t-1}^R + (1 - \chi) \{ \xi_1(\hat{\pi}_t) + \xi_2(\hat{Y}_t) \} + \epsilon_t. \quad (1.130)$$

Using (1.15), total loans to intermediate good producers in log linear form can be written as,

$$\hat{L}_t^{FW} = \hat{N}_t + \hat{\omega}_t, \quad (1.131)$$

whereas, the capital good producer’s demand for credit from (1.24) is,

$$\hat{L}_t^{FI} = \hat{I}_t. \quad (1.132)$$
Log-linearizing equation (1.30), total loans to firms are,

\[
\hat{L}_t^F = \frac{\kappa^W \omega N}{L^F} \left[ \hat{\dot{N}}_t + \ddot{\omega}_t \right] + \frac{I_t}{L^F}.
\]  

(1.133)

From (1.37), borrowing from the central bank is,

\[
\hat{L}_t^B = \frac{L^F \hat{\dot{L}}_t^F}{L^B} - \frac{D}{L^B} \left[ \hat{D}_t - \mu^{TR} \hat{D}_t - \mu^{TR} \hat{\dot{D}}_t \right].
\]  

(1.134)

Log-linearizing (1.53) gives the money market equilibrium, from which \( \dot{i}_t^B \) is obtained,

\[
M^H \hat{\dot{M}}_t^H + D \hat{D}_t = 0.
\]  

(1.135)

New capital goods from equation (1.25) is given by,

\[
\dot{K}_{t+1} = \frac{I}{K} \hat{I}_t + (1 - \delta) \dot{K}_t.
\]  

(1.136)

From (1.50), the log-linearized equation for the equilibrium condition of the goods market which is used to determine investment is,

\[
Y \dot{Y}_t (1 - \psi) = CC_t + \delta \dot{K} \hat{I}_t.
\]  

(1.137)

Taxes from (1.48) are,

\[
T \hat{T}_t - G \hat{G}_t = i^M TR(R_{t-1} - \hat{\pi}_t) + \left[ i^B B^C - (1 + i^B) \bar{B} \right] \hat{\pi}_t
\]

\[
+ (1 + i^B) (\bar{B} - B^C) \hat{i}^B_{t-1} - L^B (1 + i^R) \hat{i}^R_{t-1} - i^R L^B (\hat{L}^B_{t-1} - \hat{\pi}_t).
\]  

(1.138)
Chapter 2

Fiscal Rules for Resource Windfall Allocation: The Case of Trinidad and Tobago

2.1 Introduction

A key issue facing policymakers in resource-rich developing countries is the prudent management of natural resource wealth. Resource revenue is difficult to manage due to highly volatile commodity prices and production discoveries. This volatility leads to increased revenue fluctuations and overall macroeconomic instability as it creates boom-bust cycles in natural resource-rich countries (Asik (2013)). Revenue volatility is the key reason why fiscal policy has been procyclical in some resource-abundant countries, such as Trinidad and Tobago (see Artana et al. (2007), International Monetary Fund (2012a) and Céspedes and Velasco (2014)). Also, the exhaustibility of non-renewable resources poses uncertainty about future income and complicates fiscal planning. This raises concern about how living standards are maintained once resources are depleted. The exhaustibility and volatility of natural resource revenue therefore pose great challenge to policymakers and raise concern about how much of the resource wealth to consume or save. Moreover, empirical evidence has shown that resource-rich developing countries are not successful in using their natural resource

1Frankel et al. (2013) noted that procyclical spending arises because the government increases spending proportionately, or more than proportionately, when revenue rises in booms.
wealth to obtain higher economic growth.²

There are different views on the management of natural resource revenues. The Permanent Income Hypothesis (PIH) approach recommends that a resource-rich country should sustain a constant flow of consumption that is equal to the implicit return on the present value of future resource revenue (International Monetary Fund (2012a)). Another approach, the Bird-in-Hand policy, suggests that resource revenue should be used to accumulate financial assets in a sovereign wealth fund, and only the interest accrued from these assets should be spent. Also, it has been argued that because citizens own the resources, the resource rents should be transferred to them in the form of direct transfer programmes or conditional cash transfer schemes (Gelb and Grasmann (2010)).³ Furthermore, Takizawa et al. (2004) examined the Hand-to-Mouth rule, which posits that countries can be better off spending all their resource wealth upfront if the initial capital stock is low. Other studies have noted that resource revenue should be saved in the form of government financial assets, which can then be used to make domestic and international loans (Collier et al. (2010)).

Given the infrastructure gaps and capital scarcity in resource-rich developing countries, saving all the resource windfalls impose severe constraints for these economies. By contrast, spending all the resource windfalls can make these countries more susceptible to boom-bust cycles and create macroeconomic instability. These bring the issue of optimal fiscal management of resource windfalls to the fore. Several researchers provide formal discussions on the management of natural resource revenue. Contributions along these lines include Collier et al. (2010), Venables (2010), van der Ploeg (2011), van der Ploeg and Venables (2011, 2013), van der Ploeg (2012), and van den Bremer and van der Ploeg (2013). Some of these studies also address the issue of optimal allocation of resource windfalls, using arbitrary allocation rules

²Matsen and Torvik (2005) argue that lower growth in resource-rich countries can reflect an optimal growth path.
³Gelb and Grasmann (2010) also noted that resource rents can be transferred to citizens in the form of lower nonoil taxes, lower prices, increased employment opportunities and subsidies.
to determine how much of the windfall should be saved. One limitation though is because of the nonstochastic nature of the models used in these studies, they are unable to determine the optimal allocation based on measures of volatility. At the same time, existing stochastic models that examine the transmission of resource price shocks focus on combining fiscal and monetary policy to mitigate Dutch disease effects, and the implications of using natural resource revenue for public investment. Therefore, these studies did not examine the critical issue of optimal resource windfall allocation (see Dagher et al. (2012), Berg et al. (2013), Richmond et al. (2013) and Samake et al. (2013)).

Agénor (2014) is the first paper to provide a methodological contribution to the literature on the issue of optimal allocation of resource windfalls in a Dynamic Stochastic General Equilibrium (DSGE) model using a social loss function defined in terms of consumption volatility and fiscal or macroeconomic stability. The Agénor framework incorporates a range of externalities associated with public infrastructure, which include a direct complementary effect with private investment and lower distribution costs, to capture the constraints faced by low-income countries. Additionally, public capital is subject to congestion and absorption constraints. The key insight of Agénor’s analysis is that the optimal allocation rule of resource windfalls involves internalizing a dynamic volatility trade-off: spending less today tends to reduce volatility today in the economy, but the greater the proportion of the windfall that is saved, the greater the proceeds from these assets that governments can spend later on, and the greater the volatility that is injected back in the economy over time. The slope of this trade-off depends in general on the structure of the model and the parameters that characterize the economy, including the accumulation rule for foreign assets. The optimal policy (that is, the optimal share of a resource windfall that must be accumulated today in a sovereign fund) minimizes a social loss function defined earlier. Because Agénor’s analysis is fundamentally a

---

4 Agénor also shows that following a temporary increase in resource prices the optimal fiscal policy always dominates a policy of direct cash transfer to households.
methodological contribution, developed with a new oil producer in mind, it is important to apply some of the features of this model to a mature resource producing country.

Although the Trinidad and Tobago economy has been producing oil for over 100 years, it only established an interim sovereign wealth fund in 2000, which was later formalized in 2007. Despite the fact that the sovereign wealth fund specifies rules regarding deposits into the fund, these guidelines were not based on any rigorous framework but rather on adhoc rules which may not have taken specific issues such as household welfare and fiscal stability into account. Thus, a key issue facing policymakers in Trinidad and Tobago is how to determine the optimal allocation of resource windfalls between spending today and saving in the sovereign wealth fund, so welfare can be improved and at the same time there can be a lasting impact on development (Velculescu and Rizavi (2005); Williams (2013)). The aim of this study is to examine the transmission of energy price and production shocks, and to determine the optimal allocation of resource windfalls between spending and saving. To do so this chapter applies a modified version of the model developed in Agénor (2014) to the Trinidad and Tobago economy. The contribution of this research is that it is the first country application of the Agénor framework. This chapter is also the first attempt to provide a rigorous assessment of how much of the resource windfall should be used for consumption and savings in a general equilibrium framework which takes some of the features of the Trinidad and Tobago economy into account.

This study departs from Agénor (2014) in the following ways: distribution costs are excluded because of the low cost of transport fuel in Trinidad and Tobago; there is no complementary effect with private investment; the model accounts for domestic consumption of natural resource products; the framework includes imperfect capital mobility; and the overall primary balance to output ratio (rather than the nonresource primary balance to output ratio) is the key fiscal indicator. Further, owing to the fact that Trinidad and Tobago is a country with absorptive capacity
concern, public capital is subject to absorption constraints which affects investment efficiency. The results show that spending all the resource windfall on consumption and investment creates a lot of volatility, whereas saving all the windfall reduces volatility and mitigates Dutch disease effects initially, but increases volatility later, as interest income is spent. As noted earlier, this dynamic volatility trade-off is the key insight of the analysis in Agénor (2014). Moreover, if the government is equally concerned about household welfare and fiscal stability, the optimal rule suggests that the government should save about 80 percent of the excess resource revenues. In general, the greater the concern for fiscal stability, the larger the proportion of the surplus resource revenue that should be saved. These findings provide evidence that fiscal policy can help to reduce the effects of resource price and production shocks.

The rest of this chapter is organized as follows. Section 2.2 provides some background information on the natural resource sector in Trinidad and Tobago. Section 2.3 presents the model and Section 2.4 outlines the key steady-state and log-linearized equations of the model. Section 2.5 provides a discussion of the calibration for the Trinidad and Tobago economy. The dynamic transmission of resource price shocks under alternative fiscal rules is examined in Section 2.6, while Section 2.7 presents the determination of the optimal allocation of resource windfalls between spending and saving. In Section 2.8, sensitivity analysis is provided to test the robustness of the results obtained from the optimal allocation rule. Penultimately, Section 2.9 examines the transmission and optimal allocation of windfalls emanating from a shock to resource production. The final section summarizes the key results and discusses their implications for fiscal policy in Trinidad and Tobago.

### 2.2 Background

This section discusses the importance of the energy sector to the Trinidad and Tobago economy and provides a brief overview of the Heritage and Stabilisation
2.2.1 The Importance of the Energy Sector

Trinidad and Tobago is a high-income economy\(^5\), endowed with vast energy resources (oil and natural gas). The economy is classified as being "resource-rich", given the significant share of export earnings and government revenue obtained from oil and natural gas.\(^6\) The heavy dependence on the fortunes of the energy sector makes the economy highly vulnerable to energy price shocks. Table 2.1 shows the economic contribution of the energy sector to the Trinidad and Tobago economy. Since 2000, the economy has become more fiscally dependent on the energy sector—which accounts for over 80 percent of merchandise export earnings. However, although the energy sector is a major source of wealth, it accounts for less than 4 percent of the labour force, because the capital intensive nature of oil and gas industries cannot provide substantial employment opportunities.

Over the last decade, Trinidad and Tobago has benefited from surpluses on its fiscal accounts, supported largely by buoyant energy prices. High energy prices have been accompanied by increased government expenditure, which are likely to be unsustainable if oil and gas prices decrease dramatically. Between 2000 and 2013 for example, government expenditure to GDP increased by over 10 percent. In addition, the higher level of government spending, coupled with lower non-energy revenue, has caused a deterioration in the non-energy fiscal deficit as a ratio of GDP, which deteriorated from 2.4 percent in 2000 to 10.2 percent in 2013 (see Figure 2.1).

Although there have been some fluctuations in the overall primary balance as a percent of GDP, it recorded surpluses for most of the period, with the exception of 2009 and 2012.

The energy sector has contributed significantly to the economic growth and de-

---
\(^5\)GNI per capita of US$14,710 in 2012 (see The World Bank (2014)).
\(^6\)Lundgren et al. (2013) define a resource-rich economy as one in which resource revenue exceeds 20 percent of total government revenue, and at least 25 percent of total exports are from natural resources.
velopment of the Trinidad and Tobago economy. However, the inherent volatility of commodity prices leads to growth instability in the energy sector and affects overall economic activity. Figure 2.2 shows that total GDP growth is highly correlated with growth in the energy sector, whereas growth in the non-energy sector follows the same trajectory as growth in the energy sector for most of the period—suggesting possible interlinkages between the sectors. Moreover, fluctuations in energy prices are reflected in the Terms of Trade Index which has been volatile over the last two decades (see Figure 2.3).

The abundance of oil and gas in the Trinidad and Tobago economy has caused a decline in the non-energy traded goods sector. Figure 2.4 shows that since 1996, the non-energy tradable sector has been constantly shrinking as a share of GDP. At the same time, the energy sector has expanded, making the economy more resource-dependent and increasing the risks associated with commodity price shocks. Despite the decline in the relative size of the nontradable sector over the period, it still accounts for the largest share of total output. Overall, the characteristics of the production structure provide supporting evidence to Dutch disease effects, which appear to be a permanent feature of the economy given the historical preponderance of oil and natural gas in government revenue and export receipts. The inflow of capital from the oil boom has caused the real exchange rate to appreciate (see Figure 2.5). The real appreciation resulted in a loss of international competitiveness in nonresource tradable goods, compounding the reduction in manufacturing output and employment.

The World Economic Forum’s (WEF) Global Competitiveness Index (GCI) indicates indeed that Trinidad and Tobago’s international competitiveness has deteriorated over the years. In the 2006-2007 GCI report, Trinidad and Tobago was ranked 67 with a score of 4.0 (measured on a 1-to-7 scale), whereas in the 2013-2014 report, the economy obtained a ranking of 92, with a score of 3.9 (Figure 2.6).7 Also, with

---

7In light of this, the government is taking measures to improve the country’s global competitiveness rankings (see International Monetary Fund (2013)).
regard to the sectoral distribution of employment, Figure 2.7 shows that since 1996, there have been declining employment opportunities in the non-energy tradable sector. By contrast, employment increased steadily in the nontradable sector because of a shift in productive resources to that sector.

In natural resource-rich developing countries and developing countries in general, public resources are often wasted. Trinidad and Tobago, like many resource-rich developing countries, has a low efficiency of public investment. Dabla-Norris et al. (2012) estimated the efficiency of public investment to be 0.275, which indicates that more than 70 percent of investment spending is unproductive. In addition, Trinidad and Tobago’s ranking for Government Effectiveness has declined from 70 in 2000 to 60 in 2006, but then increased to 65 in 2012.\footnote{See The Worldwide Governance Indicators (WGI) at www.govindicators.org/}

Moreover, despite the abundant resource wealth, infrastructure in the economy is inadequate and poor when compared to other high-income countries (Artana et al. (2007)). The data presented in Table 2.2 shows that the most limited infrastructure seems to be roads, followed by port facilities and telecommunications. For example, internet penetration in Trinidad and Tobago is 55 percent compared with 75.8 percent in high-income countries. The poor infrastructure facilities in the economy are primarily due to underinvestment. Having realized this, the government has recently been increasing investment in infrastructure through the Public Sector Investment Programme (PSIP) in an attempt to improve the level of infrastructure. However, governance reforms are also critical, in light of the poor efficiency of investment spending alluded to earlier.

\section*{2.2.2 Characteristics of the Energy Sector}

Commercial oil production began in Trinidad and Tobago in 1908. Over the years, there has been a gradual rise in oil production, with substantial increases over the period 1975 to 1980, during which there was an oil boom. Some of the crude oil
obtained from local oil fields is considered to be "light" in quality and is therefore exported; in turn, a heavier type of crude oil is imported. The imported crude oil, along with some of the indigenous crude oil, is used to produce refined products—gasoline, kerosene, diesel, naphtha, aviation fuel and Liquefied Petroleum Gas (LPG). An analysis of the data from the Central Bank of Trinidad and Tobago shows that over the period 2009-2012, approximately 20 percent of these refined products were consumed locally. Further, there has been a continuous decline in crude oil production since 2006 (see Figure 2.8). The declines have been attributed to maturing oilfields and operational challenges. Despite the trend observed, The Ministry of Energy and Energy Affairs has noted that oil reserves are expected to increase with more exploration and new technologies allowing for secondary recovery.

Since 2000, natural gas production has been increasing significantly (Figure 2.9). The production of petrochemicals also recorded large increases, mirroring the trend in natural gas production. The natural gas reserves in Trinidad and Tobago are used to produce Liquefied Natural Gas (LNG), methanol, ammonia, ammonia derivatives (urea, urea ammonium nitrate, melamine), iron and steel, as well as for other industrial and commercial fuel applications, and for power generation. Trinidad and Tobago is the world’s largest exporter of ammonia and a leading exporter of methanol. The economy is also a world renowned producer of LNG, and currently operates the second largest LNG train in the world (International Monetary Fund (2012b)).

The expansion in the production of petrochemicals provides evidence that the Trinidad and Tobago economy has achieved vertical diversification within the energy sector. However, the government has struggled to extend diversification to the horizontal path. Although the issue of economic diversification has been at the

---

9 Citizens of Trinidad and Tobago are able to share in the energy wealth through low priced transport fuel, which is extended by the government through a fuel subsidy. The fuel subsidy was approximately 3 percent of GDP in 2012.

10 Commercial natural gas production began in Trinidad and Tobago in 1953.

11 Longmore et al. (2014) found that between 1980 and 2010 Trinidad and Tobago’s Herfindahl-Hirschman Index declined by 71.5 percent, implying that the economy has made progress in terms
core of policy circles for decades, the economy is still heavily dependent on the economic fortunes of the oil and gas sector. Economic diversification, outside of the energy sector, is critical to reduce reliance on revenues from the country’s finite energy resources, as well as to ensure sustainable growth after depletion of oil and gas resources.

2.2.3 The Heritage and Stabilisation Fund (HSF)

The Heritage and Stabilisation Fund (HSF) is a Sovereign Wealth Fund that was established in March 2007 by the government of Trinidad and Tobago. The purposes of the Fund are: to cushion the impact on or sustain public expenditure capacity during periods of revenue downturn, caused by a fall in crude oil or natural gas prices; to generate an alternate stream of income so as to support public expenditure capacity as a result of revenue downturn caused by the depletion of non-renewable petroleum resources; and to provide savings for future generations (The Heritage and Stabilisation Fund Act, No. 6 of 2007, pp. 3-4).

The HSF replaced the Interim Revenue Stabilisation Fund (IRSF), which was introduced in 2000 to promote fiscal discipline, cushion the impact of unexpected drops in oil prices on the economy, and strengthen public sector savings. With the establishment of the HSF, all the proceeds from the IRSF were transferred to the Fund. Figure 2.10 shows the HSF as a proportion of GDP since 2007. In 2013 total assets in the HSF were approximately 19 percent of GDP.13

of diversification. This diversification was however mainly in gas based industries.

12During the 1970s and early 1980s the economy benefited tremendously from higher oil prices and an increase in oil production. But because there was no saving fund in place, government spending went unchecked and the windfalls were not properly managed (Williams (2011)). In the mid-1980s when oil prices declined sharply the economy faced financial difficulties and had to enter into structural adjustment programmes with the International Monetary Fund and the World Bank (see The World Bank (1989); Hilaire (2000); and Sergeant et al. (2003)). These experiences caused the government to formally establish a sovereign wealth fund (The Sovereign Wealth Fund Initiative (2012)).

13The Strategic Asset Allocation (SAA) for the Fund’s investment portfolio is: 25 percent in U.S. Short Duration Fixed Income Mandate; 40 percent in U.S. Core Domestic Fixed Income Mandate; 17.5 percent in U.S. Core Domestic Equity Mandate; and 17.5 percent in non U.S. Core International Equity Mandate. The diversification of the Fund helps to minimize possible losses
To ensure that the Fund fulfills its functions, the HSF Act provides guidelines on deposits into, and withdrawal from the Fund (see The Heritage and Stabilisation Fund Act, No. 6 of 2007, pp. 7-9). The deposit rules state that quarterly deposits are made to the fund: when actual petroleum revenues in each quarter of the financial year exceed the estimated petroleum revenues for that quarter by more than 10 percent; and when actual revenues exceed estimated revenues by less than 10 percent. Furthermore, a minimum of 60 percent of the excess total revenues shall be deposited to the Fund in any financial year. The withdrawal rules state: withdrawals are permitted from the Fund in cases where the petroleum revenues collected in any financial year fall below the estimated petroleum revenues for that financial year by at least 10 percent. Withdrawals are however limited to 60 percent of the amount of the shortfall of petroleum revenues for the relevant year; or 25 percent of the balance of the Fund at the beginning of that year, whichever is the lesser amount. Also, the HSF Act precludes any withdrawal where the balance standing to the credit of the Fund would fall below one billion U.S. dollars if such withdrawal were to be made.

A key issue on the agenda of policymakers in Trinidad and Tobago is to determine an appropriate deposit rule for the HSF that is backed by a rigorous framework. This is particularly important given the decline in oil production, and the fall in Trinidad and Tobago’s exports of LNG to the U.S.—arising from an increase in U.S. shale gas production. These two developments have caused a decline in energy sector revenues. It is therefore important to determine the share of the excess revenue that should be deposited into the Fund, to provide a balance between immediate consumption and savings.

---

14 In the case where the surplus is by less than 10 percent, the Minister of Finance may deposit all or part of the excess into the Fund.
2.3 The Model

The framework considered is an open economy general equilibrium model with three production sectors: a nonrenewable resource sector (which represents the oil and natural gas sector and is identified with superscript $O$), a nonresource tradable sector (identified with superscript $T$), and a nontradable sector (identified with superscript $N$). Resource output is a flow endowment that is owned by all citizens, where the government acts as the trustee or custodian for the resources.\textsuperscript{15} Some of the resource products are consumed domestically (by households), and the rest are exported.\textsuperscript{16} Tradable output and nontradable output are produced competitively. The tradable good can either be consumed or invested, whereas the nontradable good is a pure consumption good.

Households purchase and consume both tradables and nontradables, whereas the government buys the nonresource tradable and nontradable goods and consumes only nontradables. Private investment consists of tradables only, whereas public investment consists of both tradables and nontradables. As is common in developing countries, public capital is subject to absorption constraints, which affect the efficiency of public investment (See Agénor (2010, 2012)). The model also accounts for imperfect intersectoral capital mobility, and both households and the government have imperfect access to world capital markets.

In the model, prices are flexible and the resource price is exogenously determined outside the home country. The world price of a unit of the nonresource tradable good is unity and purchasing power parity (PPP) holds at the wholesale level and retail level for tradable goods.

\textsuperscript{15} This is the case in many countries, such as Trinidad and Tobago (see McGuire et al. (2009)).
\textsuperscript{16} For instance, as noted earlier, in Trinidad and Tobago some of the refined oil products are consumed domestically.
2.3.1 Total Output

Total domestic output, $Y_t$, measured in foreign currency, is given by,

$$Y_t = Y_t^T + z_t^{-1}Y_t^N + P_t^O Y_t^O,$$  \hspace{1cm} (2.1)

where $Y_t^T$, $Y_t^N$, $Y_t^O$ denote nonresource tradable output, nontradable output and natural resource output, respectively. $P_t^O$ is the world resource price and $z_t^{-1}$ is the real exchange rate.

2.3.2 Tradable Production

Labour, $L_t^T$, capital, $K_t^T$, and public capital, $K_t^G$ are used to produce tradable goods. The production function of tradables is given by,

$$Y_t^T = (L_t^T)^\beta (K_t^T)^{1-\beta} (K_t^G)^{\omega_T},$$  \hspace{1cm} (2.2)

where $\beta \in (0, 1)$ and $\omega_T > 0$.

The first-order conditions for the economy-wide wage rate, $w_t$, and rental rate of capital in the tradable sector, $r_t^{K,T}$, take the standard form,

$$w_t = \beta \left( \frac{Y_t^T}{L_t^T} \right),$$  \hspace{1cm} (2.3)

$$r_t^{K,T} = (1 - \beta) \left( \frac{Y_t^T}{K_t^T} \right).$$  \hspace{1cm} (2.4)

2.3.3 Nontradable Production

Nontradable goods are produced using labour, $L_t^N$, private capital, $K_t^N$, and public capital. The production function is given by,

$$Y_t^N = (L_t^N)^{\eta}(K_t^N)^{1-\eta}(K_t^G)^{\omega_N},$$  \hspace{1cm} (2.5)
where $\eta \in (0, 1)$, $\omega_N > 0$. The elasticity of output of nontradables with respect to public capital is assumed to be same in both production sectors, so that $\omega_N = \omega_T$.

The first-order conditions are,

$$z_t w_t = \eta \frac{Y^N_t}{L^N_t}, \quad (2.6)$$

$$z_t r^{K,N}_t = (1 - \eta) \frac{Y^N_t}{K^N_t}, \quad (2.7)$$

where $r^{K,N}_t$ is the rental rate of capital in the nontradable sector.

### 2.3.4 Resource Production and Prices

In the model, natural resource output follows an exogenous stochastic process:

$$Y^O_t = (Y^O_{t-1})^{\rho_{Y^O}} \exp(\epsilon_{t}^{Y^O}), \quad (2.8)$$

where $\rho_{Y^O} \in (0, 1)$ is the autoregressive coefficient, and $\epsilon_{t}^{Y^O}$ a normally distributed random shock with zero mean and a constant variance. The coefficient $\rho_{Y^O}$ is related to the rate of depletion of resources.

The international resource price, $P^O_t$, follows an exogenous process given by

$$P^O_t = (P^O_{t-1})^{\rho_{P^O}} \exp(\epsilon_{t}^{P^O}), \quad (2.9)$$

where $\rho_{P^O} \in (0, 1)$ is the autoregressive coefficient, and $\epsilon_{t}^{P^O}$ a normally distributed random shock with zero mean and a constant variance. The combination of (2.8) and (2.9) implies that any resource windfall, due to shocks to either production or prices, is only temporary.
2.3.5 Households

In the first stage, households determine the optimal level of total consumption, and in the second stage, the optimal level of consumption chosen is allocated between spending on tradable goods and nontradable goods. The objective of the representative household is to maximize the following utility function,

\[ E_t \sum_{s=0}^{\infty} \Lambda^s \left\{ \frac{(C_{t+s})^{1-\varsigma^{-1}}}{1 - \varsigma^{-1}} - \frac{\eta_L}{1 + \psi}(L_{t+s})^{1+\psi} \right\}, \quad (2.10) \]

where \( E_t \) is the expectations operator conditional on the information available in period \( t \), and \( \Lambda \in (0, 1) \) denotes the discount factor. The term \( \varsigma \) represents the intertemporal elasticity of substitution for consumption, whereas \( \psi \) is the inverse of Frisch elasticity of labour supply, and \( \eta_L > 0 \) is a preference parameter.

There is imperfect capital mobility across production sectors. The accumulation equation for the stock of private capital is given by,

\[ K^P_t = (1 - \delta^P)K^P_{t-1} + I^P_t - \Gamma(K^P_t, K^P_{t-1}), \quad (2.11) \]

where \( I^P_t \) is private investment, \( \delta^P \in (0, 1) \) gives a constant rate of depreciation, and \( \Gamma() \) is a capital adjustment cost function specified as,

\[ \Gamma(K^P_t, K^P_{t-1}) = 0.5\kappa \left( \frac{K^P_t}{K^P_{t-1}} - 1 \right)^2 K^P_{t-1}, \quad (2.12) \]

where \( \kappa > 0 \) measures the magnitude of adjustment costs.

Households own both types of firms but do not earn any profit from them because of perfect competition. Their net income consists of after-tax nonresource income and after-tax resource income. The households’ end-of-period budget constraint is given by,
where $D_p^t$ represents foreign-currency debt, $r^W_t$ is the world interest rate, $\tau^{NO} \in (0, 1)$ denotes the nonresource tax rate, $\tau^O \in (0, 1)$ is the resource tax rate, and $\psi^O \in (0, 1)$ is the share of the non-taxed resource windfall that domestic households (as opposed to nonresidents) receive.

Each household maximizes lifetime utility with respect to $C_t$, $L_t$, $K^P_t$, and $D^P_t$. Thus, maximizing (2.10) subject to (2.11) to (2.13) yields the following first-order conditions,

$$C_t = \Lambda \left( 1 + r^W_t \right) E_t(C_{t+1}^{\gamma-1}), \quad (2.14)$$

$$L_t = \left[ \frac{(1 - \tau^{NO})w_t}{\eta L C^{\gamma-1}_t} \right]^{\frac{1}{\psi}}, \quad (2.15)$$

$$E_t \left\{ \left[ \kappa \left( \frac{K_{t+1}^P}{K_t^P} - 1 \right) + 1 \right]^{-1} \left[ 1 - \tau^{NO} r^K_{t+1} + 1 - \delta^P + \frac{\kappa}{2} \left( \frac{\Delta(K_{t+1}^P)^2}{(K_{t+1}^P)^2} \right) \right] \right\} = 1 + r^W_t, \quad (2.16)$$

where $\Delta(K_{t+2}^P)^2 = (K_{t+2}^P)^2 - (K_{t+1}^P)^2$. Equation (2.14) is the standard Euler equation which describes the optimal consumption path. Equation (2.15) defines labour supply which is positively related to the real wage and negatively related to consumption. Equation (2.16) shows the expected return on capital is related to the world interest rate.

Private consumption is a bundle of tradable consumption, $C^T_t$, and nontradable consumption, $C^N_t$,

$$C_t = (C^N_t)^{\theta} (C^T_t)^{1-\theta}, \quad (2.17)$$

where $\theta \in (0, 1)$.

The representative household maximizes (2.17) subject to the static budget con-
The first-order conditions are given by,

\[ C_t^N = \theta z_t C_t, \quad (2.19) \]

\[ C_t^T = (1 - \theta) C_t, \quad (2.20) \]

 Tradable consumption consists of a bundle of natural resource products, \( C_t^{TO} \), and nonresource related goods \( C_t^{TNO} \),

\[ C_t^T = (C_t^{TO})^{\theta_T} (C_t^{TNO})^{1-\theta_T}, \quad (2.21) \]

where \( \theta_T \in (0, 1) \), and the budget constraint for tradable goods is,

\[ C_t^T = C_t^{TNO} + P_t^O C_t^{TO}. \quad (2.22) \]

Maximizing (2.21) subject to (2.22) the solution is given by\textsuperscript{17}

\[ C_t^{TO} = \theta_T (P_t^O)^{-1} C_t^T, \quad (2.23) \]

\[ C_t^{TNO} = (1 - \theta_T) C_t^T. \quad (2.24) \]

\textbf{2.3.6 Government}

The government collects resource revenue, \( T_t^O \), nonresource revenue, \( T_t^{NO} \), and lump-sum taxes, \( T_t^L \). It also receives interest income on the stock of foreign-currency assets, \( F_t \), held in a sovereign wealth fund. The interest rate accrued on the assets

\textsuperscript{17}Details of the derivations are presented in Appendix 2.A.1.
in the sovereign wealth fund is $r^F_t$. Thus, total government revenue, $T_t$, is given by,

$$T_t = T^O_t + T^{NO}_t + T^L_L + r^F_t F_t. \quad (2.25)$$

As noted earlier, resource output is taxed at the rate $\tau^O$, and the tax rate on nonresource output is $\tau^{NO}$. Thus, resource revenue and nonresource revenue collected each period are,

$$T^O_t = \tau^O P^O_t Y^O_t, \quad (2.26)$$

$$T^{NO}_t = \tau^{NO} (Y^T_t + z^{-1} Y^N_t). \quad (2.27)$$

Therefore, (2.25) can be written as,

$$T_t = \tau^O P^O_t Y^O_t + \tau^{NO} (Y^T_t + z^{-1} Y^N_t) + T^L_L + r^F_t F_t. \quad (2.28)$$

Government spending, $G_t$, is allocated in fixed fractions to investment, $I^G_t$, and consumption, $C^G_t$,

$$I^G_t = \psi^G G_t, \quad (2.29)$$

$$C^G_t = (1 - \psi^G) z_t G_t, \quad (2.30)$$

where $\psi^G \in (0,1)$. Government spending in foreign-currency terms is,

$$G_t = I^G_t + z_t^{-1} C^G_t. \quad (2.31)$$

In the log-linearized system, where variables are defined as deviations from the steady state, the definition of government spending will depend on the fiscal rule at hand, whereas in the steady state, government spending is calculated as a constant fraction, $\psi^G \in (0,1)$, of output.

Investment spending is allocated in fixed shares between spending on nontraded
goods, $I_t^{G,N}$, and nonresource traded goods, $I_t^{G,T}$:

$$I_t^{G,N} = v^{G,N} z_t I_t^G,$$  \hfill (2.32)  

$$I_t^{G,T} = (1 - v^{G,N}) I_t^G,$$  \hfill (2.33)  

where $v^{G,N} \in (0, 1)$. Thus total public investment, $I_t^G$, is given by,

$$I_t^G = I_t^{G,T} + z_t^{-1} I_t^{G,N}.$$  \hfill (2.34)  

The public capital stock is given by,

$$K_t^G = (1 - \delta^G)K_{t-1}^G + \varphi_{t-1} I_{t-1}^G,$$  \hfill (2.35)  

where $\delta^G \in (0, 1)$ is the depreciation rate and $\varphi_t$ is an indicator of efficiency of spending on infrastructure, as first proposed in Agénor (2010). The efficiency parameter—which captures absorption constraints—is negatively related to the ratio of public investment to public capital,

$$\varphi_t = \varphi_0 \left( \frac{I_t^G}{K_t^G} \right)^{-\varphi_1},$$  \hfill (2.36)  

where $\varphi_1 > 0$.

The government’s flow budget constraint is,

$$D_t^{G} = (1 + r_t^W) D_t^G + G_t - T_t,$$  \hfill (2.37)  

where $D_t^G$ is the government’s foreign-currency denominated debt.\footnote{In the calibration, I assume the government does not issue additional debt to finance its deficit.}

The overall primary balance, $OPB_t$, is defined as,

$$OPB_t = T_t^O + T_t^{NO} + T_t^L - G_t.$$  \hfill (2.38)
2.3.7 World Interest Rate and Risk Premium

The market cost of foreign borrowing, \( r^W_t \), depends on the world risk-free (constant) rate, \( r^{W,R} \), and a risk premium, \( PR_t \),

\[
r^W_t = (1 + r^{W,R})(1 + PR_t) - 1. \tag{2.39}
\]

In line with the literature on sovereign debt spreads for developing countries (see Agénor and Montiel (2015)), the premium is positively related to the government net debt to total output ratio,

\[
PR_t = \left( \frac{D^G_t}{Y_t} \right)^{pr1}, \tag{2.40}
\]

where \( pr1 > 0 \). Therefore, an increase in total output lowers the risk premium.

2.3.8 Market-Clearing Conditions

The market-clearing condition of the nontradable sector is,

\[
Y^N_t = C^N_t + C^G_t + I^{G,N}_t. \tag{2.41}
\]

The labour market equilibrium condition is,\(^\text{19}^\)

\[
L_t = L^N_t + L^T_t. \tag{2.42}
\]

The CES aggregator for total private capital is given by,

\[
K^P_{t-1} = [\zeta_K (K^T_t)^{(\eta_K-1)/\eta_K} + (1 - \zeta_K)(K^N_t)^{(\eta_K-1)/\eta_K}]^{\eta_K/(\eta_K-1)}. \tag{2.43}
\]

\(^\text{19}^\) I assume that total labour is allocated between the nonresource tradable and nontradable production sectors only. This is realistic because employment in the resource sector is usually small, due to (as noted earlier) the capital intensive nature of that sector. See Table 2.1 and Figure 2.7 which provide supporting evidence for Trinidad and Tobago.
The aggregate rental rate of capital is,

\[
    r^K_t = \left[ (\zeta_K)^{\eta_K} (r^{K,T}_t)^{1-\eta_K} + (1 - \zeta_K)^{\eta_K} (r^{K,N}_t)^{1-\eta_K} \right]^{1/(1-\eta_K)}.
\] (2.44)

The asset accumulation rule is,

\[
    F_{t+1} = (1 - \phi^F) F_t + \chi T_t^O,
\] (2.45)

where \( \phi^F \in (0, 1) \) represents a management fee levied on the stock of assets held in the sovereign wealth fund and \( \chi \in (0, 1) \) is the fraction of the resource windfall saved in the sovereign wealth fund.

The current account balance is given by,\(^{20}\)

\[
    D_{t+1} - F_{t+1} = (1 + r^W_t) D_t - Y^T_t + C^T_t + I^P_t + I^{G,T}_t
\] (2.46)

\[-(1 + r^F_t - \{1 - \nu\} \phi^F) F_t - \left[ \psi^O + (1 - \psi^O) \tau^O \right] P^O_t Y^O_t,\]

where \( D_t = D^P_t + D^G_t \) denotes total debt and \( \nu \in (0, 1) \) is the fraction of the management fee that goes to domestic agents.

As in Agénor (2014), the competitive equilibrium in this framework consists of sequences of allocations \( \{C^N_t, C^T_t, I^P_t, D_t, F_t, L^N_t, L^T_t, K^P_t, K^N_t, K^{G,T}_t, G_t\}_{t=0}^\infty \), final good and factor prices, \( \{w_t, r^K_t, r^{K,T}_t, r^{K,N}_t\}_{t=0}^\infty \), such that, taking as given \( K^P_{-1}, K^G_{-1}, D_{-1}, F_{-1} \), the exogenous processes \( \{P^O_t, Y^O_t\}_{t=0}^\infty \), constant policy parameters \( \chi, \tau^O, \tau^{NO}, v^G, v^{G,N} \), and constant public debt,

a) \( \{C_t, C^N_t, C^T_t, L_t, I^P_t, D^P_t, K^P_t\}_{t=0}^\infty \) solve households’ optimization problem;

b) \( \{L^N_t, K^N_t\} \) solve the nontradable good firm’s optimization problem;

c) \( \{L^T_t, K^{G,T}_t\} \) solve the nonresource tradable good firm’s optimization problem;

d) the government sets a sequence of total spending \( \{G_t\}_{t=0}^\infty \), its components

\(^{20}\)Details of the derivations are presented in Appendix 2.A.1.
\( \{C_t^G, I_t^G\}_{t=0}^\infty \), a sequence of lump-sum taxes \( \{T_t^L\}_{t=0}^\infty \), and a sequence of assets \( \{F_t\}_{t=0}^\infty \), held in the sovereign wealth fund so that its flow and lifetime budget constraints are satisfied; and

e) market-clearing conditions for nontradable goods, labour, private capital, and nonresource tradable goods are satisfied.

2.4 Steady State and Log-Linearization

This section presents some of the key steady-state and log-linearized equations of the model. The steady-state equations of the model are listed in Appendix 2.A.2, whereas the log-linearized equations are presented in Appendix 2.A.3.

The steady-state world interest rate is given by the standard equation,

\[
r^W = \frac{1}{\Lambda} - 1.
\]

The real exchange rate is solved from the equilibrium condition between supply and demand of nontradables,

\[
z = \frac{1}{\partial C} \left[ Y^N - C^G - I^{G,N} \right].
\]

In the steady state, the risk premium is given by,

\[
(1 + PR) \left( 1 + r^{W,R} \right) = 1 + r^W.
\]

The model is solved by log-linearizing each variable around the steady state. In particular, the overall primary balance represents total revenues less noninterest government spending,

\[
\overline{OPB_t} = \frac{1}{OPB} \left[ T^O \hat{T}_t^O + T^{NO} \hat{T}_t^{NO} + T^L \hat{T}_t^L - G \hat{G}_t \right].
\]
Efficiency of public capital depends positively on the public capital stock and is negatively related with public investment,

\[ \hat{\varphi}_t = \varphi_1 \left[ \hat{K}_t^G - \hat{I}_t^G \right]. \]

### 2.5 Calibration

The model is calibrated using data for Trinidad and Tobago because of the importance of the resource sector to the economy, and the critical need to determine how resource windfalls should be managed—as highlighted in Section 2.2. The main data sources are The Central Bank of Trinidad and Tobago, The Central Statistical Office of Trinidad and Tobago, The Ministry of Energy and Energy Affairs of Trinidad and Tobago, and The Ministry of Finance of Trinidad and Tobago. In cases where data and country-specific parameters are not available, estimates from other studies are used.

A summary of the benchmark set of parameters is provided in Table 2.3. Considering the parameters characterizing the household behaviour, the intertemporal discount factor, \( \Lambda \), is set at 0.972 based on estimates of real interest rates.\(^{21}\) The intertemporal elasticity of substitution, \( \varsigma \), is 0.2 (Agénor and Montiel (2015)), and the preference parameter for labour, \( \eta_L \), is set at a low value of 0.2. The Frisch elasticity of labour supply, \( \psi \), is calibrated at 12, implying an inelastic labour supply. The share of nontradables in total private consumption, \( \theta \), is set at 0.55. This is the same value used in Pieschacón (2012), and it is in line with the share of nontradable goods reported in the Household Budget Survey (HBS) for Trinidad and Tobago.\(^{22}\)

Using data from the HBS, the share of household spending on oil and gas products

---

\(^{21}\) The world real interest rate, \( r^W \), is 2.875 percent (see calculation stated later). Using the standard formula \( r^W = \Lambda^{-1} - 1 \) gives \( \Lambda = 0.972 \).

\(^{22}\) The Household Budget Survey (HBS) is carried out to collect data on income and expenditure of private households for the Retail Price Index (see Central Statistical Office of Trinidad and Tobago n.d.). The latest data published for the HBS is for the period 1997/1998. The survey was updated during 2008/2009; however the data are not yet available.
in total tradable consumption, $\theta^T$, is calculated to be 0.06. The adjustment cost parameter for private investment, $\kappa$, is set at 30, whereas the depreciation rate for private capital, $\delta^P$, is 0.045, in line with estimates in the literature. The share of capital in the nonresource tradable sector, $\zeta_K$, is calibrated at 0.6, to reflect the fact that the nonresource tradable sector is more capital intensive. Furthermore, the elasticity of substitution between nonresource traded and nontraded goods, $\eta_K$, is set to 0.5, and sensitivity analysis using a higher degree of substitution is reported later on. The share of the nontaxed resource windfall that domestic households receive, $\psi^O$, is set as 88.4 percent, given that the profits repatriated by nonresidents for the period 2007-2010, $(1 - \psi^O)$, is 11.6 percent.

Given that the resource commodities are oil and natural gas, the degree of persistence in resource production is calculated similar to Agénor (2014). Therefore, assuming that proven oil and natural gas reserves may last about 15 years, $\rho^{YO}$ is calibrated at 0.912.\textsuperscript{23,24} For energy prices, the degree of persistence ($\rho^{PO}$) is 0.93, in line with empirical estimates (see Maliszewski (2009)).\textsuperscript{25} Also, in the nonresource sector, as production in the nontradable sector is more labour intensive, the elasticity of production with respect to labour in that sector, $\eta$, is set at a value of 0.65; this is greater than the elasticity of production in the tradable sector, $\beta$, which is

\textsuperscript{23}In Trinidad and Tobago, the exact period before oil and gas reserves are fully depleted is unknown. In 1983 gas reserves were estimated to last up to 70 years (see Auty and Gelb (1986)); whereas the 2011 Ryder Scott report noted that proven natural gas reserves was estimated to last about 9 years. However, given the economy’s resource base, there are a lot of gas reserves to be discovered via increased exploration (see Trinidad and Tobago Newday (January 2012)). With regard to oil production, since the 1980s concerns were raised about the depletion of crude oil. Auty and Gelb (1986) noted that by 1981 oil reserves were estimated to last 10 years, but this period has been long out-lived as there continues to be new discoveries. It has also been noted that the decline in oil in recent years is not due to a decline in oil reserves but rather a lack of drilling. Krishna Persad noted that there are at least 3.5 billion barrels of crude oil remaining. He also pointed out that because primary recovery has already yielded 3.5 billion over 104 years, the economy still has a lot of oil remaining (see Trinidad and Tobago Express Newspapers (November 2012)). This is consistent with a study by Hosein et al. (2010) which found that only 20 percent of the heavy oil onshore in Trinidad and Tobago has been recovered.

\textsuperscript{24}Assuming that proven energy reserves will last approximately 15 years, the formula yields $(\rho^{YO})^{7.5} = 0.5$; therefore $\rho^{YO} = 0.912$. It should be noted that changing the period that proven reserves are expected to last does not alter the results.

\textsuperscript{25}Maliszewski’s study focuses on oil prices; however, because natural gas prices comove with crude oil prices, the same number is used for energy prices.
equal to 0.6. Similar to Agénor (2014), the elasticities with respect to public capital, \( \omega_T \) and \( \omega_N \), both take a value of 0.17.

Moreover, for the government, revenue from the oil and gas sector represents 17.9 percent of GDP on average for the period 2009-2012. Given that the value of oil and gas production for the same period is 44 percent of GDP, then the tax rate on energy income, \( \tau^O \), is calculated as 41 percent.\(^{26}\) Using data for the period 2009-2012 on the tax revenue-to-GDP ratio, the tax rate on non-energy income, \( \tau^{NO} \), is calibrated at 14.7 percent. Furthermore, data for the same period reveal that government spending is 13.8 percent of total output; hence this value is used for \( \psi^G \). Using information from the Ministry of Planning and Sustainable Development (2012), the actual amount the government spent on infrastructure investment during the fiscal year 2012 was used to estimate the initial share of infrastructure investment in government spending, \( \nu^G \), to be 0.151. The parameter that captures the allocation of investment in infrastructure to nontraded goods, \( \psi^{G,N} \), is set at 0.41 based on the estimate of the share of nontradables in total investment reported in Bems (2008) for Trinidad and Tobago. In addition, the efficiency parameter for public investment, \( \varphi \), is 0.275 based on the value reported in Dabla-Norris (2012) for Trinidad and Tobago, whereas the absorption constraint elasticity for public investment, \( \varphi_1 \), is set at a low value of 0.05. The rate of depreciation of public capital, \( \delta^G \), is equal to 0.035, in line with Dagher et al. (2012).

To calculate the average interest rate earned by the country’s sovereign fund, \( r^F \), data from the Heritage and Stabilisation Fund Quarterly Investment Report were used.\(^{27}\) The nominal interest rate for 2009-2012 was 5.1 percent on average. Given that in the same period, inflation in the U.S. was 1.6 percent on average, the real return on the sovereign wealth fund is set at 3.5 percent. The risk-free

\(^{26}\)Given that there are several taxes for oil and gas producing companies operating in Trinidad and Tobago, it is difficult to determine a single effective tax rate. Therefore, similar to Pieschacon (2012), the identity \( \tau^O / Y = \tau^O \left( P^O Y^G \right) / Y \) is used to compute the resource tax rate.

\(^{27}\)See Trinidad and Tobago Heritage and Stabilisation Fund, Quarterly Investment Report (various years).
world interest rate, \( r^{W,R} \), is computed as 1.0 percent, based on the real yields on U.S. treasury bonds issued in 2014. To calculate the world interest rate, \( r^W \), I used the nominal yield on recent sovereign bonds issued by Trinidad and Tobago on the international financial market in December 2013. Given that the bonds had a yield of 4.375 percent, the real bond rate is 2.875—accounting for a 1.5 percent average U.S. inflation rate for 2013. Therefore, using \( PR = \left[ \frac{(1 + r^W)}{(1 + r^{W,R})} \right] - 1 \) from (2.39), the risk premium (in foreign-currency terms) is calculated as 1.86 percent.

The elasticity of the risk premium with respect to the debt to output ratio, \( pr_1 \), is set at a low value of 0.25. Furthermore, to manage the assets in the Heritage and Stabilisation Fund, a fee—which is set as a fraction of the assets in the Fund—is paid to the external fund managers and to the Central Bank of Trinidad and Tobago, who is the manager of the Fund.\(^{28}\) In line with the recent data on sovereign wealth funds, the total fee paid for managing the Fund, \( \phi^F \), is set at 1.10 percent; whereas, the share of the management fee that goes to residents, \( \nu \), is 0.80 percent.

Table 2.4 in the Appendix presents the initial steady-state values. The percent of resource output, nonresource tradable output and nontradable output to total output is set at 44.0 percent, 4.74 percent and 53.76 percent, respectively, to reflect the composition of output in the Trinidad and Tobago economy over the period 2007-2012. The steady-state value of private consumption for the period 2007-2012 is 67.4 percent, whereas private investment was estimated to be 11.5 percent for the same period. Total debt of the government as a share of GDP is set equal to 45.8 percent, which is consistent with the observed data for the period 2007-2011. Using Salandy and Henry (2013), the average stock of private capital flight for the same period represented 20.4 percent of GDP. Therefore, the economy’s stock of external debt as a share of GDP is calibrated at 45.8 – 20.4 = 25.4 percent. The sovereign wealth fund represents 17.8 percent of GDP, based on data for the period 2009-2012.

\(^{28}\)See The Heritage and Stabilisation Fund Act, No. 6 of 2007.
2.6 Dynamics of Resource Price Shocks

This section examines the transmission of a positive temporary shock to commodity prices under two "extreme" fiscal rules. The simulations show the percent deviation of the variables from their steady-state values, with the exception of the risk premium and the rental rate of capital, which are expressed in percentage points. In the first fiscal rule, the government spends all the excess revenue from the windfall. This is quite common in many resource-rich countries that have not established a sovereign wealth fund, or any other formal mechanism to manage the proceeds from natural resources. In the second fiscal rule, all the resource windfall is saved in a sovereign wealth fund. Under both rules, it is assumed that public debt is constant and lump-sum taxes adjust to clear the government budget.

2.6.1 Full Spending of Resource Windfall

The full spending experiment corresponds to the Hand-to-Mouth policy. This experiment is consistent with the view that governments in developing countries should use natural resource revenue to address their development needs. This is particularly important in capital scare economies that have infrastructure deficits, and poor education and health care services. Hence, under this rule, the government spends all the windfall on consumption and investment, so government spending rises by the amount of the windfall, and there is no asset accumulation in the sovereign wealth fund. Formally,

\[ G_t = T^O F_t, \]  \hspace{1cm} (2.47)

\[ F_t = 0, \]  \hspace{1cm} (2.48)

where (2.48) corresponds to \( \chi = 0 \) in (2.45).

Lump-sum taxes are solved residually from the government budget constraint,
(2.37), using (2.28),

\[
\hat{T}_t^L = \frac{1}{T^L} [-T^{NO} \hat{T}_t^{NO} - T^O \hat{T}_t^O - (1 + r^F) F(\hat{r}_t^F + \hat{F}_t) + F \hat{F}_t + G \hat{G}_t + (1 + r^W) D^G \hat{r}_t^W].
\]

Using (2.47) and (2.48), and with \( \hat{r}_t^F = 0 \), lump-sum taxes are given by,

\[
\hat{T}_t^L = \frac{1}{T^L} [-T^{NO} \hat{T}_t^{NO} + (1 + r^W) D^G \hat{r}_t^W].
\] (2.49)

Figure 2.11 shows the general equilibrium effects of a 5 percent temporary increase in resource prices. On impact of the shock, there is a fiscal effect, which causes an immediate increase in government resource revenues, and in turn leads to higher government spending, as well as a rise in public investment. The rise in government spending dominates the increase in resource revenues, thereby reducing the overall primary balance and the nonresource primary balance. Also, on impact of the shock, there is a temporary wealth effect created by higher income to household. The wealth effect causes households to increase total private consumption. The higher level of current consumption increases the demand for leisure and lowers labour supply. Thus, employment falls in the tradable and the nontradable sectors. The expansion in aggregate demand for nontradable goods leads to a real appreciation and causes the product wage in that sector to increase. The nonresource tradable sector shrinks because of the resource movement effect, as well as a result of the real appreciation which reduces the competitiveness of the nonresource tradable goods. Overall, under the full spending experiment, Dutch disease effects are significant. The expansion in demand for nontradable goods increases production of nontradables, as well as nonresource revenues.

Upon impact of the shock, total output increases which in turn reduces the risk premium and the world interest rate. The drop in the interest rate exerts downward
pressure on the aggregate rental rate of capital and increases private investment and
the total stock of physical capital. The lower interest rate also amplifies the increase
in private consumption today, through the intertemporal effect. Initially, there is
also a temporary reallocation of capital from the tradable sector to the nontradable
sector. This can be attributed to the real appreciation which dampens the effect of
the increase in the rental rate of capital in the nontradable sector, bringing about a
higher stock of capital in that sector. However, over time the increase in capital in
the nontraded goods sector quickly dissipates.

Due to absorption constraints, the higher level of public investment reduces the
efficiency of public investment and leads to a marginal increase in the public capital
stock. The slow rate of accumulation of both private and public capital causes the
public-private capital ratio to remain unchanged for a while before falling overtime.

2.6.2 Full Saving of Resource Windfall in Sovereign Wealth
Fund

The full saving rule corresponds to the Bird-in-Hand policy, which has been dis-
cussed in the literature. In this case all the resource revenue is accumulated in a
sovereign wealth fund and only the interest income generated from the fund is used
to finance government spending on consumption and investment, in proportion of
initial spending allocations. A key point to note is that saving from natural resource
rents can be used as a stabilization buffer to smooth fluctuations that can emanate
from future resource revenue shocks. In this experiment, which corresponds to $\chi = 1$
in (2.45), government spending is,

$$\hat{G}_t = \frac{1}{G} \left[ (1 + r^F) F(\hat{r}_t^F + \hat{F}_t) - F \hat{F}_t \right], \quad (2.50)$$
and the accumulation rule for the stock of assets is given by,

\[ \hat{F}_t = \frac{1}{F} \left[ (1 - \phi^F) F \hat{F}_{t-1} + \chi T^O \hat{T}^O_{t-1} \right]. \] (2.51)

The equation for lump-sum taxes, which excludes resource revenues, can be written as,

\[ \hat{T}^L_t = \frac{1}{F_L} \left[ -T^{NO} \hat{T}^{NO}_t - (1 + r^F) F (r^F_t + \hat{F}_t) \right. \]
\[ + F \hat{F}_t + G \hat{G}_t + (1 + r^W) D^{G}_{t}^{W} \] (2.52)

where using (2.50), lump-sum taxes are also determined by (2.49).

Figure 2.12 shows the simulations of a 5 percent temporary shock to resource prices under the full saving rule—compared to the full spending rule. Notably, if all the resource windfall is saved, Dutch disease effects are eliminated, and volatility in the fiscal variables is reduced. In comparison to the full spending rule, under the full saving rule government spending rises slowly, causing public investment to increase at a slower pace and government consumption to fall. The marginal and gradual rise in public investment reduces the absorption pressures; hence the efficiency of public capital falls by substantially less compared to the full spending experiment. The overall primary balance records a surplus in this case, and as a fraction of output the drop in the balance is mitigated. The sovereign fund assets as a fraction of output increases to around 30 percent of output.

Also, with the full saving rule, the increase in total output—which is less than the full spending case—causes the risk premium to fall, thereby lowering the cost of borrowing abroad, which in turn raises consumption today but by less than the previous case. The positive effect on consumption raises the demand for leisure and lowers labour supply but by less than the full spending case. The overall impact on aggregate demand is mitigated so the appreciation of the exchange rate is less significant. In comparison to the full spending experiment, the rental rate of capital
in the tradable sector falls by substantially less before increasing marginally. However, the drop in private capital in the nontradable sector is more substantial under the full saving experiment. The aggregate private capital stock rises because of the higher level of private investment. Overall, the fall in both employment and capital in the nontradable sector causes a contraction in the production of nontradables, which in turn lowers the product wage in the nontradable sector. Also, the drop in the nonresource tradable output is slightly less when all the windfall is saved. The contraction in the production of both nonresource tradables and nontradables lowers the increase in nonresource tax revenues, and mitigates the rise in total output. Given the lower increase in total output, volatility in the risk premium is lower, which in turn reduces fluctuations in the world interest rate and consumption.

2.7 Optimal Allocation of Resource Windfalls

An important practical issue for Trinidad and Tobago is how to determine the optimal allocation of the resource windfall between spending on consumption and investment, and saving in a sovereign wealth fund. Because of the volatility of resource revenue flows, it is necessary for some of the windfall to be set aside as a precautionary liquidity buffer. To examine this issue, a partial spending rule is considered whereby a fraction of the resource windfall, $\chi$, is saved—when there is a 5 percent temporary increase in resource prices. Under the partial spending approach, the asset accumulation rule is given by (2.51), and government spending and lump-sum taxes are adjusted to account for the share of the windfall that should be allocated to spending, $1 - \chi$. Thus,

\[
\dot{G}_t = \frac{1}{G} \left[ (1 - \chi)T^O \dot{T}_t^O + (1 + r^F)F(\dot{r}^F_t + \dot{F}_t) + F \dot{F}_t \right], \tag{2.53}
\]

\[
\dot{T}_t^L = \frac{1}{T^L} \left[ -T^{NO} \dot{T}^{NO}_t - (1 - \chi)T^O \dot{T}_t^O + (1 + r^W)D^G \dot{i}_t^W \right]. \tag{2.54}
\]
2.7.1 Social Loss Function

Using a similar approach to Agénor (2014), to determine the optimal level of resource windfalls that should be saved, $\chi$, the partial spending rule is applied to minimize a social loss function defined as a weighted geometric average of the volatility of private consumption, $\sigma_C^\chi$, normalized to its steady-state value, $C^{SS}$, and the volatility of the overall primary balance to output ratio, $\sigma_{OPBY}^\chi$, normalized to its steady-state value, $OPBY^{SS}$.\(^{29}\) The criterion used therefore accounts for both household welfare, which is affected by volatility of private consumption, and fiscal stability. Owing to the fact that in Trinidad and Tobago consumption is highly volatile, an important concern to policymakers is to minimize welfare losses. The overall primary balance is used as the fiscal indicator because Trinidad and Tobago has a long reserve horizon; therefore, the aim is to manage revenue volatility.\(^{30,31}\) The social loss function is given by,

$$
L_t^S(\chi) = \left(\frac{\sigma_C^\chi}{C^{SS}}\right)^\mu \left(\frac{\sigma_{OPBY}^\chi}{OPBY^{SS}}\right)^{1-\mu},
$$

where $\mu \in (0,1)$. The loss is calculated using the asymptotic variances, for $\mu$ and $\chi$ both varying between 0 and 1 with a grid of 0.1. If the government is mainly concerned about fiscal stability then $\mu = 0$; whereas, if the government sets policy only on the basis of household welfare, $\mu = 1$.

Table 2.5 presents the results of the social loss function, with the optimal values

\(^{29}\)The specification of the social loss function (as well as the generalized loss function, discussed later) differs slightly from Agénor (2014) who used the nonresource primary balance instead of the overall primary balance to output ratio.

\(^{30}\)Baunsgaard et al. (2012) and International Monetary Fund (2012a) use the threshold of less than or greater than 35 years to distinguish between short and long reserve horizons. These studies also recommend that the nonresource primary balance be used in countries with a short reserve horizon. If the proven, possible, probable and explorative resources are considered, oil and gas reserves in Trinidad and Tobago exceed 35 years. This therefore means that the economy is considered to have a long reserve horizon. In addition, as mentioned previously, the economy is a mature energy producer.

\(^{31}\)Le Fort (2013) pointed out that because the government of Trinidad and Tobago obtains significant revenues from the resource sector, the overall (primary) balance is a better indicator of the fiscal policy stance.
in red. The results reveal that if the government is mainly concerned about fiscal stability, then all the excess revenue should be saved ($\chi = 1$). In the case where there are equal weights on consumption volatility and fiscal volatility ($\mu = 0.5$), then $\chi = 0.8$ which implies that 80 percent of the resource windfall should be saved. If the government is only concerned about consumption volatility ($\mu = 1$), then $\chi = 0.6$. Contrary to Agénor (2014), these findings indicate that if the government is concerned more about household welfare, a greater fraction of the excess revenue should be spent, as this can help to improve welfare. An analysis of the data for Trinidad and Tobago shows that as the share of revenues from the energy sector increases, the share of social expenditure rises. Similarly, Spatafora and Samake (2012) found that commodity price shocks are associated with a significant increase in social expenditure in commodity-exporting developing countries.

### 2.7.2 Alternative Specification of Loss Function

This section extends the social loss function given in (2.55) to obtain a generalized loss function similar to Agénor (2014). In addition to the volatility of private consumption, the generalized loss function includes a broader measure of macroeconomic volatility defined in terms of a weighted average of the volatility of the overall primary balance to output ratio and the volatility of the real exchange rate, $\sigma^Z$, scaled to their respective steady-state values. The generalized loss function is given as,

$$L^G_t(\chi) = (\frac{\sigma^X_C}{C^{SS}})^\mu[(-\frac{\sigma^X_{OPBY}}{OPBY^{SS}})^{0.8}(\frac{\sigma^X_Z}{Z^{SS}})^{0.2}]^{1-\mu}, \quad (2.56)$$

where $Z^{SS}$ represents the steady-state value for the real exchange rate.

Table 2.6 illustrates the results of the optimal value of $\chi$, using weights of 0.8 and 0.2 on the fiscal indicator and the real exchange rate, respectively, when the gen-

---

32 A main concern for policymakers is to minimize losses in household welfare (as indicated earlier). In light of this, the generalized loss function is specified to capture the trade-off between household welfare only, and macroeconomic volatility.
eralized loss function is used. These weights were chosen to consider a government that—while being concerned with real exchange rate volatility—remains mainly focused on mitigating fiscal instability as a source of macroeconomic instability. The findings show that the optimal allocation parameter is lower in general. Therefore, if the government is concerned solely about macroeconomic stability, $\mu = 0$, 80 percent of the windfall should be saved, whereas if the main focus is on consumer welfare, $\mu = 1$, 60 percent of the excess revenue should be saved.

Figure 2.13 shows the volatility of consumption, the overall primary balance to output ratio and the real exchange rate, with $\chi$ varying between 0 and 1. In the case where $\chi = 0$ (the full spending rule) the overall primary balance to output ratio is highly volatile, but as more of the windfall is saved (as $\chi$ tends to 1) fiscal volatility is consistently reduced. In a similar way, consumption is more volatile under the full spending rule, but as the proportion of resource revenue saved in a sovereign fund increases volatility is reduced. However, because the interest income from the assets tends to raise spending on consumption and investment over time, volatility increases once again. As noted earlier, this is the main insight from Agénor’s (2014) contribution and it explains why consumption volatility takes a convex shape. With regard to the real exchange rate, there is a gradual increase in volatility initially, but as more of the windfall is saved volatility rises because the higher interest income from the assets in the fund increases spending and creates pressure on the exchange rate.

2.8 Sensitivity Analysis

This section tests the robustness of the results for the optimal value calculated for $\chi$ using the social loss function in Section 2.7.1—which is the benchmark case. To conduct this exercise, I consider changes in some parameter values to assess: a higher degree of capital mobility; less resources to domestic residents via a lower
share of the management fee; and tighter absorption constraints. I also examine an alternative specification of the risk premium and an investment-only spending rule.

2.8.1 Higher Degree of Capital Mobility

Table 2.7 shows the optimal values for the social loss function when there is an increase in the elasticity of substitution between $K_t^N$ and $K_t^T$, $\eta_K$, from 0.5 to 0.8. If private capital is more mobile across sectors then it is much easier to shift resources between the production of traded and nontraded goods. A higher degree of capital mobility will increase the volatility of a commodity price shock on output and consumption, and should therefore require a higher optimal $\chi$. The results presented in Table 2.7 show that if $\mu = 0.5$ the optimal value is 0.9 compared to 0.8 in the benchmark case (Table 2.5). If more emphasis is placed on fiscal stability ($\mu = 0$ or $\mu = 0.1$), the optimal value for $\chi$ is 1.0—which is the same value in Table 2.5. Hence, to better distinguish these results, a smaller grid of 0.01 was done for $\chi$ varying between 0.9 and 1.0. The results (which are not reported) show that if $\mu = 0.1$ a higher optimal value of 1.0 is required compared to a value 0.97 under the benchmark case.

2.8.2 Lower Share of Management Fee to Residents

If residents receive a lower share of the management fee, it means that a larger proportion of the windfall will leave the country to nonresidents. This therefore reduces the wealth effect to household and lowers aggregate demand, thereby reducing on impact volatility in consumption, the real exchange rate and output, so less (given the form of the loss function and the nature of the government’s optimization problem) of the windfall should be saved. The results, which are reported in Table 2.8, show that as the share of the management fee that goes to residents, $\nu$, is reduced from 0.8 percent to 0.5 percent, the optimal value for $\chi$ is lower. For example, if the sole concern is about fiscal stability, the optimal $\chi$ is 0.9 compared to 1.0 under
the benchmark case (see Table 2.5). Also, if the government is concerned about consumption volatility and fiscal volatility equally ($\mu = 0.5$), then the optimal value for $\chi$ is 0.7 as compared to 0.8. But when the focus shifts more towards household welfare, the results show that more of the windfall should be spent. Thus, if $\mu = 0.8$, the optimal value is 0.4 as compared to 0.7 in Table 2.5. Intuitively, because households have less income the magnitude of the wealth effect is smaller, so consumption increases by less, which in turn reduces volatility. Because a higher weight is attached to consumption volatility (or household welfare), then the government can afford to spend more and save less.

2.8.3 Higher Incidence of Absorption Constraints

Due to absorption constraints in developing countries, an increase in public investment causes efficiency to fall. A lower efficiency of public investment should therefore reduce the volatility of the public capital stock, which in turn will reduce fluctuations in macroeconomic variables, and hence require a lower optimal $\chi$. The results from this experiment (which are not reported) show that when $\varphi_1$ increases from 0.05 to 0.06 the optimal values are the same as the benchmark case (Table 2.5). To examine this closer I calculate the optimal values using a finer grid of 0.01 for $\chi$ varying between 0.9 and 1.0. The results show that with $\mu = 0.2$, the optimal value is 0.94 compared with 0.95 in the benchmark case, thereby implying a lower optimal value with a higher absorption constraint. However, this effect is not very strong in the present case.

2.8.4 Alternative Specification of the Risk Premium

Consider now a different specification of the risk premium, where government debt is scaled by total nonresource output, instead of total output. Thus, equation (2.40) is now specified as,
\[ PR_t = \left( \frac{D_t^G}{Y_t^F + \zeta_t^{-1}Y_t^N} \right)^{pr1}. \] (2.57)

Given the inherent volatility and uncertainty of resource revenues, they can be seen as a weakness and may not be considered by markets in determining the premium countries pay on international capital markets. Therefore, by using (2.57), the effect of the shock on the risk premium and the world interest rate will be mitigated. Thus, volatility in the interest rate will be reduced, which in turn, will lower volatility in total output and consumption—thereby implying a lower optimal \( \chi \).

Table 2.9 shows that under the new specification for the risk premium, the optimal value for \( \chi \) is reduced. If the government is concerned about fiscal volatility, the optimal value is 0.9 compared to 1.0 in Table 2.5. Also, as more emphasis is placed on household welfare, the optimal value falls. For example, if \( \mu = 0.9 \), then 50 percent of the windfall should be saved compared to 70 percent in Table 2.5.

### 2.8.5 Public Investment of Resource Windfalls

In the previous analysis, it was assumed that the government spent the resource windfall or interest income accrued on the assets in the sovereign fund on consumption and investment, and based on this the social loss function was used to determine the optimal allocation that should be saved and spent. This section examines the case where instead the resource windfall or interest income is used for investment purposes only. Therefore, the social loss function is used to calculate the optimal share of the windfall that should be saved, \( \chi \), and the fraction that should be spent on infrastructure investment \((1 - \chi)\). In this case, public investment and government spending are given by,

\[ \hat{I}_t^G = \frac{1}{I_t^G} \left[ (1 - \chi)T^O \hat{I}_t^O + (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) - FF_t \right], \] (2.58)

\[ G\hat{G}_t = I_t^G \hat{I}_t^G + \zeta^{-1}C_t^G(\hat{C}_t^G - \hat{z}_t). \] (2.59)
Combining (2.58) and (2.59) and then inserting the result in (2.52), lump-sum taxes are,

\[ \hat{\tau}_t^L = \frac{1}{TL} \left[ -T^NO \hat{T}_t^{NO} + z^{-1} C^G (\hat{\tau}_t^G - \hat{z}_t) + (1 + r^W) D^G \hat{r}_t^W \right]. \] (2.60)

The results, which are presented in Table 2.10, show lower optimal values for \( \chi \), implying therefore that if the resource windfall is used for investment, a smaller share should be saved. For instance, if the concern is about fiscal stability the optimal \( \chi = 0.4 \) compared with \( \chi = 1 \) in Table 2.5. Interestingly, for \( \mu = 0.2 \) to \( \mu = 1 \), the optimal rule recommends that all the windfall be spent on investment. Depending on an economy’s development needs, it can therefore be optimal to use all the excess resource revenue to reduce infrastructure deficits.

### 2.9 Resource Production Shock

A resource windfall can also occur if there is an increase in resource production, created by the discovery of new reserves. This experiment examines the transmission of a temporary positive shock to resource production under the full spending and full saving rules, as well as the optimal allocation between spending (on consumption and investment) and saving.

Figure 2.14 shows the simulations for a 5 percent shock to resource production under the full spending rule, compared to the results from the 5 percent price shock. The simulations show that in most cases, the dynamics of the resource production shock under the full spending rule follow the same pattern as the resource price shock. A key difference to note is that on impact of the production shock, the rental rate of capital in the nontraded goods sector declines, thereby amplifying the increase in private capital and output in the nontradable sector. Furthermore, the real exchange rate appreciates by substantially less, reducing the volatility in private consumption and total output—in comparison to the shock to resource prices. Also,
volatility in the fiscal variables is slightly lower but fluctuations in private investment are more notable when there is an increase in natural resource production.

The results for the 5 percent resource production shock under the full saving rule (compared to the 5 percent shock to resource prices) are shown in Figure 2.15. Similar to the full spending experiment, although the appreciation of the real exchange rate is less significant under the production shock, the marginal drop in the rental rate of capital in the nontradable sector leads to a higher private capital stock in that sector and in turn a greater expansion in nontradable production. In addition, primarily owing to the slight reduction in the volatility of total output, fluctuations in the risk premium and the world interest rate are reduced. This in turn reduces volatility in consumption and private investment under the output shock—in comparison to the price shock.

The results for the optimal values of \( \chi \) when the social loss function (2.55) is applied under the resource production shock are presented in Table 2.11. In general, when compared to the price shock, the optimal values appear the same in most cases under the output shock—with the exception of the case where the government is only concerned about household welfare. Therefore, if there is a resource windfall, as a result of a production shock, the optimal allocation rule provides a similar suggestion to the case where the windfall is emanated from a price shock—that is, a greater share of the excess revenue should be saved if the government is concerned about fiscal stability. However, if \( \mu = 1 \), the optimal value under the output shock is 0.5 compared with 0.6 under the price shock in Table 2.5, which implies that more of the windfall should be spent if the aim is to reduce consumption volatility.

2.10 Summary and Policy Implications

This chapter applied a three-sector Dynamic Stochastic General Equilibrium model to determine the transmission of a temporary resource price shock and a produc-
tion shock under two fiscal rules: a full spending rule and a full saving rule. The model was calibrated for Trinidad and Tobago—a resource-rich developing country that faces the challenge of prudent management of resource windfalls. The chapter also examined an optimal allocation rule between spending today and saving in a sovereign wealth fund. Thus, an important contribution of this research has been to determine the fraction of the resource windfall that should be deposited into the country’s sovereign wealth fund. The allocation rule used to determine the optimal share is defined to minimize a social loss function, that is specified in terms of the volatility of private consumption—which is used to capture household welfare—and fiscal stability.

The results show that spending all the resource windfall on consumption and investment creates a lot of volatility, in general, and amplifies Dutch disease effects—whereas if all the windfall is saved, the contraction in the nonresource tradable sector, as well as the real appreciation, is mitigated. Also, under the full saving rule, the expansion in the nontraded sector is eliminated. This implies that because the level of government spending is lower when all the resource windfall is saved, aggregate demand pressures are substantially reduced in the economy, which in turn lowers demand for production of nontradables.

Furthermore, similar to Agénor (2014), the results from the social loss function show that under the optimal allocation rule of resource windfalls, there is a dynamic volatility trade-off (overall) between spending today and tomorrow. In addition, the findings from this study reveal that there is a trade-off between each volatility measure in the loss function; this trade-off is more apparent for consumption. Thus, as the share of the windfall saved in the sovereign wealth fund increases over time, the interest income accumulated from the assets rises, causing an increase in spending, which in turn raises consumption volatility once again. By contrast, saving a larger proportion of the resource windfall does not increase fiscal volatility but rather lowers fluctuations in the overall primary balance to output ratio. Also, although spending
all the resource windfall on consumption and investment creates a lot of volatility in both consumption and the overall primary balance to output ratio, fluctuations in consumption are greater, in general, than fiscal volatility.

It is important to note that if the government is equally concerned about household welfare and fiscal stability, neither the full spending rule nor the full saving rule is the optimal fiscal response to resource windfalls. Saving a fraction of the windfall in a sovereign wealth fund can help to reduce the impact of an increase in resource prices on welfare, and lower fiscal volatility. The share that should be saved will depend on whether the government is concerned about consumption volatility or fiscal stability. In addition, the findings reveal that an increase in new reserves, or a resource production shock, can have similar effects as a temporary rise in commodity prices.\textsuperscript{33} This is because both types of shock translate into higher government resource revenues and a wealth effect to the private sector. Therefore, following a resource production shock, it is also optimal for a larger share of the excess revenues to be saved, if the focus is more towards fiscal stability.

According to the optimal rule, if the government of Trinidad and Tobago is relatively more concerned about fiscal stability than household welfare, a larger proportion of the resource windfall should be deposited in the Heritage and Stabilisation Fund. In the case where the government is equally concerned about fiscal stability and household welfare, the optimal rule suggests that about 80 percent of the windfall should be saved—which is greater than the fraction of the excess revenue that the government is mandated to save according to the deposit rule for the Heritage and Stabilisation Fund.\textsuperscript{34} Also, considerations should be given for the excess revenue to be deposited into the Fund on an annual (or semi-annual) basis, rather than on a quarterly basis as specified by the Heritage and Stabilisation Fund Act.

\textsuperscript{33}This result is similar to a study by Pieschacón (2012) that found new oil discoveries have the same effects as an increase in oil prices and therefore requires a similar fiscal policy response.

\textsuperscript{34}The Parliament Republic of Trinidad and Tobago established the Heritage and Stabilisation Fund by an Act in 2007. In practice, implementing this optimal rule requires an amendment to the Heritage and Stabilisation Fund Act, which must be approved by the Parliament.
Furthermore, similar to the deposit rule for the Heritage and Stabilisation Fund, the optimal rule can be applied if actual energy revenues exceed budgeted revenues by at least 10 percent. In the case where the actual revenues exceed the budgeted revenues by less than 10 percent, the authorities can consider the current economic conditions to determine the fraction of the excess revenue (if any) to be saved.

Overall, these findings indicate that fiscal policy can help to mitigate the effects of shocks to resource prices and production. Also, the government of Trinidad and Tobago should review its policy so that a larger proportion of the proceeds from the energy sector is saved. Thus, as posited by van den Bremer and van der Ploeg (2013), in countries where resource income make up a larger share of total income—as in Trinidad and Tobago—it is critical for the size of the liquidity fund (or the stabilization buffer) to be larger. Furthermore, owing to the fact that increases in commodity prices and non-renewable reserves are temporary, the government should (gradually) reduce dependence on surplus resource inflows. This is necessary because of the recent fall in resource revenue—which resulted from both a fall in energy reserves and a decline in world oil prices.

Moreover, the efficiency of public investment spending in Trinidad and Tobago was estimated to be 27.5 percent—which is substantially low for a high-income country (see Dabla-Norris et al. (2012)). In light of the low quality of government investment spending, it can therefore be optimal to save a larger proportion of the windfall gains. Put differently, saving more of the windfall until the efficiency of government spending improves, can help to reduce wastage of the country’s natural resource wealth. This finding underscores the importance of governance reforms to improve the efficiency of investment spending, before optimum benefits can be gained from spending a larger proportion of the resource windfall.

\[^{35}\text{Similarly, the International Monetary Fund (2012a) suggested that resource-rich developing countries should save a high proportion of their resource revenues. This is necessary to delink spending from the dynamics of resource revenue to avoid boom-bust cycles.}\]

\[^{36}\text{If indeed the government were to improve the quality of spending, then it would be optimal to save less. This is corroborated by simulations (which are not reported here) with a higher value for the efficiency of public investment.}\]
Although there have been similar attempts by other researchers to determine the optimal fiscal response of temporary resource windfalls, this study departs from those in the literature because it uses the Dynamic Stochastic General Equilibrium methodology. Nonetheless, the overall findings of this research can be compared to other studies. Similar to Collier et al. (2010) and van der Ploeg (2012), I find that spending all the revenue from a temporary resource windfall leads to an increase in aggregate demand pressures on the nontraded sector and an appreciation of the real exchange rate. However, van der Ploeg and Venables (2011) found that if the excess resource revenue is not spent on nontradables, the real exchange appreciation and the contraction in the nonresource tradable sector are avoided. In addition, van der Ploeg and Venables (2013) found that optimal revenue management of a resource windfall requires investing in the nonresource tradable sector and building up consumption slowly. This is contrary to the results in this study which show that the optimal fiscal response requires reducing the share of the windfall spent on both consumption and investment, while simultaneously increasing savings.
Table 2.1: Economic Contribution of the Energy Sector (percent, 2000-2012)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy GDP to Total GDP</td>
<td>31.3</td>
<td>36.0</td>
<td>47.0</td>
<td>34.6</td>
<td>43.7</td>
</tr>
<tr>
<td>Energy Revenue to Total</td>
<td>30.2</td>
<td>42.8</td>
<td>61.9</td>
<td>49.5</td>
<td>54.3</td>
</tr>
<tr>
<td>Government Revenues*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy Exports to Total Exports</td>
<td>81.2</td>
<td>83.3</td>
<td>91.1</td>
<td>86.1</td>
<td>81.4</td>
</tr>
<tr>
<td>Energy Sector Employment to Total Employment</td>
<td>3.2</td>
<td>3.2</td>
<td>3.5</td>
<td>3.3</td>
<td>3.5</td>
</tr>
</tbody>
</table>

Note: Government revenues only include taxes and royalties paid by companies in the exploration and production business and the refinery business.

Source: Central Bank of Trinidad and Tobago, Annual Economic Survey (various years).
### Table 2.2: Infrastructure Indicators in Trinidad and Tobago compared to the Upper Middle-Income and High-Income Groups

<table>
<thead>
<tr>
<th>Item</th>
<th>Trinidad &amp; Tobago</th>
<th>Year</th>
<th>Upper Middle-Income Group**</th>
<th>High-Income Group**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed broadband Internet subscribers (per 100 people)</td>
<td>12</td>
<td>2011</td>
<td>9.96</td>
<td>27.3</td>
</tr>
<tr>
<td>Internet users (per 100 people)</td>
<td>55</td>
<td>2011</td>
<td>38.2</td>
<td>75.8</td>
</tr>
<tr>
<td>Fixed telephone lines (per 100 people)</td>
<td>22</td>
<td>2011</td>
<td>20.9</td>
<td>47.3</td>
</tr>
<tr>
<td>Mobile cellular subscriptions (per 100 people)</td>
<td>137</td>
<td>2011</td>
<td>92.4</td>
<td>114.1</td>
</tr>
<tr>
<td>Quality of port infrastructure</td>
<td>4</td>
<td>2011</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>(1=extremely underdeveloped to 7=well developed and efficient)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roads, paved (% of total roads)</td>
<td>51.1</td>
<td>2001*</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Access to electricity (% of population)</td>
<td>99</td>
<td>2011</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Water and Sanitation (out of 100)</td>
<td>52.08</td>
<td>2014</td>
<td>n/a</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Notes:*Latest data available; **Data corresponds to 2011.

Sources: World Development Indicators, World Bank; United Nations Educational, Scientific, and Cultural Organization (UNESCO) Institute for Statistics; and the Environmental Performance Index.
Table 2.3: Calibrated Parameter Values: Benchmark Case

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>0.972</td>
<td>$\lambda$</td>
</tr>
<tr>
<td>Intertemporal elasticity of substitution</td>
<td>0.2</td>
<td>$\zeta$</td>
</tr>
<tr>
<td>Preference parameter, labour in utility function</td>
<td>0.2</td>
<td>$\eta_L$</td>
</tr>
<tr>
<td>Inverse of labour supply elasticity</td>
<td>12</td>
<td>$\psi$</td>
</tr>
<tr>
<td>Share of nontradables in total private consumption</td>
<td>0.55</td>
<td>$\theta$</td>
</tr>
<tr>
<td>Share of energy products in total tradable consumption</td>
<td>0.06</td>
<td>$\theta^T$</td>
</tr>
<tr>
<td>Adjustment cost parameter, private investment</td>
<td>30</td>
<td>$\kappa$</td>
</tr>
<tr>
<td>Depreciation rate, private capital</td>
<td>0.045</td>
<td>$\delta^P$</td>
</tr>
<tr>
<td>Share of capital in the traded sector</td>
<td>0.6</td>
<td>$\zeta_K$</td>
</tr>
<tr>
<td>Elasticity of substitution between $K^N_t$ and $K^T_t$</td>
<td>0.5</td>
<td>$\eta_K$</td>
</tr>
<tr>
<td>Share of resource windfall households receive</td>
<td>0.884</td>
<td>$\psi^O$</td>
</tr>
<tr>
<td>Persistence parameter, resource output</td>
<td>0.912</td>
<td>$\rho^O^Y$</td>
</tr>
<tr>
<td>Persistence parameter, world resource price</td>
<td>0.93</td>
<td>$\rho^O^P$</td>
</tr>
<tr>
<td>Labour shares, tradable and nontradable sectors</td>
<td>0.6, 0.65</td>
<td>$\beta, \eta$</td>
</tr>
<tr>
<td>Elasticity of output with respect to public capital</td>
<td>0.17</td>
<td>$\omega_T = \omega_N$</td>
</tr>
<tr>
<td>Effective tax rate on resource income</td>
<td>0.41</td>
<td>$\tau^O$</td>
</tr>
<tr>
<td>Effective tax rate on nonresource income</td>
<td>0.147</td>
<td>$\tau^NO$</td>
</tr>
<tr>
<td>Share of government spending on output</td>
<td>0.138</td>
<td>$\psi^G$</td>
</tr>
<tr>
<td>Share of spending on infrastructure investment</td>
<td>0.151</td>
<td>$\nu^G$</td>
</tr>
<tr>
<td>Share of infrastructure investment on nontraded goods</td>
<td>0.41</td>
<td>$\nu^G,N$</td>
</tr>
<tr>
<td>Investment efficiency parameter</td>
<td>0.275</td>
<td>$\varphi$</td>
</tr>
<tr>
<td>Absorption constraint parameter, public investment</td>
<td>0.05</td>
<td>$\varphi^1$</td>
</tr>
<tr>
<td>Depreciation rate, public capital</td>
<td>0.035</td>
<td>$\delta^G$</td>
</tr>
<tr>
<td>Management fee on sovereign assets</td>
<td>0.011</td>
<td>$\phi_F$</td>
</tr>
<tr>
<td>Share of management fee paid to residents</td>
<td>0.80</td>
<td>$\nu$</td>
</tr>
<tr>
<td>World risk-free interest rate</td>
<td>0.01</td>
<td>$r_{W,R}$</td>
</tr>
<tr>
<td>Elasticity with respect to the debt to output ratio</td>
<td>0.25</td>
<td>$pr^1$</td>
</tr>
</tbody>
</table>
Table 2.4: Trinidad and Tobago: Initial Steady-State Values (in percent of total output, unless otherwise indicated)

<table>
<thead>
<tr>
<th>Description</th>
<th>Steady-State Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resource output</td>
<td>0.44</td>
</tr>
<tr>
<td>Nontradable output</td>
<td>0.5376</td>
</tr>
<tr>
<td>Nonresource tradable output</td>
<td>0.0474</td>
</tr>
<tr>
<td>Share of employment in nontradable sector</td>
<td>0.926</td>
</tr>
<tr>
<td>Private consumption</td>
<td>0.674</td>
</tr>
<tr>
<td>Share of energy products consumed in total consumption</td>
<td>0.003</td>
</tr>
<tr>
<td>Private investment</td>
<td>0.115</td>
</tr>
<tr>
<td>Total government spending</td>
<td>0.138</td>
</tr>
<tr>
<td>Total revenue</td>
<td>0.151</td>
</tr>
<tr>
<td>Resource revenue</td>
<td>0.22</td>
</tr>
<tr>
<td>Nonresource revenue</td>
<td>0.086</td>
</tr>
<tr>
<td>Private debt</td>
<td>-0.204</td>
</tr>
<tr>
<td>Government debt</td>
<td>0.458</td>
</tr>
<tr>
<td>Total foreign liabilities</td>
<td>0.254</td>
</tr>
<tr>
<td>Private capital</td>
<td>2.07</td>
</tr>
<tr>
<td>Public-private capital ratio</td>
<td>0.11</td>
</tr>
<tr>
<td>Overall primary balance</td>
<td>12.42</td>
</tr>
<tr>
<td>Risk premium</td>
<td>0.0186</td>
</tr>
<tr>
<td>Assets in sovereign wealth fund</td>
<td>0.178</td>
</tr>
<tr>
<td>VARIABLE</td>
<td>Rel SD</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
</tr>
<tr>
<td>( \chi = 0.0 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>10.6870</td>
</tr>
<tr>
<td>( \chi = 0.1 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>10.3195</td>
</tr>
<tr>
<td>( \chi = 0.2 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.9793</td>
</tr>
<tr>
<td>( \chi = 0.3 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.6693</td>
</tr>
<tr>
<td>( \chi = 0.4 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.3927</td>
</tr>
<tr>
<td>( \chi = 0.5 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.1523</td>
</tr>
<tr>
<td>( \chi = 0.6 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.9510</td>
</tr>
<tr>
<td>( \chi = 0.7 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.7916</td>
</tr>
<tr>
<td>( \chi = 0.8 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.6764</td>
</tr>
<tr>
<td>( \chi = 0.9 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.6073</td>
</tr>
<tr>
<td>( \chi = 1.0 )</td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.5850</td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
Table 2.6 Optimal Allocation of Resource Windfalls under Generalized Loss Function

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\mu = 0.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>10.6870</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>3.6843</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>10.3195</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>3.7247</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.9793</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>3.8609</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.6693</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>3.8609</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.4$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.3927</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>3.9550</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.1523</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.0647</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.9510</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.1890</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.7$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.7916</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.3265</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.8$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.6764</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.4761</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 0.9$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.6073</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.6365</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\mu = 1.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.5850</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>4.8067</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Z is the real exchange rate; Rel SD is the Relative Standard Deviation.
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>( \mu = 0.0 )</th>
<th>( \mu = 0.1 )</th>
<th>( \mu = 0.2 )</th>
<th>( \mu = 0.3 )</th>
<th>( \mu = 0.4 )</th>
<th>( \mu = 0.5 )</th>
<th>( \mu = 0.6 )</th>
<th>( \mu = 0.7 )</th>
<th>( \mu = 0.8 )</th>
<th>( \mu = 0.9 )</th>
<th>( \mu = 1.0 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPB/Y</td>
<td>11.8762</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \mu = 1.0 )</td>
<td>9.8626</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi = 0.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.4$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.7$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.8$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.9$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 1.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPB/Y</td>
<td>9.9598</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.6063</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>9.2833</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.9941</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.7425</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.5313</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.3640</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.2428</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.1701</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.1472</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.1745</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
Table 2.10 Social Loss Function: Public Investment of Resource Windfalls

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>χ = 0.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>22.2701</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>22.0331</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>21.8716</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>21.7866</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>21.7796</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>21.8503</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>21.9981</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>22.2215</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>43.9222</td>
<td>22.5182</td>
<td>24.0740</td>
<td>25.7373</td>
<td>27.5156</td>
<td>29.4167</td>
<td>31.4491</td>
<td>33.6220</td>
<td>35.9450</td>
<td>38.4285</td>
<td>41.0836</td>
<td>43.9222</td>
</tr>
<tr>
<td>OPB/Y</td>
<td>22.5182</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 0.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>46.1076</td>
<td>22.8853</td>
<td>24.5459</td>
<td>26.3269</td>
<td>28.2372</td>
<td>30.2861</td>
<td>32.4837</td>
<td>34.8407</td>
<td>37.3687</td>
<td>40.0802</td>
<td>42.9884</td>
<td>46.1076</td>
</tr>
<tr>
<td>OPB/Y</td>
<td>22.8853</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>χ = 1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>23.3196</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author’s calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
### Table 2.11 Social Loss Function: Resource Production Shock

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>Rel SD</th>
<th>0</th>
<th>0.1</th>
<th>0.2</th>
<th>0.3</th>
<th>0.4</th>
<th>0.5</th>
<th>0.6</th>
<th>0.7</th>
<th>0.8</th>
<th>0.9</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\chi = 0.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.9032</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.1$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.5617</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.2$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>8.2447</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.3$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.9552</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.4$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.6963</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.5$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.4710</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.6$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.2828</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.7$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.1343</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.8$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>7.0283</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 0.9$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>6.9664</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\chi = 1.0$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPB/Y</td>
<td>6.9499</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Author's calculations.
Notes: C denotes consumption; OPB/Y is the overall primary balance to output ratio; Rel SD is the Relative Standard Deviation.
Figure 2.1: Trinidad and Tobago: Overall Primary Balance and Non-Energy Primary Balance (as a percent of GDP)

Source: Central Bank of Trinidad and Tobago.
Figure 2.2: Real GDP Growth in Trinidad and Tobago

Source: Central Bank of Trinidad and Tobago.
Figure 2.3: Trinidad and Tobago’s Terms of Trade Index

Source: Central Bank of Trinidad and Tobago.
Figure 2.4: Production Structure in Trinidad and Tobago

Source: Central Statistical Office of Trinidad and Tobago.
Figure 2.5: Trinidad and Tobago’s Real Effective Exchange Rate (2005=100; increase in index represents an appreciation)

Source: International Monetary Fund Database.
Figure 2.6: Trinidad and Tobago’s Global Competitiveness Index (GCI)

Figure 2.7: Sectoral Distribution of Employment in Trinidad and Tobago (percent of Total Employment)

Source: Central Bank of Trinidad and Tobago.
Figure 2.8: Crude Oil Production in Trinidad and Tobago

Source: Central Bank of Trinidad and Tobago Database.
Figure 2.9: Natural Gas Production in Trinidad and Tobago

Source: Central Bank of Trinidad and Tobago Database.
Figure 2.10: Assets of the Heritage and Stabilisation Fund (HSF) as a percent of GDP

Source: Trinidad and Tobago Heritage and Stabilisation Fund, Quarterly Investment Report (various issues).
Absolute deviations from baseline, unless otherwise indicated.
Figure 2.12: Full Saving Experiment versus Full Spending Experiment

Absolute deviations from baseline, unless otherwise indicated.
Figure 2.13: Volatility of Consumption, the Real Exchange Rate and the Overall Primary Balance to Output Ratio as a Fraction of the Resource Windfall Saved

Note: $x$ represents the share of the resource windfall saved in the Sovereign Wealth Fund.
Figure 2.14: Full Spending Experiment: Resource Price Shock versus Resource Production Shock

Absolute deviations from baseline, unless otherwise indicated.
Figure 2.15: Full Saving Experiment: Resource Price Shock versus Resource Production Shock

Absolute deviations from baseline, unless otherwise indicated.
2.A Appendix

2.A.1 Solution to Optimization Problems

The Lagrangian for the tradable consumption problem is,

$$C_t^T = (C_t^{TO})^{\theta T} (C_t^{TNO})^{1-\theta T} + \mu [C_t^T - C_t^{TNO} - P_t^O C_t^{TO}]. \quad (2.61)$$

The first-order conditions for $C_t^{TO}$ and $C_t^{TNO}$ are,

$$\theta^T (C_t^{TO})^{(\theta T - 1)} (C_t^{TNO})^{1-\theta T} = \mu P_t^O, \quad (2.62)$$

$$(1 - \theta^T) (C_t^{TO})^{\theta T} (C_t^{TNO})^{-\theta T} = \mu. \quad (2.63)$$

Combining (2.62) and (2.63),

$$C_t^{TNO} / C_t^{TO} = [(1 - \theta^T) / \theta^T] P_t^O. \quad (2.64)$$

Substituting for $C_t^{TNO}$ in the budget constraint gives,

$$C_t^{TO} = \theta^T (P_t^O)^{-1} C_t^T. \quad (2.65)$$

Similar manipulations yield,

$$C_t^{TNO} = (1 - \theta^T) C_t^T. \quad (2.66)$$

The derivation of the savings-investment balance can be given by first adding the private sector and government budget constraints,

$$D_{t+1}^P = (1 + r_t^W)D_t^P - (1 - \tau^{NO})(Y_t^T + z_t^{-1}Y_t^N)$$

$$-\psi^O (1 - \tau^O)P_t^O Y_t^O + C_t + I_t^P + T_t^L,$$
and

\[ D_{t+1}^G = (1 + r_t^W)D_t^G + G_t - T_t, \]

which gives,

\[ D_{t+1}^P + D_{t+1}^G = (1 + r_t^W)D_t^P + (1 + r_t^W)D_t^G - (1 - \tau^{NO})(Y_t^T + z_t^{-1}Y_t^N) \]

\[ -\psi^O(1 - \tau^O)P_t^OY_t^O + C_t + I_t^P + T_t^L + G_t - T_t, \]

or,

\[ D_{t+1} = (1 + r_t^W)D_t - (1 - \tau^{NO})(Y_t^T + z_t^{-1}Y_t^N) \]

\[-\psi^O(1 - \tau^O)P_t^OY_t^O + C_t + I_t^P + T_t^L + G_t - T_t, \]

substituting for \( T^L \) from (2.28) gives,

\[ D_{t+1} = (1 + r_t^W)D_t - (Y_t^T + z_t^{-1}Y_t^N) - \psi^O(1 - \tau^O)P_t^OY_t^O + C_t \]

\[ +I_t^P - (1 - \chi)\tau^OP_t^OY_t^O - r_t^F F_t + G_t, \]

or,

\[ D_{t+1} = (1 + r_t^W)D_t - Y_t^T - \xi^OP_t^OY_t^O \]

\[ -z_t^{-1}Y_t^N + C_t + I_t^P - r_t^F F_t + G_t, \]

where \( \xi^O = \psi^O(1 - \tau^O) + (1 - \chi)\tau^O \). Substituting (2.18) and (2.41) gives,

\[ D_{t+1} = (1 + r_t^W)D_t - Y_t^T - \xi^OP_t^OY_t^O - z_t^{-1}C_t^G \]

\[ -z_t^{-1}I_t^{G,N} + C_t^T + I_t^P - r_t^F F_t + G_t, \]

169
using \( G_t = I_t^{G,T} + z_t^{-1} I_t^{G,N} + z_t^{-1} C_t^G \) then subtracting (2.45) gives,

\[
D_{t+1} - F_{t+1} = (1 + r_t^W) D_t - Y_t^T - \xi^O P_t^O Y_t^O + C_t^T + I_t^P + r_t^F F_t
\]

\[
+ I_t^{G,T} - \left[ (1 - \phi^F) F_t + \chi^O P_t^O Y_t^O \right],
\]

using the definition of \( \xi^O \),

\[
\xi^O + \chi^O = \psi^O + (1 - \psi^O) \tau^O,
\]

substituting this back gives (2.46),

\[
D_{t+1} - F_{t+1} = (1 + r_t^W) D_t + C_t^T + I_t^{G,T} + I_t^P - Y_t^T
\]

\[
-(1 + r_t^F - \phi^F) F_t - \left[ \psi^O + (1 - \psi^O) \tau^O \right] P_t^O Y_t^O,
\]

or,

\[
D_{t+1} - F_{t+1} = (1 + r_t^W) D_t - Y_t^T + C_t^T + I_t^P + I_t^{G,T}
\]

\[
-(1 + r_t^F - (1 - \nu \phi^F) F_t - \left[ \psi^O + (1 - \psi^O) \tau^O \right] P_t^O Y_t^O,
\]

where \( \nu \in (0, 1) \) represents the fraction of the management fee that goes to domestic agents.
2. A. 2  Steady-State Equations

This section presents the steady-state values of the variables in the model. These values are computed by dropping the time subscripts from the variables.

For the resource sector, the steady-state value of resource prices, $P^O$, is set to unity, whereas the steady-state value of resource production, $Y^O$, is set as a fraction of output (see Section 2.5).

Total domestic output from (2.1) is given by,

$$ Y = Y^T + z^{-1}Y^N + P^O Y^O. \quad (2.71) $$

Production of tradable goods and nontradable goods from (2.2) and (2.5) is,

$$ Y^T = (L^T)^{\beta}(K^T)^{1-\beta}(K^G)^{\omega T}, \quad (2.72) $$

$$ Y^N = (L^N)^{\eta}(K^N)^{1-\eta}(K^G)^{\omega N}. \quad (2.73) $$

The real wage from (2.3) is,

$$ w = \beta \left( \frac{Y^T}{L^T} \right). \quad (2.74) $$

Labour supply from (2.15) is given by,

$$ L = \left[ \left( \frac{1 - \tau^{NO}}{\eta_L C^{\kappa - 1}} \right) \bar{w} \right]^{1/\bar{v}}. \quad (2.75) $$

Using (2.42) and (2.6), labour demand in the tradable sector and nontradable sector is,

$$ L^T = L - L^N, \quad (2.76) $$

$$ L^N = \eta \left( \frac{Y^N}{zw} \right). \quad (2.77) $$
The rental rate of capital from (2.16) is,

$$r^K = \frac{1}{(1 - r^{NO})} (r^W + \delta^P).$$  \hspace{1cm} (2.78)

It is also assumed that the rental rate of capital in the traded and nontraded sector is equal. Thus, \( r^K = r^{K,T} = r^{K,N}. \)

Total stock of private capital from (2.43) is,

$$K^P = \left[ \zeta_K (K^T)^{(\eta_K-1)/\eta_K} + (1 - \zeta_K) (K^N)^{(\eta_K-1)/\eta_K} \right]^{\eta_K/(\eta_K-1)}. \hspace{1cm} (2.79)$$

Capital in the tradable sector and nontradable sector from (2.4) and (2.7) is,

$$K^T = (1 - \beta) \left( \frac{Y^T}{r^{K,T}} \right), \hspace{1cm} (2.80)$$

$$K^N = (1 - \eta) \left( \frac{Y^N}{z^{K,N}} \right). \hspace{1cm} (2.81)$$

Total investment is,

$$I = I^G + I^P. \hspace{1cm} (2.82)$$

Private investment and government investment from (2.11) and (2.29) are,

$$I^P = \delta^P K^P, \hspace{1cm} (2.83)$$

$$I^G = u^G G. \hspace{1cm} (2.84)$$

Government investment on traded goods and nontraded goods from (2.33) and (2.32) is,

$$I^{G,T} = (1 - u^{G,N}) I^G, \hspace{1cm} (2.85)$$

$$I^{G,N} = u^{G,N} z I^G. \hspace{1cm} (2.86)$$
From (2.46), total consumption is,

\[ C = \frac{1}{1}{Y^T - r^W D - I^P - I^{G,T} + r^F F} \]
\[ - \{ 1 - \nu \} \phi^F F + (\psi + (1 - \psi^O)\tau^O) P^O Y^O \].

Consumption in the tradable sector and nontradable sector from (2.20) and (2.19) is,

\[ C^T = (1 - \theta)C \]
\[ C^N = \theta z C \.

 Tradable consumption of natural resource products and nonresource products from (2.23) and (2.24) is,

\[ C^{TO} = \theta^T (P^O)^{-1} C^T \]
\[ C^{TNO} = (1 - \theta^T) C^T \.

From (2.41), the real exchange rate is given by,

\[ z = \frac{1}{\theta C} [Y^N - C^G - I^{G,N}] \.

Lump-sum taxes from (2.28) are,

\[ T^L = T - \tau^O P^O Y^O - \tau^{NO} (Y^T + z^{-1} Y^N) - r^F F \.

Total revenue from (2.37) is,

\[ T = r^W D^G + G \.

173
Revenue on resource production is,

\[ T^O = \tau^O P^O Y^O. \]  \hspace{1cm} (2.95)

Nonresource revenue is given by,

\[ T^{NO} = \tau^{NO} (Y^T + z^{-1}Y^N). \]  \hspace{1cm} (2.96)

In the steady state, government spending is,

\[ G = \psi^G Y. \]  \hspace{1cm} (2.97)

From (2.30), government consumption is,

\[ C^G = (1 - \psi^G)zG. \]  \hspace{1cm} (2.98)

Using (2.35), public capital is given by,

\[ K^G = \frac{\varphi}{\delta^G} I^G. \]  \hspace{1cm} (2.99)

Government debt from (2.40) is,

\[ D^G = PR_{\bar{m}1}^{-1} (Y). \]  \hspace{1cm} (2.100)

From (2.13), foreign-currency household debt is,

\[ D^P = \frac{1}{r^W} \{(1 - \tau^{NO})(Y^T + z^{-1}Y^N) \]

\[ + \psi^O (1 - \tau^O) P^O Y^O - C - I^P - T^L \}. \]  \hspace{1cm} (2.101)
Total debt is,

\[ D = D^P + D^G. \]  \hspace{1cm} (2.102)

The steady-state world interest rate from (2.14) is,

\[ r^W = \frac{1}{\Lambda} - 1. \]  \hspace{1cm} (2.103)

The risk premium from (2.39) is,

\[ PR = \frac{(1 + r^W)}{(1 + r^W_R)} - 1. \]  \hspace{1cm} (2.104)

From (2.38), the overall primary balance in the steady state is,

\[ OPB = T^O + T^{NO} + T^L - G. \]  \hspace{1cm} (2.105)
2.A.3 Log-Linearized Equations

The log-linearized equations of the model are presented in this section. Variables with a hat represent percentage point deviations for interest rate variables from the steady state, and log-deviations around a non-stochastic steady state for the other variables.

Total output from (2.1) is given by,

\[
\hat{Y}_t = \frac{1}{Y} \left[ Y^TY_t + z^{-1}Y^N(\hat{Y}_t^N - \hat{z}_t) + P^OY^O(\hat{P}_t^O + \hat{Y}_t^O) \right].
\]  

(2.106)

Output in the nonresource tradable sector and nontradable sector from (2.2) and (2.5) yields,

\[
\hat{Y}_t^T = \beta \hat{L}_t^T + (1 - \beta) \hat{K}_t^T + \omega_T \hat{K}_t^G,
\]  

(2.107)

\[
\hat{Y}_t^N = \eta \hat{L}_t^N + (1 - \eta) \hat{K}_t^N + \omega_N \hat{K}_t^G.
\]  

(2.108)

Using (2.3) and (2.42), the economy-wide real wage is,

\[
\hat{w}_t = \left( \frac{L^T}{L} \right) \hat{Y}_t^T + \left( \frac{L^N}{L} \right)(\hat{Y}_t^N - \hat{z}_t) - \hat{L}_t.
\]  

(2.109)

Labour supply from (2.15) is,

\[
\hat{L}_t = \frac{1}{\psi} \left[ \hat{w}_t - \frac{1}{\zeta} \hat{C}_t \right].
\]  

(2.110)

Labour demand in the tradable sector and nontradable sector from (2.42) and (2.6) is,

\[
\hat{L}_t^T = \hat{Y}_t^T - \hat{w}_t.
\]  

(2.111)

\[
\hat{L}_t^N = \hat{Y}_t^N - \hat{z}_t - \hat{w}_t.
\]  

(2.112)
The rental rate of capital from (2.16) is,

\[ \hat{r}^K_{t+1} = \frac{(1 + r^W)}{(1 - \tau^{NO})(1+r^K)} \left[ K \left( \hat{K}^P_{t+1} - \hat{K}^P_t \right) + \hat{r}^W \right] \]

(2.113)

\[- \frac{K}{(1 - \tau^{NO})(1 + r^K)} \left( \hat{K}^P_{t+2} - \hat{K}^P_{t+1} \right).\]

The rental rate of capital in the tradable sector and nontradable sector from (2.4) and (2.44) is,

\[ \hat{r}^{K,T}_t = \hat{Y}^T_t - \hat{K}^T_t, \]

(2.114)

\[ \hat{r}^K_t = (\zeta_K)^{\eta_K} \left( \frac{1 + r^{K,T}}{(1 + r^K)} \right)^{1 - \eta_K} \hat{r}^{K,T}_t + (1 - \zeta_K)^{\eta_K} \left( \frac{1 + r^{K,N}}{(1 + r^K)} \right)^{1 - \eta_K} \hat{r}^{K,N}_t. \]

(2.115)

From (2.11), private capital is given by,

\[ \hat{K}^P_t = (1 - \delta^P) \hat{K}^P_{t-1} + \frac{I^P}{K^P} \hat{I}^P_t. \]

(2.116)

Capital in the tradable sector and nontradable sector from (2.43) and (2.7) is,

\[ \hat{K}^P_{t-1} = \zeta_K \left( \frac{(K^T)}{(K^P)} \right)^{(\eta_K-1)/\eta_K} \hat{K}^T_t + (1 - \zeta_K) \left( \frac{(K^N)}{(K^P)} \right)^{(\eta_K-1)/\eta_K} \hat{K}^N_t, \]

(2.117)

\[ \hat{K}^N_t = \hat{Y}^N_t - \zeta_t - \hat{r}^{K,N}_t. \]

(2.118)

Total investment is,

\[ \hat{I}_t = \frac{1}{\Gamma} \left[ I^G_t \hat{I}^G_t + I^P_t \hat{I}^P_t \right]. \]

(2.119)

Private investment from (2.46) is,

\[ \hat{I}^P_t = \frac{1}{I^P} \left[ D^P \Delta^P_t - F \hat{F}^P_{t+1} - (1 + r^W)D^P (\hat{r}^W + \hat{D}^P_t) + Y^T \hat{Y}^T_t ight. \]

(2.120)

\[- C^T \hat{C}^T_t - I^{G,T} \hat{I}^{G,T}_t + (1 + r^F)F (\hat{r}^F + \hat{F}_t) - \{1 - \nu\} \phi^F F \hat{F}_t \]

\[ + \left[ \psi^O + (1 - \psi^O)\tau^O \right] P^O Y^O (\hat{P}^O + \hat{Y}^O). \]
Total investment spending by the government from (2.29) is,

\[ \hat{I}_t^G = \hat{G}_t. \]  
(2.121)

Investment spending by the government on traded and nontraded goods from (2.33) and (2.32) is,

\[ \hat{I}_t^{G,T} = \hat{I}_t^G, \]  
(2.122)

\[ \hat{I}_t^{G,N} = \hat{z}_t + \hat{I}_t^G. \]  
(2.123)

From (2.14), total consumption is,

\[ E_t \hat{C}_{t+1} = \hat{C}_t + \hat{\delta}_t^{GW}. \]  
(2.124)

Consumption in the tradable sector and nontradable sector from (2.20) and (2.19) is,

\[ \hat{C}_t^T = \hat{\hat{C}}_t, \]  
(2.125)

\[ \hat{C}_t^N = \hat{z}_t + \hat{\hat{C}}_t. \]  
(2.126)

Using (2.23) and (2.24), tradable consumption of natural resource products and nonresource products is,

\[ \hat{\hat{C}}_t^{TO} = \hat{\hat{C}}_t^T - \hat{\hat{P}}_t^O, \]  
(2.127)

\[ \hat{\hat{C}}_t^{TNO} = \hat{\hat{C}}_t^T. \]  
(2.128)

The real exchange rate from (2.41) is,

\[ \hat{\delta}_t = \frac{1}{\theta_{zC}} \left[ Y_t^{N} \hat{Y}_t^{N} - C_t^G \hat{\hat{C}}_t^G - I_t^{G,N} \hat{I}_t^{G,N} \right] \hat{\hat{C}}_t. \]  
(2.129)

Household foreign-currency debt from (2.13),
\[ \hat{D}_t^P = \frac{1}{D^P}[(1 + r^W)D^P \left( \hat{r}_{t-1}^W + \hat{D}_{t-1}^P \right) - (1 - \tau^{NO}) \left\{ Y^T \hat{Y}_{t-1}^T - z^{-1}Y^N \hat{z}_{t-1} + z^{-1}Y^N \hat{Y}_{t-1}^N \right\} - \psi^O(1 - \tau^O)P^OY^O \left\{ \hat{P}_{t-1}^O + \hat{Y}_{t-1}^O \right\} + C\hat{C}_{t-1} + I^P \hat{r}_{t-1}^P + T^L \hat{T}_{t-1}^L]. \]

In the fiscal experiments, public debt is kept constant \((\hat{D}_t^G = 0)\), but the log-linearized equations for total government spending, \(\hat{G}_t\), lump-sum taxes, \(\hat{T}_t^L\), and assets in the sovereign wealth fund, \(\hat{F}_t\), differ for the alternative fiscal rules.

In the Full spending experiment, \(\hat{G}_t\), \(\hat{T}_t^L\) and \(\hat{F}_t\) are given by,

\[
\hat{G}_t = T^O \hat{t}_t^O, \tag{2.131}
\]

\[
\hat{T}_t^L = \frac{1}{T^L} \left[ -T^{NO} \hat{t}_t^{NO} - T^O \hat{t}_t^O - (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) \right] + F \hat{F}_t + G\hat{G}_t + (1 + r^W)D^G\hat{r}_t^W, \tag{2.132}
\]

\[
\hat{F}_t = 0, \tag{2.133}
\]

In the Full saving experiment, \(\hat{G}_t\), \(\hat{T}_t^L\) and \(\hat{F}_t\) are given by,

\[
\hat{G}_t = \frac{1}{G} \left[ (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) - F\hat{F}_t \right], \tag{2.134}
\]

\[
\hat{T}_t^L = \frac{1}{T^L} \left[ -T^{NO} \hat{t}_t^{NO} - (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) \right] + F \hat{F}_t + G\hat{G}_t + (1 + r^W)D^G\hat{r}_t^W, \tag{2.135}
\]

\[
\hat{F}_t = \frac{1}{F} \left[ (1 - \phi^F)F\hat{F}_{t-1} + T^O \hat{t}_{t-1}^O \right]. \tag{2.136}
\]

In the Partial spending experiment (which is used to determine the optimal
allocation of resource windfall), \( \hat{G}_t, \hat{T}_t^L \) and \( \hat{F}_t \) are given by,

\[
\hat{G}_t = \frac{1}{G} \left[ (1 - \chi)T^O \hat{T}_t^O + (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) - F \hat{F}_t \right], \tag{2.137}
\]

\[
\hat{T}_t^L = \frac{1}{T^L} \left[ -T^{NO} \hat{T}_t^{NO} - (1 - \chi)T^O \hat{T}_t^O - (1 + r^F)F(\hat{r}_t^F + \hat{F}_t) \right. \\
\left. + F \hat{F}_t + G \hat{G}_t + (1 + r^W) D^G \hat{r}_t^W \right], \tag{2.138}
\]

\[
\hat{F}_t = \frac{1}{F} \left[ (1 - \phi^F)F \hat{F}_{t-1} + \chi T^O \hat{T}_{t-1}^O \right]. \tag{2.139}
\]

Total revenue from (2.37) is given by,

\[
\hat{T}_t = \frac{1}{T} \left[ (1 + r^W) D^G \hat{r}_t^W + G \hat{G}_t \right]. \tag{2.140}
\]

Revenue on resource production is,

\[
\hat{T}_t^O = \hat{F}_t^O + \hat{Y}_t^O. \tag{2.141}
\]

Nonresource revenue is,

\[
\hat{T}_t^{NO} = \frac{1}{T^{NO}} \left[ \tau^{NO} Y^T \hat{Y}_t^T - \tau^{NO} z^{-1} Y^N (\hat{z}_t - \hat{Y}_t^N) \right]. \tag{2.142}
\]

From (2.30), government consumption is,

\[
\hat{C}_t^G = \hat{z}_t + \hat{G}_t. \tag{2.143}
\]

The overall primary balance from (2.38) is,

\[
\hat{OPB}_t = \frac{1}{OPB} \left[ T^O \hat{T}_t^O + T^{NO} \hat{T}_t^{NO} + T^L \hat{T}_t^L - G \hat{G}_t \right]. \tag{2.144}
\]
Public capital from (2.35) is,

\[ \dot{K}_t^G = (1 - \delta^G)\dot{K}_{t-1}^G + \frac{\varphi^G}{K^G} \left( \dot{\varphi}_{t-1} + \dot{i}_{t-1}^G \right). \]  

(2.145)

Using (2.36), the efficiency of public capital is given by,

\[ \dot{\varphi}_t = \varphi_1 \left[ \dot{K}_t^G - \dot{i}_t^G \right]. \]  

(2.146)

From (2.9), the resource price is,

\[ \hat{P}_t^O = \rho^P \hat{P}_{t-1}^O + \epsilon_t^P. \]  

(2.147)

Resource production from (2.8) is given by,

\[ \hat{Y}_t^O = \rho^Y \hat{Y}_{t-1}^O + \epsilon_t^Y. \]  

(2.148)

The risk premium from (2.40) is,

\[ \hat{P}R_t = \rho_1 \left( -\hat{Y}_t \right). \]  

(2.149)

The market cost of foreign borrowing from (2.39) is,

\[ \hat{r}_t^W = \hat{P}R_t. \]  

(2.150)
Summary and Conclusions

This thesis examined two of the key macroeconomic issues that policymakers in Trinidad and Tobago have been grappling with for decades. These challenges are high persistent excess bank reserves and the volatility of resource revenues. Firstly, to quantify the effects of excess reserves, a Dynamic Stochastic General Equilibrium model—which includes a financial sector that explicitly accounts for excess bank reserves—was developed and calibrated to the Trinidad and Tobago economy. The model was used to examine the effects of several macroeconomic and financial shocks, and to assess two policy rules for managing financial volatility. Secondly, to determine the optimal management of the economy’s resource revenues, a three-sector open economy Dynamic Stochastic General Equilibrium model was applied to Trinidad and Tobago. The framework was used to examine the transmission of temporary shocks to resource prices and resource production, as well as the optimal allocation of the resource windfall between spending and saving in a sovereign wealth fund.

The analysis conducted in the previous chapters yielded several important policy lessons, which can be summarized as follows:

1) A contractionary monetary policy shock raises the demand for financial assets and increases the opportunity cost of holding excess reserves. As a result, banks demand less excess reserves.

2) The required reserve ratio is an effective liquidity management tool that can be used to sterilize excess reserves. However, raising reserve requirements to reduce bank liquidity creates an expansionary effect for real economic activity. This indicates that financial stability may come at a cost of macroeconomic stability.

3) A policy rule in which the policy interest rate responds directly to deviations in excess reserves can be used to reduce volatility in real variables when there is an increase in bank liquidity.
4) Reserve requirements can be used in a countercyclical fashion to reduce volatility in excess reserves. This, however, is achieved at the expense of inflation and output being more volatile.

5) Under the optimal allocation rule of resource windfalls, there is a *dynamic volatility trade-off*: spending less today reduces volatility in the economy but as more of the windfall is saved, the interest income accumulated from the assets increases, causing a rise in spending and higher volatility once again.

6) Neither full spending nor full saving of resource windfalls is the optimal fiscal policy response to resource price or production shocks. Saving a fraction of the windfall gains in a sovereign wealth fund can help to reduce fluctuations in consumption and lower fiscal volatility. Overall, these findings imply that fiscal policy can help to mitigate the impact of energy price and production shocks on resource-rich developing economies.

7) If the government of Trinidad and Tobago is relatively more concerned about fiscal stability than household welfare, then a larger fraction of the resource windfall should be saved. Further, if the government is equally concerned about both consumption volatility and fiscal stability, about 80 percent of the resource windfall should be saved.

8) It can be optimal for the government of Trinidad and Tobago to save a larger proportion of the windfall gains, given the low efficiency of public investment spending. Governance reforms are therefore critical to improve the quality of government spending.
Bibliography


[25] Central Bank of Trinidad and Tobago, Annual Economic Survey (various issues), Port-of-Spain: Central Bank of Trinidad and Tobago.

[26] ——— (2004), Role and Functions, Port-of-Spain: Central Bank of Trinidad and Tobago.
[27] ——— (2005), "The Implementation of Monetary Policy in Trinidad and Tobago," Port-of-Spain: Central Bank of Trinidad and Tobago.


[29] Central Statistical Office of Trinidad and Tobago (n.d.), "Methodology: Index of Retail Prices (January 2003 = 100)," Port-of-Spain: Central Statistical Office.


190


[104] The Heritage and Stabilisation Fund Act, No. 6 of 2007, Republic of Trinidad and Tobago.


Trinidad and Tobago Express Newspapers (November 2012), "Are we really running out of oil?," Port-of-Spain: Trinidad and Tobago Express.

Trinidad and Tobago Heritage and Stabilisation Fund, Quarterly Investment Report (various years).

Trinidad and Tobago Newsday (January 2012), "Ryder Scott Reports TT Gas Reserves Fall," Port-of-Spain: Trinidad and Tobago Newsday.


