ASSESSMENT OF NEPALESE MONETARY POLICY: A DSGE MODEL APPROACH

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By

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DECLARATION

I hereby declare that this Masters thesis titled "Assessment of Nepalese Monetary Policy: A DSGE Model Approach" is my own work which I carried out after enrolling for the Masters Degree at Tribhuvan University. This work has not been included in a dissertation or submitted to any other institution for any other degree.

Signature: ....

Date: ....

LETTER OF RECOMMENDATION

This thesis, titled: “Assessment of Nepalese Monetary Policy: A DSGE Model Approach”, has been prepared by Mr. Ajay Gautam under my supervision. I hereby recommend this dissertation for examination by the Thesis Committee as a partial fulfillment of the requirements for Masters degree in Arts in Economics.

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ABSTRACT

Monetary policy is one of the major policy of a central government of a country. Monetary policy contributes to stabilize the economy in many respects. As such, there is a practice instating suitable monetary policy going back to the time of the great depression. Since then, monetary policy has become one of the intense area to research and study by the economists. Theories like monetarism and New Keynesianism were developed to understand the monetary dynamics and formulate robust monetary policies.

Over the past 30 years, New Keynesian theory has been used to understand and formulate new monetary policies with great success. Until recent years, applications of these theories were mostly confined to developed economies. Lately, there have been a substantial number of studies attempting to understand monetary policy using these frameworks in the setting of emerging economies. This thesis is a continuation of that effort in the Nepalese context. Here, I develop a New Keynesian framework to study and identify the features of Nepalese monetary policy using the data for the period of 2002/03 to 2014/15. In particular, I compare three different monetary policy rules to find out which one best represents Nepalese monetary policy, as carried out by Nepal Rastra Bank. I find that Nepalese monetary policy largely resembles Friedman's k-percent rule, and Taylor rule is an improper model for Nepalese monetary policy. Using this setup, this thesis presents the analysis on the importance of exogenous shocks. The finding of this analysis suggests that Nepalese business cycle is primarily driven by monetary policy shocks and supply shocks. I also find significant level of price rigidity, investment adjustment costs and habit formation in consumption in Nepalese economy. In regards to optimal monetary policy, I find that a policy regime that aggressively targets inflation along with fixed money growth rate maximizes aggregate household welfare, thus is an optimal policy.

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Ajay Gautam
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ABBREVIATIONS

ADB Asian Development Bank

BFIs Banks and Financial Institutions

CPI Consumer Price Inflation

CRR Credit Reserve Ratio

DSGE Dynamic Stochastic General Equilibrium

GDP Gross Domestic Product

HP Hodrick-Prescott

HPDI Highest Probability Density Interval

LMFF Liquidity Monitoring and Forecasting Framework

MEI Marginal Efficiency of Investment

M2 Broad Money Supply

NK New Keynesian

NRB Nepal Rastra Bank

OMOs Open Market Operations

OMOTC Open Market Operation Transactions Committee

RE Rational Expectations

RBC Real Business Cycle

SLR Statutory Liquidity Ratio

TFP Total Factor Productivity

US United States

VAR Vector Auto Regression

ZLB Zero Lower Bound

CHAPTER 1
INTRODUCTION

1.1 Background

Problems related to inflation and liquidity are endemic to every modern economy. These problems impede proper functioning of an economy. As such, every modern economy has a governing monetary agency, the Central Bank, whose soul aim is to mitigate such problems should they arise. This is the area of monetary policy, and it is extremely important given the economic ramifications associated with volatility in inflation and available capital in the market. *Prima facie*, monetary policy analysis looks like a quantitative problem that can easily be solved with meticulous accounting. Unfortunately, that is not the case. Because it is an important problem, not making an attempt to solve it, on the grounds of difficulty, is untenable. As such, economists have developed a few tools for quantifying the dynamics of inflation, liquidity and other macroeconomic variables to aid in monetary policy analysis. The aim of this thesis is to use one such tool to understand Nepalese monetary policy.

In order to motivate the analysis in the thesis let us first discuss the history of Nepalese monetary policy and its contemporary state.

1.1 History of Nepalese Monetary Policy

Monetary policy in Nepal started with the establishment of Nepal Rastra Bank in 1956; Nepal Rastra Bank was established under Nepal Rastra Bank Act 1955. At the time, both Nepalese and Indian currency were in circulation. To remedy this, and to establish Nepalese currency as the only currency for domestic transactions, Foreign Exchange Act 1962 was introduced. Along with the Commercial Bank Act, 1968, this act expanded the domain of operation of NRB. In 1966, NRB began conducting monetary policy through interest rate regulation and reserve control. It introduced monetary policy instruments like Credit Reserve Ratio (CRR) and fixed interest rates on deposits and loans to implement the foregoing policy objectives; over the next few decades, NRB introduced a few more policy instruments like Statutory Liquidity Ratio (SLR). Despite an increasing emphasis on conducting monetary policy during this period, no formal framework was developed to aid monetary policy formulation and implementation.

In mid 1980s NRB began approaching monetary policy through the use of indirect methods. Under this approach, it deregulated interest rates starting in 1984, introduced Open Market Operations (OMOs) in 1988 and treasury bills in 1994. It also abandoned credit ceilings in 1991/92 to facilitate the indirect approach to monetary policy. Around the same time, 1993 in particular, the exchange rate with Indian currency was fixed at 1.6 Nepalese Rupees per Indian Rupees. Furthermore, NRB introduced formal policy objectives of price and Balance of Payment (BoP) stability. These reforms during the 1980s and the 1990s paved a way for introduction of formal monetary policy framework in the early 2000s.

In 2002, Nepal Rastra Bank Act was introduced. NRB act provided a clear framework for conducting monetary policy comprised of policy instruments, operating targets, nominal anchors, intermediate targets and policy objectives. Under this approach, NRB uses monetary aggregates as an intermediate target, exchange rate as a nominal anchor, excess reserve as an operating target and various monetary policy instruments. The act also updated regulations surrounding OMOs and made it possible for NRB to conduct OMOs at the discretion of Open Market Operation Transactions Committee (OMOTC), rather than having to wait for Banks and Financial Institutions (BFIs) to request the operation. Similarly, a provision was made to formally announce monetary policy; NRB has been announcing yearly monetary policy ever since. Furthermore, many new instruments were added under the framework to ease monetary policy operations; an example of this is Liquidity Monitoring and Forecasting Framework (LMFF) which has been used by the NRB since 2004/05 to facilitate OMOs.

The primary objectives of Nepalese monetary policy are price stability and external sector stability. The rationale for these objectives drive from the large trade account with India, and the exchange rate peg with Indian currency. Results in Budha (2015) and Suzuki (2019) suggest that the long run inflation of Nepalese and Indian economy converge. As such, the goals of price and external stability are indispensable. NRB manipulates broad money (M2) balance to attain the required goal. Since NRB does not have direct control over M2, it uses excess reserves of BFIs to attain the desired balance of M2; in recent years, it has been targeting annual M2 growth rate of 18%, which it attains though the preceding scheme. Excess reserves can be influenced through a variety of direct monetary policy instruments. NRB currently uses CRR, bank rate, OMOs and interest rate corridor etc.

While the intermediate target and the nominal anchor have not changed in a long time, policy instruments have been both introduced and discontinued in accordance to the requirements of NRB. For instance, Statutory Liquidity Ratio (SLR) was discontinued in 1993 and reintroduced again in 2009. On each monetary policy announcement, NRB updates its stance on the use of various policy instruments discussed in the foregoing. Monetary policy actions to be carried out through policy instruments like CRR, Interest rate corridor and bank rate are precisely defined through the announcement, while that involving policy instruments like OMOs are less precise. In this sense, OMOs are used to flatten short-term volatility in the market and other policy instruments are used to flatten longer-term volatility.

Remittance inflows have come to be a major factor in Nepalese monetary policy in present times (Maskay et al., 2015). The period of 2010-2015 was associated with frequent episodes of significant remittance inflows. In fact, this trend extends to the period after 2015, primarily due to the earthquake of 2015. Remittance inflows arrive into the economy in the form of foreign currency. Owing to the strict capital controls, Nepalese citizens must exchange the received foreign currency for Nepalese currency in order to engage in the market. As such, NRB liquidates foreign currency, while simultaneously injecting Nepalese currency into the market. This has an after effect of a surge in M2 balance. Sudden surge in M2 balance has monetary repercussions as it can lead to a rise in inflation unless proper monetary policy is put in place to counterbalance the surge in M2 (Maskay et al., 2015). In fact, Nepal Rastra Bank attempts to sterilize the remittance inflow through the use of various instruments. One such instrument is the Liquidity Monitoring and Forecasting Framework (LMFF) which is used to monitor liquidity in the market.

1.1 Contemporary Nepalese Monetary Policy

As the framework of Nepalese monetary policy has not changed since the introduction of Nepal Rastra Bank Act in 2002[1], contemporary Nepalese monetary policy closely resembles past instances of monetary policy. However, due to the emergence of COVID-19 in recent times, the focus of monetary policy has changed from tweaking the economy to pulling the economy out of the ongoing recession. For instance, NRB raised the mandatory Credit Cum Deposit (CCD) ratio from 80% to 85% for Banks and Financial Institutions (BFIs) in the monetary policy for 2020. This suggests an attempt of NRB to boost the availability of credit in the market, thereby increasing economic activity. In addition, it extended loan installments repayment and interest repayment deadlines by periods ranging from six months to one year according to the severity of impact, of COVID-19, on the particular business sector. It also made a provision for additional credit upto 20 % of the working capital of the BFIs. Furthermore, NRB has made it mandatory for BFIs to allocate at least 15 % of the total available credit to agriculture sector. All of these policies demonstrate a commitment to fight the ongoing recession.

Recent theoretical developments provide some insights into the optimal monetary policy in the present environment. Guerrieri et al. (2020) suggest that the supply shocks created

[1] See: https://www.nrb.org.np/contents/uploads/2020/01/nepal_rastra_bank_act_2002_english.pdf

by the onset of COVID-19 pandemic resemble Keynesian shocks; Keynesian shocks are a kind of supply shock that induce a demand shock larger in magnitude than the original supply shock. These kinds of shocks inevitably lead to a deficiency of aggregate demand, induced by deficient aggregate supply. The authors suggest a dual approach to stabilize the economy in presence of such shocks. They recommend an expansionary monetary policy regime targeted toward preventing exits of business firms, and a fiscal policy targeted toward providing social insurance. In particular, they acknowledge that a joint policy effort is required to tackle recession induced by COVID-19.

From the foregoing discussion, one can see that Nepalese monetary policy stance resembles the monetary policy recommendation of Guerrieri et al. (2020). On the fiscal side, the government of Nepal has expanded social insurance policies in response to the recession induced by COVID-19. For instance, a budget of 11.60 billion Nepalese rupees has been allocated under the Prime Minister Employment Program with an intent to generate 200,000 additional employment opportunities. Similarly, plans have been put in place to create 50,000 jobs through skill based training, 75,000 jobs through technical and vocational training, 40,000 jobs through small farmers credit, 179,000 jobs through Youth and Small Entrepreneur Self-employment fund and 50,000 jobs through the private sector. Meanwhile, other social transfers have been continued as before. Therefore, Nepalese policy stance at the present resembles the policy recommendation made by Guerrieri et al. (2020).

Given this background discussion, we can now say something more about the main problem discussed in this thesis.

In recent years, NRB has been setting its target to limit the growth of M2 balance within about 18% per year[2], and it has had remarkable success in meeting this target. The data suggests that NRB has been adhering to its target irrespective of other issues that could require discretionary measures. Given this information, it seems natural to conjecture that NRB adheres to a rule similar to Friedman's k-percent rule in conducting monetary policies.

Taylor rule is a preferred choice of a rule-based monetary policy regime in developed economies[3]. Despite its attractive features, the primary appeal of the Taylor rule comes

[2]See: https://www.nrb.org.np/contents/uploads/2019/12/Monetary_Policy_Collection_of_Monetary_Policy-Collection_of_Monetary_Policy_Part_2-new.pdf.

[3]The Global Financial Crisis of 2007/08 exposed the Taylor rule as originally formulated in Taylor (1993). Prior to the Global Financial Crisis, Taylor rule appeared in majority of DSGE models, see: Christiano et al. (2005),Fernández-Villaverde (2010),Smets and Wouters (2007). In the post crisis period, various modifications of Taylor rule have been proposed to incorporate ZLB constraint, see: Lindé and Trabandt (2019) and Gust et al. (2017)

from the fact that it matches the behaviour of Federal Reserve during the 'Great Moderation' period spanning mid-1980s to 2007. Smets and Wouters (2003) have demonstrated its efficacy in Euro area monetary policy as well, but when it comes to emerging economies, it does not possess the same kind of appeal. Laxton and Pesenti (2003) find that simple Inflation Forecast Based (IFB) rules perform better than conventional Taylor rule in emerging countries. Similarly, Shrestha and Semmler (2014) find that Taylor rule does not properly reflect the monetary policy in five crisis affected east Asian countries. While these results cannot be used to ascertain the unreliability of Taylor rule for Nepalese economy, they do provide a necessary motivation to question its reliability. Moreover, given the monetary policy stance of NRB, characterized by monetary aggregate targeting as opposed to the interest rate targeting, it seems reasonable to consider money growth rule to model Nepalese monetary policy. While this is reasonable, there is no evidence in the literature to suggest that it is correct. In fact, Nepalese monetary policy literature is rich in different types of simple rules. For instance, Suzuki (2019) models Nepalese monetary policy using Taylor rule, and Budha (2015) models Nepalese monetary policy using excess reserve equation. The choice of monetary policy rule severely constrains the set of options that a Central Bank has; for example: a Central Bank that chooses to implement Friedman's k-percent cannot effectively implement inflation targeting regime. Therefore, it is imperative that one settle on the correct model for monetary policy before proceeding with detailed monetary policy analysis.

The discussion in the previous paragraph raises a few natural questions pertaining to Nepalese monetary policy. For instance: which policy rule describes Nepalese monetary policy? What are the implications of the monetary policy stance of NRB? The purpose of this thesis is to tackle these questions. As stated, these questions are not precise. Making them precise is the subject matter of the following sections.

1.2 Objectives

While monetary policies themselves are complicated, there is a growing consensus among economists that their essence can be captured using simple rules (Williams, 2003). With a motive of modeling Nepalese monetary policy through a simple rule, I propose three simple monetary policy rules: two for monetary aggregate targeting, and one for interest rate targeting. For interest rate targeting, I use the Taylor rule, and for the monetary aggregate targeting, I use a Taylor-type rule, which responds to inflation and output gap, and a Friedman-type rule, which indexes the nominal money growth on the growth rate of the previous period. The primary objective of this thesis is the comparison of these three rules in the setting of a DSGE model to ascertain which of these rules best describe Nepalese monetary policy. DSGE models provide a natural framework in which to carry out alternative policy analysis. As such, one of the objectives of this thesis is to develop a DSGE model with Nepalese characteristics.

The choice of monetary policy rule, along with its parameterization, determines a model for Nepalese economy. One can then use this model to entertain counter-factual analyses. One such counter-factual analysis is an optimal monetary policy analysis. There is a large literature on the theory of optimal monetary policy which aims to find the parameterization of monetary policy rule that maximizes the aggregate household welfare. It is one of the objective of this thesis to carry out an optimal monetary policy analysis and present a policy rule that is most conducive to aggregate household welfare.

The previous two objectives pertain directly to monetary policy analysis. Remittance inflows, while not directly related to monetary policy, display traits of short-term monetary policy shocks in the context of Nepalese economy. For instance, owing to strict capital controls, the foreign currency received through remittance inflows is liquidated by NRB in exchange of Nepalese currency. This invariably results in a rise in nominal money balance in the market, which is what happens in an expansionary monetary policy that targets monetary aggregates; this effect is detailed in Maskay et al. (2015). As such, it is imperative to understand the nature of remittance inflows to Nepalese economy in order to understand Nepalese monetary policy. Suzuki (2019) finds that remittance inflows to Nepalese economy are counter-cyclical in nature. If this is true, then there can be episodes of sharp rise in inflation in the short run, even during recessions. I intend to investigate this assertion of counter-cyclicality of remittance inflow in this thesis. For this purpose I model remittance inflow explicitly in the DSGE model alluded to earlier.

In an attempt to build a realistic model for Nepalese economy, I entertain five exogenous shocks: technology shock, monetary policy shock, Marginal Efficiency of Investment (MEI) shock, remittance inflow shock and intratemporal preference shock. Consideration of exogenous shocks leads to a natural question: which shocks drive the variations in output and inflation? It is one of the objectives of this thesis to provide an answer to this question. Similarly, I consider various market rigidities: price rigidity and wage rigidity, investment adjustment cost, habit formation in consumption etc. to add realism to the model. This again leads to a natural question: which market rigidities are prominent in Nepalese economy? I intend to provide an answer to this question as well.

To sum it all up, here are the major objectives of this thesis:

a) To find a monetary policy rule that best represents Nepalese monetary policy.

b) Examine the influence of remittance inflows on Nepalese monetary sector.

c) Develop a DSGE model that best reflects Nepalese characteristics with aim of carrying out counterfactual monetary policy analysis.

1.3 Significance of the study

In order to find a policy rule which reflects Nepalese monetary policy regime, I estimate three different DSGE models for each of the monetary policy rules described in an earlier section. Through the use of Bayes' ratio, I ascertain that a model with Friedman-type monetary policy best matches the actual data. The model with Taylor-type monetary growth rule has goodness of fit slightly below that of the model with Friedman-type rule, however the goodness of fit of the model with Taylor rule is drastically low compared to the preceding two models. Owing to the large variation in goodness of fit, Taylor rule can be rejected as a model for Nepalese monetary policy. In fact, the result suggests that Nepalese monetary policy strongly coheres to Friedman-type policy. This result is in coherence with the *prima facie* observation regarding Nepalese monetary policy, as described in the initial section. Moreover, this seems to suggest that the yearly announcements made by Nepal Rastra Bank do reflect their inner workings.

Optimal monetary policy in the case of Friedman-type rule is given by zero indexation to the past nominal money growth rate. In the case of Taylor-type rule, it is given by a perfect indexation to the past nominal money growth rate and aggressive inflation targeting. As Friedman-type rule is a special case of the Taylor-type rule, there is no loss of generality in carrying out optimal monetary policy simulation using the Taylor-type rule in the context of model with Friedman-type rule, where Friedman-type rule is replaced with Taylor-type rule but the calibrations are retained. In this case, I obtain results similar to that in the case of model with Taylor-type rule, i.e. household utility can be maximized by almost perfect indexation to past growth rate and aggressive inflation targeting. Moreover, the welfare index under this optimal monetary policy simulation is much higher than under the simulation with strict Friedman-type rule. These results are are easy to interpret: perfect indexation to past growth implies absence of volatility in money growth rate, and aggressive inflation targeting implies stable price level. In essence, optimal monetary policy for Nepalese economy is the one that minimizes the volatility in nominal money growth and the price level.

Remittance inflows to Nepalese economy are highly counter-cyclical. They induce a persistent rise in consumption and the real wage, while also increasing the household leisure; increase in leisure is much less persistent compared to increase in consumption. In contrast, output falls in response to remittance inflow shocks, owing to the rise in leisure. This finding is similar to the results in Chami et al. (2008). Monetary effect of remittance is much less pronounced in the model with Friedman-type rule, while it is accompanied by a small rise in inflation about 2-3 quarters after the shock in remittance inflows. This latter effect is difficult to ascertain due to the downward pressure experienced by inflation as a result of fall in output in response to remittance inflow shocks.

Variance decomposition of output and inflation in the context of the model with Taylor-type rule implies the importance of monetary policy shocks, intratemporal preference shocks and productivity shocks in modeling Nepalese economy. Similarly, the same analysis in the context of the model with Friedman-type rule suggests that monetary policy shocks and productivity shocks are important. MEI shocks and remittance shocks do not play a big part in determination of output and inflation in both models. Two models considered here are much more similar in the context of frictions. In both models, price rigidity, habit formation in consumption and investment adjustment costs have empirical significance, while wage rigidity, price and wage indexation do not.

This thesis presents one of the first DSGE models designed for Nepalese economy. DSGE models have been used to study various types of macroeconomic phenomena like news shocks, see (Khan and Tsoukalas, 2012), investment shocks, see (Justiniano et al., 2011), remittance shocks, see (Mandelman, 2013), Zero Lower Bound (ZLB) problem, see (Hirose and Inoue, 2015), and financial frictions, see (Merola, 2015), etc. Given the scope of DSGE models in macroeconomics analysis, many Central Banks around the world use it in policy formulation[4]; as of 2012, Nepal Rastra Bank has also been using a DSGE model, known as SHERPA model, developed with the assistance of Asian Development Bank (ADB)[5]. Against this background, DSGE models presented here have a significance in policy analysis and further research.

1.4 Limitations

The discussion presented in this thesis is not without limitations. There are both theoretical and empirical limitations that encumber the results presented here.

One of the foremost limitations in this study is the availability of data. Lack of observable variables severely impedes the estimation of the model parameters. Guerron-Quintana (2010) finds that Bayesian estimation of a medium-scale DSGE model with-

[4]Some of the Central Banks that use of DSGE models are: Bank of Canada, Bank of England, Central Bank of Chile, Central Reserve Bank of Peru, European Central Bank, Norges Bank, Sveriges Riksbank, US Federal Reserve etc.

[5]See:`https://www.adb.org/sites/default/files/project-document/78428/41126-012-nep-tacr-02.pdf`

out using real wages as an observable keeps parameters like Calvo wage parameter, ϕ_w, Frisch labour supply elasticity , χ, from being identified. Moreover, absence of data on wages produces qualitatively different dynamic response for several variables. Similarly, the investment adjustment cost parameter, κ, is influenced by investment data. Using these findings, the author proposes an optimal set of observable variables containing output, consumption, interest rates, inflation, total hours, investment and real wages. Only three data series from this list are used in this thesis, excluding nominal money balance — which is more relevant in models considered here. Furthermore, The output and consumption series used here were available only in yearly frequency.

Several parameters have been calibrated in the models proposed here. For example, intertemporal discounting parameter, β, is calibrated using the data on 91 days treasury bill, and steady state remittance parameter, τ, is calibrated using remittance to GDP ratio for the sample period. Other parameters have been calibrated using the literature. Calvo wage parameter is calibrated using Nepalese literature, while the parameters like: a_0, a_1, δ, α, χ are calibrated using foreign literature. There are obvious drawbacks to this strategy of calibration, especially the calibration using foreign literature. In fact, these limitations are quite pervasive in DSGE literature for emerging economies.

On top of empirical limitations, this thesis suffers from methodological limitations as well. Estimation and comparison of models in this thesis largely depend on Bayesian methods. Bayesian statistics is fundamentally different from classical statistics as it is an epistemic approach to statistics, and therefore involves a fair amount of subjectivity. Subjectivity enters our analysis in the choice of prior density for the estimated parameters and probability assignment to the three models considered. Given the high enough Bayes' ratio in favour of money growth rules, the probability assignment to the different hypotheses does not appear to be a big problem. However, the choice of prior densities does create problems in the study given the length of data series used for estimation. In limited data scenarios the prior densities often overpower the likelihood functions for the estimated parameters, which can result in posterior densities that look exceedingly like prior densities. This problem goes away if the samples are large enough [6], but in the present case the possibility highlighted in the foregoing cannot be ruled out.

1.5 Organization of the Thesis

In the next chapter, I present a discussion on the history of monetary policy and contemporary Nepalese monetary policy practices.

[6] See: `https://plato.stanford.edu/archives/spr2017/entries/statistics/` for the discussion on "Washing out " phenomenon.

In chapter 3, I present a literature review surrounding monetary policy and DSGE models. Firstly, I present the historical overview of DSGE models dating all the way back to Lucas (1976). Then, I review the contemporary literature that is relevant to the study, and close the chapter by highlighting the research gap.

In chapter 4, I discuss the research methodology. In the first section I develop a medium-scale DSGE model following Christiano et al. (2005), Fernández-Villaverde (2010) and Sims (2013). The model comprises of households, firms and a government. The households are owners of capital, which they lease out to the firms, and recipient of remittances and profits. Firms are subdivided into two sectors: competitive final goods sector and monopolistic intermediate goods sector. I ignore the fiscal sector, under a few assumptions, and assume that the government sector carries out monetary policy using one of the three types of monetary policy rules discussed earlier. In the following section I describe the observable variables. Then in the final section, I present the details of the estimation, including calibrated values and prior densities.

In chapter 5, I discuss the results of the estimation and use the estimated models to answer a few questions posed in an earlier section. In the first section, I present posterior densities of the estimated parameters. In the following section, I compare the three different monetary policy rules using their respective estimated models. Then using the two money growth rules, I carry out impulse response analysis in the subsequent section; for the remainder of analyses in chapter 4, I only use these two money growth rules. The remainder of the chapter presents the results relating to forecast error variance decomposition, friction analysis and optimal monetary policy analysis.

Finally, I present conclusion of the study in the last chapter. Here I discuss the major findings, provide a few policy recommendations, and lay out a direction for future research.

CHAPTER 2
LITERATURE REVIEW

Prior to presenting a review of literature surrounding contemporary monetary policy relevant for this thesis, let us first review the evolution of monetary policy over the years to provide some context.

2.1 Monetary Policy

Monetary policy is designed to stabilize the economy through the management of liquidity in the market. It is generally implemented by the Central Bank of the country. In developed economies, this implies moderation of interest rates based on the given level of inflation, output and other macroeconomic variables. Traditionally, Central Banks used quantity of money balance to manage the economy. Under this regime, Central Banks inject liquidity into the market in times of recession to promote economic activities, and absorb necessary liquidity from the market whenever the economy is overheating[1]. In present times, Central Banks function in a similar way, but with more emphasis on interest rates than on monetary aggregates.

Monetary policy target variables like monetary aggregates and interest rates are determined by the nominal anchor of the monetary policy. In the period after the second world war, the Federal Reserve targeted federal funds rate to conduct monetary policy. The crisis of late 1970s exposed this approach to monetary policy, so the Federal Reserve switched to targeting monetary aggregates to pull the economy out of the crisis. The monetary policy carried out by the Federal Reserve in the aftermath of the crisis resembled inflation targeting regime (Taylor, 1993); in fact, the relation postulated in Taylor (1993) held until the Global Financial Crisis of 2007/08. This result, along with the remarkable economic stability in the aftermath of the crisis of late 1970s provided an impetus for many developed and rapidly developing economies to switch to inflation targeting. This trend has continued to the present day. The case of underdeveloped and small Emerging economies is quite different. These economies mostly use either the monetary aggregates or fixed exchange rates as nominal anchors. For instance, China has rigorously moderated its exchange rate with the United States in the recent past, and this has had repercussions on how monetary policy is conducted by the People's Bank of China. Li and Liu (2017) and Zhang (2009) find that Chinese monetary policy is defined by a strong monetary aggregate targeting. Nominal anchor for conducting Nepalese monetary policy is the existing exchange rate peg with Indian currency, and given this

[1] An economy is generally said to be overheating if the actual output surpasses potential output. Such a situation can have adverse effects over long time horizons.

nominal anchor NRB targets monetary aggregates to implement monetary policy. Targeting monetary aggregates is a fairly common practice in emerging economies. Taylor (2000) provides a few reasons why targeting monetary aggregates is better than targeting interest rates in the context of emerging economies.

Despite a few differences in how a monetary policy is conducted, the monetary authorities in emerging and developed economies often have the same goal: namely macroeconomic stabilization. Based on this goal, one can categorize monetary policies into two categories. The first is an expansionary monetary policy. This type of monetary policy is usually implemented in times of recession with an intent to reduce unemployment and bolster economic activities. Either the interest rates are lowered or the money supply is expanded in order to make capital resources cheaper, which then induces economic activity. Lowering the interest rate does not work when the interest rate is already near zero. This is the Zero Lower Bound (ZLB) problem that the economy of the United States experienced during the Global Financial Crisis of 2007/08. In an attempt to curb the effects of recession, the Federal Reserve resorted to unconventional monetary policy instruments like quantitative easing and forward guidance to conduct expansionary monetary policy; conventional policy instruments, by definition, work only when the interest rate is significantly different from zero[2]. Use of unconventional instruments notwithstanding, the response of Federal Reserve to the Global Financial Crisis of 2007/08 is an instance of an expansionary monetary policy regime. The second is a contractionary monetary policy. This type of monetary policy is usually implemented in the time of high inflation. High inflation signifies excess liquidity in the market, and given the negative externalities associated with high inflation, it is imperative to manage inflation in order to restore economic health. As such, monetary authority either raises the interest rate or contracts the money supply in order to make capital resources scarcer, which then cools down the economy. Contractionary monetary policy was implemented by the Federal Reserve in response to the crisis of the late 1970s and early 1980s. Inflation rose up to about 13 % by the late 1970s, and in order to curb the high inflation, the Federal Reserve raised the Federal Funds rate to 20 % to tighten the money supply. This policy brought down the inflation to about 3 % by 1983. Similar instances of monetary policy exercises are carried out by all monetary authorities.

The present practice of monetary policy is deeply rooted in its history. I discuss the history of monetary policy in the next section.

[2]Note that the nominal interest rate cannot be below zero. This is the point of Zero Lower Bound.

2.2 History of Monetary Policy

The modern history of monetary policy goes back to the very first Central Bank, the Bank of England, which was established in 1694. Bank of England was authorized to create gold-backed currency, maintain its value and keep it in circulation. It wasn't until the nineteenth century that the Central Banks were established all throughout the Europe. The Central Banks during this period used gold standard to back their currencies, and other modern Central Banking roles like Lender of last resort were largely absent. In the 1870s, Bank of England took on the function as a lender of last resort in response to the criticisms that originated in the aftermath of the crisis of 1866. Subsequently, this Central Banking function was adopted by many other Central Banks around the world. In fact, the Federal Reserve, the Central Bank of the United States, was established in 1913 primarily to function as a lender of last resort. It was around this time that the gold standard was also abandoned by most countries; the cost of the first world war and Great Depression in the following decade made it difficult for these countries to keep the gold standard intact. Central Banks did not have much leeway to conduct effective monetary policy in the presence of gold standard due to the requirement that any expansion in money supply be backed with gold. As such, abandonment of gold standard made it possible for the Central Banks to engage effectively in monetary policy exercises.

Great Depression had an enormous impact on the economy. The ensuing deflation resulted in high unemployment, high cost of capital and low economic activity. In an attempt to curb the deflation, the United States government abandoned the gold standard in 1933 and nationalized all the gold; the gold standard was reintroduced in 1934 by the congress through Gold Reserve Act while devaluing the value of the US dollars, relative to gold, from $ 20.67 for an ounce to $ 35 for an ounce.

In the aftermath of the second world war, the Bretton Woods system was established. Many countries pegged their currencies to the US dollars under this system, and the Central Banks of these countries were allowed to exchange their dollar holdings for gold. This system continued onto the early 1970s. By then the gold value of dollar had plummeted to $ 42.22 for an ounce. As a result of this devaluation, the US government severed ties between the US dollars and gold in 1976, effectively establishing a fiat currency regime. Fiat currency regime has continued on to the present day.

Modern practice of monetary policy is intertwined with corresponding theoretical developments. Monetarism was a prominent school of macroeconomics in the period after the second world war. They argued that money supply has non-trivial impact on the real economy, and recommended a monetary policy rule characterized by a low and constant rate of money growth. This monetary policy was used by the Federal Reserve to get the US economy out of stagflation. When the policy regime of targeting federal funds rate did not yield results against stagflation, the Federal Reserve introduced a monetary policy regime that targeted money supply in 1979 to control the soaring level of inflation; inflation soared to over 13 % by the late 1970s. The switch in monetary policy regime helped bring the inflation down by 1983. In the years after that, the Federal Reserve began de-emphasizing strict monetary aggregate targeting and completely abandoned it in 1993. At the same time, there were corresponding developments in theoretical macroeconomics. Real Business Cycle (RBC) theory was introduced in the 1980s, but it failed to capture monetary policy effectiveness, which was pretty much established, partly due to the success that the Federal Reserve had in controlling the inflation during the early 1980s, so it was eventually discarded. The rational optimization framework introduced by RBC theory had quite a few merits, so it was later made a basis for New Keynesian Theory. A major component of the New Keynesian Theory is the Taylor rule. The Taylor rule is a simple monetary policy rule that stipulates a more than one for one change in the interest rate in response to a change in inflation rate; this rule matches the behaviour of the Federal Reserve during the great moderation period spanning mid-1980s to 2007/08. It satisfies several requirements for an optimal policy rule, see (Woodford, 2001), and for that reason it has been adopted by many Central Banks around the world. In particular, introduction of the Taylor rule redefined how monetary policies are conducted around the globe. Its influence soared in the period preceding the Global Financial Crisis of 2007/08. Since then, it has not had the same level of influence, although it is still widely used to model monetary policies.

Much like the Great Depression, the Global Financial Crisis of 2007/08 challenged the conventional approach to Central Banking, and in turn the monetary policy. The Taylor rule fell out of favour due to emergence of Zero Lower Bound (ZLB) during the Global Financial Crisis. As a result, conventional policy instruments could not be used to stabilize the economy. Policy instruments like quantitative easing and forward guidance had to be introduced to pull the economy out of recession. Essentially, how monetary policy is conducted was redefined.

Before moving on to review of literature pertinent to this thesis, it is imperative that we review the history of DSGE models to motivate their usage in monetary policy analysis.

2.3 History of DSGE Models

The germ of DSGE models can be traced back to Lucas (1976), where Lucas formulated his famous critique of macro-econometric models. Lucas critique is targeted towards the use of non-structural parameters in macro-econometric models geared for policy analysis. Non-structural parameters are not policy invariant in general, therefore a policy recommendation formulated using macro-econometric models that use such parameters can be erroneous. An illustrative example of one such instance is the original Phillips curve à la Phillips (1958). The Phillips curve demonstrates the trade-off between inflation and unemployment; Phillips originally observed this trade off in the data for United Kingdom. While the historical data corroborated the findings of Phillips (1958), it was challenged by Friedman (1968) and Phelps (1967) on the grounds that unemployment-inflation trade-off is a short run phenomenon, and in the long run, inflation targeting policies do not decrease unemployment due to variability in expectations; this was confirmed in early 1970s when the United States (US) economy experienced simultaneous high inflation and unemployment[3]. Lucas suggested that one can resolve the worry, revealed by his critique, by modeling robust parameters that govern the optimal behaviour of the individuals; in particular, the parameters arising from the microeconomic theory. This vision led to the formulation of Rational Expectations (RE) Theory and then in early 1980s Real Business Cycle (RBC) Theory was formulated based on this theory. Kydland and Prescott (1982) built on a prior work of Lucas and Prescott (1971) to develop the earliest RBC model. The model they developed marks a departure from conventional econometric methodology in that they based their model on the theory of microeconomics. Using their model, they were able to demonstrate a remarkable adherence of the simulated data, generated from simulation of the model, to the real-world data in terms of volatility and persistence. RBC model they developed implied neutrality of money, ineffectiveness of government policies and generated business cycles as an optimal response of aggregate economy to technology shocks; Prescott (1986) used Total Factor Productivity (TFP) as a proxy for technological shocks. The nature of their model and various assumptions they made gave way to harsh criticisms. For instance, Summers (1986) criticized both the use of total factor productivity as a proxy for technological shocks and technological shocks as a driver of business cycles; he cites empirical evidence to make his case. In fact, RBC models came under harsh criticisms from all fronts of macroeconomic literature on grounds of empirical plausibility given that they were largely at odds with empirical literature; see (Rebelo, 2005) for survey on RBC models. One of the primary reason for these criticisms was policy ineffectiveness; this meant that RBC models were not applicable for monetary and fiscal policy analysis[4]. Cooley and Hansen (1989) attempted to remedy the problem of money neutrality by introducing money into the economy through cash-in-advance constraint. However, this workaround did not offer much promise in terms of applications. In fact, the opti-

[3]this phenomenon is often referred to as stagflation.

[4]The DSGE models in the present times are useful precisely because of their relevance in analysis of monetary policies.

mal monetary policy analysis they conducted found that the welfare cost of persistent inflation is lower than the ones calculated in Fischer (1981) and Lucas (1981).

The New Keynesian Theory also originated in the aftermath of Lucas critique, much like RBC theory. The foundational work in this area is Fischer (1977). In it, Fischer constructed a Rational Expectations (RE) model with wage contracts to introduce short-run wage stickiness. Using this rigidity, he was able to introduce real effects of monetary policy in the short run. Given the importance of nominal-rigidities in deriving monetary non-neutrality, Calvo (1983) introduced a mathematically feasible method of characterizing nominal rigidities, in the form of price and wage rigidities, into rational expectations model. Nominal rigidities can be introduced using other methods as well. For example, Mankiw (1985) introduced a concept of menu cost as a potential source of nominal rigidity. Blanchard and Kiyotaki (1987) took a more systematic approach in introducing nominal rigidities into RE models. They modeled an economy with monopolistic competition in both labor and goods markets where the firms and households take on price and wage setting decisions while considering the menu costs. Using this model they concluded that monopolistic competition, along with other market imperfections, explains the variation in output resulting from movement in aggregate demand. The literature up to this point essentially established the necessity of market imperfections like nominal rigidities and monopolistic competition to explain the variations in output. However, the problem of modeling monetary policies was not completely resolved. After attempts over several years, Taylor (1993) introduced an interest rate rule which matched the behaviour of Federal Reserve Bank of United States with remarkable accuracy. The interest rate rule he prescribes models monetary policy as a function of inflation and output gap targeting. The determinate solution[5] of the monetary problem requires that the Central Bank adjust the interest rate more than one for one with changes in inflation rate; this is called the *Taylor Principle*. New Keynesian models by this time had an enormous advantage over the RBC models. However, there were no non-obvious advantages of using New Keynesian models over RBC models outside policy-making scenarios. This changed with the observation made by Gali (1999). There Gali found a negative correlation between positive technology shocks and hours worked, which in turn generated a negative co-movement between hours worked and productivity. This empirical evidence is difficult to explain using RBC theory, but can be explained easily using New Keynesian Theory.

By early 2000s, New Keynesian DSGE models were applied to the problem of optimal monetary policy, see (Woodford, 2001), and formulated in terms of open economies, see (Schmitt-Grohe and Uribe, 2003). In addition, DSGE models were augmented with

[5]This condition is known as Blanchard-Kahn condition. See (Blanchard and Kahn, 1980).

other forms of rigidities to build better class of models. For example, Smets and Wouters (2003) built on the work of Christiano et al. (2001) and developed a DSGE model for the Euro area economy featuring habit formation in consumption, variable capital utilization, adjustment costs in capital accumulation, investment adjustment costs and 10 different orthogonal shocks[6], among other things. Furthermore, they estimated the model parameters, using Bayesian econometrics, as opposed to calibration of parameters, which was previously the preferred method of simulating DSGE models. Similarly, Christiano et al. (2005) developed a DSGE model with characteristics of real economy as implied by Vector Auto Regression (VAR) models. They used impulse response matching to estimate the model parameters. The model thus estimated implied a larger role of wage rigidity, as compared to price rigidity, in influencing the variations in real variables. Smets and Wouters (2007) built on the work of Smets and Wouters (2003) and Christiano et al. (2005) to develop a DSGE model to study the dynamics of US business cycles. Smets and Wouters (2007) differs from Smets and Wouters (2003) in terms of number of exogeneous shocks and the use of labor-augmenting technology; the use of labor-augmenting technology made it possible to estimate the model without filtering the data. Similar to the DSGE models in Smets and Wouters (2003) and Christiano et al. (2005), the model they developed performed at least as well as the VAR models, and in contrast to Christiano et al. (2005), they found both price and wage rigidities to be equally important. Furthermore, they found that the demand shocks explain most of the short-run variations in output, while the productivity and wage markup shocks explain most of the medium-run and long-run variations in output.

Despite the prevalence of DSGE models in macroeconomic analysis, they do not have the same level of acclaim as they did prior to the Global Financial Crisis of 2007/2008. The Global Financial Crisis created tension in macroeconomic literature owing to apparent inability of DSGE models, as in Smets and Wouters (2003), Christiano et al. (2005), Smets and Wouters (2007), to predict economic downturns. As a result, DSGE models were heavily criticized. Korinek (2015) criticizes contemporary DSGE models on methodological grounds. He contends the soundness of the idea of microfodundations in doing macroeconomics, and suggests the existence of purely macroeconomic phenomena which cannot be traced back to microeconomics; he argues that aggregate demand is one such example, which does not have a clear microeconomic counterpart[7]. The author also contends that DSGE models are not fully consistent with Lucas critique

[6]productivity shock, inflation objective shock, preference shock, government spending shock, labor supply shock, investment shock, interest rate shock, equity premium shock, price markup shock and wage markup shock.

[7]This criticism is reminiscent of Sonnenschein-Mantel-Debreu theorem which (roughly) states that the aggregate demand function is not as well-behaved as consumer demand functions. The introduction of representative agent framework in contemporary DSGE models is an attempt to work around this theorem.

as not every equation is derived from microeconomic theory[8]. Furthermore, he finds the DSGE model methodology of matching moments, of real-world data to the model data, to determine goodness of fit of the model incredibly dubious; the practice of using eye-ball comparison to establish the goodness of fit of the model definitely lacks scientific rigour. Lastly, Korinek points out that the network effect of DSGE approach has made macroeconomic profession susceptible to negative externalities.

Stiglitz (2018) similarly criticizes contemporary DSGE models, but takes a different stance. He makes the core theory of DSGE models the target of his criticism. According to Stiglitz, DSGE theorists have made wrong choices regarding micro foundations. He argues that a version of macro dynamics à la Fisher (1933) that emphasizes results of flexibility and debt-inflation is much more apt compared to Hicksian interpretation of Keynes which emphasizes price and wage rigidities; the latter form of micro-dynamics is a characteristic feature of modern DSGE models. In addition, He contends that the DSGE models have added complexities in areas where a much simpler theory would have sufficed. The representative agent framework is the target of his criticism as well, as he stresses that the dynamics involved in financial friction simply cannot arise from the representative agent framework where the role of lender and borrower is not clear.

The critique of DSGE models presented in the foregoing have assisted the debate that originated in the aftermath of the Global Financial Crisis. Christiano et al. (2018) tackle some of the worries raised by Stiglitz. They contend Stiglitz's view that DSGE models have nothing interesting to say about the real-world economy. As to Stiglitz's claim that DSGE models cannot explain the Global Financial Crisis, the authors refer to the cutting edge research on DSGE literature aimed at introducing heterogeneous agent and financial frictions; Gertler and Kiyotaki (2015), Christiano et al. (2014) propose models with financial frictions, and Kaplan et al. (2018), McKay and Reis (2016) propose models with heterogeneous agents. Furthermore, they attempt to recall the macroeconomic atmosphere prior to the crisis. Prior to the crisis, they argue, macro-economists, for the large part, were in agreement that the financial frictions do not spill over to economy proper. They further suggest that macroeconomics discipline as a whole, and not just DSGE models, failed to predict the Global Financial Crisis of 2008.

The foregoing discussion involved the evolution of DSGE models. DSGE models are important to this thesis from methodological view-point. In the next section, I present a literature review that is more pertinent to the research questions raised in the first chapter.

[8]The Calvo pricing methodology and Taylor rule are not micro-founded and are elements of conventional DSGE models that can make them susceptible to Lucas critique.

2.4 Pertinent Literature

Introduction of the Taylor rule has had an enormous impact on monetary policy analysis. Its success in modeling the federal funds rate of the US economy made it a popular choice for a monetary policy rule to be used in DSGE models. This rule has also been applied in the context of Euro Area with good results, see (Smets and Wouters, 2003). Monetary policy based on simple rules, like the Taylor rule, demands some degree of Central Bank Independence, which makes Taylor rule an inappropriate choice for many emerging economies. In the late 1990s, a switch in monetary policy regime occurred in many emerging economies. Countries like Brazil, Chile, Colombia, Mexico, South Korea etc. are a few who made the switch. This switch increased the degree of Central Bank independence in these countries, and as a result Taylor rule became an appropriate policy rule with which to model the monetary policy. One of advantages of the Taylor rule is that it circumvents problems associated to strict inflation targeting. Strict inflation targeting can have disastrous consequences in the context of adverse supply shocks leading to drastic fall in real GDP. Taylor rule can counterbalance this negative effect by targeting output gap as well. In recent times, much of monetary policy literature uses some form of Taylor rule, including the emerging economy literature; see: (Copaciu et al., 2015), (Medina and Soto, 2007), (Gabriel et al., 2010), (Li and Liu, 2017), (Li and Wang, 2019).

Monetary policy in emerging economies is quite different from monetary policy in developed economies. While the developed economies target interest rates, Taylor (2000) suggests that monetary aggregate targeting is superior to interest rate targeting in emerging economies due to uncertainties involved in measuring real interest rates. Central Banks in small developing countries indeed follow this policy recipe, including Nepal Rastra Bank. Chinese monetary policy is fairly similar to Nepalese monetary policy. Much like Nepal Rastra Bank, Chinese monetary authority has a quantitative intermediate target, primarily M2 balance, and a nominal anchor which aims at keeping the exchange rate, with the US dollars, within certain bounds. In fact, the literature on Chinese monetary policy, see: (Zhang, 2009), (Li and Liu, 2017) and (Li and Wang, 2019), suggests that quantity targeting monetary policy rule best describes the Chinese monetary policy. Nepalese monetary policy is much simpler, but the basic characteristics like intermediate target, nominal anchor, stance on capital account convertibility[9] are quite similar. Therefore, Chinese literature provides a useful proxy for Nepalese monetary policy literature that is deficient.

Theory of optimal monetary policy originated with the introduction of the Taylor rule.

[9] Here I mean to suggest that Chinese capital account is not fully convertible.

The foundational work in this area can be found in Rotemberg and Woodford (1997), Woodford (2001) and Woodford (2003), where the authors use optimal control theory in the context of structural macroeconomic models. Woodford (2001) found that the inflation and output gap targeting regime implied by the Taylor rule meets several requirements of an optimal monetary policy rule for certain classes of macroeconomic models. This result suggests that the Central Bank can use simple monetary policy rules to maximize its policy objective function, often-times modeled in the literature as a household welfare function. While this theory primarily originated in the context of Taylor rule, it has since been adapted for money growth rules as well; simple monetary policy rules, both interest rate rules and money growth rules, have been studied in Gali (2002) in the context of optimal monetary policy. The adaptation of theory of optimal monetary policy for money growth rules has made it easier to carry out optimal monetary analysis in the context of economies with monetary policy stance similar to China or Nepal. The usefulness of this theory hinges upon the independence of the Central Bank, which is questionable in economies with exchange rate management and strict capital account controls. While this is certainly a binding constraint in the long run, Budha (2015) suggests, using narrative analysis, that Nepalese monetary authority is fairly independent in the short run, which makes it possible to entertain such analysis. Even in the absence of Central Bank independence, however, such an analysis can be useful in that it allows the Central Bank to identify the monetary policy stance which can maximize its objective function.

DSGE modeling in the context of emerging economies requires additional considerations. For instance, any DSGE model designed for Nepalese economy should incorporate remittance inflows, given its magnitude relative to the GDP; remittance inflows to GDP ratio in Nepalese economy is roughly 0.25. There have been sizable research efforts in regards to remittance inflows to emerging economies. Chami et al. (2008) analyze remittance inflows to emerging economies and find that they are counter-cyclical in nature. They further find that the remittance inflows increase household consumption and leisure. Acosta et al. (2009) introduce a framework to model remittance inflows, where they divide remittance inflows into two categories: altruistic remittances and self-interested remittances. Altruistic remittances are further divided into close family ties remittances, that are modeled as exogeneous stochastic process, and distant family ties remittances, that are countercyclical in nature. Meanwhile, self-interested remittances are no different from any other capital inflows that are driven by selfish interests; these are modeled as a certain fraction of foreign investment goods. Using El Salvadoran data, they find results similar to Chami et al. (2008), that is, remittance inflows improve overall welfare of the households through increased consumption and leisure. Mandelman (2013) develops a more realistic model featuring two types of households: rule-of-thumb households, with no access to financial markets, and Ricardian households. He assumes that only the rule-of-thumb households receive altruistic remittances and then models remittance inflows as stochastic processes that negatively co-move with real wages. Using this model, he finds that the inflow of altruistic remittances provides an insurance mechanism against various macroeconomics shocks. In the context of Nepal, Suzuki (2019) finds that remittance inflows to Nepalese economy are counter-cyclical in nature. Thapa and Acharya (2017) find that the remittance inflows to Nepalese economy have increased the welfare of recipient households. Remittance inflows to Nepalese economy are associated with sudden surge in liquidity in the economy as Nepal Rastra Bank absorbs foreign currency received as remittances and injects Nepalese currency in the Market. The expansionary effect of remittance inflows is largely unsterilized in the short run, and as a result Maskay et al. (2015) find that the episodes of remittance inflows are associated with positive and transitory rise in inflation. Similar result can be found in Narayan et al. (2011).

2.5 Research Gap

In recent years, Nepal Rastra Bank has been announcing M2 growth target of 18% per year in its yearly monetary policy announcement. These announcements are made according to the monetary policy framework introduced through Nepal Rastra Bank Act, 2002; although, NRB did not announce such targets right from the outset. Since the intermediate target of Nepalese monetary policy comprises primarily of monetary aggregates, one could model Nepalese monetary policy using a money growth rule. Given the primary goals of price and monetary stability of NRB, the monetary policy model might be sophisticated than an AR(1) process. One cannot completely rule out Taylor rule as a model for Nepalese monetary policy as well for it has been used in Nepalese monetary policy literature; see (Suzuki, 2019). This state of affairs suggests that there haven't been enough studies on how Nepalese monetary policy is actually conducted[10]. In particular, there haven't been enough studies to suggest a simple monetary policy rule that best describes Nepalese monetary policy. As such, I attempt to answer this question in this thesis.

Partial equilibrium approach to macroeconomics do not provide a general condition in which all markets simultaneously equilibriate. Simultaneous equilibration is required to analyze questions related to monetary policy as it affects the aggregate economy and not just the isolated parts of the economy. This necessitates a general equilibrium approach.

[10] Of course, monetary policy is announced every year, and the targets are set. But these announcements do not contain any information on how the monetary policy instruments are used within the bounds set by the announcements. For instance, the announcements do not pin down OMOs as they do other instruments like CRR, SLR etc.

Vector Auto Regression (VAR) models are compatible with general equilibrium analysis, and are used frequently in Nepalese literature, but they are purely statistical methods whose results are not particularly amenable to economic interpretation. DSGE models, on the other hand, are founded upon economic theory and are compatible with general equilibrium analysis, by definition, therefore represent a better alternative to carry out macroeconomic analysis. Moreover, DSGE models are a natural framework in which to base monetary policy analysis. This is a methodological gap in Nepalese literature, which this thesis aims to fill.

Resolution of these two gaps in Nepalese macroeconomics literature presents a researcher with the tools to conduct further analysis pertaining to monetary policy. For instance, Nepalese macroeconomics literature does not feature results on optimal monetary policy, exogenous shocks that drive the business cycle, and frictions pervasive in Nepalese market. I undertake these analyses as well.

CHAPTER 3
RESEARCH METHODOLOGY

3.1 Model

DSGE model described in this chapter is largely based on the medium-scale models in Sims (2013), Christiano et al. (2005) and Fernández-Villaverde (2010), except for the remittance equation and monetary policy rules. The remittance equation is developed following Chami et al. (2008) and Acosta et al. (2009), and the monetary policy rules are based on Friedman k-percent rule and Taylor rule[1]. The primary features of the model are:

1. Habit formation in consumption.
2. Money demand in utility function.
3. Variable capital utilization.
4. Investment adjustment cost.
5. Fixed cost in production function.
6. Price and wage rigidities.
7. Price and wage indexation to past inflation.
8. Remittance inflow.
9. Money growth rule.

The model economy is populated by a continuum of identical households who solve utility maximization problem in each period. Households are the owners of capital stock and bonds, and they engage in capital accumulation decision based on adjustment costs. They also engage in wage setting decision in each period with fixed probability; the labour supply decision is based on the resulting wage rate. In addition to profits, from firms, and earnings from bonds, households receive remittances in each period. There are two production sectors in the model economy: final goods sector and intermediate goods sector. The final goods sector is perfectly competitive. It bundles heterogeneous output from the intermediate sector to manufacture the final goods which is then consumed by the households. The intermediate sector features some degree of monopolistic competition. In each period, intermediate goods firms get to update their prices with fixed probability. The government raises its revenue through lump-sum taxes and the

[1]Although, it does not necessarily satisfies the Taylor principle.

monetary authority conducts monetary policy through various rule-based policies.

Other than the features described in the previous paragraph, the model economy can experience five different types of exogenous shocks: technology shock, Marginal Efficiency of Investment (MEI) shock, remittance inflow shock, intratemporal preference shock and monetary policy shock.

3.1 Households

There are a continuum of households indexed by $j \in [0,1]$. The utility function of households is separable in consumption, labor and real money holdings. Assuming the existence of state-contingent bonds as in Erceg et al. (2000), one can assume that the households are identical in consumption and bond holding, and heterogeneous in labour supply. Given these assumption, the utility function takes the form

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - bC_{t-1})^{1-\sigma}}{1-\sigma} - \psi_t \frac{N_t(j)^{1+\chi}}{1+\chi} + \theta \ln \left(\frac{M_t}{P_t} \right) \right]$$

where β is the intertemporal discount factor, b is the habit persistence in consumption[2], σ is the inverse of intertemporal elasticity of substitution, M_t is the nominal money holding, P_t is the price level, C_t is the consumption, $N_t(j)$ is the household labour supply, and χ is the inverse of Frisch Labor supply elasticity. ψ_t is an intertemporal preference shock. I model it as an $AR(1)$ process

$$\ln \psi_t = \rho_\psi \ln \psi_{t-1} + \varepsilon_{\psi,t}, \quad \varepsilon_{\psi,t} \sim \mathcal{N}(0,1). \tag{3.1.1.1}$$

Households are owners of capital, and make capital accumulation decision in each period on the basis of adjustment costs. They hold government bonds, which pay a nominal gross interest rate R_t each period, and make investments I_t. Furthermore, they receive remittances, Ξ_t, from relatives living abroad, and nominal profits, Π_t, in each period. Totality of these details gives us the budget constraint

$$P_tC_t + P_tI_t + B_{t+1} + M_t - M_{t-1} \leq W_t(j)N_t(j) + R_tu_tK_t - a(u_t)P_t\frac{K_t}{Z_t} + \Pi_t + P_tT_t + (1+i_{t-1})B_t + \Xi_t$$

where T_t represents lump-sum government transfer, $W_t(j)$ the wage charged by jth household, u_t the utilization rate of capital and Z_t the exogeneous Marginal Efficiency of Investment (MEI) shock. The MEI shock is modeled as an $AR(1)$ process

$$\ln Z_t = \rho_Z \ln Z_{t-1} + \varepsilon_{Z,t}, \quad \varepsilon_{Z,t} \sim \mathcal{N}(0,1). \tag{3.1.1.2}$$

[2]The habit formation in consumption is important to capture the slow and hump-shaped response of consumption to the policy shocks; see (Fuhrer, 2000).

The adjustment cost function $a(u_t)$ takes the form as in Fernández-Villaverde (2010)

$$a(u_t) = a_0(u_t - 1) + \frac{a_1}{2}(u_t - 1)^2$$

satisfying the relation $a(1) = a^{'}(1) = 0$ and $a^{''}(1) = a_1 \geq 0$. The law of motion of capital is given by

$$K_{t+1} = Z_t \left[1 - S\left(\frac{I_t}{I_{t-1}}\right)\right] I_t + (1-\delta)K_t$$

where $S(1) = S^{'}(1) = 0$ and $S^{''}(1) = \kappa \geq 0$. As described in Christiano et al. (2010) the functional form

$$S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2$$

helps capture the empirical evidence, see (Christiano et al., 2005), according to which investment moves in a hump-shaped fashion in response to policy shocks.

Workers' remittance inflow Ξ_t is a major component of Nepalese economy. I follow Chami et al. (2008) to model remittance inflow using the equation

$$\Xi_t = \Xi\left(\frac{Y}{Y_{t-1}}\right)^{\eta} + \varepsilon_{\Xi}, \quad \varepsilon_{\Xi} \in \mathscr{N}(0, \sigma^2) \tag{3.1.1.3}$$

where Ξ is the steady state remittance inflow, and Y is the steady state output; I assume that $\Xi = \tau \cdot Y$ where τ is the steady-state remittance to GDP ratio. Acosta et al. (2009) divides the above remittance evolution equation into two components: close ties altruistic remittances and distant ties altruistic remittances. Foreign residents with close ties to the households in the economy send remittances regularly, independent of the health of other economic variables. This type of remittances is modeled as a exogeneous process. Distant ties family member send remittances when the families are facing hardship due to economic downturn. This is modeled by the first summand in the above remittance equation.

Summing up, the utility maximization problem of an individual household is given by

$$\max_{C_t, K_{t+1}, I_t, B_{t+1}, M_t, N_t(j), W_t(j), u_t} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{(C_t - bC_{t-1})^{1-\sigma}}{1-\sigma} - \psi_t \frac{N_t(j)^{1+\chi}}{1+\chi} + \theta \ln\left(\frac{M_t}{P_t}\right)\right]$$

subject to

$$P_t(C_t + I_t) + B_{t+1} + M_t - M_{t-1} \leq W_t(j)N_t(j) + R_t u_t K_t - a(u_t)P_t\frac{K_t}{Z_t} + \Pi_t - P_t T_t + (1 + i_{t-1})B_t + \Xi_t$$

$$K_{t+1} = Z_t \left[1 - \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] I_t + (1-\delta) K_t.$$

Solving the above maximization problem, one obtains the following first order conditions:

$$\lambda_t = \frac{1}{(C_t - bC_{t-1})^{\sigma}} - \mathbb{E}_t \frac{\beta b}{(C_{t+1} - bC_t)^{\sigma}} \tag{3.1.1.4}$$

$$\lambda_t = \beta \mathbb{E}_t \lambda_{t+1} (1+i_t)(1+\pi_{t+1})^{-1} \tag{3.1.1.5}$$

$$\mu_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \left(r_{t+1} u_{t+1} - \frac{a(u_t)}{Z_t} \right) + \mu_{t+1}(1-\delta) \right] \tag{3.1.1.6}$$

$$\lambda_t = \mu_t Z_t \left[1 - \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \kappa \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta \mathbb{E}_t \mu_{t+1} Z_{t+1} \kappa \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \tag{3.1.1.7}$$

$$\frac{\theta}{m_t} - \lambda_t = -\beta \mathbb{E}_t \lambda_{t+1} (1+\pi_{t+1})^{-1}. \tag{3.1.1.8}$$

$$r_t = \frac{a^{'}(u_t)}{Z_t} \tag{3.1.1.9}$$

Here λ_t and μ_t are Lagrange multipliers, $\pi_t = \frac{P_t}{P_{t-1}} - 1$, $r_t = \frac{R_t}{P_t}$ and $m_t = \frac{M_t}{P_t}$.

Households own labour, so they engage in labour supply decisions in each period. Labour supplied by each household is aggregated by the Labour packer using the Dixit-Stiglitz aggregator[3]

$$N_t = \left[\int_0^1 N_t(j)^{\frac{\nu_w - 1}{\nu_w}} dl \right]^{\frac{\nu_w}{\nu_w - 1}}, \quad \nu_w > 1$$

to produce final labour that is then supplied to the firms. Here ν_w is the elasticity of substitution between labour inputs from different households, $N_t(j)$ is the labour supply from jth household, and N_t is the aggregate final labour produced by the labour packer. The labour packer solves the following maximization problem to determine the quantity of labour input from each household

$$\max_{N_t(j)} W_t \left[\int_0^1 N_t(j)^{\frac{\nu_w - 1}{\nu_w}} \right]^{\frac{\nu_w}{\nu_w - 1}} - \int_0^1 W_t(j) N_t(j) dj.$$

[3]This is a model for monopolistic competition as developed in Dixit and Stiglitz (1977).

Here W_t is the aggregate nominal wage and $W_t(j)$ is the labour wage of jth household. The first order condition corresponding to this problem is

$$N_t(j) = \left[\frac{W_t(j)}{W_t}\right]^{-\nu_w} N_t \tag{3.1.1.10}$$

where

$$W_t = \left[\int_0^1 W_t(j)^{1-\nu_w} dj\right]^{\frac{1}{1-\nu_w}} \tag{3.1.1.11}$$

is the wage index.

The value of labour wage $W_t(j)$ is assumed in the above problem. In reality, households have to solve an optimization problem to get this wage level. To make this optimization process mathematically less onerous, I assume that a given household can update its labour wage in each period with a fixed probability of $1-\phi_w$ as in Calvo (1983). If a household is unable to update its labour wage in any given period, it indexes the current wage to the lagged inflation with indexation parameter $\xi_w \in [0,1]$. This gives us the labour wage setting function

$$W_t(j) = \begin{cases} W_t^*(j) & \text{If } W_t(j) \text{ is chosen optimally} \\ (1+\pi_{t-1})^{\xi_w} W_{t-1}(j) & \text{Otherwise} \end{cases}$$

Let us suppose that a household gets to update its labour wage in period t and cannot re-update its labour wage in subsequent n periods. Then its labour wage in $(t+n)$th period is given by

$$W_{t+n}(j) = \prod_{s=0}^{n-1}(1+\pi_{t+s})^{\xi_w} W_t^*(j) = \left[\frac{P_{t-n-1}}{P_{t-1}}\right] W_t^*(j).$$

Given a chance to optimize its labour wage, households minimize their labour dis-utility subject to the constraints. Due to the separability of the household utility function, labour wage setting problem only involves the labour part of the utility function. Solving this utility maximization problem gives us the following first order condition:

$$\begin{aligned} \nu_w W_t(j)^{*,-\nu_w(1+\chi)-1} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi_w)^s \psi_t \left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\xi_w \nu_w (1+\chi)} W_{t+s}^{\nu_w(1+\chi)} N_{t+s}^{1+\chi} \\ = (\nu_w - 1) W_t(j)^{*,-\nu_w} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi_w)^s \frac{\lambda_{t+s}}{P_t} \left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\xi_w(1-\nu_w)} W_{t+s}^{\nu_w} N_{t+s}. \end{aligned}$$

Then, rewriting the first order condition in a recursive form and in terms of real values gives us the equation

$$w_t^{*,1+\nu_w\chi} = \frac{\nu_w}{\nu_w - 1}\frac{f_{1,t}}{f_{2,t}} \tag{3.1.1.12}$$

where

$$f_{1,t} := \psi_t w_t^{\nu_w(1+\chi)} N_t^{1+\chi} + \beta\phi_w(1+\pi_t)^{-\xi_w\nu_w(1+\chi)}\mathbb{E}_t(1+\pi_{t+1})^{\nu_w(1+\chi)} f_{1,t+1} \tag{3.1.1.13}$$

and

$$f_{2,t} := \lambda_t w_t^{\nu_w} N_t + \beta\phi_w(1+\pi_t)^{\xi_w(1-\nu_w)}\mathbb{E}_t(1+\pi_{t+1})^{\nu_w-1} f_{2,t+1}. \tag{3.1.1.14}$$

This completes the discussion of the household problem.

3.1 Firms

Firms are divided into final goods sector and intermediate goods sector. The final goods sector is perfectly competitive, so one can assume that it consists of only one firm. On the other hand, the intermediate goods sector is monopolistically competitive, and the firms are indexed by $l \in [0,1]$. The final goods producer takes the output from intermediate goods firms as inputs and uses the Dixit-Stiglitz aggregator of the form

$$Y_t = \left[\int_0^1 Y_t(l)^{\frac{\nu_p-1}{\nu_p}} dl\right]^{\frac{\nu_p}{\nu_p-1}}, \quad \nu_p > 1$$

to produce final goods that is then sold to the households for consumption. Here ν_p is the elasticity of substitution between the output of different intermediate firms, $Y_t(l)$ is the output produced lth intermediate goods firm and Y_t is the total output produced by the final goods producer. To determine the optimal quantity of input to be used from each intermediate goods producer, the final goods producer solves the following profit maximization problem

$$\max_{Y_t(l)} P_t\left[\int_0^1 Y_t(l)^{\frac{\nu_p-1}{\nu_p}} dl\right]^{\frac{\nu_p}{\nu_p-1}} - \int_0^1 P_t(l)Y_t(l)dl.$$

Here $P_t(l)$ is the price charged by lth intermediate producer and P_t is the aggregate price level. Solving this problem gives the first order condition

$$Y_t(l) = \left[\frac{P_t(l)}{P_t}\right]^{-\nu_p} Y_t. \tag{3.1.2.1}$$

where

$$P_t = \left[\int_0^1 P_t(l)^{1-\nu_p} \right]^{\frac{1}{1-\nu_p}}. \tag{3.1.2.2}$$

is the price index.

Each intermediate goods firm uses Cobb-Douglas type production function

$$Y_t(l) = A_t \hat{K}_t(l)^{\alpha} N_t(l)^{1-\alpha} - \Phi, \quad l \in [0,1]$$

where $\hat{K}_t(l) = u_t K_t$ is the capital services utilized by the firm, $N_t(l)$ is the labour input, α is the proportion of capital in the production function, Φ is the fixed cost, and A_t is a neutral technology that is modeled as an $AR(1)$ process

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t}, \quad \varepsilon_{A,t} \sim \mathcal{N}(0,1).$$

Inclusion of fixed cost in the production function makes sure that profits are zero in the steady state, the case for which is made in Rotemberg and Woodford (1999). Zero profits in steady state ensures that new firms do not enter the market place and simplifies the model significantly.

In each period, intermediate goods firms first solve the following cost minimization problem

$$\min_{\hat{K}_t(l), N_t(l)} \; W_t N_t(l) + R_t \hat{K}_t(l)$$

subject to

$$A_t \hat{K}_t(l)^{\alpha} N_t(l)^{1-\alpha} - \Phi \geq \left[\frac{P_t(l)}{P_t} \right]^{-\nu_p} Y_t.$$

Here R_t denotes the nominal cost of capital and W_t denotes the nominal wage rate. The first order condition for this problem is

$$\frac{w_t}{r_t} = \frac{1-\alpha}{\alpha} \left(\frac{\hat{K}_t(l)}{N_t(l)} \right). \tag{3.1.2.3}$$

The above equation implies constant capital-labour ratio across the entire intermediate goods sector. As a result, the marginal cost must also be the same for all intermediate goods firms. In particular, we get

$$mc_t = \frac{w_t}{(1-\alpha) A_t \left(\frac{\hat{K}_t}{N_t} \right)^{\alpha}}. \tag{3.1.2.4}$$

Let us assume that an intermediate goods firm can update its price in each period with a fixed probability of $1-\phi_p$, as in labour wage setting problem. If it is unable to update its price in any given period, then it indexes the current price to the lagged inflation with indexation[4] parameter $\xi_p \in [0,1]$. This information gives us the price setting function

$$P_t(l) = \begin{cases} P_t^*(l) & \text{If } P_t(l) \text{ is chosen optimally} \\ (1+\pi_{t-1})^{\xi_p} P_{t-1}(l) & \text{Otherwise.} \end{cases}$$

Now, let us assume that an intermediate goods firm gets to update its price in period t and cannot re-update its price in subsequent n periods. Then its goods price in $(t+n)$th period is given by

$$P_{t+n}(k) = \prod_{s=0}^{n-1}(1+\pi_{t+s})^{\xi_p} P_t^*(l) = \left[\frac{P_{t+n-1}}{P_t}\right]^{\xi_p} P_t^*(l).$$

Using these details, we can state the profit maximization problem solved by intermediate goods firms as

$$\max_{P_t^*(l)} \mathbb{E}_t \sum_{s=0}^{\infty} (\beta\phi_p)^s \frac{\lambda_{t+s}}{\lambda_t}\frac{P_t}{P_{t+s}}(P_{t+s}(l)Y_{t+s}(l) - \varphi_{t+s}Y_t(l) - \varphi_t \Phi).$$

Solving this maximization problem gives us the first order condition

$$(1-\nu_p)P_t^*(k)^{-\nu_p}\mathbb{E}_t \sum_{s=0}^{\infty}(\beta\phi_p)^s \frac{\lambda_{t+l}}{\lambda_t}\frac{P_t}{P_{t+s}}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{\xi_p(1-\nu_p)} P_{t+s}^{\nu_p}Y_{t+s}+$$
$$\nu_p P_t^*(l)^{-\nu_p-1}\sum_{s=0}^{\infty}(\beta\phi_p)^s \frac{\lambda_{t+s}}{\lambda_t}\frac{P_t}{P_{t+s}}\varphi_{t+s}\left(\frac{P_{t+s-1}}{P_{t-1}}\right)^{-\xi_p\nu_p} P_{t+s}^{\nu_p}Y_{t+s} = 0.$$

Then, rewriting the first order condition in a recursive form and in terms of real values gives us the equation

$$1+\pi_t^* = \frac{\nu_p}{\nu_p-1}(1+\pi_t)\frac{x_{1,t}}{x_{2,t}}. \tag{3.1.2.5}$$

where $\pi^* = \frac{P_t^*}{P_{t-1}} - 1$, and

$$x_{1,t} := \lambda_t mc_t Y_t + \phi_p\beta(1+\pi_t)^{-\xi_p\nu_p}\mathbb{E}_t(1+\pi_{t+1})^{\nu_p}x_{1,t+1} \tag{3.1.2.6}$$

and

$$x_{2,t} := \lambda_t Y_t + \phi_p\beta(1+\pi_t)^{\xi_p(1-\nu_p)}\mathbb{E}_t(1+\pi_{t+1})^{\nu_p-1}x_{2,t+1}. \tag{3.1.2.7}$$

This completes the discussion of the firm problem.

[4]The price indexation induces rapid fall in inflation in response to the neutral technology shock Christiano et al. (2010).

3.1 Government

I consider a government that pursues Ricardian fiscal policy and engages in lump-sum transfer. In this case, the details of fiscal policy do not have an impact on the aggregate economic variables Christiano et al. (2005), so we may abstract from the fiscal policy altogether.

I consider three different types of monetary policy rules. The first rule is the conventional Taylor rule à la Taylor (1993). The second rule is a Taylor-type money growth rule which specifies nominal money growth as a function of past nominal growth rate, inflation gap and output gap. Policy rules similar to this have been considered in Li and Liu (2017) and Zhang (2009). The third rule I consider is a Friedman-type money growth rule which indexes the nominal money growth rate to the past nominal growth rate. This rule is in the spirit of Friedman's k-percent rule, and is discussed extensively in Gali (2002).

1. Taylor rule:
   Under this rule, we specify monetary policy by the equation

   $$i_t = (1-\rho_i)i + \rho_i i_{t-1} + \phi_\pi(\pi_t - \pi) + \phi_Y(\ln Y_t - \ln Y) + \varepsilon_{i,t}, \quad \varepsilon_{i,t} \sim \mathcal{N}(0,1) \tag{3.1.3.1}$$

   where ϕ_π is the measure of inflation targeting and ϕ_Y is the measure of output-gap targeting.

2. Taylor-type money growth rule:
   Under this rule, we specify monetary policy by the equation

   $$\Delta \ln M_t = \rho_m \ln M_{t-1} - \phi_\pi(\pi_t - \pi) - \phi_Y(\ln Y_t - \ln Y) + \varepsilon_{m,t}, \quad \varepsilon_{m,t} \sim \mathcal{N}(0,1) \tag{3.1.3.2}$$

   where $\phi_p i$ is the measure of inflation targeting and ϕ_Y is the measure of output-gap targeting.

3. Friedman-type money growth rule:
   Under this rule, we specify monetary policy by the equation

   $$\Delta \ln M_t = \rho_m \ln M_{t-1} + \varepsilon_{m,t}, \quad \varepsilon_{m,t} \sim \mathcal{N}(0,1) \tag{3.1.3.3}$$

   where $\rho_m \in [0,1]$ is the measure of persistence of money growth.

The Friedman-type money growth rule is a special case of the Taylor-type money growth rule.

3.1 Equilibrium and Aggregation

The aggregate equilibrium is given by the aggregate demand equation

$$Y_t + \Xi_t = C_t + I_t + a(u_t)\frac{K_t}{Z_t} \tag{3.1.4.1}$$

where Y_t is an aggregate production function defined as

$$A_t \hat{K}_t^{\alpha} N_t^{1-\alpha} - \Phi = Y_t v_t^p. \tag{3.1.4.2}$$

Here v_t is a measure of price dispersion given by

$$v_t^p = (1-\phi_p)\left(\frac{1+\pi_t^*}{1+\pi_t}\right)^{-\nu_p} + (1+\pi_{t-1})^{-\xi_p \nu_p}(1+\pi_t)^{\nu_p}\phi_p v_{t-1}^p. \tag{3.1.4.3}$$

The price index is given by

$$(1+\pi_t)^{1-\nu_p} = (1-\phi_p)(1+\pi_t^*)^{1-\nu_p} + (1+\pi_{t-1})^{\xi_p(1-\nu_p)}\phi_p \tag{3.1.4.4}$$

and the wage index is given by

$$w_t^{1-\nu_w} = (1-\phi_w)w_t^{*,1-\nu_w} + (1+\pi_{t-1})^{\xi_w(1-\nu_w)}\phi_w(1+\pi_t)^{\nu_w-1}w_{t-1}^{1-\nu_w}. \tag{3.1.4.5}$$

Each monetary policy rule determines a separate DSGE model. As such, I estimate three different models. Friedman-type monetary policy rule is a special case of Taylor-type monetary policy rule, with $\phi_\pi = \phi_Y = 0$, so the model $\mathscr{M}_F$ differs from model $\mathscr{M}_T$ only in respect to absence of the aforementioned parameters, namely ϕ_π and ϕ_Y. Model $\mathscr{I}_T$ differs from model $\mathscr{M}_T$ in the definition of parameter that specifies persistence of monetary policy shock, namely ρ_i. By abuse of notation, I denote the inflation and output gap targeting parameters by ϕ_π and ϕ_Y respectively in model $\mathscr{I}_T$ as well. While the difference between the three models is apparent in terms of parameter definition, they are exactly the same in terms of definition of endogenous variables. Table 3.1 lists all the parameters in the model $\mathscr{M}_T$.

Endogenous Variables		Parameters	
Y_t	Output	β	Intertemporal discounting factor
C_t	Consumption	σ	Intertemporal elasticity of substitution
I_t	Investment	b	Habit formation
K_t	Capital	δ	Depreciation rate
N_t	Labour	κ	Investment adjustment cost
m_t	Real money balance	θ	Share of real money balance in utility
w_t	Real wage	ν_p	Elasticity of substitution between goods
w_t^*	Reset wage	ν_w	Elasticity of substitution between labours
mc_t	Marginal Cost	χ	Frisch labour supply elasticity
π_t	Inflation	ϕ_p	Calvo price parameter
π_t^*	Reset inflation	ϕ_w	Calvo wage parameter
i_t	Interest rate	ξ_p	Price indexation to past inflation
$v_{p,t}$	Price dispersion	ξ_w	Wage indexation to past inflation
$v_{w,t}$	Wage dispersion	α	Share of capital
Ξ_t	Remittance inflow	ρ_M	Persistence of money growth shock
Z_t	MEI	ρ_A	Persistence of technology shock
A_t	Technology	ρ_Z	Persistence of investment shock
u_t	Capital utilization	ρ_ψ	Persistence of preference shock
ψ_t	Intratemporal preference	η	Measure of cyclicality of Remittance inflow
$x_{1,t}$	Price auxiliary variable 1	ϕ_π	Inflation targeting in monetary policy rule
$x_{2,t}$	Price auxiliary variable 2	ϕ_Y	Output gap targeting in monetary policy rule
$f_{1,t}$	Wage auxiliary variable 1	τ	Steady state share of Remittance inflow
$f_{2,t}$	Wage auxiliary variable 2	a_0	Parameter 1 in convex adjustment cost
λ_t	Lagrange multiplier 1	a_1	Parameter 2 in convex adjustment cost
μ_t	Lagrange multiplier 2	ρ_i	Persistence of interest rate shock

Table 3.1: List of endogenous variables and Model parameters

This completes the discussion on model specification. To estimate the model, one needs relevant data and equations to connect the data series to the model variables. I discuss the observable variables and specification of observation equations in the next section.

3.2 Observable Variables

Parameters are estimated using five data series. I use the data series for Consumer Price Inflation (CPI), Remittance inflow, Broad money (M2), Private consumption, and Nominal Gross Domestic Product (GDP), for the period 2002/03 - 2014/15. The first three of these data series are in quarterly frequency and the latter two series are in yearly frequency. The range of data series spans the period between Nepal Rastra Bank Act, 2002, and the earthquake/trade embargo of 2015/16.

During the specified time period, 2002/03-2014/15, CPI base year is updated three times. I take the most recent series and backcast it all the way through using the overlapping periods to obtain an uniform series. Data series for M2 similarly requires backcasting. The original M2 series naturally split into two series; the first series only accounts for deposits at class 'A' financial institutions, while the second series accounts for deposits at class 'A', 'B' and 'C' financial institutions. To obtain an uniform series, I start with the latter series and backcast all the way back using growth rates as described in Pfeifer (2018).

Since the model specification, as provided in the previous chapter, does not model growth trends, observation equations are required to link model variables, which are stationary, to the observable variables, which may be non-stationary. Among the considered data series, all series except inflation possess trend growth. I specify the observation equation for inflation as

$$\pi_t = \ln \pi_{t,d} - \overline{\ln \pi_{t,d}}$$

where $\pi_{t,d}$ is the observed gross inflation for period t and π_t is the model variable. To define observation equation for the rest of the series, I first use the series on inflation to obtain the corresponding real series, then I apply one-sided HP filter with smoothing parameter $\lambda = 1600$ to the log of the resulting series. This separates the trend and cycle components of the original series; the cycle component is stationary, and is the one relevant here. The observation equations for remittance inflow and real M2 balance are exactly similar to the observation equation for inflation specified above; specifying observation equation for consumption and output requires some care. Since the model frequency is quarterly, observation equations must define how to relate model variables with observable variables for output and consumption, which are in yearly frequency. Following Pfeifer (2018), I specify the observation equation for these two variables as

$$x_{y,t} = x_t + x_{t-1} + x_{t-2} + x_{t-3}$$

where $x_{y,t}$ is the model variable in yearly frequency, which matches the observed variable, and x_t is the model variable in quarterly frequency. The Kalman filter then imputes the missing observations in the data from the available data, as outlined in Durbin and Koopman (2012).

This concludes the discussion on observable variables. In the next section, I describe the Bayesian estimation methodology.

3.3 Bayesian Estimation

I specify parameter values using both calibration and estimation. I follow standard procedures to calibrate the parameters, and I rely on the data series described in the previous section to estimate the model parameters. Calibration process is fairly straightforward, but the estimation process requires some deliberation. I employ Bayesian methods, as described in Koop (2003) and Fernández-Villaverde (2010), to estimate the model parameters. Deferring the calibration to the next section, I discuss the theoretical underpinning of Bayesian estimation in this sections.

The primary tool in Bayesian statistics is the Bayes' rule. Given two random variables A and B, Bayes' rule can be expressed using an equation

$$p(B \mid A) = \frac{p(A \mid B)p(B)}{p(A)}$$

where $p(A)$ is the probability of obtaining A and $p(B \mid A)$ is the probability of obtaining B given A. Denoting the data-set by $\mathscr{Y}$ and the vector of parameters by Θ, Bayes' rule says

$$p(\Theta \mid \mathscr{Y}) = \frac{p(\mathscr{Y} \mid \Theta)p(\Theta)}{p(\mathscr{Y})}.$$

Parameter estimation being the main interest in Bayesian econometrics, one can to ignore the term $p(\mathscr{Y})$ in the above equation. This gives us the relation

$$p(\Theta \mid \mathscr{Y}) \sim p(\mathscr{Y} \mid \Theta)p(\Theta).$$

The term $p(\Theta)$ is the prior density function, $p(\mathscr{Y} \mid \Theta)$ is the likelihood function and $p(\Theta \mid \mathscr{Y})$ is the posterior density function. Prior density function $p(\Theta)$ reflects our prior beliefs about the parameters Θ. According to Del Negro and Schorfheide (2008), prior densities represent the empirical evidence excluded from the likelihood function. The authors point out that the pre-sample data, data from different economy or observations from sample period excluded from observable series, that goes into forming likelihood function, can be used to define prior densities. Some form of subjective judgement is unavoidable in forming prior densities, as mentioned earlier in limitations of Bayesian approach, and aforementioned procedure merely are guidelines and lack strong theoretical foundation; lack of hard and fast rules for forming prior densities is described in Koop (2003). The likelihood function $p(\mathscr{Y} \mid \Theta)$ is estimated using the observable data series, and it specifies the distribution of the data given the model parameters. The product of the prior and the likelihood function defines $p(\Theta \mid \mathscr{Y})$, the probability density function for the model parameters given the observable data, upto a scalar multiple. This probability density function is referred to as a posterior density function.

Fernández-Villaverde (2010) discusses a few benefits of Bayesian econometrics over frequentist approach. One major advantage of Bayesian methods over frequentist methods is that one can update the prior density to reflect suspected non-stationarities in the model, thereby solving unit-root problems without aid of complex techniques often used in frequentist approach. Another advantage, close at heart to economics, is that the Bayesian approach is consistent with the Likelihood Principle and rational behaviour of agents as described by the decision theory. DSGE modeling, in particular, has benefited immensely from the emergence of Bayesian econometrics. Prior to the introduction of Bayesian methods in DSGE models, calibration and classical estimation were used to parameterize DSGE models. The problem with strict calibration is exacerbated by the contrast between parameter values found in micro and macro literature; see (Christiano et al., 2010), where the authors describe the difference in value of labour supply elasticity in micro and macro literature. On the other hand, classical estimation is inappropriate in an environment where the data is sparse and rich in non-stationarities. Bayesian approach provides an elegant resolution to these problems, and helps assert the role of DSGE models as a story telling tool[5].

Guerron-Quintana (2010) reports that an observable data set comprising of consumption, output, investment, interest rates, total hours, inflation and real wages is optimal for estimating parameters in a generic medium-scale DSGE model. The author presents the influence of different data series in the identification of model parameters. According to him, the data on consumption is necessary for the identification of habit formation parameter b, while the data on inflation is required for the identification of Calvo price parameter, ϕ_p. Similarly, the identification of investment adjustment cost parameter κ is dependent on data on output, investment and inflation, and the identification of inverse Frisch labour supply elasticity parameter χ is strongly influenced by interest rates and real wages. Furthermore, the author finds that the exclusion of data on real wage, consumption and inflation has severe repercussions on the model fit, while exclusion of data on labour and investment do not influence the model significantly. The set of observable variables I have used in this thesis is significantly smaller than the optimal set as described in Guerron-Quintana (2010), therefore, I only estimate a few parameters using Bayesian methods; I calibrate rest of the parameters to avoid identification issues.

The details involving the calibration and prior densities is presented in the next section.

[5] See (Edge et al., 2007).

3.4 Calibration and Prior Information

Among the model parameters, I calibrate the parameter set $(\beta,\ \delta,\ \theta,\ \tau,\ \alpha,\ \chi,\ \phi_w,\ \xi_p,\ \xi_w,\ a_0,\ a_1)$ and estimate rest of the parameters. In the setting of model $\mathscr{I}_T$, I also calibrate the parameter κ for reasons that I will address later.

The steady state of the model considered in the previous chapter is provided in the Appendix. There, I assume zero steady state inflation. This assumption allows one to simplify the calibration. Using the data on 91-days Treasury Bill for the sample period, I calibrate the intertemporal discounting parameter to 0.9708[6]. Depreciation in emerging countries is found to be higher than in developed economies, see (Bu, 2006), and since the depreciation parameter, δ, is often calibrated at 0.025 in the context of developed economies, I calibrate this parameter at 0.035. Similarly, noting the labour intensive production in emerging economies, I calibrate output elasticity of capital, α, at 0.25. The value of the parameter a_0 is determined by the value of β and δ, which turns out to be 0.055. The parameter a_1, is not determined by other parameters, so I calibrate it at 0.01, which is midway between the calibration in Smets and Wouters (2003) and Fernández-Villaverde (2010). The steady state remittance share parameter, τ, is calibrated at 0.25 using the remittance to GDP data for the sample period. Due to absence of data on real wage, I use the estimate by Poudel (2019) to calibrate the Calvo wage parameter, ϕ_w, at 0.7982. In the baseline model, I calibrate ξ_p and ξ_w at zero to indicate the lack of indexation to past inflation in both price and wage setting decision. The finding of Guerron-Quintana (2010) suggests that the inverse Frisch labour supply parameter, χ, depends on data on interest rates and real wages for the identification. As such, this parameter must be calibrated. However, there are no studies in the literature to suggest the value of this parameter for Nepalese economy, therefore I calibrate this parameter at the value of 2, following the literature on developed economies. Furthermore, I calibrate the parameter θ to 1. Following the literature, I calibrate the elasticity parameters ν_w and ν_p at 10. In the case of model $\mathscr{I}_T$, I also calibrate the investment adjustment cost parameter, κ, at 4; I estimate this parameter for the other two models. Table 3.2 lists all the calibrated parameters.

[6] This corresponds to 3% steady state interest rate, which is the average of 91 days Treasury Bill for the sample period.

Parameter	Calibrated value		
	Model $\mathscr{I}_T$	Model $\mathscr{M}_T$	Model $\mathscr{M}_F$
β	0.9708	0.9708	0.9708
δ	0.035	0.9708	0.9708
θ	1	1	1
τ	0.25	0.25	0.25
α	0.25	0.25	0.25
χ	2	2	2
ϕ_w	0.7982	0.7982	0.7982
ξ_p	0	0	0
ξ_w	0	0	0
ν_p	10	10	10
ν_w	10	10	10
a_0	0.055	0.055	0.055
a_1	0.01	0.01	0.01
κ	4.0	-	-

Table 3.2: List of calibrated parameters

The rest of the parameters are estimated. To estimate these parameters one needs to specify prior densities. To begin with, I follow Smets and Wouters (2007) and define the prior densities of the standard errors of exogenous shocks to be Inverse Gamma distribution with mean 0.1 and standard deviation 2.0. For the parameters that specify persistence of the exogenous shocks, namely ρ_M, ρ_A, ρ_i, ρ_Ξ, ρ_Z and ρ_ψ, I define the prior densities to be given by a Beta distribution with mean 0.7 and standard deviation 0.2. The parameter η is the measure of cyclicality of the remittance inflow. Analysis in Suzuki (2019) suggests that the remittance inflow into Nepalese economy is counter cyclical. Therefore, following Chami et al. (2008) and Acosta et al. (2009), I define its prior density to be a Normal distribution with mean 1.5 and standard deviation 0.2. For the habit formation parameter b, I define the prior density to be a Beta distribution with mean 0.7 and standard deviation 0.1. Following Smets and Wouters (2007), I define the prior density for inverse intertemporal elasticity of substitution, σ, to be a Normal distribution with mean 1.5 and standard deviation 0.2. The investment adjustment cost parameter κ is often estimated in the literature using a prior density defined as a normal/gamma distribution with mean 4 and standard deviation approximately equaling 1.5; see: Smets and Wouters (2003), Smets and Wouters (2007) and Fernández-Villaverde (2010). In absence of relevant information on this parameter pertaining to Nepalese economy, I define its prior density to be a Normal distribution with first and second moment information specified earlier. Finally, I use the estimate by Poudel (2019) of Calvo price parameter to define its prior density to be a Beta distribution with mean 0.6873 and standard deviation 0.05.

There is no consensus on prior density of monetary policy parameters, ϕ_π and ϕ_Y, in the context of emerging economies. For Taylor-type money growth rule, Zhang (2009) calibrates these parameters at $\phi_\pi = 1$ and $\phi_Y = 0.5$ for the Chinese economy, while Li and Wang (2019) estimates these parameters, also in the context of Chinese economy, using Beta distribution centered at 0.6, and finds the posterior means of $\phi_\pi = 0.648$ and $\phi_Y = 0.474$. The situation is very similar in the context of Taylor rule. As such, I define the prior densities for these parameters by appealing to my beliefs on the nature of Nepalese monetary policy. One of the primary objective of NRB is to maintain price stability, so a significantly positive value of the parameter ϕ_π seems plausible. However, given the fact that the average inflation in Nepalese and Indian economy for the period 1965-2019 were 7.9% and 7.7 % respectively, it seems reasonable[7] to assume that NRB does not pursue price stabilization objective aggressively. Therefore, Central Bank independence only seems possible in the short run; Banaerjee and Basu (2015) confirm this observation. Based on these findings, I define the prior density of ϕ_π to be a Normal distribution with mean 1.0 and standard deviation 0.1. Keeping in mind that the promotion of sustainable growth is one of the secondary objectives of Nepalese monetary authority, I define the prior density of ϕ_Y to be a Normal Distribution with mean 0.125 and standard deviation 0.025. The preceding arguments apply equally well to the case of both interest rate rule and money growth rule, so for the lack of more information, I fix these priors for parameters in both models $\mathscr{I}_T$ and $\mathscr{M}_T$.

Table 3.3 presents the list of estimated parameters and their prior distributions for each models. $\mathscr{B}(-,-)$, $\mathscr{N}(-,-)$, $\mathscr{G}(-,-)$ and $\mathscr{IG}(-,-)$ represent Beta distribution, Normal distribution, Gamma distribution and Inverse Gamma distribution respectively; the first and second arguments in each are mean and standard deviation respectively.

[7] Engle-Granger test suggests that there is a statistically significant co-movement between the two series.

Parameter	Prior distribution		
	$\mathscr{I}_T$	$\mathscr{M}_T$	$\mathscr{M}_F$
b	$\mathscr{B}(0.7,0.1)$	$\mathscr{B}(0.7,0.1)$	$\mathscr{B}(0.7,0.1)$
σ	$\mathscr{N}(2,0.37)$	$\mathscr{N}(2,0.37)$	$\mathscr{N}(2,0.37)$
κ	-	$\mathscr{N}(4,1.5)$	$\mathscr{N}(4,1.5)$
η	$\mathscr{N}(1.5,0.2)$	$\mathscr{N}(1.5,0.2)$	$\mathscr{N}(1.5,0.2)$
ϕ_p	$\mathscr{B}(0.6873,0.05)$	$\mathscr{B}(0.6873,0.05)$	$\mathscr{B}(0.6873,0.05)$
ϕ_π	$\mathscr{N}(1.0,0.1)$	$\mathscr{N}(1.0,0.1)$	-
ϕ_Y	$\mathscr{N}(0.125,0.025)$	$\mathscr{N}(0.125,0.025)$	-
ρ_A	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$
ρ_Z	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$
ρ_M	-	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$
ρ_i	$\mathscr{B}(0.7,0.2)$	-	-
ρ_ψ	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$	$\mathscr{B}(0.7,0.2)$
stderr ε_A	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$
stderr ε_Z	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$
stderr ε_M	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$
stderr ε_ψ	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$
stderr ε_Ξ	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$	$\mathscr{IG}(0.10,2.00)$

Table 3.3: List of estimated parameters

To estimate the models, I use DYNARE Toolbox Adjemian et al. (2011). Given the prior densities of the parameters and the data, DYNARE uses Kalman filter to construct the likelihood function. The likelihood function along with the prior distribution gives us the posterior distribution. Due to difficulties in making draws from the posterior distribution $p(\Theta \mid \mathscr{Y})$ directly, DYNARE employs Metropolish-Hastings algorithm to conduct Markov Chain Monte Carlo (MCMC) simulations and perform draws from the posterior distribution. For each of the model I perform $1,000,000$ MCMC draws to estimate the moments of the parameters.

CHAPTER 4
RESULTS

In this chapter, I present the estimated models and use them to analyze various facets of the model economy.

4.1 Posterior Estimates

Estimation of DSGE models is largely dependent on MCMC simulation. Figures 4.1, 4.2 and 4.3 display the multivariate convergence diagnostics of the MCMC simulation for models $\mathscr{I}_T$, $\mathscr{M}_T$ and M_F respectively. The figures suggest that the MCMC simulations have converged in each case.

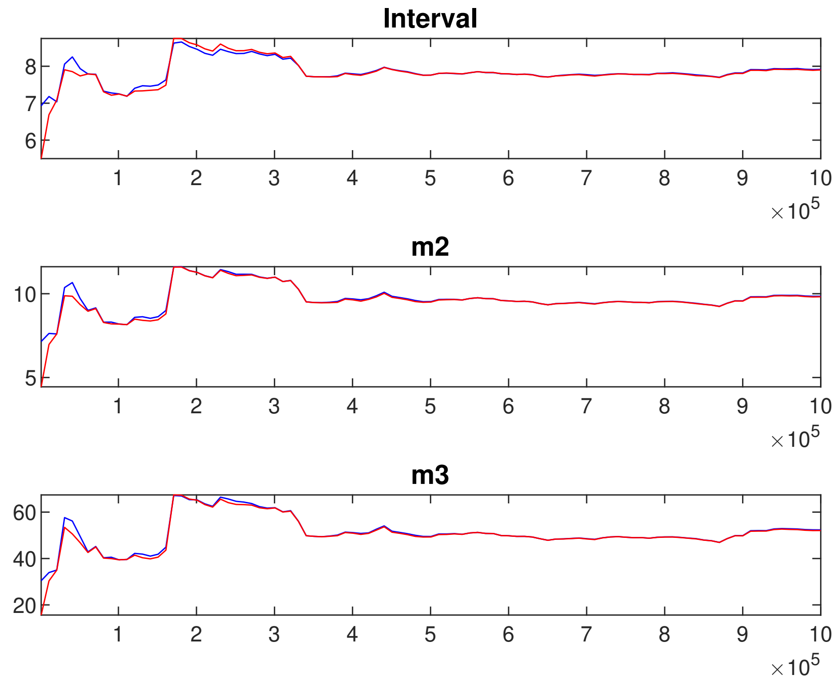

Figure 4.1: Brooks and Gelman Multivariate Convergence Diagnostics (model $\mathscr{I}_T$)

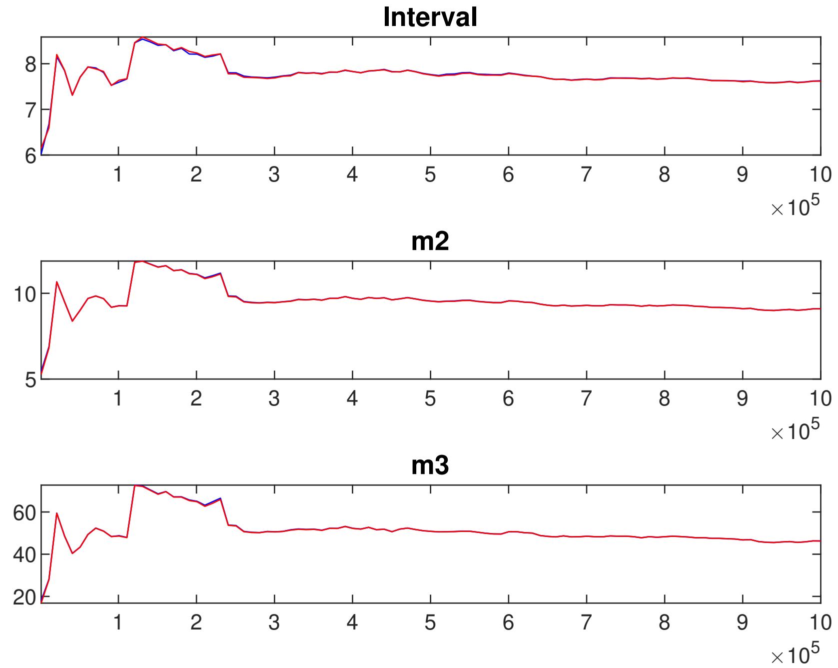

Figure 4.2: Brooks and Gelman Multivariate Convergence Diagnostics (model $\mathscr{M}_T$)

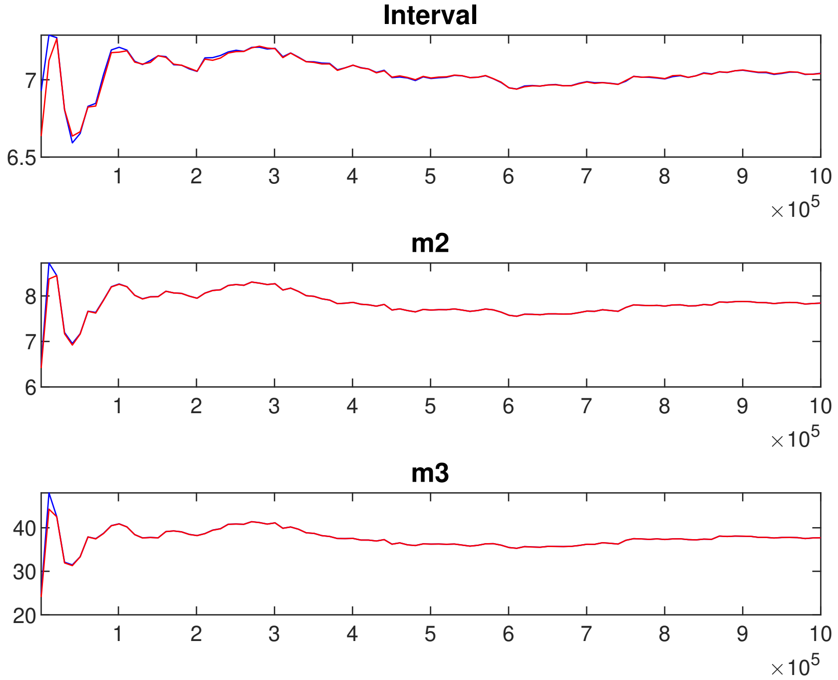

Figure 4.3: Brooks and Gelman Multivariate Convergence Diagnostics (model $\mathscr{M}_F$)

I provide the figures of posterior distribution and smoothed shocks for the observable period for all three models in the Appendix.

Table 4.1 presents the posterior information of the estimated parameters for each model. The term 90% HPDI in the title of the table stands for 90% Highest Posterior Density Interval[1].

Parameter	model $\mathscr{I}_T$		model $\mathscr{M}_T$		model $\mathscr{M}_F$	
	Mean	90% HPDI	Mean	90% HPDI	Mean	90% HPDI
b	0.4981	[0.35, 0.64]	0.6144	[0.49, 0.73]	0.7714	[0.71, 0.82]
σ	1.3339	[0.99, 1.66]	1.4192	[1.08, 1.75]	1.1153	[0.83, 1.41]
κ	-	-	4.2832	[1.81, 6.62]	4.8324	[2.64, 6.98]
η	1.2591	[0.97, 1.55]	1.2777	[0.97, 1.57]	1.3118	[1.01, 1.59]
ϕ_p	0.6083	[0.54, 0.67]	0.6130	[0.54, 0.67]	0.6330	[0.57, 0.69]
ϕ_π	0.7158	[0.55, 0.86]	0.7662	[0.58, 0.94]	-	-
ϕ_Y	0.0706	[0.03, 0.10]	0.0083	[-0.01, 0.03]	-	-
ρ_A	0.3370	[0.13, 0.52]	0.3546	[0.13, 0.56]	0.4759	[0.27, 0.67]
ρ_Z	0.5553	[0.29, 0.81]	0.4704	[0.19, 0.72]	0.5269	[0.24, 0.78]
ρ_M	-	-	0.7737	[0.53, 0.99]	0.4800	[0.29, 0.66]
ρ_i	0.9400	[0.87, 1.00]	-	-	-	-
ρ_ψ	0.8423	[0.66, 0.99]	0.9390	[0.86, 0.99]	0.9284	[0.86, 0.99]
stderr ε_A	0.0866	[0.05, 0.11]	0.0837	[0.05, 0.11]	0.0978	[0.06, 0.13]
stderr ε_Z	0.0829	[0.04, 0.12]	0.0874	[0.04, 0.12]	0.0871	[0.04, 0.12]
stderr ε_M	-	-	0.0296	[0.02, 0.03]	0.0186	[0.01, 0.02]
stderr ε_i	0.0190	[0.01, 0.02]	-	-	-	-
stderr ε_ψ	0.8329	[0.09, 1.81]	0.2841	[0.08, 0.49]	0.7065	[0.26, 1.14]
stderr ε_Ξ	0.0890	[0.07, 0.10]	0.0883	[0.07, 0.10]	0.0880	[0.07, 0.10]

Table 4.1: Posterior distributions of the estimated parameters

The estimates of the standard errors of the exogeneous shocks for the three models are quite comparable except for the estimate of ε_ψ. Relatively high value of ε_ψ in all three models suggests high volatility of intratemporal preference shock compared to other exogenous shocks. In regards to monetary policy shock, the variability is quite low in all three models, compared to the variability of other exogeneous shocks. Estimates of the persistence parameter (ρ_A, ρ_Z, ρ_M, ρ_i ρ_ψ) are comparable in all three models, except for the monetary policy persistence parameters. Monetary policy shock displays a high degree of persistence in models $\mathscr{I}_T$ and $\mathscr{M}_T$, while there is only a moderate degree of persistence in model $\mathscr{M}_F$. The parameter ρ_ψ has a high estimated value in all three models. On the other hand, the parameter ρ_A, which determines persistence of technology shocks, has somewhat low value in all three models, estimated at 0.3370, 0.3546 and 0.4759 respectively. Similarly, the parameter ρ_Z, which determines the persistence of MEI shock, also does not have high values.

[1]It is important to note the difference between frequentist confidence interval and Bayesian HPD interval to interpret this result.See (Koop, 2003).

The habit formation parameter b, in model $\mathscr{M}_F$, reflects a high degree of habit formation in consumption. Estimate of this parameter for the model $\mathscr{M}_T$ reflects only a moderate level of habit formation in consumption, and its value in model $\mathscr{I}_T$ reflects a low degree of habit formation in consumption. The parameter σ is a measure of willingness of the consumers to substitute consumption between different periods in time. For high values of σ, the value of the marginal utility falls more rapidly in response to a rise in consumption. This implies that the households are less willing to substitute present consumption for future consumption at high values of σ. Therefore, given the estimated parameter values, the consumers are less willing to substitute consumption in two different time periods in model $\mathscr{M}_T$, compared to the other two models. Christiano et al. (2005) interpret the investment adjustment cost κ as the inverse of elasticity of investment to 1 percent increase in the current price of installed capital, $1/\kappa$. Our estimate of $1/\kappa$ is roughly 0.25 in models $\mathscr{M}_T$ and $\mathscr{M}_F$. Using the measure, $1/(\kappa(1-\beta))$, developed in Christiano et al. (2005), a 1 percent permanent change in the price of the capital induces roughly 8% change in investment in our model. Estimated values of Calvo price parameter, ϕ_p, suggest a moderate level of price stickiness in all three models. This implies that the prices are updated every 2.5 quarters on average. This estimate is similar to the estimate of this parameter in Poudel (2019), who estimates the parameter using micro-data. However, this estimate differs drastically compared to the estimate in Suzuki (2019), where the prices are updated every 0.125 quarters on average.

Positive estimated values of remittance parameter η confirms the countercyclicality of remittance inflows to Nepalese economy. This confirms the finding of Suzuki (2019). Remittance inflows to Nepalese economy are aided mostly by the large number of migrant workers who emigrate to the gulf countries and the east-Asian countries every year. The targets of their remittance inflow are their families (close ties) for the most part. The result suggests low random variation in close ties remittance inflow.

Estimates of the monetary policy parameters ϕ_π and ϕ_Y are very similar in both models $\mathscr{I}_T$ and $\mathscr{M}_T$. Estimated values of parameters ϕ_π and ϕ_Y in model $\mathscr{M}_T$ are comparable to to the calibration in Zhang (2009), where money growth rule is used to model monetary policy in China. These estimated values imply that Nepalese monetary policy responds to inflation more aggressively than to the output gap. This is in confirmation with the primary objective of Nepal Rastra Bank, which is price stabilization. Despite the comparable estimates of the parameters ϕ_π and ϕ_Y, the degree persistence of monetary policy in models $\mathscr{I}_T$ and $\mathscr{M}_T$ are quite different; monetary policy in model $\mathscr{I}_T$ is far more persistent than in model $\mathscr{M}_T$.

The estimated values of the monetary policy parameters, do not provide an answer to the question: Which monetary policy rule better reflects the characteristics of Nepalese monetary policy? Since the resolution of this question is the primary objective of this thesis, I turn to this issue in the next section.

4.2 Which monetary policy rule?

In this section, I analyze the goodness of fit of the three models considered in the previous section. The goodness of fit of DSGE models can be evaluated either by comparing the second moments of the model variables with that of the actual data, or by computing the Bayes' factor. Let us start by comparing the second moments of model variables with that of the actual data. Table 4.2 displays the second moments of (one-sided) HP-filtered model variables and actual variables.

Variable	Second Moment(One sided HP filtered)			
	Model $\mathscr{I}_T$	Model $\mathscr{M}_T$	Model $\mathscr{M}_F$	Actual Data
C_y	0.032405	0.019909	0.025564	0.012251
Y_y	0.092078	0.071534	0.097732	0.020667
Ξ	0.149039	0.100502	0.136724	0.0924
π	0.021715	0.008319	0.010244	0.0213
m	1.018554	0.079938	0.051351	0.0261

Table 4.2: Comparison of second moments of model and actual variables

The variables C_y and Y_y represent percentage deviation from the steady state of yearly consumption and output respectively, while the variables Ξ, π and m represent the percentage deviation from the steady state of remittance inflow, inflation and real money balance respectively. For the variable C_y, the second moment of the actual data is fairly comparable with the estimate for each model. As for the variable Y_y, the second moments of the model variables are fairly higher than the second moment of the actual data. The case of variable Ξ is roughly the same. In regards to the variable π, model $\mathscr{I}_T$ matches the actual data very well, while the estimates, of the second moments, for other two models are fairly different. The situation is quite different in the case of variable m; model $\mathscr{I}_T$ misses the mark by a huge margin, while the other two models do a much better job. In general, one can see that the second moments of model variables are significantly larger compared to that of the actual data. This phenomenon, however, is fairly common in the literature; see for example Justiniano et al. (2011).

Comparison of the second moments gives us some idea on the fit of the models. For example, even with this approach, one can see that model $\mathscr{I}_T$ does a poor job of matching the model variables with the actual data. However, this information is not enough to conclusively decide which model adheres best to the data. To reach a fairly sharp conclusion I compute the Bayes' factor for each model. For the computation of Bayes' factor, I assume that each model is equally likely to represent the actual behaviour of Nepalese economy. Results from this computation are presented in Table 4.3.

	Model $\mathscr{I}_T$	Model $\mathscr{M}_T$	Model $\mathscr{M}_F$
Log Marginal Density	167.9	334.6	351.5
Bayes' Ratio	exp(0)	exp(166.7)	exp(183.6)

Table 4.3: Comparison of Models $\mathscr{I}_T$, $\mathscr{M}_T$ and $\mathscr{M}_F$

Log marginal density of model $\mathscr{I}_T$ is significantly different from the respective log marginal densities of the other two models. This implies that there is a very low probability[2] that model $\mathscr{I}_T$ is the correct model for Nepalese economy. In fact, the magnitude of Bayes' ratio for model $\mathscr{M}_T$ and model $\mathscr{M}_F$ are different enough to conclude that model $\mathscr{M}_F$ best represents Nepalese economy.

The result in this section provides us with a fairly conclusive evidence that the Taylor rule cannot be used to understand Nepalese monetary policy. As such, I exempt model $\mathscr{I}_T$ from analyses for the rest of this thesis and only consider the models $\mathscr{M}_T$ and $\mathscr{M}_F$.

4.3 Impulse Response Analysis

In this section, I analyze dynamic response of a few endogenous variables to exogenous shocks in the context of models $\mathscr{M}_T$ and $\mathscr{M}_F$. This simultaneous comparison of the two models is useful in recognizing the peculiarities in each model.

Figure 4.4 displays dynamic response of a few endogenous variables to a positive technology shock. In both the models, consumption displays a hump-shaped dynamic movement. Magnitude of the rise in consumption is higher in model $\mathscr{M}_T$ than in model $\mathscr{M}_F$. However, owing to the larger value of habit formation parameter, it is much more persistent in model $\mathscr{M}_F$. Similar to consumption, output rises immediately in response the technology shock in a humped-shaped fashion. It reaches the peak level at around a year, and it drops back to its steady state level by the end of two years. The movement of investment is similar to that of output. Owing to the rise in marginal productivity in response to the technology shock, employment experiences a drop. However, at precisely around the time that output reaches the maximum, the employment level gets back to the steady state. This is consistent with evidence in Gali (1999).

[2]In contrast to classical statistics, Bayesian statistics assigns probabilities to the hypotheses which allows one to argue as such.

Unlike other variables, inflation drops in response to the technology shock, but slowly gets back to the steady state level in about a year. The drop in inflation, along with the rise in factor productivity induces a rise in real wage immediately after the technology shock. In model $\mathscr{M}_F$, monetary authority does not respond to technology shocks, and as a result nominal money growth and the interest rate remain at the steady state level. On the other hand, in model $\mathscr{M}_T$, nominal money growth jumps in response to the technology shock, which in turn results in a lowering of the interest rate; the interest rate movement displays a hump-shaped response in this case.

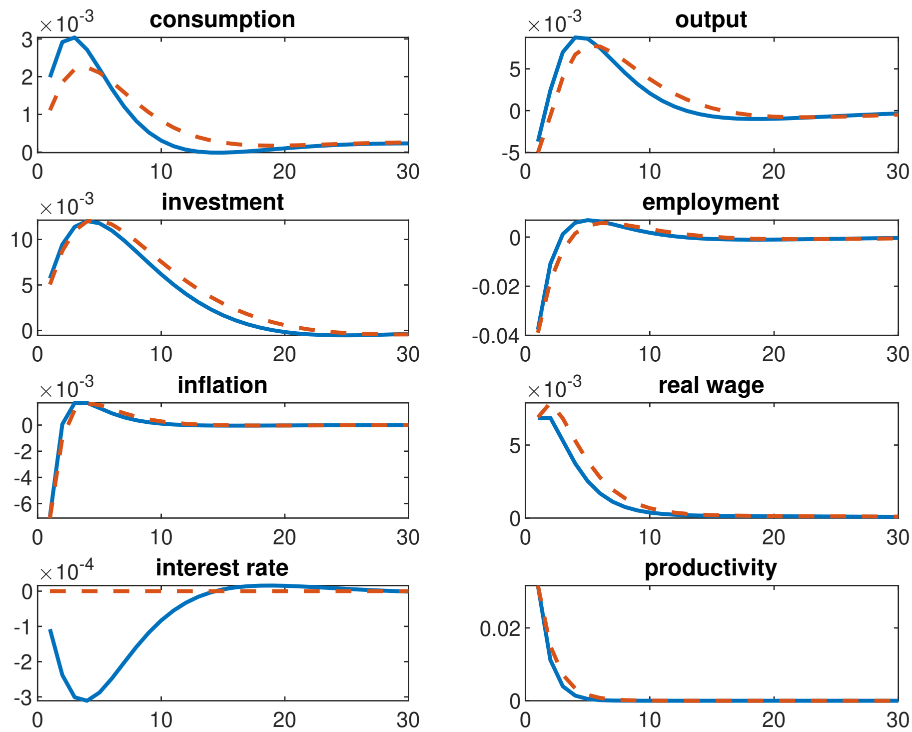

Figure 4.4: Impulse Response to Technology Shock. Model $\mathscr{M}_T$ (thick line); Model $\mathscr{M}_F$ (dashed line).

Figure 4.5 displays dynamic response of a few endogenous variables to a Marginal Efficiency of Investment (MEI) shock. Consumption rises in a hump-shaped fashion in response to the shock. The movements differ in magnitude and persistence in the two models. Within the setting of model $\mathscr{M}_T$, consumption rises immediately in response to the shock, but there is a significant volatility in subsequent periods. In the setting of model $\mathscr{M}_F$, the movement is quite a bit more persistent, although the initial increase in consumption is significantly lower. In either case, the co-movement of investment and consumption immediately in response to the MEI shock is in strong contrast to the result in Justiniano et al. (2011), where investment rises in a hump shaped fashion while the curve traced out by the movement of consumption is similar to a logistic function.

However, in light of the empirical evidence, which supports the co-movement of consumption and investment in response to an MEI shock Furlanetto and Seneca (2014), this result is significant.

The nature of movement of other endogenous variables in both the models are exactly the same. Output, investment and employment (not shown in the figure) move in a hump-shaped fashion. The drop in inflation boosts the rise in the real wage. The significant difference between the two models is again apparent in the movement of nominal money growth and the interest rate. In model $\mathscr{M}_T$, nominal money growth rises in response to the MEI shock, while the interest rate falls. Both these trends are absent in model $\mathscr{M}_F$ owing to the fact that monetary authority does not react to the change in output or inflation gap. The co-movement of output, consumption, investment and employment in response to the MEI shock is in line with the results in Christiano et al. (2010).

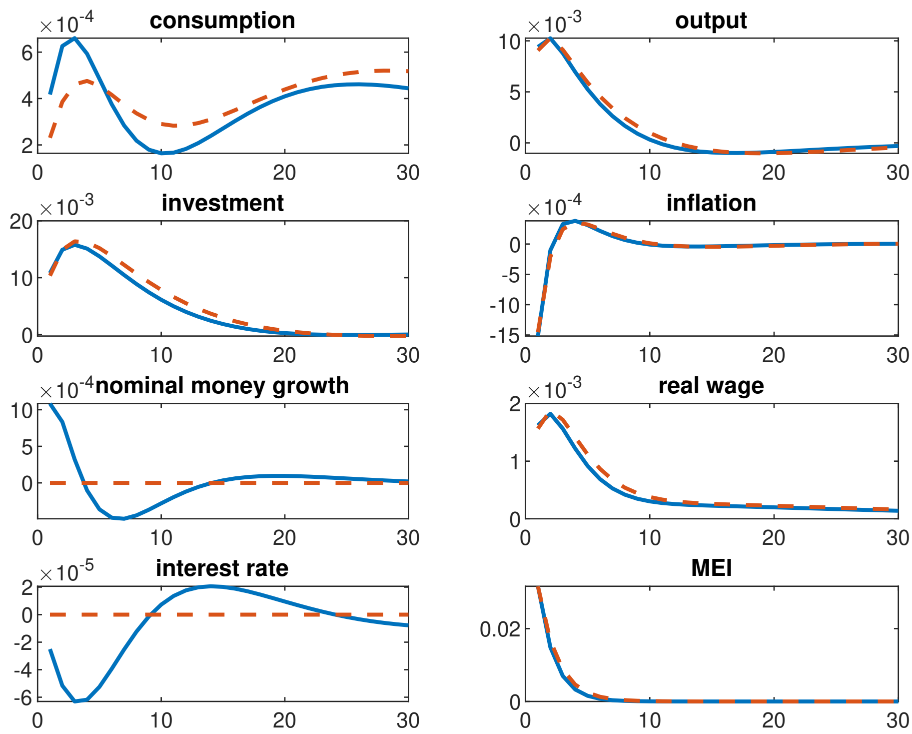

Figure 4.5: Impulse Response to Marginal Efficiency of Investment Shock. Model $\mathscr{M}_T$ (thick line); Model $\mathscr{M}_F$ (dashed line).

Figure 4.6 displays dynamic movement of a few endogenous variables to an Intratemporal Preference shock. Due to a large persistence of intratemporal preference, the effect on endogenous variables is fairly persistent. Consumption, output and employment fall in a hump-shaped fashion immediately in response to the shock. In contrast to these variables, inflation and the real wage rise in response to the shock. This essentially is a feature of a supply shock, which explains the terminology "Labour supply shock" which is often used in the literature to refer to intratemporal preference shocks.

The interest rate and nominal money growth move in opposite direction as in previous impulse response analyses. Meanwhile, these variables do not show any trace of movement away from the steady state in model $\mathscr{M}_F$.

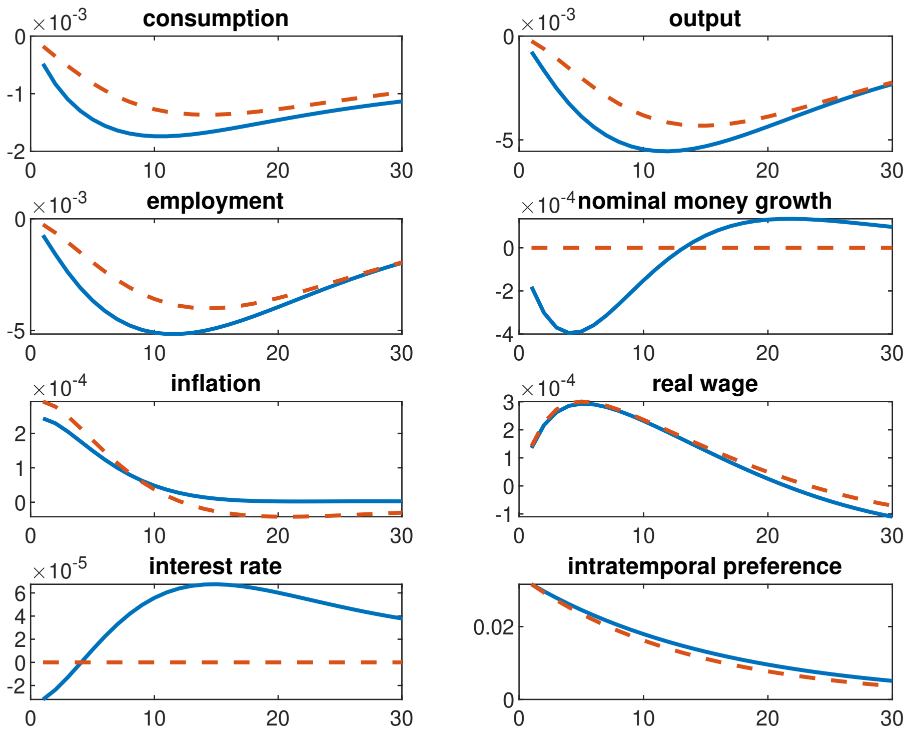

Figure 4.6: Impulse Response to Intratemporal Preference Shock. Model $\mathscr{M}_T$ (thick line); Model $\mathscr{M}_F$ (dashed line).

Figure 4.7 displays dynamic movement of a few endogenous variables to a Remittance inflow shock. The welfare effect of remittance inflow induces a rise in consumption immediately in response to the shock, in a hump-shaped fashion. This reflects the fact that recipient households set aside a large portion of remittance for consumption. There is a significant difference in the movement of consumption between the two models. In model $\mathscr{M}_T$, the magnitude of rise in consumption, in response to the shock, is much larger compared to the magnitude of rise in consumption in model $\mathscr{M}_F$; although, the persistence of rise in comparable in both models. We can explain this difference by looking at the magnitude of increase in nominal money growth and the fall in inflation in response to the shock. In model $\mathscr{M}_T$, nominal money growth rises and inflation falls immediately in response to the shock. This leads to a rise in real money balance available to the household, which is then used for consumption. On the other hand, in model $\mathscr{M}_F$, in absence of a rise in nominal money balance, the rise in real money balance is only driven by a fall in inflation, which is negligible. As a result, the households have much less real balance available for consumption.

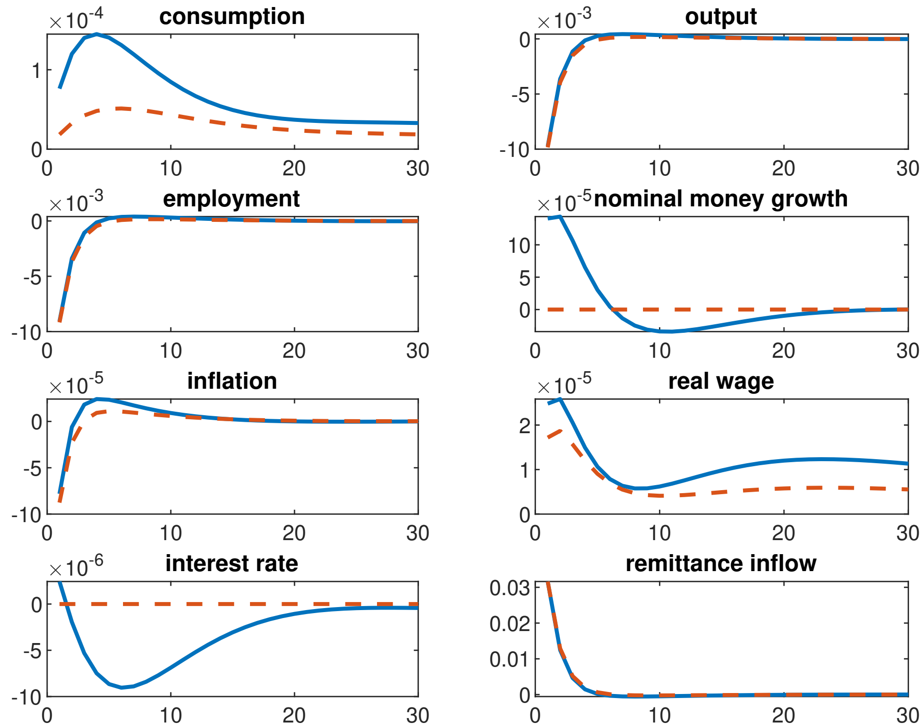

Figure 4.7: Impulse Response to Remittance Shock. Model $\mathscr{M}_T$ (thick line); Model $\mathscr{M}_F$ (dashed line).

Another implication of the welfare effect is an increase in leisure. One can clearly see this through the fall in employment immediately in response to the shock. The fall in employment leads to a drop in output, roughly by the same percentage. These two macroeconomic variables return to the pre-shock steady state as soon as the persistence of remittance inflow dies out. The ascent of inflation to the pre-shock steady state, and beyond, is much quicker in model $\mathscr{M}_T$. This suggests that the upward pressure in inflation caused by remittance inflow is neutralized, to the large extent, by the downward pressure in inflation caused by the fall in output. The upward pressure in inflation in response to the shock is posited in Maskay et al. (2015). However, a deeper analysis is required to confirm this behaviour of inflation in the context of model $\mathscr{M}_T$. This effect is absent in model $\mathscr{M}_F$ owing to the lack of nominal money growth in response to the shock.

Figure 4.8 displays dynamic response of a few endogenous variables to a nominal money supply shock. Consumption, output, investment and employment all rise in a hump-shaped fashion in response to the shock. The magnitude of the rise in these variables is higher in model $\mathscr{M}_F$. The reason for this is that for the money market to clear output must increase or the interest rate must decrease, and given the values of estimated parameters, model $\mathscr{M}_F$ prefers the increase in output as opposed to the decline in the interest rate. This also means that the interest rate rises in response to the shock and slowly drops back down to the steady state. In particular, the liquidity effect is absent in model $\mathscr{M}_F$. This is in line with the result in Gali (2002). In contrast, in model $\mathscr{M}_T$, the interest rate drops slowly in response to the shock and helps clear the money market. As a result, output does not rise as much as in model $\mathscr{M}_F$. The increase in inflation is, similarly, strong in model $\mathscr{M}_F$ compared to model $\mathscr{M}_T$, and owing to the increased economy activity, the increase in real wage is strong as well.

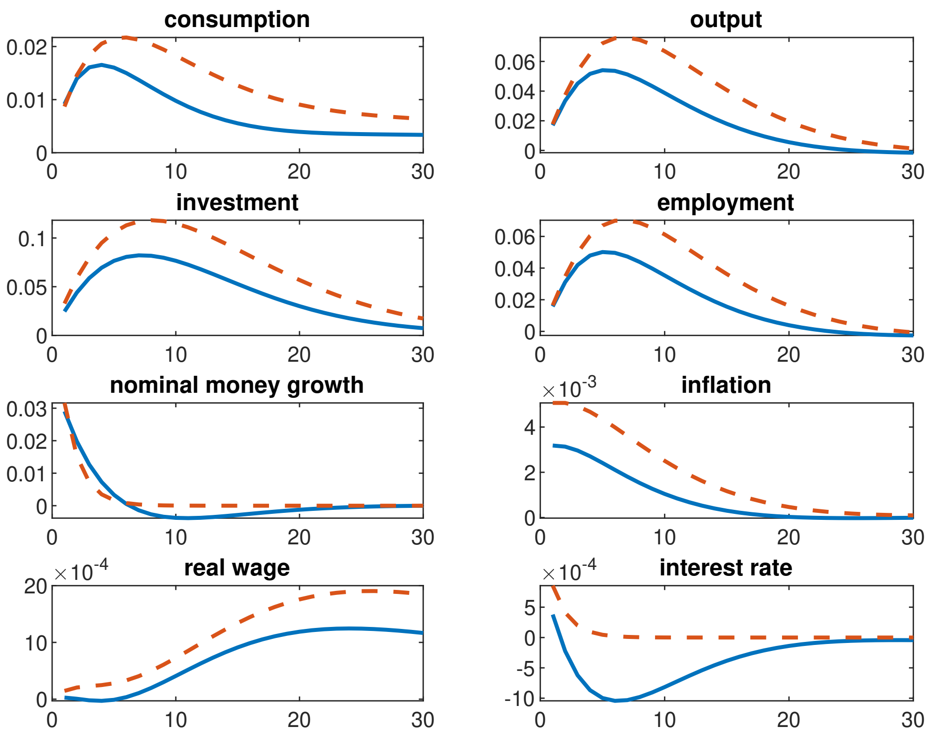

Figure 4.8: Impulse Response to Nominal Money Supply Shock. Model $\mathscr{M}_T$ (thick line); Model $\mathscr{M}_F$ (dashed line).

Two things are important to note here. The first is the negative co-movement of the interest rate and inflation in model $\mathscr{M}_T$. This is a common feature of DSGE models with interest rate rules as discussed in Bhattacharjee and Thoenissen (2007). The second is the co-movement of nominal money growth and the interest rate in model $\mathscr{M}_F$. This co-movement is apparent in Nepalese data for the time period considered[3].

[3] I carried out Engle-Granger test for these two series. The test reported a p-value of 0.0001 which

In the next section, I analyze the importance of exogenous shocks, considered here, in determining the variations in output and inflation.

4.4 Forecast Error Variance Decomposition

Table 4.4 reports the forecast error variance decomposition of output and inflation. The decomposition in each model are visibly different, so they require separate discussions. Let us start with model $\mathscr{M}_T$. Output is greatly influenced by monetary policy shocks, remittance inflow shocks and MEI shocks in the short run. The effect of remittance shocks starts to dissipate immediately, however it takes longer for the effect of MEI shocks to dissipate. In the medium run, the effect of monetary shocks is prominent, and the effect of intratemporal preference shocks starts to become apparent. Over the longer time horizons, the effect of monetary policy shocks attenuates, while the intratemporal preference shocks become increasingly prominent in explaining the variations in output. Productivity shocks do not have much to offer in explaining the variations in output, however they are quite important for explaining the variations in inflation. In the short run, inflation is almost completely determined by technology shocks. Over the longer time horizons, monetary policy shocks become important, but technology shocks remain the primary determinant of variations in inflation. The effect of other three shocks remains constant and negligible over all time horizons. The result of this analysis is analogous to the result in Smets and Wouters (2007) where the authors find that the supply shocks: wage markup shocks, price markup shocks and productivity shocks determine the variations in output and inflation over the long run. While I have not considered markup shocks in this thesis, the supply shocks: intratemporal preference shocks and productivity shocks are instrumental in determining the variations in output and inflation over the long run.

In the case of model $\mathscr{M}_F$, monetary policy shocks largely determine the variations in both output and inflation. In the short run, monetary policy shocks are the primary determinant of output variations, although remittance inflow shocks and MEI shocks play a significant role as well. Over the longer time horizons, the impact of shocks other than monetary policy shocks completely washes over; monetary policy shocks determine the variations in output completely. Monetary policy shocks are, almost, equally important in determining the variations in inflation. In the short run, technology shocks are the primary determinant of the inflation, however monetary policy shocks become prominent progressively with time. Over the long run, inflation is largely determined by monetary policy shocks, although the effect of productivity shocks remains non-negligible.

implies the rejection of null-hypothesis of no cointegration relation between the data series.

Variable	Time Horizon	ε_M	ε_A	ε_Ξ	ε_Z	ε_ψ
Model $\mathscr{M}_T$						
Output	1	13.88	5.31	40.88	37.38	2.55
	4	47.39	9.03	7.56	21.62	14.41
	8	50.65	8.01	2.95	9.76	28.63
	12	44.66	5.60	1.97	6.52	41.24
	20	34.32	4.01	1.40	4.69	55.58
	40	29.33	3.47	1.19	4.04	61.98
Inflation	1	2.38	91.60	0.01	4.72	1.28
	4	7.05	85.21	0.01	4.38	3.34
	8	9.31	82.44	0.01	4.28	3.96
	12	9.92	81.77	0.01	4.24	4.06
	20	10.01	81.66	0.01	4.25	4.06
	40	10.01	81.66	0.01	4.25	4.07
Model $\mathscr{M}_F$						
Output	1	60.53	4.88	18.73	15.85	0.01
	4	94.31	0.92	1.23	3.49	0.04
	8	97.38	0.90	0.36	1.25	0.10
	12	98.05	0.70	0.24	0.83	0.19
	20	98.14	0.58	0.19	0.69	0.40
	40	97.95	0.58	0.19	0.69	0.58
Inflation	1	32.71	64.47	0.01	2.70	0.11
	4	62.57	35.74	0.01	1.51	0.17
	8	70.99	27.68	0.00	1.16	0.16
	12	73.62	25.17	0.00	1.05	0.14
	20	74.51	24.32	0.00	1.02	0.14
	40	74.56	24.26	0.00	1.02	0.15

Table 4.4: Forecast Error Variance Decomposition of output and inflation

Output and inflation can be decomposed into their shock components over the sample period. This allows one to understand which shocks were important in driving variations in output and inflation over the sample period. Figure 4.9 presents the historical decomposition of output for the observable period in the context of model $\mathscr{M}_T$. The significance of monetary policy shocks and labour supply shocks over the observable period is apparent. As can be seen, there are some episodes where the impact of MEI and technology shocks are pronounced. Remittance shocks, in contrast, have very low significance in explaining variations in output over the observable period.

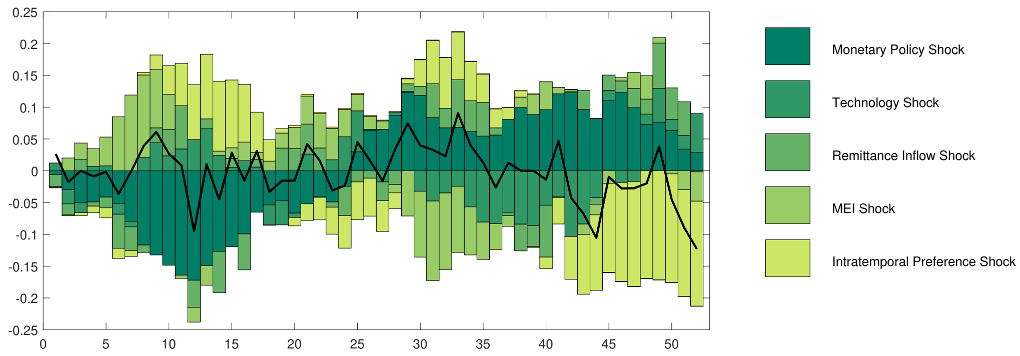

Figure 4.9: Historical Decomposition of Output (model $\mathscr{M}_T$)

Figure 4.10 presents the historical decomposition of output for the observable period in the context of model $\mathscr{M}_F$. Qualitatively, the historical decomposition under model $\mathscr{M}_F$ is virtually identical to the historical decomposition under model $\mathscr{M}_T$, which is apparent through comparison with figure 4.9.

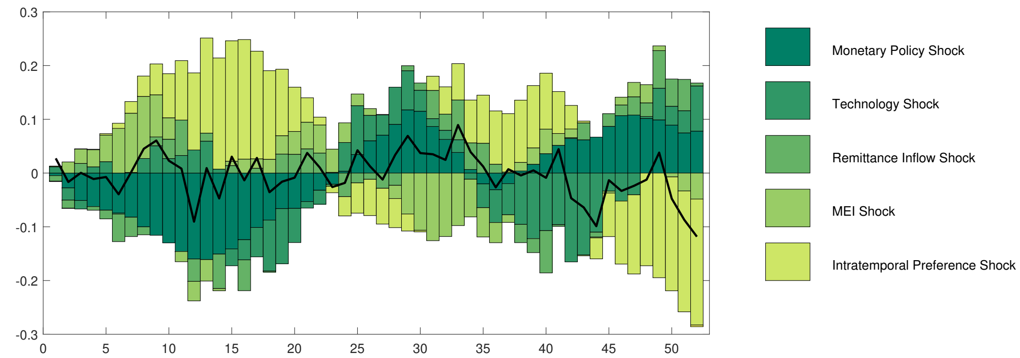

Figure 4.10: Historical Decomposition of Output (model $\mathscr{M}_F$)

Figure 4.11 presents the historical decomposition for inflation over the observable time period in the context of model $\mathscr{M}_T$. Technology shocks are the primary determinants of the variations in inflation over the observable period. Monetary policy shocks and intratemporal preference shocks seem significant in some sporadic episodes, while the influence of remittance and MEI shocks is non-existent.

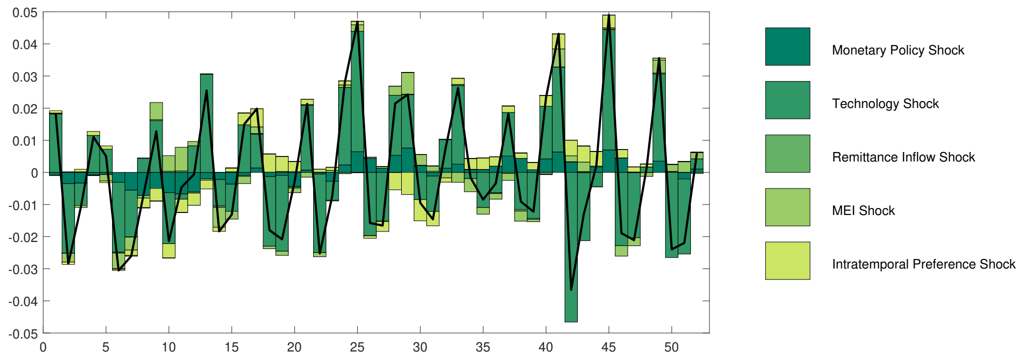

Figure 4.11: Historical Decomposition of inflation (model $\mathscr{M}_T$)

Figure 4.12 presents the historical decomposition for inflation over the observable time period in the context of model $\mathscr{M}_F$. Here the situation is virtually identical to figure 4.11, although there are a few more episodes where the impact of intertemporal preference shocks is significant.

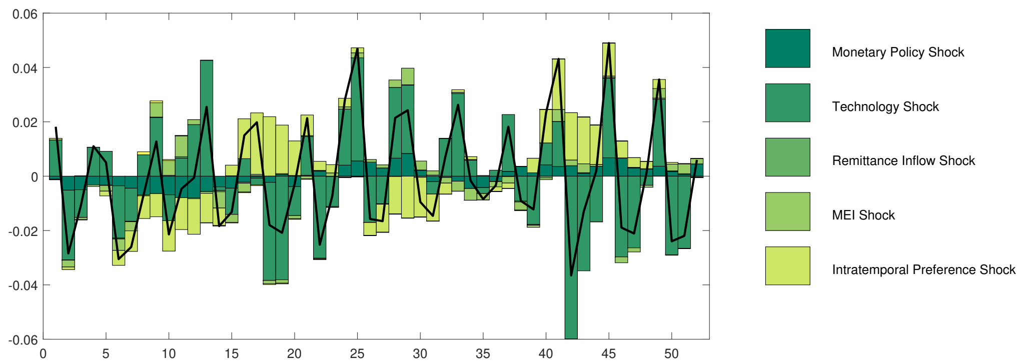

Figure 4.12: Historical Decomposition of inflation (model $\mathscr{M}_F$)

The analysis of historical decomposition of output and inflation suggests that technology shocks, intratemporal preference shocks and monetary policy shocks had a major part in determining the variations in output and inflation over the observable time period. Over the same time period, remittance inflow shocks and MEI shocks did not have much influence on the variations in output and inflation.

In the next section, I carry out sensitivity analysis to determine which frictions are empirically significant.

4.5 Which frictions are important?

The analysis in the previous section demarcates exogenous shocks according to their influence in inducing variations in output and inflation. In this section, I present results from the counter-factual analysis aimed at demarcating the frictions that are integral component of Nepalese economy from those that are not. Table 4.5 presents the value of log marginal density for alternative values of the friction inducing parameters: ϕ_p, ϕ_w, b, ξ_p, ξ_w, κ.

Parameters	Log Marginal Density (Laplace Approximation)	
	Model $\mathscr{M}_T$	Model $\mathscr{M}_F$
Baseline	334.6	351.5
$\phi_p = 0.1$	316.9	340.9
$\phi_w = 0.1$	337.3	349.2
$b = 0.1$	340.6	195.52
$\xi_p = 0.75$	326.9	345.31
$\xi_w = 0.75$	335.2	351.6
$\kappa = 0.00$	325.4	307.7

Table 4.5: Counter-factual analysis model parameters that drive friction

In both models, the log marginal density drops significantly when the value of Calvo price parameter is set to $\phi_p = 0.1$. This suggests that Calvo price parameter is empirically important. On the other hand, when the value of Calvo wage parameter is set to $\phi_w = 0.1$, the log marginal density rises in model $\mathscr{M}_T$ and falls in model $\mathscr{M}_F$ by roughly the same magnitude. Since the magnitude is quite small, we can assert that the parameter ϕ_w is much less empirically significant. The habit formation parameter when set to $b = 0.1$, demonstrates a similar, but much more pronounced, behaviour. This suggests the empirical significance of habit formation in consumption in both models. The price indexation parameter, ξ_p, is somewhat significant in both models. However, the change in log marginal density in response to wage indexation parameter, ξ_w, is negligible, which suggests that this parameter can be dropped altogether. Investment adjustment cost parameter when set to $\kappa = 0.0$ results in a lower log marginal density in both models. This suggests the empirical significance of this parameter, and much more so in model $\mathscr{M}_F$.

The above discussion demonstrates empirical significance of price rigidity, habit formation and investment adjustment costs. Wage rigidity, price and wage indexation do not appear to have an empirical significance in Nepalese economy.

In the next section I present the results of optimal monetary policy analysis.

4.6 Optimal Monetary Policy

Following the literature, I assume that the monetary authority seeks to maximize the aggregate welfare of the economy. Aggregate welfare is defined as the sum total of the welfare of all the households in an economy. The welfare equation of jth household takes the form

$$W_t(j) = \frac{(C_t(j) - bC_{t-1}(j))^{1-\sigma}}{1-\sigma} - \psi_t \frac{N_t(j)^{1+\chi}}{1+\chi} + \theta \ln m_t + \beta \mathbb{E}_t W_{t+1}(j).$$

Then the aggregate welfare function is $\mathbb{W}_t = \int_0^1 W_t(j) dj$. In expanded form, we have

$$\mathbb{W}_t = \frac{(C_t - bC_{t-1})^{1-\sigma}}{1-\sigma} - \psi_t v_t^w \frac{N_t^{1+\chi}}{1+\chi} + \theta \ln m_t + \beta \mathbb{E}_t \mathbb{W}_{t+1}(j) \tag{4.6.0.1}$$

where $v_t^w = \int_0^1 N_t(j)^{1+\chi} dj$ is a wage dispersion term. The monetary authority seeks to maximize the unconditional expectation of this welfare function subject to monetary policy parameters. There does not exist an analytic solution to this maximization problem, so to compute the optimal value of monetary policy parameters, one needs to use approximation techniques. Linear approximation does not yield an optimal solution because the linearized unconditional expectation of this welfare function is just the steady-state value of this function, which is independent of monetary policy. Therefore, one needs to use higher order approximation; second-order approximation is sufficient.

Maximization of aggregate welfare function, using quadratic approximation, subject to monetary policy parameters in model $\mathscr{M}_T$ gives an optimal welfare value of 1314.9. Corresponding values of monetary policy parameters are: $\rho_M = 0.99$, $\phi_\pi = 2.00$ and $\rho_Y = 0.00$. This welfare value is 71.6% behind the flexible welfare[4] value of 4633.9; this suggests a loss of welfare resulting from market frictions. Parameter values suggest that the optimal monetary policy is characterized by persistent nominal money growth, aggressive inflation targeting and no response to output gap. This result is easy to interpret. Aggressive inflation targeting ensures price stability and persistent nominal money growth ensures that the monetary expectations are realized. It is then easy to see how this can help the households maximize their life-time utility.

Zero value of output-gap targeting in the optimal monetary policy result is troubling. A monetary policy stance characterized by pure inflation targeting can lead to disastrous results in the presence to adverse supply shocks. In such cases, monetary authority aims

[4]Flexible economy is defined to be the economy without nominal rigidities: price and wage rigidities. Flexible welfare then is the maximum value of welfare function assuming there are no price and wage rigidities.

to tighten the monetary policy in order to keep the prices from rising, which then leads to a contraction of nominal GDP. This in turn causes the real GDP to fall drastically, thus plunging the economy into a deep recession. Therefore, it is imperative to note that the optimal monetary policy obtained above is not optimal in all circumstances.

Table 4.6 provides optimal welfare values for various combinations of ρ_M, ϕ_π and ϕ_Y. We see that the optimal welfare value increases with the increment in value of ρ_M and ϕ_π. In contrast, optimal welfare value decreases with the increment in value of ϕ_Y.

Parameter	Parameter Value	Welfare	% from flexible welfare	ρ_M	ϕ_π	ϕ_Y
ρ_M	0.0	1131.1	-75.6	n/a	2.00	0.00
	0.3	1154.5	-75.1	n/a	2.00	0.00
	0.5	1178.5	-74.6	n/a	2.00	0.00
	0.7	1216.4	-73.8	n/a	2.00	0.00
	0.9	1279.9	-72.4	n/a	2.00	0.00
	0.99	1314.9	-71.6	n/a	2.00	0.00
ϕ_π	0.0	973.58	-78.98	0.00	n/a	0.00
	0.5	1043.2	-77.5	0.10	n/a	0.00
	1.0	1159.6	-75.0	0.90	n/a	0.00
	1.3	1253.5	-73.0	0.99	n/a	0.00
	1.7	1280.0	-72.4	0.99	n/a	0.00
	2.0	1314.9	-71.6	0.99	n/a	0.00
ϕ_Y	0.0	1314.9	-71.6	0.99	2.00	n/a
	0.1	916.13	-80.2	0.99	2.00	n/a
	0.3	-350.49	-107.5	0.0	2.00	n/a
	0.5	-1401.6	-130.2	0.0	2.00	n/a
	0.7	-2295.3	-149.5	0.0	2.00	n/a
	0.9	-3036.5	-165.5	0.0	2.00	n/a

Table 4.6: Maximum welfare for various monetary policy parameters combination (model $\mathscr{M}_T$)

Solving the same optimization problem in the context of model $\mathscr{M}_F$ gives the optimal welfare value of 426.02 at $\rho_M = 0$. This welfare value is 96.6% behind the flexible welfare value of 12789.41. This result suggests that the optimal monetary policy is characterized by a constant M2 balance in each period. One can explain this result using Quantity Theory of Money. According to this theory, in absence of M2 growth, and constant velocity, the inflation is close to zero, and thus provides households with price stability. However, if this explanation suffices is difficult to ascertain at this point.

Now let us consider a Taylor-type monetary policy regime under the calibration of model $\mathscr{M}_F$. Table 4.7 displays optimal welfare values for various combination of ρ_M, ϕ_π and ϕ_Y in the setting of model $\mathscr{M}_F$.

Parameter	Parameter Value	Welfare	% from flexible welfare	ρ_M	ϕ_π	ϕ_Y
ρ_M	0.0	837.30	-93.43	n/a	2.00	0.00
	0.3	925.81	-92.73	n/a	2.00	0.00
	0.5	1014.5	-92.0	n/a	2.00	0.00
	0.7	1148.6	-91.0	n/a	2.00	0.00
	0.9	1358.6	-89.3	n/a	2.00	0.00
	0.99	1472.2	-88.5	n/a	2.00	0.00
ϕ_π	0.0	426.01	-96.65	0.00	n/a	0.00
	0.5	932.93	-92.68	0.99	n/a	0.00
	1.0	1189.2	-90.7	0.99	n/a	0.00
	1.3	1339.9	-89.5	0.99	n/a	0.00
	1.7	1393.7	-89.1	0.99	n/a	0.00
	2.0	1472.2	-88.5	0.99	n/a	0.00
ϕ_Y	0.0	1472.2	-88.5	0.99	2.00	n/a
	0.1	-357.24	-102.8	0.99	2.00	n/a
	0.3	-6553.1	-151.4	0.0	2.00	n/a
	0.5	-11676.0	-193.0	0.0	2.00	n/a
	0.7	-15919.0	-225.0	0.0	2.00	n/a
	0.9	-19371.0	-252.0	0.0	2.00	n/a

Table 4.7: Maximum welfare for various monetary policy parameters combination (model $\mathscr{M}_F$)

Using the Taylor-type monetary policy rule, it is clear that zero nominal money growth is not a globally optimal monetary policy. In fact, the optimal monetary policy in this setup is quite similar to the monetary policy in the setting of model $\mathscr{M}_T$. Furthermore, similar results in the setting of both the models increase the likelihood that a monetary policy characterized aggressive inflation targeting along with persistent nominal money growth is indeed optimal.

These results, however, are to be taken with a grain of salt. Implementation of optimal monetary policy hinges upon the independence of the Central Bank. In the context of Nepal, there are grounds to be skeptic about the independence of the Central Bank. In the context of Nepalese economy, Budha (2015), using narrative approach, finds that the Central Bank independence is non-existent over the long run as Nepalese inflation converges to Indian inflation. In the short run, he argues, there is still some leeway to implement an independent monetary policy. Therefore, the foregoing optimal monetary policy can be implemented, at most, in the short run, however it remains an open question if the policy remains optimal under these circumstances.

CHAPTER 5
CONCLUSION

New Keynesian DSGE models are well suited to study developed economies. Modeling emerging economies, like Nepalese economy, using tools designed for developed economies is not an ideal approach. Therefore, necessary modifications have to be made to the model in order to use it in the setting of emerging economies. This was my approach in this thesis. I made two important modifications to the standard New Keynesian Model to make it suitable for modeling Nepalese economy. These modifications involved monetary policy and remittance inflows. Monetary policy is quite different in emerging economies compared to the developed economies. To understand the difference, I considered three different monetary policy rules. Remittance inflows are quite a peculiar characteristic of emerging economies. In developed economies, it is extremely small in quantity, compared to the GDP, however it makes up a sizable portion of earnings by citizens in many emerging economies like Nepal; remittance inflows to Nepalese economy is about 25% the size of the GDP as of 2020 and it used to be above 30 percent of the GDP. If one does not model this big a chunk of the economy, then the variations in consumption, investment and output cannot be properly ascertained. For this reason, I incorporated a remittance inflow equation following Chami et al. (2008).

The model thus developed allowed me to conduct several analyses. Major findings from these analyses are reported in the next section.

5.1 Major Findings

Primary objective of this thesis being the identification of monetary policy rule which describes Nepalese monetary policy, I found that a Friedman-type money growth rule best describes Nepalese monetary policy. I was also able to confirm that the model with Taylor rule is highly unlikely to represent Nepalese economy. However, the implication of following a Friedman-type monetary policy is that Nepal Rastra Bank has a limited leeway to ensure price and output stability.

All the models estimated in this thesis confirm the fact that remittance inflows to Nepalese economy are counter-cyclical. This suggests that remittance inflows provide a good insulation to the economy during the time of recession. In fact, this is what Nepalese economy experienced after the earthquake of 2015; the growth rate of remittance inflow was 3.2% during the year 2014, and in response to the earthquake, the remittance inflow grew by 20.9 % during the year 2015. Apart from the counter-cyclicality, the welfare effect of remittance inflows is pronounced in the two models, models $\mathscr{M}_T$ and $\mathscr{M}_F$, analyzed. I found that the rise in consumption persists long after the impact of remittance inflow shock has dissipated. This is an important finding.

Another finding concerns the optimal monetary policy. The optimal monetary policy for a Friedman-type monetary policy rule is given by zero money growth. In the case of a Taylor-type monetary policy rule, the corresponding optimal monetary policy is given by constant money growth and aggressive inflation targeting. Nepalese monetary environment is characterized by exchange rate peg with Indian currency and stringent capital account controls. The exchange rate in particular constrains the activity of Nepalese monetary authority significantly. As established in Budha (2015), Nepalese monetary authority seems to have some leeway to conduct effective monetary policy in the short run, however it loses this control over longer time horizon. Given this scenario, the optimal monetary policy target might be accessible in the short run, but, most definitely, not in the long run.

Apart from the findings discussed above, I found that Nepalese business cycles are driven by monetary policy shocks and supply shocks. Also, several market frictions are prominent in Nepalese market.

5.2 Recommendation

I considered three models in this thesis. Model $\mathscr{M}_F$ definitely matches the data better, but it seems that it is not in the best interest of Nepal Rastra Bank to continue implementing Friedman-type monetary policy rule. The problem with this policy rule is that it does not react to the events in the market. Since the primary objective of any monetary policy is to react to the events in the market, conducting a monetary policy that does not react to the market is counter-productive. Given the results presented in Budha (2015), there is some space for Nepal Rastra Bank to target inflation aggressively in the short run and, thereby, maximize the consumer welfare. This implies that an approach to monetary policy along the lines of Taylor-type money growth rule is feasible for Nepalese economy, in principle. However, there are a few caveats to this sort of approach to monetary policy. Aggressive inflation targeting in the presence of adverse supply shocks while neglecting output gap can lead to drop in inflation. Since the nominal GDP would already be low, owing to the supply shock, the real GDP would drop further, thus plunging the economy into a deeper recession. Therefore, discretionary policies have to be put in place in some exceptional cases if this approach to monetary policy is to be implemented. Since this approach to monetary policy is optimal outside some exceptional cases, it is a good alternative policy for Nepal Rastra Bank as long as discretionary approaches are put in place to handle the exceptional cases.

As mentioned in the section on introduction, there are quite a few empirical and methodological limitations in this thesis. I did not consider much the limitations of the models consider here. These limitation, unlike the limitations described earlier, can be remedied through further research. In the next section, I highlight a few limitations of the current version of the models, and motivate further research in that area.

5.3 Further Research

The real-world economy is enormously complicated. DSGE models attempt to simplify the economy using a small system of simultaneous difference equations. In doing so, a lot of complexity is left out, but the purpose of modeling of any kind is to provide a simple explanation of a complicated process. As such, DSGE models, like the ones considered here, do a pretty good job of explaining the general trends in the economy. However, incremental extensions of these models are necessary to get better results. Below I list out a few extensions, which can, possibly, help attain better results in modeling Nepalese economy.

1. *Open Economy Extension:*
   It is important to understand the open economy dynamics due to the monetary policy constraints implied by Mudell-Flemming Trilemma. A DSGE model that explicitly models current account, exchange rate, foreign aid might be required to explain better the nuances of Nepalese economy. Furthermore, a foreign economy might also need to be modeled in order to obtain realistic remittance and foreign aid inflows. There are several approaches to implement this extension. One approach would be to model open economy as in Adolfson et al. (2007) using identified VAR to model a foreign economy. Another approach could be to develop a two country model as in de Walque et al. (2005). Alternatively, one could construct a DSGE model where separate equations that govern the exchange rate and the capital account are defined, as I did here for remittance inflows.

2. *Improved Remittance framework:*
   The remittance framework considered here is rather simplistic. One approach to improve the remittance is considered in Mandelman (2013), where the households are divided into rule-of-thumb households, which receive remittances, and Ricardian households, which do not receive remittances. This framework seems apt for Nepalese economy as only about half of the total Nepalese households receive remittances.

3. *Monetary Policy Rule:*
   I have only entertained simple monetary policy rules in this thesis. Among the

ones chosen , the data prefers Friedman-type monetary policy rule. However, the list of policy rules entertained in this thesis is not exhaustive. One can come up with augmented policy rules that reflect the monetary policy better. For example, Li and Liu (2017) find that Chinese monetary policy can be described better by a money growth rule, than the Taylor rule, but it is best described by an interest rate rule that augments monetary aggregates into the Taylor rule. A similar approach might be required to pin down Nepalese monetary policy completely. Dhakal and Timsina (2020) show that a dual operating target comprised of inter-bank rate and excess reserves is suitable for Nepalese economy. This suggests that an approach taken by Li and Liu (2017) might be fruitful in Nepalese context as well.

These extensions do not exhaust the set of all possible extensions which can help to characterize Nepalese economy in a better way. Instead, these are a few key extensions that must be made moving forward.

REFERENCES

Acosta, P., Lartey, E., and Mandelman, F. (2009). Remittances and the dutch disease. *Journal of International Economics*.

Adjemian, S., Bastani, H., Juillard, M., Karamé, F., Maih, J., Mihoubi, F., Perendia, G., Pfeifer, J., Ratto, M., and Villemot, S. (2011). Dynare: Reference manual version 4. Dynare Working Papers 1, CEPREMAP.

Adolfson, M., Laséen, S., Lindé, J., and Villani, M. (2007). Bayesian estimation of an open economy dsge model with incomplete pass-through. *Journal of International Economics*.

Banaerjee, S. and Basu, P. (2015). A dynamic stochastic general equilibrium model for india. *NCAER Working Paper*.

Bhattacharjee, A. and Thoenissen, C. (2007). Money and monetary policy in dynamic stochastic general equilibrium models. *The Manchester School*, 75(1).

Blanchard, O. and Kiyotaki, N. (1987). Monopolistic competition and the effects of aggregate demand. *American Economic Review*.

Blanchard, O. J. and Kahn, C. M. (1980). The solution of linear difference models under rational expectations. *Econometrica*, 48(5):1305–1311.

Bu, Y. (2006). Fixed capital stock depreciation in developing countries: Some evidence from firm level data. *The Journal of Development Studies*, 42(5).

Budha, B. B. (2015). Monetary policy transmission in nepal. *NRB Working Paper*.

Calvo, G. (1983). Staggered prices in a utility-maximizing framework. *Journal of Monetary Economics*.

Chami, R., Barajas, A., Cosimano, T., Fullenkamp, C., Gapen, M., and Montiel, P. (2008). *Macroeconomic Consequences of Remittances*. International Monetary Fund.

Christiano, L. J., Eichenbaum, M., and Evans, C. (2001). Nominal rigidities and the dynamic effects of a shock to monetary policy. *NBER Working Papers*.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*.

Christiano, L. J., Eichenbaum, M. S., and Trabandt, M. (2018). On dsge models. *Journal of Economic Perspectives*.

Christiano, L. J., Motto, R., and Rostagno, M. (2014). Risk shocks. *American Economic Review*, 104(1).

Christiano, L. J., Trabandt, M., and Walentin, K. (2010). *Handbook of Monetary Economics*, volume 3, chapter DSGE Models for Monetary policy Analysis. Elsevier.

Cooley, T. F. and Hansen, G. D. (1989). Inflation tax in a real business cycle model. *American Economic Review*.

Copaciu, M., Nalban, V., and Bulete, C. (2015). R.e.m. 2.0, an estimated dsge model for romania. *Dynare Working Paper*.

de Walque, G., Smets, F., and Wouters, R. (2005). An estimated two-country dsge model for the euro area and the us economy.

Del Negro, M. and Schorfheide, F. (2008). Forming priors for dsge models (and how it affects the assessment of nominal rigidities). *Journal of Monetary Economics*, 55(7):1191–1208.

Dhakal, N. K. and Timsina, M. P. (2020). Assessing the effectiveness of operating target of monetary policy in nepal. *NRB Working Paper No. 49*.

Dixit, A. K. and Stiglitz, J. E. (1977). Monopolistic competition and optimum product diversity. *The American Economic Review*.

Durbin, J. and Koopman, S. J. (2012). *Time Series Analysis by State Space Methods: Second Edition*. Oxford University Press.

Edge, R., Kiley, M., and Laforte, J.-P. (2007). Natural rate measures an estimated dsge model of the u.s. economy. *FEDS Working Paper No. 2007-08*.

Erceg, C. J., Henderson, D. W., and Levin, A. T. (2000). Optimal monetary policy with staggered wage and price contracts. *Journal of Monetary Economics*, 46(2):281–313.

Fernández-Villaverde, J. (2010). The econometrics of dsge models. *NBER Working Papers*.

Fischer, S. (1977). Long-term contracts, rational expectations, and the optimal money supply rule. *Journal of Political Economy*, 85(1):191–205.

Fischer, S. (1981). Towards and understanding of the costs of inflation: Ii. *Carnegie-Rochester Conference Series on Public Policy*, 15:5–41.

Fisher, I. (1933). The debt-deflation theory of great depressions. *Econometrica*.

Friedman, M. (1968). The role of monetary policy. *American Economic Review*.

Fuhrer, J. C. (2000). Habit formation in consumption and its implications for monetary-policy models. *American Economic Review*, 90(3):367–390.

Furlanetto, F. and Seneca, M. (2014). Investment shocks and consumption. *European Economic Review*, 66:111–126.

Gabriel, V., Levine, P., Pearlman, J., and Yang, B. (2010). An estimated dsge model of the indian economy. *National Institute of Public Finance and Policy Working Paper*.

Gali, J. (1999). Technology, employment and the business cycle: Do technology shocks explain aggregate fluctuations? *American Economic Review*.

Gali, J. (2002). New perspectives on monetary policy, inflation, and the business cycle. *NBER Working Paper No. w8767*.

Gertler, M. and Kiyotaki, N. (2015). Banking, liquidity, and bank runs in an infinite horizon economy. *American Economic Review*, 105(7).

Guerrieri, V., Lorenzoni, G., Straub, L., and Werning, I. (2020). Macroeconomic implications of covid-19: Can negative supply shocks cause demand shortages? *NBER Working Paper*.

Guerron-Quintana, P. A. (2010). What you match does matter: the effects of data on dsge estimation. *Journal of Applied Econometrics*, 25(5).

Gust, C., Herbst, E., López-Salido, D., and Smith, M. E. (2017). The empirical implications of the interest-rate lower bound. *The American Economic Review*, 107(7).

Hirose, Y. and Inoue, A. (2015). The zero lower bound and parameter bias in an estimated dsge model. *Journal of Applied Econometrics*.

Justiniano, A., Primiceri, G. E., and Tambalotti, A. (2011). Investment shocks and the relative price of investment. *Review of Economic Dynamics*, 14(1):102–121.

Kaplan, G., Moll, B., and Violante, G. L. (2018). Monetary policy according to hank. *American Economic Review*, 108(3).

Khan, H. and Tsoukalas, J. (2012). The quantitative importance of news shocks in estimated dsge models. *Journal of Money, Credit and Banking*.

Koop, G. (2003). *Bayesian Econometrics*. John Wiley & Sons.

Korinek, A. (2015). Thoughts on dsge macroeconomics: Matching the moment, but missing the point? In *Towards a Just Society: Joseph Stiglitz and 21st Century Economics*. Columbia University Press.

Kydland, F. E. and Prescott, E. C. (1982). Time to build and aggregate fluctuations. *Econometrica*.

Laxton, D. and Pesenti, P. (2003). Monetary rules for small, open, emerging economies. *Journal of Monetary Economics*, 50(5):1109–1146.

Li, B. and Liu, Q. (2017). On the choice of monetary policy rules for china: A bayesian dsge approach. *China Economic Review*.

Li, X. and Wang, H. (2019). The effective of china's monetary policy: Quantity versus price rules. *North American journal of Economics and Finance*.

Lindé, J. and Trabandt, M. (2019). Resolving the missing deflation puzzle. Discussion Paper 13690, Center for Economic Policy Research.

Lucas, R. (1976). Econometric policy evaluation: A critique. In *Carnegie-Rochester Conference Series on Public Policy*.

Lucas, R. (1981). Discussion of: Stanley fischer,"towards an understanding of the costs of inflation: II". *Carnegie-Rochester Conference Series on Public Policy*, 15:43–52.

Lucas, R. E. and Prescott, E. C. (1971). Investment under uncertainty. *Econometrica*.

Mandelman, F. S. (2013). Monetary and exchange rate policy under remittance fluctuations. *Journal of Development Economics*, 102:128–147.

Mankiw, N. G. (1985). Small menu costs and large business cycles: A macroeconomic model of monopoly. *The Quarterly Journal of Economics*.

Maskay, N. M., Steinkamp, S., and Westermann, F. (2015). The impact of remittances on central bank balance sheets and inflation in nepal. *NRB Economic Review*.

McKay, A. and Reis, R. (2016). The role of automatic stabilizers in the u.s. business cycle. *Econometrica*, 84(1).

Medina, J. P. and Soto, C. (2007). The chilean business cycles through the lens of a stochastic general equilibrium model. *Working Papers Central Bank of Chile*.

Merola, R. (2015). The role of financial frictions during the crisis: An estimated dsge model. *Economic Modeling*.

Narayan, P. K., Narayan, S., and Mishra, S. (2011). Do remittances induce inflation? fresh evidence from developing countries. *Southern Economic Journal*, 77(4).

Pfeifer, J. (2018). A guide to specifying observation equations for the estimation of dsge models.

Phelps, E. S. (1967). Phillips curves, expectations of inflation and optimal unemployment over time. *Economica*.

Phillips, A. W. (1958). The relation between unemployment and the rate of change of money wage rates in the united kingdom 1861-1957. *Economica*.

Poudel, S. (2019). Price and wage rigidity in nepal. *NRB Working Paper No. 47*.

Prescott, E. C. (1986). Theory ahead of business cycle measurement. *Carnegie-Rochester Conference Series on Public Policy*, 25:11–44.

Rebelo, S. (2005). Real business cycle models: Past, present and future. *Scandinavian Journal of Economics*, 107.

Rotemberg, J. and Woodford, M. (1997). *NBER Macroeconomics Annual 1997*, volume 12, chapter An Optimization-Based Econometric Framework for the evaluation of monetary policy, pages 277–361. National Bureau of Economic Research, Inc.

Rotemberg, J. J. and Woodford, M. (1999). *Handbook of Macroeconomics*, volume 1, chapter The Cyclical Behavior of prices and costs, pages 1051–1135. Elsevier.

Schmitt-Grohe, S. and Uribe, M. (2003). Closing small open economy models. *Journal of International Economics*, 61:1630185.

Shrestha, P. K. and Semmler, W. (2014). Monetary policy and international reserves: Empirical evidence from east asian countries. *International Journal of Finance & Economics*.

Sims, E. (2013). Growth or the gap? which measure of economic activity should be targeted in interest rate rules?

Smets, F. and Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *Journal of European Economic Association*.

Smets, F. and Wouters, R. (2007). Shocks and frictions in us business cycles: A bayesian dsge approach. *American Economic Review*.

Stiglitz, J. E. (2018). Where modern macroeconomics went wrong. *Oxford Review of Economic Policy*.

Summers, L. H. (1986). Some skeptical observations on real business cycle theory. *Federal Reserve Bank of Minneapolis Quarterly Review*.

Suzuki, T. (2019). Counterfactual inflation targeting in nepal. *South Asian Journal of Macroeconomics and Public Finance*, 8(2):97–117.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*.

Taylor, J. B. (2000). Using monetary policy rules in emerging market economies. In *Stabilization and Monetary Policy: The International Experience*.

Thapa, S. and Acharya, S. (2017). Remittances and household expenditure in nepal: Evidence from cross-section data. *Economies*, 5(2):1–17.

Williams, J. C. (2003). Simple rules for monetary policy. *Economic Review*.

Woodford, M. (2001). The taylor rule and optimal monetary policy. *American Economic Review*, 91(2).

Woodford, M. (2003). *Interest and prices: Foundation of theory of monetary policy*. Princeton University Press, Princeton, New Jersey.

Zhang, W. (2009). China's monetary policy: Quantity versus price rules. *Journal of Macroeconomics*.

APPENDIX

Full Set of Equilibrium conditions

The full model is described by the following system. Note that we have listed all three monetary policy rules.

Consumption Equation

$$\lambda_t = \frac{1}{(C_t - bC_{t-1})^{\sigma}} - \mathbb{E}_t \frac{\beta b}{(C_{t+1} - bC_t)^{\sigma}} \tag{5.3.0.1}$$

Interest Rate Equation

$$\lambda_t = \beta \mathbb{E}_t \lambda_{t+1}(1+i_t)(1+\pi_{t+1})^{-1} \tag{5.3.0.2}$$

Bond Accumulation Equation

$$\mu_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \left(r_{t+1}u_{t+1} - \frac{a(u_t)}{Z_t} \right) + \mu_{t+1}(1-\delta) \right] \tag{5.3.0.3}$$

Investment Equation

$$\lambda_t = \mu_t Z_t \left[1 - \frac{\kappa}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \kappa \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} \right] + \beta \mathbb{E}_t \mu_{t+1} Z_{t+1} \kappa \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \tag{5.3.0.4}$$

Money Demand Equation

$$\frac{\theta}{m_t} - \lambda_t = -\beta \mathbb{E}_t \lambda_{t+1}(1+\pi_{t+1})^{-1}. \tag{5.3.0.5}$$

Cost of Capital Equation

$$r_t = \frac{(a_0 + a_1(u_t - 1))}{Z_t} \tag{5.3.0.6}$$

Auxiliary Equation 1 for Reset Wage

$$f_{1,t} = \psi_t w_t^{\nu_w(1+\chi)} N_t^{1+\chi} + \beta \phi_w (1+\pi_t)^{-\xi_w \nu_w (1+\chi)} \mathbb{E}_t (1+\pi_{t+1})^{\nu_w(1+\chi)} f_{1,t+1} \tag{5.3.0.7}$$

Auxiliary Equation 2 for Reset Wage

$$f_{2,t} = \lambda_t w_t^{\nu_w} N_t + \beta \phi_w (1+\pi_t)^{\xi_w(1-\nu_w)} \mathbb{E}_t (1+\pi_{t+1})^{\nu_w - 1} f_{2,t+1}. \tag{5.3.0.8}$$

Reset Wage Equation

$$w_t^{*,1+\nu_w\chi} = \frac{\nu_w}{\nu_w - 1} \frac{f_{1,t}}{f_{2,t}} \tag{5.3.0.9}$$

Capital-Labour Ratio

$$\frac{w_t}{r_t} = \frac{1-\alpha}{\alpha}\left(\frac{\hat{K}_t}{N_t}\right) \tag{5.3.0.10}$$

Marginal Cost Equation

$$mc_t = \frac{w_t}{(1-\alpha)A_t\left(\frac{\hat{K}_t}{N_t}\right)^{\alpha}} \tag{5.3.0.11}$$

Auxiliary Equation 1 for Reset Price

$$x_{1,t} = \lambda_t mc_t Y_t + \phi_p \beta (1+\pi_t)^{-\xi_p \nu_p} \mathbb{E}_t (1+\pi_{t+1})^{\nu_p} x_{1,t+1} \tag{5.3.0.12}$$

Auxiliary Equation 1 for Reset Price

$$x_{2,t} = \lambda_t Y_t + \phi_p \beta (1+\pi_t)^{\xi_p(1-\nu_p)} \mathbb{E}_t (1+\pi_{t+1})^{\nu_p - 1} x_{2,t+1}. \tag{5.3.0.13}$$

Reset Price Equation

$$1+\pi_t^* = \frac{\nu_p}{\nu_p - 1}(1+\pi_t)\frac{x_{1,t}}{x_{2,t}} \tag{5.3.0.14}$$

Aggregate Equilibrium Equation

$$Y_t + \Xi_t = C_t + I_t + \left(a_0(u_t - 1) + \frac{a_1}{2}(u_t - 1)^2\right)\frac{K_t}{Z_t} \tag{5.3.0.15}$$

Law of Motion of Capital

$$K_{t+1} = Z_t\left[1 - \frac{\kappa}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right] I_t + (1-\delta)K_t \tag{5.3.0.16}$$

Capital Utilization Equation

$$\hat{K}_t = u_t K_t \tag{5.3.0.17}$$

Production Function

$$A_t \hat{K}_t^{\alpha} N_t^{1-\alpha} - \Phi = Y_t v_t^p \tag{5.3.0.18}$$

Price Dispersion Equation

$$v_t^p = (1-\phi_p)\left(\frac{1+\pi_t^*}{1+\pi_t}\right)^{-\nu_p} + (1+\pi_{t-1})^{-\xi_p \nu_p}(1+\pi_t)^{\nu_p}\phi_p v_{t-1}^p \tag{5.3.0.19}$$

Price Index Equation

$$(1+\pi_t)^{1-\nu_p} = (1-\phi_p)(1+\pi_t^*)^{1-\nu_p} + (1+\pi_{t-1})^{\xi_p(1-\nu_p)}\phi_p \tag{5.3.0.20}$$

Wage Index Equation

$$w_t^{1-\nu_w} = (1-\phi_w)w_t^{*,1-\nu_w} + (1+\pi_{t-1})^{\xi_w(1-\nu_w)}\phi_w(1+\pi_t)^{\nu_w-1}w_{t-1}^{1-\nu_w} \quad (5.3.0.21)$$

Technology Shock Equation

$$\ln A_t = \rho_A \ln A_{t-1} + \varepsilon_{A,t} \quad (5.3.0.22)$$

Remittance Inflow Shock Equation

$$\Xi_t = \Xi_0\left(\frac{Y}{Y_{t-1}}\right)^{\eta} + \varepsilon_{\Xi,t} \quad (5.3.0.23)$$

Marginal Efficiency of Investment Shock Equation

$$\ln Z_t = \rho_Z \ln Z_{t-1} + \varepsilon_{Z,t} \quad (5.3.0.24)$$

Intratemporal Preference Shock Equation

$$\ln \psi_t = \rho_\psi \ln \psi_{t-1} + \varepsilon_{\psi,t} \quad (5.3.0.25)$$

Taylor Rule

$$i_t = (1-\rho_i)i + \rho_i i_{t-1} + \phi_\pi(\pi_t - \pi) + \phi_Y(\ln Y_t - \ln Y) + \varepsilon_{i,t} \quad (5.3.0.26)$$

Taylor-type Money Growth Rule

$$\Delta \ln M_t = \rho_m \ln M_{t-1} - \phi_\pi(\pi_t - \pi) - \phi_Y(\ln Y_t - \ln Y) + \varepsilon_{m,t}, \quad \varepsilon_{m,t} \sim \mathcal{N}(0,1) \quad (5.3.0.27)$$

Friedman-type Money Growth Rule

$$\Delta \ln M_t = \rho_m \ln M_{t-1} + \varepsilon_{m,t}, \quad \varepsilon_{m,t} \sim \mathcal{N}(0,1) \quad (5.3.0.28)$$

Steady States

$$A = 1 \qquad Z = 1$$
$$u = 1 \qquad \psi = 1$$
$$\pi = 0 \qquad \pi^* = 1$$
$$i = \frac{1}{\beta} - 1 \qquad \lambda = \mu$$
$$r = \frac{1}{\beta} - (1-\delta) \qquad a_0 = r$$
$$m = \frac{\theta}{(1-\beta)\lambda} \qquad v = 1$$
$$mc = \frac{\varepsilon_p - 1}{\varepsilon_p} \qquad w = (1-\alpha)mc\left(\frac{\alpha mc}{r}\right)^{\frac{\alpha}{1-\alpha}}$$
$$w^* = w \qquad \frac{K}{N} = \left(\frac{\alpha mc}{r}\right)^{\frac{1}{1-\alpha}}$$
$$C = \left[(1+\tau)\left(w + r\frac{K}{N}\right) - \delta\frac{K}{N}\right]^{\frac{\chi}{\sigma+\chi}}\left[\frac{1-\beta b}{(1-b)^{\sigma}}\frac{v_w - 1}{v_w}\frac{w^*}{\psi}\right]^{\frac{1}{\sigma+\chi}} \qquad \lambda = \frac{1}{C^{\sigma}}\frac{1-\beta b}{(1-b)^{\sigma}}$$
$$N = \left(\lambda\frac{v_w - 1}{v_w}\frac{w^*}{\psi}\right)^{\frac{1}{\chi}} \qquad K = \left(\frac{\alpha mc}{r}\right)^{\frac{1}{1-\alpha}} N$$
$$\Phi = N\left[\left(\frac{K}{N}\right)^{\alpha} - \left(w + r\frac{K}{N}\right)\right] \qquad Y = K^{\alpha}N^{1-\alpha} - \Phi$$
$$\Xi = \tau Y \qquad I = \delta K$$
$$x_1 = \frac{\lambda mcY}{1-\phi_p\beta} \qquad x_2 = \frac{\lambda Y}{1-\phi_p\beta}$$
$$f_1 = \frac{\psi w^{v_w(1+\chi)}N^{1+\chi}}{1-\beta\phi_w} \qquad f_2 = \frac{\lambda w^{v_w}N}{1-\beta\phi_w}$$

Model $\mathscr{I}_T$ (Figures)

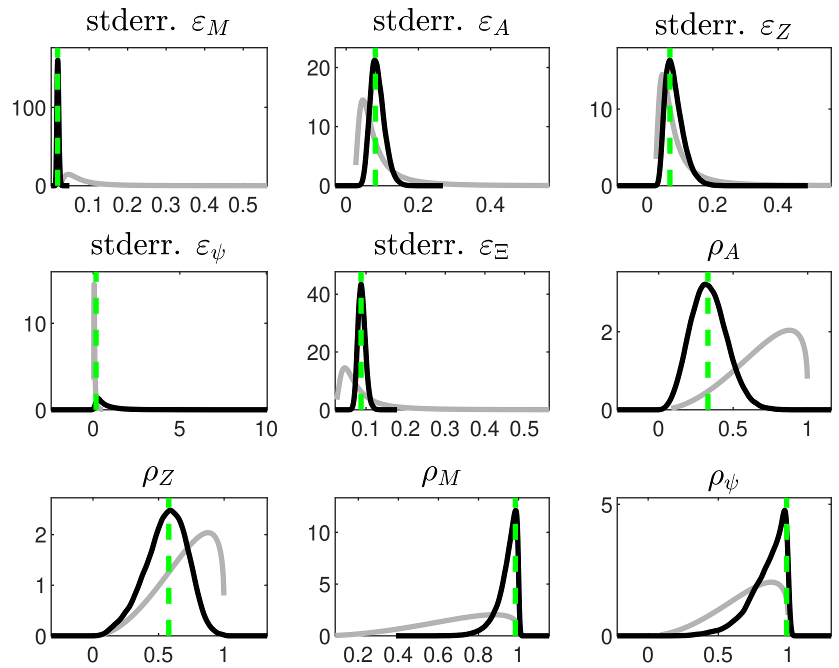

Figure 5.1: Posterior distributions of the estimated parameters (exogeneous shocks)

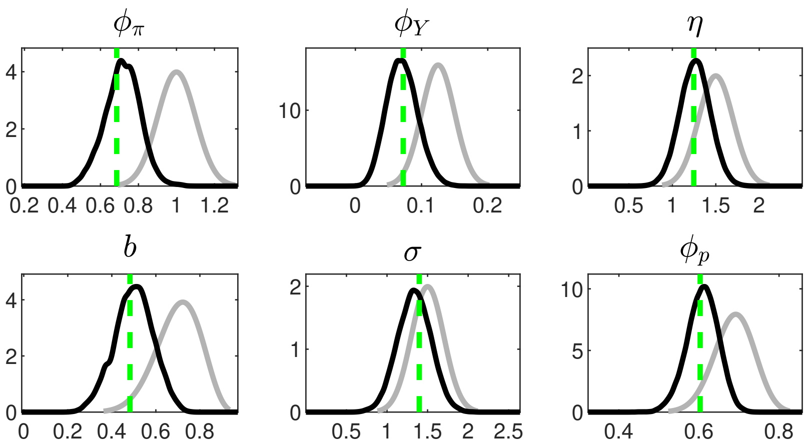

Figure 5.2: Posterior distributions of the estimated parameters (primary model)

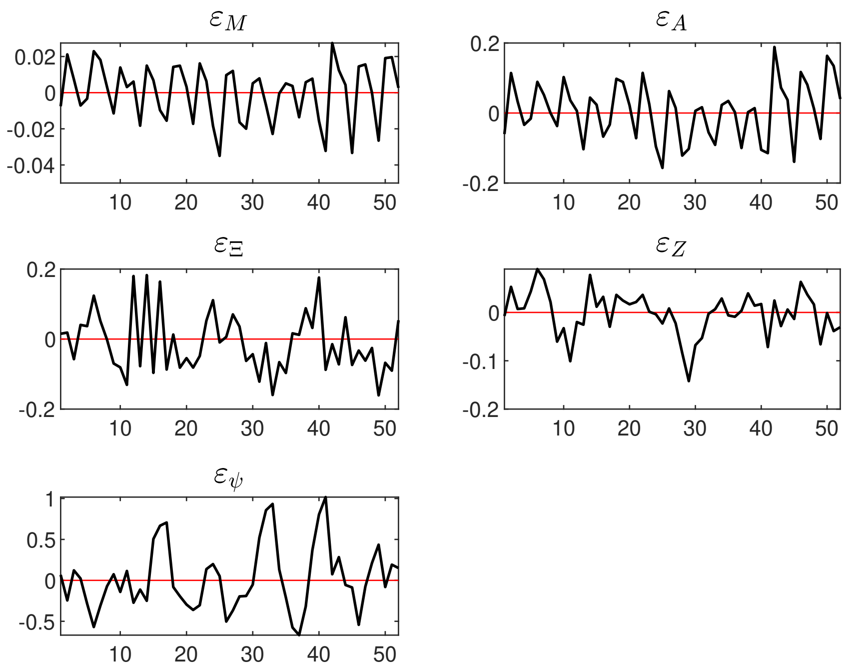

Figure 5.3: Estimates of smoothed structural Shocks (derived from Kalman smoother at posterior mean)

Model $\mathscr{M}_T$ (Figures)

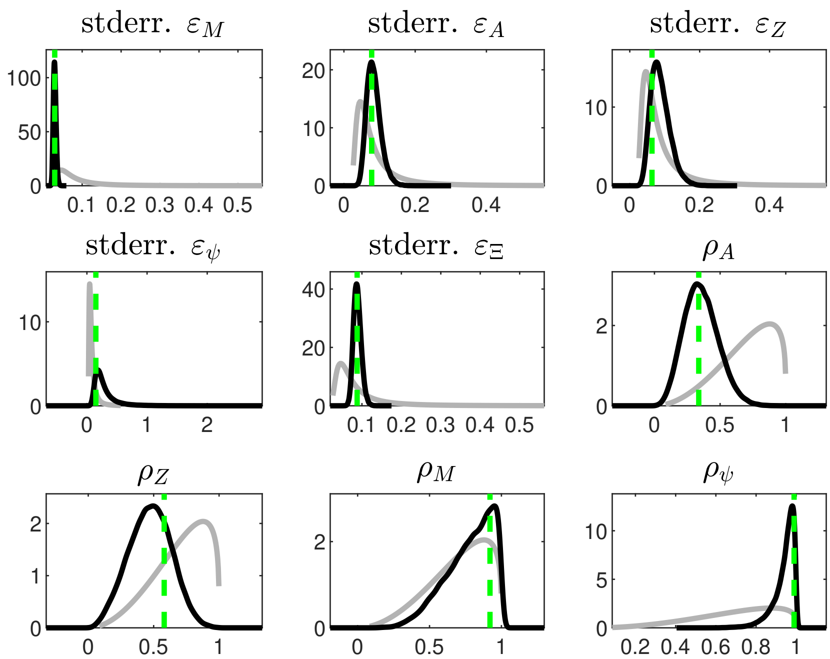

Figure 5.4: Posterior distributions of the estimated parameters (exogeneous shocks)

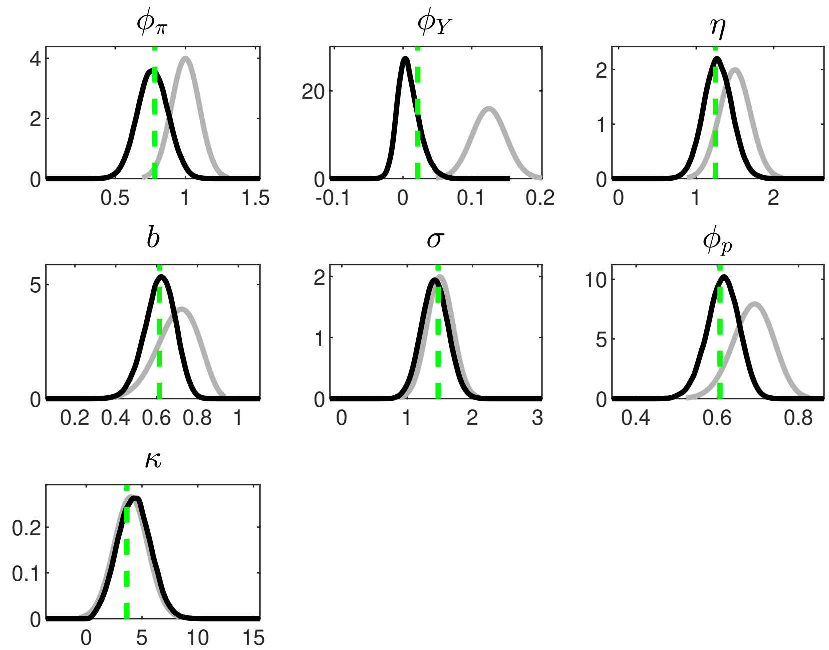

Figure 5.5: Posterior distributions of the estimated parameters (primary model)

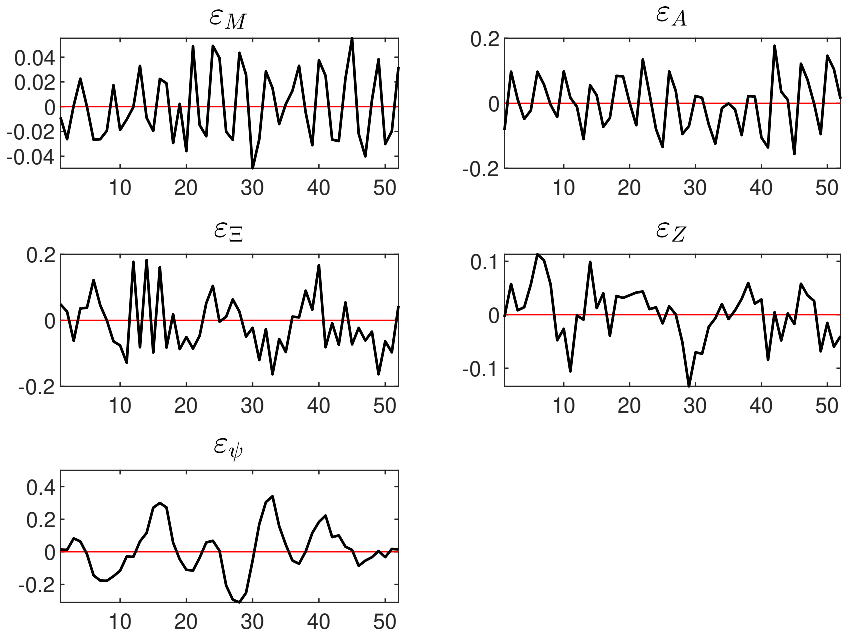

Figure 5.6: Estimates of smoothed structural Shocks (derived from Kalman smoother at posterior mean)

Model $\mathscr{M}_F$ (Figures)

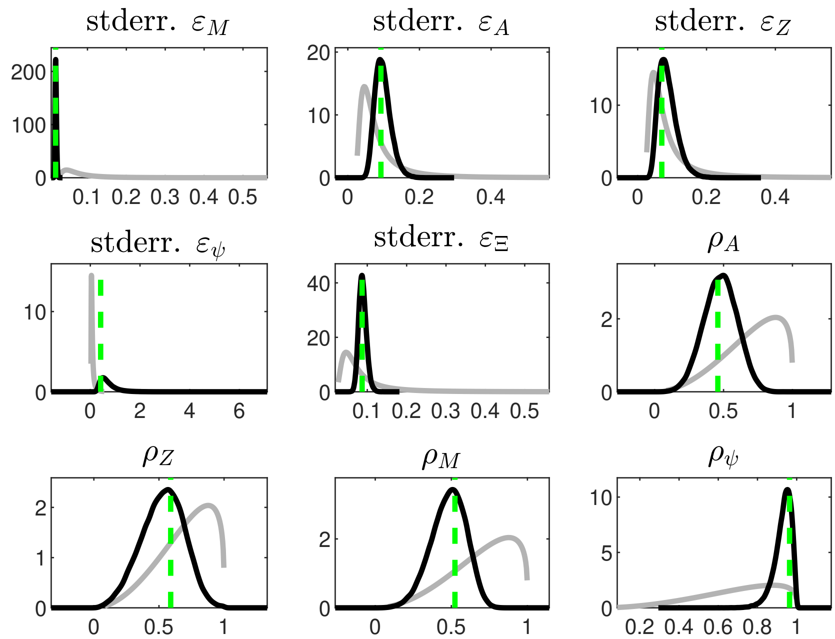

Figure 5.7: Posterior distributions of the estimated parameters (exogeneous shocks)

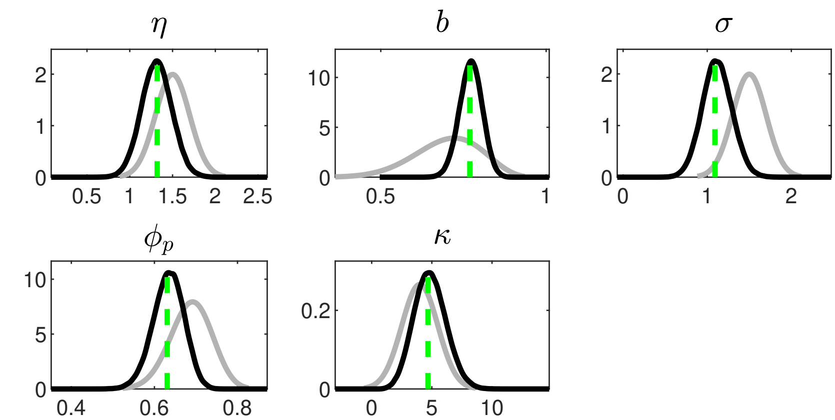

Figure 5.8: Posterior distributions of the estimated parameters (primary model)

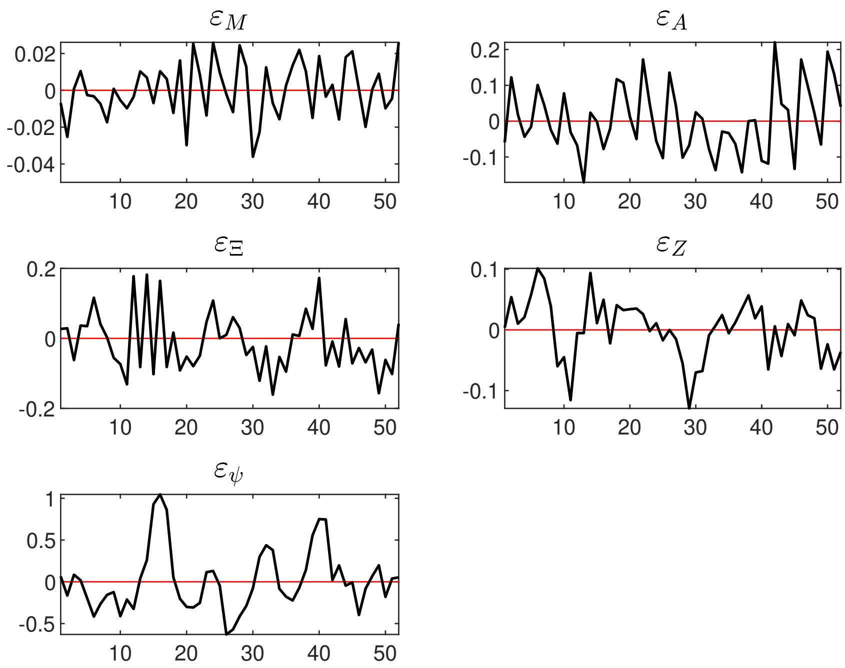

Figure 5.9: Estimates of smoothed structural Shocks (derived from Kalman smoother at posterior mean)