ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

MONETARY POLICY RULES AND ECONOMIC SHOCKS IN THE DSGE MODELS OF SUB-SAHARAN ECONOMIES

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ABSTRACT

The objective of the study is to explain the applicability of the monetary policy rule of the kind widely used in the standard DSGE models to the DSGE models of SSA economies. It also attempted to analyze the relative importance of the domestic and external source of economic shocks as well as the impact of some selected shocks on macroeconomic variables of SSA economies using a DSGE model. The results are the following: first, in response to the baseline structural shocks, the monetary aggregate rule better explains SSA economies than the Taylor type interest rate rule. To put differently, the simple Taylor interest rate rule needs modification to apply it in the DSGE model of SSA economies. Second, the study shows that both internal and external economic shocks are responsible for macroeconomic fluctuations in SSA countries, however, the study found that external economic shocks are importance vis-à-vis the domestic economic shocks. Third, in most economic shocks which are used by the study, price of imported goods and exchange rate appreciation or depreciation are the major determinant of the inflation pressure in SSA economies. Moreover, currency depreciation does not promote export, and domestic energy supply shock creates higher inflation and demand in the economy. In this paper, it is recommended that in modeling the monetary policy rules in macroeconomic models of sub-Saharan economies, incorporating the monetary base instrument and external influence on the monetary management of such economies is essential.

ACRONYMS

CGE	Computational general Equilibrium
DSGE	Dynamic Stochastic General Equilibrium
EU	European Union
FDI	Foreign Direct Investment
GDP	Gross Domestic Product
GEM	Global Economy Model
IMF	International Monetary Fund
LDCs	Least Developing Countries
LLDCs	Landlocked Developing Countries
ODA	Official Development Assistance
RBC	Real Business Cycle
SIDS	Small Island Developing States
SSA	Sub Saharan Africa
UN	United Nation
UNDP	United Nation Development Program
US	United States
VARs	Vector Auto Regressions
WB	World Bank
WDI	World Development Indicators
WDI-GDF	World Development Indicators- Global Development Finance

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CHAPTER ONE

1. INTRODUCTION

1.1.Background of the Study

The puzzle that business cycles, which are provoked by uncertain economic shocks, significantly determines countries growth performance has been accepted by many economists.[1] The empirical relationship between uncertain economic shocks and growth supports economic uncertainty do matter in the growth performance of countries (see for example Alimi (2016) and Caldara et al., 2016). While relevant economic shocks on aggregate variables have been driving countries output fluctuations, these shocks found to be strong and persistent for emerging economies (see Swallow and Cespedes, 2013). Empirical evidence for developing countries demonstrate that both internal and external economic shocks (demand and supply and monetary or fiscal) have been continuing noteworthy in explaining macroeconomic performance (see among others Rasaki and Malikane (2015), Loyaza et al. (2007)). For instance, Sissoko and Dougulu, (2006) reported that internal economic shocks, dominated by supply-side shocks, and external economic shocks, dominated by terms of trade shocks, are partly responsible for volatile nature of SSA economies.

Eris and Ulasan (2013) emphasized domestic shocks like inflation and government consumption shocks are crucial for the aggregate output fluctuations in the economy. Others like Rasaki and Malikane (2015) reported that domestic shocks have an equal share as the external shocks in explaining business cycles. With regard to external shocks, as SSA economies are characterized by the export of unfinished products and by the import of capital and semi-finished products in the international market, volatility in values of exportable primary commodities disturbs the economy (See Kose and Riezman (2001), Addison and Ghoshray (2013)). In addition to the empirical evidence on external shocks verses growth, reports, for example the WB (2016), supported that instability in the price of export alters output performance of SSA exporting countries through the current account deficit and fiscal deficit. In 2015, those SSA economies which export oil, metal and agricultural products showed fall in their output growth whereas the revenue gain of cocoa and tea exporters rises as a result of fall and rise in the prices of these commodities, respectively.

[1] Additional references can be obtained from Lee (2009) and Jetter (2014).

Evidently, according to Global Economic Prospects (2016) report GDP growth rate decreased from 4.6% in 2014 to 3.4% in 2015 in sub Sharan Africa which is recorded as the weakest performance in the region since 2009. In specific cases, in the same year the statistics indicated that economic activity decelerated mostly among oil exporters (like Nigeria) and politically unstable countries like Burundi and South Sudan. In contrast, economic activity expanded in major mineral and metal exporters (like Mauritania, South Africa, and Zambia) and some fragile states like Côte d'Ivoire, Rwanda, and Tanzania.

For small open economies, mainly for low income countries, the choice of a monetary policy strategy is more complex. On the one hand, their economies are influenced by domestic economy transmission processes that were described above; on the other hand, the effects of external shocks are too strong to be neglected in the formulation of a monetary policy strategy. From this point of view, whether a central bank aims to use as its operating target a target value for the money market rate ('interest rate targeting'), or a target value for the volume of central bank money ('monetary base targeting'). In the case of monetary base targeting, the money market interest rate will fluctuate. In the case of interest rate targeting, the interest rate level will always remain constant since the central bank will here adjust the supply of money in such a way that the interest rate target is always met (see Bofinger, 2001).

The choice of policy types and instruments, whether the monetary or fiscal policy, can affect the best strategy for stabilization concerns and growth performances in emerging economies. Effective monetary or fiscal policy considers the countries' respective history, political and socio-economic institutions (Mishikin, 1999). According to Mollick et al. (2011), for example, for emerging economies, inflation targeting monetary instrument can achieve growth than other policy instruments available for these economies. However, the findings of Ghosh et al. (2015) conveys the choice of discretionary versus inflation targeting monetary policy by central banks depends on the volatility of shocks relative to the central bank's time inconsistency problem. Others clarified the key to formulate good monetary policy in the country is understanding the main variable in the monetary transmission mechanisms of the economy (Mishkin, 1995). Under such circumstances, nevertheless, many researchers use DSGE model that contains a monetary policy block based on

the Taylor type interest rate rule which is developed by Taylor (1993) to discuss SSA economies business cycle.[2]

In a specific country case, according to Owusu (2014), both internal and external shocks have been playing a great role in the macro-economic performance of the Ethiopian economy. According to the author, the Ethiopian economy is exposed to the external environment influence and fewer commodity exports and energy prices are the main driving forces for aggregate fluctuation. The volatile nature of the external environment was the key to the country economic crisis in 2008, as the report explains. If volatility caused by both internal and external shocks matters at all and has an effect on monetary policy management in SSA economies and the transmission mechanisms of interest rate is weak in the economy, the Taylor rule based on simple interest rate as a rule in modeling the countries macroeconomic environment may not be appropriate to these economies. As a part of DSGE models building block, monetary policy rules used in these model are mostly copied from advanced nations directly without modification. As a result, alternative rules can be compared in terms of their implications for sub-Saharan economy's dynamic adjustment to shocks to resolve and understand the need for modification of the standard models. Further, relying on the above evidence, analyzing the source of shocks and macroeconomic fluctuation of SSA is quite important. That is, there is a need to study the sources of shocks that have greater relative importance in explaining economic aggregate fluctuations in sub-Saharan economies. In addition, further understanding of the macroeconomic effect of these internal and external shocks is very important. To do so, the study presented a calibrated DSGE model for the SSA economies.

1.2. Statement of the Problem

SSA economies are characterized by distinctive features of historical vulnerabilities to external factors and resulting periods of high macroeconomic instability (Adam et al., 2008). In addition, as Agenor and Montiel (2008) stated, these economies have distinctive features related to consumption and saving decisions, credit rationing, uncertainty and macroeconomic instability, the relationship between public and private investment, and monetary and fiscal policies which

[2] See among others Anand et al. (2015), Nampewo(n.d) and Mwabutwa et al. (2013) how researchers use the simple Taylor type interest rate rule in the application of DSGE model to discuss business cycles in SSA economies.

makes dichotomies with advanced economies. Adam et al. (2009) argued that monetary policy in low-income countries including SSA dominantly depends on the price of exports, the flow of official aids, foreign direct investments and the performance of the formal financial sector over the informal one.

From the theoretical perspective, countries with the objective of interest rate stability can use interest rate targeting whereas monetary targeting can be used when policymakers aim to stable money multiplier. Monetary targeting might be used as a target when money demand and credit access is possibly affected by monetary disturbances (Bofinger, 2001). From the empirical point of view, the idea of the use of monetary and interest rate targeting for monetary stability has been a debating subject so far. For example, Thornton, (2013) explained monetary targeting is preferable for price control and interest rate targeting is not feasible in practice. In addition, the application of interest rate rule as a monetary instrument by central banks in African is very limited compared to monetary base targeting. This can be supported by the statement made by Adam et al. (2008:p3):

> *"Operationally, countries that practice strict inflation targeting almost uniformly employ short-term interest rate as the primary policy instrument. For this approach to be effective there must be a reliable transmission mechanism from short-term interest rates to expected inflation. But interest rates do not play as central a role in the transmission mechanism in most African economies, consistent with the rudimentary nature of the financial sector. Instead, monetary equilibrium tends to play the key role and remains at the core of most programs of monetary management in sub-Saharan Africa".*

The above statement support that the simple Taylor type interest rate rule used in the standard DSGE model is questionable. This motivates for investigation of the monetary rules used in the standard DSGE models to study SSA economies business cycle. This paper attempts to address whether the standard Taylor type interest rate rule used in the standard DSGE models is applicable to the DSGE models of sub-Saharan economies or needs modification.[3] None of

[3] Some researchers used the monetary aggregate as a monetary policy reaction function in their model (see for example Rasaki (2015)) whereas used the standard simple Taylor interest rate rule as a policy reaction function (see for example Anand et al. (2015)).

the models developed ever hold alternative non-Taylor monetary policy rules to understand its implication to such economies. To put differently, this paper is the first which develop a benchmark DSGE model by introducing a modified non-Taylor monetary rule to the standard model to make a comparison with the benchmark model to understand the need for modification.

Although economists have a consensus that internal and external shocks can cause business cycles, the empirical findings on the major source of the business cycle, however, have been rather divergent. While some authors argue that internal shocks are largely responsible for macroeconomic fluctuations (see for example Hoffmaister and Roldos (2001) and Eris and Ulasan (2013)), others posit that external shocks are significantly responsible than the domestic one (see Kose and Riezman, 2001). This paper is also motivated by the puzzle of this inconclusive nature of the existing evidence on the source of economic fluctuations. Hence, this paper also attempted to answer the question related to the source of shocks which is relative importance for macroeconomic fluctuations of the SSA economies and analyzing some domestic and external shocks to understand their effect on these economies.

1.3. Objective of the Study

The paper has the following main and specific objectives.

1.3.1. General Objective

The general objective of the study is to understand monetary policy rules and economic shocks in the DSGE models of SSA economies.

1.3.2. Specific Objectives

The study focus on three central specific objectives:

- ✓ To test the applicability of the standard Taylor type interest rate rule to macroeconomic models of sub-Saharan economies mainly in the DSGE models.
- ✓ To identify the source of shocks which have relatively importance in explaining fluctuations in aggregate economic variables in SSA economies.
- ✓ To understand the macroeconomic effect of some domestic and external economic shocks in SSA economies.

1.4. Significance of the Study

The study examines the relative contributions of internal and external shocks to economic fluctuations of sub-Saharan economies and the application of simple Taylor type interest rate rule in SSA countries' macroeconomic models. This result may have its empirical contributions to the existing literature related to economic shocks and monetary policy rules. First, understanding of the sources of macroeconomic fluctuations will assist the policymakers in the formulation of appropriate macroeconomic policies that could promote macroeconomic stability. Second, the study formulates an alternative monetary policy in the DSGE model which incorporate the role of money aggregate, real exchange rate and external aid dynamics in sub-Saharan African economies. This is significant for the conduct of monetary policy particularly, the question of whether monetary policy should react to exchange rate and external fluctuations or not. Finally, the study may contribute to future research mainly through pointing out how to manage monetary policy rules in macroeconomic models.

1.5. Limitation of the Study

The study has the following limitations. The first weakness can be outlined in the context of general equilibrium models. First, the study assumes that the monetary policymakers have full knowledge of the economy to formulate monetary aggregates. Berg et.al. (2010) and O'Connell (2011) emphasized that quite often monetary authorities may take actions with incomplete information. Hence, a model which encompasses exogenous labor supply decisions and incomplete information in the monetary policy formulation process is a good option for future research. Second, calibration methodology has been implemented under its limitation. Selection of calibration parameters for DSGE models is a challenging task (Clarida et al., 1998) as there appears to be no clear consensus on the values of some parameters and those used in the literature are mostly based on microdata from advanced countries. One of the problems of macroeconomic calibration in low-income countries is the lack of appropriate data and limited microeconomic study. Finally, it is important to acknowledge the limitations of DSGE models in business cycle analysis. In conclusion, while DSGE models are interesting as alternative analytical frameworks,

it is important to recognize their weaknesses including those outlined above. They can and must be used in combination with other approaches that fill the gap left by general equilibrium models.

1.6. Organization of the study

The rest of the study is organized as follows. The first chapter is the introduction part which incorporates background of the study, problem statement, and objective of the study limitation as well as the significance of the study. The second chapter investigates theoretical and empirical evidence available about domestic shocks, external shocks, and monetary policy rules. The third chapter presented the model economy which is composed of households, firms, government, the central bank, coffee producers and the rest of the world. The fourth chapter explains the methodology of the study including the method of parameter calibration and analysis of impulse response functions. The fifth chapter analysis the study's empirical findings and results of internal and external shocks as well as monetary policy rules. Finally, the last chapter encompasses conclusion and recommendation part of the study.

CHAPTER TWO

2. LITERATURE REVIEW

The theoretical reviews of the first part discuss the New Keynesian analysis of aggregate macroeconomic fluctuations as well as their DSGE model. The discussion followed by the theory of monetary policy, its instruments, and rules in the literature. In the first part, the main quantitative and qualitative approaches used in the DSGE models framework have also been discussed in the literature. The second part of the chapter concern with the empirical evidence of domestic and eternal shock in low-income economies under the DSGE framework. Finally, the last part discusses the empirical evidence of the applicability of the DSGE framework to sub-Saharan economy.

2.1. Theoretical Literature Review

In this section of the literature, the theoretical aspects of how economic shocks are a source of the business cycle from the New Keynesian point of view, the DSGE model of the New Keynesian analysis and the transmission mechanism of external shocks are discussed. The theory of monetary policy has been reviewed with respect to the theory of monetary policy goals, rules and instruments. Finally, the theory of DSGE model is discussed in the last part of this section.

2.1.1. The New Keynesian Economic Theory

The New Keynesian economic theory is being used as an alternative to the real business cycle theory in the analysis of business cycle. The New Keynesian model builds in a friction that generates monetary non-neutrality and gives rise to a welfare justification for activist economic policies. However, later business cycle model features monetary neutrality and emphasizes that there should be no active stabilization policy by governments. The fundamental difference New Keynesian model with the real business cycle model is that the assumption of sticky price and wage even though both models built using the assumption of optimizing households and firms, who interact in markets and whose interactions give rise to equilibrium prices and allocations (see Romer,1993). According to the new Keynesian explanation, when only nominal shocks of minor magnitude are plausible, the presence of real rigidities become a necessary condition in order to justify large macroeconomic fluctuations. As Ball and Romer (1990) aptly write:

'Nominal rigidity is an equilibrium if an agent does not adjust his real price when demand shifts. An increase in real rigidities means that an agent desires a smaller change in his real price after a given change in demand. When the desired change is smaller, the cost of foregoing it is smaller'.

The new Keynesian macroeconomics recognize that Walrasian microeconomics and the neoclassical synthesis did not provide adequate theoretical foundations for Keynesian macroeconomics. Strategic complementarity has a direct relation to real rigidities (whatever the source of such rigidities). The higher the degree of strategic complementarity the more rigid is the relative price desired by maximizing imperfectly competitive firms, hence the lower is the individual price change induced by a change in the quantity of money. In turn real rigidity and strategic complementarity are lower the higher is the degree of monopoly power. Thus the degree of monopoly power has a negative influence on the desired rigidity of relative prices through strategic complementarity (See Sims, 1993). The New-Keynesian theory has the following common features:

A. Holds Essential Features of Keynesian Economics

The Keynesian economics builds their model based on the assumption of a non-market clearing conditions in the market, one in which prices fail to adjust rapidly enough to clear markets within some relatively short period of time. One of the major component of the Keynesian models is the prediction that in response to a decline in nominal demand, the aggregate price level will decline less than proportionately over a substantial time period, during which the actual price level is above the equilibrium price level consistent with the maintenance of the initial equilibrium level of real output. A surprising number of new- Keynesian models share in common the neglect of aggregation; the aggregate economy is simply the representative agent multiplied by all agents available in the economy. Accordingly, one can find unsatisfactory those new- Keynesian models that neglect aggregation issues, and it shall emphasize the central role of interactions among agents, including coordination failures, macroeconomic externalities, and producer supplier relations (see Gordon, 1990).

B. Micro Agents, Macro Spillovers, and Coordination Failures

As Hanes and Hurry (1992) described New-Keynesian economics starts from the recognition that individuals have to organize their own trading activities themselves. If the coordination device like the Walrasian auctioneer is not present to establish (by assumption) equilibrium price and exchange arrangements, not all the available information is revealed to the market. A restricted dissemination of information affects all economic interactions, between agents, between periods and between sectors. Coordination failure may arise as agents now have to act upon their beliefs about their mutual interdependence of their trading activities. Thus the perception of possible trades defines the actual scope for trade.

C. Real Rigidities, Nominal Rigidities, and the Indexation Puzzle

The new Keynesian economists make a distinction between price setting in product markets and wage setting in labor markets. Moreover, they also make a distinction between nominal rigidity and real rigidity. The necessary condition for non-market- clearing is a barrier to the full adjustment of nominal prices, that is, something that prevents movements in nominal prices that are equi-proportionate to movements in nominal demand. However, some of the new-Keynesian theories explain real rigidities as the stickiness of a wage relative to another wage, of a wage relative to a price, or of a price relative to another price. Explanations of real rigidities in product markets include customer markets, inventory models, and theories of markups under imperfect competition, while those of labor markets include implicit contracts, efficiency wages, and insider outsider models. But theories of real rigidities are subject to the criticism that they do not explain nominal rigidity, because nothing prevents each individual agent from indexing its nominal price to nominal aggregate demand (Romer, 1993).

The literature on nominal rigidities enters an argument that Keynesians appeared to be losing. Members of the new classical school that developed in the 1970s challenged Keynesians to explain the rigidities in Keynesian models. In response, Keynesians sometimes cited costs of adjusting prices. But as the classicalist pointed out, these costs, while surely present, appear small. Indeed, the frequently mentioned "menu costs"-the costs of printing new menus and catalogs, of replacing price tags, and so on-sound trivial. Thus the impediments to nominal flexibility in actual economies appear too small to provide a foundation for Keynesian models. A common but

mistaken response is that there are many obvious sources of large wage and price rigidities: implicit contracts, customer markets, efficiency wages, insider-outsider relationships, and so on. The problem is that these phenomena imply rigidities in real wages and prices, while the Keynesian theory depends on rigidities in nominal wages and prices (Gordon, 1990)..

2.1.2. The New Keynesian DSGE Model

The New Keynesian model with staggered wage and price setting also constitutes the core of the dynamic stochastic general equilibrium (DSGE) frameworks that have become popular in recent years, and that have been adopted by many central banks and policy institutions as an analytical tool. While the model lacks many of the bells and whistles that have been incorporated in the estimated medium-scale models, it remains useful in elucidating the implications of nominal rigidities for the design of monetary policy (Chiristaino et al. 2005).

The standard new Keynesian model consists of Calvo price and/or wage staggering in its supply side. On the demand side, it is composed of an Euler equation and a Taylor rule. With more explicit microeconomic foundations than its Keynesian ancestor, and more relevance than its RBC predecessor, it has become the workhorse in discussions of fluctuations, policy, and welfare. The model is also compatible with a variety of assumptions regarding aspects of the model unrelated to unemployment, including the specific forms of price and wage rigidities, household utility, or the determinants of variable desired markups. Still the proposed framework has limitations. In particular, it abstracts from potential sources of unemployment other than noncompetitive wages, including those associated with the costly reallocation of labor across firms or sectors (in terms of time and other resources) that can give rise to frictional unemployment (Hall, 2005).

The key elements of the new Keynesian model that will be used as a reference framework in the remainder of the paper is characterized by the following conditions. First, imperfect competition in the goods market is introduced by assuming that each firm produces a differentiated good for which it sets the price (instead of taking the price as given). Second, some constraints are imposed on the price adjustment mechanism by assuming that only a fraction of firms can reset their prices in any given period. In particular, and following much of the literature, a model of staggered price

setting due to Calvo (1983) and characterized by random price durations is adopted. The resulting framework is referred to as the basic New Keynesian model. The model has become in recent years the workhorse for the analysis of monetary policy, fluctuations, and welfare. Once again, the model assume a representative infinitely-lived household, seeking to maximize a utility which is a function of consumption and labor which in turn depend on its budget constraint. In addition to the consumption/savings and labor supply decision, the household now must decide how to allocate its consumption expenditures among the different goods. This requires that the consumption index C_t be maximized for any given level of expenditures (Blanchard and Gali, 2007).

The model assume a continuum of firms indexed by $i \in [0, 1]$. Each firm produces a differentiated good, but they all use an identical technology, represented by the production function and the level of technology, assumed to be common to all firms and to evolve exogenously over time. Following the formalism proposed in Calvo (1983), each firm may reset its price only with probability $1-\theta$ in any given period, independent of the time elapsed since the last adjustment. Thus, each period a measure $1-\theta$ of producers reset their prices, while a fraction θ keep their prices unchanged. As a result, the average duration of a price is given by $(1-\theta)^{-1}$. In this context, θ becomes a natural index of price stickiness. Moreover, it is assumed that households/workers have some monopoly power, which allows them to set the wage for the differentiated labor services they supply. Furthermore, as was done with the price-setting firms in chapter 3, the assumption here is that workers face Calvo-type constraints on the frequency with which they can adjust wages (Romer, 2011).

2.1.3. External Economic Shocks and Its Transmission to Small Open Economies

External economic shocks are unanticipated foreign economic events that can affect the domestic economy through different channels. One of the transmission channels is the balance of payment which is an important element in the analysis of external shocks. As this shock hits the economy, the balance of payment shows fluctuation and takes its influence. International linkage with the domestic environment has been putting positive and negative welfare effect (Owusu, 2014). Depending on their strength, countries face external challenges through uncertainty and

unprecedented events in the global economy. Eventually, developed economies able to defend and sustain with less fluctuation relative to developing economies in response to these shocks. These international shocks have manifested themselves through unstable global financial markets (see Jilberto and Momment (2002)). Theoretically, however, domestic economies able to reduce the total effects of external shocks through following a flexible exchange rate system. The benefit of flexible exchange rate could be more if the shocks, happening in the domestic and the foreign economy, move in different directions (when, for example, while aggregate demand falls in one country, it rises in another)(see for example Rodseth (2004)). The effect of international economic shocks can be transmitted to the domestic economy in different bridges. These channels include the balance of trade, capital movements, interest rate and demand shocks, and supply-side shocks. Some of the dominant transmission channels of external shock have been discussed in the next sections.

The Balance of Payment: merely defined as the general record of a country total economic transaction in the international markets in a given period of time which includes exports and imports of goods and services, unilateral transfers and financial and capital movement. This definition implies that inflow and outflows in goods and services, in financial and capital goods exists among nations in the international market (Salvator and Diulio, 2003). However, the intuition is that demand and supply-side shocks can transmit among countries. For example, (Rodseth, 2004) emphasizes that a rise in demand and output of a country leads to a rise in the demand for other countries export through this channel which expands the former economy again.

Private Capital Flows and Foreign Policy: cyclical nature of monetary and fiscal policy in the foreign nations affects the domestic economy. However, the theory on the effect of foreign policy states that the magnitude and the speed of the effect depend on the nature of the economy. If the economy is small compared to the one which changes its policy, the effect is large and deep, and vice versa. Accordingly, if the saving rate changes in the foreign market, the investment could be affected through interest rate change (Mankiw, 2009). Theoretically, private capital flows are the result of the difference in saving and investment which is defined as net capital inflow minus net capital outflow. How this channel is used as a transmission mechanism for international business cycles? When countries investment is above it's saving, they try to cover the gap through a call for

international foreign direct investments (Mankiw, 2009). Hence, when the economies of developing nations are in contact with the external environment in this phenomena, shocks transmit through technological and market mechanisms (IMF, 2015).

International Trade and International Reserves: reserves are all assets held by central banks to manage the balance of payments. Among these assets, international reserves are foreign assets held by the domestic central banks for the successful stabilization of balance of payment. These sources are one of the major transmission mechanism of external shocks through exchange rate (see for example Gandolfo, 2002). The traditional theory of international trade states that countries' specialization could bring more gain to each country and more total world output growth and welfare. However, the countries also face challenges from international trade (Salvatore, 2013).

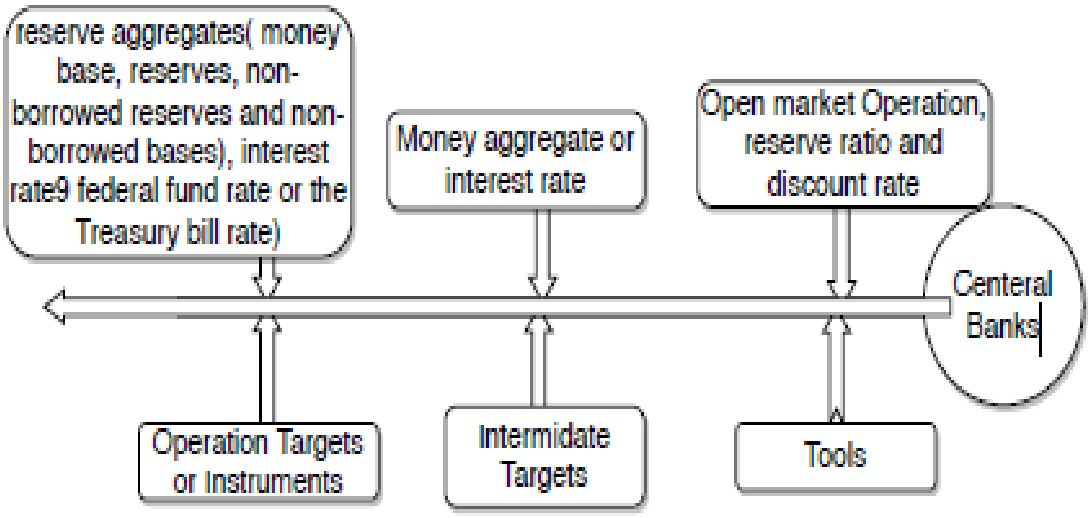
2.1.2. Monetary Policy

The policy mechanism by which how the aggregate quantity of money supplied is managed is called monetary policy (Mankiw, 2009). Despite the policy is relevant to guard the economy from domestic and global influences and for growth through stable prices, developing nations have been contested by the development of sound monetary policy since these countries have been facing the problem of sound financial market and external influences. Among the external influence, for example, the vulnerability of the capital account, like through aid, is explained as a significant factor which makes monetary policy complex to conduct. In addition, fiscal dominance, central bank dependency, as well as weak financial and market institutional arrangements are factors which play a role to complicate the choice of monetary policy strategies in developing economies (Prasad et al., 2009). As Adam et al., (2009) stated that tight monetary policy is ineffective to manage such problems. Rather, committing to put accumulation of reserves is the right way to manage aid volatility problems to inflation.

Central banks might have goals like achieving employment, price stability, lower inflation and exchange rate/ interest rate stability. To achieve these goals, however, it is imperative to use some operating tool which affects the goal indirectly (such as open market operation, reserve ration and discount rate). Such strategies, which are intermediate targets, are found between the goal and the tool (which includes money aggregate (M1, M2, and M3) or interest rate). In addition, these

intermediate variables cannot be directly influenced by the central bank, hence, it would select an operation targets (instruments) for these intermediate targets. One of the instrument is reserve aggregates like money base, reserves, non-borrowed reserves and non-borrowed bases, and interest rate like the federal fund rate or the Treasury bill rate (see Mishkin and Eakins (2006) and Mishkin (2010)). This theoretical framework is discussed in figure one below.

Figure 1: Central bank goals, tools, intermediate targets, and instruments.



Source: Own Depiction (2018)

In the coming sections, monetary policy regimes and policy rules have been discussed to further understanding of monetary policy.

2.1.2.1. Monetary Policy Strategies

Monetary policy can be implemented in a framework of policy targets or policy instruments. When we talk about the instrument rules, the policy instrument is defined as an explicit function of economic variables. The typical examples of the instrument rules includes the interest rate rule (the Taylor rule (1993)), which define the interest rate as a function of output and inflation gaps, and money base as a monetary intermediate rule of McCallum (1988), which explains GDP as an explicit function of money growth rate (see among others (see for example Rudebusch and Svensson (1999)). According to Bofinger (2001), for example, McCallum (1988) developed this rule through the application of certain modification of the equation of quantity theory of money. In his work, central banks respond through money base growth rate, when output deviates from its target. On the other hand, the target rule, which is the implicit rule, is defined as setting an

operational target to keep small (no) deviation of the target variable from its target. In this case, central banks focus on how to achieve the target variable close to the target level. The well-known example of the target policy rule is inflation targeting and monetary targeting. In this section of the literature, theoretical literature of different monetary policy regimes has been discussed.

Target Rules

1). Exchange Rate Targeting: in this strategy policy makers adjusts monetary policy instruments to keep the exchange rate fixed within a narrow range of some announced target level (i.e., par value). This monetary policy regime can be used if the economy fears high and persistent inflation in the domestic economy. As DeRosa (2009), discussed, in this scenario, the goal of the central bank is to keep the target value of the exchange rate through purchase and sell foreign currencies. This implies the participation of the bank is handled through foreign reserve policies. Fixed and managed exchange rate system fall under this category. Most emerging economies follow an exchange rate anchor, in which hard peg exchange rate is part of it. Theoretically, the hard peg system of exchange rate is very relevant to control domestic inflation, given that the foreign economies have low inflation position (see among others Prasad et al. (2009). In general, monetary policy rule has no scope in managing price stability, however, the exchange rate stability can be achieved in the short run, not in the long run.

2). Monetary Targeting: In this strategy policy makers adjusts monetary policy instruments to target the growth rate of some selected measure of the money supply (Mishkin, 2010). Using monetary aggregate (such as fiat money, reserves, and deposits) as an instrument with the objective of controlling price instability through the quantity theory of money (DeRosa, 2009). From the theoretical point of view, the importance of monetary targeting as a policy is still not denied by economists. Some argue that monetary targeting is relevant since it is very simple and effective to implement in underdeveloped financial institutions. For example, Goodhart (2009) explained that money is relevant and cannot be neglected in the analysis of monetary policy. Still, others postulated that yet monetary aggregate is influenced by the globalization and underdeveloped financial markets and institutions, the policy regime is difficult and complicated. In addition, the rule does not show the correct relationship between inflation rate and money aggregate. Relying on this logic, as a result, they conclude that the policy regimes should be replaced with an alternative policy.

Economists also believe that the policy has countercyclical properties, alike the Taylor interest rate rule. The monetary targeting rules that if output falls followed by the reduction in interest rate which adjusts output once again to rise. The Taylor rule also suggests that higher output leads to inflation, then followed by interest rate, to rise (see among others Solow and Taylor (1998) and Prasad et al., (2009)). Minford (2006) explained that monetary targeting has an effect on those who are employed in the economy, as money targeting makes the price more volatile which adversely affect real wage and consumption. However, the phenomena are different for those who are unemployed. Yet, Adam et al., (2009) explained that there is no fundamental difference between the two rules, though there is a difference in operational targets. However, these authors never denied that when countries plan to price stability, and when they face monetary policy transmission problems to aggregate demand, the monetary aggregate is indispensable than the interest rate instrument.

3). Inflation Targeting: The strategy requires the central bank to announce a target (in some range) level of inflation that it intends to do so (Bernanke et al., 2011). Under this strategy, monetary policy can be used to manage output and price level. Yet, the major goal of the central banks under this strategy is to achieve the predetermined inflation target in the long run. It involves adjusting monetary policy instruments to keep the central bank's forecast of inflation consistent with an announced target. This rule is strict rule based numerical mid-term inflation target with the goal of achieving some level of inflation level which is not too far from the target (DeRosa, 2009). In most theoretical literature, inflation targeting, supported with flexible inflation targeting, is the best monetary policy for high output growth and low inflation rate (Prasad et al., 2009). Like the monetary targeting, inflation targeting depends on explicit and implicit rules. Bofinger (2001) emphasized that, in the notion of explicit rule, inflation forecast and inflation targeting play a significant role: monetary policymaker balances inflation forecast with the inflation target. In the concept of the implicit rule of inflation targeting, increasing/decreasing the short-term interest rate if the conditional inflation forecast is higher/lower than the inflation target increase (decrease) in the short-term interest rate is required. Growing and large literature (see for example Mishkin (2010)) stated that inflation targeting has comprised the following major elements. Firstly, the strategy mainly depends on the message conveyed by forecasted inflation and the quantitative

inflation target set by policymakers (between 1.5 and 2.5 percent per year). The second element is central banks have no formal rue to use to implement their instrument. Thirdly, this strategy is preferable under a floating exchange rate regime and the final is that a high degree of transparency and accountability.

Instrument Rule

1). Interest Rate Rule-The Taylor Rule: involves adjusting monetary policy instruments to pursue stable economic growth and low inflation, but with no formally announced targets. The proponents of this policy rule argue that central banks should respond in response to both GDP and inflation rather than the exchange rate. To do so, central banks should use interest rate as a policy instrument. For example, if the inflation rate goes beyond its target value by one percent, central banks should raise the interest rate by 0.5 percent. This statement implies central banks which uses the interest rate rule need to increase the nominal interest rate, which would increase the real, by some percent more than the percentage rise in inflation. Central banks also responds to adjust output gaps at the time of increase/decrease output leads to deviation from its trend (Solow and Taylor (1998), and DeRosa (2009)).

One of the prominent interest rate rule developed is the simple Taylor type interest rate rule formulated by Taylor (1993). According to Wagner (2002), the Taylor rule combines the IS and Philip curve with a policy rule. Central banks should prefer the interest rate as a reaction instrument when money shocks happen which is provoked by demand-side shocks. As Rotemberg and Woodford (1999), one of the advantages of this rule is its simplicity to implement and monitor. As a result, the rule is important to check accountability of policymakers to the large people, since the rule is simple to follow and manage. Proponents of this rule also argue Taylor type interest rate rule can achieve results which are similar with other alternative policy rules; and it is also relevant since policymakers react in response to the current inflation and output of the economy, rather than its past value. These authors forwarded that the simple interest rate rule should consider, not only current output and inflation, the past lags of the current inflation and output level. Despite these advantages, the application of the Taylor rule has raised a lot of debate in monetary policy rules for emerging economies, as these countries suffer from difficulty in choosing the best monetary policy strategy that captures both internal and external influences. Some economists argue that

using Taylor simple interest rule or monetary aggregate as the operational instrument is likely similar. This is because in one side both instruments are countercyclical; on the other hand, as suggested by Taylor himself, money aggregate can replace interest rate instruments in emerging economies, since the financial market may be underdeveloped(See among others Solow and Taylor(1998) and DeRosa (2009)). On the other hand, some economists argue still some form of difference can be explained between the two and However, Goodhart (2009) argues that since all monetary shocks are not inspired by demand-side shocks, the monetary aggregate rule is still relevant to manage supply size monetary shocks. Moreover, Adam et al. (2009) stated that the Taylor rule may not be effective for emerging countries where the informal financial sector dominated the formal one; and where economies worried about price stability than a monetary policy rule. Furthermore, Wagner (2002), described that the Taylor rule needs to be adjusted with respect to globalization and monetary uncertainties. One way of doing that is incorporating the exchange rate in the equation, though including exchange rate in the equation has raised a debate.

2.1.3. DSGE Models

DSGE model is based on macroeconomic models of the neoclassical and the New Keynesian models. Proponents of the neoclassical model, initiated by Kydland and Prescott (1982), developed a model called Real Business Cycle model which interprets the large business cycle movements observed in the economy is consistent with the perfect market equilibrium of neoclassical growth model supplemented with labor-leisure choice and exogenous technology shocks. This implies the well-known statement 'money is neutral' in the busineses cycle (See for example Gali, 1999). The conclusion made by this model, specifically neutrality of money, has been challenged and faced many criticisms from many economists whose arguments have been made from solid empirical evidence. The empirical work documented by Gali(2008) and Villaverde (2010) are among others that reflect the idea of non-neutrality of money in the account of business fluctuations. In this section of the literature, more emphasis is given to the later the New-classical model.

In New Keynesian monetary models with a real and nominal rigidity, economic agents decision-making process are derived based on assumptions made on information, technologies, preferences, and the prevailing monetary and fiscal policy regime by solving intertemporal maximization problems. Therefore, according to the proponents of these DSGE models, (see Villaverde (2010))

these features of the model paradigm provides strong empirical models consistent with theoretical evidence that is found as a laboratory for policy experiments. Moreover, nowadays these models used to accurately track and forecast macroeconomic time series. Furthermore, the theoretical coherence have a two-fold benefit. The first is related to misspecification problems that emerged from tight cross-equation restriction observed by poorer fit compared to less-restrictive time series models like DSGE (Del Negro, 2007). Second, in practical works, it might be relevant to make a prediction for economic variables that do not explicitly appear in medium-scale DSGE models. The traditional system-of-equations approach incorporates a core set of macroeconomic aggregates variables such as real gross domestic product (GDP), consumption, investment, wages, hours, inflation, and interest rates. (See Schorfheide et al, 2009).

2.2. Empirical Literature Review

This part reviews the studies conducted in developing countries on monetary policy rules. Then it is followed by the effect of demand and supply side internal and external shocks in developing countries.

2.2.1. Monetary Policy Rules in Developing Countries

Developing countries have been implementing fiscal and monetary policies for better macroeconomic management and performance. Some economist argues these monetary or fiscal policies should consider the countries respective history political and socio-economic institutions (Mishkin, 1999). Moreover, in his other work, that is (Mishkin, 1997), this author has explained the key to formulate and the best monetary policy is understanding the main variable in the monetary transmission mechanisms of the economy. As Montiel (1991) claimed the financial system is not yet developed and it is dominated by informal sectors which helps to the rise of parallel markets. This implies the transmission mechanism of monetary policy instrument may not as the same as with the developed one.

Evidently, the puzzle that what monetary policy should the developing economies should use has been controversial among economists. Some economists argued money aggregate instrument, rather than the interest rate, is preferable for developing economies using an empirical solution for African's economy. For example, (Adam et al., 2008) explained the transmission mechanism of

interest rate is weak in SSA economies compared to other transmission mechanisms. They claimed that the reason for this frail transmission mechanism of interest rate is due to external vulnerabilities and resulting periods of high macroeconomic instability. Some argues (see Adam et al. (2009) that, as developing economies monetary policy in low-income countries including SSA dominantly depends on the price of exports, the flow of official aids, foreign direct investments and the performance of the formal financial sector over the informal one, the monetary policy rules to be used in macroeconomic models of sub Saharan economies shall consider domestic and external influences of conducting monetary policy in such economies. Moreover, Tornton, (2013) explained monetary targeting is preferable for price control and interest rate targeting is not feasible in practice. In addition, the application of interest rate rule in African is very limited compared to monetary base targeting. If countries have a more independent central bank and experienced higher inflation, inflation targeting is preferred strategy to formulate credible monetary policy and promote price stability.

However, some still argue that one monetary policy rules that have been undertaken by developing countries have as equal benefit as the others. For example Taylor (2000) claimed that many of the monetary policy rules are applicable to developing economies since they have the same benefit. Despite his low tendency to denying the need for modification of monetary policy rules with respect to the properties of the developing economies, he argued that flexible exchange rate system and inflation targeting with monetary policy are the best policies for countries which follow non-fixed exchange rate system. Mollick et al. (2010) supported that inflation targeting monetary instrument can achieve growth than other policy instruments available for these economies. Many argues that if countries have an independent monetary policy system, inflation targeting is the best to do. For example, as explained by Mishkin and Schmidt-Hebbel (2002), if countries have a more independent central banks and experienced higher inflation, inflation targeting is preferred strategy to formulate credible monetary policy and promote price stability, However, the findings of Ghosh et al., (2016) shows a choice of discretionary versus inflation targeting monetary policy by central banks depends on the fundamentals of shocks volatility. For example, many countries have selected inflation targeting based on cum-floating as their preferred strategy to implement a more independent and effective monetary policy.

2.2.2. Shocks and Business Cycle in Developing Economies

To answer the puzzle that what shocks dominantly drives and causes business cycles in developing economies, researches have been studied with the help of DSGE and panel data models. To do so, researchers have been discovering both internal and external shocks to identify which one of the shocks play a major role. Even though different studies try to show either the domestic or external shocks are the source of fluctuations, some of others supports both shocks are relevant and described that the domestic shocks as equally as the external shocks in influencing macroeconomic environments (see among others Sissoko and Dougulu, (2006) Rasaki and Malikane (2014) and Loyaza et al. (2007)).Hence, in this section of the literature review, firstly, the domestic shocks has been discussed, followed by the discussion of external shocks. With regard to the supply-side domestic shocks, some researchers still argue that these shocks are a source of macroeconomic fluctuation. In specific cases, productivity shocks, as a domestic source of shocks have got a great attention by different studies as cause of the business cycle in many developing economies. For example, studies by Jakab (2006), Sissoko and Dougulu, (2006) and Noah and Frederic (2011) explained that productivity is one of the major sources of the business cycle in these economies. However, others still claims concluded that demand-side domestic shocks appeared as important sources of output and private consumption dynamics. Studies like Eris and Ulasan (2013), Peiris and Saxegaard (2007), Nalban et al. (2015), who developed DSGE model and estimated for Romania and Jakab (2006), who developed DSGE small open-economy model for the Hungarian economy with standard new Keynesian small open economy framework, claims that investment shocks, consumer preference, and the government spending shocks are the key in driving output fluctuation in developing economies. Moreover, the evidence shows that financial market shock is one source of business fluctuation in different researches (see for example Nalban et al. (2015)). These authors revealed high contributions of the financial sector (like risk premium and bankruptcy rate) plays a role for Romanian macroeconomic fluctuation. Moreover, they claim that the financial sector (risk premium included) related shocks explain much of the fluctuations in investment, interest rate spreads and exchange rate. This result of the authors has been confirmed by other studies like for example Noah and Frederic (2011), who builds DSGE model for South Africa. Their conclusion includes the financial market shocks predominantly induces the domestic interest rate to change. The literature on domestic monetary policy shocks seems dynamic. While

some argue the shocks has a direct impact on output fluctuation, some others argues the influence depends on some criteria. For example, Ezezew (2015) used a stochastic general equilibrium model to analyze macroeconomic fluctuations in Ethiopia. This paper constructs a medium-size small New Keynesian general equilibrium model with active banking sector for Ethiopia. The findings suggest that monetary policy shock depends on the credit market imperfections. According to the author, credit market imperfection play a greater role to measure the magnitude of the monetary policy shock effect.

External shocks, on the other hand, have been studied by researchers to understand their effect on the economy of low-income countries. Some of the researchers generally studied external shocks in their model while other studied external shocks via some selected variables. In general level, for instance, Bourdet (2004) structurally analyses the effect of external shocks on the economies of primary product exporters especially Burkina Faso and Mali. The author finds that the economic performance of developing economies is greatly influenced by external shocks, in particular savings and economic growth, of the two countries. According to the author, this impact, however, dependent upon the economic policy responses and exchange rate regime (other arguments can be seen from Jakab (2006) and Noah and Frederic (2011)). In addition, Erceg et al (2007) used an open economy DSGE model to examine the link between trade openness and domestic economic activity The results indicate that the more the domestic economy is open and in international linkages, the more the domestic real activity and inflation are influenced through foreign shocks like world price shocks and world real interest rate shocks. With regard to specific variable cases, the trade shocks and world demand shocks have a greater role in driving macroeconomic fluctuations in low-income countries (especially) African economies. This fact is well recognized by recognized by many of the researchers (see among others Sissoko and Dougulu, (2006), Kose and Riezman (2001), Addison and Ghoshray (2013)). Kose and Riezman (2001), for example, developed the first dynamic multi-sector small open economy DSGE model capturing main structural characteristics of African economies to understand external trade shocks like fluctuations in the relative prices goods. These authors recognized that the role played by trade shocks in driving macroeconomic fluctuations in African economies is significant (they argue that trade shocks explain 44% in output variability, more than 86% of investment and 80% of labor

supply fluctuations). Kose, (2002), an extended model of the previous, developed stochastic dynamic multi-sector small open economy model which captures the major structural characteristics of developing economies. He utilizes variance decomposition methods to quantitatively evaluate the impact of world price shocks. The results indicate that world price shocks account for a significant fraction of business cycle variability in developing countries which is in support of the argument presented by Kose and Riezman (2001). Others like Eric et al (2014) analyzed the effect of oil price shock on the Ghanaian macroeconomic aggregates and on price levels. The author developed a benchmark simulation based on an increased interest rate. The finding of the study is that the rise in interest rate leads to a sharp rise in prices, output and money stock which means an increase in interest rate affects the marginal cost. The model also shows that a positive output shock has the same effect on consumption, investment, prices and wages as it occurred when there is an interest rate shock. In addition to the above studies, Beidas-Strom and Poghosyan (2011) also presented an estimated dynamic stochastic general equilibrium (DSGE) model for the Jordanian economy. While foreign demand shocks raise the income and consumption of the domestic economy which causes the real exchange rate to appreciate and deteriorate the current account, the foreign interest rate shocks have reverse causality. Fourth, international and domestic oil price shocks result in a large negative income effect, depreciating the real exchange rate, and improving the current account. In Africa, the main driving forces of the growth rates of real GDP, consumption, and investment, as well as the trade balance to GDP ratio, are the export demand shock, and the terms of trade shocks.

Literature on the effect of foreign monetary policy shocks, like EU and US monetary policy, on SSA economies documented that external monetary policy has a great influence on the economy of low-income countries, given that the response of these shocks rely on the source of the shock and the type of exchange rate regimes they follow. For example, countries with floating exchange rate shows contraction, and expansion for countries with the fixed exchange rate following the US shock through currency appreciation/ depreciation and debt channels, and vice versa for EU monetary policy shock.

In general, the empirical evidence suggests that demand-side shocks appeared as important sources of output and private consumption dynamics. The trade shocks and world shocks have a greater role in driving macroeconomic fluctuations in low-income countries (especially) African

economies. From world shock point of view, world price shock and interest rate shock took a major share to drive the economies' low-income countries. Majorly, the monetary policy rule of the foreign nation, mainly the US and EU interest rate, have also determined the macroeconomic fluctuation of low-income countries. This evidence shows that the effect of domestically induced shocks is taken a balanced weight with the externally induced shocks in driving the macroeconomics of low-income countries.

2.2.3. Application of the DSGE models to Sub-Saharan Economies

In this section, the study has discussed papers developed to study the need for modification of the standard macroeconomic models in general and the DSGE model in particular for low-income countries. With this regard, the study has got limited literature to discuss. Even if the literature is limited, however, the study discussed these works of literatures as follow.

Many argue that the DSGE model to be used to analyze business cycle should involve the realistic nature of the economy, especially for developing countries (see for example Agnor et al. (2008) and Adam et al. (2008)). Subsequently, some researchers explained that it is the time to develop DSGE model that properly encompasses the real features of African economies in general and sub-Saharan economies in particular (See for example O'Connell (2009)). Rule-based evaluation of policies in the DSGE model is not a real representative of low-income economies. For instance, Mwabutwa (2013) demonstrates that the monetary policy intervention of low-income countries depends on aid on domestic financing requirement. Particularly, the impact of increased aid inflows produces inflation and interest rate pressure on low-income countries in general and Malawi economy in particular. The author also presented monetary authority in these economies are able to minimize the impact of aid inflows when these authorities apply monetary targeting than a simple Taylor rule and incomplete sterilization. Moreover, Senbeta (2011, 2013) analyzed the assumptions of the standard small open economy New Keynesian DSGE model within the context of the economic environment of a typical low-income economy. The paper presented that incorporating the structural specificities of low-income countries in the models to explain or predict economic phenomena is important.

In general, from the above evidence, it is easy to explain that DSGE models that are used for advanced economies cannot be blindly used to the economies of low-income countries. This is based on the evidence that the real structure of low-income economies is very different from the advanced nations. One of the major difference is that developing economies are so volatile to the external shocks, and; domestic policy instruments are affected by external shocks and movements. Moreover, monetary authority in these economies is able to minimize the impact of aid inflows when these authorities apply monetary targeting than a simple Taylor rule and incomplete sterilization. Since these models require some sort of modification like foreign exchange constraint, labor market segmentation, and imperfect or no access of the economies to international financial or monetary and fiscal policies used in the main model.

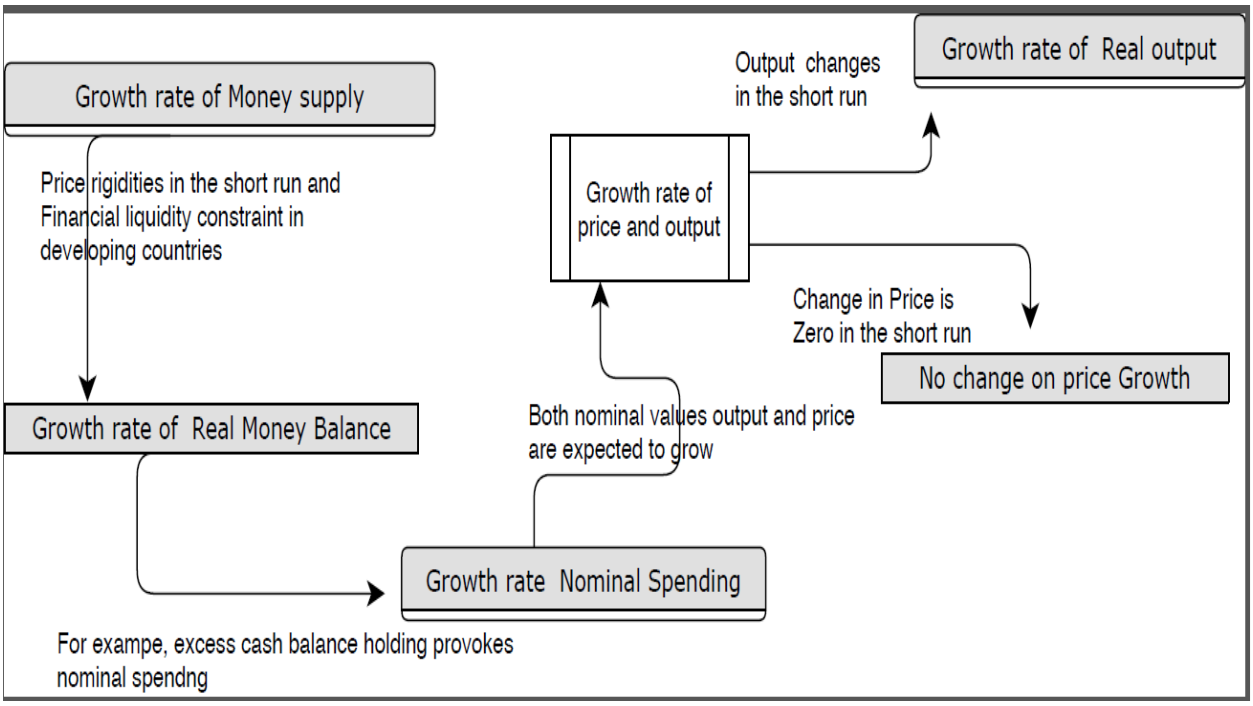
CHAPTER THREE

3. METHODOLOGY

3.1. Theoretical Framework of the Model

Using the quantity theory of money, the Classical economists do believe that excess money leads to excess demand. This idea can be interpreted as money can affect expenditure behavior of consumers. To put differently, according to them, money has a direct impact on output. The classical argues the transmission mechanism of money to the economy is through expenditure growth, which in turn affects output and price growth. It implies that money growth affects only price growth directly in the long run since output never changes in the long run. However, as prices do not grow in the short run, the growth in money affects output growth directly. For the Keynesian, however, money supply does not directly affect output, rather through interest rate and output. For example, when the price of the bond is low (its interest rate is high), the people would be motivated to buy bonds with the excess money on their hands. This situation makes interest rate to fall and investment to grow. As a result output growth can be achieved. Indeed, the transmission mechanism in developing countries seems similar with the Classical economist's description of money rather than the Keynesian economists. This is because the response of interest rate to money growth and interest rate may be weak. For example, if people hold the excess money as a cash balance, not buying bonds, output remains unaffected (See for example Hossain and Chowdhury (1996)). Hence in the short run, the transmission mechanism of the money supply is given in figure 2.

Figure 2: Money Transmission Mechanism



Source: own depiction based on Hossain and Chowdhury (1996)

1.7. Model Description

The study employed a DSGE model where households maximize a utility function consisting of consumption, leisure and real money balances. The study also takes in to account two types of households: consumers which make inter-temporal consumption and savings decisions in a forward- looking intertemporal optimizations –the Ricardian household, and those which consume their entire disposable income- non-Ricardian households (these households are characterized by no profits from the firms and no saving from their disposable income). Three types of firms are assumed in the economy. The first are firms producing varieties of intermediate tradable goods using labor, capital, and energy as inputs, and sell their product domestic and foreign markets. This energy input can be domestically produced or imported. When they import energy as an intermediate input, it is assumed that energy importing firms face foreign exchange constraint. They have monopoly power over the varieties they produce and power to set prices. The second type of firms are importers that distribute foreign intermediate varieties to the domestic economy. These firms have monopoly power in output and price as well. The other firms produces a commodity good which is completely exported abroad. This firm is characterized by no power in

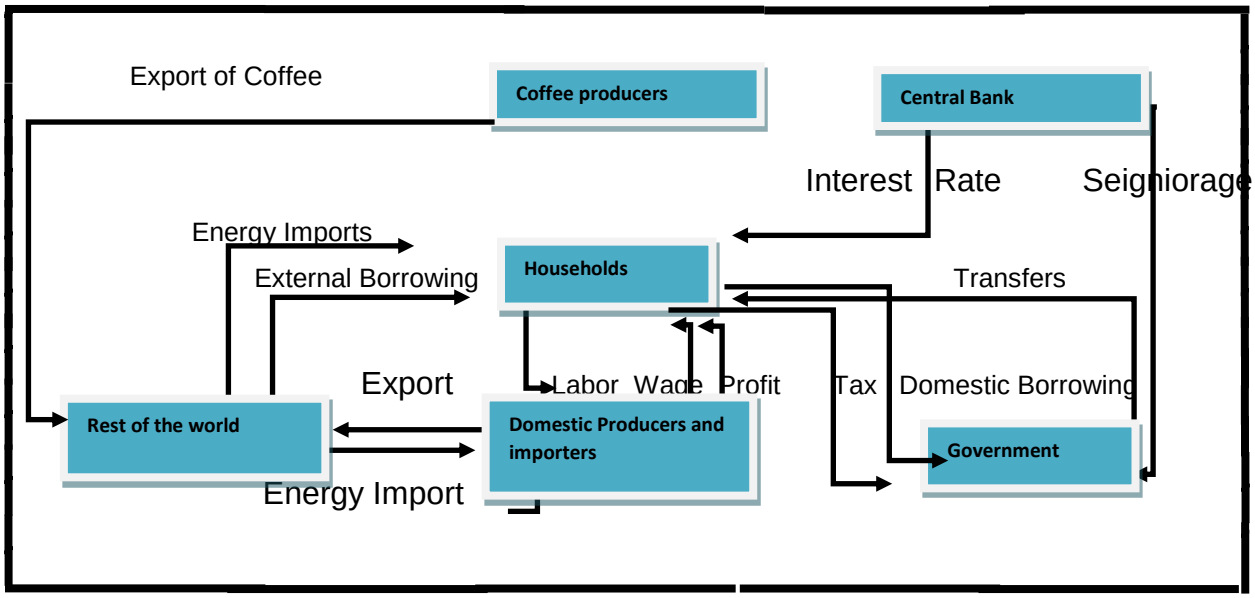
the price determination where its production depends only depends on natural resources. This commodity-exporting sector is mean to characterize the coffee sector.

The domestic economy is open and it is small vis-a-vis the rest of the world (see figure 3).[4] The model is constructed based on prices and wages rigidities. Price and wage are adjusted infrequently, and they are partially indexed to past inflation. The introduction of wage rigidities together with price rigidities, as Smet and Wouters (2003) pointed out, is very important in the model not only because it increases the realism of the model but also because it implies a stronger trade-off between inflation and output fluctuations.

Certain aspects of the current model used in this paper are novel especially the incorporation of the following. Firstly, the economy has been divided into two major sectors: energy and non-energy sector. Secondly, the consumption basket of the representative consumer holds energy goods consumption, which enables us to explicitly model energy supply and energy goods price. Third, to understand the effect of world coffee price shock, the productive sector divided into the domestic intermediate tradable sector, and a commodity-exporting sector. Fourth, we assume that the technology available to domestics firms producing tradable goods requires using imported energy as an input, which is an imperfectly substitute of labor and capital. Fifth, the study has incorporated foreign exchange constraint in the model, which is limited in many DSGE works, based on Senbeta (2011) who develop a foreign exchange constraint DSGE model for the sub-Saharan economy. Six, alternative monetary policy instrument is incorporated into the model. Finally, as mentioned above, some of the structural shocks that are introduced in the model are novel. Figure 3 briefly explain our model economy where the SSA economies integrates with the rest of the world.

Figure 3: The SSA Economies and the rest of the world

[4] The latter assumption implies that international prices, the foreign interest rate and foreign demand are not affected by domestic agents' decisions



Source: Own Depiction (2018)

Monetary policy is conducted through a standard policy rule for the interest rate and the bench mark policy through monetary equilibrium while fiscal authority behaves in a manner that resembles to some form of structural balance rule implemented by the Government.

1.8. Model Economy

The model is similar with Medina and Soto (2005, 2007). The household utility function; equation numbers of 11-23, 29-31, 34-39 and 54-58 are directly taken from Medina and Soto (2005, 2007) with a different explanation of each equations. The study choose these equations form Medina and Soto (2005, 2007) is because the model has equations which are relevant for this study to address its objective and the researcher easily understands its equations. In other words, this paper has gone a far to build the one model which is similar to Medina and Soto (2005, 2007). The study has a contribution in generating new equations. The household constraint function; equation numbers of 1-10, 25-28, 32-33, and 40-53 are its contribution.

3.2.1 Households

The preference of a variety of household's which attain utility from consumption, leisure and cash balances is represented by

$$U_t = E_t\left\{\sum_{i=0}^{\infty}\beta^i \varsigma_{C,t+i}\left[\log\left(C_{t+i}(j) - \tilde{h}C_{t+i-1}\right) - \frac{1}{1+\sigma_L}\ \mathrm{L}_{t+i}(\mathrm{j})^{1+\sigma_L} + \frac{\varsigma_{\mathrm{M}}}{\mu}\left\{\frac{\mathrm{M}_{t+i}(\mathrm{j})}{P_t}\right\}^{\mu}\right]\right\},$$

where $C_t(j)$ is aggregate consumption level , $L_t(j)$ is labor supplied by the j household, and $M_t(j)$ corresponds to nominal cash balances held at a time t. The inverse real-wage elasticity of labor supply is symbolled by σ_L where as P_t is domestic price level. The parameter $\varsigma_{C,t}$ is a consumption preference shock and ς_M measures the weights of leisure and nominal balances in the households preferences μ while defines the semi-elasticity of money demand to the nominal interest rate. $\tilde{h}$ measures preferences display habit formation.

These types of households are assumed to have access to three types of assets: money cash balance Mt (j), domestic bond$B_t(j)$, foreign bonds (denominated in foreign currency) which is denoted by $B*(j)$. The study assigned a share of (1-Ϙ)of the households for Ricardian households which means that Ϙ measures the weight of non-Ricardian households in the economy. Ricardian households are also assumed to earn wage, profit and dividend .The budget constraint of a representative household j is given by:

$$P_{C,t}C_t(j) + B_t(j) + \frac{\varepsilon_t B^*(j)}{(1+i^*_t)\Theta \mathcal{b}_t} + \text{ᴍ}_t(j) = B_{t-1}R_{t-1}(j) + \text{ᴍ}_{t-1}(j) + \varepsilon_t B^*_{t-1}(j) + W_t(j)L_t(j) + \pi_t(j) + T_{p,t}$$

where $\pi_t(j)$are profits received from domestic firms(like dividends or rental income), W_t (j) is the nominal wage set by the household, $T_{p,t}$ is per-capita lump-sum net taxes from the government, and R_{t-1} is gross nominal return on bonds (i.e, it is 1 plus the nominal interest rate) and $B_t(j)$ is the domestic bond. Assuming the existence of a full set of contingent bonds ensures that consumption of all Ricardian households is the same, independently of the labor income they receive each period. The Variable i^*_t is the interest rate on foreign bond denominated in foreign currency, and the term Θ is the premium that domestic households have to pay when they borrow from abroad. This premium is a function of the net foreign asset positions relative to GDP, $\mathcal{b}_t$which is given by $\mathcal{b}*_t = (\frac{\varepsilon_t B_t^*}{P_{Y,t}\, Y_t})$, where $P_{Y,t}\, Y_t$ is nominal GDP $B_t^*$and is the aggregate net asset position of the economy.[5]

Consumption-savings decisions by Ricardian households

[5] where$B^*(j) = \int_0^1 B^*(j)dj$ is the aggregate net foreign asset position of the economy

Ricardian households choose the path of C_t, L_t, M_t, B_t, Bt^* that maximize expected utility. The Lagagian function can be constructed as:

$$\mathbb{L}=\max_{Ct,Lt,Mt,Bt,Bt^*} E_t\left\{\sum_{i=0}^{\infty}\beta^i\zeta_{C,t+i}\left[\log\left(C_{t+i}(j)-\tilde{h}C_{t+i-1}\right)-\frac{1}{1+\sigma_L}\ \mathrm{L}_{t+i}(\mathrm{j})^{1+\sigma_L}+\right.\right.$$

$$\left.\frac{\zeta_{\mathrm{M}}}{\mu}\left\{\frac{\mathrm{M}_{t+i}(\mathrm{j})}{P_t}\right\}^{\mu}\right]-\lambda\beta^i\left[\mathrm{P}_{\mathrm{C,t}}\mathrm{C}_{\mathrm{t}}(j)+\mathrm{B}_{\mathrm{t}}(j)\ +\frac{\varepsilon_t B^*(\mathrm{j})}{(1+i^*_t)\Theta\mathfrak{b}_t}+\ \mathrm{ᴍ}_{\mathrm{t}}(\mathrm{j})-\mathrm{B}_{\mathrm{t-1}}\mathrm{R}_{\mathrm{t-1}}(j)+\mathrm{ᴍ}_{\mathrm{t-1}}(\mathrm{j})+\right.$$

$$\left.\left.\varepsilon_t B^*_{t-1}(\mathrm{j})+\ \mathrm{W}_{\mathrm{t}}(j)\mathrm{L}_{\mathrm{t}}(j)+\pi_{\mathrm{t}}(j)+\mathrm{T}_{\mathrm{p,t}}\right]\right\} \qquad (1)$$

The first order conditions are

$$\mathbb{L}_C=\zeta_C\left(C_t-\tilde{h}C_{t-1}\right)-\lambda_t\mathrm{P}_{\mathrm{C,t}}=0, \qquad (2)$$

$$\mathbb{L}_L=\zeta_C\ \mathrm{L}_t{}^{\sigma_L}-\lambda_t W_t=0, \qquad (3)$$

$$\mathbb{L}_M=\zeta_{\mathrm{M}}\left\{\frac{\mathrm{M}_t}{P_t}\right\}^{\mu-1}+\beta E_t\lambda_{t+1}-\lambda_t=0, \qquad (4)$$

$$\mathbb{L}_B=-\lambda_t+\beta E_t\lambda_{t+1}(\mathrm{R}_{\mathrm{t-1}})=0, \qquad (5)$$

$$\mathbb{L}_{B*}=-\frac{\varepsilon_t\lambda_t}{(1+i^*_t)\Theta\mathfrak{b}_t}+\beta E_t\lambda_{t+1}(\varepsilon_t) \qquad (6)$$

$$\mathbb{L}_{\lambda_t}=\mathrm{P}_{\mathrm{C,t}}\mathrm{C}_{\mathrm{t}}(j)+\mathrm{B}_{\mathrm{t}}(j)\ +\frac{\varepsilon_t B^*(\mathrm{j})}{(1+i^*_t)\Theta\mathfrak{b}_t}+\ \mathrm{ᴍ}_{\mathrm{t}}(\mathrm{j})-\mathrm{B}_{\mathrm{t-1}}\mathrm{R}_{\mathrm{t-1}}(j)+\mathrm{ᴍ}_{\mathrm{t-1}}(\mathrm{j})+\varepsilon_t B^*_{t-1}(\mathrm{j})+$$
$$\mathrm{W}_{\mathrm{t}}(j)\mathrm{L}_{\mathrm{t}}(j)+\pi_{\mathrm{t}}(j)+\mathrm{T}_{\mathrm{p,t}}=0 \qquad (7)$$

Equation 2 and 3 are used to derive the marginal rate of substitution between consumption and labor supply which can be written as:

$$\frac{\zeta_C\left(C_t-\tilde{h}C_{t-1}\right)^{-1}}{\mathrm{P}_{\mathrm{C,t}}}=\frac{\zeta_C\ \mathrm{L}_t{}^{\sigma_L}}{W_t}$$

This function can be log linearized to obtain the marginal rate of substitution between consumption and labor supply. That is,

$$\frac{1}{1-\tilde{h}}\left(\hat{c}_t-\tilde{h}\hat{c}_{.t-1}\right)-\hat{p}_{\mathrm{C,t}}=\sigma_L\hat{l}_t-\widehat{w_t}$$

Equation 2 and 4 can be used to derive the consumption Euler equation which can be written as

$$\frac{\varsigma_C\left(C_t-\tilde{h}C_{t-1}\right)^{-1}}{\mathrm{P_{C,t}}}=E_t\lambda_{t+1}(\mathrm{R_{t-1}})$$

Rearranging the above equation gives the following expression

$$\mathrm{E_t}\left[\beta(1+\mathrm{i_t})\frac{\mathrm{P_{C,t}}}{\mathrm{P_{C,t+1}}}\frac{\varsigma_{C,t+1}}{\varsigma_{C,t}}\left(\frac{C_{t+1}(j)-\tilde{h}C_t}{C_t(j)-\tilde{h}C_{t-1}}\right)\right]=1, \qquad (8)$$

Moreover, rearranging the first order condition with respect to foreign bond holdings implies the following expression:

$$\mathrm{E_t}\left[\beta(1+i^*{}_t)\Theta\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{\mathrm{P_{C,t}}}{\mathrm{P_{C,t+1}}}\frac{\varsigma_{C,t+1}}{\varsigma_{C,t}}\left(\frac{C_{t+1}(j)-\tilde{h}C_t}{C_t(j)-\tilde{h}C_{t-1}}\right)\right]=1, \qquad (9)$$

The mathematical expression for the uncovered interest parity condition (UIP) can be obtained by combining equation 8 and 9.

$$\frac{1+i_t}{1+i^*{}_t}=\frac{\mathrm{E_t}\left[\beta(1+i^*{}_t)\Theta\frac{\varepsilon_{t+1}}{\varepsilon_t}\frac{\mathrm{P_{C,t}}}{\mathrm{P_{C,t+1}}}\frac{\varsigma_{C,t+1}}{\varsigma_{C,t}}\left(\frac{C_{t+1}(j)-\tilde{h}C_t}{C_t(j)-\tilde{h}C_{t-1}}\right)\right]}{\mathrm{E_t}\left[\beta(1+\mathrm{i_t})\frac{\mathrm{P_{C,t}}}{\mathrm{P_{C,t+1}}}\frac{\varsigma_{C,t+1}}{\varsigma_{C,t}}\left(\frac{C_{t+1}(j)-\tilde{h}C_t}{C_t(j)-\tilde{h}C_{t-1}}\right)\right]} \qquad (10)$$

The foreign interest rate is subject to shocks and unobservable which follows an Auto Regressive (1) process and capture all foreign financial factors, including price, risk premia and any other factors associated with the exchange rate arbitrage.

Aggregate consumption is a composite goods consists of non-energy and energy goods consumption: the consumption bundle of household j is given by

$$\mathrm{C_t\,(j)}=\left[\alpha_c{}^{\frac{1}{\omega_c}}\left(C_{Z,t}\,(j)\right)^{\frac{\omega_c-1}{\omega_c}}+(1-\alpha_c)^{\frac{1}{\omega_c}}\left(C_{E,t}\,(j)\right)^{\frac{\omega_c-1}{\omega_c}}\right]^{\frac{\omega_c}{\omega_c-1}},$$

where $C_{Z,t}$ and $C_{E,t}$ is non-energy and energy consumption, respectively. While parameter ω_c is a proportion which measures the rate of substitution between these two types of goods, α_c measures the ratio of energy consumption in the aggregate bundle. The optimal allocation of the two bundle determines the demands for each type of goods:

$$C_{Z,t}=\alpha_c\left[\frac{P_{z,t}}{P_{C,t}}\right]^{-\omega_c}C_t\,, \qquad C_{E,t}=(1-\alpha_c)\left(\frac{P_{E,t}}{P_{C,t}}\right)^{-\omega_c}C_t$$

where $P_{z,t}$ and $P_{E,t}$ are the prices for non-energy and energy consumption, respectively. The aggregate consumption price level is given by the following expression.

$$P_{C,t} = \left[\alpha_c P_{Z,t}^{\,1-\omega_c} + (1-\alpha_c) P_{E,t}^{\,1-\omega_c}\right]^{\frac{1}{1-\omega_c}},$$

Similarly, the non-energy consumption bundle is given by the following constant elasticity of substitution (CES) aggregator of home and foreign goods,

$$\mathrm{C_{Z,t}}\,(\mathrm{j}) = \left[\gamma_C^{\frac{1}{\eta_C}} \left(C_{H,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}} + (1-\gamma_C)^{\frac{1}{\eta_C}} \left(C_{F,t}(j)\right)^{\frac{\eta_C-1}{\eta_C}}\right]^{\frac{\eta_C}{\eta_C-1}},$$

γ_C measures the weights of home and foreign goods and η_C measures the elasticity of substitution between the two goods in the bundle. The minimization problem for this bundle determines the demands for home, $C_{H,t}(j)$ and foreign goods $C_{F,t}(j)$ by the household

$$C_{H,t}(j) = \gamma_C \frac{P_{H,t}^{\,-\eta_C}}{P_{Z,t}} \mathrm{C_{Z,t}}\,(\mathrm{j})$$

$$C_{F,t}(j) = (1-\gamma_C) \frac{P_{F,t}^{\,-\eta_C}}{P_{Z,t}} \mathrm{C_{Z,t}}$$

where $P_{H,t}$ and $P_{F,t}$ are the price indices of home and foreign goods, and $P_{Z,t}$is the price index of the core consumption bundle, defined as: $\mathrm{P_{Z,t}} = \left[\gamma_C P_{H,t}^{\,1-\eta_C} + (1-\gamma_C) P_{F,t}^{\,1-\eta_C}\right]^{\frac{1}{1-\eta_C}}$

Labor supply and wage setting by Ricardian households

Assuming firms hire under the perfectly competitive labor market and a monopolistic supplier of a labor service by households. The labor service unit is defined as:

$$L_t = \left[\int_0^1 L_t(j)^{\frac{\epsilon_L-1}{\epsilon_L}} dj\right]^{\frac{\epsilon_L}{\epsilon_L-1}} \qquad (11)$$

Labor is a part of input in domestic production process. Parameter ϵ_L measures to the elasticity of substitution among different labor services. The labor service provided by each household is obtained by minimizing its cost, given the different wages set by different households. In particular, the demand for the labor service provided by household j is:

$$L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\epsilon_L} \mathrm{L_t}, \qquad (12)$$

where $W_t(j)$ and W_t are wage rate set by household j and aggregate wage index, respectively. The aggregate wage index is defined as:

$$W_t = \left[\int_0^1 \ W_t(j)^{1-\epsilon_L} dj\right]^{\frac{1}{1-\epsilon_L}} \quad (13)$$

Since the model is based on nominal and real rigidities, it is assumed that wage setting is subject to a nominal rigidity. Each type of households has a constant probability $(1-\phi_L)$ to re-optimize its nominal wage at a time t. If a given household is not going to re-optimize during i periods then the level of wage at a time t+1 can be written as:

$$W_{t+i}(j) + \Gamma^{i}_{w,t} W_t(j) \quad (14)$$

Given that $\Gamma^{i}_{w,t}$, which is adjustment rule for wages, implies that labor suppliers who do not optimally reset their wages re-optimize their wage with respect to geometric weighted average of past CPI inflation and the inflation target set by the authority, πt. Moreover the expression (1+gy) avoids large real wage dispersion along the steady state growth path. The expression for the adjustment rule then written as

$$\Gamma^{i}_{w,t} = \prod_{j=1}^{i} \left[1+\pi_{t+j-1}\right]^{\xi_L} \left[\overline{\pi}_{t+j}\right]^{1-\xi_L} (1+g_y) \quad (15)$$

A particular household j, depending on the wage rate ,supplies a given quantity of labor ,that is able to re-optimize its wages at t solves the following problem:

$$\max_{W_t(j} E_t \left\{\sum_{i=0}^{\infty} \Phi^{i}_{L} \Lambda_{t,t+i} \left(\frac{(W_t(j))\Gamma^{i}_{w,t}}{P_{C,t+i}} L_{t+i}(j) \ - \varsigma_{L,t} \frac{(L_{t+i}(j)^{1+\sigma_L}}{1+\sigma_L} (C_{t+i} - \tilde{h} C_{t+i-1}) \right) \right\} \text{ or}$$

$$\max_{W_t(j} E_t \left\{\sum_{i=0}^{\infty} \Phi^{i}_{L} \Lambda_{t,t+i} \left(\frac{(W_t(j))\Gamma^{i}_{w,t}}{P_{C,t+i}} - \varsigma (L_{t+i}(j)^{\sigma_L} (C_{t+i} - h C_{t+i-1}) \right) \ L_{t+i}(j) \right\} \quad (16)$$

subject to the labor demand $L_t(j) = \left(\frac{W_t(j)}{W_t}\right)^{-\epsilon_L} L_t$ and the updating rule for the nominal wage $\Gamma^{i}_{w,t} = \prod_{j=1}^{i} \left[1+\pi_{t+j-1}\right]^{\xi_L} \left[\overline{\pi}_{t+j}\right]^{1-\xi_L} (1+g_y)$. The variable $\Lambda_{t,t+i}$ is the relevant discount factor between periods t and t + i, and is given by

$$\Lambda_{t+i} = \ \frac{\beta^i (C_t - h(1+g_y) C_{t-1})}{C_{t+i} - h(1+g_y) C_{t+-1}}$$

Non-Ricardian households

Unlike the Ricardian households, non-Ricardian households have no access to assets and own no shares in domestic firms. To put differently, they have no access to dividend. Moreover, these households do not save to the future. They consume all of their disposable after-tax disposable income. Hence their consumption behavior is represented by:

$$C_t(j) = \frac{W_t}{P_{C,t}} (L_t(j) - \frac{T_{P,t}}{P_{C,t}} \quad (17)$$

Given that Tp,t are per-capita lump-sum taxes. The study assumed that these households are setting wages equal to the average wage set by Ricardian households. This assumption implies that labor effort of non-Ricardian households coincides with the average labor effort of Ricardian households.

3.2.2. Investment and Capital Goods

Firms which assemble new capital goods are represented by a firm that rents capital goods to firms producing intermediate varieties. Investment, in this model is represented by home and foreign goods. Such firm are represented by using a CES technology as follow

$$\mathrm{I_t} = \left[\gamma_I^{\frac{1}{\eta_I}} \left(I_{H,t}\right)^{1-\frac{1}{\eta_I}} + (1-\gamma_I)^{\frac{1}{\eta_I}} \left(I_{F,t}\right)^{1-\frac{1}{\eta_I}}\right]^{\frac{\eta_I}{\eta_I - 1}} \tag{18}$$

where $\mathrm{I_t}$ is total investment, parameter η_I measures the elasticity of substitution between home and foreign goods, γ_I measures the share of home goods in investment. Moreover, the investment price index, $P_{I,t}$, is also represented by CES technology as:

$$\mathrm{P_{I,t}} = \left[\gamma_I {P_{H,t}}^{1-\eta_I} + (1-\gamma_I) {P_{F,t}}^{1-\eta_I}\right]^{\frac{1}{1-\eta_I}} \tag{19}$$

The demands for home and foreign goods by the firm are expressed as

$$I_{H,t} = \gamma_I \frac{P_{H,t}}{P_{I,t}}^{-\eta_I} \mathrm{I_t}$$

$$I_{F,t} = (1-\gamma_I) \frac{P_{F,t}}{P_{I,t}}^{-\eta_I} \mathrm{I_t} \tag{20}$$

This paper assumes firms adjust investment but not able change investment since it is costly (Christiano et al. (2005). This assumption is introduced to model investment inertia. The given firm solves the following problem:

$$\max_{K_{t+i}, I_{t+i}} \mathrm{E_t} \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left(\frac{(Z_{t+i})\left((K_{t+i}) - (P_{I+i})((I_{t+i}))\right)}{\mathrm{P_{C,t+i}}} \right) \right\} \tag{21}$$

$\mathrm{Z_t}$ represents the rental price of capital .The above objective must be solved subject to law of motion of the capital stock which is defined as:

$$K_{t+1} = (1-\delta)K_t + \varsigma_{I,t} S\left(\frac{I_t}{I_{t-1}}\right) I_t \tag{22}$$

The parameter δ is its depreciation rate and the function S (.) characterizes the adjustment cost for investment. This adjustment cost satisfies: $S\left(1+\mathrm{g}_y\right)=1$, $S'\left(1+\mathrm{g}_y\right)=0, S''\left(1+\mathrm{g}_y\right)=$

$\mu_s < 0$, the variable $\varsigma_{I,t}$ is a shock which assumed to be a domestic supply stochastic shock, implies technology to capital accumulation, which measures how investment transformed to productivity capital (for example the rise of this variable implies the same amount of investment generates more productive capital).

$$\mathbb{L} = \max_{K_{t+i}, I_{t+i}} \mathrm{E_t} \left\{ \sum_{i=0}^{\infty} \Lambda_{t,t+i} \left(\frac{(Z_{t+i}) \left((K_{t+i}) - (P_{I+i}) \left((I_{t+i}) \right) \right)}{\mathrm{P_{C,t+i}}} \right) - \lambda_t \left[K_{t+1} - (1-\delta) K_t + \varsigma_{I,t} S\left(\frac{I_t}{I_{t-1}}\right) I_t \right] \right\}$$

The above maximization problem is solved as

$$\frac{P_{I,t}}{P_{C,t}} = \frac{Q_t}{P_{C,t}} \left[S\left(\frac{I_t}{I_{t-1}}\right) + S'\left(\frac{I_t}{I_{t-1}}\right)\left(\frac{I_t}{I_{t-1}}\right) \right] \left[\varsigma_{I,t} - \mathrm{E_t} \left\{ \Lambda_{t,t+1} \frac{Q_{t+1}}{P_{C,t+1}} \left[S'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2 \varsigma_{I,t+1} \right] \right\} \right] \quad (23)$$

$$\frac{Q_t}{P_{C,t}} = \mathrm{E_t} \left\{ \Lambda_{t,t+1} \left[\left(\frac{Z_{t+1}}{P_{C,t+1}}\right) + \left(\frac{Q_{t+1}}{P_{C,t+1}}\right)(1-\delta) \right] \right\} \quad (24)$$

The equilibrium condition of the above two equations will determine the evolution of the shadow price of capital, Q_t, and real investment expenditure.

3.2.3. Domestic production

The firm's production technology is represented as a function of labor, capital and energy which the firm combine to produce total quantity of a particular variety z_H, which is symbolled by $Y_{H,t}(z_H)$. The available technology is given by:

$$Y_{H,t(ZH)} = A_{H,t} \left[\alpha_H^{\frac{1}{\omega_H}} (V_{H,t(ZH)})^{1-\frac{1}{\omega_H}} + (1-\alpha_H)^{\frac{1}{\omega_H}} (E_{E,t(ZH)})^{1-\frac{1}{\omega_H}} \right]^{\frac{\omega_H}{\omega_H - 1}} \quad (25)$$

where $V_{H,t(ZH)}$ is a composite of labor and capital as an intermediate input, variable $E_{H,t(ZH)}$ is the amount of energy used as intermediate input. Parameter ω_H determines the degree of substitution between $V_{H,t(ZH)}$ and $E_{E,t(ZH)}$. Variable $A_{H,t}$ represents a stationary temporary productivity shock common to all firms. Energy used in the intermediate input can be domestically produced or imported which is represented with its own law of motion. The law of motion of energy is given by:

$$E_{E,t+1(ZH)} = \left\{ E_{E,t(zh)}^{(1-\delta_{ED}+\delta_{REGR})} \right\}^{\cdot} \quad (26)$$

where $E_{H,t(ZH)}$ is a composite total energy supply , $E_{H,tH}$ is domestic supply of energy and $E_{H,tF}$ is the amount of energy supplied through import that can be used as intermediate input. Parameters like t_t, $A_{EH}, \delta_{ED} and\ \delta_{REGR}$ are the share of domestic energy from total energy supply, energy technology, energy depletion rate and renewable energy growth rate respectively. Energy supply through imports are highly influenced by the foreign exchange constraint than the domestic energy supply. Hence the domestic energy supply take the form of AR process where

$$E_{H,th} = E^{p_{ehth}}{}_{Hh,t-1}\ exp\ \varepsilon_{H,th}$$

To model the energy supply from import we first analysis what type constraint firms will face in the foreign exchange market. We will assume that the law of one price (H=1) holds for this good (energy). Therefore, its domestic-currency price is given by, $P_{s,t} = \varepsilon_t P^*S,t$,This is true when the law of one price (H=1), we can rearrange this mathematical representation using the law one price as

$$H = \frac{\varepsilon_t P^*E,t}{P_{E,t}}$$

where $P_{E,t}$ is the domestic imported energy and $P^*_{E,t}$ is international price of energy goods in domestic price . In this economy firms (energy supply agencies which can be government or non-government agencies) in the non-tradable sector face a foreign exchange constraint for the purchase of intermediate inputs. The study introduce this constraint based on Senbeta (2011) as:

$$\Omega_t = \frac{P^*_{E,t} E_{H,tF}}{\varepsilon_t} \qquad (27)$$

where $P^*_{E,t}, E_{H,tF}, \varepsilon_t$ are the average price level of imported goods in terms of domestic currency, imported intermediate inputs, and the nominal exchange rate, respectively, as defined in the previous sections. Ω denotes the quantity of foreign exchange available at the beginning of period t to import energy inputs for production during that period.

The study assume that at time t the quantity of foreign exchange available for the importers of intermediate inputs is a certain proportion of the export earnings of the economy. That is, in each period the central bank sells some proportion of foreign currency inflows to firms importing intermediate energy inputs. Assuming that the foreign exchange constraint is binding, the

relationship between import of intermediate energy inputs and export earnings can be approximated as

$$\Omega_t = \frac{\mathrm{P^*E,t}\, E_{H,tF}}{\varepsilon_t} = \varphi P_{X,t} X_t = \varphi {P_t}^* {C_{H,t}}^* \quad (28)$$

$$\text{This gives } E_{H,tF} = \frac{\varepsilon_t \varphi \mathrm{P^*_t} {C_{H,t}}^*}{\mathrm{P^*E,t}}$$

where φ is some constant, ${P_t}^*$ overall price index of the rest of the world and ${C_{H,t}}^*$ is consumption by the rest of the world of domestically produced tradable goods (exports). It is believed that this assumption simplifies the analysis and does not change the dynamics of the model significantly. The composite of labor and capital is given by a Cobb-Douglas technology:

$$(V_{H,t(ZH)}) = \left[T_t L_{t\,,ZH}\right]^{\eta_H} \left[K_{t\,,ZH}\right]^{1-\eta_H}) \quad (29)$$

where lt (z_H) is the amount of labor utilized, and Kt(zH) is the amount of physical capital rented. Parameter η_H defines their corresponding shares in production. The variable T_t is a stochastic trend in labor productivity, given by

$$\frac{T_t}{T_{t-1}} = \varsigma_{T,t}$$

The exogenous shocks to both types of technology process are given by

$A_{H,t} = {A^{p_{a,H}}}_{H,t-1}\ exp\ \varepsilon_{aH,t}$, $\varsigma_{T,t} = (1+g_y)^{1-p_T}\ {\varsigma_T}^{p_T}{}_{t-1}\quad exp\ \varepsilon_{T,t}$

$\varepsilon_{aH,t} \sim N(0,\ {\sigma^2}_{aH})$ and $\varepsilon_{aH,t} \sim N(0,\ {\sigma^2}_{T})$

By representing $(1-\phi_H)$ is the probability that a domestic firm adjust their price irrespective of size and type, and $(1-\phi_F)$ is that parameter comprises the probability of how foreign firms adjust their price (for all types of firms). Firms update its price using weights past inflation and the inflation target set by the central bank if the firm does not show a sign to adjust its price. The maximization problem for firm's price adjustment for the domestic and the foreign firm is given as

$$\max_{P_{H,t\,(ZH)}} \mathrm{E_t}\left\{\sum_{i=0}^{\infty} \Lambda_{t,t+i} {\phi_H}^i{}_D \left(\frac{{\Gamma^i}_{H_{D,t}} P_{H,t\,(ZH)} - MC_{H,t+i}}{\mathrm{P_{C,t+i}}} Y_{H,t+i(ZH)}\right)\right\} \quad (30)$$

$$\max_{P^*_{H,t\,(ZH)}} \mathrm{E_t}\left\{\sum_{i=0}^{\infty} \Lambda_{t,t+i} {\phi_H}^i{}_F \left(\frac{\varepsilon_{t+i} {\Gamma^i}_{H_{F,t}} {P^*}_{H,t\,(ZH)} - MC_{H,t+i}}{\mathrm{P_{C,t+i}}} {Y^*}_{H,t+i\,(ZH)}\right)\right\} \quad (31)$$

Subject to $Y_{H,t(ZH)} = \left[\frac{P_{H,t\,(ZH)}}{P_{H,t}}\right]^{-\epsilon_H}$ and ${\Gamma^i}_{H_{D,t}}$ for the domestic firm and ${Y^*}_{H,t(ZH)} = \left[\frac{P^*_{H,t(ZH)}}{P^*_{H,t}}\right]^{-\epsilon_H} {Y^*}_{H,t}\ and\ {\Gamma^i}_{H_{F,t}}$ for the foreign firm. Where $Y_{H,t(ZH)}$ and ${Y^*}_{H,t}$ demands for a

particular intermediate variety z_H by these assemblers. The constraint $\Gamma^{i}{}_{H(F)_{F,t}}$ is the constraint for firms that do not optimize prices. Given this pricing structure, the New Keynesian Philips curve is used for the optimal path for inflation which rely on both last period's inflation, expected inflation next period and marginal cost.

Demand for inputs and marginal cost

Cost minimization problem subject to the technology of the firm gives the optimal input choice. Taking the first-order condition it gives:

$$\frac{1-\alpha}{\alpha}\frac{E_{H,t(ZH)}}{L_{H,t(ZH)}} = \left(\frac{W_t}{P_{E,t}}\right)^{\omega} \qquad (32)$$

The marginal cost of production is obtained from this cost minimization problem and from production technology described above. The nominal marginal cost of production which depends on price of inputs and technology is expressed as:

$$MC_{H,t} = A_{H,t}{}^{-1}\left[(1-\alpha)\,(W_t)^{1-\omega} + \alpha^{\frac{1}{\omega}}P_{E,t}{}^{1-\omega}\right]^{\frac{1}{1-\omega}} \qquad (33)$$

This form of the marginal cost expresses its independency from the scale of production of a particular firm depending on constant return to scale and no adjustment cost for inputs.

Import goods retailers

In the short run, exchange rate movement could affect expenditure allocation of households through substitution between home and foreign goods. Therefore, exchange rate pass-through will be incomplete in the short-run. In the long-run firms freely adjust their prices, so the law-of-one-price holds up to a constant. Imported verities $Y_{F,t(ZF)}$ might be consumed by households or used by firms for investment which is represented by CES technology. The demand for variety zF is given by the following expression which can be obtained through optimization mix of imported final foreign goods:

$$Y_{F,t(ZF)} = \left[\frac{P_{F,t\,(ZF)}}{P_{F,t}}\right]^{-\epsilon_F} \mathrm{Y_{F,t}} \qquad (34)$$

Such that $P_{F,t}(z_F)$ is the price of imported variety z_F in the domestic market which is given in terms of domestic-currency, ϵ_F is the elasticity of substitution among imported varieties, and $P_{F,t}$ is the aggregate price of import goods in this market. Hence these firms imports foreign verities

and supply them with a monopoly power with sticky price (infrequent price adjustment). When there is a gesture to adjust price, an importing firm has a probability of $(1-\phi_F)$ in each period. Given this, an importing firm z_F , when there is a gesture for price adjustment , it chooses a new price by maximizing the present value of expected profits, given $P^*_{F,t(ZF)} = P^*_{F,t}$:

$$\max_{P_{F,t\,(ZF)}} \mathrm{E_t}\left\{\sum_{i=0}^{\infty} \Lambda_{t,t+i}\phi_F{}^{i}{}_{*}\left(\frac{\Gamma^{i}{}_{F,t}P_{F,t\,(ZF)}-\varepsilon_{t+i}P^*{}_{F,t+i(ZF)}}{\mathrm{P_{C,t+i}}}Y_{F,t+i(ZF)}\right)\right\} \quad (35)$$

Subject to $Y_{F,t(ZF)} = \left[\frac{P_{F,t\,(ZF)}}{P_{F,t}}\right]^{-\epsilon_F} \mathrm{Y_{F,t}}$ and $\Gamma^{i}{}_{H_{F,t}}$ and the updating rule for prices.

3.2.4. Commodity sector

This sector is assumed to produce a good only for the foreign market (only for export) using natural resources and labor. To represent this sector, we used a coffee sector which can represent this phenomena. An increase in the production of this sector tells output and export have raised. This sector may also provoke currency appreciation/depreciations. This is very relevant for analyzing the change in world coffee price shock. Its aggregate production defined as:

$$Y_{S,t} = \left[\frac{T_t}{T_{t-1}}Y_{S,t-1}\right]^{\rho_{ys}} T_t\, \mathrm{Y_{S,0}}^{1-\rho_{ys}} \exp(\varepsilon_{ys,t}) \quad (36)$$

Where $Y_{S,t}$ the total aggregate production of coffee is, $\varepsilon_{ys,t} \sim N(0,\ \sigma^2{}_{ys})$ is a stochastic shock and ρ_{ys} measures the persistence of the shock to coffee production process.

3.2.5. Government Sector

In this section, the government fiscal policy is discussed where the government asset is measured in domestic and foreign assets. In the model, the only asset of the government is its share from the commodity sector and has liability like public bonds.

Fiscal Policy

The total net asset position of the government growth is given as follow, Given that $\mathrm{B^*_{G,t}}$ and $\mathrm{B_{G,t}}$ be the net asset position of government in foreign and domestic currency, respectively.

$$\frac{\varepsilon_t B^*{}_{G,t}}{(1+i^*{}_t)\Theta(\frac{\varepsilon_t B_t{}^*}{\mathrm{P_{Y,t}\ Y_t}})} + \frac{B_{G,t}}{(1+i_t)} = \varepsilon_t B^*{}_{G,t-1} + B_{G,t} + T_t - P_{G,t}G_t \quad (37)$$

Variable G_t is total government expenditure and T_t are total net fiscal nominal revenues, $(1+\ i^*{}_t)\Theta(.)$ is the relevant gross interest rate for public asset denominated in foreign currency

while $(1 + i_t)$ is the public asset domestic currency. Government consumption s assumed to be composed of both home and foreign goods:

$$G_t = \left[\gamma_G^{\frac{1}{\eta_G}} \left(G_{H,t}\right)^{\frac{\eta_G - 1}{\eta_G}} + (1 - \gamma_G)^{\frac{1}{\eta_G}} \left(G_{F,t}\right)^{\frac{\eta_G - 1}{\eta_G}}\right]^{\frac{\eta_G}{\eta_G - 1}} \quad (38)$$

Hence like consumption and investment, cost minimization of this government problem provides government demand for home and foreign goods as follow:

$$G_{H,t} = \gamma_G \left(\frac{P_{H,t}}{P_{G,t}}\right)^{-\eta_G} G_t$$

$$G_{F,t} = (1 - \gamma_G) \left(\frac{P_{F,t}}{P_{G,t}}\right)^{-\eta_G} G_t \quad (39)$$

Prices of these goods is also composed of both home and foreign goods price, which is known as deflator of government expenditure:

$$P_{G,t} = \left[\gamma_G P_{H,t}^{\,1-\eta_G} + (1 - \gamma_G) P_{F,t}^{\,1-\eta_G}\right]^{\frac{1}{1-\eta_G}}$$

Assuming the government consumes only home goods: $\gamma_G = 1$. Whether households are Ricardian or non-Ricardian has a significance influence on government debt analysis. As described above, relevant fraction of households are non-Ricardian ($\lambda > 0$).To formulate the fiscal policy rule, four variables$B^*_{G,t}$, $B_{G,t}$, T_t and G_t has been characterized. The study also assume that public asset position is completely denominated in foreign currency ($B_{G,t} = 0$).

Finally, by examining that the government expenditure, the study follow structural balance fiscal rule according to government expenditure, as a share of GDP, evolves as follows:

$$\frac{P_{G,t} G_t}{P_{Y,t} Y_t} = \left\{\left(1 - \frac{1}{(1 + i^*_t)\Theta_{t-1}}\right) \frac{\varepsilon_t}{\varepsilon_{t-1}} \frac{\varepsilon_{t-1} B^*_{G,t-1}}{P_{Y,t-1} Y_{t-1}} \frac{P_{Y,t-1} Y_{t-1}}{P_{Y,t} Y_t} + \tau \left(\frac{\overline{Y_t}}{Y_t}\right) + \varepsilon_t \overline{P^*_{S,t}} \chi \frac{Y_{S,t}}{P_{Y,t} Y_t} - \frac{B_{S,t}}{P_{Y,t} Y_t} + \rho d \left(\frac{Aid}{P_{Y,t} Y_t}\right)\right\} \quad (40)$$

Where $T_{p,t}$ is government tax income from the private sector, which is a function of GDP, $T_{p,t} = (\tau_t P_{Y,t} Y_t)$, and revenues from coffee which are given by $P_{S,t}\chi Y_{S,t}$ where $\chi Y_{S,t}$ are coffee sales from the state company. The other source of revenue is from aid (Aid). The parameter χ defines the public share of ownership in total coffee production. The variable τ_t corresponds to the average income tax. The parameter ρd determine by how much the government expenditure as a

percentage of GDP changes as aid (as percentage of GDP) changes, and $\overline{P^{*}_{S,t}}$ is the long-run ("reference") price of coffee, that we treat as a constant in the model. The study assumes that aid is fully utilized for expenditure by the government in the economy

Monetary policy rule

The first monetary policy is characterized as a simple Taylor rule for the interest rate, as the standard model. The variable accented by the bar indicates the steady state of the variable.

$$\frac{R_t}{\overline{R}_t} = \left(\frac{R_{t-1}}{\overline{R}_t}\right)^{pi} + \left(\frac{Y_t}{\overline{Y}_t}\right)^{pyi} \left(\frac{\pi_{zt}}{\overline{\pi}_t}\right)^{ppay} \qquad (41)$$

where $\pi_t = \frac{Pt}{Pt-1} - 1$ is the inflation and $\overline{\pi}_t$ is the inflation target set for period t. To derive the alternative monetary policy rule, the first order condition of the household's problem with respect to nominal money holding and domestic bond asset holding was equated. That is:

$$\varsigma_M \left\{\frac{M_{t+i}(j)}{p_{t+i}(j)}\right\}^{\mu-1} + \beta E(\boldsymbol{\vartheta}_{t+1}) = \beta E(\boldsymbol{\vartheta}_{t+1})\boldsymbol{R}_{t-1} \qquad (42)$$

To avoid parameter confusion, we used $\boldsymbol{\vartheta}$ in place of lambda. Through log linearization (42) and using $\boldsymbol{R}_{t-1} = 1 + \boldsymbol{R}_t$,

$$\hat{r}_t = (\mu - 1)\hat{m}_t - (\mu - 1)\hat{p}_t \qquad (43)$$

The real exchange rate can be defined as $(RER_t)^{\cdot} = \frac{(\varepsilon_t)^{\cdot}(PF.t)^{\cdot}}{(p_t)^{\cdot}}$, log linearizing this equation and using a steady state ratios, it gives that $\hat{p}_t = \gamma_{pf}\hat{p}_{F,t} - \gamma_{rer}\widehat{rer}_t + \gamma_e\hat{e}_t$, where variables under hat is the percentage deviations from their respective steady state, The parameter γ_j is the steady state ratio of variable j to domestic price level,

$$\hat{r}_t = (\mu - 1)\hat{m}_t - (\mu - 1)(\gamma_{pf}\hat{p}_{F,t} - \gamma_{rer}\widehat{rer}_t + \gamma_e\hat{e}_t) \qquad (44)$$

From the log linearized form of equation the above the same can be said for real exchange rate:

$$\widehat{rer}_t = \gamma_{pf}\hat{p}_{F,t} + \gamma_e\hat{e}_t - \gamma_p\,\hat{p}_t$$

Take one period lag and rearrange for $\hat{e}_t$ from $\widehat{rer}_t = \hat{e}_t + \hat{p}_{F,t} - \hat{p}_t$

$$\widehat{rer}_t - \widehat{rer}_{t-1} = (\hat{e}_t - \hat{e}_{t-1}) + (\hat{p}_{F,t} - \hat{p}_{F,t-1}) - (\hat{p}_t - \hat{p}_{t-1})$$

$$\hat{e}_t = \widehat{rer}_t - \widehat{rer}_{t-1} + \hat{e}_{t-1} + \hat{\pi}_{F,t} - \hat{\pi}_t \qquad (45)$$

Accorrding to Macallum and Nelson (2000), net export (nx) is defined as

$$\left(\hat{p}_{x,t} + \hat{x}_t\right) - \left(\hat{p}_{m,t} + \hat{m}_t\right) = ϡ_{yF}\hat{y}_{Ft} - ϡ_y\hat{y}_t + ϡ_{rer}\widehat{rer}_t$$

$$\widehat{nx}_t = ϡ_{yF}\hat{y}_{Ft} - ϡ_y\hat{y}_t + ϡ_{rer}\widehat{rer}_t$$

Where $ϡ_i$ is the steady state ratios, rearrange for $\widehat{rer}_t$

$$\widehat{rer}_t = \frac{\widehat{nx}_t}{ϡ_{rer}} - \frac{ϡ_{yF}\hat{y}_{Ft}}{ϡ_{rer}} + \frac{ϡ_y\hat{y}_t}{ϡ_{rer}} \qquad (46)$$

$$\hat{e}_t = \frac{\widehat{nx}_t}{ϡ_{rer}} - \frac{ϡ_{yF}\hat{y}_{Ft}}{ϡ_{rer}} + \frac{ϡ_y\hat{y}_t}{ϡ_{rer}} - \widehat{rer}_{t-1} + \hat{e}_{t-1} + \hat{\pi}_{F,t} - \hat{\pi}_t \qquad (47)$$

Substitute equation (47) in to (44),

$$\hat{r}_t = (\mu-1)\hat{m}_t - (\mu-1)\left[ϟ_{pf}\hat{p}_{F,t} - ϟ_{rer}\widehat{rer}_t + ϟ_e\hat{e}_t\left(\frac{\widehat{nx}_t}{ϡ_{rer}} - \frac{ϡ_{yF}\hat{y}_{Ft}}{ϡ_{rer}} + \frac{ϡ_y\hat{y}_t}{ϡ_{rer}} - \widehat{rer}_{t-1} + \hat{e}_{t-1} + \hat{\pi}_{F,t} - \hat{\pi}_t\right)\right] \qquad (48)$$

$$\hat{r}_t = (\mu-1)\hat{m}_t + \rho_{pf}\hat{p}_{F,t} - \rho_{rer}\widehat{rer}_t + \rho_{nx}\widehat{nx}_t - \rho_{yf}\hat{y}_{Ft} + \rho_y\hat{y}_t + \rho_{re\pi}\left(\hat{e}_{t-1} - \widehat{rer}_{t-1} + \hat{\pi}_{F,t} - \hat{\pi}_t\right) \qquad (49)$$

Where $-(\mu-1)ϟ_{pf} = \rho_{pf}$, $-(\mu-1)ϟ_{rer} = \rho_{rer}$, $-(\mu-1)\frac{ϟ_e}{ϡ_{rer}} = \rho_{nx}$, $-(\mu-1)\frac{ϟ_e ϡ_{yF}}{ϡ_{rer}} = \rho_{yf}$, $-(\mu-1)\frac{ϟ_e ϡ_{yt}}{ϡ_{rer}} = \rho_{yt}$ $ϟ_e = \rho_{re\pi}$

The determining equation for the monetary aggregate is based on slight modification of Muhanji and Ojah (2011). The monetary aggregate Taylor-type rule is:

$$\frac{M_t}{\bar{M}} = \left(\frac{M_{t-1}}{\bar{M}}\right)^{p_{mm}} - (1-p_{mm})\left[\left(-\frac{Y_t}{\bar{Y}_t}\right)^{p_{yy}}\left(\frac{\pi_{zt}}{\bar{\pi}_t}\right)^{p_{\pi\pi}} - \left(\frac{Q_t}{\bar{Q}}\right)^{p_{rerrer}} - \left(\frac{AIDt}{\overline{AID}}\right)^{p_{AID}}\right] \qquad (50)$$

where AID_t is the aggregate aid at time t and $\overline{AID}$ is the steady state level of aid.

3.2.6. Foreign sector

This good is assumed to be consumed by the foreign sector. To discuss the law of one price in the commodity sector (coffee sector), its demand is considered as completely elastic. Therefore, its domestic-currency price is given by,

$$P_{s,t} = \varepsilon_t P*_{s,t}. \qquad (51)$$

Where $P_{s,t}$ the domestic currency price of the commodity good and $P*_{s,t}$ its foreign currency price. The same can be done for the energy sector

$$P_{E,t} = \varepsilon_t P*_{E,t} \quad (52)$$

Where $P_{E,t}$ is the domestic currency price of the energy and P^*_{Et} is the international price of energy. The real exchange rate is defined as the relative price of a foreign price index, P^*_t, and the domestic price index in the economy:

$$RER_t = \frac{\varepsilon_t P^*_t}{P_t} \quad (53)$$

Where P^*_t is not necessarily equal to $P^*_{E,t}$. Rather it is given by the following relation:

$$P^*F, t = P^*_t \zeta^*_{F,t} \quad (54)$$

Such that the shock (transitory) $\zeta^*_{F,t}$ is a holds shocks like the relative price of imports abroad. Foreign demand for home goods depends on the relative price of this type of goods abroad and the total foreign aggregate demand,

$$Y^*_{Ht} = \zeta^* \left(\frac{P^*_{Ht}}{P^*_t}\right)^{-\eta_*} Y^*_t \quad (55)$$

Where Y^*_t the foreign output, ζ^* measures the share of domestic intermediate goods in the foreign consumption basket and $-\eta_*$ is the price elasticity of the demand.

3.2.7. Aggregate equilibrium

Different domestic goods supplied any quantity demanded at those given prices by which the firm set. Given $Y_{H,t} = C_{H,t} + I_{H,t} + G_t$ and Y^*_{Ht} which is defined in (55) , the market clearing condition for each variety implies that:

$$Y_{H,t(ZH)} = \left[\frac{P_{H,t(ZH)}}{P_{H,t}}\right]^{-\epsilon_H} Y_{H,t} + \left(\frac{P^*_{Ht(ZH)}}{P^*_{H,t}}\right)^{-\epsilon_H} Y^*_{H,t} \quad (56)$$

In addition, the equilibrium condition total labor is that labor demand by intermediate varieties producers must be equal to labor supply: $\int_0^1 L_{t(ZH)} dzH = L_t$ where L_t is defined above. The net foreign asset position is represented using the equilibrium conditions in the goods and labor markets, and the budget constraint of households and the government as:

$$\frac{\varepsilon_t B t^*/P_{Y,t}Y_t}{(1 + i^*_t)\Theta(\frac{\varepsilon_t B t^*}{P_{Y,t}Y_t})(\xi^*_t)} = \frac{\varepsilon_{t-1} B^*_{t-1}}{P_{Y,t}Y_t} - (1-\chi)\frac{P_{S,t}Y_{S,t}}{P_{Y,t}Y_t} + \frac{P_{Xt}X_t}{P_{Y,t}Y_t} - \frac{P_{M,t}M_t}{P_{Y,t}Y_t}$$

The parameter χ is the share of the government in the revenues from the commodity sector which means that $(1-\chi)$ is the share of foreigners. Moreover the nominal GDP of the open economy is given by :

$$P_{Y,t}Y_t = P_{C,t}C_t + P_{H,t}G_t + P_{I,t}I_t + P_{X,t}X_t - P_{M,t}M_t \qquad (57)$$

And

$P_{M,t}M_t = \varepsilon_t(P_{F,t}{}^{*}Y_{F,t} + P_{E,t}{}^{*}(C_{E,t} + E_{H,t}))$ And

$P_{X,t}X_t = \varepsilon_t(P_{H,t}{}^{*}Y_{H,t}{}^{*} + P_{S,t}{}^{*}Y_{S,t})$, respectively. (58)

Where $P_{Y,t}Y_t$ is the nominal value of GDP, $P_{M,t}M_t$ are nominal value of import and $P_{X,t}X_t$ is nominal value of export.

List of Total Equations and Variables for the Models

The full log-linearized model for the above model is presented below

Consumption of households

$$\hat{c}_t = (1-\lambda)\cdot\frac{1-h}{1+h}\mathrm{E}_t(\hat{\imath}_t + \hat{\pi}_{C,t+1}) + \frac{1}{1+h}\mathrm{E}_t(\hat{c}_{t+1}{}^{R}) + \frac{h}{1+h}(\hat{c}_{t-1}{}^{R}) + \frac{1-h}{1+h}(\widehat{\varsigma_{C_t}} - \mathrm{E}_t(\widehat{\varsigma_{C,t+1}})) - \frac{1}{1+h}(\widehat{h\varsigma_{T_t}} - \mathrm{E}_t(\widehat{\varsigma_{T,t+1}})) + \lambda\left[\frac{W}{P_C C}(\widehat{wr}_t + l_t) - \frac{T_p}{P_C C}\tau_{p,t}\right]$$

Consumption goods bundle

$\hat{c}_{F,t} = \hat{c}_{Z,t} - \eta_C\widehat{pr}_{F,t}$

$\hat{c}_{H,t} = \hat{c}_{Z,t} - \eta_C\widehat{pr}_{HD,t}$

$\hat{c}_{E,t} = \hat{c}_t - \omega_C\widehat{pr}_{E,t}$

$0 = \alpha_C\widehat{pr}_{z,t} + (1-\alpha_C)\widehat{pr}_{E,t}$

$\widehat{pr}_{z,t} = \gamma_C\widehat{pr}_{HD,t} + (1-\gamma)\widehat{pr}_{F,t}$

Uncovered interest parity condition

$\hat{\imath}_t = \hat{\imath}_t{}^{*} + \mathrm{E}_t\Delta\hat{e}_{t+1} + \varrho\hat{b}_t{}^{*}$

Labor supply

$$[\kappa_L + (1+\beta)]\,\widehat{wr}_t = \kappa_L\left(\sigma_L\hat{l}_t + \frac{1}{1-h}\hat{c}_t - \frac{h}{1-h}\hat{c}_{t-1} + \widehat{\varsigma_{L_t}}\right) + \widehat{wr}_{t-1} + \beta\mathrm{E}_t(\widehat{wr}_{t+1}) - (1+\beta\chi_L)\hat{\pi}_{C,t} + \chi_L\hat{\pi}_{C,t-1} + \beta\mathrm{E}_t(\widehat{\pi_{C,t+1}})$$

Capital accumulation

$$\hat{k}_{t+1} = \frac{1-\delta}{(1+n)(1+g_{y)}}\hat{k}_t + 1 - \frac{1-\delta}{(1+n)(1+g_{y)}}\left(\widehat{\imath nv}_t + \widehat{\zeta_{I}}_t\right)$$

Investment goods bundle

$$\widehat{\imath nv}_{H,t} = \widehat{\imath nv}_t - \theta_1(\widehat{pr}_{HD,t} - \widehat{pr}_{I,t})$$

$$\widehat{\imath nv}_{F,t} = \widehat{\imath nv}_t - \theta_1(\widehat{pr}_{F,t} - \widehat{pr}_{I,t})$$

$$\widehat{pr}_{I,} = \gamma_1\widehat{pr}_{HD,t} + (1-\gamma_1)\widehat{pr}_{F,t}$$

$$\widehat{pr}_{I,t} = \frac{Q_r}{P_{rI}}\left(\widehat{qr}_t + \varepsilon_{I,t}\right) - \frac{Q_r}{P_{rI}}\left(1+\frac{1}{1+r}\right)\mu_s(1+g_{y)}{}^2\widehat{\imath nv}_t + \frac{Q_r}{P_{rI}}\mu_s(1+g_{y)}{}^2\widehat{\imath nv}_{t-1} +$$

$$\frac{Q_r}{P_{rI}}\mu_s(1+g_{y)}{}^2\frac{1}{1+r}\widehat{\mathrm{E_t}(\imath nv}_{t+1})$$

$$\widehat{qr}_t = \mathrm{E_t}(\hat{\pi}_{C,t+1} - \hat{\imath}_t) + \frac{1}{1+r}\frac{Z_r}{Q_r}\mathrm{E_t}\,(\widehat{zr}_{t+1}) + \frac{1}{1+r}(1-\delta)\mathrm{E_t}\,(\widehat{qr}_{t+1})$$

Input prices and marginal cost

$$-1/\theta h(\hat{k}_t - \widehat{\zeta_{T}}_t + \hat{u}_t - \hat{l}_t) = \widehat{wr}_t - \widehat{zr}_t \qquad ;$$

$$\widehat{zr}_t = \widehat{qr}_t + \sigma_l\hat{u}_t$$

$$\widehat{mcr_{Ht}} = \frac{z_{rk}}{MC_{rH}Y_H}\left(\widehat{zr}_t + \hat{k}_t\right) + \frac{W_{rI}}{MC_{rH}Y_H}\left(\widehat{wr}_t + \hat{l}_t\right) + \frac{P_E E_H}{MC_{rH}Y_H}\left(\widehat{Pr}_{E,t} + \hat{E}_{H,t}\right) - \hat{y}_{H,t}$$

Phillip curves for goods

$$\hat{\pi}_{HD,t} = \frac{\beta}{1+\beta\chi_{HD}}\mathrm{E_t}\,(\hat{\pi}_{HD,t+1}) + \frac{\chi_{HD}}{1+\beta\chi_{HD}}(\hat{\pi}_{HD,t-1}) + \frac{\kappa_{HD}}{1+\beta\chi_{HD}}(\widehat{mcr_{Ht}} - \widehat{pr}_{HD,t})$$

$$\hat{\pi}_{HF,t} = \frac{\beta}{1+\beta\chi_{HD}}\mathrm{E_t}\,(\hat{\pi}_{HF,t+1}) + \frac{\chi_{HF}}{1+\beta\chi_{HF}}(\hat{\pi}_{HF,t-1}) + \frac{\kappa_{HF}}{1+\beta\chi_{HF}}(\widehat{mcr_{Ht}} - \widehat{rer}_t - \widehat{pr}_{HF,t})$$

$$\hat{\pi}_{F,t} = \frac{\beta}{1+\beta\chi_F}\mathrm{E_t}\,(\hat{\pi}_{F,t+1}) + \frac{\chi_F}{1+\beta\chi_F}(\hat{\pi}_{F,t-1}) + \frac{\kappa_F}{1+\beta\chi_F}(\widehat{rer}_t + \widehat{\zeta^*}_{F_t} - \widehat{pr}_{F,t})$$

Government fiscal balance and its consumption

$$\frac{P_G G}{P_Y Y}\hat{g}_t = \frac{T_P}{P_Y Y}\left(\hat{\tau}_{P,t} - \hat{y}_t\right) + \chi\frac{P_S Y_S}{P_Y Y}\left(\widehat{\widehat{pr}}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{y,t} - \hat{y}_t\right) + + \Big(1 - \frac{1}{(1+i^*{}_t)\Theta}\Big)\frac{B_G}{P_Y Y}\frac{1}{(1+\pi^*)_.(1+g_y)(1+n)}\left(\Delta\hat{e}_t - \hat{\pi}_{C,t} + \hat{b}_{Gt-1} - \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t - \hat{\zeta}_{T,t}\right) + \frac{1}{(1+i^*{}_t)\Theta}\frac{B_G}{P_Y Y}\quad\frac{1}{(1+n)_.(1+g_y)(1+n)}\widehat{\imath^*}_{d,t-1} + \frac{P_G G}{P_Y Y}\left(\hat{\zeta}_{G,t} + \widehat{pr}_{HD,t} - \widehat{pr}_{Y,t} - \hat{y}_t\right) + \rho d\left(\frac{Aid}{\mathrm{P_{Y,t}Y_t}}\right).$$

$$\frac{\varepsilon B^*{}_G}{P_Y Y}\frac{1}{(1+i^*{}_t)\Theta}\hat{b}_{G,t} = \frac{1}{(1+\pi^*)_.(1+g_y)(1+n)}\frac{\varepsilon B^*{}_G}{P_Y Y}\left(\Delta\hat{e}_t - \hat{\pi}_{C,t} + \hat{b}_{Gt-1} - \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t - \hat{\zeta}_{T,t}\right) + \frac{T_P}{P_Y Y}\left(\hat{\tau}_{P,t} - \hat{y}_t\right) + \chi\frac{P_S Y_S}{P_Y Y}\left(\widehat{\widehat{pr}}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{y,t} - \hat{y}_t\right) - \frac{P_G G}{P_Y Y}\hat{g}_t + \frac{B_G}{P_Y Y}\frac{1}{(1+i^*{}_t)\Theta}\widehat{\imath^*}_{d,t-1}$$

$$\widehat{geps}_t - \widehat{pr}_{HD,t} + \widehat{pr}_{Y,t} + \hat{y}_t = 0$$

Standard monetary policy rule

$\hat{r}_t = p_i \hat{r}_{t-1} + p_{pay}\hat{\pi}_{Z,t} + p_y \hat{y}_t$

Foreign demand for domestic goods.

$\hat{y}_{Ht}^* = \hat{y}_t^* - \eta^* \widehat{pr}_{H,Ft}$

Domestic price of energy and coffee

$\widehat{pr}_{S,t} = \widehat{rer}_t + \widehat{pr}_{St}^*$

$\widehat{pr}_{E,t} = \widehat{rer}_t + \widehat{pr}_{Et}^*$

Law of motion for relative prices.

$\hat{\pi}_{Z,t} = \widehat{pr}_{Z,t} - \widehat{pr}_{Z,t-1} + \hat{\pi}_{C,t}$

$\hat{\pi}_{HD,t} = \widehat{pr}_{HD,t} - \widehat{pr}_{HD,t-1} + \hat{\pi}_{C,t}$

$\hat{\pi}_{HF,t} = \widehat{pr}_{HF,t} - \widehat{pr}_{HF,t-1} + \hat{\pi}_t^*$

$\hat{\pi}_{F,t} = \widehat{pr}_{F,t} - \widehat{pr}_{F,t-1} + \hat{\pi}_{C,t}$

Exchange rate law of motion

$\Delta\hat{e}_t = \widehat{rer}_t - \widehat{rer}_{F,t-1} + \hat{\pi}_{C,t} - \hat{\pi}_t^*$

Domestic output supply and total output

$\hat{y}_t = \frac{P_C C}{P_Y Y}\hat{c}_t + \frac{P_G G}{P_Y Y}\left(\hat{g}_t - \widehat{pr}_{HD,t} + \widehat{pr}_{Y,t} + \hat{y}_t\right) + \frac{P_I I}{P_Y Y}\widehat{inv}_t + \frac{P_X X}{P_Y Y}\hat{x}_t - \frac{P_M M}{P_Y Y}\hat{m}_t$

$\hat{y}_{H,t} = \hat{a}_{H,t} + \gamma_H^{\frac{1}{\omega_H}}\left(A_H \frac{E_H}{Y_H}\right)^{\frac{\omega_H - 1}{\omega_H}}\hat{E}_{H,t} + (1-\gamma_H)^{\frac{1}{\omega_H}}\left(A_H \frac{V_H}{Y_H}\right)^{\frac{\omega_H - 1}{\omega_H}}\eta_H \hat{L}_t + (1 -$

$\gamma_H)^{\frac{1}{\omega_H}}\left(A_H \frac{V_H}{Y_H}\right)^{\frac{\omega_H - 1}{\omega_H}}(1-\eta_H)(\hat{K}_{t-1} - \hat{\varsigma}_{T,t}$

Energy law of motion

$\hat{E}_{E,t+1} = (1 - \delta_{ED} + \delta_{REG})\hat{e}_{E,t}$

Domestic energy supply and total aid

$\hat{E}_{H,t} = \rho_\xi \widehat{E_{Ht}} + \varepsilon_{\xi,t}$

$\widehat{aid}_t = \rho_\xi \widehat{\text{aid}}_t + \varepsilon_{\xi,t}$

Energy imports and terms of trade

$\hat{E}_{F,t} = \hat{e}_t - \hat{p}_{E,t}^* + \hat{p}_t^* + \hat{c}_{H,t}^* = \hat{h}_t + \hat{x}_t$

$\hat{h}_t = \hat{e}_t - \hat{p}_{E,t}^* + \hat{p}_t^*$

Government Foreign Bond Asset position

$$\frac{(1-\varrho)B^*}{(1\ +\ i^*_t)\Theta(B^*)}b^*_t$$
$$= \frac{B^*}{(1\ +\ i^*_t)\Theta(B^*)}ihat^*_t - (1-\chi)e_t\frac{Y_s P_s^*}{P_Y Y}(\widehat{pr}_{S,t} + \hat{y}_{S,t} - \widehat{pr}_{Y,t} - \hat{y}_t$$
$$+ \frac{B^*}{\left(1\ +\ \pi^*\right)_\cdot(1+g_y)(1+n)}(\Delta\hat{e}_t - \hat{\pi}_{C,t} + \hat{b}_{Gt-1} - \Delta\widehat{pr}_{Y,t} - \Delta\hat{y}_t$$
$$- \hat{b}_{t-1}^* - \hat{\zeta}_{T,t})\frac{P_X X}{P_Y Y}(\widehat{pr}_{X,t} + \hat{x}_t - \widehat{pr}_{Y,t} - \hat{y}_t)\frac{P_M M}{P_Y Y}\hat{m}_t(\widehat{pr}_{M,t} + \hat{m}_t - \widehat{pr}_{Y,t} - \hat{y}_t)$$

Auxiliary foreign interest rate equation

$$\hat{\imath}_{Fa} = \hat{\imath}_F - \rho_{ift}\widehat{bF} + \rho_{det}(\Delta\hat{e}_{t+1} + \Delta\hat{e}_t)$$

Domestic output demand

$$\frac{P_H Y_H}{P_Y Y}\hat{y}_{H,t} = \gamma_C\frac{P_C C}{P_Y Y}\hat{c}_{H,t} + \frac{P_G G}{P_Y Y}\left(\hat{g}_t - \widehat{pr}_{HD,t} + \widehat{pr}_{Y,t} + \hat{y}_t\right)\gamma_I\frac{P_I I}{P_Y Y}\widehat{inv}_{H,t} + \frac{P_H Y_H^*}{P_Y Y}\hat{y}_{H,t}^*$$

Current Account

$$\widehat{ca}_t = (1-\chi)\mathrm{Ys}_{\mathrm{Y}(\widehat{rer}_t + \widehat{pr}^*_{st} + \hat{y}_{st})} + \mathrm{X}_{\mathrm{Y}(\widehat{pr}_{xt} + \hat{x}_t - \widehat{pr}_{Yt} - \hat{y}_t)} - \mathrm{M}_{\mathrm{Y}(\widehat{pr}_{mt} + \hat{m}_t - \widehat{pr}_{Yt} - \hat{y}_t)} +$$
$$\frac{\mathrm{eBF_Y}}{(1+\hat{\pi}_t)(1+\mathrm{n})\left(1+\mathrm{g_y}\right)(1+\mathrm{iF})\vartheta\hat{\imath}_{fa,t-1}} + \frac{\mathrm{eBF_Y}}{(1+\hat{\pi}_t)(1+\mathrm{n})\left(1+\mathrm{g_y}\right)(1+\mathrm{iF})(\vartheta_{t-1})\hat{\imath}_{f,}}(\hat{b}_{Ft-1} - \widehat{\Delta e}_t - \hat{\pi}_{ct} + \widehat{pr}_{Yt-1} -$$
$$\hat{y}_{t-1} - \widehat{pr}_{Yt} - \hat{y}_t - \hat{\varsigma}c_t$$

Energy uses from total imported energy only
$$\widehat{mo}_t = \alpha_c\mathrm{C\_Y/M\_Y/Mo\_M}\,\widehat{ec}_t + (1-\ \alpha_c)\mathrm{C\_Y/M\_Y/Mo\_M}\,\hat{e}_{et}$$

Return on capital
$$\widehat{Rk}_t = \frac{\mathrm{Zr}}{(\mathrm{Pri}*(1+\mathrm{r})(1+\mathrm{pre\_s})}\ \widehat{zr}_t + \frac{(1-\delta_I)}{(1+\mathrm{r})(1+\mathrm{pre\_s})}\widehat{qr}_t - \widehat{qr}_{t-1}$$

Net foreign asset position
$$\hat{b}_{Ft}^* = \mathrm{Ns\_Y}(\widehat{rer}_t - \widehat{pr}_{Yt} - \hat{y}_t)$$

$$0 = (1-\rho\mathrm{s})(-\hat{r}_t + \hat{\imath}_t - \widehat{pr}_{ct}) + (\rho\mathrm{s})(-\hat{r}_t + \hat{\imath}_t - \widehat{pr}_{zt})$$

Import and export

$$\hat{x}_t = e_t\frac{P_s^* Y_s}{P_X X}\hat{y}_{S,t} + \left(1 - \frac{P_s^* Y_s}{P_X X}\hat{y}_{S,t}\right) + \hat{c}_{H,t}^*$$

$$\widehat{pr}_{X,t} = e_t\frac{P_s^* Y_s}{P_X X}\widehat{pr}_{S,t} + \left(1 - e_t\frac{P_s^* Y_s}{P_X X}\right)\left(\widehat{pr}_{HF,t} + \widehat{rer}_t\right)$$

$$\widehat{m}_t = (1-\gamma_C)\frac{P_C C}{P_M M}\hat{c}_{F,t} + (1-\gamma_I)\frac{P_I I}{P_M M}\widehat{inv}_{F,t} + \left[\frac{P_E(C_E+E_H)}{P_M M}\frac{C_E}{(C_E+E_H)}\widehat{c_E}_t + \frac{E_H}{(C_E+E_H)}\widehat{o_H}_t\right]$$

$$\widehat{pr}_{M,t} = \widehat{rer}_t + \left(1-\frac{P_E(C_E+E_H)}{P_M M}\right)\hat{\varsigma}_{F,t}^{\ *} + \frac{P_E(C_E+E_H)}{P_M M}\widehat{pr}_{E,t}^{\ *}$$

Foreign exchange constraint in energy sector and real exchange rate

$$\widehat{fox}_t = \widehat{pr}^*_{Et} + \hat{E}_{F,t} - \hat{e}_t$$

$$\widehat{rer}_t = \hat{e}_t + \hat{p}_{Ft} - \hat{p}_t$$

Exogenous process

$$\hat{e}_t = \rho_e \hat{e}_{t-1} + \varepsilon_{e,t}$$

$$\widehat{ah}_t = \rho_{ah}\widehat{ah}_{t-1} + \varepsilon_{ah,t}$$

$$\hat{y}_{St} = \rho_{YS}\hat{Y}_{st-1} + \varepsilon_{YS,t}$$

$$\hat{p}_{SFt} = \rho_{st}\hat{p}_{sFt-1} + \varepsilon_{sF,t}$$

$$\hat{y}_{Ft} = \rho_{YF}\hat{Y}_{YF-1} + \varepsilon_{YF,t}$$

$$\hat{\imath}_{Ft} = \rho_{iF}\hat{\imath}_{IF-1} + \varepsilon_{if,t}$$

$$\hat{\pi}_{Ft} = \rho_{\pi F}\hat{\pi}_{Ft-1} + \varepsilon_{\pi F,t}$$

$$\widehat{\varsigma_{m}}_t = \rho_{mt}\widehat{\varsigma_{m}}_{.t-1} + \varepsilon_{m,t}$$

$$\widehat{\varsigma_{w}}_t = \rho_{wt}\widehat{\varsigma_{w}}_{.t-1} + \varepsilon_{c,t}$$

$$\widehat{\varsigma_{c}}_t = \rho_{ct}\widehat{\varsigma_{c}}_{.t-1} + \varepsilon_{c,t}$$

$$\widehat{\varsigma_{I}}_t = \rho_{It}\widehat{\varsigma_{I}}_{.t-1} + \varepsilon_{I,t}$$

$$\hat{pm}_t = \rho_{im}\widehat{pm}_{t-1} + \varepsilon_{im,t}$$

$$\widehat{gex}_t = \rho_{gex}\widehat{gex}_{t-1} + \varepsilon_{gex,t}$$

$$\hat{p}_{EtF} = \rho_{im}\hat{p}_{EtF,t-1} + \varepsilon_{im,t}$$

$$\widehat{\widehat{\varsigma_{T}}}_{.t} = \rho_{st}\widehat{\widehat{\varsigma_{T}}}_{.t-1} + \varepsilon_{st,t}$$

$$\widehat{aeh}_t = \rho_{st}\widehat{aeh}_{t-1} + \varepsilon_{aeh,t}$$

Auxiliary Equations

$$\hat{E}_{lag} - \hat{E}_{t-1} = 0$$

$\widehat{ysa}_t - \widehat{ys}_t = 0$

$\widehat{yFa}_t - \widehat{yF}_t = 0$

$\hat{k}lag_t - \hat{k}_{t-1} = 0$

$p_{si\tau}\hat{\tau} - (1 - p_{si\tau}\hat{\tau}) * \hat{g} = 0$

$\widehat{dr}_t = \hat{r}_t - \hat{r}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{drer}_t = \widehat{rer}_t - \widehat{rer}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dl}_t = \hat{l}_t - \hat{l}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dm}_t = \widehat{m}_t - \widehat{m}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dx}_t = \hat{x}_t - \hat{x}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{de}_t = \hat{e}_t - e_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dy}_t = \hat{y}_t - \hat{y}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dmcrh}_t = \widehat{mcrh}_t - \widehat{mcrh}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dwr}_t = \widehat{wr}_t - \widehat{wr}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dınv}_t = \widehat{ınv}_t - \widehat{ınv}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{de}_t = \hat{e}_t - \hat{e}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dc}_t = \hat{c}_t - \hat{c}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dprsF}_t = \widehat{prsF}_t - \widehat{prsF}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dys}_t = \widehat{ys}_t - \widehat{ys}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dyF}_t = \widehat{yF}_t - \widehat{yF}_{t-1} + \widehat{\zeta_{T}}_t$

$\widehat{dpr}_{Et}^{\ *} = \widehat{pr}_{Et}^{\ *} - \widehat{dpr}_{Et-1}^{\ *} + \widehat{\zeta_{T}}_t$

Exogenous Variables

$\widehat{\xi_t} = \rho_\xi \widehat{\xi_t} + \varepsilon_{\xi,t}$ where $\varepsilon_{\xi,t} \sim N(0, \sigma^2{}_\xi)$

With $\boldsymbol{\xi}$=($\varepsilon_{e,t}$, $\varepsilon_{ah,t}$, $\varepsilon_{YS,t}$, $\varepsilon_{st,t}$, $\varepsilon_{YF,t}$, $\varepsilon_{if,t}$, $\varepsilon_{\pi F,t}$, $\varepsilon_{m,t}$, $\varepsilon_{prs,t}$, $\varepsilon_{c,t}$, $\varepsilon_{I,t}$, $\varepsilon_{im,t}$, $\varepsilon_{gex,t}$, $\varepsilon_{im,t}$, $\varepsilon_{st,t}$, $\varepsilon_{aeh,t}$, $\varepsilon_{aid,t}$, $\varepsilon_{ehth,t}$.)

Additional Log linearized Equations for the modified model which makes the study's standard model different with the study's modified model.

$$\hat{r}_t = (\mu - 1)\hat{m}_t + \rho_{pf}\hat{p}_{F,t} - \rho_{rer}\widehat{rer}_t + \rho_{nx}\widehat{nx}_t - \rho_{yf}\hat{y}_{Ft} + \rho_y\hat{y}_t + \rho_{re\pi}\left(\hat{e}_{t-1} - \widehat{rer}_{t-1} + \hat{\pi}_{F,t} - \hat{\pi}_t\right) \quad \text{Where}$$

$$\hat{m}_t = p_{mm}\hat{m}_{t-1} - (1 - p_{mm})\left[p_{paypay}\hat{\pi}_{Z,t} - p_{yy}\hat{y}_t + p_{rerrer}\widehat{rert} - p_{Aid}\widehat{aid}_t\right]$$

To summarize, the study has a total of 88 main and supporting log linearized equations and 88 unknowns which can be solved together.. The endogenous variables of the model used by this study are $\hat{e}_t$, $\widehat{ah}_t$, $\hat{y}_{St}$, $\widehat{ps}_t$, $\hat{y}_{Ft}$, $\hat{\imath}_{Ft}$, $\hat{\pi}_{Ft}$, $\widehat{\varsigma_{m_t}}$, $\widehat{\varsigma_{w_t}}$, $\widehat{\varsigma_{c_t}}$, $\widehat{\varsigma_{I_t}}$, $\hat{p}m_t$, $\widehat{gex}_t$, $\hat{p}_{EtF}$, $\widehat{\varsigma_{T_t}}$, $\widehat{aeh}_t$, $\hat{E}_{lag}$, $\widehat{ysa}_t$, $\widehat{yFa}_t$, $\hat{k}lag_t$, $\hat{\tau}$, $\widehat{rer}_t$, $\widehat{fox}_t$, $\widehat{pr}_{M,t}$, $\hat{m}_t$, $\widehat{pr}_{X,t}$, $\hat{x}_t$, $\widehat{ca}_t$, $\widehat{mo}_t$, $\widehat{Rk}_t$, $\hat{b}_{Ft}{}^*$, $\hat{u}_t$, $\hat{\imath}_{Fa}$, $\hat{y}_{H,t}$, $b^*{}_t$, $\hat{h}_t$, $\hat{E}_{F,t}$, $\widehat{aid}_t$, $\hat{E}_{H,t}$, $\hat{E}_t$, $\hat{y}_t$, $\Delta\hat{e}_t$, $\hat{\pi}_{F,t}$, $\hat{\pi}_{HF,t}$, $\hat{\pi}_{HD,t}$, $\hat{\pi}_{Z,t}$, $\widehat{geps}_t$, $\hat{r}_t$, $\hat{y}_{Ht}{}^*$, $\widehat{pr}_{S,t}$, $\widehat{pr}_{E,t}$, $\hat{b}_{G,t}$, $\hat{g}_t$, $\widehat{dc}_t$, $\widehat{dprsF}_t$, $\widehat{dys}_t$, $\widehat{dyF}_t$, $\widehat{dpr}_{Et}{}^*$, $\widehat{dinv}_t$, $\widehat{dr}_t$, $\widehat{drer}_t$, $\widehat{dl}_t$, $\widehat{dm}_t$, $\widehat{dx}_t$, $\widehat{d\pi}_{zt}$, , $\widehat{dy}_t$, $\widehat{dmcrh}_t$, $\widehat{dwr}_t$, $\widehat{pr}_{HD,t}$, $\widehat{pr}_{HF,t}$, $\hat{\pi}_t$, $\widehat{mcr}_{Ht}$, $\widehat{wr}_t$, $\widehat{zr}_t$, $\widehat{qr}$, $\widehat{inv}_{H,t}$, $\widehat{inv}_t$, $\widehat{inv}_{F,t}$, $\widehat{pr}_{I,}$, $\hat{k}_t$, $\hat{l}_t$, $\hat{\imath}_t$, $\widehat{pr}_{z,t}$, $\hat{p}_{c,t}$, $\hat{c}_{E,t}$, $\hat{c}_{H,t}$, $\hat{c}_{F,t}$, $\hat{c}_t$. Whereas the exogenous variables are $\varepsilon_{e,t}$, $\varepsilon_{ah,t}$, $\varepsilon_{YS,t}$, $\varepsilon_{st,t}$, $\varepsilon_{YF,t}$, $\varepsilon_{if,t}$, $\varepsilon_{\pi F,t}$, $\varepsilon_{m,t}$, $\varepsilon_{prs,t}$, $\varepsilon_{c,t}$, $\varepsilon_{I,t}$, $\varepsilon_{im,t}$, $\varepsilon_{gex,t}$, $\varepsilon_{im,t}$, $\varepsilon_{st,t}$, $\varepsilon_{aeh,t}$, $\varepsilon_{aid,t}$, $\varepsilon_{ehth,t}$. The modified model is different with the standard by encompassing monetary aggregate equation ($\hat{m}_t$) after modifying the monetary policy rule equation.

3.4. Selection of the Study Area

Low income countries, specifically the SSA, was chosen as an area of study because for these economies the choice of a monetary policy strategy is more complex. On the one hand, their economies are influenced by domestic economy transmission processes; on the other hand, the effects of external shocks are too strong to be neglected in the formulation of a monetary policy strategy. In addition these economies have their own characteristics which make them differ from the advanced nations (see Adam et al., 2008). Some macroeconomists argued that modeling and capturing the dynamics of such economies is not easy; and the standard models used by advanced economies cannot be used unless some modification are made on the standard macroeconomic models. This is partly related to idiosyncratic structural features exhibited by these economies, as well as due to the historical vulnerabilities to external factors and resulting periods of high macroeconomic instability (see for example Adam et al(2009) and Agenor and Montiel (2008)).

3.5. Method of Calibration and Data Sources

Structural parameters calibration can be made through values used in applied studies or by match long-run average values described (Diridi et al., 2006). The first step corresponding to calibration is the most controversial one. Indeed, several authors have shown that parameters obtained from micro-applied studies can be plugged to a representative agent model to produce empirically concordant aggregate model only under very special circumstances (see Hansen and Heckman (1996) for a discussion on this point). However, matching long-run properties is more conformable to the estimation step in classical econometrics. In fact, this practice consists in matching a just-identified set of moments where the corresponding instrumental parameters are the long-run averages. For instance, Kydland and Prescott (1982) calibrate the deterministic version of their model so that consumption/investment shares, factor/income shares, capital/output ratio, leisure/ market-time shares, and depreciation shares match the average values of US economy. Accordingly, to simulate the model and then to know the dynamics of some fundamental macroeconomic variables in response to various internal and external shocks, the parameters of the model are calibrated. In this paper, the study employed both techniques: borrowing from other studies and obtain some of the parameters from the long run averages using SSA data from WDI database from the year 1980-2017.

Actually, the core principle of the calibration approach as illustrated in Mehra and Prescott(1985) consists in concluding that the structural model is rejected on grounds of ‘‘computational experiments" leading to unlikely values of the parameters of interest. Namely, in Mehra and Prescott (1985), it is argued that computed values of the discount factor and the relative risk aversion parameter outside their commonly acknowledged range ($0<B<1,0<r<10$) proves the misspecification of the structural model.

3.6. Method of Analysis

In order to gain some insights in to the transmission mechanisms implied by the model, the study discussed the impulse-response functions. Firstly, to address the issue of modification of monetary policy rule in DSGE models of sub-Sharan economies, the impulse responses of the simple Taylor rule and the modified rule is compared. Hence, our analysis basis on the difference between these impulse responses of the former and the latter rule. Second, the study used impulse response of its

identified domestic and external shocks to analyze their effect on the economy. Third, the forecast error variance decomposition is used to discuss the relative contribution of domestic and external shocks to output dynamics of sub-Sharan economies at different time horizon. Money supply shock as a domestic shock has been added for further understanding of shocks in output dynamics. For the purpose of analysis, the contribution of each shock on output dynamics is summed up under the domestic or external shock block. Moreover, time horizons of 1,4,8,12,16 and 20 years are selected (as variance decomposition the time horizon selection is left for the researcher). The analysis was done using MATLAB version R2015 combined with dynare 4.5.4 which fits with the mentioned MATLAB version.

CHAPTER FOUR

4. RESULTS AND DISCUSSION

This chapter addressed the following issues. First, it analyses how model parameters are calibrated to simulate the model. Second, it discusses the dynamics of key macroeconomic variables using the impulse response function. Third, it examines the monetary policy rules in DSGE models of sub-Saharan economy. Fourth, it analyses the sources of economic fluctuations: domestic and external shocks. Finally, it explains the sensitivity of the model through varying parameter values.

4.1. Calibration of parameters

Selection of calibration parameters for DSGE models is a challenging task (Clarida. et al., 1998) as there appears to be no clear consensus on the values of some parameters and those used in the literature are mostly based on microdata from advanced countries. As discussed in the previous section, structural parameters calibration can be made through values used in applied studies or by match long-run average values. One of the problems of macroeconomic calibration in low-income countries is lack of appropriate data and limited microeconomic study. Predominantly, the availability of economic and energy sector data as well as microeconomic studies in the energy sector is very limited in the country. These make the calibration process somewhat difficult. In spite of that, parameters were chosen so as to match the steady-state of the model from some microeconomic studies of SSA, East Africa, and developing countries; and long-run trend data in the SSA economy from WDI from the period 1980-2017. These data are used to tie down the steady-state ratios as long-run averages.

This part discussed first the calibration process for consumption and investment, production side and monetary and the rest of the world part in line with the order of our presentation of the model in the model section. The share of energy in total consumption (α_C) is assumed to be 12.5%. This is value comes from Faye (n.d) who calculate the share of monthly energy goods expenditure from monthly households total expenditure on goods and services using a panel data. The share of home goods in core consumption (γ_C) calibrated based on own calculation. This is done by first calculating the total share of core consumption from the total as (100%-12.5%=87.5%). Then deduct the share of import goods from the total share (30%) to obtain 57.5%. The study have

assumed that home goods contribute 50% in total investment (γ_1=0.5)). The subjective discount factor (β), habit formation (h), inverse elasticity of labor supply (σ_L) and intertemporal elasticity of consumption (η_C) is set based on (Senbeta, 2013) as 0.999 (annual basis), 0.25 and 3 respectively. Intertemporal elasticity of substitution (σ_C), Calvo probability in nominal wages (phi_ L), indexation of nominal wages (xi_ L) intertemporal elasticity of investment (θ_1) and investment inertia (S_I) has been taken from Medina and Soto (2007). The parameters calibrated in consumption and investment part are given in table 1.

Table 1: Parameter Calibration (Consumption and Investment)

Parameter	value	Parameter Definition	Source
beta	0.999	discount factor	(Anand et al.(2015)
alpha_C	0.125	share of energy in consumption	(Faye(n.d))
sigma_C	1	intertemporal elasticity of substitution	(Medina and Soto, 2007)
gamma_C	0.575	share of home goods in core consumption	(Faye(n.d))
gamma_I	0.5	share of home goods in investment	(Anand et al.(2015)
Lambda	0.5	share of non-Ricardian households	(Prasad and Zhang-2015)
h	0.25	habit formation	(Senbeta 2013)
sigma_L	3	inverse elasticity of labor supply	(Senbeta 2013)
phi_L	0.82	Calvo probability in nominal wages	(MS-2007)
xi_L	0.44	indexation of nominal wages	(MS-2007)
eta_C	2.96	intratemporal elasticity of consumption	(Senbeta2013)
theta_I	1.04	intratemporal elasticity of investment	(MS 2007)
S_I	1.48	investment inertia	(MS 2007)

In the calibration of parameters in the production side, the shared parameter of labor in the production of domestic goods (η_H) is set to 0.62. The share of coffee production for GDP (Ys_Y=0.04) is derived from the microeconomic study conducted by Boansi et al, (2013). The study also calculated government share in coffee production (chi) by taking data from FAO which states that the government owns 22,000 hectares covered by the coffee plant from the total 320,000 hectares. Working out this statistics gives 0.068. In addition, a share of domestic energy from the total supply (t_t=0.9) is calibrated based on the study conducted by Guta (2015). Moreover, the value of the share of energy in the production of home goods calibrated through own calculation. The literature in low-income countries has assigned a value of 0.01 for electricity. According to (EDRI, 2005, Page 22),) petroleum products took a share 0.038. By adding these two values, the study calibrated γ_H=0.048. According to Senbeta (2013), the problem in calibrating the model comes from the parameters of price stickiness. Another problem challenge this study is parameters related to investment. There is no study on price stickiness on Ethiopia and there are few studies that calibrated or estimated parameters of the price- setting behavior of firms for the countries. As a result, the study borrows the value of elasticity of substitution and price sickness parameters as well as investment parameters from Medina and Soto, (2007) for our calibration. Table 2 below in the appendix presented the parameters discussed above.

Table 2:Parameter Calibration (Production side)

Parameter	value	Definition	Source
Ys_Y	0.04	share of coffee production in GDP	(Boansi et al, 2013)
chi	0.068	government share in coffee production	(Getachew,2015)
t_t	0.90	share of domestic energy from the total supply	(Guta,2015)
delta_I	0.058	depreciation rate	(MS-2007)
theta_H	1	elasticity of substitution (labor-capital)	(MS-2007)
gamma_H	0.048	share of energy in production of home goods (Oil equivalence)	
eta_H	0.62	labor share in value added production	(Senbeta,2013)
omega_H	0.3	elast. of substitution of energy (production)	(MS-2007)

eps_L	11	elasticity of substitution (labor)	(MS-2007)
eps_H	11	elasticity of substitution (home goods)	(MS-2007)
eps_F	11	elasticity of substitution (foreign goods)	(MS-2007)
phi_Hd	0.74	Calvo prob. in domestic price (home goods)	(MS 2007)
xi_Hd	0.34	indexation of domestic price (home goods)	(MS 2007)
phi_Hf	0.59	Calvo prob. in foreign price (home goods)	(MS 2007)
xi_Hf	0.31	indexation of foreign price (home goods)	(MS 2007)
phi_F	0.66	Calvo prob. in price of imported goods	(MS 2007)
xi_F	0.28	indexation of price of imported goods	(MS 2007)
n_prsF	40	periods for reference price calculation	(MS-2007)

The parameters of the standard monetary policy rule are determined using the estimated values in Anand et al., (2015) and Rasaki (2015), which are studies in SSA. The parameter values in alternative monetary policy rule is determined from the steady state long run averages . The entire parameters used in the monetary policy is presented in the appendix below. Intertemporal elasticity in foreign demand (η_F) and the elasticity of the external premium were also taken from Medina and Soto (2007). Foreign steady state GDP growth (g_yF), foreign labor force growth (nF), foreign steady-state inflation, and foreign steady state nominal interest rate were calculated by using SSA and world data from WDI. First, the data file constructed by deducting SSA data from the world data. Then steady-state ratios were calculated based on taking the average growth rate in the sample period of the data (See table 3)

Table 3: Parameter Calibration (Monetary Policy Rule and Rest of the world)

Parameter	value	Definition	Source
Mi_u	1.25	Elasticity of money holding	(Rasaki, 2015)
ρi	0.74	Policy response to interest rate	(Anand, 2015)
ρpaypay	2	Policy response to inflation	(Anand, 2015)
ρyy	0.5	Policy response to output	(Anand, 2015)
ρAid	0.5	Policy response to aid	(Rasaki, 2015)
ρmm	0.75	Policy rate smoothing	(Rasaki, 2015)
$\rho rerrer$	0.5	Policy response to real exchange rate	(Rasaki, 2015)
ρe	0.5	Policy response to nominal exchange rate	(Rasaki, 2015)
ρf	0.25	Policy response to foreign output	(Rasaki, 2015)
eta_F	0.79	intertemporal elasticity in foreign demand	(MS 2007)
mvarrho	0.01	elasticity of the external premium	(MS 2007)
ρrer	0.51	RER steady sate ratio to interest rate	(steady calculation)
ρnx	0	NX ratio to interest rate	(>>)
ρYf	0.21	Foreign output SS ratio to interest rate	(>>)
ρyt	0.52	Domestic output SS ratio to interest rate	(>>)
$\rho re\Pi$	0.11	NER steady sate ratio of steady state to price	(>>)
ρrer	0.51	RER steady sate ratio to interest rate	(>>)
g_yF	0.02	foreign steady state GDP growth	(World-SSA data)
nF	0.01	foreign labor force growth	(World-SSA Data)
piF	0.02	foreign ss inflation	(world -SSA data)
iF	0.05	foreign nominal interest rate ss	(world -SSA data)

The shocks persistence parameters of the domestic and external sector are estimated from data and application of the Autoregressive process. Exchange rate shock persistent (o_o) is set to 0.9 which indicates that the current exchange rate set by monetary authority heavily rely on the exchange rate of the previous year. The shock persistent value for world oil price (ρ_proF)/proxy for world energy price/ has also the same feature. In contrast, world coffee price shock persistent slightly depend on its previous value which is set to be (ρ _ prsF) =0.578, like that of domestic energy supply shock persistent (a_a=0.5). World interest rate shock persistence (ρ _iF), world inflation shock persistence (ρ _piF), permanent productivity shock persistence (ρ _T) were calibrated based

on Senbeta (2013) who using the annual data of OECD member countries of the WDI-GDF for the period 1961-2011(see table 4).

Table 4:Parameter Calibration (Shock Persistent parameters)

Parameter	value	Definition	Source
O_O	0.99	Exchange rate shock persistent	(AR)
rho_prsF	0.578	world coffee price shock persistent	(AR)
a_a	0.50	domestic energy supply shock persistent	(AR)
rho_proF	0.97	world oil price AR coefficient/proxy for energy	(AR)
rho_ah	0.89	transitory productivity shock persistence	(MS 2007)
rho_iF	0.51	world interest rate shock persistence	(Senbeta, 2013)
rho_piF	0.49	world inflation shock persistence	(Senbeta, 2013)
rho_sh_w	0.89	labor supply shock persistence	(MS-2007)
rho_sh_c	0.87	preference shock persistence	(MS-2007)
rho_sm	0.5	monetary policy shock persistent	(MS-2007)

So as to match the steady state of the model, parameter values for domestic labor force growth , domestic labor productivity growth, domestic steady-state inflation target, steady-state net export over GDP ratio, government expenditure over GDP ratio, and steady-state real interest rate for the domestic economy were calculated based on the data from WDI in the sample period. The steady state ratio was obtained by calculating the average of the data in the sample period. After tough discussion of the experience in low-income countries and detail examination of the economic theory, we have attached the inflation target value of 3% per year. Finally, some calibration practice were undertaken based on the theoretical and mathematical relationship of variables in the model equation. Most of the parameters are the value of the endogenous variable in the form of non-deviation from the steady state. As a result, to calibrate their value, it is easy to look on the mathematical relationship of our model at the steady state. The other method used in this paper is to look at the theoretical relationship of variables out of the model. The value of parameters and its meaning as well as the values of some parameters from the theoretical relationship is given in table 5.

Table 5: Parameter Calibration (Steady state Ratios) and other parameters

Parameter	value	Definition	Source
n	0.015	domestic labor force growth	(Steady State Ratio)
g_y	0.035	domestic labor productivity growth	(Steady State Ratio)
pi_C	0.03	domestic steady state inflation target	(Subjective)
NX_Y	-0.1144	steady state net export / GDP ratio	(Steady State Ratio)
CCq_Y	-2.968	steady state current account / GDP ratio	(Steady State Ratio)
Gh_Y	0.11	government expenditure / GDP ratio	(Steady State Ratio)
r	0.042	ss real interest rate	(Steady State Ratio)
BalG_Y	= 0.01;		
Tau_Y	= 0.092;		
prsF_ref	= 1;		
psi_mon	= 1;		
psi_tau	= 1;		
rhoaoh	= 0;		
che	=-0.01;		
Tau_Y	= 0.092		
d_d	= 0.42;		

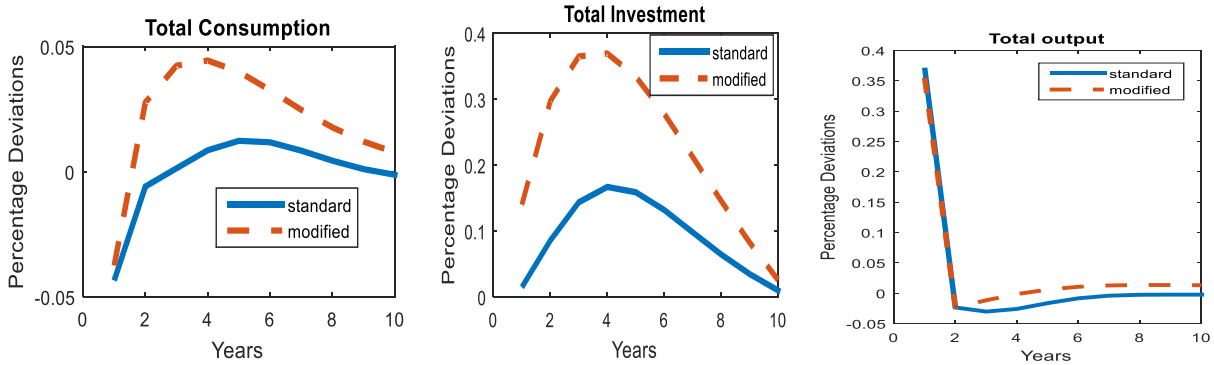
premio_s	= 0;
Prh	= 1;
Prf	= 1;
Wr	= 1;
RER	= Prf*(eps_F-1)/eps_F;
PrFo	= 1/RER;
PrFs	= 1/RER;
Pro	= RER*PrFo;
Prs	= RER*PrFs;
Pri	= 1;
RenNs_Y	= Ren_Y+Prs*Ys_Y*(1-chi);
C_Y	= 1-NX_Y-Gh_Y-I_Y;
M_Y	= RER*Mf_Y+Pro*(Oh_Lh/Y_Lh+alpha_C*C_Y);
X_Y	= NX_Y+M_Y;
Ys_X	= Ys_Y/X_Y;

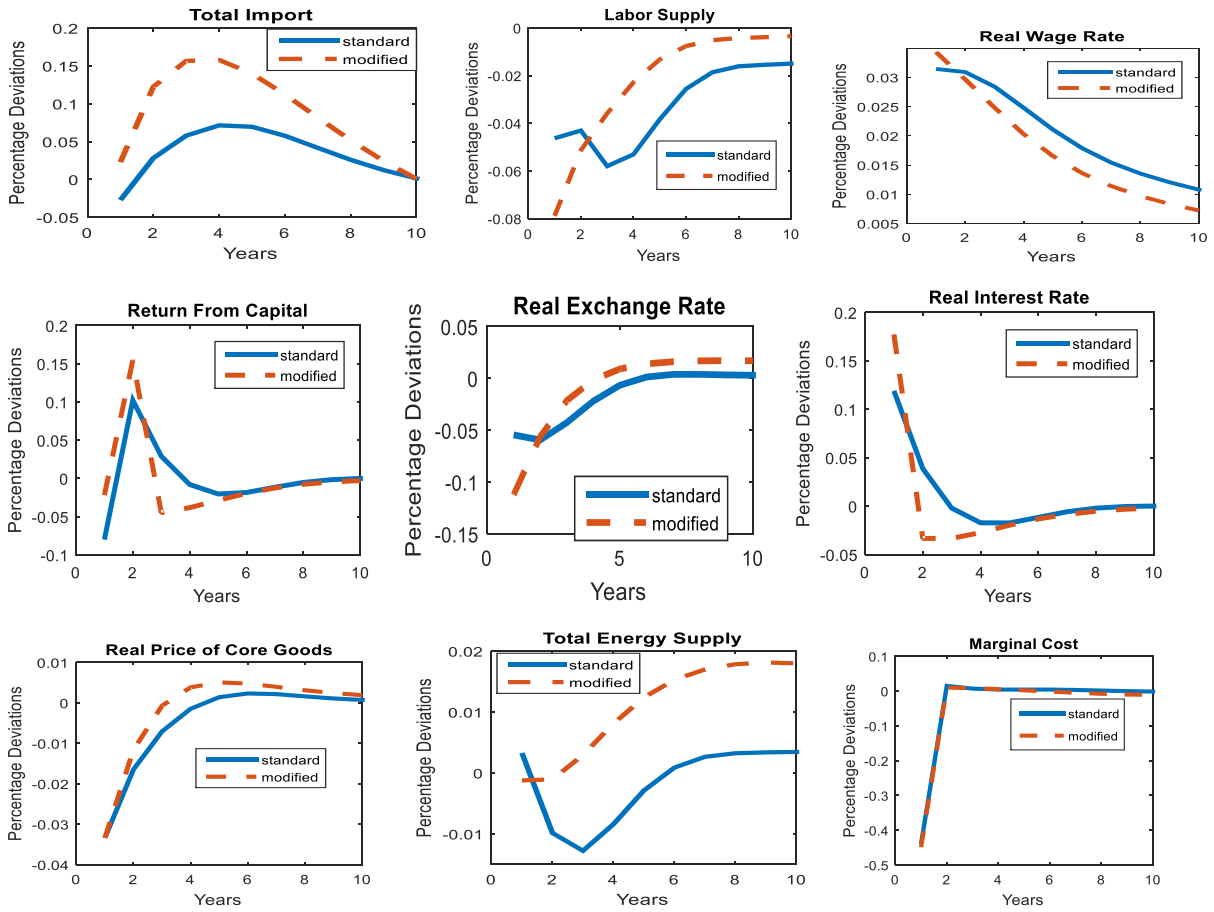
4.2.Testing the simple Taylor rule

In this part of the study, the study discussed how the monetary aggregate rule result has worked vis-à-vis to the standard Taylor rule. As explained in the model part of this paper, the monetary aggregate rule is organized by incorporating real exchange rate and aid to consider external influences and letting interest rate to determine implicitly in the model. The endogeneity of interest rate in the model shows that the instrument which used by monetary authority is monetary base targeting (not simple interest rate rule). The examination is made by comparing the magnitude and the direction of the impulse response of the first model (Taylor type interest rate rule) and the benchmark model (monetary aggregate rule) using the same baseline parameters, shocks and key economic variables specified in the model. To capture the real similarity and difference between the two models, the impulse response of 10 years is generated. The figures which are presented below are given in percentage deviations of variables from the steady state.

As shown in figure 4, in response to productivity shocks, the monetary base rule model generates more volatility vis-à-vis the first model. In other words, key variables are sensitive to money base targeting than interest rate targeting in response to productivity shocks. Total consumption, total investment, total import, labor supply, and total energy supplied in the economy are major macroeconomic variables which showed more volatility in the alternative (modified) model than the standard model. However, in response to the shock to productivity, all key variables used in the analysis showed the same direction in the first and alternative model. With the shock to productivity, money balance equilibrium of the monetary policy better explains the volatility of key variables than the Taylor type interest rate rule.

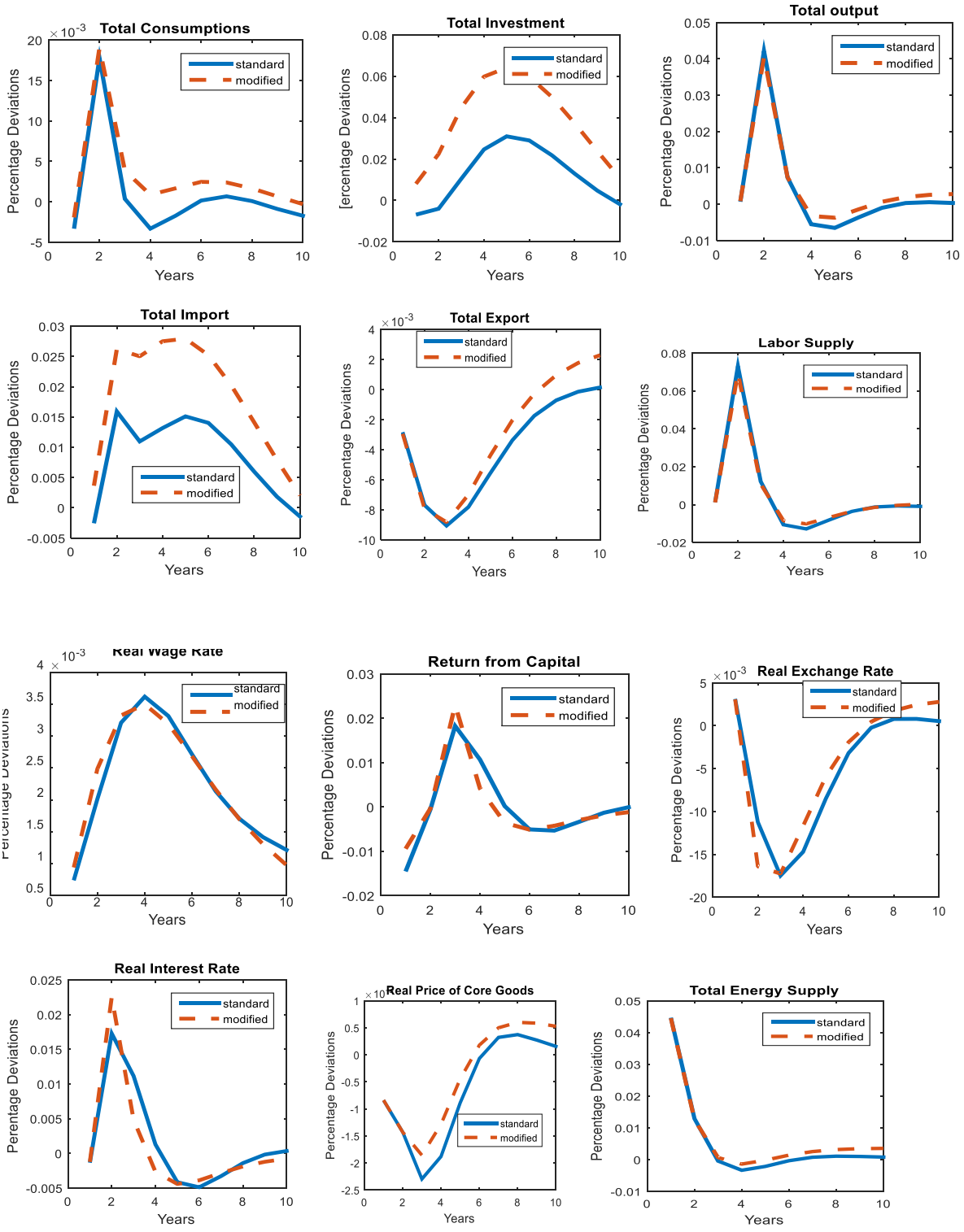
Figure 4: Impulse Response of Key Variables to productivity shock





After the domestic energy supply shock hits the economy, most of the key macroeconomic variables behave the same direction in both models but the magnitude is more prominent for the benchmark model. In response to the shock to domestic energy supply, all key variables used in the analysis showed the same direction and magnitude (with a slight difference) in the first and the alternative model. As it can be seen in figure 5, these variables are the total investment, import, real exchange rate, and real interest rate. With the shock to the domestic supply of energy, money balance equilibrium of the monetary policy better explains the volatility of some of the key variables than the Taylor type interest rate rule. It can be concluded that, under such shocks, monetary policy rule based on the monetary equilibrium (money aggregate) in macro models is better than the Taylor type interest rate rule to explain the real effect of economic shocks.

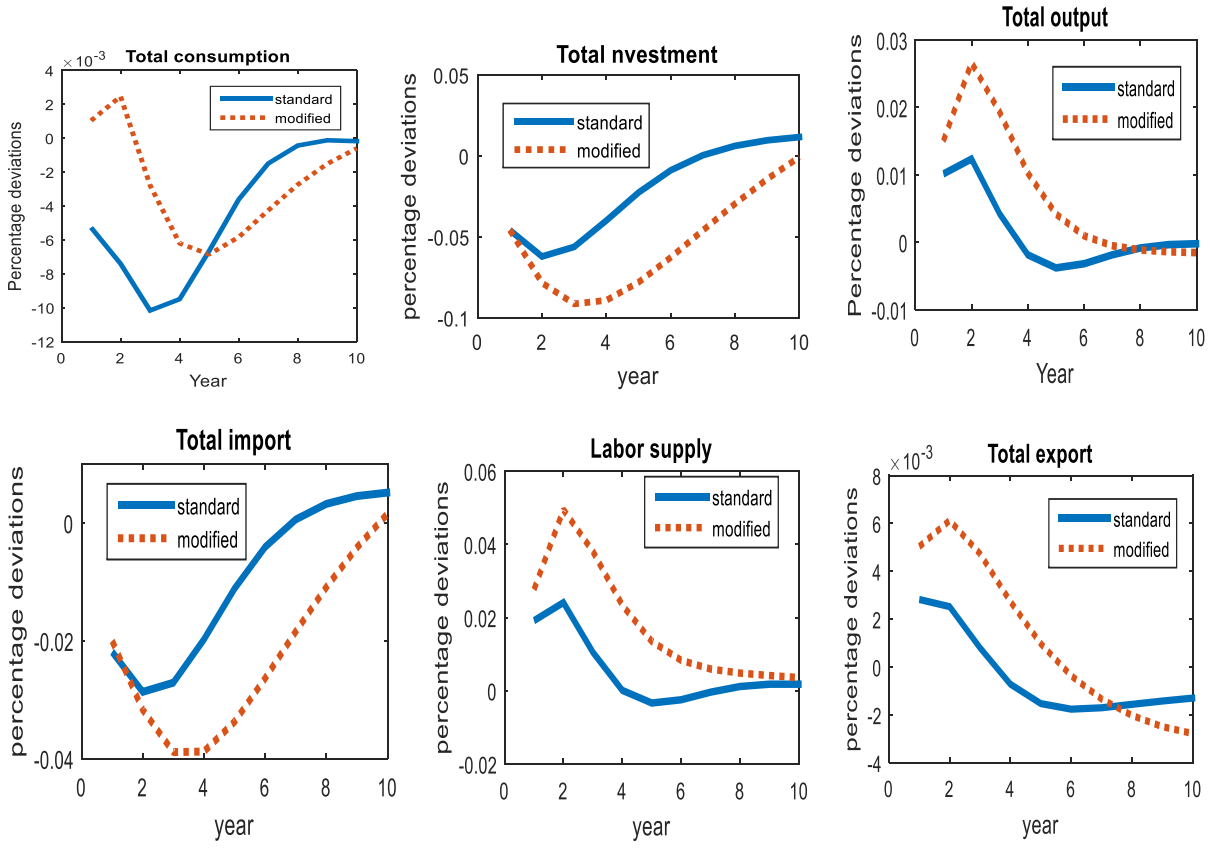
Figure 5: Impulse response of key variables to domestic energy supply shocks



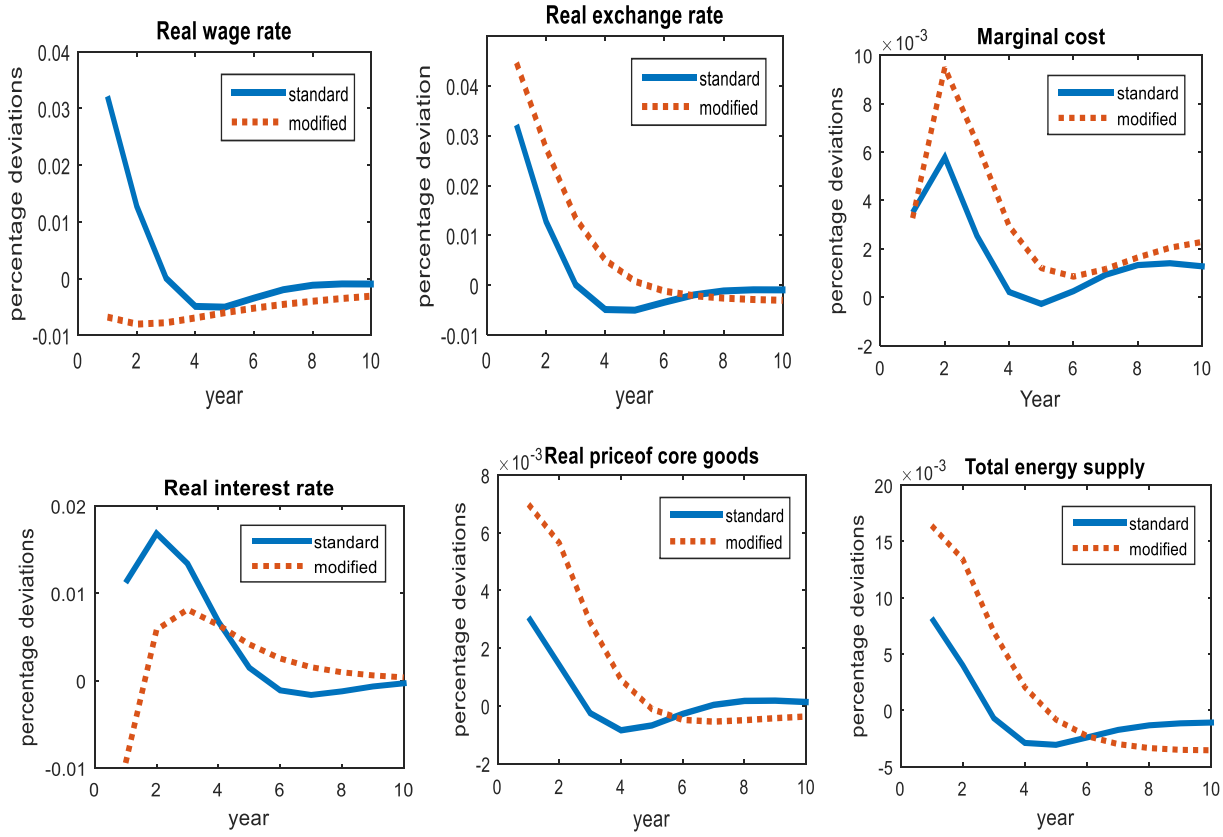
As can be seen in figure 6, in response to the shock to foreign interest rate, most key macroeconomic variables generate the same direction in both models but with the different magnitude as discussed above. Mainly the benchmark model generates a higher volatile total

consumption, total output, total import and export, labor supply, total investment, real exchange rate, the real price of core goods, total energy supply and marginal cost than the first model. Directional differences in the real wage rate and real interest rate is observed in this shock. In the standard model, a rise in the foreign interest rate leads to a rise in the domestic real wage rate; and the opposite result occurs as a result of foreign interest rate socks in the benchmark model. The difference in magnitude, as discussed before, can be the result of external influence on the monetary policy of low-income countries. An increase in the foreign interest rate leads to the debt burden of sub-Saharan economies to grow and this burden may have an inflationary pressure through debt management policies like domestic borrowing or seignorage. Compared to the domestic shocks observed above, the foreign interest rate shock generates highly volatile key macroeconomic variables. This is another evidence to show that external influence has a paramount effect on the monetary management of low-income countries including the sub-Saharan economy. This result is consistent with the explanation made by O'Connell (2009).

Figure 6: Impulse Response of key variables to foreign interest rate shocks



v

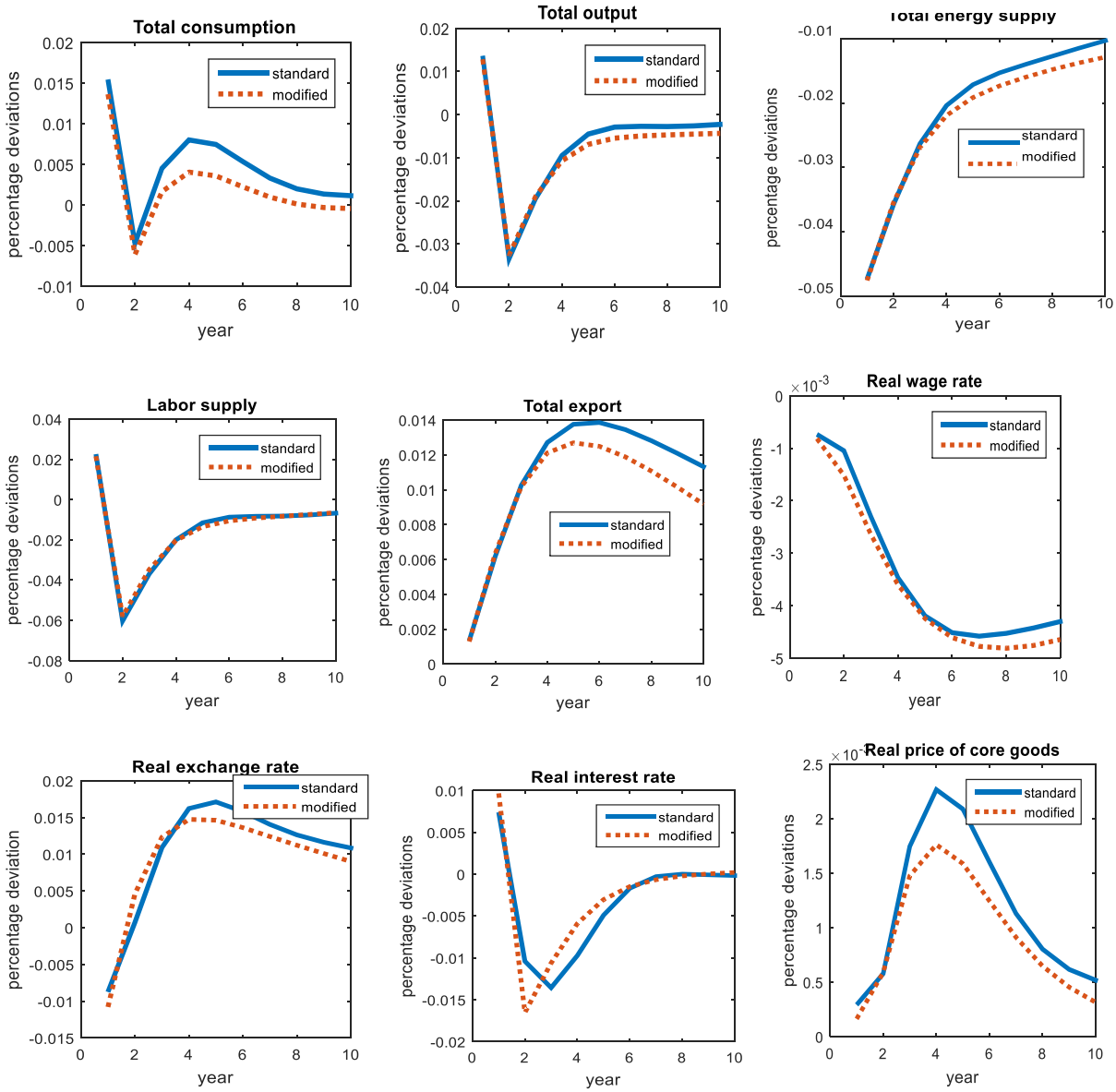


For instance, the increase in US interest rates will lead to an appreciation of the US currency making debt burdens more expensive for low-income countries, if the domestic interest rate remains unchanged. To reduce their debt burden, these countries may look on domestic or external borrowing or seignorage as a solution. All options available to these nations fraises the base money via the direct channel or through domestic credit creation. Evidently, the domestic interest rate is less sensitive to change in the sub-Saharan economy. As most of these countries have the bulk of their debt denominated in US dollars, they are more sensitive to this issue than they were in the case of the EU shock. However, fixed exchange rate economies are less affected by US monetary policy shocks which may lead to experiencing GDP expansions.

Figure 7 shows the effect of the world price of energy by comparing the two models. After the shock hits the economy, all of the key macroeconomic variables behave the same direction and magnitude in both models. This can occur as a result that the world price of energy has little influence on the money balance and overall monetary policy of sub-Saharan economies. Since the nominal money balance equilibrium explains the volatility of key variables that are influenced by

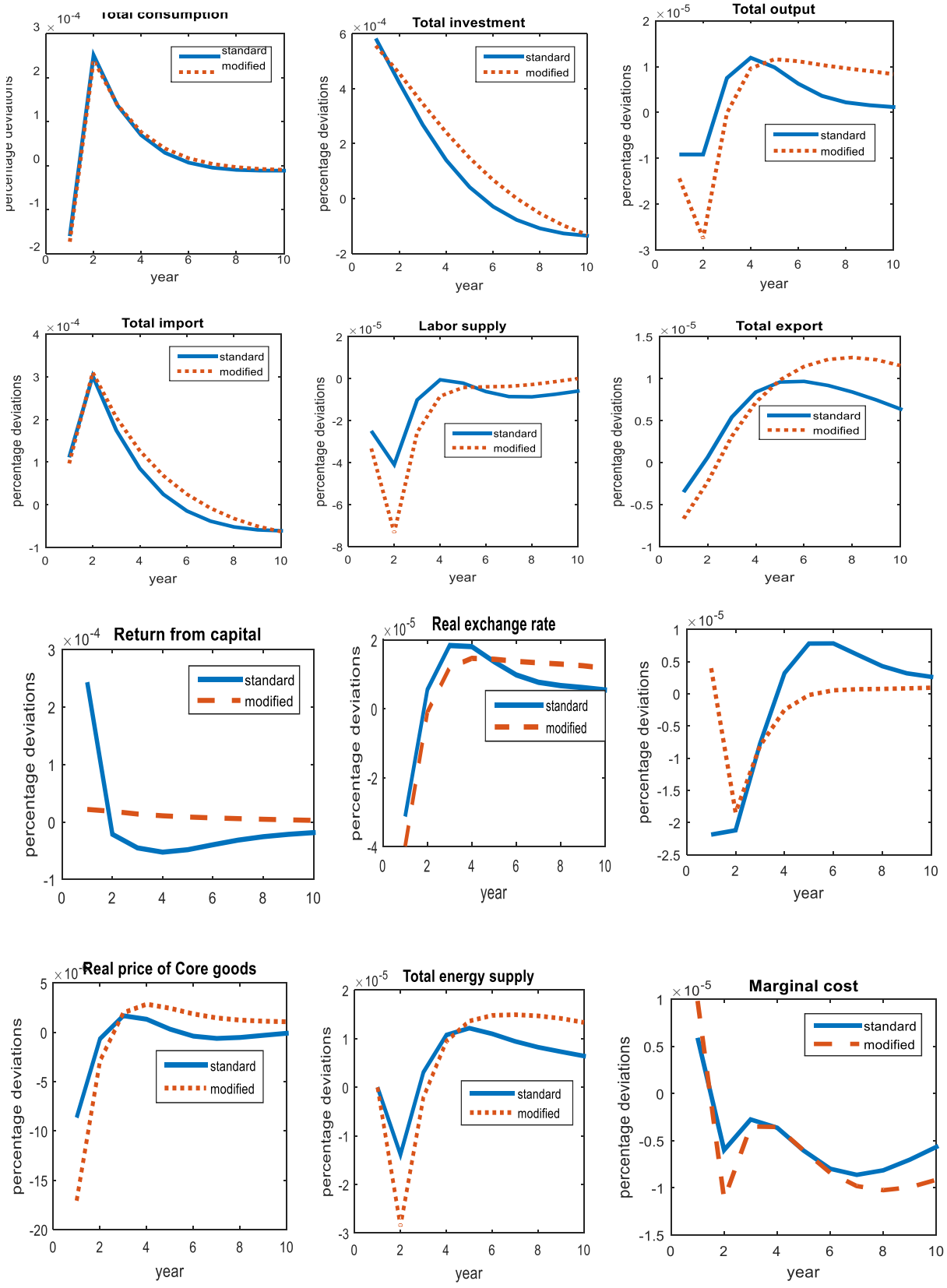
the real money balance as equally as the interest rate rule. This variable includes consumption, investment, import, and export, real interest rate and real exchange rate.

Figure 7: Impulse Response of Key Variables to the world energy price shock



The other external shock observed to compare the first and the bench mark model is world coffee price shock. This external shock generates higher volatility on macro-economic variables as can be seen in figure 8.

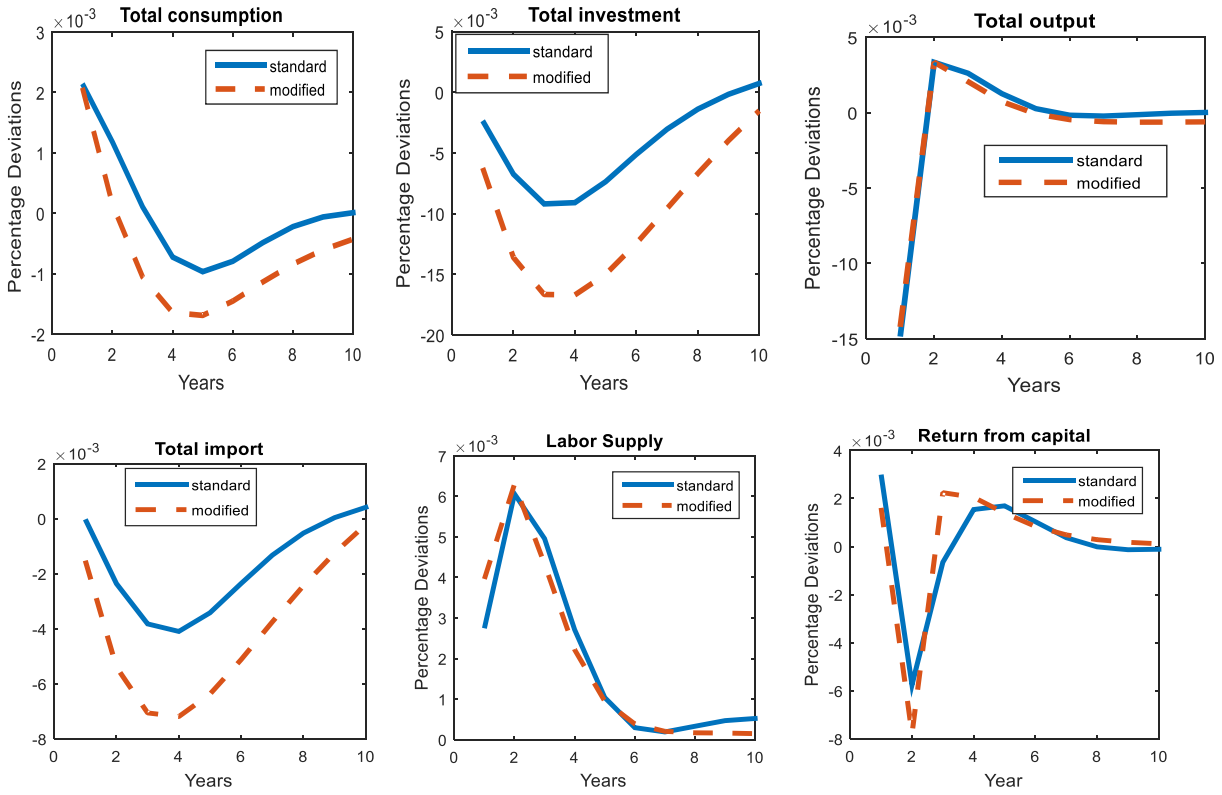
Figure 8: Impulse Response of Key Variables to world price of coffee shocks

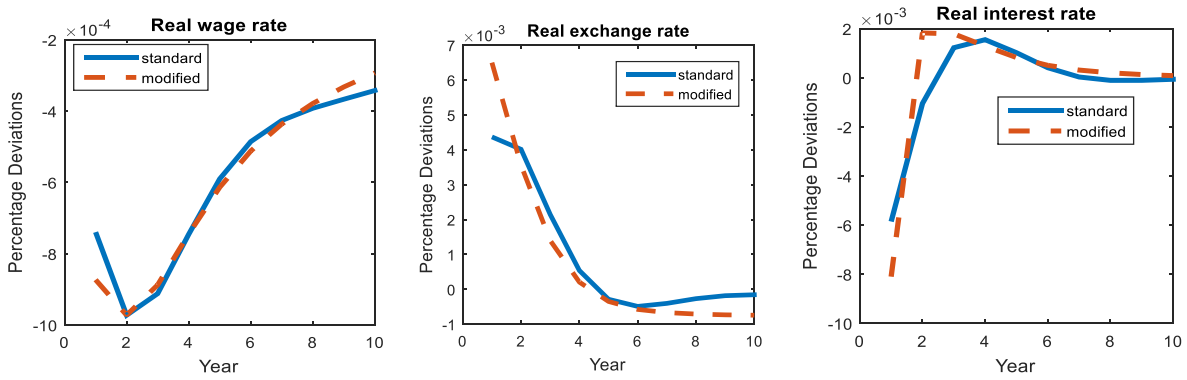

Total consumption
Total investment
Total output
Total import
Labor supply
Total export
Return from capital
Real exchange rate
Real price of Core goods
Total energy supply
Marginal cost
standard
modified
percentage deviations
year

The price of coffee volatility affects the Ethiopian government revenue and foreign exchange market. This forces policymakers to take foreign exchange interventions or debt management instruments. In the meantime, this intervention affects the monetary base. The standard model does not show such volatility behavior; that can be the reason why the benchmark model generates highly volatile variables. It can be inferred that the benchmark model better explains the volatility nature of these economies. The difference in magnitude observed in marginal cost, total energy supply, real price pf core goods, output, and labor supply. The directional difference observed in return from the capital after the second year. The standard model shows the return from capital decrease as a result of coffee price shock except in the first year. The alternative model, however, shows return from capital increase before the economy reaches its steady state.

The shock to consumer preference, as a domestic shock, shows the same result like other domestic shocks. Figure 9 shows that how key macroeconomic variables behave in response to consumption preference shock.

Figure 9: Impulse Response of Key Variables to consumption preference shocks

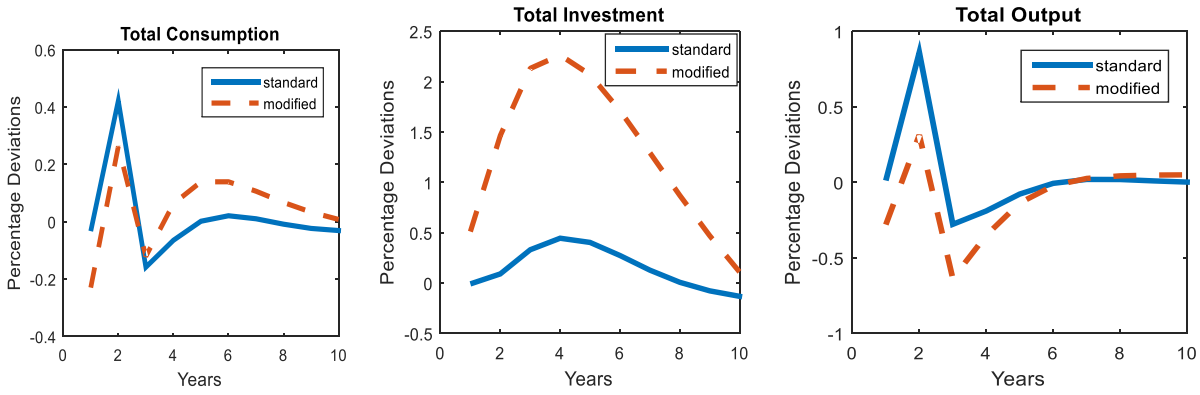


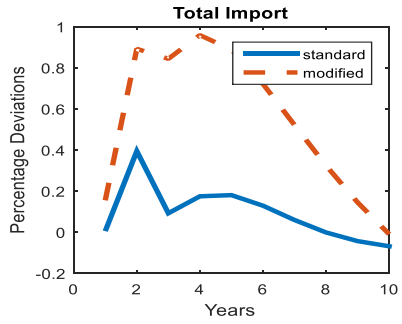


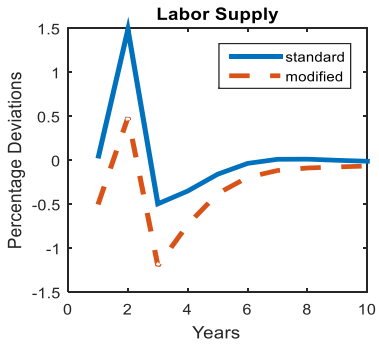
The standard and the benchmark model generate variables that change in the same in direction but different in magnitudes of the change observed from key economic variables. A rise in consumption preference rises aggregate demand, and thus inflation. But the simple interest rate is weak in low-income countries to capture such conditions, unlike the monetary base which can able to handle. As a result, the simple Taylor rule misrepresents the model to study monetary management of the sub-Saharan economy.

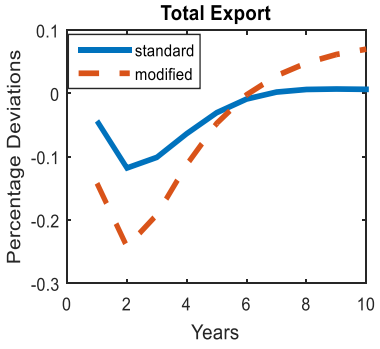
The benchmark model better captures the effect of nominal exchange rate shock on the key macroeconomic variables than the standard model. Such variables include total investment, total import, total export, real wage rate, return from capital, real exchange rate, real interest rate and the real price of core goods. The benchmark model result is more volatile than the standard model as can be seen in figure 10.

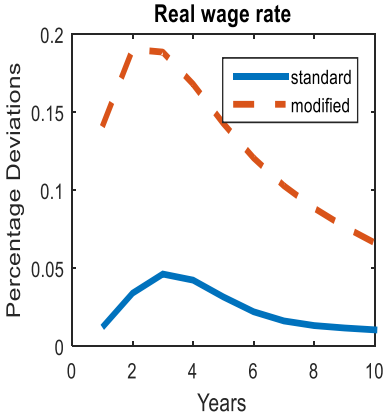
Figure 10: Impulse Response of Key Variables to nominal exchange rate shocks

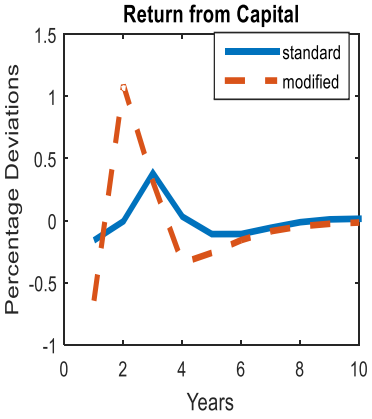


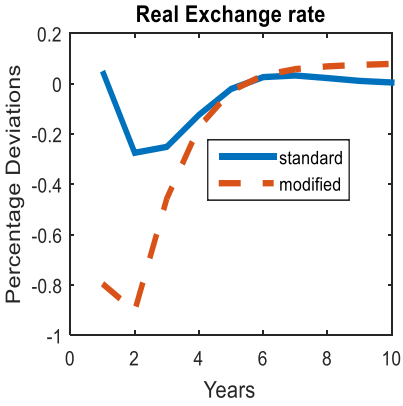

Total Import
standard
modified
Percentage Deviations
Years

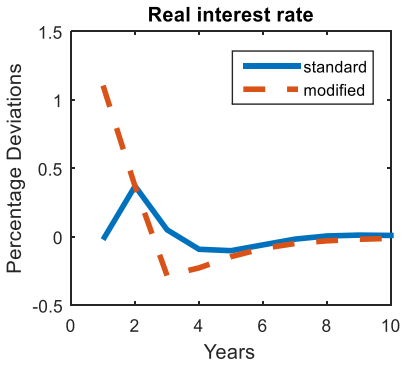

Labor Supply
standard
modified
Percentage Deviations
Years

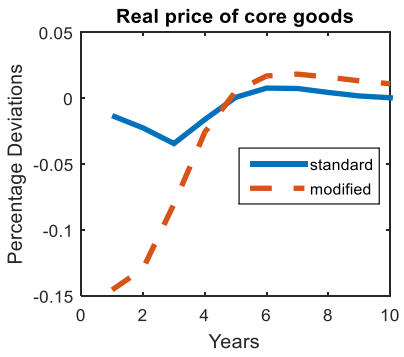

Total Export
standard
modified
Percentage Deviations
Years

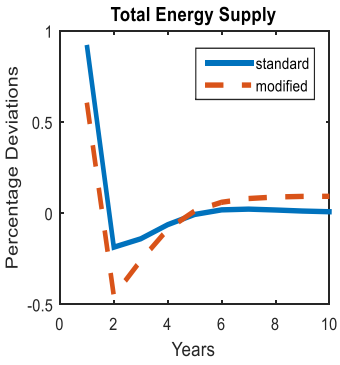

Real wage rate
standard
modified
Percentage Deviations
Years

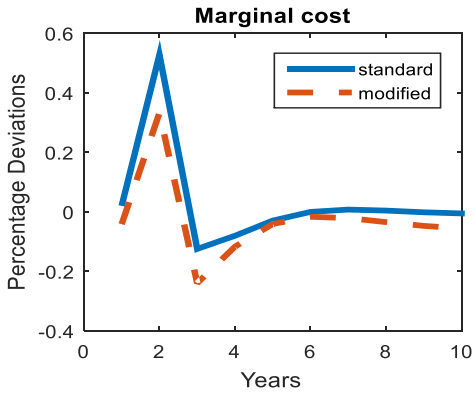

Return from Capital
standard
modified
Percentage Deviations
Years


Real Exchange rate
standard
modified
Percentage Deviations
Years


Real interest rate
standard
modified
Percentage Deviations
Years

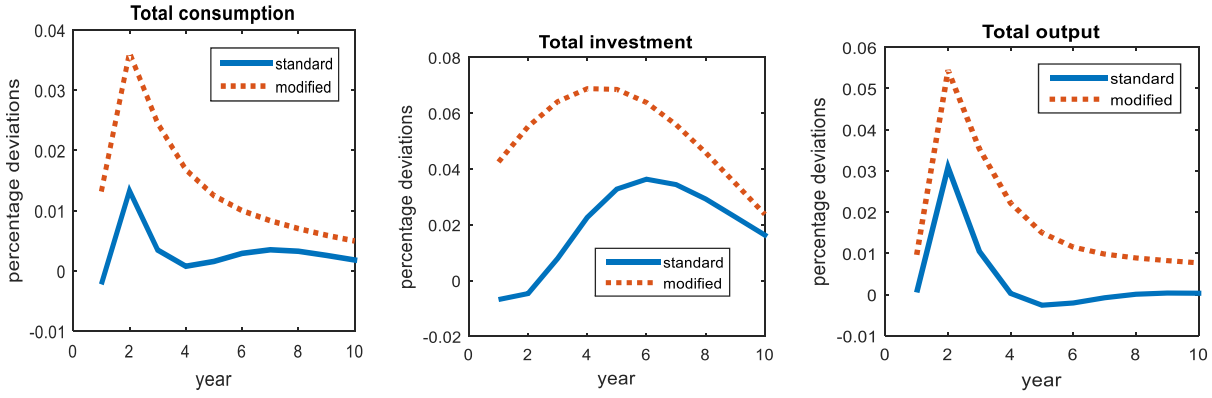

Real price of core goods
standard
modified
Percentage Deviations
Years

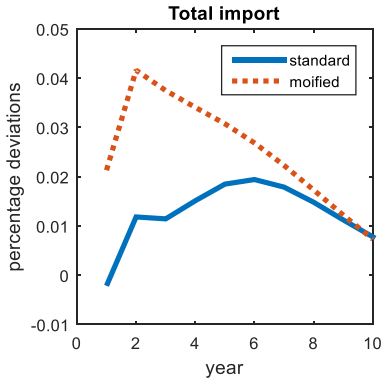

Total Energy Supply
standard
modified
Percentage Deviations
Years

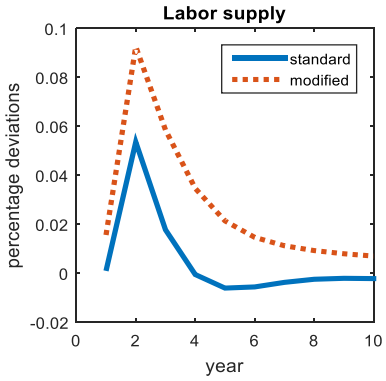


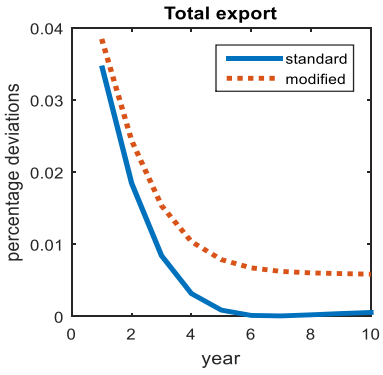
The last shock observed in the model was foreign output shock. Like the other results, the shock generates different results for different variables when the comparison is made between the standard and the benchmark model. The increase in foreign demand increase export and remittance earnings which in turn leads to currency appreciation. Appreciation of the real exchange rate reduces real interest rate and inflation in the domestic economy. This affects the management of monetary policy in the sub-Saharan economy. As can be seen in figure 11, most of the variables generate different results in the standard and the alternative model. The benchmark model generates highly volatile variables. This implies the most macroeconomic variables in the sub-Saharan economy are sensitive to monetary base targeting than interest rate targeting. These variables include total consumption, total investment, total output, total import, labor supply, total export, return from the capital, and total energy supplied in the economy. The difference in direction is also seen in the real exchange rate, real wage rate and the real price of core goods. This analysis implies that using the standard model for analyzing sub-Saharan economies is sometimes misleading.

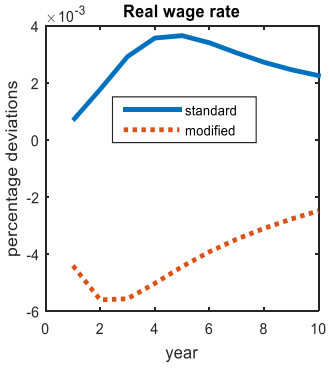
Figure 11: Impulse Response of Key Variables to foreign output shocks

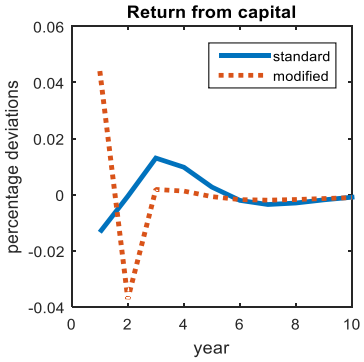


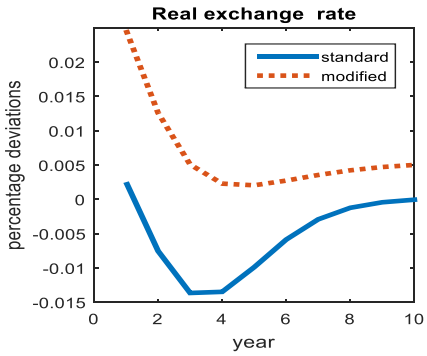

Total import
standard
moified
percentage deviations
year

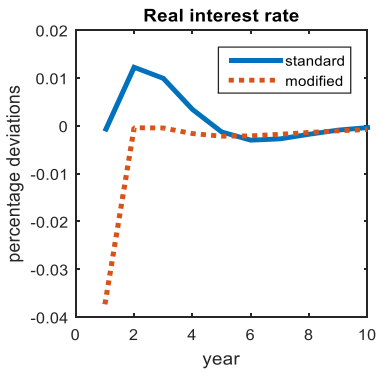

Labor supply
standard
modified
percentage deviations
year

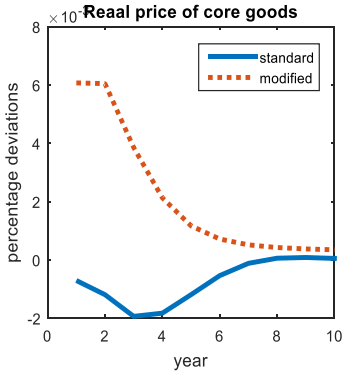

Total export
standard
modified
percentage deviations
year

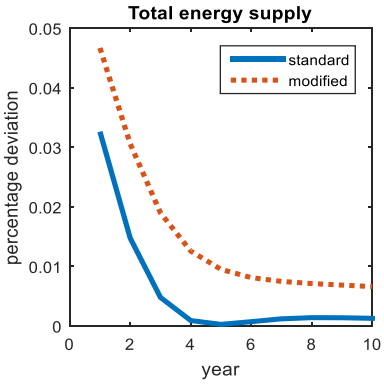

Real wage rate
standard
modified
percentage deviations
year

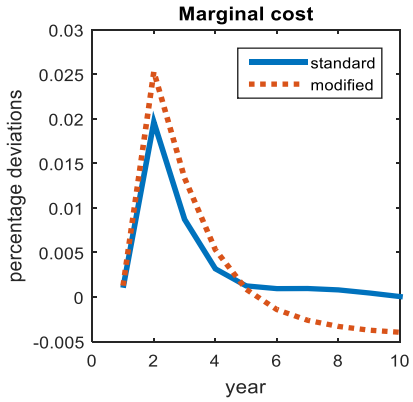

Return from capital
standard
modified
percentage deviations
year


Real exchange rate
standard
modified
percentage deviations
year


Real interest rate
standard
modified
percentage deviations
year


Reaal price of core goods
standard
modified
percentage deviations
year


Total energy supply
standard
modified
percentage deviation
year


Marginal cost
standard
modified
percentage deviations
year

To summarize, after different shock hits the economy, most of the key macroeconomic variables behave the same direction in both models but the magnitude is more prominent for the benchmark model. Since the nominal money balance equilibrium better explains the volatility of key variables that are influenced by the real money balance. Our result confirm the result found by Adam et al (2008)) and O'Connell (2009). Higher volatility with the benchmark model is mainly resulted by high external influence on the money balance through exchange rate and aid, and less sensitivity of key macroeconomic variables in response to interest rate than money aggregate targeting. Sometimes using the standard model for analyzing sub-Saharan economies is sometimes misleading. Relying on this evidence, the study set that the application of the simple Taylor rule in DSGE model requires modification with respect to the feature of the economy of SSA (confirms findings of Senbeta (2013) and Agenor et al (2008). It can be concluded that monetary policy rule based on the monetary equilibrium (money aggregate) in macro models is better than the Taylor type interest rate rule to explain the real effect of economic shocks hence the simple interest rate rule does not capture the domestic and external monetary phenomena.

4.3. Relative Weights of Domestic and External Shocks

The result of the model provides an evidence to make the judgment on the source of shocks and the dynamic response of key macroeconomic variables. To explore the relative weight of the source of shocks, productivity, domestic energy supply, nominal exchange rate shock, consumption preference shocks, world output, world interest rate, world coffee price, and world energy price have been used through their impulse responses. The forecast error variance decomposition is used to discuss the relative contribution of these shock to output dynamics of sub-Sharan economies at different time horizon. Money supply shock as a domestic shock has been added for further understanding of shocks in output dynamics. For the purpose of analysis, the contribution of each shock on output dynamics is summed up under the domestic or external shock block. Moreover, time horizons of 1,4,8,12,16 and 20 years are selected (in variance decomposition the time horizon selection is left for the researcher). Generally, the variance decomposition (see table 6) shows that both internal and external shocks significantly influence output variations in sub-Saharan African economies.

Table 6: Forecast Error Variance Decomposition (In Percent).

		Structural Shocks											
Variable	Horizon (Years)	Ah	ehth	sh_i	sh_c	sh_m	iF	yF	proF	E	prsF	Domestic	External
Output	1	61.4	0.02	0.01	0.1	0.12	0.1	0.05	0.08	38.1	0.02	61.62	38.38
	4	15	0.22	0.01	0.03	0.17	0.17	0.57	0.2	83.62	0.01	15.43	84.57
	8	14.7	0.2	0.01	0.03	0.17	0.17	0.62	0.21	83.9	0.01	15.1	84.9
	12	14.6	0.2	0.01	0.03	0.17	0.16	0.63	0.22	83.99	0.01	15	85
	16	14.53	0.2	0.01	0.03	0.17	0.16	0.64	0.22	84.04	0.01	14.94	85.06
	20	14.51	0.2	0.01	0.03	0.17	0.16	0.65	0.23	84.04	0.01	14.91	85.09

The variance decomposition reveals that internal shocks are mainly dominant in the 1st year. Among internal shocks, productivity shocks contribute most to output fluctuations in many African countries. This demonstrates the significance of supply shocks in output dynamics. This is in line with findings by Hoffmaister and Roldós (2001) for Korea. An increase in productivity reduces the cost of production, increases investment and output. The money supply shocks and consumption preference shock only play a minor role in output swings for African economies.

External shocks appear to be the most persistent shocks driving output dynamics in African countries. These shocks are dominance over the 4th, 8th, 12th 16th and 20th years to show their greater impact to output fluctuations. The effect of external shocks over these periods may be resulted by trade and financial exposure of African countries to the international markets. Nominal exchange rate shocks account for most of the variance of output in sub Saharan African countries.

Exchange rate depreciation may increase the cost of capital, reduce investment and output. Depreciation may also worsen country's balance sheet, increase debt service payments and reduce output. In addition, foreign interest rate shocks slightly affect output variations in sub-Saharan Africa. A positive shock to foreign interest rate may not only increase debt service cost but may also cause capital outflow in sub-Saharan African countries. These will lead to a fall in investment and output. Moreover, output fluctuations are slightly affected by commodity price shocks. The effects of commodity price shocks have been found to be asymmetric in African countries. While negative commodity price shocks have been found to hamper growth, positive price shocks have not promoted growth (see, Dehn, 2000). Further, a positive shock to world energy price has a minimal role to increase output through trade channel or decrease output through the supply shock channel. This confirms the findings by Kose and Riezman (2001) for African economies. Lastly, foreign output shocks play a minimal role in the variance of output. To sum up, the study found that both internal and external shocks account for output fluctuations in SSA economies. But in general, it can be inferred that the external aggregates shocks are superior vis-à-vis to the domestic aggregate shocks which results more volatility of aggregate economic output (confirms the result found by Kose and Reizman (2001). In addition, as it can be seen from table 6, the effects of internal shocks are short-lived; whereas external shocks have long-lasting impacts (confirms the result found by Rasaki (2015). The dominance of external shocks in output variability of sub-Saharan economies can be attributed to their dependence on exports of few primary commodities, reliance on foreign inputs for domestic production, and exposure to foreign currency denominated debt. These expose them to commodity price fluctuations, exchange rate volatility and world interest rate shocks. The significance of external shocks in influencing output fluctuations in African countries raises the question over their exchange rate system. While many African countries maintain that their national currencies are floating, empirical findings suggest otherwise. Slavov (2011) finds that many African countries operate soft peg and display "fear of floating". The tendency to defend the exchange rate may be responsible for the greater impacts of external shocks in African economies. The fear of floating may be attributed to liability dollarization, high level of exchange rate pass-through and low level of financial development in African countries.

4.4. The Effect of Domestic and External Shocks to the Ethiopian Economy

With the baseline parameters and shock processes, we conduct simulations to understand the effect of domestic and external shocks under the simple Taylor rule. The analysis relies on the standard deviations of major variables of interest in response to a 5% standard deviation of each shock from the steady state. To investigate the results more carefully, the study analyzes the response of key variables following different shocks. The study includes all eight shocks: productivity, domestic energy supply, and foreign interest rate, the world price of energy, the world price of coffee, consumer preference, and labor supply and world output shock. Let's discuss each one by one.

4.4.1. Productivity Shock

Following an increase in productivity, total consumption increased before it comes to the steady state except for the first two years. This is can be accounted for the reduction in the price of home goods and overall inflation for the first five years and back to stability conditions. This reduction in the price of home goods leads to an increase in the real wage rate and the real interest rate in the short run following the fall in inflation. Productivity has also a positive effect on import. Total import rise in response to increases in productivity. The fall in import rises total consumption and investment from imported goods. Government consumption of goods and service also showed short-lived increase. This all dynamics in these macroeconomic variables leads output to rise from its steady state which is in line with the theory of economics. This has resulted in an increase in investment and this investment is supported by the higher domestic supply of goods. This increase in output (GDP) is also the result of, growth in capital stock, growth in total export. The effect of productivity on employment is also consistent with economic theory: a rise in productivity cause contraction on employment and vice versa. Firms employ less labor to produce goods and services, in response to the rise in productivity (or uses capital-intensive technologies). These results imply that productivity has an expansionary effect on economic variables and contractionary effect on employment and inflation. Our results supported the findings of Francis and Remey (2005) and Kollman (2017) and Gali (1999)) and Jakab (2006).

4.4.2. Domestic Energy Supply Shock

There is a noticeable increase in total consumption, investment, labor supply, real interest rate, real wage rate, the total output including energy supplied in the economy, import of goods and services as soon as the shock hits the economy. The real price of core goods also falls in the first 5 years

before rising through an increase in marginal cost- the real purchasing power of economic agents could be improved. The increase in aggregate demand components reflects that firms have win power supply problems. This can solve employment problems in the market by creating a new entry or existing entry to supply more hours of work. On the other side, a rise in real wage rate well accounted for the rise in total consumption. The contemporaneous rise in total consumption, interest rate, output, labor supply, and real wage rate, domestic energy supply reach its highest peak in the first two years after the shock and comes to attain its stable condition. Domestic energy supply shock has a short-term consequence on variables. However, the shock has a positive long-term effect on the price of home goods, total investment and total import. On the contrary, the shock has a negative effect on the real exchange rate following the fall in export and the rise import. The fall in the real exchange rate may also be induced by the rise in the price of home goods which leads to depreciation. This depreciation again causes foreign goods consumption from import to increase and fall in international demand for home goods. This result confirms that real depreciation of the domestic currency causes low demand for domestic goods in the international market leads to export to decline.

4.4.3. World Energy Price shock

The paper also explores the response that surfaces as a result of a surge in the world price of energy. Households in the domestic economy responded by reducing energy consumption as the shock happened. The reduction in this expensive energy goods consumption reduces total consumption. This implies the effect of the shock on total consumption is significant. In the separate analysis, the shock creates inflation in core goods which leads to a negative effect on home goods consumption. As soon as the rise in the price of energy in the international market, the quantity of energy import decrease for some time which forced total import to fall. Moreover, the inflation leads to the real interest rate to depart downward from its steady state. In addition, the other effect of world energy price is its negative effect on output. Fortunately, this leads to a labor supply to fall. The result backs up the statement of Kose and Riezman (2001), Kose and Riezman (2002) and Medina and Soto (2005). The authors indicated that world price shocks account for a significant fraction of business cycle variability in developing countries which is in support of the argument presented by Kose and Riezman (2001). This result is not against the conclusion made to advanced economies. For example Medina and Soto (2005) found that oil-price shock has a

contractionary effect on output for Chile economy. they show that a 13% increase in the real price of oil leads to a fall in output of about 0.5% and an increase in inflation of about 0.4%.

4.4.4. Consumption preference shocks

The other shock observed in this model is consumption preference shock. For example, a positive consumption preference leads to high demand for home but low demand for foreign goods which resulted from consumption to increases in the first three years before going to fall. It also induces a rise real price of goods to increase i.e. inflation and a lower import. Low import, in turn, causes the real exchange rate to rise. However, output never rises as soon as the shock happens. This is partly as a result of low investment and low capital stock in response to the shock. However, after some time, total output rises. The rise in output accounted by more labor supplied in the economy but the economy produces a lower real wage rate for these labor. Real depreciation is not the remedy for rising export. According to Gali (1999), for instance, the feature of the impulse responses to the various "demand" shocks that may be less in line with existing evidence is the strong crowding-out effect. This is particularly the case for the government consumption preference shock.

4.4.5. Nominal Exchange rate Shock

Aggregate output and domestic supply of goods slightly deviate down from its steady state following the rise in the nominal exchange rate. In sub-Saharan economies, like Ethiopia, a fall in output generates a higher inflation; the higher the inflation rate, the higher the interest rate and mark up prices. High domestic price of goods decreases the real exchange rate. The depreciated currency is then unable to rise total export. The fall in output may also cause by the reduction in total investment. As a result, the shock has an immediate consequence on total consumption through the fall in home goods consumption, total investment, output, import and export, real wage rate and interest rate. From this, it can be concluded that a fall in aggregate demand component reduces output in low-income countries. However, aggregate demand components do not play a great role in determining the amount of inflation in the economy in this shock. Rather, the amount of total production of goods drives inflation of sub-Saharan economies. More importantly, depreciation of domestic currency does not improve the current account balance of these economies (rather increase import and decreases export). This evidence is against an economic theory which states that depreciation can improve the current account and the balance of payment.

4.4.6. Foreign interest rate

Most of the aggregate demand components like consumption and investment have fallen as soon as the shock happens, but not government total consumption. The high price of imported goods reduces total import. The higher foreign price relative to a lower domestic price generates a rise in the real exchange rate of the domestic economy. Some of the findings in this paper are not consistent with the existing evidence. For example, Beidas-Strom and Poghosyan (2011) stated that foreign interest rate shocks contract consumption and output, depreciate the real exchange rate and improve the current account. However, this paper found that the appreciation real exchange rate of the domestic currency promotes total exports to the rest of the world for some periods. The rise in the foreign interest rate generates a higher price of imported goods which reduce the real wage rate. However, the fall in real wage rate does not cause a fall in total labor supplied in the economy. This confirms the result obtained by Kronick (2014) which dictates that countries in SSA with the fixed exchange rate, they experienced more expansionary in the medium and long-term in response to the shock in the world interest rate. When the aggregate demand components fall, the amount of inflation prevailed in the economy continue to rise. This finding stands against the Keynesian School which states a fall in aggregate demand reduces inflation in the economy. A rise in inflation is induced by the rise in the price of imported goods.

4.4.7. World GDP Shock

World output shock is another examined source of fluctuations for the economy of sub-Saharan African countries. As the shock occurs, there is a rise in the total export of goods and services. This is consistent with the theory which manifests that an increase in the income foreigners increases the total demand for exported goods from the domestic economy. The rise in export leads to the rise in the real exchange rate and appreciation of the domestic currency, however, higher inflation rate and with a small effect on the interest rate. Consequently, total aggregate demand components such as household consumption, investment, and government consumption increases. In this scenario, a rise in aggregate demand components provoked inflation. This implies the inflation pressure in low-income countries mainly depends on aggregate demand components and exchange rate appreciation or depreciation.

4.4.8. World Coffee Price Shocks

The last discussion in this part is to analyze the response of major macroeconomic variables in response to coffee price shock in the international market. As the shock hits the economy, the world demand for domestic goods decreases. As a result, total export grow and the real exchange rate appreciates in respnse to the shock except for the first two years, which in turn, reduces the real interest rate. This finding is in track with the conventional economic theory which states the rise in world demand appreciates the domestic currency. This is because, in the world market, sub-saharan countries exporters are price takers. As a result, marginal cost reduced in the economy. The shock generates a fall in domestic supply of goods in the economy in the first three years. This can be accounted for that the total rise in output as a result of consumption and investment is fully reduced by the rise in import. This left the output to change in small from its equilibrum point. The price oh home goods slightly incraese as a result of high mark up prices. The mark up prices reduce the real wage rates in the economy.

4.5. Sensitivity Analysis

In this section, we report results from a variety of experiments to test the robustness of our results to changes in the values of key parameters which is based on a range of values assigned by different researchers. Among different parameters, we concentrate on some parameters which are different in their values in different researches. These parameters selected were the share of Ricardian households, the share of domestic energy and price sickness in home goods. All these parameters were tested based on the impulse they generate in response to productivity shocks. Our result shows that increasing or decreasing the share of Ricardian households has no effect on the impulse response of total investment, output, and export. Our results held up quite well to changes in values of most parameters. However, consumption seems sensitive in response to the change in the share of Ricardian households. The second parameter tested was the share of domestic energy supply from the total supply. As can be seen in the table below in the appendix part the study found that the impulse responses of most of the variables remain the same. However, when the share of domestic energy supply getting close to 1, the impulse response of output gets a decline. The third parameters tested was price stickiness of home goods. In this case, some key variables, like investment shows a different impulse in response to productivity shocks. In general, the study finds that the weight of the sticky price sector (investment) in the optimal price index increases with the degree of price stickiness which confirms the result of Anand et al. (2015)

CHAPTER FIVE

5. CONCLUSIONS AND IMPLICATIONS

5.1. Conclusion

The study developed and calibrated a DSGE model to examine the application of the simple Taylor type interest rule in the DSGE model of a sub-Saharan economies. In addition, the study also examined the relative importance of domestic and external shocks to such economies. Moreover, the study identified the impact of structural shocks on key macroeconomic variables of the sub-Saharan economies. These structural shocks are productivity shock, domestic energy supply, world energy price, world coffee price, consumer preference, nominal exchange rate, world output, and world interest rate shocks. The model used in this paper is the new Keynesian DSGE model under sticky price and wage which is similar with Medina and Soto (2005, 2007).

To test the Taylor type interest rate rule, the analysis relied on two simulations and the impulse response of the two simulations. The first model, the standard, encompasses the Taylor type interest rate rule and the second model, the benchmark simulation, captured the monetary base as a monetary policy instrument. To measure the relative importance of domestic and external sources of shocks, variance decomposition of each shock is used for analysis. The results are the following: first, in response to the baseline structural shocks, the monetary base rule model generates more volatility vis-à-vis the Taylor type interest rate rule. Higher volatility with the benchmark model is mainly resulted by high external influence on the money balance through exchange rate and aid, and less sensitivity of key macroeconomic variables in response to interest rate than money aggregate targeting. Hence using the standard model for analyzing sub-Saharan economies is sometimes misleading. Relying on this evidence, the study set that the application of the simple Taylor rule in DSGE model requires modification with respect to the feature of the economies of SSA. To sum up, on this point, monetary policy rule based on the monetary equilibrium (money aggregate) in macro models is better than the Taylor type interest rate rule to explain the real effect of economic shocks hence the simple interest rate rule does not capture the domestic and external monetary phenomena.

Second, the variance decomposition analysis shows that both internal and external shocks are responsible for macroeconomic fluctuations in African countries. Among internal shocks, productivity shocks contribute most to output fluctuations in sub-Saharan African countries. However, external shocks account for greater variations in output than internal shocks. This is in line with findings by Hoffmaister and Roldós (2001) for Korea and Rasaki (2015) for South Africa However, external shocks account for greater variation in output and appear to be the most persistent shocks driving output dynamics in African countries vis-à-vis to the domestic shocks. The effects of internal shocks are short-lived; whereas external shocks have long-lasting impacts (confirms the result found by Rasaki (2015). The dominance of external shocks in output variability of sub-Saharan economies can be attributed to their dependence on exports of few primary commodities, reliance on foreign inputs for domestic production, and exposure to foreign currency denominated debt(in general trade and financial exposure).

Third, productivity has an expansionary effect on economic variables and contractionary effect on employment and inflation. Our results supported the findings of Kollman (2017), Gali (1999)), Senbeta(2013) and Jakab (2006). Domestic energy supply has a positive long-term effect on the price of home goods, total investment and total import and a negative short-term effect on the real exchange rate and foreign demand for domestic goods following the fall in export and the rise in import. World energy price shocks have a positive effect on investment and output in sub Sharan economies but the effect of the shock on total consumption is insignificant. Consumption preference shock induces inflation through aggregate demand and causes depreciation. However, this depreciation causes export to decline. As the world coffee price shock hits the economy, total export grow and the real exchange rate appreciates in response to the shock except for the first two years, which in turn, reduces the real interest rate. This finding is in track with the conventional economic theory which states the rise in world demand appreciates the domestic currency. This is because, in the world market, sub-Saharan countries exporters are price takers. Foreign output shock there is arise in the total export of goods and services. This is consistent with the theory which manifests that an increase in the income foreigners increases the total demand for exported goods from the domestic economy. The rise in export leads to the rise in the real exchange rate and the appreciation of the domestic currency. Most of the aggregate demand components like consumption and investment have fallen as soon as the foreign interest rate shock happens, but not

government total consumption. In response to nominal exchange rate shock, the amount of total production of goods drives inflation of sub-Saharan economies. More importantly, depreciation of domestic currency does not improve the current account balance of these economies (rather increase import and decreases export).

In most shocks, the rise in inflation is induced by the rise in the price of imported goods. This implies partly the inflation pressure in low-income countries mainly depend on the price of imported goods and exchange rate appreciation or depreciation. Related to domestic energy supply, the shock creates higher inflation and demand in the economy. Moreover, the result implies, in many shocks, currency depreciation does not promote export. When the aggregate demand components fall, the amount of inflation prevailed in the economy continue to rise in some shocks and fall in other shocks.

5.2. Policy Implications

The results of the study have important policy implications for SSA economies. The study presented the implications of the above conclusion as follow. First, in macroeconomic models of sub-Saharan economies, considering the domestic and external phenomena in macroeconomic models as well as modifications of model equations is necessary. Likewise, the standard Taylor interest rate rule should be modified in accordance with the money aggregate equilibrium and the external influences that affect this aggregate. In this paper, it is recommended that in modeling the monetary policy rules in macroeconomic models of sub-Saharan economies, incorporating the monetary base instrument and external influence on the monetary management of such economies is essential. This is because of high external influence on the money balance of sub-Saharan economies and less sensitivity of key macroeconomic variables in response to interest rate than money base targeting. In fact, money balance equilibrium better explains the volatility of key variables that are influenced by the real money balance. In addition, modifications should be made on monetary instruments with the feature of sub-Saharan economies to analyze the inflation situation of such economies.

Second, policymakers should give attention to domestic and external shocks to lessen the volatility of aggregate economic variables. Moreover, it is better to understand that making macroeconomic

generalizations of the effect of domestic shocks based on the external shock, or vice versa, is misleading. However, SSA economies need to concentrate on external shocks to minimize their economic volatility. In view of the vulnerability of SSA countries to external shocks, it is commanding that these countries formulate policies such as sound external debt management and hedging strategies to insulate or mitigate the effects of external shocks, create a buffer against adverse external shocks is to set up sovereign wealth funds (as discussed by Rasaki (2015)).

Third, the policy related to increasing domestic energy supply has a positive long-term effect on investment and output. However, this policy will have a negative short-term effect on the real exchange rate and foreign demand for domestic goods. Effective policies related to the total production of goods, imported goods and exchange rate is important for inflationary management of sub-Saharan economies. However, aggregate demand management cannot reduce inflation. With related to the domestic supply of energy, market priority should be given to protect the economy from inflation and high energy demand. This priority may include supplying new energy sources to only to the international market or formulate good pricing and market strategies for managing the new energy sources.

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APPENDIX

Appendix 1: Sensitivity Analysis

Table 7: Sensitivity Analysis with different Parameter Value

Parameter value	Productivity shock			
	The average values of key macro-economic variables(Percentage deviation from the steady state			
Share of Ricardian households	Total Consumption	Total Investment	Total output	Total Export
0.4	0.002274	-0.02872	0.004911	0.037775
0.5	-0.00086	-0.02221	0.004712	0.038351
0.6	-0.00403	-0.02819	0.004501	0.038979
Share of domestic energy				
0.7	0.002274	-0.02872	0.031516	0.037775
0.8	0.002274	-0.02872	0.031516	0.037775
0.9	0.002274	-0.02872	0.004911	0.037775
Price stickiness in home goods (Calvo probability).				
0.64	0.003232	-0.03934	0.004425	0.039869
0.74	0.002274	0.00529	0.004911	0.037775
0.84	0.000239	-0.0169	0.005625	0.033825

Note: Each value is given in percentage deviation from the stedy The baseline values of these parameter are 0.4, 0.9 and 0.74 for share of Ricardian households, share of domestic energy and price stickiness in home goods.