MACROECONOMIC SHOCKS AND INFORMAL SECTOR DYNAMICS IN NIGERIA: EVIDENCE FROM NEW KEYNESIAN DSGE MODEL

BY

Usman Adamu Bello
B.Sc. (Hons.) M.Sc. (ABU)

P16SSEC9006

A THESIS SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA

IN PARTIAL FULFILMENT FOR THE AWARD OF DOCTOR OF PHILOSOPHY
DEPARTMENT OF ECONOMICS

FEBUARY, 2020

Declaration

I declare that the thesis entitled **Macroeconomic Shocks and Informal Sector Dynamics in Nigeria: Evidence from New Keynesian DSGE Model** has been performed by me in the Department of Economics. The information derived from the literature has been duly acknowledge in the text and a list of references provided. No part of this thesis was previously presented for another degree at this or any other institution.

Usman Adamu Bello …… ……

Signature Date

Certification

This thesis entitled **MACROECONOMIC SHOCKS AND INFORMAL SECTOR DYNAMICS IN NIGERIA: EVIDENCE FROM NEW KEYNESIAN DSGE MODEL** by Usman Bello ADAMU meets the regulations governing the award of the degree of Doctor of Philosophy of the Ahmadu Bello University, and is approved for its' contribution to knowledge and literary presentation.

Dr. Aliyu Rafindadi Sanusi	……	……
Chairman Supervisory Committee	Signature	Date
Professor Peter P. Njiforti	……	……
Member Supervisory Committee	Signature	Date
Dr. Dahiru Suleiman	……	……
Member Supervisory Committee	Signature	Date
Dr. Aliyu Rafindadi Sanusi	……	……
Head of Department	Signature	Date
Professor Sani Abdullahi Rabah	……	……
Dean School of Postgraduate Studies	Signature	Date

Dedication

To Almighty ALLAH (the one), AR RASHID (the guide) AR RAZZAQ (the provider), AL WAHHAB (giver), AL FATTAH (the opener) & AL ALEEM (the knower)

Acknowledgments

My whole hearted gratitude goes to the chair of my supervisory committee **Dr. Aliyu Rafindadi Sanusi** for the immeasurable insights and time he invested during this study. I could not have come this far without your support and mentorship. I would like to express my deep appreciation to the members of my supervisory committee **Professor Peter P. Njiforti** and **Dr Dahiru Suleiman** for investing time and effort in ensuring this research is completed. I owe you all immense gratitude for all the valuable comments. I would also like to thank the staffs of the Department of Economics who have in one way contributed at any stage of my writing. I must mention **Mallam Abdulrahman Ahmad, Ibrahim Bambale, Dr. M. T. Jume** and **Professor Mike Kwanashie** for the resources, comments and discussions. I am grateful and I thank you all. I would like to extend my gratitude to my parent **Alhaji Adamu Bello** and **Hajiya Hauwa Aliyu** for the encouragement and prayers. I would also like to mention my good friend **Ahmed Aliyu** and my brother **Eng. Mohammed Adamu** also my wife **Farida** for her patient and understanding. Lastly, I must say thank you to my big uncle **Alhaji Ashiru Danliman** for his kind support during my stay on and off campus.

Abstract

The efficacy of economic policy partly resides on a good understanding of the underlying features of the economy. Unlike developed economies, developing economies are characterized by the existence of a large informal economy with contrasting optimizing constraint faced by economic agents in the formal economy. This study attempts to simulate a New Keynesian DSGE model that mimics reality by incorporating key features of the underlying economy, such as the informal sector, distortionary tax, commodity sector (oil export) and openness. In developing the model, the study introduced price stickiness in the formal sector, and this distinguishes the flexible prices in the informal sector. Other elements introduced in the informal economy include non-Ricardian households and untaxed credit constraint firms that produce tradable and non-tradable goods. Thus, the formal sector has Ricardian households with credit and non-credit constraint firms. The model was taken to data and estimated using Nigerian data. The study simulates four distinct shocks in order to examine the unique roles of the underlying economy. Two of these shocks were domestic originating shocks, which reflects the adoption of technology in the domestic economy. That captures and accounts for the productivity shock. Also, a sector-specific shock originating from the informal sector, which accounts for the existence of a large informal economy. The other two shocks are external shocks in line with oil commodity export and the openness of the economy. Thus, the study examines oil price shock and foreign inflationary shocks. Also, the effects of macroeconomic policies (monetary and fiscal policies) were analyzed. The result shows that positive markup shock from the informal economy, the oil price shock, and foreign inflationary shock have an inflationary effect on the domestic economy. However, productivity shock has a short-run deflationary effect. Across all the shocks considered, informality was found to have a distortionary effect on output. It has the resilient to withstand recessionary periods, and it has a distortionary effect on fiscal revenue with a propensity to create fiscal imbalance and debt accumulation. The result shows that informal goods-producing firms are inefficient but have lower marginal cost due to non-remittance of tax. Monetary policy was found to have a potency threshold in curbing inflation that originates from domestic economy and oil price shock, but such potency (optimal) threshold is ineffective in tackling inflation associated with external shocks (foreign inflationary shock). Furthermore, monetary policy was found to be weak and less effective in credit constraint informal economy but more effective in the formal sector. This study recommends strengthening the credit market in credit constrain informal economy through microfinance banks and improving financial inclusion measures (including thrift and cooperative societies) in order to improve the efficacy of monetary policy. Also, fiscal policy should aim at channeling expenditure through aggregate supply than aggregate demand in order to reduce revenue leakage associated with the consumption of goods produced in the informal sector

TABLE OF CONTENT

List of Tables

List of Figures

CHAPTER ONE
GENERAL INTRODUCTION

1.1 Background of the Study

Complex and dynamic features associated with small white noise shocks appear to have become critical factors in the propagation of economic fluctuations. The propagation of the impulses (shocks) that translates to either minor or major fluctuation in the economy may hardly tell the source of the shocks. Sometimes the magnitude of the shocks might be associated with the size of fluctuation but even if so, it is challenging to infer if a fluctuation in the economy is a product of isolated (large) or accumulated (small) shocks. It is indeed imperative for policy purpose to know how the sources and nature (isolated or accumulated) translate to the size of fluctuations.

Generally, macroeconomic shocks could be identified as stochastic[1] and, in other times, they could be deterministic[2]. The probabilistic characteristics of their occurrence could define the nature in which these impulses are triggered. Depending on the source, a shock could be originating either from the demand or supply side, in which case, it could be referred to as *demand* or *supply shock*. Also, the source of shock could be coming from within the economy (internal shock) or from outside (external shock) (see also Blanchard, 2010). Furthermore, because different types of shocks may continue to occur at different time intervals, economies may continually move in cycles of booms and bursts. More so, the frequency of the occurrence of the shocks may determine how rapidly economies move over the cycles.

[1] Stochastic events are generally random and occur suddenly. Their occurrences may trigger series of changes or one-time change in the economy. Example of random event could be a completely unexpected oil price change.

[2] The deterministic event is more or less predetermine, example of such shock is political cycle that occur during elections or democratic change of governments.

Beliefs about *ex-post* data over the years in most countries appear to suggest that shocks are linked to cyclical movement of economies through business cycles. It could be admitted that macroeconomic shock[3] and impending cyclical movement that follows, might likely be permanent features of short-run dynamics of economies (see Kydland & Prescott, 1982). Similarly, bubbles and bursts may follow each other along the short-run trajectory. In any case, the structure of an economy may bear some significance on sources, frequency, and nature of macroeconomic shocks. For instance, the degree of openness of an economy could determine its exposure to external shocks. Besides, an economy characterized by large dependence on exports of mono-product and imports of multiple products may be exceptionally vulnerable to external shocks, hence shorter and deeper cycles.

One key feature inherent in most economies is the existence of the *shadow economy* (see Frey & Schneider, 2005 and Schneider, 2014). The existence and size of this shadow economy appear to differ from country to country. Particularly, Schneider (2014) suggests that the causes and size of the informality are much more in the developing and emerging economies. Therefore, it is expected that economic agents in the informal economy, which predominates in these economies, might be facing different intertemporal constraints from economic agents in the formal economies, given their respective objective functions. Thus, shocks and macroeconomic fluctuations tend to affect economic agents differently, depending on the structure of the economy and the underlying economic fundamentals. It also implies that the agents' reaction could be substantially different under the two economies, depending on whether it is in the formal or informal sector. These potential differences in the effect of shocks on the economic agent as well as their reaction have important implications on the model on which economic policies are planned and executed.

[3] Either a demand or supply side shock

The structure of the Nigerian economy is substantially dominated by informal activities. Evidence from Frey & Schneider (2005) suggests that up to 70 percent of the energy consumption in Nigeria is accounted for by the informal economy. That means that the formal sector consumes only about 30 percent of the total energy consumed in the economy. Besides, Schneider (2014) observed that 60 percent of the domestic Gross Domestic Product (GDP) comes from the informal economy. This evidence further sheds light on the relative significance of the informal economy, particularly its relevance in explaining the output (employment) stability in the Nigerian economy.

Furthermore, it appears that the dynamic effect of the informal economy provides some resilience in terms of the level of depression the Nigerian economy slides into whenever macroeconomic shock hits the economy. That is because the consumption of goods produced in the informal predominantly subsistence sector may provide buffers to the household in the informal economy. That means macroeconomic fluctuations emanating from shocks as observed by Agenor, Dermot & Prasad (2000) could have an interesting and diverse effect that may be contrasting to formal economy.

Macroeconomic management policies put in place over the years to curtail the effects of these shocks and to mitigate the fluctuations in Nigeria were based on several macro models. The first macroeconomic model, which was constructed by the Central Bank of Nigeria (CBN), can be traced back to Ojo (1972). Other models were collaborative CBN-World bank (1974) macro model; Uwujaren (1977); Olofin *et al.* (1977 and 1985); Nigeria Institute of Social and Economic Research (NISER, 1983-1984). Others are National Planning Commission/Federal Office of Statistics macroeconomic Input-Output (I-O) table by Aboyade (1985, 1987, the 1990s); Iyoha (2003); CEAR MAC III (2006) and CEAR MAC IV (2007-2010). Also, another collaborative attempt was by CBN, African Institute of Applied Economics (AIAE), CEAR, NISER (2010) macroeconomic model. It is noteworthy to point out that all the attempts in the

construction of these models which are limited to the Cowles Commission Approach, which in itself is defective, due to several issues including the difficulty of estimation arising from irreducibility of a large number of simultaneous equations. Also, there is the problem of long dynamic lag, which is lacking prior information. Other fundamental problems are autocorrelation of the residual, the unresolved issue of multivariate forecasting and incapability of incorporating seasonal adjustment. Above all, these class of models they lack micro-foundations, and because the parameters are not policy invariant, they are not immune to Lucas critique[4].

Given the issues associated with the Cowles Commission approach[5] to modeling, especially their lack of micro-foundations and susceptibility to Lucas critique, Mordi *et al.* (2013) and Adebiyi & Mordi (2016) built and estimated a Dynamic Stochastic General Equilibrium (DSGE) model for the Nigerian economy. No doubt, the DSGE model addresses the issues inherent in the simultaneous system of equation entrenched in the Cowless Commission approach. For instance, the intertemporal optimizing behavior of economic agents (households and firms) and the forward-looking behavior addresses the Luca's critique and are some of the key strengths the DSGE approach to the macro modeling. Besides, because the model is correctly specified (Cogley & Yagihashi, 2010) and validation test suffices, the issue of policy invariance of the parameters becomes adequately resolved.

Despite the fundamental problems addressed by the DSGE built-in CBN (Mordi *et al.* 2013 and Adebiyi, 2016), other compelling issues appear to be imminent, that could, at best, raise significant doubt on the estimate representation of the shocks in the model and, at worst, could

[4]In addition, the data requirements of these class of models, and in the absence of timely and quality data, these models were hardly ever used for monetary policies in Nigeria. They were, at best used for planning purposes, leaving the Central Bank to rely on financial programming, whose foundation was the work of Polak (1957)

[5] The simultaneous equation system (pioneered by Tinbergen, 1939) and the general equilibrium model (championed by Dresch, 1937, 1940).

mar the outcome and mislead policymakers. For instance, the government sector in the applied model needs not to rely on lump-sum tax as the baseline model suggests. Furthermore, given an oil economy with so large a shadow, it is imperative to discount the size of tax revenue lost and introduce the revenue from oil exports. Also, the optimal monetary policy must internalize the managed exchange rate policy as against the Taylor rule assumed in the baseline model. Other unresolved aspects in the literature include the role of informal labour and labour market friction, informal intermediate and final goods-producing firms, which coexist with the formal firms. The few attempts (Mordi *et al.* and Adebiyi) have therefore underspecified the DSGE by ignoring this important feature of the Nigerian economy. Therefore, given the implication of under-specification of the DSGE model and the need to manage effectively macroeconomic shock, it then becomes desirous of constructing a model in line with the economic fundamentals of the Nigerian economy.

In examining the sources, frequency, and nature of macroeconomic shocks, which should depend on the structure of the economy; hence, it is crucial in taking this assumption into modeling an economy such as the Nigeria economy. Similarly, macroeconomic management effort must consider a model that better mimics reality, and that is also consistent with the structural fundamentals of the economy. Overlooking the significance of a feature such as informality, which may bear some implications on the conduct of both fiscal and monetary policy remains a critical issue. As such, in advancing this study, a review of the relevant literature which entails conceptual, theoretical and empirical is documented. In the conceptual literature, the concept of informality is operationalized, and a trace of informality in the developing economy was provided, including an overview of all the macroeconomic models applied in the management of the Nigerian economy. A review of the theoretical literature provided an insight into the historical overview of macroeconomics and the competing approaches. Also, the empirical reveals the ongoing debate that is existing and the gap that

emerges thereof. The main focus of the literature is resting on two aspects. The first is divergent of findings on the role of informality on the economy. The second is the differences in the modeling and handling of the informal sector.

The focus of this study is to develop a New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model with some fundamental features that reflect the Nigerian economy. One of these key features is the significance of the informal economy. The major attribute of the informal sector that may be too important to ignore is the flexibility of prices relative to the price stickiness in the formal sector. Other elements introduced in the informal economy includes non-Ricardian households and untaxed credit-constrained firms that produce tradable and non-tradable goods. Thus, the formal sector has Ricardian households with credit and non-credit constrained firms. Furthermore, introducing a commodity sector into the Small Open Economy NK-DSGE model, which accounts for the natural resource endowment (crude oil) that is extracted and traded to Rest of the World (ROW). The open nature of the economy rationalizes its exposure to external shocks due to the degree of openness.

1.2 Statement of the Research problem

Macroeconomic fluctuations originating from stochastic shocks have been observed to be prominent features[6]of many economies. Macroeconomic management strategies that target short-run stability,[7]which reduces propagation of these shocks and amplification of associated fluctuation are hardly effective, especially in many developing economies. That is because the use of both monetary and fiscal policies appears to be affected by the structural features such as informality. Similarly, incorrect diagnostics of the source and nature of macroeconomic shocks could contribute in misleading policymakers in the use of policy prescriptions which

[6] At least it is evident in the RBC theory in the spirit of Kydland and Prescott (1982)
[7] As required in the current medium-term Economic Recovery Growth Plan (ERGP)

may, by some measure, increase the cost of the shock or even prolong the period of fluctuation and instability.

Thus, more importantly aftermath effect of poor empirical understanding of macroeconomic shocks and the underlaying structural features may not only lead to ineffective macroeconomic management policies, but it could also generate greater costs including fiscal imbalance. This common mismanagement has remained a scar on the Nigerian economy, compelling devaluations and deregulation of the economy. On the monetary policy side, wrong diagnostics could enforce insensitivity of macroeconomic target to the instrument (see CBN, 2013). In some cases, it could result in the exercise of accommodative policy where it is required to be non-accommodating (invalidating). Thus, this may have gross implication not only on general prices and output, but it could also deepen the magnitude of an impending recession. Therefore, increasing the intensity of cyclicality.

Over the years, the effort to stir the economy in the right direction and the need to better manage macroeconomic shocks has compelled the CBN to construct and apply a series of macroeconomic models. Starting with Ojo (1972), CBN-World bank (1974) macro model; Uwujaren (1977); Olofin*et al.* (1977 and 1985); NISER (1983-1984). Other are Aboyade I-O table (1985, 1987, the 1990s); Iyoha (2003); CEAR MAC III (2006) and CEAR MAC IV (2007-2010) including CBN, AIAE, CEAR, NISER (2010). All of these were traced to be culpable in terms of efficacy for policy guidance largely because they susceptible to Lucas critique and evidently failing to incorporate the informal sector.

In a recent attempt, the CBN has estimated a DSGE model twice (Mordi *et al.*, 2013 and Adebiyi 2016). Notwithstanding much is desired, in terms of conformity of the model with the underlying economic fundamentals. More so, the recent economic recession which lasted for

about 12 quarters (3 years), suggest that much is needed, in terms of efficacy of policy and macroeconomic management.

Therefore, this study argues that effective macroeconomic management effort must not only match with the appropriate model, but it should also incorporate unique features that mimic the economy in question. Hence this study sets out to investigate within the context of the New Keynesian DSGE, how does the size of informality affect the effectiveness of macroeconomic policy in managing shocks. Thus, the question that begs for answers follows:

1.3 Research questions

i. What is the significance of large informal economy in the analysis of macroeconomic shocks within the NK-DSGE model?

ii. What are the effects of monetary policy in the NK-DSGE model with a large informal economy?

iii. What is the effect of fiscal policy in the NK-DSGE model with a large informal economy?

In order to provide answers to the research questions, the study intends to accomplish some sets of objectives.

1.4 Objective of the Study

The broad objective of the study is to estimate a DSGE model for a SOOE with a large shadow using Nigeria's data. Thus, to achieve the broad objective, the following specific objectives come to bear:

i. To determine the significance of large informal economy in the analysis of macroeconomic shocks within the NK-DSGE model.

ii. To examine the effects of monetary policy in the NK-DSGE with the large informal economy.

iii. To examine the effects of fiscal policy in the NK-DSGE with a large informal economy.

1.5 Justification of the Study

The argument put forward in this study can be justified from both theoretical and empirical bases. Theoretically, unlike the extension of the baseline DSGE that incorporates Small Open Economy[8] (SOE) feature and its somewhat dominant application in many countries. As it has been applied in advanced-high income economies Canada by Murchison and Rennisson (2006), in the euro area by Smets & Wouters (2003, 2007) in the United States; Jokivuolle, Kilponen & Kuusi (2007) in the case of central bank of Finland; Burriel, Fernandez-Villervade & Rubio-Ramirez (2010) also applied it to the Spanish economy. In the case of middle and low-income economies, its application in Jakab & Vilagi (2007) for Hungarian central bank; Gelain & Kulikov (2009) applied it in Estonia and Central Bank of Nigeria (2013). The SOE variant at best is only able to capture the open nature of the developing economies. However, its adequacy and applicability in developing economies leave a lot to be desired.

Unlike the case of Nigeria in Mordi *et al.* (2013) and Adebiyi (2016) that were restricting their specification to the baseline model. The need to apply a DSGE model that reflects key and important feature such as the large and significant informal economy with economic agents that are optimizing based on informal labor market friction and informal firms (both final and intermediate) is very imperative. Unlike Sebate (2013), Esfandyari & Dahmardeh (2014), Haider *et al*. (2015), Dellas *et al.* (2017) and Batini (2011) who introduced informality using the labour friction but failed to introduce the informality in the household's objective function. Although Bandaogo (2016 and 2017) incorporates informality in the household objective function, he fails to give prominence to informal intermediate and final goods-producing firms.

[8] This is consistent with the model estimated by the CBN (2013).

It is noted that incorporating these key features concurrently, suggests a possible existence of asymmetries arising from the heterogeneity of economic agents. On one side, for instance, are representative agents that optimize objective function subject to intertemporal constraint and remit tax to the government. On the other side are agents with objective function subject to intertemporal constraint but do not pay taxes. With plausible representative agent differentiated by intertemporal optimizing constraints. Empirically, therefore the need to extend the standard log-linearized DSGE model in the spirit of Smet and Wouters (2003, 2007), which predominates developed and developing economies estimation of the DSGE is desired. Thus, this study intends to advance a Nonlinear DSGE model using Particle Filter in order to see the effects of macroeconomic shocks on SOOE with large shadow economy. Furthermore, the SOOE DSGE will bear aggregate structural equations that define the economy's aggregate demand and supply. Hence the model will be closed with optimal monetary and fiscal policy. That means this study will contribute to the ongoing debate on the role of informality in the macroeconomy and to empirically establish the propagation of shocks in the shadow economy.

1.5 Significance of the study

The outcome of this study will contribute to knowledge and serves as reference material for further studies in academics. Similarly, it will open up a better understanding of the framework and its applicability in developing economy like Nigeria. It will equally illuminate the inner working of the Nigerian economy to policymakers and academics.

1.6 Scope and Limitation of the Study

The scope of the study will cover the period 1990Q1 to 2017Q4. Thus, this is because data availability has restricted some of the variables. The accuracy of the secondary data will limit the study. Hence the accuracy of the findings may fall short of perfection. The use of proxies for unobservable variables such as the detrended natural logarithm of GDP to measure the output gap may induce biases in the estimates. Therefore, the marginal cost will use instead.

Also, some of the auxiliary assumptions needed to derive the SOOE are very strong and may not hold in the data.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides a review of the contending issues in the literature, focusing on conceptual clarifications, including an overview of stylized fact. It also reviews the key theoretical and empirical issues relating to macroeconomic models building.

2.1 Conceptual Literature

This section focuses on the conceptual literature review. Therefore, the review of various concepts that relate to the economic phenomena of the study is presented.

2.1.1 Concept of Small Open Economy

In discussing the concept of a Small Open Economy (henceforth, SOE), within the scope of this study, both the institutional and empirical perspectives of the concept, are put forward. It has been established by empirical studies, such as Sutton (2011) and Quintna (2013) and accepted by global institutions such as World Trade Organization (2003) and Food and Agricultural Organization (2002) that SOE is generally economies whose output and income are small[9] relative to world market output and income. However, the International Economics Glossary (2011) extends the meaning of SOE as a concept to include any country who is a price taker in the world market.

One complication with the extension made by International Economics Glossary is that, while an economy may be price taker in some product it may not necessary be true for all products. Thus, this is particularly peculiar to countries that have specialized in the production of some products, hence attain economies of scale in the production of these products that it has a comparative advantage over any other competitor in the world market. Furthermore, the

[9] Small in the sense that SOE's output or income cannot influence the world market output or income.

concept, as followed in the literature, does not embody the openness feature that is often reflected in open economies as desired in an open DSGE model.

Thus, this study will pitch a tent in the use of the concept in terms of policy and relative output. Therefore, the concept of SOE strictly refers to as an economy whose output is small relative to the world market output (this means a change in the country's output will not affect the output from the rest of the world). Secondly, it monetary and fiscal policy decisions (of both interest rate and government expenditure) does not affect the rest of the world interest rates or expenditure, yet it responds to changes (or shocks) that could emanate from the world market. Hence the necessary condition for the SOE existence is on output criteria while the sufficient condition rests with the significance of the influence of policy decision (monetary and fiscal). The justification of adopting this conceptualization is to enable the two keywords of small (size of output) and openness to reflect on the conceptual definition, but more fundamentally, it is expected that the SOE responds to external shocks. As a caveat, the concept of SOE adopted in this study is consistent with the formalization of Obstfeld & Rogoff (1995) and Chari *et al.* (2002 and 2007) which underpins on the New Keynesian Open Economic framework.

2.1.2 Concept of Informal Economy (Informality)

There is a vast literature on the concept of the informal economy. The concept of the informal economy is believed to be coined by Keith Harter in his classic in 1973. It is also referred to as ***shadow economy*** or ***underground economy*** in the literature and is identified to be a somewhat complex concept in terms of definition. However, literarily, these terms are interchangeably used because; factors of production are considered to be used in the underground or the shadows. In trying to trace the conceptual origin of shadow or informal economy, one of the early attention in empirical studies is trace to Castells & Portes (1989). Their definition of the concept started with a blurry premise by arguing what the informal economy is *not* rather than what it is. The first attempt was not to restrict informality to mean marginal economic activities

carried out within the fringes of low-income economic activities. Castells & Portes (1989) enforce some social dimension to their definition. Divorcing the concept of informality from social marginality and economic dualism appears to be informed by the view that there is a linkage between the formal economy and the shadow economy. Hence this conceptualization is rather imprecise and more confusing.

A lot of arguments and disagreements have surfaced over the years in defining the concept, and it is apparent that the difficulty in the conceptual definition arises due to the variation in the measurement of informality. One of the dominant definitions which are followed by Feige (1979, 1989 and 1994), Schneider (1994), Schneider & Enste (2000) and Schneider (2005), consider the underground economy as all currently unregistered economic activities but contribute to the official computed Gross Domestic Product (GDP) of a country. This definition may suffer when the unregistered economic activities that are included in the measurement of the GDP are taxable yet illegitimate[10] in terms of production. Therefore, the extent to which informality is defined has a close correlation with how it is measured. Hence, any acceptable definition must provide the limits of the economic activities that could be included in the measurement of informality in an economy.

A taxonomy is provided by Schneider (2006 and 2014) which classified the shadow economy that excludes illegal economic activities that are an addition to the GDP. He argued that even when untaxed productive economic activities account for a significant measure of the shadow economy, yet they cannot be possibly factored in the tax net of the government largely because its production is outside what the law prescribes.

On the contrary Smith (1994) define shadow economy as "market production of goods and services, which escapes official GDP detection irrespective of the legitimacy of its production.

[10] For instance, the production and consumption of illegal hard drugs like Indian hemp, cocaine and so on the are not included in the GDP and hence not taxable.

It is based on Smith's conceptualization that Jie *et al.* (2011) provided an extended taxonomy of the shadow economy that includes illegal economic activities. Therefore, the definition suggests that shadow economy includes all aspects of production that is insulated and unobserved by the government.

Motivated by the work of Hart (1973), Maloney & Saavedra-Chanduvi (2007) provided a definition based on three levels. At the first level, the study argues that shadow economy is characterized by labor, where workers that "prefer jobs with standard labor protection but unable to get" and workers that quit formal jobs and take up microbusinesses. The second level is characterized by micro-firms with no intention or potential for growth. Also, the micro firms are self-restricted to expansion in order to avoid formalization. The last level is characterized by firms avoiding taxation and order mandated regulation due to weak enforcement capacity of institutions. Also, these firms partake in only partial registration.

Therefore, based on the competing conceptual definitions, an important component that is responsible for the divergent of views on the concept of shadow economy the inclusion or exclusion of illegal economic activities such prostitution, drugs, gambling, human trafficking among others. These studies follow Feige (1979, 1989 and 1994), Schneider (1994), Schneider & Enste (2000), Schneider (2005), Maloney & Saavedra-Chanduvi (2007) and Schneider (2006, 2014), which excludes illegal economic activities in the concept. The justification for excluding illegal activities in the shadow economy is based on two reasons. The first is that the illegal activities hardly have an equilibrium market price due to its market abnormalities, hence even if the government wishes to tax, such tax becomes difficult. Secondly, it is excluded, because some of the illegal transactions are counterproductive to legitimate production and consumption due to their ability to distort consumption and welfare of individuals.

2.1.2.1 Causes of Informality

Just as the economy is dynamic over time, so does the shadow economy expand and contract due to the entry and exit of economic agents into the shadow economy. In this view, Schneider & Enste (2000) suggest an analogy that "shadow economy develops all the time according to the principle of running water." From there view, they suggest five major factors that cause informality. These include the *increased burden of tax and social security; increased intensity of regulation; the presence of social transfer; over-regulation of labour market; and decline in public sector services*.

Empirical evidence from Rei & Battacharya (2008) contradicts the cause of both the burden of tax and regulation of the formal labor market on informality. However, they argued, informality responds to weak institutions, which is also consistent with Dreher *et al.* (2005). Thus, this suggests that the prevalence of weak enforcement capacity in institutions or governance increases informality which supports an earlier finding in Loyaza (1996) and Hill & Kabir (1996) who argue in support of the role of tax as a cause of informality. Later findings in Hibbs & Piculescu (2005) also confirm the causative effect of the taxation.

Having identified the various causes of informality, there is a compelling reason to identify some reasonable causes that could be considered as causative factors. This study reflects on the causative effect of both exogenous factors like famine or crop failure, natural disaster, and catastrophic health disease. Also, endogenous factor such as macroeconomic shocks that leads to recession or inflation, as broad classification of causes of informality. Thus, in addition to that established in the literature. The justification for this brief taxonomy is the fact that all of these are sources of distortion in the economy. Hence economic agents could adjust by exiting the formal sector and enter the shadow economy. The exit and entry could be compelling by the absence of social transfer, especially in developing economies with low income.

2.1.2.2 Measuring Informal (Shadow) Economy

There are two distinct approaches to measuring informality or the size of a shadow economy based on the conceptual definition of a shadow economy (see also Batini *et al.* 2010). These are *direct* and *indirect approaches*. However, Frey & Schneider (2000), as well as Maloney & Chanduvi (2007), suggest an additional measurement of informality based on margins (sets of criteria) and the interest of policymakers. Thus, they consider three approaches to the measurement of informality. These include the *model approach* in addition to the direct and indirect approaches:

- **Direct approach**

This approach follows the microeconomic procedure which adopts either of survey data or results from a tax audit, from which an estimate of unofficial measured and unmeasured economic activity is obtained (see Batini *et al*, 2010). A key flaw of this approach is that it is sensitive to the questions posed on the respondent and the sincerity or truthfulness of the respondents.

- **Indirect (Indicator) approach**

This approach applies macroeconomic proxies, and there are four procedures of measuring the unofficial economic activity under this approach. These include determining the *differences between aggregate income and expenditure*; the second is by taking the *differences between the total labor force and formal employment*; the third procedure is the *monetary methods*, and the last is the *physical methods*.

- **Model approach**

This approach is a derivative of causes of informality. Identifying the cause of switching or moving from the formal economy to informal, which could be due to any of the three factors that include: need to evade the increasing burden of tax, weak institutional framework that

checks the activities of the shadow economy participation and disincentive of the high cost of production in the midst of poor infrastructure. Therefore, the model approach attempts to capture the shadow economy as an unobservable variable. Hence this is consistent with Chaudari *et al*. (2006).

As a caveat to the measurement approaches highlighted, the study takes caution due to the drawbacks of each of the methods. First, in the case of the direct method, though, it has the benefit of providing the actual structure of the shadow, it still falls short because most of the activities in the shadow economy are illegal, respondents may not reveal accurate and adequate information. That means the true reflection of the size of the shadow economy will still be insulated. Similarly, because the tax evaders are conscious of the penalty, the tax audit method of direct approach will still give an inconsistent outcome with the true reflection of the shadow economy. Therefore, for empirical purpose, the direct approach is limited provide only point estimates. Because the approach does not show the changes in the size of the shadow economy over some time (see also Frey & Schneider, 2005).

Secondly, the indirect approach has its fault because in determining the discrepancy between official national income and actual national income can be misleading. The difference may be due to inaccuracy in computation or measurement of the national income and may not be as a result of the hidden income in the shadow. The monetary method used in the indirect approach also has its pitfall. The gross failure of the monetary method comes from the assumption that the size of the shadow is a measure of all cash transactions made, which do not pass through the banking system. Thus, this is particularly faulty in developing countries where the banking habit is grossly lacking. It is also a query that requires a response when establishing a reference period or base period with which the discrepancy in income or labor participation can be measured to assume completely zero informality. The assumption that the base period is 100% formal is unscientific and a major flaw.

Therefore, this study will rely on the *model approach* in measuring the informal economy. The plausibility of modelling the informal sector in this study rests on the advantage offered by the Bayesian econometrics, which handles the problem of unobservable variables.

2.1.2.3 Informal Credit Market and Credit Market Constraint

In line with the rational theoretical assumption, this study expects that economic agents in both formal and shadow economy are optimizing agents. However, because the operational pattern of optimizing economic agents in shadow economy might be different, understanding the key features of the shadow economy helps to illuminate the constraint under which the economic agents optimize in the underground economy. From the evolving literature, there are two major streams in which the shadow economy can be modeled and incorporated into macro models. One strand of this literature focuses on the informal labor market behaviour, which the other strand dwells on the credit market. However, recent attempts have studied both components of informality together (see, for instance, Batini *et al.* 2011).

In the first attempt, we examine the informal credit market, under which the firms in the informal economy operate (demand for credit). Essentially the consensus in this literature is that credit markets in the developing economies are less developed (Hoff and Stiglitz, 1990; Madestam, 2009 and also Batini, *et al.,* 2010). As a result of the less developed nature of the credit market, there is segmentation in the credit market Barth *et al.* (2004) also Beck *et al.* (2004). Thus, this observation also corroborates (Batini *et al.,* 2010 and De-Lima, 2014).

However, the emergence of microfinance appears to have some weight on the influence of the informal credit market. This suggestion follows evidence found in China, as reported by Degryse (2008). Batini *et al.* (2010) reported that "there are mixed trends in the distribution of credit in the shadow economy in the presence of both formal and informal credit market." Hence, this suggests that formal credit supply is more accrued to relatively large firms while that of informal credit favors more of small firms. This argument lends support towards Gine

(2007). Therefore, due to limited credit size in the informal credit market, formal credit market supply credit to informal credit market (see Madestam, 2009 and Batini *et al.,* 2010). The cost of transfer of formal credit to informal credit market is suggested to be greater than prevailing cost of borrowing in the shadow market (see Banerjee, 2003 and also Batini *et al.,* 2010).

To greater extent the issue surrounding interest rate differential between the formal credit market and informal credit market can be linked to the asymmetry of information between the formal and shadow economy. This asymmetry is the cornerstone in situating the informal credit market in the imperfect market, and this view supports by Ghosh and Ray (2001). Since higher interest rate charges in the informal credit has been pin down to asymmetry, it is apparent that credit allocation in the money market (by either microfinance bank or rural moneylenders) might suffer from adverse selection, moral hazard of borrowers and by extension the externality associated with the cost of searching for creditworthy borrowers.

Intuitively it is feasible that high externality of searching for either lender or borrower may further increase the cost of credit. Hence this could be seen as a source of informal credit market friction and credit constraint facing the informal firms.

In response to the problem of asymmetry Ghosh & Ray (2001) survey of the informal credit, market pointed out rationing of credit as a rational attempt to smoothing the effect of asymmetry that could exclude non-collateral informal firms from partaking in the credit market. Thus, this does not imply the need for strengthening the institutional environment (borrowers bargaining power and competitiveness) to ensure enforceability as argued. Batini *et al.* (2010 and 2011) contribution to the argument follows in the spirit of Yunus & Weber (2007), which were consensus to initial argument.

Batini *et al.* (2010) provided evidence of informal credit constraint. The survey of the literature indicated that it is the forward and backward linkage between the formal and informal credit market and the associated information gap that creates credit constraint. They identified two

frameworks that account for credit constraint. The vertical and horizontal linkages describing the behavior of the linkages between the informal credit market and the formal money market appear to shed light on the existence of the informal credit market constraint. The argument in favour of the vertical linkage is that the informal credit market has a direct link in terms of accessibility with the formal money market.

Despite divergent of opinion within the proponent of the vertical link hypothesis in terms of how the changes in the formal credit market affect the informal credit, there is common consensus within them. That is, decrease (increase) in the cost of credit in the formal credit market which may be in the form of government subsidies to agriculture will lead to an influx of moneylenders in the informal credit market. Therefore, this results in high transaction cost due to the inclusion of more borrowers with a high risk of default into the informal credit market. This view is consistent with Hoff & Stiglitz (1997), Bose (1998) and Madestam, (2009) which means that the informal credit market is vertically linked to the formal credit market through the interest rate channel.

On the other hand, the proponent of horizontal linkage of informal credit market opined that there is a competitive behavior between formal and the informal lenders in the shadow economy for borrowers. In this case, microfinance or cooperatives partake in the informal credit market and offer a competitive rate to the borrowers. As such, there is no direct linkage between the formal and the informal, but rather there exists a lateral link between them.

The literature report on the causes of credit constraint in the informal economy is tied to the work of Ghosh & Ray (2001) also Madestam (2009). The argument on the source of credit constrain stem follows from the assumption that firms in the informal economy lack the requisite collateral to participate in the formal credit market. Therefore, in the presence of imperfection in the credit market due to the asymmetry between the borrowers that are searching for lenders and the lenders that are in search for borrowers and the externality

associated with the search march creates trading friction (see also Wasmer & Weil 2004, Batini 2010). Thus, this means that trading friction in the credit market increases as search-march decreases due to imperfect market condition. The credit market friction serves as discouraging force to informal credit market lenders because of the increased probability of finding a borrower. The high cost of externality in searching is accentuated by the exit of money-lender from the informal credit market because of the increasing cost. The falling out of moneylenders from the informal credit market creates a credit gap in the informal credit market. Hence the credit gap explains the credit constraint faced by firms in the shadow market.

2.2 Empirical Regularities and Stylized Facts

This section presents the stylized fact on any model that incorporates informality must internalize.

2.2.1 Causes & Size of Shadow Economy: Empirical Regularities

The causes and sizes of the shadow economy in most developing countries appear to differ considerably. The reason for variation in size may not be farfetched from the dynamics in the economy. Hence because of the size changes in response to economic fundamentals such as recession (increase in inequality and poverty) or boom (increase income and employment) which increases or reduces the size respectively. Changes in the size might also be as a response to fiscal policy (effects of tax evasion).

Table 2 1 Causes of Shadow Economy in Africa (1999-2003)

Cause variable	**Estimated coefficient (%)**
Share of direct tax	16
Share of indirect tax & customs duties	25.6
The burden of state regulation	30.9
Unemployment quota	29.9
GDP per capita	-15.1
Effect of past size of shadow economy (lag endogenous)	34.1

Source: Schneider (2014)

Over the years, empirical studies such as from Schneider (2014), provided evidence of empirical on both the cause factors and the size of the shadow. The study suggests four causes of informality in Africa which are; share of direct tax, the share of indirect tax & customs duties, the burden of state regulation (proxy by Heritage index), unemployment quota and GDP per capita. The table below shows the size of the cause factor of the shadow economy:

According to the evidence, indirect tax and customs duties are more significant in causing an increase in shadow economy than direct tax. However, in terms of magnitude, the burden of state regulation contributes more to informality than any of the enlisted causes in Africa. This evidence provides the fact that more unemployment provides more incentive for informality, and an increase in GDP per capita reduces the size of informality. This evidence further supports the notion that an economy with a high and increasing level of unemployment will have more growth in informality with about 30%. As such, the observed level of unemployment in Nigeria is a panacea for an increase in the level of informality.

The empirical regularities in terms of sizes of informality using two different measurements, which follows Schneider (2014) and Frey & Schneider (2005). The first measure using relative percentage share of GDP indicates that the relative size of the GDP accounted by the informal sector in Nigeria over three years, which averages at about 58%. However, this is above the continental average, which averages at 42%, year on year growth from 1999 to 2003.

Table 2 2: Size of Shadow Economy in Nigeria in % of GDP

Country	1999-2000 (YoY)	2001-2002 (YoY)	2002-2003 (YoY)
Nigeria	57.9	58.6	59.4
Weighted Africa average	41.3	42.3	43.2

Source: Schneider (2014); YoY means Year-on-Year

The trend of the evidence presented in Schneider (2014) shows for the period under review, the relative size of the informal sector increases over time from about 58% to 59%. Thus, this indicates the dynamic nature of the sector in terms of how it expands over time.

Following Frey and Schneider (2005) who estimate the size of informality in Nigeria, using the share of electricity consumption indicates that the informal economy accounts for about 68-76 percent of electricity consumption. Therefore, the evidence further suggests that the relative size of the informal sector is substantially large.

Table 2 3: Size of Informality in the 1990's: Based on Electricity Demand

Countries	**Size**
Egypt	68-76%
Morocco	39-45%
Nigeria*	**68-76%**
Tunisia	39-45%

Source: Frey & Schneider (2005)

Comparing the size of energy consumption in the informal sector in Nigeria with some frontier developing African countries. The evidence from Frey and Schneider (2005) indicates that only Egypt has equal proportion with Nigeria. However, given the relative population size of the two countries in terms of population and GDP, it is deducible that the informal sector in Nigeria outstrips that of Egypt. Furthermore, the result points to the relevance of countries' population size in determining a possible magnitude of the informal sector as the evidence suggests. Morocco and Tunisia with approximate similar population size tend to have almost equal informal sector energy consumption.

2.2.2 Macroeconomic Fluctuations in Nigeria

The following are some stylized facts on the macroeconomic fluctuation of the SOOE. The business cycle estimate is based on the Hodrick Prescott. The evidence indicates that cyclical fluctuation of varying magnitude remains prominent as well as a permanent feature of the Nigerian economy, which in line with Agenor, Dermot & Prasad, (2000). The summary of their evidence shown in table 2.4 substantiates the persistence of the fluctuation over a complete cycle.

Table 2 4 Main Feature of Macroeconomic Fluctuation in Nigeria: Stylized Facts

Domestic Output Business cycle: Cross-Correlation

Cyclical Behaviour	8-quarter lag	4-quarter lag	Zero-lag	4-quarter lead	8-quarter lead
Industrial output	0.22	0.26	0.03	-0.22	-0.05
World real interest rate	-023	0.32	-0.01	-0.05	0.22
Price level	0.01	0.14	-0.23	-0.05	0.16
Inflation	-0.02	0.08	-0.27	0.16	0.14
Broad money (M2)	-0.05	-0.18	-0.14	0.22	0.00
Velocity of M2	0.15	-0.10	-0.48	0.21	-0.02
Trade balance	0.00	-0.02	0.46	-0.19	-0.32
Nominal effective exchange rate	0.06	-0.13	-0.04	-0.13	-0.14
Real effective exchange rate	0.08	-0.06	-0.09	-0.19	-0.12

Source: Agenor, Dermot & Prasad (2000)

The evidence reveals that across diverse macroeconomic variables, cyclical fluctuations are volatile. Thus, the economy responds to both domestic and external shocks. The amplification of the fluctuation depends on the macroeconomic variable and the source of the shock.

2.2.3 Overview of Macroeconomic Models in Nigeria

The first macroeconomic model developed for the Nigerian economy was Ojo (1972), which targets at enhancing contributions into the preparation of a medium-term plan during the first National Development Plan (NDP) (1962-1968). In addition to meeting the short-term needs of the period. The structural form of the model was rooted in the Keynesian aggregate demand-driven philosophy with an external sector which incorporates variables such as private consumption, private investment, exports, and imports were endogenized, and variables like government consumption and investment expenditures were exogenously determined.

The model included the agricultural sector (3 equations), external sector (2 equations), and public sector (4 equations). The dynamic specification of the model was estimated using the method of 2-stage least square and tested the predictability of the model. The estimated model showed that the multiplier effect of a change in ROW output was very large on Nigeria's output. There are four (4) major shortfalls of this model. These are its lack of incorporating the

monetary sector, non-existence of inflationary effect on macroeconomic variables, absence of production side, and demand for labour functions.

The construction of the macroeconomic model by World Bank (1974), was design to stimulate an economic growth that was consistent with growth in agriculture and oil sectors. The model was also rooted in Keynesian aggregate demand-driven philosophy. It introduces a two-gap model which specifies investment/saving functions on the one hand, and the export-import functions on the other (Mordi, 1988 and CBN, 2010). A prominent element of the model was the employment-income nexus, which was used to stimulate demand for employment and income in each sector (CBN, 2010). The outcome of the model was applied in constructing national income accounts and compute consumption, investment, and employment. The structural form of the model contains 105 relations. There two (2) primary challenge of this model, the problem of the irreducibility of the equation and failure to incorporate the monetary sector.

The macroeconomic model put forward by Uwujaren (1977) represents the third econometric model of the Nigerian economy. The medium-term development plan of the late 1970s specifically anchored on it as a guide. Hence the model has the step-up of the Ojo's (1972). It augmented the money and price blocks into his model, including the demand and the supply sides of the economy, which were lacking in the first macro model put forward by Ojo (1972). It took a collaborative effort of Olofin *et al.* (1977 and 1985) and Centre for Econometric and Allied Research (CEAR) to usher in the first multi-sector macroeconomic model that was flexible in forecasting and projecting macroeconomic aggregates for development plans during the 1970s and 1980s. This model provides the impetus for landmark advancement in the construction of two distinct macroeconomic models by CEAR (2006), which targets at generating forecasts for the second phase of National Economic Empowerment and Development Strategy (NEEDS II) 2007-2011. The two macroeconomic models were MAC

III and MAC IV. Thus, the structure of the models was identical to Olofin *et al.* (1977), except that they are more detailed because of the disaggregated approach entrenched in the models. The additional refinement upgraded the applicability of the model. Hence, they are considered to be the first macroeconomic models that became operational for the Nigerian economy.

The baseline element of the models (MAC III and MAC IV) constitute eight blocks, which are: supply, aggregate consumption, capital formation (investment), labour demand and supply, wages and prices, public sector, monetary, and foreign trade sectors. The supply block of CEAR-MAC III was further disaggregated to nine sectors, these include (crop, livestock, forestry, fisheries, oil & other mining, manufacturing & crafts, utilities, construction, transport & communication, public sector & other services). Thus, the supply block in CEAR-MAC IV model was extended by disaggregating it into twelve sectors.

Based on the report of CBN (2010) indicates that the structural form of the CEAR-MAC III model comprises of 43 stochastic equations and 54 identities, which constitute 97 endogenous variables and 28 predetermined (policy) variables. On the other hand, CEAR-MAC IV model constitutes 137 equations. Where 76 are stochastic equations and 61 identities specification. The significance of oil revenue, fiscal, and monetary policy were well entrenched in these models.

There are two prominent flaws of CEAR MAC III and MAC IV. The first is the application OLS in a set of dynamic models producing parameter estimates which were biased and not consistent. To a large extent, inefficient because of the small sample data size from 1969-1981. The second weakness of the CEAR models is the weak linkage of the monetary and financial block to the other blocks.

According to CBN (2010) between the period of 1983-1984, Nigeria Institute of Social and Economic Research (NISER) constructed a macroeconomic model consisting of seven blocks which include: production; the balance of payments; aggregate demand; external sector; labour

sector; price and monetary sector. The structural macro model comprises of 77 structural models, that are further classified into 44 are a stochastic equation, and 33 are identities equations. The production or output block consists of 18 stochastic equations, 10 behavioural equations, and 8 identities. From the 10 stochastic equations, 5 are agricultural sector-specific and 1 (one) for each of manufacturing, oil sector, other mining, utilities/construction sector. The benefit of disaggregating the mining sector into oil and other mining enhance endogeneity in the estimation of the production block.

The composite of the demand block were 17 equations, which composed of 6 behavioural equations and 11 identities. The behavioural equations were further disaggregated into aggregate consumption, aggregate investment, and government taxes. Foreign trade block is made up of 16 stochastic equations, 11 behavioural equations, and 5 identities. From the 11 behavioural equations, 5 were specified for aggregate export, where one equation is a specification of the following categories of export: food, raw materials, oil & refinement, and miscellaneous exports. There were 6 behavioural equations under imports, where each is representing: food, raw materials & intermediate products, capital, manufactured goods, and other unclassified commodities.

In terms of specification, the exports followed the export-demand approach. Thus, the imports internalize level of foreign exchange reserves as exogenous, which justifies the constraint to the level of aggregate import into the country. The labour demand block comprises of 6 equations and a single identity and other behavioural equations. Thus, the aggregate labour supply specification has an aggregate labour force stochastic equation.

The price block of the NISER macroeconomic model was made up of 11 equations, out of which are 9 behavioural equations and the remaining are identities equations. An implicit deflator equation was introduced for each of the sectors. The inflation dynamics was captured as general prices, and it was also disaggregated into food prices and housing. The monetary

block consists of 5 equations, behavioural are 3 equations, and the remaining 2 are identities equations. The specifications of the behavioural equations are the currency in circulation equation, demand deposits equation, and time deposits equation. The other reaming 4 equations in the NISER macro model are all identities equations and are specifications if the balance of payments block.

Even when the NISER macro model is considered to be the most disaggregated model, yet it has its faults. In respect of the weakness of NISER macroeconomic model. There appear to be two (2) major concerns, one of which is it suffered a weak linkage between the monetary block and other aggregate blocks which is inherent in the CEAR MAC III and MAC IV. The second issue is the estimation procedure used. In which the estimation was conducted in a repeated block by block using the OLS method. Notwithstanding, the NISER model attained one of the highest levels of disaggregation ever, of any model of the Nigerian economy.

The National Planning Commission/Federal Office of Statistics, in 1985 assign the Aboyade committee to construct a feasible Input-Output (I-O) table for the Nigerian economy. Thus, this was used as a framework that illuminates the linkages between the various sectors in the economy. Hence the I-O table multiplier and the technological coefficients, as well as the Leontief matrix inversion, were computed for the Nigerian economy. The constructed I-O table was made up of more than 60 sectors, and the intersectoral linkages were well entrenched in the I-O. According to the CBN (2010) document, in addition to the 1985 I-O table, another I-O table was constructed for the economy 1987. These tables reinforce the linkages that were lacking in the previous macroeconomic models. It also highlights the growth of potentials and the interlinkages within the various sectors. The I-O table in the later period has 19 sectors, and it became the benchmark for NISER policy analysis. In the mid-1990s, the table was updated to guide the general equilibrium in the multiple sectors of the Nigerian economy. Even with

the wide prospect of the I-O model, the shortcoming of the framework was apparent. Largely due to the absence of macro policy feedback in the model.

In the new millennium, Iyoha (2003) took stock of the earlier macro-econometric models put forward by Ojo (1972) and Olofin *et al.* (1977) among others. A moderate 5 sector macro model was deduced, which was made up of 39 structural equations. Where 20 are stochastic equations and the remaining 19 identities equations. The specification of the model includes aggregate domestic expenditure; public sector; external sector; aggregate production; including price & monetary sector. Even though the estimation of the model using OLS and simulation to confirm the robustness of the model. The model was found to be weak and incapable of incorporating financial sector and policy changes in the economy.

In 2010 the CBN, African Institute of Applied Economics (AIAE), CEAR, NISER developed a macro-econometric model for the Nigerian economy. The model was made up of 6 major blocks, which include: aggregate supply, private demand, government, external, monetary &financial, and the price block. The production block was disaggregated into oil and non-oil sector. The private demand constitutes private consumption and private investment. The investment component was further broken down to oil and non-oil investment. The government block has recurrent government expenditure and government revenue. Also, the revenue side was further disaggregated into oil and non-oil revenue. The external block breaks into trade balance, export (oil and non-oil), import, and remittances. The monetary block was disaggregated into a net foreign asset, net domestic credit (credit to private sector and credit to the government) and demand for real money balances. Also, the price block has headline consumer price index, nominal exchange rate, domestic maximum lending rate, and the GDP deflator. The model was estimated using the OLS, and the dynamics were captured using the Error Correction Model (ECM). The estimate and the result of the simulation attest the parsimony and the robustness of the model. However, the model is not devoid of some fault,

one of which is the absence of the labour demand equations, and above all, the model lacks in micro-foundations. The issue of autocorrelation, multivariate forecasting the seasonal adjustment makes the model susceptible to diagnostics failure.

2.3 Theoretical Literature

The theoretical foundations of macroeconomics traces back to the 16th-century monetary theory of Martin Azpilcueta, who initiated the *quantity theory of money*. In the 19th century, the business cycle theory of Stanley Jeavons provided another dimension to macroeconomics. However, it was Keynes General theory that provided an impetus for modern macroeconomics, and since the inception of Keynesian economics in the 1930s, various theoretical extensions to macroeconomics has been made. The desire for advancement in the approaches informs by defects in the existing approaches. After the Keynesian macroeconomic postulates in 1936, two approaches confront the development of macroeconomics. The first is the theoretical approach as followed by John Hicks IS-LM framework in 1937, and the other approach is the Structural Macroeconometric modeling approach as followed by the Cowles Commission.

The parallel approach to the theoretical methodology taken by the Cowles commission had its roots in the work of Alfred Cowles and the Econometric Society led by Irving Fisher in 1932. The Macroeconometric approach emphasis the relevance of methods as against theoretical interrogation. The Cowles foundation advanced the econometric methods from two standpoints. First is the relevance given to probability, and the second is the construction of the model as a system and the inclusion of the random term (see Fair, 1992 and Malinvaud 1983 as cited in Snowden & Vane, 2003).

In providing the progress and journey under the theoretical approach, it is identified that Hicks was the first to synthesis the Keynesian postulate into the classical general equilibrium framework in 1937. The central thesis of the Hicksian IS-LM framework is the role of interest rate on money supply and how it determines investment and output. As an extension of the IS-

LM framework, Franco Modigliani incorporated labor market into the general equilibrium IS-LM in 1944. He provided evidence of unemployment in the presence of nominal rigidities within the framework. This development paid attention to the short-run perspective of the Keynesian postulate.

The long-run aspect of the Keynesian postulates was fashion into the growth models, even though the development in this area embodies more of the neoclassical doctrine. The earliest contributors are Roy Harrod and Evsey Domar. Their major argument center on the accelerator model of investment and the equivalence of growth to the ratio of saving rate to that of capital-output ratio. The climax of the long-rum macro model is found in the work of Robert Solow and Trevor Swan, which was championed in 1956.

The implicit treatment of price level in the tradition IS-LM insulated behaviour of the price level in the Keynesian macroeconomic as such A. W. Philips, in 1958, took up the challenge of explaining the persistent inflation of the late 1950s. Hence the core argument is the tradeoff between inflation and unemployment. This phase of the development of macroeconomics was short-lived because of the emergence of the monetarist thesis by Milton Freidman in the 1960's and Robert Lucas critique in the 1970s. After the critique comes along a response that serves as a major watershed to modern macroeconomics in the seminal work of Kydland and Prescott in 1982, this provided the foundation of the Dynamic Stochastic General Equilibrium (DSGE) Model which was extended into the New Keynesian model (see Snowdon and Vane, 2003).

In the light of the journey so far, the Lucas critique was a fundamental turning point for both approaches (theoretical and structural macro-econometrics). Each approach will be reviewed on its merit in addition to the fundamental critique by Robert Lucas. Hence the reference point for the review to be used is pre and post-Lucas critique.

2.3.1 Traditional Modern Theoretical Approaches (IS-LM)

Essentially the traditional theoretical approach to macroeconomics can be grouped according to their thought (central arguments) and policy prescription. The dividing line is clear between the traditional arguments. Therefore, competing for theoretical thoughts are as follows:

2.3.1.1 Classical Macroeconomic Theory

The classical macroeconomic roots on demand-side which was founded on the quantity theory with a demand function for money that is interest inelastic and a constant velocity of circulation. The aggregate demand is given by:

$$AD = M/kY \qquad (2.1)$$

Where$\boldsymbol{AD}$is the aggregate demand, $\boldsymbol{M}$ is the aggregate money supply,$\boldsymbol{Y}$ is the aggregate output and$\boldsymbol{k}$ is the constant of proportionality that determines the velocity of circulation. The supply is argued to be driven by market forces. Therefore, the market is assumed to be perfect, and prices are flexible. Also, due to the instantaneous adjustment of the market aggregate supply is vertical at potential output. The classical contends that both fiscal and monetary policy do not affect employment or output.

In terms of the policy, the classical macroeconomic theory holds that since the liquidity preference equals money supply (LM curve) is vertical, any attempt to expand output will only affect aggregate demand and only prices will rise. Similarly, an effort to use expansionary policy to increase output will only lead to crowding-out of private investment by increasing the cost of borrowing (see also Snowdon and Vane, 2003).

There is no doubt that the market mechanism upon which the classical relied heavily on is efficient. However, the extent of efficiency of the market depends on perfect information; the existence of asymmetry of information have grossly undermined this strong assumption (see Stiglitz & Weiss 1992). It is also true that the use of monetary policy to expand output can lead to inflation, but this is only true when the economy is operating at its potential or very close to

its potential. The argument about the neutrality of on money and the independence of money demand on interest rate is entirely flowed because of the role interest rate has on investment demand (see Gali and Gertler, 1985). Also, the instantaneous adjustment believed by the classical and the irrelevance of the fiscal policy culminated in the great depression of 1929, which has led to more job losses and market failure. Therefore, the classical macroeconomic theory is highly defective in both its arguments and policy prescription in macroeconomic management.

2.3.1.2 Keynesian Macroeconomic Theory

Building on the weaknesses and failures of the classical theory, the Keynesian theory initiated a new foundation with a more aggregate demand side economics. The Keynesian theory relaxed the flexibility assumption of the classical, which gave the impetus for the instantaneous adjustment., the Keynesian theory using the aggregate demand management strategy argues that fiscal policy is effective in increasing aggregate demand. Significance dwells on the autonomous component of the aggregate demand. The theory points out that expansionary fiscal policy will dis-equilibrate the goods market and the position of investment equality to savings (IS) will depend on the ratio of the money supply to general prices (see Coddington, 1976:1258-73). The expression of the theory provides that:

$$C(Y - T) + I(r) + G \qquad 2.2$$

Where $\boldsymbol{C}$ is the aggregate consumption, $\boldsymbol{Y}$ is the aggregate output, $\boldsymbol{T}$ is the lump-sum tax, $\boldsymbol{I}$ is the aggregate investment, $\boldsymbol{r}$ is the interest rate, and $\boldsymbol{G}$ is the aggregate government spending.

The Keynesian theory went further to hold a strong position about the ineffectiveness on the monetary policy. That investment is irresponsive to the interest rate. Even when:

$$L(Y, r) \qquad 2.3$$

Where $\boldsymbol{L}$ is the liquidity demand, and $\boldsymbol{Y}$ is the aggregate income. This suggestion provides the liquidity trap, and hence, the aggregate demand (henceforth, AD) is not responsive to monetary policy (see Patinkin, 1990).

It is true in the Keynesian theory that fiscal policy is effective, but the effectiveness might be at the detriment of investment, especially when the interest rate adjusts upward due to crowding out. Since investment is highly responsive to interest rate, dependence on fiscal policy might not clear the factor market. Similarly, the Keynesian theory failed to incorporate expectation when fiscal policy is carried out to increase employment. The culpability of the Keynesian theory to expectation is a significant failure because economic agents learn from a policy change that affects prices.

2.3.1.3 Monetary Macroeconomic Theory

The monetary theory made three key contributions that highlight the defects of the Keynesian theory. First, the theory argues that investment is highly sensitive to the interest rate as such, it contends on the flatness of the IS –curve. Impliedly, it means the fiscal policy is ineffective because of the crowding-out effect it has on private investment. Secondly, the theory introduced Adaptive Expectation into its theory to explain how economic agents learn from previous policies. Lastly, the monetary theory argued that the demand for money response to the interest rate is low as such the money demand follows the classical money demand (see Blinder, 1988: 278-94). The theory contends that monetary policy has a real effect on general prices. That is:

$$M = kPY \qquad 2.4$$

That changes in the money supply will have a direct effect on prices by almost the same magnitude. The theory further argues that the real effect of any change that may come from the output (Y) will depend on expectation and the disequilibrium and wages in the factor market. Hence according to the monetarist because agents are backward-looking and adjust adaptively,

at equilibrium any further change in monetary policy that affects real output and employment is only temporary.

Given that monetary policy is effective in managing the general price level. This argument is only true when the economy is in the short-run equilibrium. The use of monetary policy is ineffective when the economy is operating at potential or close to potential. The monetary policy is also ineffective when there is a liquidity trap. The introduction of adaptive expectation in the monetary policy has important consideration in macroeconomic management. However, this is only a narrow and incomplete treatment of expectation because economic agents are not only backward-looking, as suggested in the adaptive expectation hypothesis. In addition to backward-looking, agents are equally forward-looking which is consistent with the rational expectation hypothesis (see Friedman, 1968: 1-17; Mayer, 1975: 191-215; Laidler, 1981: 1-28 and Modigliani, 1988: 3-18).

2.3.1.4 Neo Classical Macroeconomic Synthesis

Within the traditional macroeconomic theory, the neoclassical synthesis emerges as a result of the combination of short run features of the Keynesian macroeconomics and the long run elements of the classical macroeconomics. Two major stages emanate as a result of the traditional synthesis. The first synthesis holds a strong feature of the Keynesian nominal wage rigidities. The synthesis assumed the aggregate supply (AS) shape is upward sloping and is subsumed as the Philips curve. Therefore, disequilibrium in the factor market will be restored by the use of the combination of appropriate fiscal and monetary policy. The second stage of the synthesis bears a stronger feature of the classical, in that it argues that nominal wages are fully flexible while prices have some frictional adjustment due to backward-looking behavior in the adaptive expectation (see Laidler, 1986: 27-55). The synthetic representation provides that:

$$IS: Y = \bar{C} + cY + \bar{I} - br \qquad 2.5$$

$$LM: \frac{M}{P} = kY - \beta r \qquad 2.6$$

Therefore, the equilibrium prices and output are given by:

$$P = \frac{bM}{[(1-c)\beta + bk]Y - \beta(\bar{C} - \bar{I})} \qquad 2.7$$

and

$$Y = bM + \frac{\beta(\bar{C} - \bar{I})P}{[(1-c)\beta + bk]P} \qquad 2.8$$

Where β and b are the sensitivity of money and investment to interest rate, respectively. After incorporating adaptive expectation, the synthesis provides:

Goods market as:

$$C = C_0 + b(1 - \emptyset)Y \qquad 2.9$$

$$I = I_0 + \beta(i - \pi^e) \qquad 2.10$$

Money market as:

$$lnM_d = kY - \gamma i \qquad 2.11$$

$$lnM_s = lnM - lnP \qquad 2.12$$

The AD is express as:

$$Y = \frac{C_0 + I_0 + G + \frac{\beta}{\gamma}\ln\left(\frac{M}{P}\right) + \beta\pi^e}{1 - b(1-\tau) + \frac{\beta k}{\gamma}} \qquad 2.13$$

$$Y = \alpha_0 + \alpha_1(lnM - lnP) + \alpha_2\pi^e \qquad 2.14$$

Where

$$\alpha_0 = \frac{C_0 + I_0 + G}{1 - b(1-\tau) + \frac{\beta k}{\gamma}} \qquad 2.15$$

$$\alpha_1 = \frac{\beta/\gamma}{1 - b(1-\tau) + \frac{\beta k}{\gamma}} \qquad 2.16$$

$$\alpha_2 = \frac{\beta}{1 - b(1-\tau) + \frac{\beta k}{\gamma}} \qquad 2.17$$

However, after the Lucas critique, the synthesis augments the AS to incorporate the rational expectation as the augmented Philips curve:

$$\pi = \lambda(Y - Y_n) + \pi^e \qquad 2.18$$

In all stages, before the Lucas critique, the Neoclassical synthesis macroeconomics have done so well in synchronizing the appealing features of Keynesian macroeconomics with the classical macroeconomic fundamentals. The outcome has produced substantial improvements

in the use of both fiscal and monetary policy. The early synthesis was susceptible to the Lucas critique because of poor modeling of expectations and the inability to internalize policy invariant parameters. Even after addressing the key issue of the Lucas critique, the early syntheses presented are culpable and lack microfoundations.

2.3.2 Cowles Commission Structural Macroeconometric Models Approach

A parallel approach to the theoretical approach is the structural macroeconometric approach. The Cowles Commission foundation introduced the simultaneous equation system (pioneered by Tinbergen, 1939) and the general equilibrium model (championed by Dresch, 1937, 1940). These macro models have representation as:

$$Y\Gamma = X\beta + U \qquad 2.19$$

Where $\boldsymbol{Y}$ is the vectors of dependent variables, $\boldsymbol{X}$ is the vector of explanatory variables and $\boldsymbol{U}$ is the vectors of error terms in the structural models.Γ^{11} and $\boldsymbol{\beta}$ is the coefficient of the regressors and regressants respectively.

The first issue with general equilibrium macro model and the simultaneous system is the difficulty in obtaining data set for all the variables in the model since the parameters are estimated using the Least Squares method. Both systems of the equation are subject to the issue of irreducibility, which is concerned with autonomy and identifiability of parameters in the system.

The second phase of the Cowles Commission approach invented the maximum likelihood estimation, which was based on the seminal work of Koopmans & Rubin (1953). This introduction eased the issue of identification and the challenge of irreducibility. Furthermore, issues surrounding the simultaneous equation concerning dynamic specifications with lagged dependent variables, multivariate forecasting, and seasonal adjustments surfaced in the Cowles

[11] This is in case where the system of equations is endogenized

approach. Other issues facing the simultaneous equation model includes efficient estimator for the parameters and the autocorrelation of the residuals, as well as long distributed lags with without prior information about the lags.

The advancement by Cowles Commission approach was the development of efficient estimator with prior information as motivated by (see Hooper, Hendry & Fair 1973 as cited in Malinvaud, 1983). Hence the specification, estimation, and analysis of macro-econometric models provided a leap for the simultaneous equation model. However, the improved simultaneous equation macro-econometrics is lacking in micro-foundations, and it is subject to specification bias.

2.3.4 Microfounded General Equilibrium Models

These categories of macroeconomic models have carved a niche in modern macroeconomics. They have offered an important feature of micro-foundations to macroeconomic models which earlier models are lacking. There are three major types of micro-founded general equilibrium models. There are Computable General Equilibrium (CGE); Real Business Cycles Dynamic Stochastic General Equilibrium Model (RBC's DSGE) and New Keynesian Dynamic Stochastic General Equilibrium Model (NK DSGE).

2.3.4.1Computable General Equilibrium Model

Standard CGE models are built based on general equilibrium theory in the spirit of Leontief's (1930). The models amalgamate behavioral optimizing conditions on rational economic agents and the analysis of the equilibrium criteria. The solutions of the market equilibrium conditions are obtained based on the differentials of the system of equations for relative changes in the variables of interest. The underlying framework of theoretical tractability of the CGE is consistent with the circular flow of income. The model builds on two distinct components: (i) the model equations which define the variables (ii) database. Both components are illustrated

with the aid of the algebraic framework. The number of algebraic equations in the CGE can extend to hundreds of equations, depending on the number of variables of interest.

A major strength in the CGE models is the micro-foundations in which it incorporates economic agents that are assumed to maximize profits subjects to technology, which is consistent with the Constant Elasticity of Substitution (CES) function and institutions, which represents the government, household and rest of the world. The Social Accounting Matrix (SAM) captures institutions (households).

Despite the strength of the CGE, it also bears some fundamental limitations, one of which is that the model is loosely and inconsistent with the assumed fundamentals of the general equilibrium tenets. It is faulted for accommodating non-market clearing attributes, which is inconsistent with the general equilibrium model. Without a theoretical basis in the framework, it provides imperfection in the commodity markets. Similarly, it includes government institution into general equilibrium, and this negates the foundation upon which it is built[12]. Another shortfall of the CGE is that it only provides for static general equilibrium analysis. Its inability to handle dynamic equilibrium conditions in the framework makes it somewhat defective in handling more realistic macroeconomic phenomena such as cyclical movements of the economy.

2.3.4.2 Real Business Cycle Dynamic General Equilibrium Model

The Real Business Cycles (RBCs) models are rooted in the seminal work of Kydland and Prescott (1982). This category of the macroeconomic model has significantly shaped the landscape of modern macroeconomics as a whole. The RBCs model adequately addresses the fundamental flows (Lucas critique), which earlier synthesis suffered. The key assumptions that cushions the concern of the critique are: firstly, the model introduced economic agents that

[12] Absence of market intervention is important, hence

optimize intertemporal objective behaviour (functions) under respective constrains. Thus this implies that both firms and household optimize profit and lifetime utility respectively. Firms optimize subject to prices of factor input and technology while household maximizes subject to lifetime income. Secondly, the model assumed economic agents that form the optimizing decision based on rational expectation[13]. Therefore, this will make the estimates of the model to be policy invariant as observed by Lucas critique[14].

Unlike the CGE model that takes for granted the perfect market equilibrium condition, the RBCs model is steadfast and consistent about the perfect competition and therefore boom and burst along the business cycle is only consistent with the intertemporal constraint[15] of the economic agents. Therefore, theoretical baseline RBC-DSGE, according to Kydland and Prescott (1982 &1984) is given by:

Objective function

$$E_0 \sum_{t=0}^{\infty} \beta^t \{u(C_t) + z(1 - N_t)\} \qquad 2.20$$

Subject to intertemporal constraint

$$C_t + D_{t+1} \leq w_t N_t + \Pi_t + (1 + i_{t-1}) D_t \qquad 2.21$$

However, two key assumptions entrenched in the RBCs model are of grave concern in how the model reflects reality. First, the model holds that money is neutral. This assumption can be vehemently challenged, given the empirical evidence documented in Freidman (1968, 1971), Gali (2008) and Bello & Sanusi (2016), among others. Secondly, the other assumption follows from the neutrality of money assumption, which considers that the slogging through the cycles

[13] Economic agents are forward looking on information about policy changes that could affect their intertemporal objective function.

[14] The critique offered by Lucas and Sargent, (1978)

[15] Intertemporal constrain such as technological shocks or budget which compels intertemporal substitution of leisure hours for labor.

is as a result of changes in real variables[16]. Hence this implies that the economic agents that fit into the RBCs model are immune to money illusion.

Another pitfall in the RBCs is the non-inclusion of government. Possibly this signifies the irrelevance of the fiscal authority in the economy. The pure classical intuition is a handicap to the realistic relevance of the model. Also, the perfect competition held by the model contravenes the existence of asymmetry in the intertemporal decision of the economic agents (see Gali 1985 and Gali & Monaceli, 2005).

2.3.4.3 New Keynesian Dynamic Stochastic General Equilibrium Model

The New Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model came as an upshoot of the RBC's DSGE model. The major advancement in NK-DSGE traces to the work of Gali (1986) and Gali & Monacelli (2005). The NK-DSGE is also termed New Neoclassical Synthesis (NNS) because the NK-DSGE is an incorporation of the Keynesian elements into the RBC's DSGE due to the shortfall in the assumption. Unlike the perfect competition in the factor and commodity markets of the RBCs, the NK-DSGE introduced the *monopolistically competitive* market assumption in the spirit of Cristiano *et al.* (2005). Other features of the Keynesian introduced into the model are the nominal rigidities as enshrine in the staggered contract following Gali (1981, 2000), Gali & Gertler (2008), as well as the *la* Calvo, *staggered price-setting behaviour* including menu cost, sticky prices, and wages. The monopolistic competition in the NK-DSGE is a phenomenal breakthrough in the DSGE model. Because it provides the micro-foundation of nominal wage and price stickiness in the Keynesian framework. The presupposed assumption of the early Keynesian argument follows the reasoning that the economic agents optimize intertemporal decision based on available

[16] This suggests that monetary policy is not relevant in stabilizing or smoothening the amplitude of the cycles.

information. Also, the consideration given to monetary policy justifies the role monetary authority can play in controlling nominal variables such as nominal wages and prices.

Given the synthesis of the NK-DSGE, it is compelling to admit that the major drawbacks of the RBCs DSGE were resolved. Besides, the NK-DSGE offers a better macroeconomic model that captures and mimics reality. However, the NK-DSGE has its defect as pointed out by Blanchard (2009) that the labor market failed in the model account for involuntary unemployment and incorporate financial market frictions.

2.4 Empirical Literature

Following the reinvention of macroeconomics by incorporating the micro-foundations in the DSGE model, monetary authorities and macroeconomists are increasingly addressing issues surrounding short-run macroeconomic management. The increased proliferation of literature in this area is an attestation to this fact. The vast and majority of early studies credit regional banks such as the European Central Banks (henceforth, ECB) and central banks of specific countries like Federal Reserve Banks of U.S., Spanish Central Bank, Portuguese Central Bank among others. For instance, early works on the DSGE such as Smet & Wouters (2003), Adolfson (2005), Jakab & Vilagi (2007), Gelain & Kulikov (2009) Burriel, Fernandez-Villervade, & Rubio-Rmirez (2010), among others are central banks studies that attempted investigating the effect of orthogonal structural shocks from various sources on developed economy. More recently central banks in emerging and developing economy like India, Pakistan, Nigeria, and South Africa are following suit. Central banks effort to manage macroeconomic shocks that are associated and accentuated by short-run dynamics is one compelling reason motivating the application of DSGE framework. In addition to some of the striking element introduced in the new Keynesian variant, which introduced nominal rigidities in both prices and wages, monopolistically competitive firms, staggered and sticky prices. These elements provide the foundation for the role of monetary policy in the framework.

In managing the effect of these shocks on macroeconomic variables, both the sources and magnitude of the shocks seem to be important across available literature. Some of the shocks are traced from productivity, labor supply, investment; preference, cost-push, and monetary shock. For instance, Smet & Wouters (2003 and 2007) as well as Christoffel, Coenen & Warne (2008) provided evidence of the vulnerability of economies to the vast and diverse shocks. Depending on the shocks and interest of the investigation, some revelations of the literature are quite interesting. One of such interesting inquiry is Bank of Spain's study which unravels the effect of shocks that emanate from forming a monetary union on the Spanish economy (see Andres, Burriel & Estrada, 2006). The study compares the magnitude and the type of shock on both the Spanish economy and the entire monetary union. The finding reveals that the shock affected the aggregate demand in Spain while the effect of the shock on the monetary union was inflationary. The outcome of this study is significant in revealing the consequences of deterministic shock on macroeconomic variables. The significance of managing short-run dynamics has been reflected in prolong financial crisis of 2008.

The downside effect of poor management of macroeconomic shocks could be enormous on macroeconomic variables. Jokivuolle, Kilponen, & Kuusi (2007) and Almeida (2009) estimation of DSGE model for Bank of Finland and Portugal respectively, is an attestation to this fact. The estimation from both studies reveals that the effect of exogenous shock on the economy leads to both GDP growth and other variables to deviate from their balanced growth path[17]. The prolonged duration of global economic turmoil may explain some the complexities of the shocks which economies are facing. Hence the depth of analysis of the shocks requires the application of framework which has equal measure in terms of theoretical foundation and sufficient capability.

In dealing with various areas of possible scenarios for managing an economy, the DSGE offers numerous options of setting up the model. In essence, it serves as a laboratory for economic

[17] Long-run steady state

analysis. Starting with setting the sticky prices and habit formation in consumption cost of adjustment in capital accumulation, capacity utilization as incorporated in the first standard DSGE model by Smet & Wouters (2003). A varied DSGE in Andres, Burriel & Estrada (2006) including Smet & Wouters (2007) estimated after introducing nominal and real friction[18] flexible prices and wages in addition to structural shocks. However, these models' setup is more or less consistent with an only closed economy.

The introduction of an open economy with a Calvo-type staggered price setting feature into model and incomplete exchange rate pass-through to import prices is one of the features in the setups of the DSGE that enabled it to mimic real-world phenomena. Adolfson *et al.* (2005) and Gali & Monaceli (2005) inspire a model with incomplete exchange rate pass-through movement to export prices. This variant of the model retains nominal and real frictions that are peculiar in other earlier setups of the model which also empirically fits closed economy. However, the important element of this open economy model is the domestic household's ability to lend and borrow at a risk-adjusted nominal interest rate in the world financial market. Other open economy DSGE with slightly different feature consistent with their economy include Murchison & Rennisson (2006), Jakab & Vilagi (2007), Christoffel *et al.* (2008) and Burriel *et al.* (2010) among others. This class of DSGE model co-opts terms of trade based on the assumption of Purchasing Power Parity (PPP), and the introduction of exchange rate followed the uncovered interest rate parity.

The DSGE model is handy when it comes to how the calibration of the model made not only to mimic real-world but also it provided unique elements that are country-specific. For instance, the introduction of risk-premium, which allows for deviation of the domestic economy's interest rate from the euro-area, was put forth by Almeida (2009). This unique setup specifically targets a particular policy implication. Similarly, Jokivuoll *et al.* (2007) gave

[18] These features are peculiar to closed economy.

prominence to financial sector stability by estimating DSGE with banking sector loan losses. These have indicated the flexibility the macro model can capture real-time changes in the economy.

Increasing evidence in the literature has shown that the application of DSGE in analyzing macroeconomic shocks has indeed stepped up macroeconomics and serves as a guide in managing economy, especially to policymakers. As such, policy makers in developing and emerging economy embraced its application in no small measure. The earliest attempt in applying the model in Sub-Sahara Africa was Peiris & Saxegard (2007) who estimated an open economy DSGE model for Mozambique. This application could only incorporate the open nature of the Mozambique economy. Despite the wide difference in both institutional structure and institutional arrangement, there appears no much variation in the set-up of the model with that which is obtainable in the developed economy. In the same vain Haider & Khan (2008) estimation of Pakistan DSGE could only incorporate the effect of exchange rate pass-through as the feature of the economy. Similarly, Steinbach, Mathuloe & Smit (2009) and Mordi *et al.* (2013) estimation of the model for the Federal Reserve Bank of South-Africa and CBN respectively, did not do much in terms of setting the model, especially to capture other key features of the economy other than the openness. Thus, even the most recent effort of estimating the DSGE model for the CBN, Adebayo (2016) restrict the model to an only open economy with exchange rate pass-through.

Later advancement in the modeling of the DSGE model that incorporates oil import and export were observed. Beidas-Strom and Poghosyan (2011), including Algozhina (2015) modeled a DSGE with oil-importing dependent feature for Jordan. This modeling is suitable in providing insight into the impact of oil price shock on the economy, especially because most countries are exposed to oil price shocks in the international market. Bergholt (2014) modeled a small open economy model with oil as a major export commodity and provided evidence of how the

shock affects the Norwegian economy. Undoubtedly this extension of the model explains the effect of exogenous shock on the domestic economies, and they offer an improvement to open economy DSGE model with exchange rate pass-through.

Despite improvements achieved in the modeling and applicability of the DSGE models in the emerging and developing economies, there is an increasing need to improve these models. Largely because the relevance of these models in both monetary and fiscal policy analysis in developing economies leaves much to be desired due to the relevance of some key features such as informality, especially in terms of how these features interact with macroeconomic policies.

2.4.1 Fiscal and Monetary Policy in an Informal economy

In response to the increasing debate on the applicability of the DSGE model in the developing economies, much improvement is desired in the model to reflect important elements of these economies (see Blanchard, 2009 and Senbeta, 2011, Batini *et al.* 2010, 2011). More so, the realization of the benefit in internalizing the informal economy into the macroeconomic model, especially for the developing economies with a large shadow economy cannot be overemphased. As Dellas *et al.* (2017) argued: "any model that omits the informal economy can systematically mis-forecast and mis-quantify the effect of fiscal policy." This view is verified and supported by Bandaogo (2016). This argument provides an important justification on why the application of the DSGE in countries that have a large informal economy, to explictly incorporate such a feature.

There is a major debate in the literature regarding the role of informality in the economy. On the one hand, is the argument put forward by Leal (2014) that there is evidence that several margins of distortions (productivity and output) in the economy are a consequence of informality. He provided the evidence of a U-shaped trade-off between aggregate output and the size of the shadow economy. On the other hand, is the argument that informality constitutes

an efficient portion of the economy, and therefore, it is beneficial to the aggregate economy. The belief within this strand of literature are that the informal economy is resilient to shocks. The proponents of this argument include Schneider & Enste (2000), Schneider (2005), Maloney & Saavedra-Chanduvi (2007) and Schneider (2006).

The divergence and the contestations on the role of informality between the proponents and the opponents are attributable to the differences in the methodological approaches used by the two sides of divide. The partial equilibrium approach used by the proponents is a stark contrast to the general equilibrium approach. However, it is a belief that the general equilibrium approach provides a far superior basis than the partial equilibrium. One strong reason for the better performance of the general equilibrium methodology is the encompassing framework that illuminates the linkages of the shadow economy with other economic agents and the institution in the formal sector. Thus, economic dynamics and business cycles do not occur partially (based on isolated sectors) rather fluctuation occurs in the general economy. Therefore, it is pertinent to ascribe the better judgment of the true reflection of the informality within the general equilibrium. Hence if this fair inference is weighty as a fact, then it is safe to suspect the shadow economy can be as a source of shock in an economy.

In DSGE models with informality, the emphasis is normally placed on the role of the informal labour market. Empirical evidence of these sets of the models includes Ahmed *et al.* (2012) Senbeta (2013), Esfandyari & Dahmardeh (2014), Lahchen (2014). Though the DSGE model estimated by Lahchen (2014) considers an informal firm that operates in a perfect competition, which is a feature that is not consistent with the Keynesian tradition but more consistent with RBC. The downside to this modeling is that informality in most developing economies has been documented in the literature to be characterized by asymmetry (see also Batini, 2010). The introduction of informality by Ahmed *et al.* (2012), Senbeta (2013) and Esfandyari & Dahmardeh (2014) consider the supply of labor from both formal and informal (segmented

labor market) economy in the model setup. The appealing future in Senbata (2013) is the inclusion of labour market friction in the supply and demand side of the labour market. This consideration makes the application of the model in economies characterized by more imperfection arising from asymmetry more befitting. *The strength of Senbeta's model lies in the ability of the model to not only incorporate shadow economy as an endogenous component of the general economy model but equally provides a substance on how the characterizing factor of the informality relates with the macroeconomic variable such as unemployment*.

However, another dimension in setting-up the DSGE model with informality is to consider the relevance of credit constraint faced by firms in the presence of informal labour which follows Batini *et al*. (2010), Brzezina, Kolasa & Makarski (2012), Haider, Din & Ghani (2012) Pesaran & Xu (2013) and Bandaogo (2016).

It is a belief that monetary policy influences aggregate demand indirectly through credit market (see Mishkin, 2013) and more importantly, models with credit friction have shown evidence a directly proportional relationship between credit constraint and size informality economy. The argument contends that the frictional constraint in the credit market faced by firm eases as the size of informal economy decline. This setup is most favored because they replicate and mimic real-life dynamics. The striking feature of this model is the relevance it gives to heterogeneity arising from multi-sector participation of the economic agents.

It is deducible from the DSGE models with an informality that unlike the strands of literature that provide the evidence of the causes and magnitude of informality in the economy, the dynamic equilibrium model provides three fundamental areas for macroeconomic analysis. First, it endogenized informality into the macroeconomic framework; secondly it establishes

how informality in the economy affects macroeconomic variables[19] , and lastly, it illuminates how it affects and how it is affected by macroeconomic policies.

2.5 Literature Gap

In line with the available literature, this study identifies a critical gap that needs attention. The evidence of further study arises from the need to apply a DSGE model that reflects key and important features. Thus, inclusion of a large and significant informal economy with economic agents that are optimizing in the presence of a flexible labor market and credit constrained informal firms (both final and intermediate) is very imperative. Unlike Sebate (2013), Esfandyari & Dahmardeh (2014), Haider *et al.* (2015), Dellas *et al.* (2017) and Batini (2011) who introduce informality using the labour friction but fail to introduce the informality in the household objective function. Likewise, Bandaogo (2016 and 2017) incorporates informality in the household objective function but fail to give prominence to informal intermediate and final goods-producing firms. Note that incorporating these key features concurrently, suggest the possible existence of asymmetries arising from the heterogeneity of economic agents. On one side (formal sector) is are representative agents that optimize objective function subject to intertemporal constraint and remits tax to the government. On the other side (informal sector) are agents with objective function subject to intertemporal constrain but do not pay tax. With plausible representative agent differentiated by intertemporal optimizing constrains. Therefore, the need to extend the standard log-linearized DSGE model in the spirit of Smet and Wouters (2003, 2007) which predominates developed and developing economies estimation of the DSGE is desired. Thus, this study intends to advance a DSGE model using Bayesian estimation in order to see the effects of macroeconomic shocks on SOOE with large shadow economy. Furthermore, the SOOE will bear aggregate structural shocks that mimic some realistic feature

[19] Especially the labor market

of the Nigerian economy. Hence the model will be closed with optimal monetary and fiscal policy.

CHAPTER THREE

METHODOLOGY OF THE STUDY

This chapter is preoccupied with three major tasks. These are a description of the theoretical DSGE model which will serve as the framework for the study, the specification of behavioral equations and methods as well as the justification of the methods to be applied in analyzing the model. Lastly, a description of the data that will fit into the model.

3.1 Theoretical Small Open Economy DSGE Model

The theoretical foundation of the SOE model is in the spirit of Gali & Monacelli (2005), Blanchard and Gali (2010) and Bergholt (2012). The justification for rooting the model in this canonical setup is to allow for the model to mimic a real-world setting with an open economy, which has an external sector and also trades with the rest of the world. In order to incorporate the multi-sector economy that bears heterogeneity with a dual economy that is made up of formal and informal economic agents consisting households and firms, the SOE model will follow Batini *et al.* (2011), Senbeta (2013), Haider *et al.* (2014) and Bandaogo (2016 and 2017). Firms are assumed to set prices in a Calvo staggered[20] manner

3.1.1 Household

$$E\sum_{t=i}^{\infty}\beta^{t}\,u_{t}\left\{C_{T};N_{\alpha i,t}^{s};N_{\alpha i,t}^{f};\frac{M_{i}(k)}{P_{i}};1-\ell_{i}(k)\right\} \qquad 3.1$$

[20] This is consistent with the La Calvo (1983) formulation of price setting behaviour of firms.

$$u_t\left\{C_T; N^S_{\alpha i,t}; N^F_{\alpha i,t}; \frac{M_i(k)}{P_i}; 1-\ell_i(k)\right\} =$$

$$= \xi_{c,t}\left[\ln(C_T(k)-\psi C_{T-1}) - \int \frac{\left(N^S_{\alpha i,t}\right)^{1+\psi}}{1+\psi} d\alpha_i \right.$$

$$\left. - \int \frac{\left(N^f_{\alpha i,t}\right)^{1+\psi}}{1+\psi} d\alpha_i \frac{\xi_m}{\mathfrak{Q}}\left(\frac{M_i(k)}{P_i}\right)^{\mathfrak{Q}} - \xi_{\ell,t}\frac{\ell_i(k)^{1+\sigma_L}}{1+\sigma_L}\right] \qquad 3.2$$

where$\xi_{c,t}$ is the households preference shock which accounts for inverse elasticity of intertemporal consumption substitution.

$$C_T(k) = \left[(1-\vartheta_1)^{\frac{1}{\rho_1}} C_t^{\frac{(\rho_1-1)}{\rho_1}} + \vartheta_1^{\frac{1}{\rho_1}} C_n^{\frac{(\rho_1-1)}{\rho_1}}\right]^{\frac{\rho_1}{(\rho_1-1)}}$$

Households' optimal consumption behaviour

$$C_{ti}(k) = (1-\vartheta_1)\left(\frac{p_{ti}}{P_T}\right)^{-\rho_1} C_T(k)$$

$$C_{ni}(k) = \vartheta_1\left(\frac{p_{ni}}{P_T}\right)^{-\rho_1} C_T(k)$$

Therefore, a composite consumer price index which constitutes tradable and non-tradable commodities that enters the household at any given time is:

$$P_T = [(1-\vartheta_1){p_{ti}}^{1-\rho_1} + \vartheta_1 {p_{ni}}^{1-\rho_1}]^{\frac{1}{1-\rho_1}}$$

$$C_{t,i}(k) = \left[(1-\vartheta_2)^{\frac{1}{\rho_2}} C_{D,i}(k)^{\frac{(\rho_2-1)}{\rho_2}} + (\vartheta_2)^{\frac{1}{\rho_2}} C_{M,i}(k)^{\frac{(\rho_2-1)}{\rho_2}}\right]^{\frac{\rho_2}{(\rho_2-1)}}$$

$$C_{M,i}(k) = (\vartheta_2)\left(\frac{p_{M,i}}{P_{t,i}}\right)^{-\rho_2} C_t(k)$$

$$C_{D,i}(k) = (1-\vartheta_2)\left(\frac{p_{D,i}}{P_{t,i}}\right)^{-\rho_2} C_t(k)$$

Tradable price index

$$p_t = \left[(1-\vartheta_2){p_{D,i}}^{1-\rho_2} + \vartheta_2 {p_{M,i}}^{1-\rho_2}\right]^{\frac{1}{1-\rho_2}}$$

Households' optimal labour supply behaviour

$$\ell_{T,i}(k) = \left[(1-\theta_\ell)^{-\frac{1}{\mu_\ell}} \ell_{s,i}(k)^{\frac{(\mu_\ell-1)}{\mu_\ell}} + (\theta_\ell)^{-\frac{1}{\mu_\ell}} \ell_{f,i}(k)^{\frac{(\mu_\ell-1)}{\mu_\ell}}\right]^{\frac{\mu_\ell}{(\mu_\ell-1)}}$$

$$\ell_{s,i} = (1-\gamma_s)\ell_{s,t-1}$$

$$\ell_{f,i} = (1-\gamma_f)\ell_{f,t-1} + \tau_f$$

Unemployment at the beginning of the period:

$$(1-N)_t = 1-(1-\gamma)(\ell_{f,t-1} + \ell_{s,t-1})$$

Unemployment at the end of the period:

$$(1-N)_{t+i} = 1-(\ell_{f,t-1} + \ell_{s,t-1})$$

Assuming that

$$w_f > w_s$$

Given the prices of wages informal and the shadow economy, therefore household optimal objective function is subject to intertemporal budget constraint determined by the price of consumption bundle and the wage income paid to labor

$$w_f \ell_f + w_s \ell_s + d_t + r_b b_{t-1} \geq P_T C_T + b_t$$

First Order Condition FOC

$$\xi_c (C_T(k) - \psi C_{T-1})^{-1} = \lambda_T P_T$$

$$\xi_c \xi_m \left(\frac{M_T(k)}{P_T}\right)^{\mathbb{Q}-1} = \lambda_T(k)\left(1 - \beta E \frac{\lambda_{T+1}(k)}{\lambda_T(k)} \frac{P_T}{P_{T+1}}\right)$$

$$\xi_c \xi_\ell (\ell_T k)^{\sigma_\ell} = \frac{w_t \lambda_T}{P_C}$$

$$\beta E \frac{\lambda_{T+1}(k)}{P_{T+1}}$$

3.1.2 Labour market friction

Labour market tightness is given by

$$\Phi_{f,t} = \frac{\upsilon_{f,t}}{1 - N_t}$$

Both formal and shadow economy maximize expected discounted profit

$$E_t\left(\sum_{j=0}^{\infty} \text{Ш}_{t,t+1} \text{Ғ}_{t+j}\right)$$

The hiring cost faced by each firm in the formal sector

$$\check{\text{Е}}_f = \text{ȸ}_q \odot B_f^{\propto}$$

$$\text{Ғ}_t(f,q) = \frac{p_{q,f}}{P_T} \text{ȸ}_{q,t} \ell_{f,q} - \frac{1}{P_T}(w_t \ell_f + P_T \check{\text{Е}}_f \upsilon_{f,t})$$

$$\text{Ғ}_t(s,q) = \frac{p_{q,s}}{P_T} \dagger \text{ȸ}_{q,t} \ell_{s,q} - \frac{1}{P_T}(w_s \ell_s)$$

$$\text{Ғ}_t(s,\text{Þ}) = \frac{p_{\text{Þ},s}}{P_T} \text{ȸ}_{q,t} \ell_{s,\text{Þ}} - \frac{1}{P_T}(w_s \ell_{\text{Þ}s})$$

$$\left\{\frac{1}{P_T}\left[w_t + P_T \check{\text{Е}}_f - (1-\delta)\beta E_t\left(\frac{u'(C_{T+1})}{u' C_T} P_{T+1} \check{\text{Е}}_f\right)\right]\right\} = 0$$

FOC for tradable intermediate goods produced by informal firms:

$$\text{F}'_{\ell}(s,q) = \frac{p_{q,s}}{P_T}\text{†d}_{q,t} - \frac{1}{P_T}(w_s) = 0$$

That FOC of the non-tradable goods-producing firms:

$$\text{F}'_{\ell}(s,\text{Þ}) = \frac{p_{\text{Þ},s}}{P_T}\text{d}_{q,t} - \frac{1}{P_T}(w_s) = 0$$

3.1.3 Wage setting behaviour

Let $\coprod_{f,t}$and $\coprod_{s,t}$ represents the benefit a household derives as a result of a member of the household being employed in formal and informal economy, respectively.

Therefore

$$\coprod_{f,t} = \left\{ w_{f,t} - \eta(L_t)^{\frac{\varphi+\varphi\theta_L-1}{1+\theta_L}} \left(\frac{L_{f,t}}{\tau L}\right)^{\frac{1}{\theta_L}} (C_t - bC_{t-1})^{\sigma} \right.$$

$$\left. + E_t\left[E_{t,t+1}\langle(1-\delta+\delta X_{f,t+1})\coprod_{f,t} + \delta(1-X_{f,t+1})\coprod_{s,t}\rangle\right] \right\}$$

$$\coprod_{s,t} = E_t\{E_{t,t+1}[X_{f,t+1}\coprod_{f,t} + (1-X_{f,t+1})\coprod_{s,t}]\}$$

$$\coprod_{f,t} - \coprod_{s,t} = \xi_{\coprod} G_{f,t}$$

Hence

$$\xi_{\coprod} G_{f,t} = \left\{ w_{f,t} - \eta(L_t)^{\frac{\varphi+\varphi\theta_L-1}{1+\theta_L}} \left(\frac{L_{f,t}}{\tau L}\right)^{\frac{1}{\theta_L}} (C_t - bC_{t-1})^{\sigma} \right.$$

$$\left. + (1-\delta)E_t\left[E_{t,t+1}\langle\xi_{\coprod}(1-X_{f,t+1})G_{f,t+1}\rangle\right] \right\}$$

Substituting $G_{f,t} = G_{f,t+1}$ gives wage equation in formal economy

$$w_{f,t} = \left\{ \xi Z_{D,t} \Psi X_{f,t}^{\alpha} + \eta (L_t)^{\frac{\varphi + \varphi\theta_L - 1}{1+\theta_L}} \left(\frac{L_{f,t}}{\tau L} \right)^{\frac{1}{\theta_L}} (C_t - bC_{t-1})^{\sigma} \right.$$

$$\left. + (1-\delta) E_t \left(\frac{(C_t - bC_{t-1})^{\sigma}}{(C_{t+1} - bC_t)^{\sigma}} \right) \xi_{\amalg} (1 - X_{f,t+1}) Z_{D,t+1} \Psi X_{f,t+1}^{\alpha} \right\}$$

Note that for the informal economy, assumes the marginal product is equal to the real wage. That means

$$MP_N^s = w$$

Therefore, the optimal condition is determined by the marginal rate of substitution of consumption for leisure, which is equal to wages. That is:

$$MRS_{C,l}^s = w$$

3.1.4 Labour market equilibrium

The labour market equilibrium condition is distinct in the two economies. For the formal economy, the labour market equilibrium is determined in the factor market by the optimal condition of intermediate goods-producing firms. That is :

$$w_{f,t} = \frac{P_{D,f}}{P_t} Z_{D,t} - Z_{D,t} \Psi X_{f,t}^{\alpha} + (1-\delta) \beta E_t \left(\frac{(C_t - bC_{t-1})^{\sigma}}{(C_{t+1} - bC_t)^{\sigma}} \right) \frac{P_{t+1}}{P_t} Z_{D,t} \Psi X_{f,t+1}^{\alpha}$$

$$L_{f,t} = \frac{P_{D,f}}{P_t} Y_{D,f} \left[\frac{1}{w_{f,t} + Z_{D,t} \Psi X_{f,t}^{\alpha} - (1-\delta) \beta E_t \left(\frac{(C_t - bC_{t-1})^{\sigma}}{(C_{t+1} - bC_t)^{\sigma}} \right) \frac{P_{t+1}}{P_t} Z_{D,t} \Psi X_{f,t+1}^{\alpha}} \right]$$

Therefore, the labour supply in the tradeable formal economy is given by

$$w_{f,t} = \left\{ \xi Z_{D,t} \Psi X_{f,t}^{\alpha} + \eta (L_t)^{\frac{\varphi + \varphi\theta_L - 1}{1+\theta_L}} \left(\frac{L_{f,t}}{\tau L} \right)^{\frac{1}{\theta_L}} (C_t - bC_{t-1})^{\sigma} \right.$$

$$\left. + (1-\delta)\beta E_t \left(\frac{(C_t - bC_{t-1})^{\sigma}}{(C_{t+1} - bC_t)^{\sigma}} \right) \xi_{\amalg} (1 - X_{f,t+1}) Z_{D,t+1} \Psi X_{f,t+1}^{\alpha} \right\}$$

For the informal economy, the demand for labour that determines the intermediate informal tradeable goods and non-tradeable goods-producing firms.

$$L_{D,t}^{s} = \frac{P_{D,t}^{s}}{W_{,t}^{s}} Y_{D,t}^{s}$$

$$L_{D,n}^{s} = \frac{P_{D,n}^{s}}{W_{,t}^{s}} Y_{D,n}^{s}$$

So, the aggregate informal labour demand is given by:

$$L_t^s = L_{D,t}^{s} + L_{D,n}^{s} = \frac{P_{D,t}^{s}}{W_{,t}^{s}} Y_{D,t}^{s} + \frac{P_{D,n}^{s}}{W_{,t}^{s}} Y_{D,n}^{s}$$

the supply side of the labour is governed by the intertemporal optimal condition of the households, that is:

$$MRS_{C,l}^{s} = w$$

Therefore⇒

$$\eta \left[\left[\tau_L^{-\frac{1}{\theta_L}} (L_{f,t})^{\frac{1}{\theta_L}} + (1-\tau_L)^{-\frac{1}{\theta_L}} (L_{s,t})^{\frac{1+\theta_L}{\theta_L}} \right] \right]^{\frac{\theta_L \varphi - 1}{1+\theta_L}} \left(\frac{L_{f,t}}{1-\tau L} \right)^{\frac{1}{\theta_L}} (C_t - bC_{t-1})^{\sigma} = \frac{W_{,t}^{s}}{P_t}$$

$$L_t^s = (1-\tau_L) \left[\left[\frac{W_{,t}^{s}}{P_t} \frac{1}{\eta} (L_t)^{\frac{1-\varphi-\varphi\theta_L}{1+\theta_L}} (C_t - bC_{t-1})^{-\sigma} \right] \right]^{\theta_L}$$

3.1.5 Formal Economy production

Final Goods Producing and Exporting Firms

$$q_f = \left[\int_0^1 q_f k_d^{\frac{\rho_6-1}{\rho_6}} dk_d\right]^{\frac{\rho_6}{\rho_6-1}}$$

Final good exports:

$$q_f^* = \left[\int_0^1 q_f^* k_d^{\frac{\rho_6-1}{\rho_6}} dk_d\right]^{\frac{\rho_6}{\rho_6-1}}$$

$$\Pi_t = (1-T_d)p_t q_d - \int_0^1 p_t\,(k_t) q_d(k_t) dk_d$$

$$\Pi_t^* = (1-T_d)p_t q_d - \int_0^1 p_t\,(k_d) q_d(k_d) dk_d$$

Final goods foreign demand

$$q_f(k_d) = \left(\frac{p_t(k_d)}{(1-T_d)p_t}\right)^{-\rho_6} q_t$$

$$q_f^*(k_d) = \left(\frac{p_f^*(k_d)}{(1-T_d)p_t}\right)^{-\rho_6} q_f^*$$

Final Goods Importing Firm

$$q_{f,im} = \left[\int_0^1 q_{f,im} k_d^{\frac{\rho_7-1}{\rho_7}} dk_d\right]^{\frac{\rho_7}{\rho_7-1}}$$

Profit:

$$\Pi_{im} = \left(1 - T_{im,d}\right) p_t q_d - \int_0^1 p_{im,t}\,(k_t) q_{im}(k_t) dk_d$$

Demand:

$$q_{im,f}(k_d) = \left(\frac{p_{im,t}(k_d)}{(1 - T_{im,d}) p_t}\right)^{-\rho_7} q_{im,t}$$

Intermediate Goods Producing Firm

$$q_i(g_t) = Ά_d \left[\alpha_d^{\frac{1}{\rho_3}} h_d(k_t)^{\frac{\rho_3^{-1}}{\rho_3}} + (1 - \alpha_d)^{\frac{1}{\rho_3}} En_d(k_t)^{\frac{\rho_3^{-1}}{\rho_3}}\right]^{\frac{\rho_3}{\rho_3^{-1}}}$$

The composite of factor inputs is given by:

$$h_d(k_t) = (\xi_\ell \ell_d k_t)^{\theta_2} (V_d k_t)^{1-\theta_2}$$

$$\frac{\xi_{\ell,t}}{\xi_{\ell,t-1}} = \zeta_\ell$$

$$Ά_d = Ά_{d_{t-1}}^{\rho_4} \exp(\xi_{Ά,t})$$

$$\zeta_\ell = (1 + g_y)^{1-\rho_5} \zeta_{\ell,t-1} \exp(\xi_{\ell,t})$$

$$max_{k_d p_t} E_t \left\{\sum_{i=0}^{\infty} Ƶ_{t,t+1} \emptyset_d^i \frac{\epsilon_{t+1} ∐ p_d(k_d) - MC_{d,t+1}}{P_{T+1}} q_{t+1}\,(k_t)\right\}$$

$$MC_d = \frac{w_d \ell_d(k_d) + h_t V_d(z_d) + p_{En} En_t(k_d)}{Ⱶ_d(k_t)}$$

3.1.6 Domestic Shadow Economy Production

Informal Firms' Final Goods

$$q_s = \left[\int_0^1 q_s k_s^{\frac{\rho_S - 1}{\rho_S}} dk_s\right]^{\frac{\rho_S}{\rho_S - 1}}$$

Profit:

$$\Pi_s = p_{s,t} q_{s,t} - \int_0^1 p_{u,t}\left(k_{s,t}\right) q_{s,t}\left(k_{s,t}\right) dk_{s,t}$$

Demand for intermediate product:

$$q_{s,}(k_s) = \left(\frac{p_{s,t}(k_{s,t})}{p_{s,t}}\right)^{-\rho_s} q_{s,t}$$

Informal Intermediate Goods Production Firm

$$q_s(g_s) = Ά_s\left[\alpha_s^{\frac{1}{\rho_s}} h_s(k_s)^{\frac{\rho_S - 1}{\rho_S}} + (1 - \alpha_d)^{\frac{1}{\rho_S}} En_s(k_t)^{\frac{\rho_S - 1}{\rho_S}}\right]^{\frac{\rho_S}{\rho_S - 1}}$$

The composite of factor input is given by:

$$h_s(k_s) = (\xi_s \ell_s k_t)$$

The stochastic trend in informal labour:

$$\frac{\xi_{s,t}}{\xi_{s,t-1}} = \zeta_{s,t}$$

$$\zeta_\ell = (1 + g_y)^{1-\rho_5} \zeta_{\ell,t-1} \exp(\xi_{\ell,t})$$

$$max_{k_s p_s} E_t \left\{ \sum_{i=0}^{\infty} \mathrm{Z}_{t,t+1} \emptyset_s^i \frac{\epsilon_{s,t+1} \amalg p_{s,t}(k_s) - MC_{s,t+1}}{P_{T+1}} q_{s,t+1}(k_s) \right\}$$

Nominal marginal cost:

$$MC_d = \frac{w_d \ell_d(k_d) + h_t V_d(z_d) + p_{En} En_t(k_d)}{\mathrm{Ꮒ}_d(k_t)}$$

3.1.7 Capital Market and Formal Firm Investment Decision

An investment decision on new capital good follows CES production function:

$$I_T = \left[\mathrm{Ꮓ}_I^{\frac{1}{\theta_I}} (\zeta_{I,d} I_d)^{\frac{\theta_I - 1}{\theta_I}} + (1 - \mathrm{Ꮓ}_I)^{\frac{1}{\theta_I}} (\zeta_{I,im} I_{im})^{\frac{\theta_I - 1}{\theta_I}} \right]^{\frac{\theta_I}{\theta_I - 1}}$$

Demand for domestic investment:

$$\zeta_{I,d} I_d = \mathrm{Ꮓ}_I \left(\frac{p_d}{p_I} \right)^{-\theta_I} I_T$$

Demand for imported capital good:

$$\zeta_{I,im} I_{im} = \mathrm{Ꮓ}_I \left(\frac{p_{im}}{p_I} \right)^{-\theta_I} I_T$$

Therefore, the aggregate price index for investment in the economy is given as:

$$P_I = \left[\mathrm{Ꮓ}_I {P_D}^{1-\theta_I} + (1 - \mathrm{Ꮓ}_I) {P_D}^{1-\theta_I} \right]^{\frac{1}{1-\theta_I}}$$

The capital accumulation follows Smet and Wouters (2007) and Haider *et al.* (2014) which is also consistent with the intertemporal capital accumulation law of motion as:

$$K_{D,t+1} = \zeta_t^I I_D S\left(\frac{I_{D,t+1}}{I_{D,t-1}}\right) + (1-\delta)K_{D,t}$$

Therefore, the objective function of a formal tradeable goods producing firm is given as:

$$Max_{K_{D,t+1}I_{D,t+1}} E_t\left[\sum_{i=0}^{\infty} E_{t,t+1}\frac{J_{t+1}K_{D,t+1} + P_{I,t+1}I_{D,t+1}}{P_{C,t+1}}\right]$$

FOC

$$\frac{P_{I,t}}{P_{C,t}} = \frac{Q_{I,t}}{P_{C,t}}\left[S\left(\frac{I_{D,t}}{I_{D,t-1}}\right) + S'\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\frac{I_{D,t}}{I_{D,t-1}}\right]\zeta_t^I$$

$$\frac{Q_{I,t}}{P_{C,t}}\left[S'\left(\frac{I_{D,t}}{I_{D,t-1}}\right)\left(\frac{I_{D,t}}{I_{D,t-1}}\right)^2\right]\zeta_t^I$$

$$\frac{Q_{I,t}}{P_{C,t}} = E_t E_{t,t+1}\left\{\frac{J_{t+1}}{P_{C,t+1}} + (1-\delta)\frac{Q_{t+1}}{P_{C,t+1}}\right\}$$

3.1.8 Real Exchange rate Incomplete Pass-through

According to law of one price, for all goods $k \in [0,1]$ in every country $j \in [0,1]$:

$$p_{jkt} = e_{jt}p_{jkt}^j$$

This assumes for specific commodity k. In the case of aggregation of all imported commodities:

$$p_{jt} = \left(\int_0^1 p_{jkt}^{1-e_p} dk\right)^{\frac{1}{1-e_p}} = \left[\int_0^1 (e_{jt}p_{jkt}^j)^{1-e_p} dk\right]^{\frac{1}{1-e_p}} = \left(e_{jt}\int_0^1 p_{jkt}^{1-e_p}\, dk\right)^{\frac{1}{1-e_p}}$$

Therefore, the real exchange rate is determined by the bilateral terms of trade between the domestic economy and a country *r* is given by:

$$\omega_t = \frac{e_t p_t^r}{p_t^d}$$

3.1.9 International Risk-Sharing

This provides the link between the consumption level of the rest of the world and the consumption level of the domestic economy. Using the Euler equation for domestic household consumption

$$\beta E_t \frac{\lambda_{t+1}}{\lambda_t} = \beta E_t \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j} = \beta E_t \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j} = \frac{1}{r_t}$$

We introduce the stochastic discount factor $\mathcal{Q}_{t,t+1}^{-1}$

$$E_t(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j} = E_t(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}$$

Dividing through by $E_t(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}$

$$\frac{E_t(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j}}{E_t(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}} = 1$$

$$E_t \left\{ \frac{(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j}}{(\mathcal{Q}_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}} \right\}$$

$$(C_T(k) - \psi C_{T-1}) = \Omega (C_T(k) - \psi C_{T-1}) \mathcal{Q}_t^{\frac{1}{\sigma}}$$

Where Ω is the determines the relative initial conditions in asset holding

3.1.10 Uncovered interest rate parity

This condition provides the households with the incentive of choosing to investin or either domestic or foreign or both. This is attainable from the objective function:

$$\beta E_t \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T-1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j}$$

$$E_t(Q_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j}$$

Subject to budget constrain

$$P_T C_T + Q_{t,t+1} b_{t+1} + Q_{t,t+1}^* e_{t+1} b_{t+1}^* \leq b_t + e_t b_t^* + w_t N_t + T_t$$

$$\frac{E_t(Q_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{p_t^j}{p_{t+1}^j}}{E_t(Q_{t,t+1}^{-1}) \frac{(C_{T+1}(k) - \psi C_T)^{-\sigma}}{(C_T(k) - \psi C_{T+1})^{-\sigma}} \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}} = 1$$

$$\frac{E_t(Q_{t,t+1}^{-1}) \frac{p_t^j}{p_{t+1}^j}}{E_t(Q_{t,t+1}^{-1}) \frac{e_{jt} p_t^j}{e_{jt} p_{t+1}^j}} = 1$$

$$\frac{E_t(Q_{t,t+1}^*)}{E_t(Q_{t,t+1}^{-1}) \frac{e_{t+1}}{e_t}} = 1$$

$$E_t \frac{(Q_{t,t+1}^*)}{(Q_{t,t+1}^{-1})} = \frac{e_{t+1}}{e_t}$$

$$\frac{(Q_{t,t+1}^*)}{(Q_{t,t+1}^{-1})} = E_t \frac{e_{t+1}}{e_t}$$

3.2 Aggregate Equilibrium

3.2.1 Aggregate demand and output

In the domestic economy, market clearing condition for good$k$ is given by:

$$Y_{kt} = C_{Dkt} + \int_0^1 C_{Dkt}^j \, d_j$$

Demand in sub market is given by:

$$C_{Dkt} = \left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p}$$

Hence,

$$C_{Dt} = (1 - \varepsilon_B)\left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p}\left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t$$

Aggregate domestic consumption of domestically produced goods k produced in-country j is given by:

$$C_{Dkt}^j = \left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} C_{Dt}^j$$

Similarly, the aggregate domestic consumption of foreign-produced country j is express as:

$$C_{Dt}^j = \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j}\right)^{-\varepsilon_F} C_{Ft}^j$$

Because the aggregate domestic consumption is not only determined by the domestically produced goods

$$C_{Ft}^j = \varepsilon_B \left(\frac{P_{Dt}^j}{P_{Ft}^j}\right)^{-\varepsilon_D} C_{Ft}^j$$

but also, it is determined by the imported goods. Therefore, aggregate consumption is given by:

$$C_{Dkt}^{j} = \varepsilon_B \left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^{j}}\right)^{-\varepsilon_F} \left(\frac{P_{Ft}^{j}}{P_t^{j}}\right)^{-\varepsilon_D} C_{Dt}^{j}$$

Substituting into the market clearing condition gives:

$$Y_{kt} = (1-\varepsilon_B)\left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} \left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t + \int_0^1 \varepsilon_B \left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^{j}}\right)^{-\varepsilon_F} \left(\frac{P_{Ft}^{j}}{P_t^{j}}\right)^{-\varepsilon_D} C_{Dt}^{j}\, d_j$$

$$\therefore Y_{kt} = \left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} \left[(1-\varepsilon_B)\left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^{j}}\right)^{-\varepsilon_F} \left(\frac{P_{Ft}^{j}}{P_t^{j}}\right)^{-\varepsilon_D} C_{Dt}^{j}\, d_j\right]$$

Aggregate domestic output is then given by:

$$\Rightarrow Y_t = \left(\int_0^1 Y_{kt}^{\frac{\varepsilon_p - 1}{\varepsilon_p}}\, d_k\right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

Substituting Y_{kt} into $Y_t$we have

$$Y_t = \left\{\int_0^1 \left(\left(\frac{P_{Dkt}}{P_{Dt}}\right)^{-\varepsilon_p} \left[(1-\varepsilon_B)\left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^{j}}\right)^{-\varepsilon_F} \left(\frac{P_{Ft}^{j}}{P_t^{j}}\right)^{-\varepsilon_D} C_{Dt}^{j}\, d_j\right]\right)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} d_k\right\}^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

$$= \left\{ \int_0^1 \left(\left[\left(\frac{P_{Dkt}}{P_{Dt}} \right)^{-\varepsilon_p \frac{\varepsilon_p - 1}{\varepsilon_p}} d_k \right] \left[(1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t \right. \right. \right.$$

$$\left. \left. \left. + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j \, d_j \right] \right)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \right\}^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

$$= \left\{ \int_0^1 \left(\left[\left(\frac{P_{Dkt}}{P_{Dt}} \right)^{1-\varepsilon_p} d_k \right]^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \left[(1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t \right. \right. \right.$$

$$\left. \left. \left. + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j \, d_j \right] \right)^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \right\}^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

$$= \left\{ {P_{Dt}}^{\varepsilon_p} \int_0^1 \left(\int_0^1 {P_{Dkt}}^{1-\varepsilon_p} \, d_k \right)^{\frac{\varepsilon_p}{\varepsilon_p - 1}} \left[(1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t \right. \right.$$

$$\left. \left. + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j \, d_j \right]^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \right\}^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

$$= \left\{ {P_{Dt}}^{\varepsilon_p} \left[\left(\int_0^1 {P_{Dkt}}^{1-\varepsilon_p} \, d_k \right)^{\frac{1}{\varepsilon_p - 1}} \right]^{-\varepsilon_p} \left[(1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t \right. \right.$$

$$\left. \left. + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j \, d_j \right]^{\frac{\varepsilon_p - 1}{\varepsilon_p}} \right\}^{\frac{\varepsilon_p}{\varepsilon_p - 1}}$$

$$P_{Dt}{}^{\varepsilon_p} P_{Dt}{}^{-\varepsilon_p} \left[(1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j \, d_j \right]$$

$$Y_t = (1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 \left(\frac{P_{Dt}}{\varepsilon_{Jt} P_{Ft}^j} \right)^{-\varepsilon_F} \left(\frac{P_{Ft}^j}{P_t^j} \right)^{-\varepsilon_D} C_{Dt}^j d_j$$

$$Y_t = (1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 (P_{Dt})^{-\varepsilon_F} \left(\varepsilon_{jt} \right)^{-\varepsilon_F} P_{Ft}^{j\varepsilon_F - \varepsilon_D} P_t^{j\varepsilon_D} C_{Dt}^j d_j$$

$$Y_t = (1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 P_{Dt}^{-\varepsilon_F + \varepsilon_D} \varepsilon_{jt}^{\varepsilon_F - \varepsilon_D} \varepsilon_{jt}^{\varepsilon_D} P_{Ft}^{j\varepsilon_F - \varepsilon_D} P_t^{j\varepsilon_D} C_{Dt}^j d_j$$

$$Y_t = (1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \int_0^1 P_{Dt}{}^{-\varepsilon_D} \left(\frac{\varepsilon_{Jt} P_{Ft}^j}{P_{Dt}} \right)^{\varepsilon_F - \varepsilon_D} \left(\frac{\varepsilon_{Jt} P_t^j}{P_t} \right)^{-\varepsilon_D} C_{Dt}^j d_j$$

$$= (1-\varepsilon_B) \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} C_t + \varepsilon_B \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} \int_0^1 \left(\frac{\varepsilon_{Jt} P_{Ft}^j}{P_{Dt}} \right)^{\varepsilon_F - \varepsilon_D} \left(\frac{\varepsilon_{Jt} P_t^j}{P_t} \right)^{-\varepsilon_D} C_{Dt}^j d_j$$

$$= \left(\frac{P_{Dt}}{P_t} \right)^{-\varepsilon_D} \left[(1-\varepsilon_B) C_t + \varepsilon_B \int_0^1 \left(\frac{\varepsilon_{Jt} P_{Ft}^j}{P_{Dt}} \right)^{\varepsilon_F - \varepsilon_D} \varpi_{jt}^{\varepsilon_D} C_{Dt}^j d_j \right]$$

If the effective terms of trade in country j is given by:

$$S_t^j = \frac{\varepsilon_{Jt} P_{Ft}^j}{P_{jt}}$$

Substituting in

$$= \left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} \left[(1-\varepsilon_B)C_t + \varepsilon_B \int_0^1 \left(\frac{\varepsilon_{Jt} P_{Ft}^j}{P_{Dt}}\right)^{\varepsilon_{F-\varepsilon_D}} \varpi_{jt}^{\varepsilon_{D-\frac{1}{\sigma}}} C_{Dt}^j d_j\right]$$

Hence

$$= \left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t \left[(1-\varepsilon_B) + \varepsilon_B \int_0^1 \left(\frac{\varepsilon_{Jt} P_{Ft}^j P_{jt}}{P_{Dt} P_{jt}}\right)^{\varepsilon_{F-\varepsilon_D}} \varpi_{jt}^{\varepsilon_{D-\frac{1}{\sigma}}} C_{Dt}^j d_j\right]$$

Relevance is given to the degree of openness ε_B

$$= \left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D} C_t \left[(1-\varepsilon_B) + \varepsilon_B \int_0^1 \left(S_t^j S_{jt}\right)^{\varepsilon_{F-\varepsilon_D}} \varpi_{jt}^{\varepsilon_{D-\frac{1}{\sigma}}} C_{Dt}^j d_j\right]$$

The log-linearizing around a steady-state gives

$$Y_t \approx Y - \varepsilon_D \left(\frac{P_{Dt}}{P_t}\right)^{-\varepsilon_D - 1} \frac{1}{P} C_t \left[(1-\varepsilon_B) + \varepsilon_B \int_0^1 \left(S_t^j S_{jt}\right)^{\varepsilon_{F-\varepsilon_D}} \varpi_{jt}^{\varepsilon_{D-\frac{1}{\sigma}}} C_{Dt}^j d_j\right]$$

$$\Rightarrow y_t \approx c_t + \varepsilon_B \varepsilon_F s_t + \varepsilon_B \left(\varepsilon_D - \frac{1}{\sigma}\right) q_t$$

But

$$q_t = (1-\varepsilon_B) s_t$$

Therefore

$$y_t \approx c_t + \varepsilon_B \varepsilon_F s_t + \varepsilon_B \left(\varepsilon_D - \frac{1}{\sigma}\right)(1-\varepsilon_B) s_t = c_t + \frac{\sigma\varepsilon_B\varepsilon_F + \sigma\varepsilon_B\varepsilon_F(1-\varepsilon_B) - \varepsilon_B(1-\varepsilon_B)}{\sigma} s_t$$

$$= c_t + \frac{\varepsilon_B[\sigma\varepsilon_F + \sigma\varepsilon_F(1-\varepsilon_B) - (1-\varepsilon_B)]}{\sigma} s_t$$

$$= c_t + \frac{\varepsilon_B[\sigma\varepsilon_F + (1-\varepsilon_B) - (\sigma\varepsilon_F - 1)]}{\sigma} s_t$$

$$\Rightarrow y_t = c_t + \frac{\varepsilon_B \omega}{\sigma} s_t$$

Thus, this will apply for each specific country. Hence for the aggregate of all the countries:

$$y_t^* \equiv \int_0^1 y_t^j dj = \int_0^1 \left(c_t^j + \frac{\varepsilon_B \omega}{\sigma} s_t^j\right) dj = \int_0^1 c_t^j dj + \frac{\varepsilon_B \omega}{\sigma} \int_0^1 s_t^j dj = \int_0^1 c_t^j dj \equiv c_t^*$$

Given that $\int_0^1 s_t^j dj = 0$

Substituting in will give:

$$y_t = c_t^* + \frac{1-\varepsilon_B}{\sigma} s_t + \frac{\varepsilon_B \omega}{\sigma} s_t = y_t^* + \frac{1 - \varepsilon_B + \varepsilon_B \omega}{\sigma}$$

$$\Rightarrow y_t = y_t^* + \frac{1}{\sigma_{\varepsilon_B}} s_t$$

To obtain the IS equation, we substitute for c_t in the Euler equation

$$y_t - \frac{\varepsilon_B \omega}{\sigma} s_t = E_t\left\{y_{t+1} - \frac{\varepsilon_B \omega}{\sigma} s_{t+1}\right\} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - \rho)$$

Hence

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t \pi_{t+1} - \rho) - \frac{\varepsilon_B \omega}{\sigma} E_t \Delta s_{t+1}$$

Thus, this is only, but a closed economy IS a model. To incorporate the rest of the world, we introduce

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t\{\pi_{t+1} + \varepsilon_B \Delta s_t\} - \rho) - \frac{\varepsilon_B \omega}{\sigma} E_t \Delta s_{t+1}$$

$$y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t\pi_{t+1} - \rho) - \frac{\varepsilon_B(\omega - 1)}{\sigma} E_t \Delta s_{t+1}$$

$$\Rightarrow y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t\pi_{t+1} - \rho) - \frac{\varepsilon_B \odot}{\sigma} E_t \Delta s_{t+1}$$

If ε_F and ε_D are significantly high y_t becomes:

$$\Rightarrow y_t = E_t y_{t+1} - \frac{1}{\sigma}(i_t - E_t\pi_{t+1} - \rho) - \frac{\varepsilon_B \odot}{\sigma} \varepsilon_B \odot E_t \Delta y^*_{t+1}$$

Hence this implies that the real interest rate which consistent with the Fishers equation $i_t - E_t\pi_{t+1}$ effect on domestic output is influenced by ε_B.

3.2.2 Trade balance

Trade balance is defined by the net export (NX_t). The determination of the NX_t relative to steady-state is:

$$NX_t = \frac{Y_t \frac{P_t}{P_{Ht}} C_t}{Y}$$

FOC around the steady-state, give that P_t=$P_{Ht} = P$ and $Y_t = C_t = Y$

Therefore, a balanced trade means $NX_t = 0$ implies that:

$$NX_t = \frac{Y_t - \frac{P}{P}Y}{Y} + \frac{1}{Y}\left[(Y_t - Y) - \frac{P}{P}(C_t - C) - \frac{1}{P}C(P_t - P) + \frac{1}{P^2}PC(P_{D,t} - P)\right]$$

$$= \frac{Y_t - Y}{Y} - \frac{C_t - C}{C} - \frac{P_t - P}{P} + \frac{P_{D,t} - P}{P}$$

$$= (y_t - y) - (c_t - c) - (p_t - p) + \left(p_{D,t} - p\right)$$

$$y_t - c_t - p_t + p_{D,t}$$

$$y_t - c_t - \varepsilon_B s_t$$

3.2.3 Marginal cost and inflation dynamics (supply side)

Following from the equilibrium condition in the labour market which provides that:

$$L_t = \int_0^1 L_{i,t} di$$

Thus, it follows from:

$$L_{i,t} = \frac{Y_{i,t}}{A_t}$$

Implying that:

$$L_t = \int_0^1 \frac{Y_{i,t}}{A_t} di$$

Therefore

$$L_t = \int_0^1 \frac{Y_{i,t}}{A_t} \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon_p} di$$

$$= \frac{Y_{i,t}}{A_t} \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\varepsilon_p} di$$

The domestic inflation is consistent with the given law of motion:

$$\pi_{D,t} = \beta E_t \pi_{D,t+1} + \lambda \widehat{mc}_t^r$$

Note:

$$\lambda \sim \frac{(1-\beta\theta)(1-\theta)}{\theta} \ (deep\ papameter)$$

Also

$$\widehat{mc}_t^r = mc_t^r - mc^r$$

Thus, it means that marginal cost will follow from:

$$mc_t^r = -v + w_t + p_{D,t} - a_t$$

$$= -v + (w_t - p_t) + \left(p_t - p_{D,t}\right) - a_t$$

$$= -v + \tau c_t + \sigma l_t + \varepsilon_B s_t - a_t$$

Aligning the marginal cost for an open economy model by incorporating RoW equilibrium:

$$= -v + \tau\left(c_t + \frac{1-\varepsilon_B}{\tau} s_t\right) + \sigma(y_t - a_t) + \varepsilon_B s_t - a_t$$

$$= -v + \tau c_t^* + (1-\varepsilon_B)s_t + \sigma(y_t - a_t) + \varepsilon_B s_t - a_t$$

$$mc_t^r = -v + \sigma y_t^* + \vartheta y_t + s_t - (1+\vartheta)a_t$$

In order to incorporate the feature of an open economy, while retaining the indirect relationship, the apparent between marginal cost and output, through labour market. We can substitute for s_t. Hence,

$$mc_t^r = -v + (\sigma_{\varepsilon_B} + \vartheta)y_t + (\sigma + \sigma_{\varepsilon_B})y_t^* + s_t - (1+\vartheta)a_t$$

Note the terms of trade σ_{ε_B}bear a functional relationship with the degree of openness elasticity of substitution between foreign goods (supplied by RoW) and domestic goods.

3.2.4 New Keynesian Philips curve and dynamic IS equation

The build-up to the NKPC emanates from the difference between:

$$\{mc_t^r = -v + (\sigma_{\varepsilon_B} + \vartheta)y_t + (\sigma + \sigma_{\varepsilon_B})y_t^* + s_t - (1+\vartheta)a_t\} - \{mc_t^r$$

$$= -v + (\sigma_{\varepsilon_B} + \vartheta)y_t^n + (\sigma + \sigma_{\varepsilon_B})y_t^* + s_t - (1+\vartheta)a_t\}$$

Where $y_t^n$is the natural output in the domestic economy.

Which will reduce to:

$$\widehat{mc}_t^r = (\sigma_{\varepsilon_B} + \vartheta)\tilde{y}_t$$

Then we substitute into:

$$\pi_{D,t} = \beta E_t \pi_{D,t+1} + \lambda \widehat{mc}_t^r$$

⇒

$$\pi_{D,t} = \beta E_t \pi_{D,t+1} + \lambda(\sigma_{\varepsilon_B} + \vartheta)\tilde{y}_t$$

Hence

$$\pi_{D,t} = \beta E_t \pi_{D,t+1} + F_{\varepsilon_B}\tilde{y}_t$$

3.2.5 Optimal Monetary policy

The specification of the monetary policy in the economy with independent monetary policy (see CBN, 2007), which follow a clear mandate of undertaking a monetary policy that reacts to both inflation deviation above a single digit and exchange rate deviation outside the managed band. The study subscribes to monetary formalization is in line with Benigno & Benigno (2003) and Batini *et al.* (2010).

$$i_t = \beta_\pi \pi_{D,t} + \beta_y y_t + \beta_t e_t + \gamma_t i_{t-1}$$

Hence, because of fear of floating, monetary policy minimizes the deviation of exchange rate as:

$$\sum_{t=0}^{\infty} \beta^t \sigma(e_t)\widetilde{VE}$$

3.2.6 Fiscal Policy

The fiscal side is made up of a government that relies on revenue from the export of oil in the international market and lump-sum tax from domestic economic activities in the formal sector. That means that the informal economy is outside the tax net of fiscal revenue. The government deficit is finance through either or both domestic and foreign borrowing. The premises begin with the traditional province of the fiscal policy.

$$(S_t - R_t^{no} - R_t^o - e_t \Delta F_t) = DF_t$$

Where S_t is the total government spending as defined by:

$$S_t = G_t + i_t^D B_{t-1} + e_t i_t^f F_{t-1}$$

Therefore

$$(S_t - R_t^{no} - R_t^o - e_t \Delta F_t) + NER_t = DF_t$$

The explicit government budget constraint in line with Algozhina (2015) as:

$$b_t + T_t + e_t^{\overline{\epsilon}^{\in}}(R_t^* - 1)OF_{t-1}^* RER_t = G_t^I + G_t^c + R_{t-1}\frac{b_{t-1}}{\pi_t}$$

Where

$$R_t^o = e_t^{\overline{\epsilon}^{\in}}(R_t^* - 1)OF_{t-1}^* RER_t$$

The oil tax accrued to the government in the form of royalties and share of the government oil sector is given by:

$$T_t^o = \aleph^o P_t^{o*} Y_t^o + \text{Ц}_t^{o*}$$

Thus, this public oil tax accumulated into the Net International Reserves (NIR) in the revenue side of the fiscal policy.

$$OF_t^* = \aleph OF_{t-1}^* + T_t^o$$

Therefore, the spending side of the fiscal policy can decompose into government consumption expenditure and government investment expenditure. Thus, it is given by the following rules:

$$\widehat{G_t^I} = \aleph_{GI}\widehat{G_{t-1}^I} + (1 + \aleph_{GI})\left[\delta_{GI}\widehat{Y}_t - \gamma_{GI}\hat{b}_{t-1} + \gamma_{OF}^{GI}\widehat{OR}_t\right] + \varepsilon_t^{GI}$$

$$\widehat{G_t^C} = \aleph_{GC}\widehat{G_{t-1}^C} + (1 + \aleph_{GC})\left[\delta_{GC}\widehat{Y}_t - \gamma_{GC}\hat{b}_{t-1} + \gamma_{OF}^{GC}\widehat{OR}_t\right] + \varepsilon_t^{GC}$$

Therefore, the equilibrium between government revenue and expenditure is given by:

$$\widehat{T}_t + \gamma_I\widehat{OR}_t = \gamma_b\hat{b}_{t-1} + \gamma_I\hat{G}_t^I + \gamma_C\hat{G}_t^C$$

3.2.7 Rest of the World (ROW) Economy~ Foreign Bloc

The ROW economy is defined by:

$$\hat{Y}_t^{ROW} = \mu_{ROW}\hat{Y}_{t-1}^{ROW} + \varepsilon_t^{\hat{Y}_t^{ROW}}\ output$$

$$\pi_t^{ROW} = \beta^* E_t\pi_{t+1}^{ROW} + \left(\sigma + \frac{\theta^* + \alpha^*}{1 - \alpha^*}\right)\hat{Y}_t^{ROW}$$

$$\hat{\imath}_t^* = \theta_\pi^*\pi_t^{ROW} + \rho_Y^*\hat{Y}_t^{ROW} + \varepsilon_t^i$$

3.3 Method of Measuring Real Cycle of SOOE

In examining and verifying the consistency between theoretical established properties inherent in the RBCs and that of the SOOE's RBCs, the study intends to follow the *Limit theory of filter* in the spirit of Whittaker (1923) as reinforced by Hodrick and Prescott (1980 and 1997) use as the Hodrick Prescott (HP) filters. Thus, the filtering out will aid in separating the cycles from the trend in the series. Given the frequency of the data, the smoothing parameter (λ) to be used

in has filtered the cycle will be set at 1,600 and it assumes that the data has both deterministic and stochastic trend component. Therefore, the piecewise continuous deterministic drift function embeds in the limit process. Thus, it means that for the given series y_t we have:

$$y_t = T_t + c_t$$

$$\Rightarrow \hat{T}_t = \arg min \left\{ \sum_{t=1}^{k} (y_t - T_t)^2 + \lambda \sum_{t=l+1}^{k} (\Delta^l T_t)^2 \right\}, \hat{c}_t = y_t - \hat{T}_t$$

Therefore $\sum_{t=1}^{k}(y_t - T_t)^2$accounts for poof fitness in the series while $\sum_{t=l+1}^{k}(\Delta^l T_t)^2$reinforces lack of smoothness.

3.4 Econometric issues of the Method

The literature has provided evidence of multiplicity and competing for estimation techniques for the DSGE model. Depending on the inferential method, there are two broad subscribes of the estimation techniques (see Fernandez-Villaverde *et al.*, 2015). The first is the frequentist estimation techniques which follow the frequentist inference, and the second category is the Bayesian estimation techniques, which are consistent with the Bayesian inference.

The frequentist estimation comprises of four (4) distinct techniques. The first is the ***Likelihood-based estimation,*** which applies in Leeper and Sims (1995) and other earlier studies. These techniques are consistent with singular[21] perturbation because the number of observations is greater than the shocks. The major shortfall of this technique is the unusability of the inference of the likelihood function for inferences because the DSGE solution places a probability of one, on the event due to equality of the actual data to zero. Even though this challenge can be surmounted, by simply restricting[22] the number of observations to equate the shocks, despite

[21] Singular perturbation is obtained when the change in the approximated solution is small while the response from the shock is large.

[22] This mean conversion of singular perturbation to a regular perturbation solution.

this ad-hoc solution, the likelihood approach is still deficient in the optimization of nonlinear DSGE because the likelihood function that is filtered by particle filter cannot be differentiated. This problem arises because small changes in parameter will lead to a different set of resampled particles which will make the particle approximation of the likelihood function to be discontinuous even when it is not discontinuous.

The second frequentist technique is the ***Simulated Method of Moments estimation***. The issue with this technique arises when the DSGE model does not contain a complete set of shocks (which also means that the model has stochastic singularity). The comparison of the autocovariance from DSGE and the samples autocovariance from VAR(p) as in Smith (1993) will be divergent. In the case of the third frequentist technique, that is, ***the Impulse Response Function (IRF)Matching estimation technique,*** which allows for filtering of the data through VAR. Thus, it often suffers from the problem of misspecification of the propagation mechanism and the consequent of this issue is pronounced on the mismatch between the IRF from the VAR and that of the DSGE model. Even though the empirical application of this technique was embraced in studies like Cristiano *et al.* (2005) and more recently, Altig *et al.* (2011), yet there are fundamental flaws in its application. For instance, the empirical IRF from VAR are computed based on finite high order VAR(P) while the state space representation of the linearized DSGE are often represented as low order VAR(p) especially when it expresses about the structural shocks and number of observations. However, when the representation of the DSGE is in terms of correspondence of the structural shocks with the number of innovations, then the state space representation of the DSGE will bear an infinite order VAR and where there is no correspondence between the innovation and the structural shocks, yet the model still maintains an infinite VAR. That means there is no symmetry in the order of the matching between the VAR and the DSGE model (see also Fernandez-Villaverde *et al.*, 2015). Similarly, the issue of invertibility in the MA-process of the DSGE model can make the IRF

obtained to be inapproximable with an infinite order VAR, and this could render a spurious IRF.

The last frequentist technique is the ***Generalized Method of Moments (GMM) estimation***. This technique is superior among the frequentist inferences largely because it does not need perturbation solution. Hence it is devoid of singular perturbation solution problem associated with lesser structural shocks specification. Among studies that exploited the advantage offered by GMM are Christiano & Eichenbaum (1992), Boroditskaya (2008) and Gallant, Giacomini, & Ragusa (2013). The major drawback of this technique is incapacitated when dealing with the latent variables that are inherent in the equilibrium condition of the DSGE. More so, it is defective in the handling of the behavioural equations and the nonlinear DSGE that are filtered using the particle filter.

The second category of estimation techniques applied in the estimation of DSGE is the Bayesian estimations techniques; these appear to be far more superior in terms of estimation of the DSGE model. That is because it relies on the use of prior distribution and likelihood function to generate a posterior distribution. The priors used in the estimation of the DSGE model provides two advantages over the frequentist techniques. First is that the priors are useful in regularizing the likelihood function by making it more elliptical. Secondly, which is the most important is that the priors are the source of prior information upon which the Bayesian inference depends on it.

The use of the Bayesian inference also provides an avenue to express the likelihood function as linearize or non-linearize DSGE model. This flexibility enhances the approximation of the DSGE from lower degree to higher degree approximation. Similarly, the variant of Bayesian techniques used is rooted in the different types of posterior distribution applied in the

distribution of the DSGE. The posterior distribution may either follow the Markov Chain Monte Carlo (MCMC) algorithm which denotes posterior distribution as:

$$\pi(\theta) \text{and} \mathbb{E}_{\pi}(\theta)$$

In this case, the standard distribution that is consistent with the constructed Markov chain represents the posterior distribution. The algorithm of the MCMC generate draws from:

$$\theta^{i} = 1, \dots \dots, N$$

The draw follows a sequential order, and it converges into posterior distribution as $N \rightarrow \infty$. A specific MCMC algorithm dominantly used in the estimation of the DSGE model is the Metropolis, Rosenbluth, Rosenbluth, Teller & Teller (1953) and the generalize extension by Hastings (1970).

One important advantage offered by the Metropolis-Hastings (MH) algorithm in the estimation of DSGE is the convergence of the output. This key ingredient of the MH algorithm offers $q(\vartheta|\theta^{i})$ distribution (see Fernandez-Villaverde, Rubio-Ramirez & Schorfheide, 2015).

$$\alpha\left(\vartheta\middle|\theta^{i-1}\right) = min\left\{1, \frac{\frac{p(Y|\vartheta)p(\vartheta)}{q\left(\vartheta\middle|\theta^{i-1}\right)}}{p(Y|\theta^{i-1})p(\theta^{i-1}))/q(\theta^{i-1}|\vartheta)}\right\}$$

The Random Walk variant of the Metropolis-Hastings (RWMH) has come to provide a more empirical relevance in the estimation of the DSGE model, which is consistent with the normal distribution. A major defect of the RWMH algorithm is the decline in efficiency as the parameter vector dimension increases. Hence the blocking of the parameter vector is required, which demands to partition of the parameter space using the Bock MH algorithm. This Block MH algorithm was tailored by Chib & Ramamurthy (2010) by simulating annealing procedure in order to reduce the persistence of the MCMC chain relative to the benchmark RWMH

algorithm. The simulating annealing process which produces the modal conditional posterior distribution follows the Hessian conditional log posterior density. The shortfall of this Tailorised Random Block Meropolised Hastings (TaRBMH) it could be extremely slow in the evaluation of the likelihood function used in the simulated annealing process. Even when the suitability of the MCMC MH algorithm, especially the TaRBMH manifests in the estimation of linearized and log-linearized DSGE, its applicability in the estimation of the non-linear DSGE leaves a lot to be desired.

Thus, the estimation of the non-linear DSGE, which requires the replacement of the likelihood function with particle filter approximation relies on the Particle Filter MH (PFMH). Fernandez-Villaverde, Rubio-Ramirez & Schorfheide (2015) supports the application of the PFMH because of its exact convergence to the true posterior distribution. However, this exact convergence requires an unbiased generation of the filtered likelihood function as approximated by the particle filter. The replacement of the likelihood function by the particle filter creates the issue of persistence in the Markov chain which raises the question of accuracy in the particle filtered Monte Carlo

Conversely, Herbst & Schorfheide (2014) revealed a promising and exciting algorithm in support of Chopin (2004) and Creal (2007 and 2012) theoretical exposition of Sequential Monte Carlo (SMC) particle filter approximation. According to Herbst & Schorfheide (2014) as also buttress by Fernandez-Villaverde, Rubio-Ramirez & Schorfheide (2015), that SMC particle filter for non-linear DSGE showed an evidence of convergence for an adaptive version of the algorithm and the tailored SMC version of the algorithm provides more reliable posterior distribution for large scale DSGE model which bear multiple mode posterior distribution compared to the dominantly used TaRMH. Additional superiority of the PFSMC approximation is the high speed of estimation compared to the MCMC which roots from the parallelization advantage of the algorithm.

3.5 Bayesian Estimation

The Bayesian specification of the posterior distribution from the likelihood function and the prior information from the data is given by:

$$p(\lambda_B|Z_V, B) = \frac{p(Z_V|\lambda_B, B)p(\lambda_B|B)}{p(Z_V|B)}$$

Where $p(Z_V|B)$ represents the marginal density of the data condition on the model. Hence the Bayesian estimation of the model will be achieved through the application of the Markov Chain Monte Carlo (MCMC) algorithm. Also, because the study intends to compare the estimate of the log-linearized DSGE and the particle filtered non-linear DSGE, therefore the MCMC specification of the algorithms is given as follows.

3.5.1 Method of Estimation of DSGE (Log-Linearized Approximation)

Following the estimation, issues reviewed this study intends to adopt the Bayesian inference and estimation techniques in estimating the DSGE model. In line with the limitations of posterior distribution determination using the MCMC and the benefits it provides, the study attempts estimating the log-linearized DSGE with the widely used TaRMH. The nonlinear variant of the DSGE is estimated using both PFMCMC and the PFSMC algorithm.

Random Walk Metropolis-Hastings for the log-linearized DSGE Model

This study specifies the general path for $i = 1 \ to \ N$ as

First is to implement a draw ϑ from a density $q(\vartheta|\theta^{i-1})$. Secondly is the specification of $\vartheta = \theta^{i-1}$ so its conditional probability.

$$\alpha(\vartheta|\theta^{i-1}) = min\left\{1, \frac{p(Y|\vartheta)p(\vartheta)/q(\vartheta|\theta^{i-1})}{p(Y|\theta^{i-1})p(\theta^{i-1})/q(\theta^{i-1}|\vartheta)}\right\}$$

The RWMH algorithm uses a normal distribution centered at the previousθ^idraw as the proposal density:

$$\vartheta|\theta i \ \sim \ N(\theta^i, c^2\Sigma)$$

Given the symmetric nature of the proposal distribution, the acceptance probability becomes

$$\alpha = min\left\{1, \frac{p(\vartheta|Y)}{p(\theta^{i-1}|Y)}\right\}$$

The possible draw, ϑ, is considered and accepted with a probability of 1, where the posterior at ϑbear a greater value than the posterior at θ^{i-1}. The probability of acceptance reduces as the posterior at the proposed value declines relative to the current posterior. The proposal variance controls the relative variances and correlations in the proposal distribution.

3.5.2 Method of nonlinear approximation of SOE DSGE Model

This study applies the two competing nonlinear estimation techniques used in the literature. The first is applying the particle filter, which is consistent with the MCMC, and the second is to consider the particle filter that follows the SMC.

Particle Filter Markov Chain Monte Carlo for Nonlinear DSGE Model

Given $i = 1 \ to \ N$, the draw of ϑ in a probability density function $q(\vartheta|\theta^{i-1})$

$$\alpha(\vartheta|\theta^{i-1}) = min\left\{1, \frac{\hat{p}(Y|\vartheta)p(\vartheta)/q(\vartheta|\theta^{i-1})}{\hat{p}(Y|\theta^{i-1})p(\theta^{i-1})/q(\theta^{i-1}|\vartheta)}\right\}$$

Particle Filter Sequential Monte Carlo for Nonlinear DSGE Model

The application of the PFSMC follows the process of data tampering application and to initiate the tampering process proceeds as follows: Given that a sequence represented as

$\theta_n, where\ n = 1\ to\ N_\theta$ increases sequentially from zero to one. Therefore, the sequence of the posterior that defines the given sequence as:

$$\pi_n(\emptyset) = \frac{[p(Y|\emptyset)]^{\emptyset_n} p(\emptyset)}{\int [p(Y|\emptyset)]^{\emptyset_n} p(\emptyset) d\emptyset}$$

After filtering a magnitude of $\left[\emptyset_n^i, W_n^i\right]_{i=1}^N$ particles. This size of particles is average out using the Monte Carlo as:

$$\bar{h}_{n,N} = \frac{1}{N}\sum_{i=1}^{N} W_n^i h(\emptyset^i) \rightarrow \mathbb{E}_\pi[h(\emptyset_n)]$$

From the generated $\left[\emptyset_n^i, W_n^i\right]_{i=1}^N$ particles the PFSMC algorithm proceeds in three steps. This formalization is consistent with Chopin (2004). Having initiated the start-up which is given by:

$$\theta_0 = 0$$

Then the initial particle is drawn from the prior which is given by:

$$\emptyset_1^i \sim p(\emptyset)$$

Where W_n^i =1 for $\forall = 1, \ldots\ldots, N$

First step

Correction: In this step, the $n-1$ particles reweight by specifying the incremental weight.

$$\widetilde{w}_n^i = \left[p(Y|\emptyset_{n-1}^i)\right]^{\theta_n - \theta_{n-1}}$$

Also, the normalized weights

$$\widetilde{W}_n^i = \frac{\widetilde{w}_n^i \widetilde{W}_{n-1}^i}{\frac{1}{N}\sum_{i=1}^{N} \widetilde{w}_n^i \widetilde{W}_{n-1}^i}, \qquad i = 1 \ldots\ldots\ldots N.$$

Second step

Selection: There are two cases for selection. If $\rho_n = 1$ and if $\rho_n = 0$.

- For the case of $\rho_n = 1$, particles are resampled by multinomial resampling where the weight $\left[\theta_{n-1}^{i}\widetilde{W}_{n-1}^{i}\right]_{i=1}^{N}$ therefore we set $\widetilde{W}_{n-1}^{i} = 1$
- In the case of $\rho_n = 0$, the particles are resampled with the weight $\widetilde{W}_{n}^{i} = \widetilde{W}_{n}^{i}$. The approximation of $\mathbb{E}_{\pi,n}(h\theta)$. Which is:

$$\hat{h}_{n,N} = \frac{1}{N}\sum_{i=1}^{N} h(\theta_n^i)\,\widetilde{W}_n^i$$

Third step

Mutation: This deals with propagating the particles $\left(\theta_{n-1}^{i}\widetilde{W}_{n-1}^{i}\right)$ through the MH algorithm which bears a transition density of θ_n^i that approximate as

$$\hat{h}_{N\varphi,N} = \frac{1}{N}\sum_{i=1}^{N} h(\theta_{N\varphi}^i)\,\widetilde{W}_{N\varphi}^i$$

3.5.3 Model Evaluation

The evaluation of relative fitness of the DSGE model estimate following Chang *et al.* (2007), which requires the use of the posterior odds and Bayesian averaging. The inference on the absolute fitness of the DSGE is drawn based on both the posterior and the prior forecasting checks. Given the available information and the sampled time horizon, the forecasting distribution of Y_T given a period t.

$$p(Y_T|\mathbb{F}_t) = \int (Y_T|\theta_t)\,p(\theta_t|\mathbb{F}_t)d\theta_t$$

That means that if the absolute value of the computed statistics from the data falls within the tails of the posterior or prior forecasting distribution, it can be concluded that the model is inconsistent with the feature of the underlying data.

3.6 Sources and Description of Data

The estimation and calibration of the model apply a quarterly frequency. The quarterly frequency is predominantly used in the literature (see Mordi *et al.*, 2013, Adebiyi & Mordi, 2016; Sam, 2017). Data on Real Gross Domestic Product (RGDP), consumer price index, compensation of employee, oil prices (bony light) and monetary policy rate is drawn from 2007Q1 to 2017Q4 were obtained from the CBN bulletin. These variables measure in millions of local currencies. Data on Gross Fixed Capital Formation (GFCF), foreign GDP, proxied by the United State (U.S) GDP, foreign goods prices, proxied by the U.S goods prices, foreign interest rate, proxied by U.S interest rate were obtained from Federal Reserve statistics.

3.6.1 Data Preliminaries

The first part is a report on the preliminary treatment and handling of the data.

- **Back-Casting and Splicing Method**

In handling the data, for the period under review, the series overlaps two periods of the different base year (initial base year=1990 and rebase year=2014). As such, the two series were harmonized, rechain, and seasonally adjusted using the back-casting and splicing method in line with the United Nations Economic Commission for Africa (UNEC, 2015).

- **Hodrick Prescott One-Sided Filter**[23]

The choice and application of one-sided filter are given prominence over the conventional two-side filter in line with Stock & Watson (1999). Unlike the symmetric moving average two-side filter, which uses lags and leads series to isolate trend. The preferred one-side filter does not require lead values of a series to generate a current estimate of trend. Which means that the feature values of the series will not require to detrend the original series. Hence the potential of forecasting with the model is higher.

The degree of smoothness of trend (λ) sets as 1600 which is in line with quarterly data for emerging economies (see Marcet & Ravn, 2003)

[23] This step is very challenging because a wrong removal of cycles implies mismeasurement of growth in the series and this may affect subsequent analysis.

CHAPTER FOUR

RESULT PRESENTATION, ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter focuses on the presentation of the results of the estimated DSGE model and discussion. The first part is the presentation of the simulation of the models indicating the role of informality when both internal (domestic)and external (foreign) shock occurs. Four distinct shocks are considered, this includes two domestic shocks, namely *aggregate productivity shock* (in order to illuminate the household labour dynamics in both formal and informal economy) and *markup shock* (this is a sector-specific shock that is originating from informal goods-producing firms). The other two external shocks include *oil price shock* because we are dealing with an oil economy that exports to the ROW and *foreign inflationary shock* because the economy in question is an open economy. The second part of the work analyses the effect of monetary policy on the aggregate demand given the shocks that have occurred in the economy. The last part analyzed the effect of fiscal policy in stabilizing the economy.

4.2 Result of Preliminary Bayesian Identification test

Following Iskrev (2011), the study proceeds with preliminary identification test, see the plot in appendix 1a. The plots represent normalized curvature of the log-likelihood function at the prior mean in the direction of the parameter. The results show that the parameters are identified and the absolute value of the bars indicates evidence of strong identification. The decomposed further confirms the strength of the identification. All the deep and structural parameters are in the direction of increasing strength of identification. Similarly, the result of sensitivity is in appendix 1b; it shows that the parameters have a substantial effect on the moment of the model. Also, the result of the pairwise collinearity test shows that there is a correlation between the structural shocks in the two-bloc model.

4.3 Result of Post Diagnostic test and Model Validation

The result of Markov Chain Monte Carlo (MCMC) multivariate and univariate convergence diagnostic (Brooks and Gelman, 1998) test is in appendix 8. The plots show that the distribution of the data convergences to the true posterior distribution.

In the next section, we take the model to data and see how it fits Nigerian data. The focus of the section is to analyze the cyclical behaviour of the data.

4.4 Result of Calibration and Bayesian Estimation (Simulation of SOOE)

This section focuses on determining the role of informality in an SOOE. In line with the key features of the economy, four distinct shocks: (i). Aggregate productivity shock[24] in response to technological innovation (ii). Markup shock from the informal economy, which accounts for the vast agricultural activity in the informal economy (iii). Oil price shock, explains the commodity sector, which exports oil to ROW (hence the price of this commodity is not determined domestically) (iv). Foreign inflationary shock, this explains the economy dependent on imports due to openness. The first two shocks explain the dynamics of the entire economy based on the unique response of each sector to internal shock. The last two shocks are consistent with the characterized features of the economy these are its reliance on oil export as a source of government income and large import of goods from ROW invoiced in U.S dollar[25] (dollar-denominated prices of imported goods). In order to see cyclical behavior of the economy across the different sizes of informality, the simulation takes account of varying degree of informality. The result of the simulation comprises of three calibrated sizes of informality. High, medium and low degree of informality which are calibrated at 70 percent,

[24] Although we modelled the productivity in the two sectors to be different but it seems there is a close correlation between the two shocks. Therefore, we proceed with examining the aggregate productivity shock across the two sectors.

[25] The flexible exchange rate of dollar implies it appreciation or depreciation relative to the domestic currency might affect price of import.

50 percent and 30 percent respective. Hence the choice of the calibration parameters follows empirical evidence in Schneider (2014) and Frey & Schneider (2005).

4.4.1 Significance of Informality in SOE: Evidence from Aggregate Productivity shock

Figure 4.1 shows the effect of productivity shock on the economy under varying degree of informality. Short-run aggregate output and consumption fell below equilibrium. Both rise in the subsequent periods and adjust back to equilibrium after twenty quarters. However, aggregate investment rise in both short and long-run before adjusting to equilibrium. Thus, this means the effect of productivity shock on the economy follows a business cycle, such that period of boom follows that of recession. The initial decline in aggregate output and aggregate demand can be linked to the change in capital to labour ration. Thus, the result indicates that firms' output will decline in the short-run due to technological innovation that increases capital productivity, which makes firms substitutes labour. Which creates a temporary labor market slack, that drives wage-income downward and translates to fall in output. This result supports other literature such as Chari, Kehoe, & McGrattan (2004) and Cole, Ohanian, & Leung (2009). The evidence by Cole *et al.* (2009) attributes 2/3 of depression across heterogeneous countries to productivity shock. The subsequent rise in output comes from the increases in efficiency of capital input overtime as less working hours of household labour is replaced by the efficient new technology. Hence both firms' output and households' consumption begin to rise across formal and informal sectors. However, the rise in output of the formal firms is larger than that of the informal firms' output.

The result from the informal sector shows that the impact of the shock is greater in the informal economy, especially when there is high informality. Thus, there is a more short-run loss in output products in the informal economy, and the loss is greater when informality is higher. Therefore, the cost of the initial investment is higher, but this cost diminishes until the total cost is asymptotic to the increasing level of output.

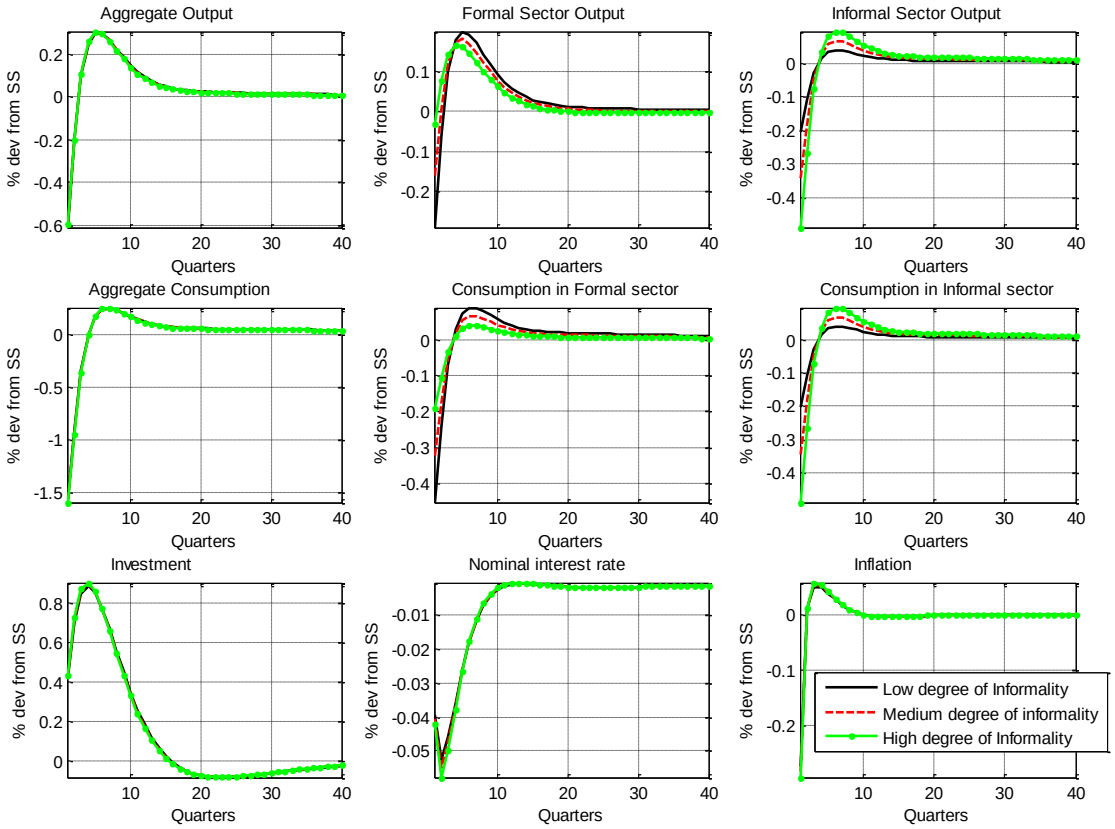


Figure 4.1: Productivity Shock in SOE with informality

The result reveals that after the initial decline in output, the formal sector experiences more boom than the informal sector before equilibrium adjustment. Therefore, this implies that the decrease in output gap is largely due to the rise in productivity of firms in the formal sector. Therefore, firms in the formal sector adopt technology faster than informal firms. A good reason is that unlike formal firms, informal firms are credit constrained[26] , and the initial cost of adoption of technology could be high. The result from the informal dynamics suggests that the size of the boom and duration depends largely on the size of the formal economy relative to informal. Formal firm accessibility to credit is a major factor that explains the higher output when productivity shock occurs. Firms in the formal sector can easily invest in new technology and raise their output, unlike the credit constrained informal firms with little or no access to

[26] Informal firms have less access to credit market and therefore productivity may remain low in the short-run. Other cost associated with training may hinder productivity of informal firms.

the credit market. That means informal firms are relatively inefficient with lower per capita output when there is productivity shock in the economy. Which also means that the rise in aggregate investment is largely is as a result of formal firms' investment. Hence it can be inferred that the increase in informality has the propensity to lower aggregate investment when there is productivity shock. Evidence from the result shows that the short-run nominal interest rate is declining in just about the same period investment is rising. This further buttress the fact that formal goods-producing firms have access to credit at a lower rate, which encourages them to invest more. While the informal goods-producing firm is constrained even when the nominal interest rate is falling

The initial slow response of consumption to productivity shock reflects both in the formal and informal economy. There is evidence of substitution and income effect[27] in the consumption of both informal and formal goods. Which could have arisen from the changes in price due to the inflationary pressure associated with the growth in output. Also, because the nominal interest rate is falling, inflationary pressure accumulates in the short-run. Generally, a rise in consumption of informal goods is also associated with an increase in wage-income coming from the increase in informal labour working hours. Similarly given that informal goods-production is more labour intensive. Therefore, productivity shock leads to an increase in both output of informal firms and consumption of informal goods before adjuting to equilibrium. This finding aligns with the evidence from Ahmed *et al.* (2012), Senbeta (2013) and Esfandyari & Dahmardeh (2014)

The result indicates that the effect of productivity shock has a deflationary effect on the overall economy. It also creates a larger output gain in the formal sector than in the informal when output begins to rise. The initial effect of shock on output leads to greater losses in the informal

[27] Households adjust their intertemporal constrain by rotating the budget line to substitute more goods (inferior goods) with luxury goods.

economy. Which suggests that the informal economy has a distortionary effect on output. Hence goods-producing firms in this sector are less efficient when productivity shock occurs, possibly due to credit constraint. Therefore, the increase in the size of informality is detrimental to a boom that is associated with a productivity shock

4.4.2 Significance of Informality in SOE: Evidence from Informal Firms' Markup Shock

Figure 4.2 shows that when markup shock occurs, the response of aggregate output, consumption, and investment differ substantially, depending on the size of informality. All these variables decline when there is markup shock from the informal economy. The result indicates that these severity of impact on aggregate output and consumption is symmetrical across equal sizes of informality. The evidence suggests that the output of the formal economy is more affected by the markup shock even when it is originating from the informal goods-producing firm. Relative to the formal sector, there is only a marginal output loss in the informal economy. Which means that there is a negative spillover effect on formal firm output when there is markup shock from the informal goods-producing firms. This spillover effect distorts the formal firms producing goods output adversely. Household labour hours decline more in the formal economy, but adjustment back to equilibrium is faster than in the informal sector. Therefore, the switch of hours of labour supply from formal to informal due to the recession caused by markup shock from the informal sector reverses very fast. Such fast reversal causes the delay in the readjustment of informal firms to output back to equilibrium. Hence the job search in the informal economy increases as job losers in the formal economy rises but the stay in the informal sector can be temporary. Furthermore, the recession in both formal and informal economy depends entirely on the relative size of informality. The larger

the size of informality, all things being equal, the deeper will be the recession[28]. Thus, this points out the fact that increase in informality is an indication of contraction in the formal economy and stability in the informal economy, which explains the resilience observed in the informal economy during the recessionary period.

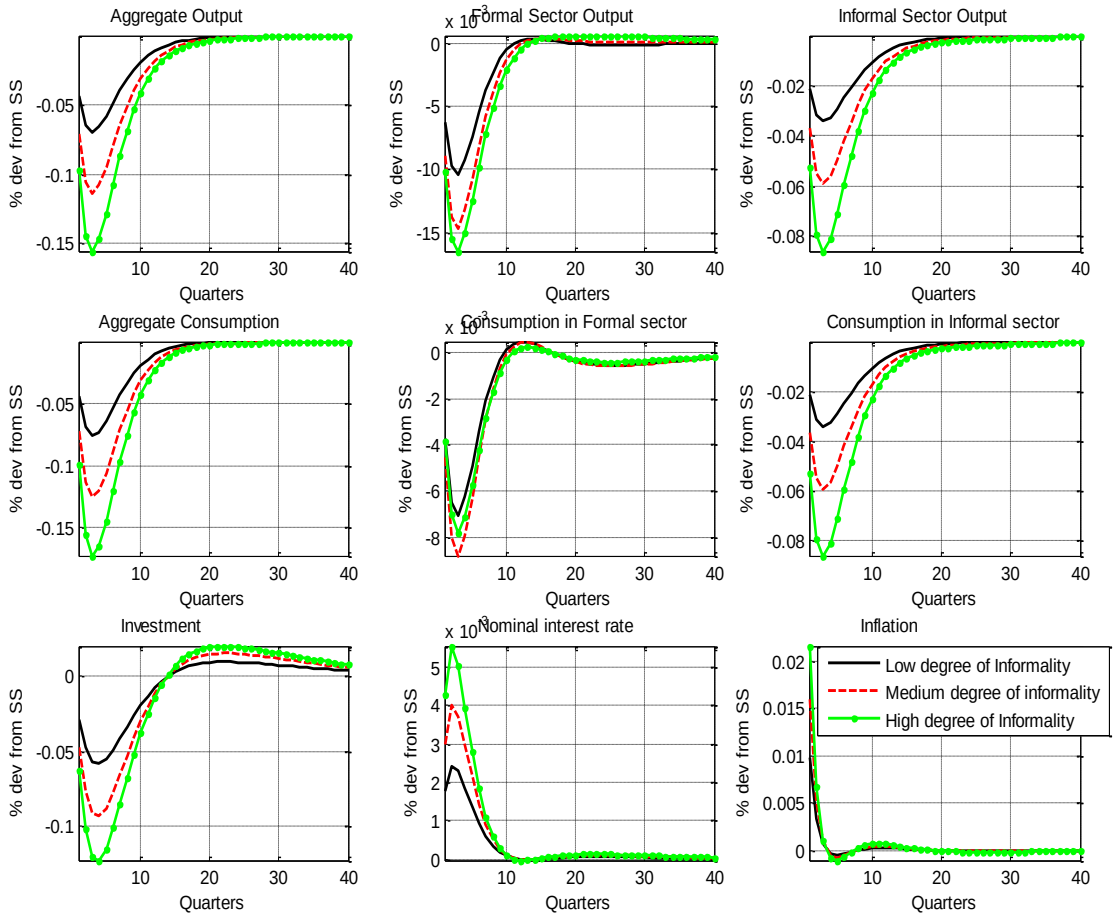


Figure 4.2: Markup Shock from the Informal Sector in SOE

The effect of the informal firms' markup shock equally has a greater negative distortionary spillover effect on consumption of formal firms' output. However, the effect relative to the size of informality on the consumption of formal firms' goods diminishes. However, this is not the case in the informal economy. The fall in consumption of informal goods increases as the size

[28] This could be the other way around, that recessionary period leads increase in informality because of formal sector job losers take up informal activity and increases the activity in the informal economy. This explains the resilient nature of the informal sector in recessionary period.

of the informal economy grows larger (this means the magnitude of the decline in consumption of informal goods depends on the size of informality). Also, it takes consumption of formal goods almost half the adjustment period of consumption of goods produced in the informal economy to return to equilibrium. Thus, this implies that the formal economy recovers faster during a recession. That is, households labour hours increases more rapidly inefficient formal goods-producing firms than in inefficient informal sector.

Because aggregate investment has also been falling due to the informal markup shock, we sum up that the effect of the shock on aggregate demand[29] (aggregate domestic consumption and investment) is negative. However, inflation and nominal interest rate rise in the short-run, and afterward, both declines. The result shows that the fall in inflation is faster and trending downward ahead of decrease nominal interest rate[30], which suggests that monetary policy can manage expected inflation. The initial increase in actual inflation explains the rise in expected inflation in short-run due to the forward-looking rational economic agent that anticipated the effect of the informal markup shock on wage-income.

Similarly, the result shows that the short-run nominal interest rate remains tight[31] because monetary authorities were also forward-looking in anticipation of the inflationary effect of the markup shock on general prices (see also Bello and Sanusi, 2016). This stance of tightening even when the additional instrument is used deflated the pressure accumulated by expected inflation. As inflation trend downward, the nominal interest rate slowly declines in response to the fall in aggregate demand. This action is necessary in order to forestall the stagflationary effect of informal markup shock on aggregate output.

[29] Note that we expect consumption of foreign goods and foreign domestic investment to form part of the aggregate demand.
[30] This means nominal interest is anchored on expectation
[31] Especially additional monetary instrument such cash reserve requirement and liquidity ratio

Overall, the result shows that sector-specific (informal sector) markup shock can have an impact on the aggregate macroeconomic variables such as aggregate output, consumption, investment, nominal interest rate, and inflation. Markup shock that originates from the informal sector has a stagflation effect on the aggregate economy. Meanwhile, the originating shock from the informal economy has a negative spillover effect on the formal sector. Thus, the severity of the stagflation is found to be greater on the formal economy. By implication, the informal sector is more resilient to stagflation largely because informal goods-producing firms will have lower marginal cost by not paying many forms of taxes to the government. This finding supports Schneider & Enste (2000), Schneider (2005), Maloney & Saavedra-Chanduvi (2007) and Schneider (2006), among others. Another important finding from this section is that the larger the size of informality, the greater the fall in consumption of informal goods arising from shock.

4.4.3 Significance of Informality in SOE: Evidence from Oil Price Shock

The ROW economy exogenously determines oil price shock in Nigeria. Figure 4.3 shows the effect of a positive oil price shock on the economy. Aggregate output, consumption, and investment rise in the short-run. This evidence suggests that there is an economic boom when positive oil price shock occurs. Aggregate investment and output are found to be more responsive than aggregate consumption. However, the effect of the shock on aggregate consumption and investment shows that they take a longer time to adjust back to equilibrium. Aggregate output is the most responsive to the oil shock, and it is faster in adjusting to equilibrium, which is consistent with the findings of Algozina (2015).

The result indicates that the informal output is relatively more responsive to oil shock than formal output, and the level of responsiveness in each sector depends on the size of informality. In the informal sector, the larger the size of informality, the greater the rise in output from the sector as aresult of oil price shock. Similarly, the responsiveness of output in the formal

economy is proportional to the size of the formal sector; however, the growth rate of output in the informal economy is higher. This anomaly of skewed output response in favour of the informal economy adversely affects the revenue side of fiscal policy. Because the gain from positive oil price shock that goes into the consumption of goods produced by informal firms does not constitute consumption tax. Hence remittance of tax (from Value Added Tax, VAT) component of consuming goods in the sector are loose by the government. Hence this serves as revenue leakage to government, which means the multiplier effect of the oil shock is affected by the increase in leakages when the size of informality is large.

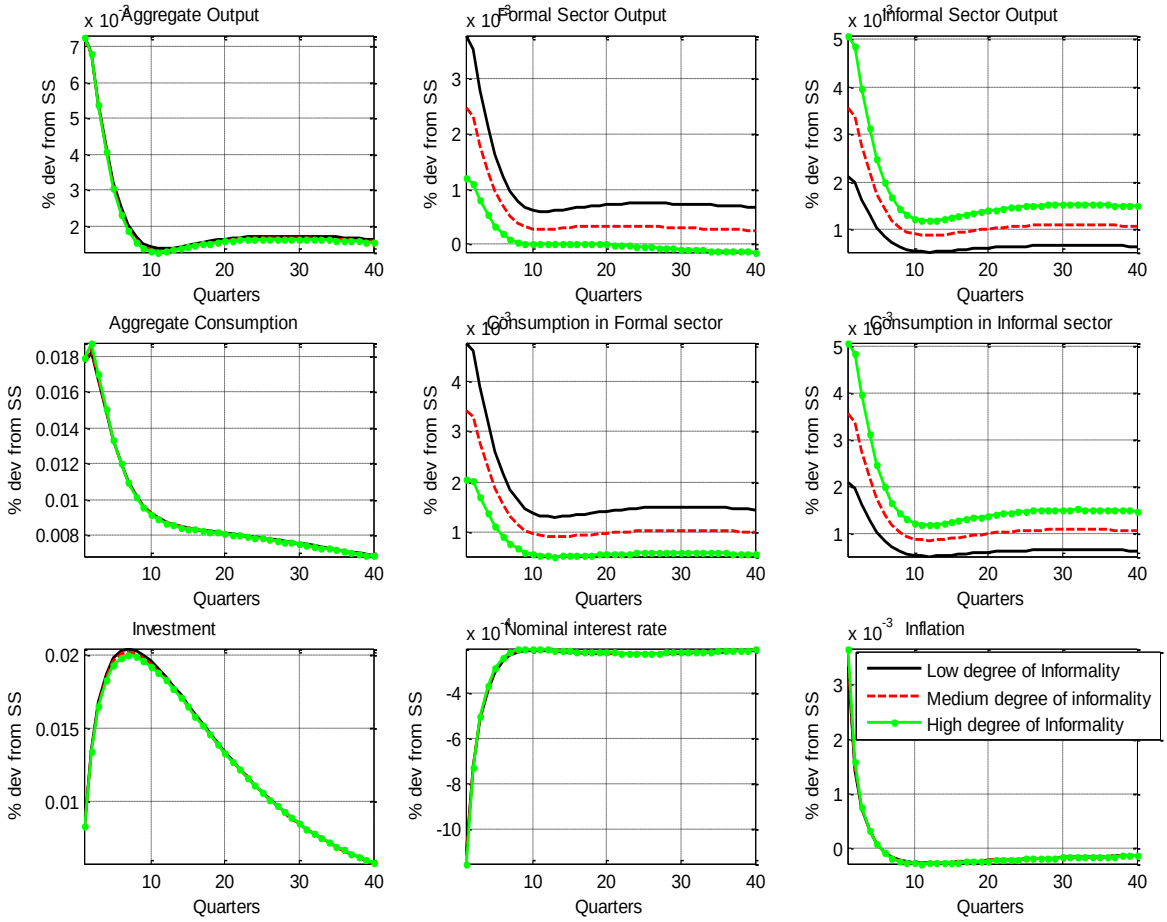


Figure 4.3: Oil Price Shock in SOE with Informality

The result suggests that the pattern of consumption of both formal and informal goods follows output growth in the respective sectors. Thus, the effect of the positive oil price shock raises

the consumption of goods produced in both sectors by almost the same magnitude by which output increases. However, the increase in consumption of goods produced in the formal sector is greater than the output produced by the formal goods-producing firms, which suggests that there is excess demand for goods produced in the formal economy. This evidence shows that nominal rigidities in expanding output as well as price stickiness characterizes the dominant firms, which is consistent with the behaviour of monopolistically competitive firms found in the formal sector (see also Christiano *et al.* 2011). As such goods importing firm in the formal sector will import in order to augment the deficit supply.

Meanwhile, the evidence from the informal economy shows that market clears. That is, there is an equilibrium between consumption of goods produced in the informal sector and output supply by informal goods-producing firms. Hence competitive and flexible price characterizes informal goods-producing firms. This finding corroborates Batini, Levine, & Lotti (2011) and Batini, *et al.* (2011). The duration of equilibrium adjustment in the two sectors shows symmetry. However, the level of increase (disequilibrium) in consumption when oil price shock occurs depends on the degree of informality. Thus, this means the larger the informality, the more there will be a rise in the consumption of goods produced in the informal economy.

Similarly, the lower the degree of informality, the more is the magnitude of the rise in consumption of goods produced in the formal economy. The effect of the shock also leads to a decline in nominal interest rate while inflationary pressure rises in the short-run due to the increase in aggregate demand (aggregate consumption and investment).

A key finding from this section that the informal economy has a distortionary effect on fiscal revenue when oil price shock occurs. The larger the size of informality, the greater the dictionary effect that comes from fiscal revenue leakages. Therefore, poor performance and

inefficiency of fiscal policy that results in higher government debt in Nigeria can be associated with large informality.

4.4.4 Significance of Informality in SOE: Evidence from Foreign Inflationary Shock

The evidence in figure 4.4 shows that monetary authority in Nigeria accommodates foreign inflationary shocks into the domestic economy. The accommodating behavior is reflected, first, in the fall in short-run nominal interest rate. Secondly, because in practice, the central bank considers the exchange rate when adjusting its monetary policy (Bello & Sanusi, 2018). The central bank exhibits non-aggressive behaviour as it smoothens the long-run interest rate path. This finding also corroborates Bello & Sanusi (2016). The accommodated external inflationary shock passes through the exchange rate as a positive shock on domestic prices in the short-run. Thus, the effect of purchasing power parity translates this shock as an appreciation of the domestic currency (naira) against the US dollar. Hence the effect of foreign inflationary shock leads to a rise in aggregate output, consumption, and investment. Although the rise in the macroeconomic aggregates is only in the short-run. In the long-run aggregate output and consumption adjust back to equilibrium. However, aggregate investment adjustment to equilibrium is much longer, and short-lived, before it begins to rise again. Because rational investors reallocate investment by transferring capital (both portfolio and others) flows from ROW economy (high inflationary environment) into the low inflationary domestic economy, which prolongs delay in equilibrium adjustment.

Output in both formal and informal economy rise in response to the positive foreign inflationary shock in equal proportion. The increase in output in each sector depends on the size of each sector relative to the other, which means the larger the degree of informality, the more the rise in output in the informal economy. Hence this suggests a directly proportional relationship between the degree of informality and the magnitude of the output in the informal economy. The implication of this shock on the goods-producing firms in both formal and

informal economy is that firms take advantage of the change in purchasing parity[32] to produce more.

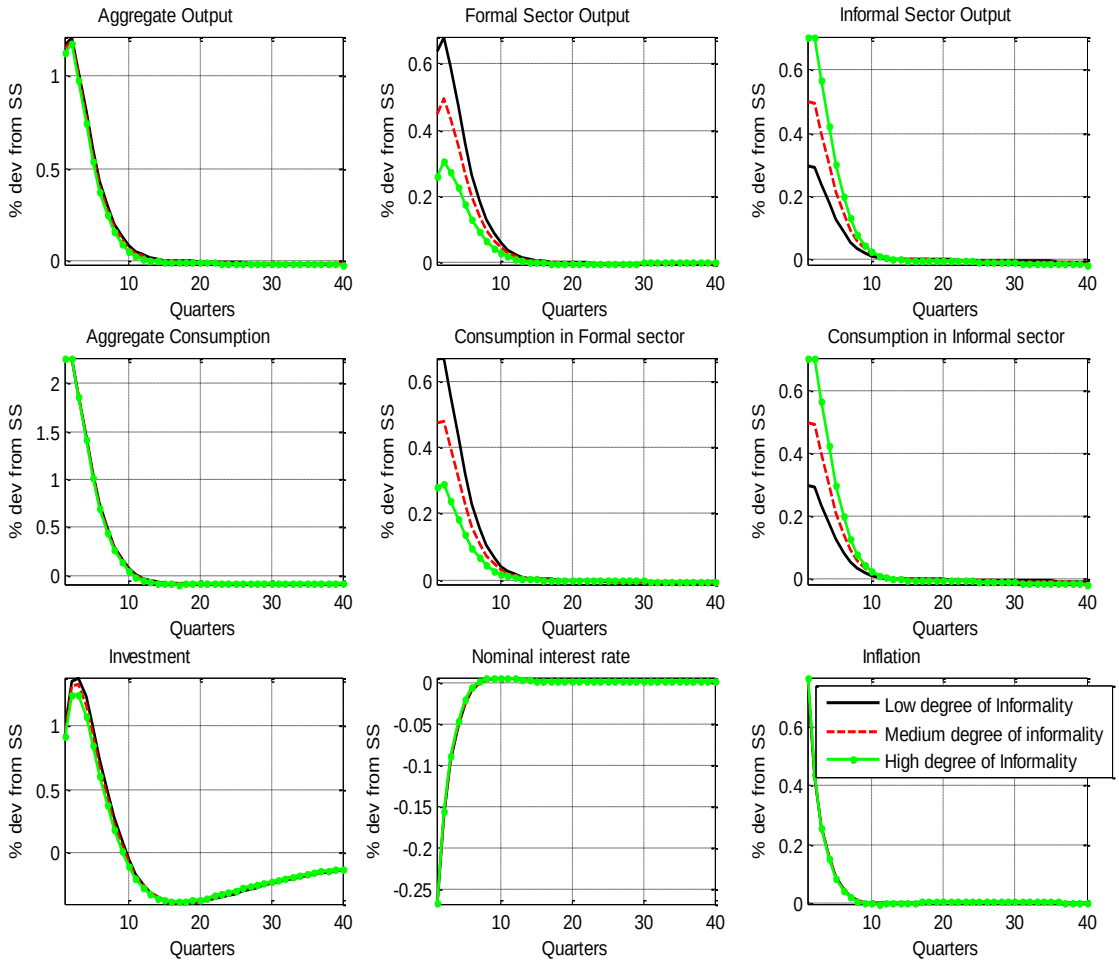


Figure 4.4: Foreign Inflationary Shock in SOE with Informality

Similarly, there is a proportional rise in the consumption of goods produced in both sectors, which is because a positive inflationary shock has made imported goods more expensive relative to goods produced in the domestic sector of the economy. The magnitude of the increase in consumption due to foreign inflationary shock is as well proportional to the size of

[32] Benefit of domestic currency appreciation against the dollar makes domestic output cheaper. Hence goods producing firms in all sectors will raise output due to increase in demand that is associated with a rise in the value of currency.

the informality. Also, the rise in consumption of goods produced in both sectors will increase household labour working hours.

The evidence has shown that the rise in aggregate demand is accompanied by a less than proportionate increase in inflation, which suggests that the output gap is large in the short-run and the aggregate supply curve, for the period under review, is flatter[33]. The result also indicates that upward adjustment of the nominal interest rate prevents capital inflow from reversing.

Generally, the result shows that the impact of the foreign inflationary shock on the domestic economy determines the magnitude of the change in the purchasing power parity between the domestic currency and the dollar. Positive foreign inflationary shock increases the purchasing parity rate and makes foreign goods relatively more expensive. Domestic firms in both informal and formal sector expand output in response to the rise in consumption of the relatively cheaper domestically produced goods in both formal and informal economy. Also, aggregate investment rises due to an increase in capital inflows, and the nominal interest rate adjusts upward to retain inflows and prevent reversal of capital.

Having established the role of informality in the presence of dynamic stochastic macroeconomic shocks. Next is to investigate the response of the SOE to macroeconomic policies that aim to stabilize these shocks.

4.5 Monetary Policy Response in SOE with Varying Degree of Informality

One of the key lessons taken from the previous sections is that all macroeconomic shocks considered, irrespective of where they originate, have different magnitude and diverse effect on aggregate demand. More so, the response of the sectors differs depending on the size of informality. Here we examine the potency and effectiveness of demand management policy in SOE with varying degree of informality.

[33] Hence domestic output is elastic

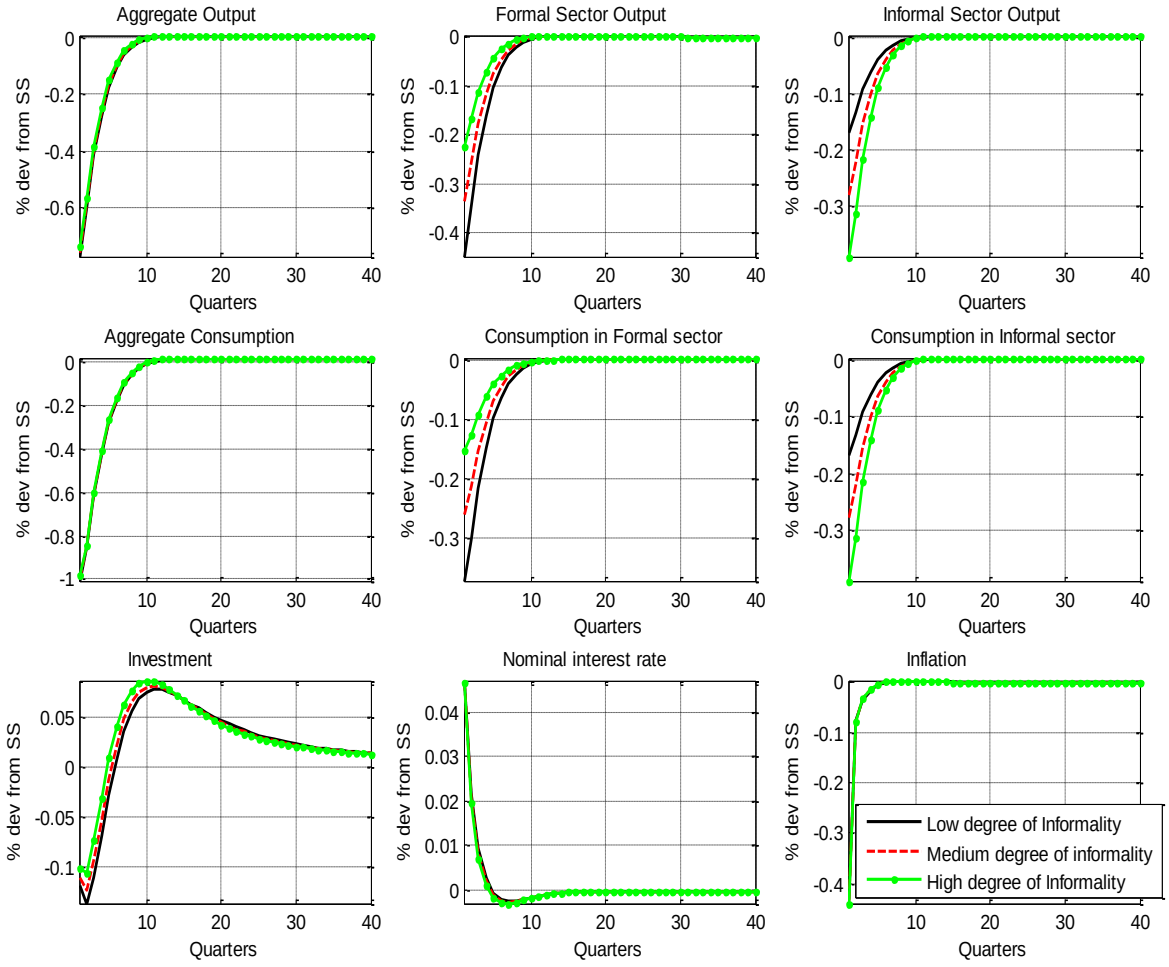
In all of the structural shocks considered only aggregate productivity shock is found to have an initial deflationary effect on the economy. Thus, oil price, foreign inflationary, and markup shocks all have an inflationary effect on the domestic economy in the short-run. Therefore, a positive response in the form of monetary policy tightening (contraction) is expected and required in managing the rise in inflation caused by demand push (increase in aggregate demand) that is associated with all or any of; *foreign inflationary shock,* the *oil price shock* and *markup shock*.

Figure 4.5 shows that the nominal interest rate rises when monetary authority tightens the monetary policy rate. As such inflation falls and its response to monetary policy tightening is fast, however, it takes about five (5) quarters for it to be stable. The evidence from the result suggests that the magnitude of the response of inflation to monetary policy in the first quarter is about 45%[34], which means that inflation falls by about 45% when positive monetary policy shock occurs. Thus, in comparison, the potency of the monetary policy in figure 4.5 with the built-up inflationary pressure across the various shocks (see figures 4.2, 4.3 and 4.4) under review, the result suggests that monetary policy is more effective in managing inflationary pressure generated from markup shock (figure 4.2). The result indicates that domestic shock associated with informal sector markup inflates the economy by only 2%, which is well within the potency limits of the monetary policy.

Conversely, the inflationary pressure of about 60% and 0.0035% from external shocks associated with foreign inflation and oil price shocks in figure 4.4 and 4.3 respectively show a mix response to monetary policy. The pressure of 0.0035% arising from oil price shock is well within the potency threshold. However, foreign inflation shock exerts a far greater pressure on the domestic economy, which is beyond the potency threshold of monetary policy. The

[34] This is considered as the potency threshold of the monetary policy in Nigeria. Beyond which monetary policy is c can be partially potent or impotent

implication is that demand for foreign goods builds additional pressure as the purchasing parity increases, which puts pressure on not only aggregate demand but as well the exchange reserves.



[35]Figure 4.5: Monetary Policy Response in SOE with Varying Degree of Informality

The result shows that aggregate output, consumption, and investment fall when there is a monetary policy response to fight inflation. Thus, aggregate demand declines when monetary policy responds in order to deflate the built-up pressure on general prices. Therefore, anti-inflationary policy has a distortionary effect on welfare. The result in figure 4.5 shows that the effect of the policy is more severe on aggregate consumption than on aggregate investment,

[35] The initial response of inflation to monetary policy is fast, largely due to forward looking behaviour of economic agent. However, inflation adjustment slows down as inflation gets closer to it targets.

even though the speed of adjustment is equal for all the macroeconomic aggregates. The behaviour of aggregate investment shows more dynamics[36] with evidence of asymmetric adjustment. These dynamics reflect in the short-run fall, which is succeeded by a rise. The asymmetry indicates the largeness in the degree of fall below equilibrium relative to the magnitude of the rise in aggregate investment above equilibrium. Hence this means that the fall in aggregate investment below equilibrium when monetary policy shock occurs is more than magnitude by which investment exceeds equilibrium. The evidence shows that the adjustment of negative partition is faster than that of the positive partition in reverting to equilibrium. Thus, the equilibrium adjustment is faster when investment falls below equilibrium than when it is above. The result also shows that the size of informality has some marginal effect on the dynamics of aggregate investment in the short-run. The larger the degree of informality, the smaller is the short-run impact of monetary policy shock on aggregate investment, and impliedly, the lower the magnitude of the fall in investment. However, in the long-run, the impact of informality dissipates.

The result (figure 4.5) shows that the impact of monetary policy tightening on the sectors (formal and informal), has a greater effect on the output of the formal economy than that of the informal sector output. The result indicates that the magnitude of fall in output of the informal economy is substantially smaller than the fall in output of the formal sector. Which suggests that credit channel terminates in the formal sector and the proportion of credit constrained firms, that have no access to the credit market constitute informal goods-producing firms. Therefore, monetary policy will not affect informal output as much through the credit channel. The result also indicates that the propensity of an output response, to monetary policy shock, depends on the degree of informality. The larger the size of informality, the less responsive is

[36] It is believed that capital inflows and outflow (surge, stops and reversal) in response to monetary policy, explains this dynamic behaviour because of degree of openness of the capital account without controls.

output to monetary policy in the formal sector. Similarly, the lower the degree of informality, the less the responsive is output in the informal economy.

The response of consumption to a monetary policy tightening in figure 4.5 shows no distinction between the two sectors. Both in terms of the magnitude of the response and equilibrium adjustment; consumption of goods produced in the informal economy shows identical behaviour with that of the formal sector. However, the degree of informality has an impact on the level of responses in the consumption of goods produced in both the informal and formal economy. The larger the size of informality relative to the formal economy, the less the response of consumption to monetary policy.

With the realization of the potency threshold of monetary policy, the inference that follows is that monetary policy in Nigeria is more effective in dealing with structural shocks that originate domestically than shocks (except the oil price shock) that originates externally. The impact of monetary policy shock on sectors (formal and informal), indicates that there is a greater effect of monetary policy on the formal economy than in the informal. The behaviour of aggregate investment to a monetary policy response in figure 4.5 shows more dynamics relative to other macroeconomic aggregates with evidence of asymmetric equilibrium adjustment. The evidence shows that the adjustment of negative partition is faster than that of the positive partition in reverting to equilibrium. Also, the degree of informality has an impact on the level of responses in the consumption of goods produced in both the informal and formal economy.

The evidence from previous sections (see figure 4.2 and 4.3) has shown the relevance of macroeconomic (monetary) policy in managing aggregate demand when there is an inflationary threat in the economy as a result of structural shocks. Next is to proceed with examining the effect of discretionary fiscal policy when the economy is deflated as a result of productivity shock, as seen in the first section (see figure 4.1).

4.6 Fiscal Policy Response in Small Open Economy with Varying Degree of Informality

As can be seen in figure 4.6, the effect of fiscal policy response on the deflationary effect of an initial productivity shock is expansionary on aggregate demand, which equally means a decrease in the output gap. Hence this has two broad implication. First is that households' supply more labour working hour to both informal and formal goods-producing firms. Secondly, the wage bill of informal and formal goods-producing firms' increases, which leads to a rise in the marginal cost of the firms.

The result in figure 4.6 shows that aggregate output and consumption rise in the short-run by an equal magnitude when there is an expansionary fiscal policy. Similarly, the speed of equilibrium adjustment is found to be the same in both cases, which is in line with the theoretical Keynesian postulate, that increase in government spending raises consumption and output in the short-run. However, aggregate investment falls in the short-run but rises in the long-run. Thus it demonstrates the effect of capital volatility in the economy because as rational investors that are forward-looking anticipate inflationary effect from the of fiscal policy expansion, there will be sudden stops in capital inflow, which will follow a period of reversal and retrenchment, this evidence lean support with the evidence in Forbes & Warnock (2012) and Forster *et al.* (2014). However, the evidence suggests that foreign portfolio[37] investment is likely to dominate the investment basket in Nigeria. Also, the degree of informality affects short-run aggregate investment, but the effect dissipates in the long-run. In essence, the decline in aggregate investment in the short-run is rapid when informality is low than when it is high, which means formal sector investment influences aggregate investment more in the short-run.

Following the expansionary fiscal policy, the nominal interest rate rises because the monetary policy authority is forward-looking, therefore anticipates the inflationary impact a positive

[37] This because portfolio investment is adjudged to be more volatile than direct investment, see also Broner *et al.*, (2012), Karanosos *et al.* (2014), Rejeb & Boughrara (2015).

fiscal policy shock could have on the economy. This forward-looking behaviour has kept the short-run rise in inflation minimal and adjusts back very fast. The result suggests that the behaviour of the monetary policy also sheds light on the dynamics of aggregate investment in both short and long-run (see figure 4.6).

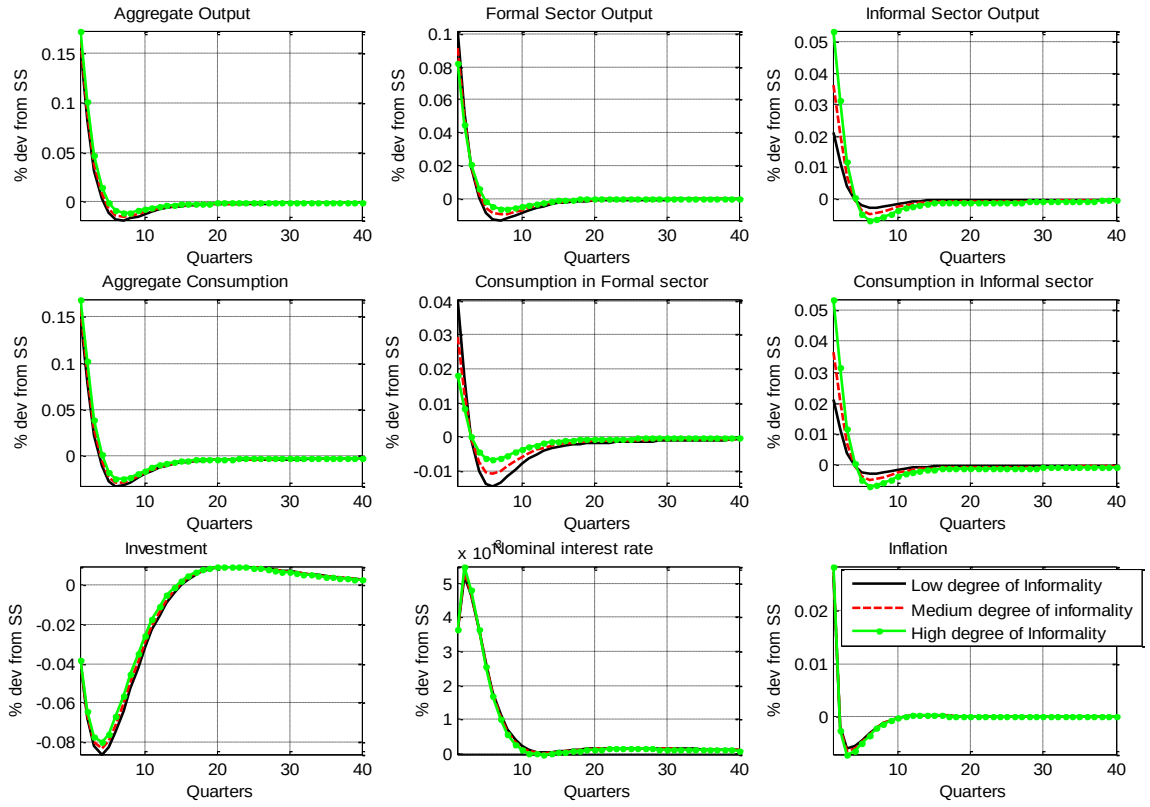


Figure 4.6: Fiscal Policy Response in SOE with Varying Degree of Informality

As figure 4.6 shows, both formal and informal sector output rises in the short-run when there is positive fiscal policy shock. However, the magnitude of the rise in formal sector output is greater than that of informal economy output. Which implies that positive fiscal policy shock has a greater impact on formal sector output than the informal economy. Hence, formal goods-producing firms will demand more hours of labour and other variable inputs than informal goods-producing firms. It is worthy to note that the share of the rise in informal sector output is a loss to the revenue side of fiscal policy, largely because sales and profit tax of informal goods-producing firms do not remit to the government treasury.

Figure 4.6 shows that consumption rises in both sectors following the expansionary fiscal policy. The consumption of goods in the informal economy increases by a larger magnitude than goods produced in the formal sector. Therefore, the effect of positive fiscal policy is greater on the consumption in the informal economy. For instance, public spending on infrastructure employs more labour hours (semi-skilled and unskilled) from the informal sector than from the formal. Therefore, the larger share of the benefit of the rise in consumption due to a positive fiscal shock, the more is the loss to government revenue because of non-remittance of tax (VAT) on the consumption of goods produced in the informal sector. Which leaks out lager revenue that should accrue to the government. Hence the leakages from the informal economy in both the production (sales or profit tax) and consumption (VAT) side constitute a significant reason for fiscal imbalance. This imbalance has the propensity to increase as the degree of informality rises. It is also the primary cause of fiscal deficit because the increasing differential between government revenue and expenditure comes through deficit financing. Therefore, Nigeria debt is likely to be increasing as informality grows, which is also the case in most developing economies with a large informal sector. This finding is consistent with other empirical evidence such as Leah (2014), Bandaogo (2016), Dellas *et al.* (2017) and others.

The degree of informality shows two contrasting impacts on each sector's output. First is that degree of informality does not matter when short-run output is responding to fiscal policy shock in the formal economy, but it matters in its equilibrium adjustment. Second is that degree of informality matter in both sizes of the short-run rise and equilibrium adjustment of output in the informal sector. In terms of dynamics in consumption, the higher the degree of informality, the lesser will be a rise in output in the formal sector, and this implies additional leakages in government revenue.

4.7 Summary of Major Findings and Policy Implication

- Based on the results presented in this chapter, the summary of major findings are: first, the study found that largeness of informality amplifies the severity of productivity shock, with a greater effect of output distortions found to be in the informal sector than the formal sector. Similarly, an increase in informality has the propensity to lower aggregate investment when there is productivity shock. Therefore, the increase in the size of informality is detrimental to a boom that is associated with a productivity shock.
- Secondly, the study found that informal markup shock has a negative spillover effect on the output of the formal economy and the adverse effect of the markup shock is even greater on the formal sector's output than in the output of the originating informal goods-producing firm. Furthermore, the result shows that the informal sector markup shock triggers stagflation in both formal and informal economy, and this depends entirely on the relative size of informality. Therefore, larger the size of informality, all things being equal, the more persistent is the shift in the Philips curve. Similarly, the result indicates that the informal firms' markup shock equally has a greater negative distortionary spillover effect on consumption of formal firms output. However, the effect relative to the size of informality on the consumption of formal firms' goods diminishes. Thus, this is not the case in the informal economy. Also, the result shows that fall in consumption of informal goods increases as the size of the informal economy grows larger (this means the magnitude of the decline in consumption of informal goods depends on the size of informality).
- Third, the result found that in the event of an oil price shock in Nigeria, the size of informality affects the output from both the formal and informal sector. Thus, the responsiveness of output in the formal economy was found to be proportional to the size of the formal sector; however, the growth rate of output in the informal economy

is higher. The result suggests that the pattern of consumption of both formal and informal goods follows output growth in the respective sectors. Thus, the effect of the positive oil price shock raises the consumption of goods produced in both sectors by almost the same magnitude by which output increases. The evidence suggests that in line with the assumption of the model, the result indicates that the informal economy market clears. That is, there is an equilibrium between consumption of goods produced in the informal sector and output supply by informal goods-producing firms. The effect of the oil price shock from the result shows that the larger the informality, the more there will be a rise in the consumption of goods produced in the informal economy. Similarly, the lower the degree of informality, the more is the magnitude of the rise in consumption of goods produced in the formal economy. The study also found that the effect of the shock also leads to a decline in nominal interest rate while inflationary pressure rises in the short-run due to the increase in aggregate demand (aggregate consumption and investment).

- Fourthly, the study found that output in both formal and informal economy rise in response to the positive foreign inflationary shock in equal proportion. The increase in output in each sector depends on the size of each sector relative to the other. The larger the degree of informality, the more the rise in output in the informal economy. Thus, a directly proportional relationship between the degree of informality and the magnitude of the output in the informal economy exists. Domestic firms in both informal and formal sector were found to expand output in response to the rise in consumption of the relatively cheaper domestically produced goods in both formal and informal economy. The result also shows that the size of informality has some marginal effect on the dynamics of aggregate investment in the short-run. The larger the degree of informality, the smaller is the short-run impact of monetary policy shock on aggregate investment,

and impliedly, the lower the magnitude of the fall in investment. However, in the long-run, the impact of informality dissipates.

- Fifthly, the study found that monetary policy is more effective in stabilizing the formal sector's output than that of the informal sector output. Therefore, the effect of monetary contraction on the output of the informal economy is substantially smaller than the magnitude of fall in output of the formal sector, and this reflects the weakness of supposing credit channel in the informal sector. Thus, the propensity of an output response, to monetary policy, depends on the degree of informality. The study found that the larger the size of informality, the less responsive is output to monetary policy in the formal sector. Similarly, the result also indicates that the lower the degree of informality, the less the responsive is output in the informal economy. The evidence reveals that the degree of informality affects the level of responses in the consumption of goods produced in both the informal and formal economy. Also, the degree of informality affects short-run aggregate investment, but the effect dissipates in the long-run. Thus, the larger the size of informality relative to the formal economy, the less effective is the monetary policy in managing aggregate demand.
- Lastly, the study found that the effectiveness of fiscal policy (expansion) in stimulating output is greater on the formal sector than the informal economy. However, the consumption of goods in the informal economy increases by a larger magnitude than goods produced in the formal sector. The found that the effect of fiscal policy is greater on the consumption in the informal economy. Given distortionary tax in the informal sector, the rise in informal sector output is a loss to the revenue side of fiscal policy, largely because sales and profit gain tax of informal goods-producing firms do not remit to the government treasury. The leakages from the informal economy in both the production (sales or profit tax) and consumption (VAT) side constitute a significant

reason for fiscal imbalance. This imbalance has the propensity to increase as the degree of informality rises. It is also the primary cause of fiscal deficit because the increasing differential between government revenue and expenditure comes through deficit financing.

Broadly there are two major implications of this study for policy. One is centered on the implication of macroeconomic shocks on the economy when there is informal sector dynamics. In line with the findings, stochastic macroeconomic shocks have a diverse effect on the economy, depending on the source and type of shocks. More so, the size of informality has serious implication on output stability as well as on the aggregate demand. Shocks that originate internally are by far better managed than shocks that come from ROW. The effect of the domestic shocks due to technological innovation or informal firms' markup that may arise from, say, unstable agricultural commodity prices, which is common in the informal sector, are both distortionary on output.

Furthermore, the net effect of the changes in aggregate demand translates to deflation of inflationary pressure in the case of technological shock. However, the net effect of informal firms' markup shock on aggregate demand is inflationary. Thus, the magnitude of the changes in aggregate demand and the impending disinflation arising from productivity shock as well as the inflationary pressure built-up by the informal markup shock is found to be well within the potency limit of monetary policy. In line with findings, informal sector dynamics accentuates the instability in output in the short-run, which implies that the larger the size of informality, the greater the loss in output resulting from productivity shock. Hence the informal sector increases distortion in output due to either of the shocks. In the case of external shocks, which are caused by dependence on oil exports or due to large degree of openness, both results on the expansion of aggregate output and aggregate demand, and in both cases, they result in inflationary pressure. However, the magnitude of the upward pressure on general prices is

found to be greater when there is imported inflation than when there is oil price shock. The implication of the higher pressure built up by the accommodation of foreign inflationary pressure is that purchasing power parity makes imported goods cheaper. This accommodative effect of foreign inflation can make the demand in both the formal and informal sector to expand proportionately. Thus, the associated net effect of aggregate demand makes inflation more persistent.

The second implication of the study relates to the potency of both monetary and fiscal policy in managing aggregate demand and stabilizing output. The finding that monetary policy instruments are relatively potent in tackling inflationary pressure and the policymakers are forward-looking; this implies that monetary policy can effectively manage aggregate demand. however, the findings suggest that the potency with which it does this depends on the size of the informal sector. The study found that the larger the size of the informal sector, the more impotent monetary policy becomes, and therefore, the more it requires the monetary policy to raise its nominal interest rate in order to get the desired response of aggregate demand. Concisely, fiscal policy is found to be more undermined by the size of the informal sector when managing macroeconomic shocks. The fiscal policy, however, is found to be effective in cushioning the distortions that arise from the shocks, but the potency is weaker in the informal sector. Also, the revenue side of the fiscal policy leakage creates fiscal imbalance because of the non-inclusion of the informal sector into the tax net.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

This study attempts to investigate nature and management of Macroeconomic Shocks in SOOE with informality using the from New Keynesian DSGE model. A New Keynesian Dynamic Stochastic General Equilibrium model was estimated and simulated across four distinct structural shocks with a varying degree of informality, in order to determine the role of informality in the effectiveness of macroeconomic management of these shocks using monetary and fiscal policies. These shocks are: aggregate productivity (domestic) shock, markup shock (domestic), the oil price shock (external), and foreign inflationary shock (external). In setting up NKDSGE model for analyzing these shocks, some key features such as price stickiness in the formal sector and flexible prices in the informal sector were introduced. Other features included into the model are non-Ricardian households and untaxed credit constraint firms that produce tradable and non-tradable goods in the informal sector. Similarly, formal sector was characterized with Ricardian households with credit and non-credit constrain firms. Lastly the model was taken to data and estimated using Nigerian data. The study found as follows:

- The effect of aggregate productivity shock has both deflationary and inflationary effect in the short-run. It also creates a larger output gain in the formal sector than in the informal. The initial effect of the shock on output leads to greater output losses in the informal economy, which suggests that the informal economy has a distortionary effect on output, hence less efficient when productivity shock occurs. This effect may be due to the credit constraint in the sector. Therefore, an increase in the size of informality was found to be detrimental to the booms that are associated with productivity shocks.

- Informal sector markup shock was found to have a significant impact on the aggregate output, consumption, investment, nominal interest rate, and inflation. It has a stagflationary effects on the aggregate output. Also, the originating shock from the informal economy has a negative spillover effect on the formal sector. Thus, the severity of the recession is found to be greater on the formal economy. By implication, the informal sector was found to be more resilient in sliding into recession largely because nonpayment of tax reduces the marginal cost of firms in the informal sector. The larger the size of informality, the greater the fall in consumption of informal goods. Because aggregate investment has also been falling due to the informal markup shock, the net effect of the shock on aggregate demand[38] (aggregate domestic consumption and investment) is negative.
- Evidence from the impact of oil price shock shows that the informal economy has a distortionary effect on fiscal revenue when oil price shock occurs. The larger the size of informality, the greater the dictionary effect that comes from fiscal revenue leakages. Furthermore, the informal output was found to be relatively more responsive to oil shock than formal output, and the level of responsiveness in each sector depends on the size of informality. In the informal sector, the larger the size of informality, the greater the rise in output from the sector. Similarly, the responsiveness of output in the formal economy is directly proportional to the size of the formal sector. However, the growth rates of output and consumption in the informal economy are higher than the formal sector. The lower marginal cost of production, which arises from the non-payment of tax by the informal firms explains the larger response of the output of the informal economy since informal firms do not pay tax. Therefore, the cost of production will be,

[38] Note that we expect consumption of foreign goods and foreign domestic investment to form part of the aggregate demand.

low, and informal goods-producing firms will expand output in order to maximize revenue in the informal economy.

- The gain from positive oil price shock spent on goods produced by informal firms do no generate revenue to the government through VAT; rather, such spending leaks revenue in the shadow of the informal sector. Hence remittance of tax (from Value Added Tax, VAT) component of consumption adversely affects the government revenue. The duration of equilibrium adjustment in the two sectors is found to be equal, however, the level of increase (disequilibrium) in consumption when oil price shock occurs depends on the degree of informality. It was found that the larger the informality, the more there will be a rise in the consumption of goods produced in the informal economy. Similarly, the lower the degree of informality, the more is the magnitude of the rise in consumption of goods produced in the formal economy.
- It was found that the impact of the foreign inflationary shock on domestic determines the magnitude of change in the purchasing power parity between the domestic currency and the dollar. Positive foreign inflationary shock increases purchasing parity and make foreign goods relatively more expensive. Domestic firms in both informal and formal sector expand output in response to the rise in consumption of the relatively cheaper domestically produced goods in both formal and informal economy. Also, aggregate investment rises due to an increase in capital flows, and the nominal interest rate adjusts upward to retain inflows and prevent reversal of capital. When monetary authority accommodates external inflationary shock, it passes through the exchange rate as a positive shock into domestic prices in the short-run. Because of purchasing power parity this shock manifests as an appreciation of the domestic currency (naira) against the US dollar. Hence the effect of foreign inflationary shock leads to a rise in aggregate output, consumption, and investment. Output in both formal and informal economy rise in

response to the positive foreign inflationary shock in equal proportion. The increase in output in each sector depends on the size of each sector relative to the other, which means the larger the degree of informality, the more the rise in output in the informal economy. Therefore, this evidence suggests a directly proportional relationship between the degree of informality and the magnitude of the output in the informal economy

- In managing these shocks, we considered the effect of monetary policy. The effect shows that inflation falls and its response to tightening is fast; however, it takes about five (5) quarters for it stabilize. Meanwhile comparing the potency of the policy with the inflationary pressure across the various structural shocks, the result indicates that monetary policy is more effective in managing inflationary domestic shocks (in this case, inflationary pressure generated from markup shock) in managing external shocks (such as foreign inflation).
- The results also show that the size of informality has some marginal effect on the dynamics of aggregate investment in the short-run. The larger the degree of informality, the lesser the short-run impact of monetary policy shock on aggregate investment, impliedly the lower the magnitude of the fall in investment. However, in the long-run, the impact of informality dissipates. The response of aggregate investment to a monetary policy shock shows more dynamics relative to other macroeconomic aggregates with evidence of asymmetric equilibrium adjustment.
- The potency threshold of monetary policy shows that monetary policy in Nigeria is more effective in fighting structural shocks that originate domestically than shocks that originate externally. The impact of monetary policy shock on sectors (formal and informal), indicates that there is a greater effect of monetary policy on the formal economy than in the informal. The result also indicates that the propensity of output to

respond to monetary policy shock depends on the degree of informality. The larger the size of informality, the less responsive is output to monetary policy in the formal sector. Similarly, the lower the degree of informality, the less responsive is output in the informal economy.

- The response of consumption to a monetary policy shock shows no difference with respect to the two sectors. Both in terms of the magnitude of the response and equilibrium adjustment, consumption of goods produced in the informal economy shows identical behaviour with that of the formal sector. However, the degree of informality has an impact on the level of responses in the consumption of goods produced in both the informal and formal economy. The larger the size of informality relative to the formal economy, the less the response of consumption to monetary policy.
- In examining fiscal policy, evidence shows that the degree of informality affects short-run aggregate investment, but such effect vanishes in the long-run. In essence, the decline in aggregate investment in the short-run is rapid when informality is low than when it is high. Both formal and informal sector output rise in the short-run when there is positive fiscal policy shock. However, the magnitude of the rise in formal sector output is greater than that of informal economy output, which means that positive fiscal policy shock has a greater impact on formal sector output than the informal economy. Hence, formal goods-producing firms will demand more working hours of labour and other variable inputs than informal goods-producing firms. It is worthy to note that the share of the rise in informal sector output is a loss to the revenue side of fiscal policy largely because sales and profit tax of informal goods-producing firms do not transmit tax revenue to the government treasury.

- The rise in consumption across the two sectors shows that the consumption of goods in the informal economy increases by a larger magnitude than goods produced in the formal sector. Therefore, it means that the effect of positive fiscal policy is greater on the consumption of goods produced in the informal economy. Also, the larger share of the benefit of the rise in consumption due to fiscal shock, the greater is a loss to informality, that is, government revenue tax (VAT) on the consumption of goods produced in the informal sector leaks out lager revenue that could improve government revenue. Hence the leakages from the informal economy in both the production (sales or profit tax) and consumption (VAT) side constitute a significant reason for fiscal imbalance. This imbalance has the propensity to increase as the degree of informality rises. It is also the primary cause of fiscal deficit because of the increasing differential between government revenue and expenditure results in deficit financing. Therefore, Nigeria debt is likely to be increasing as informality grows, which is also the case for most developing economies with a large informal sector.
- The degree of informality shows two contrasting impacts on each sector output. First is that degree of informality does not matter when short-run output is responding to fiscal policy shock in the formal economy, but it matters in its equilibrium adjustment. Second is that degree of informality matter in both sizes of the short-run rise and equilibrium adjustment of output in the informal sector. In terms of dynamics in consumption, the higher the degree of informality, the lesser will be a rise in output in the formal sector, and this implies additional leakages in government revenue.

5.2 Conclusion

Essentially this study attempts to develop a Small Open Economy New Keynesian DSGE model that mimics reality, specifically in developing economies that are characterize with a large informal sector. In developing this model, it is assumed that the size of the informal sector

is dynamic and the model assumed an economy that is exposed to shocks that emanates from the structure of the economy. The occurrence of these shocks initiates cyclical fluctuations (some form of Real Business Cycles, RBCs) in the economy and the large informal sector serves an important role in how these cyclical fluctuations persist (terminate). Specifically, expansion in the size of the informal sector induces persistent cyclicality.

The effectiveness of both monetary and fiscal policies in managing the effect of these shocks substantially depends on the relative size of the informal sector. The larger the relative size of the informal sector the less effective is monetary policy in managing the resultant cyclicality and the smaller the size of the informal sector the more potent and effective is monetary policy. The size of the informal sector also reduces the effectiveness of fiscal policy and it even erodes revenue sources of government, which creates imbalance between expenditure and revenue of government.

This study holds that the macroeconomic effect of structural shocks on the economy depends on two important factors; these are the *type of shock* and the *complexity and structure of the economy*. Similarly, the ability to manage these shocks depends also on three key elements; these are the *proper diagnosis of the shock*, *the structure of the economy* (degree of informality) and the *policy mix* between monetary and fiscal policy.

5.3 Recommendations

In managing structural shocks in Nigeria, the following must come to bare:

- Government must make deliberate effort at formalizing the economy. This must ensure continuously register businesses in the informal economy by simplifying the processes and funding incentives for the businesses to also see the need to register. This will raise the effectiveness of macroeconomic management in the face of shocks and will raise the tax revenue as well as reducing the fiscal imbalance.

- Managing external shocks requires a mix of fiscal and monetary policy, such that they complement each other in the process of sterilizing and mitigating the effect of shocks. In addition, proper diagnoses and policy coordination are needed.
- Also, the monetary authority should endeavor to establish a strong informal credit channel by, first and foremost, reinforcing policy on financial inclusion before strengthening the microfinance banking *through registration of thrift and cooperative societies, as well as increase penetration of the agent banking*. Over the years the central bank has misplaced these steps in its policy regarding microfinance banking. Because financial inclusion must precede microfinance banking in other to have meaningful informal sector participation in the credit market. Thus, banking activities can connect with the activities in the informal economy. As such, the credit channel could become a more effective tool for monetary policy in regulating activities in a large informal economy.

References

Adebiyi, A. M. and Mordi, C. N. O (2016). A Dynamic Stochastic General Equilibrium (DSGE) model of exchange rate pass-through to domestic prices in Nigeria. *Central bank of Nigeria, Occasional paper* 59

Adolfson,M., S., Laseén, J. and Lindé, M. V. (2005).Bayesian estimation of an open economy DSGE model with incomplete pass-through. *Sveriges Riks bank working paper series*, No. 179

Agenor, P. R., McDermott, C. J. and Prasad, E. S. (2000). Macroeconomic fluctuations in Developing Countries: Some Stylized facts. *The world bank review*, vol. 14, No. 2. 251-285

Ahmed, S., Ahmed, W., Khan, S., Pasha, F. and Rehman, M. (2012). Pakistan Economy DSGE Model with Informality. *State Bank of Pakistan, Research Department*. Online at http://mpra.ub.uni-muenchen.de/53135/

Algozina, A. (2015). Optimal Monetary Policy Rule and Cyclicality of Fiscal Policy in a Developing Oil Economy

Almeida, V., (2009) Bayesian estimation of a DSGE model for the Portuguese economy. *Bank of Portugal working paper.*

Altig, D., Christiano, L., Eichenbaum, M. and Linde, J. (2011): "Firm-Specific Capital, Nominal Rigidities and the Business Cycle," *Review of Economic Dynamics*, 14(2), 225–247

An, S. and Schorfheide, F. (2007). Bayesian analysis of DSGE models. Economic reviews., 26(2-4),113-172. Research collection school of economics

Andres, J., Burriel, P. and Estrada, A (). A DSGE model for the Spanish economy and the Rest of the Euro area. No. 0631

Bandaogo, M. A. S.S. (2016). Essays on fiscal policy, monetary policy and currency unions: exploring the role of informality and labor mobility. PhD dissertation submitted to University of Washinton

Bandaogo, M. A. S.S. (2016). Fiscal and Monetary Policy in the Presence of Informality and the Incentive to Join a Currency Union

Barth, J. R., Caprio Jr., G. and Levine, R. (2004). Bank Regulation and Supervision: What Works Best? *Journal of Financial Intermediation*, 13(2), 205–248.

Batini, N., Kim, Y. B., Levine, P. & Lotti, E. (2010). Informal labor and credit markets: A Survey. *International Monetary Fund Working paper*. No 10/42.

Batini, N., Kim, Y. B., Levine, P. and Lotti, E. (2010). Floating versus managed exchange rate in DSGE of India. *NIPE working paper* 31/2010

Batini, N., Kim, Y. B., Levine, P. and Lotti, E. (2011). Monetary and fiscal policy in the

presence of informal labour markets

Batini, N., Levine, P., Lotti, E. and Yang, B. (2011) Informality, Frictions and Monetary Policy. *Discussion Papers in Economics*, University of Surrey

Beck, T., Kunt, A. D. and Maksimovic, V. (2004). Bank Competition and Access to Finance: International Evidence. *Journal of Money, Credit, and Banking*, 36(3), 627–648.

Beidas-Strom, S. and Poghosyan, T. (2011). An estimated dynamic stochastic general equilibrium model of the Jordanian economy. *IMF working paper*, Middle-east and Central Asia Department./11/28

Bergholt, D. (2014). Monetary policy in oil exporting economies. Centre for applied macro- and petroleum economics, BI Norwegian Business School, and Norges Bank. *Working paper series* 5/2014

Bergholt, D. (2015). Foreign shocks. Centre for applied macro- and petroleum economics, BI Norwegian Business School, and Norges Bank. *Working paper series* 5/2015

Blanchard, O. J. (2009).

Blanchard, O. J. and Watson, M. W. (1986). Are Business Cycles All Alike? University of http://www.nber.org/chapters/c10021 p. 123 - 180

Blinder, A. S. (1988). The Fall and Rise of Keynesian Economics. Chicago Press **https://doi.org/10.1111/j.1475-4932.1988.tb02067.x**

Bose, P. (1998). Formal-Informal Sector Interaction in Rural Credit Markets. Journal of Development Economics, 56, 256–280.

Broditskaya, T. (2008). Execution and effect of monetary policy in Russia. PhD dissertation, submitted to University of Lancaster.

Buehn, A. &Schneider, F. (2012). Shadow economies around the world: novel insights, accepted knowledge and new estimates. *International tax and public finance*, vol 9, No.1, springer.

Burriel, P., Fernández-Villaverde, J. and Rubio-Ramírez, J. F. (2010). MEDEA: a DSGE model for the Spanish economy. Springer

Castells, M. and Portes, A. (1989). World Underneath: The Origins, Dynamics, and Effects of the Informal Economy. Johns Hopkins University press

CBN, African Institute of Applied Economics (AIAE), CEAR, NISER, (2010). Macroeconomic management and policy analysis.

Chari, V. V., Kehoe, P. J. & McGrattan, E. (2004). Business Cycle Accounting. *Working Paper* 625, Federal Reserve Bank of Minneapolis.

Chaudhuri, K., Schneider, F. and Chattopadhyay, S. (2005). The size and development of

shadow economy: an empirical investigation from state of India. Download @chaudhury\jdeprintready.doc

Chib, S. and Ramamurthy, S., 2010. Tailored randomized block MCMC methods with application to DSGE models. J. Econ. 155 (1), 19–38.

Chopin, N., (2004). Central limit theorem for sequential Monte Carlo methods and its application to Bayesian inference. Ann. Stat. 32 (6), 2385–2411.

Christiano, L.J. and Eichenbaum, M. (1992). Current real-business-cycle theories and aggregate labor-market fluctuations. Am. Econ. Rev. 82 (3), 430–450. http://ideas.repec.org/a/aea/aecrev/v82y1992i3p430-50.html.

Christoffel, K., Coenen, G. and Warne, A. (2008). A micro-founded open-economy model for forecasting and policy analysis. *Working paper series* 944. European central bank.

Cole, H. L., Ohanian, L. E. and Leung, R. (2009). International great depression: deflation, productivity and the stock markets. International Monetary Fund. Macroeconomic and policy challenges following financial meltdowns.

Creal, D., 2007. Sequential Monte Carlo samplers for Bayesian DSGE models. Manuscript, Chicago Booth.

Creal, D., 2012. A survey of sequential Monte Carlo methods for economics and finance. Econ. Rev. 31 (3),245–296.

Dellas, H., Malliaropulos, D., Papageorgiou, D. and Vourvachaki, E. (2017). Fiscal policy with an informal Sector. Bank of Greece, economic analysis and research department. No. 235

Dreher, A., Kotsogiannis, C. and McCorriston, S. (2005). *How do Institutions Affect Corruption and the Shadow Economy*? Public Economics

Dresch, F. W. (1939) A simplified economic system with dynamic elements. *Cowles Commission for Research in Economics, Report of Fifth Annual Research Conference on Economics and Statistics*

Erceg, C. J., Guerrieri, L and Gust, C. (2006). SIGMA: A new open economy model for policy analysis., *International finance discussion papers* No. 835

Esfandyari, M. and Dahmardeh, N. (2014). Informal employment under different shocks in Dynamic Stochastic General Equilibrium Model of Iran's Economy.

FAO (2002). Paper on selected issues relation to the WTO negotiations on agriculture, commodities and trade division.

Fagiolo, G and Roventini, A (2012). Macroeconomic Policy in DSGE and Agent-Based Models. *Working Paper Series* Department of Economics University of Verona.

Fair, R. C. (1992). The Cowless Commision Approach, Real Business Cycle Theories, and

New Keynesian Economics. Pp 133-134

Fernández-Villaverde, J. (2010). The econometrics of DSGE models. DOI 10.1007/s13209 009-0014-7

Ferna´ndez-Villaverde, J., Gordon, G., Guerro´n-Quintana, P.A. and Rubio-Ramı´rez, J.F., (2015). Nonlinear adventures at the zero-lower bound. J. Econ. Dyn. Control 57, 182–204.

Friedman, M. (1972) 'Have Monetary Policies Failed?', *American Economic Review* 62, May, pp. 11–18.

Friedman, M. (1974) *Monetary Correction,* IEA Occasional Paper no. 41, London: Institute of Economic Affairs.

Friedman, M. (1977) 'Nobel Lecture: Inflation and Unemployment', *Journal of Political Economy* 85, June, pp. 451–72.

Frey, B. S. and Schneider, F. (2000). Informal and Underground Economy. International encyclopedia of social and behavioural science.

Gallant, A.R., Giacomini, R., and Ragusa, G., 2013. Generalized method of moments with latent variables. *CEPR Discussion Papers* DP9692.

Gali, J. and Monacelli, T. (2005). Monetary policy and exchange rate volatility in a small open economy. *Review of economic studies*. No 72, 707-734.

Galiani, S. and Weinschelbaum, F. (2007). Modeling Informality Formally: Households and Firms

Gelain, P. and Kulikov, D. (2009). An estimated dynamic stochastic general equilibrium model for Estonia. *Bank of Estonia working paper series*, No. 5

Gërxhani, K. (2001). The Informal Sector in Developed and Less Developed Countries: A Literature Survey 1999-083/2 *Tinbergen Institute Discussion Paper*

Gine, X. (2007). Access to Capital in Rural Thailand: An Estimated Model of Formal vs. Informal Credit. *Research Working Paper WPS 3502 World Bank.*

Ghosh, P. and Ray, D. (2001). Information and enforcement in informal credit market. Journal of Development Economics.

Goel, R. K., Saunoris, J. W and Schneider, F. (2017). Growth in the Shadows: Effect of the Shadow Economy on U.S. Economic Growth over More Than a Century. *Institute of labour economics. Discussion paper series.* No. 10705

Haider, A. and Khan, S. U. (2008). A Small Open Economy DSGE Model for Pakistan.

Hart, K. (1973). Informal income opportunities and urban employment in Ghana. *Journal of African studies*. Vol 11; 61-89

Herbst, E., Schorfheide, F., 2014. Sequential Monte Carlo sampling for DSGE models. J. Appl. Econ. 29 (7), 1073–1098.

Herranz, M.M., (2017). The Underground economy in Spain: A Bayesian DSGE approach

Hibbs Jr., D.A. and Piculescu, V. (2005). Institutions, Corruption and Tax Evasion in the Unofficial Economy, *Working Papers in Economics 173*

Hill, R. & Kabir, M. (1996). Tax Rates, the Tax Mix, and the Growth of the Underground Economy in Canada: What can we infer? *Canadian Tax Journal*, Vol. 44, No. 6,

Hoff, K. and Stiglitz, J. E. (1997). Moneylenders and Bankers: Price-Increasing Subsidies in A Monopolistically Competitive Market. Journal of Development Economics, 52, 429–462.

Iyoha, M. A. (2003). An Overview of leading Issues in the Structure and Development of the Nigerian Economy since 1960 in: *Nigerian Economy:* Structure, Growth and Development.

Jakab Z. M. and Világi, B. (2007). An estimated DSGE model of the Hungarian economy. Central bank of Hungary, *working paper series.*

Jean-Paul K. and Vangu, T. (2015). New Keynesian DSGE models in the African context. *LAREQ working paper series WP I-006*

Jie, S. W., Tat, H. H., Rasli, A. and Chye, T. L. (2011). Underground economy: definitions and causes. *Business and management review*. Vol. 1. No. 2. Pp 14-24

Jokivuolle, E., Kilponen, J. and Kuusi, T. (2007). Gross Domestic Product at risk in a DSGE model: an application to banking sector stress testing. *Bank of Finland research discussion paper 26*

Koopmans, T. C. and Rubins, H. (1953). Linear regression analysis of economic time series. diss., University of Leiden.

Kydland, F. E. and Prescott, E. C. (1982): "Time to Build and Aggregate Fluctuations," *Econometrica* 50, no. 6, 1345–1370.

Keynes, John Maynard, The General Theory and After: Part I, Preparation, edited by Donald Moggridge, Vol. XIII of Keynes, Collected Writings.

Laidler, D. (1981). Monetarism: An Interpretation and an Assessment Economic Journal, 1981, vol. 91, issue 361, 1-28

Lucas, R. E. (1976): "Econometric Policy Evaluation: A Critique," *Carnegie–Rochester Conference Series on Public Policy* 1, 19–46.

Leal, J., (2014). The informal sector in contemporary models of the aggregate economy. *Bank of Mexico Working paper*. No. 2014-24

Leeper, E.M. and Sims, C.A., (1995). Toward a modern macroeconomic model usable for policy analysis. In: Fischer, S., Rotemberg, J.J. (Eds.*), NBER Macroeconomics Annual 1994*. MIT Press, Cambridge, pp. 81–118.

Linardi F. M., (2016) Assessing the fit of a Small Open-Economy DSGE model for the Brazilian Economy. *Central bank of Brazil. Working paper* 424.

Lima, D. C (2014). Credit Borrowing Constraints In A DSGE Framework: Income Vs. Housing

Loayza, N.V. (1994). Labour Regulations and the Informal Sector, Policy Research Working Paper No. 1335. *The World Bank.*

Malinvaud, E. (1983). Econometric methodology at the Cowles commission: Rise and Maturity, presented at the Cowles fiftieth anniversary celebration.

Maloney, W. and Chanduvi, F. (2007). Informality exit and exclusion: Informal sector: What is it, Why do we care, How do we measure it? *World Bank*, pp: 21-41

Madestam, A. (2009). Informal Finance: A Theory of Moneylenders. Mimeo, Department of Economics, Bocconi University.

Modigliani, F. (1988). The Monetarist Controversy Revisited. Volume6, Issue 4 **https://doi.org/10.1111/j.1465-7287.1988.tb00540.x**

Mordi, C. N., Adebiyi, M. A., Adenuga, A. O., Abeng, M. A., Adeboye, A. A., Adamgbe, E. T. and Evbuomwan, O. O. (2013). Dynamic Stochastic General Equilibrium (DSGE) Model for Monetary Policy Analysis in Nigeria. *Central bank of Nigeria, research department.*

Murchison, S. & Rennison, A. (2006). Terms of trade economic model: The Bank of Canada's New Quarterly Projection Model

NISER (1983). The NISER Econometric Model of the Nigerian Economy, *Nigerian Institute of Social and Economic Research*, Ibadan.

Ojo, G.O. (1972). "An Econometric-Simulation Model of the Nigerian Economy", PhD Thesis, State University of Science and Technology, Ames, Iowa.

Olofin, S. (1977). "A Tentative Specification of an Econometric Model of the Nigerian Economy", *mimeo*, University of Ibadan.

Patinkin, D. (1990). On different interpretations of the General Theory. *Journal of Monetary Economics,* vol. 26, issue 2, 205-243

Paula, A and Scheinkman, A. J. (ND). The Informal Sector: An Equilibrium Model and Some Empirical Evidence from Brazil

Peiris, S. J. and Saxegaard, M. (2007). An Estimated DSGE Model for Monetary Policy Analysis in Low-Income Countries. *IMF working paper African department. 07/282*

Peng, Y. & Yang, L. (2015). The Impact of Discriminatory Credit Constraint on Business Cycle: A DSGE Model with Endogenous Loan-to-Value

Pereira, E. Da V. (2016). Informal sector, business cycles, and fiscal policy. PhD dissertation submitted to the University of Porto.

Pesaran, M. H. and Smith, R. P. (1985). Evaluation of macroeconometric models. Journal of Economic modeling.

Peters, A (2017). Estimating the Size of the Informal Economy in Caribbean States. Inter-American Development Bank Felipe Herrera Library.

Quintna, P., G. (2013). *The economics of small open economies*. *Journal of Business review*, quarter four. Federal Reserve Bank of Philadelphia.

Rei, D. and Bhattacharya, M. (2008). The Impact of Institutions and Policy on Informal Economy in Developing Countries An econometric exploration. *Working Paper No. 84. The Policy Integration and Statistics Department*.

Sam, M. W. (2017). Evaluating the empirical performance of DSGE models: What is the role of search and matching frictions in the labor and capital markets? PhD dissertation submitted to School of Economics, Singapore Management University

Schorfheide, F. (2010). Estimation and Evaluation of DSGE Models: Progress and Challenges http://www.ssc.upenn.edu/˜Schorfield.

Schneider, F. and Klinglmair, R (2004) Shadow Economies Around the World: What Do We Know? *Working Paper No. 2004 - 03*

Schneider, F., (2006). *Shadow economies around the world: what do we really know*? European journal of political economy. Science direct; vol 2, 598-642

Schneider, F., (2007). Shadow economy and corruption all over the world: what do we really Know. *Discussion paper, No. 2315*.

Schneider, F., (2014). A shadow economy an essay. Download @http://www.econ.jku.at/Schneider.

Schneider, F. and Enste, A. (2000). Shadow economies: size, causes and consequences. *Journal of economic literature.* Vol. 38, pp 77-114.

Senbeta, S. R. (2013) Informality and macroeconomic fluctuations: A Small open economy New Keynesian DSGE model with dual labour markets. Research paper in economics. D/2013/1169/002

Snowden, B. and Vane, H. R. (2003). A Macroeconomics Reader. Routledge imprint of the Taylor & Francis Group. Collected writing.

Smets, F. and Wouters, R. (2003). An estimated dynamic stochastic general equilibrium model of the euro area. *European central bank working paper series*, No. 171

Smets, F. and Wouters, R. (2007). Shocks and frictions in us business cycles: a Bayesian DSGE approach. *European central bank working paper series*, No. 722.

Steinbach, R., Mathuloe, P. and Smit, B. (2009). An open economy New Keynesian DSGE model of the South African economy. *South African Reserve bank working paper. 09/01*

Sutton, P., (2011). *The concept of small states in the international political economy. The common wealth journal of international affairs*, vol 100, issue 413,

Stiglitz, J and Weiss, A. (1992). Asymmetric Information in Credit Markets and Its Implications for Macro-economics. *Oxford Economic Papers*, vol. 44, issue 4, 694-724

Uwujaren, G.P. (1977). "Specification and Estimation of an Economy-wide Macroeconometric Model of Nigeria", *The Nigerian Journal of Economic and Social Studies*, vol. 14, No. 3.

Wing, I. S. (ND) Computable General Equilibrium Models and Their Use in Economy-Wide Policy Analysis: Everything You Ever Wanted to Know (But Were Afraid to Ask)

Wasmer, E., and Weil, P. (2004). "The Macroeconomics of Labor and Credit Market Imperfections." *American Economic Review*, 94 (4): 944-963.

World Bank. (1974). "World Bank Long-term Projection Model of the Economy", in Nigeria, Options for Long-term Development. Baltimore: Johns Hopkins Press

Yunus, M. and Weber, K. (2007). Creating a world without poverty: Social Business and the Future of Capitalism. BB*s Public Affairs*, New York.

Appendices

Appendix 1: Review Table on Macroeconomic Models in Nigeria

Overview of Macroeconomic Models in Nigeria

Period	Objective	Structure of model	Method of estimation	Specific Weakness
Ojo (1972)	Targeted at enhancing contributions into the preparation of a short and medium-term plan.	Agricultural sector (3 equations), external sector (2 equations) and public sector (4 equations).	2-stage least square	its lack of monetary sector; non-existence of inflationary effect on macroeconomic variables; absence of production side and demand for labour functions.
World Bank (1974)	design to stimulating an economic growth that was consistent with growth in agriculture and oil sectors. model was applied in constructing national income accounts and compute consumption, investment, and employment	A two-gap model was specified with investment/saving functions on the one hand, and the export-import functions. model contains 105 relations.	OLS	the problem of irreducibility of the equation and failure to incorporate the monetary sector.
Uwujaren (1977)	medium-term development plan of the late 1970s	It augmented the money and price blocks including the demand and the supply sides of the economy lacking in Ojo 1972	OLS	Poor linkage of the sectors and lack of transmission in the sector
Olofin *et al.* (1977 and 1985) and CEAR	forecasting and projecting macroeconomic aggregates for development plans during the 1970s and 1980s	multi-sector macroeconomic model	OLS	Too aggregative and specification biased
NISER 1983-1984	the NISER model attained one of the highest levels of disaggregation ever, of any model of the Nigerian economy. Macroeconomic policy analysis	macroeconomic model consisting of seven blocks which include: production; balance of payments; aggregate demand; external sector; labour sector; price and monetary sector. model comprises of 77 structural models, that are further classified into 44 are stochastic equation and 33 are identities equations.	OLS	is it suffered a weak linkage between the monetary block and other aggregate blocks. the estimation was conducted in a repeated block by block using OLS method.
Aboyade committee 1985	a feasible Input-Output (I-O) table for the Nigerian economy	framework that illuminate the linkages between the various sectors in the economy. I-O table multiplier and the technological coefficients as well as the Leontief matrix inversion were computed for the Nigerian economy. I-O table was made up of more than 60 sectors and the intersectoral linkages were well entrenched in the I-O	Matrices Operator	absence of macro policy feedback in the model.

Iyoha (2003)	Macroeconomic management	A moderate 5 sector macro model was deduced which was made up of 39 structural equations. Where 20 are stochastic equations and the remaining 19 identities equations.	OLS and simulation	found to be weak and incapable of incorporating financial sector and policy changes in the economy.
CEAR (2006)	targeted at generating forecasts for the second phase of National Economic Empowerment and Development Strategy (NEEDS II) 2007-2011	(MAC III and MAC IV) eight blocks, which are: supply, aggregate consumption, capital formation (investment), labour demand and supply, wages and prices, public sector, monetary, and foreign trade sectors. CEAR-MAC III model comprises of 43 stochastic equations and 54 identities, which constitute 97 endogenous variables and 28 predetermined (policy) variables. On the other hand, CEAR-MAC IV model constitute 137 equations. where 76 are stochastic equations and 61 identities specification	OLS	the application OLS in a set of dynamic models producing parameter estimates which were biased and not consistent. To large extent inefficient because of the small sample data size from 1969-1981. The second weakness of the CEAR models is the weak linkage of the monetary and financial block to the other blocks.
CBN, African Institute of Applied Economics (AIAE), CEAR, NISER, 2010	Macroeconomic management and policy analysis	made up of 6 major blocks, which include: aggregate supply, private demand, government, external, monetary & financial and the price block	OLS and the dynamics were captured using the Error Correction Model (ECM).	absence of the labour demand equations and above all the model is lacking in microfoundation. The issue of autocorrelation, multivariate forecasting the seasonal adjustment make the model susceptible to diagnostics failure.