Multisector Small Open Economy DSGE Model for Oil Exporting Countries: The Case of Nigeria

By

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Specimen layout for Declaration/Statements page to be included in a thesis.

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Dedication

I would like to dedicate this work to my family for their continuous prayers, moral and financial support, I am highly proud to be part of such a wonderful family.

Abstract

Small Open Oil Exporting Countries are often identified with frequent variation in output which in turn affect other macroeconomic fundamentals. This thesis investigates the effect of Oil price shocks, Productivity shocks to Tradeable (oil and non-oil) and Non-tradeable Sectors of the Nigerian economy. The Standard Small Open Economy Dynamic Stochastic General Equilibrium (DSGE) Model is extended by segregating the Tradeable sector into Oil and Non-oil sectors. The model has been estimated by Simulated-based Indirect Inference Method on non-stationary Nigerian data. Using indirect inference test technique which compares the model's simulated behaviour generated with the actual data as represented by an auxiliary model. The results of the test show that the model has passed the Wald test. The estimated model suggests that oil has changed the structure of the Nigerian economy, but it does not seem that there is a 'resource curse' that public policy could have averted. Empirical evidence from the Estimated model indicates that an increase in government spending smoothen the variation of output growth rate from its efficient level and improve welfare of Nigerian household.

Acknowledgement

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Introduction

The sources and propagation mechanism of economic fluctuations in small open economies has been a source of concern for decades among policymakers and academicians. While business cycle fluctuations have been moderated to an extent in developed small open economies, particularly in the 2000s Stock and Watson (2004), the case is entirely different for developing small open economies where the volatilities in output and other macroeconomic variables have become pervasive.

Since the emergence Kydland and Prescott (1982) of "Time to Build and Aggregate Fluctuations" which emphasises the role of technological shocks in the propagation of business cycle, it has been argued that the business cycle can be attributed to the efficient response of the economy to changes in the production technology. The canonical model has undergone various modifications which include nominal rigidities inform of price and wage stickiness, real rigidities such as capital adjustment costs, heterogeneous agents, fiscal authority, central bank and monetary policy, information asymmetry, multisector set-ups including the energy sector, and habit formation. Each of these adjustments, to what have been termed Dynamic General Equilibrium Model (DSGE) models, has significantly improved these real business cycle models in their ability to explain the stylised facts found in the data.

These RBC models have micro-foundations, and their parameters are structural as they are parameters of preference and technology; thus, they are immune to Lucas' Critique Lucas (1976). They are important in used for determining optimal policy rules as their parameters would be invariant to these rules. They can also be considered as models of the causal structure of the economy, since with them, the effects of shocks on the economy through all the interactions of the economy's agents and variables can be traced. Hence, these models are important in permitting the determination of optimal policy, especially by central banks.

 Mendoza (1991) first introduced some extension to the small open economies of the developing world. With the emergence of small open economy into mainstream business cycle literature, numerous modifications were carried out to enhance the model fit and enable policy analysis. Some of these modifications are; trade balance, effects of foreign prices and foreign interest rates, oil price shocks, international financial markets, exchange rates policies and sovereign debts in addition to the features that are already incorporated in the closed economy version of the model.

Small open economy DSGE models are applied to both developed and developing economies on the assumption that their influence on the global economy is insignificant. However, developing small open economies are mainly characterised by heavy reliance on commodity exports as the main source of their earnings, unlike the developed open economies that are exporters of industrial or intermediate goods.

The business cycle displays different patterns in poor, emerging and developed small open developing economies, the model that fits the stylised facts of developed countries may not successfully explains stylised facts of emerging or poor countries. Hence, for a small open economy DSGE model to effectively explain the business cycle of say developing or emerging market economies it needs to be extended to capture some idiosyncratic features of such developing or emerging economies. Particular case for these small open developing economies are the oil exporting countries.

With the frequent volatility of the oil prices [1] the vulnerability level of oil-exporting economies increases, thereby creating uncertainty that invariably affect the policy decision in these economies, this has increased the quest by these countries to develop a model that incorporates the relevant structural linkages and can be used for policy analysis. The decline in the oil price by around 30% since the beginning of 2014 has adversely affected the macroeconomic indicators of these oil-exporting economies in the recent past.

Although some work has been done on business cycle for developing economies, these models need to be further elaborated by considering oil price shocks for oil exporting countries to enable it to describe the behaviour of macroeconomic variables of these economies. This thesis rises to this challenge by developing a multisector small open economy DSGE model for oil exporting economies with reference to Nigerian economy. In the thesis, I investigate the sources and propagation mechanism of economic fluctuations in the Nigerian economy from both theoretical and empirical perspectives.

I extend Meenagh et al. (2010) by incorporating oil in the production sector in line with the standard literature of small open economy DSGE models for oil exporting economies (Bruno and Portier 1995; Backus and Crucini 1999; Medina and Soto 2005; Blanchard and Gali 2007; Bergholt 2014). The model also includes land as an input into the firm production process in addition to labour and

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[1] Oil exporting countries both OPEC and Non-OPEC members have experienced dwindling oil price in 2006, 2012-17 which has adversely affected their economies particularly the OPEC members who's economy depends solely on oil. The effect of oil price fluctuation could be positive and negative, in the case of positive the economy output expands and interest rate and inflation rises accordingly.

capital. The inclusion of land aimed at reducing the volatility of oil sector output Kose (2002). The model assumes that the market for land responds to business cycle fluctuations and so, by raising costs during booms limits the expansion in the non-traded sector. Given the importance of land as a factor of production in the oil sector, also affects oil exploration in these economies.

As macroeconomic data are often non-stationary, economists have frequently used filtering methods (mainly HP-Filter) to make it stationary before calibration or estimation of the model. In the process of attaining stationarity by using HP filter or any form of transformation vital information from the actual data can be distorted or even lost at times. To overcome this challenge, the model uses raw Nigerian non-stationary data

The model assumes that the primary shocks to the economy come from productivity in the three sectors. This work follows Schmitt-Grohé and Uribe (2003) that the net foreign asset position influences the interest payable on foreign assets owed or owned by Nigeria. This has the effect of forcing net foreign assets to have a constant equilibrium.

To briefly highlight the working of the model, a permanent positive shock to traded productivity raises output, income and consumption. It also increases demand for capital (creating an investment boom[2]), labour and land. The impact raises the demand for non-traded goods; with no rise in non-traded supply in the short term, this causes a rise in the domestic relative prices thereby raising the real exchange rate, ultimately leading to market clearing in the non-traded sector. Conversely, a similar positive productivity to non-traded leads to a rise in consumption, output and income with a rise in the sector's input demands. However, the corresponding tradeable sector input demands fall. The real exchange rate rises initially and then falls sufficiently in the long run to shift supply into the traded sector. These fluctuations in the Nigerian economy work through the channel of the real exchange rate which in turn triggers real interest rate effects.

The model developed for Nigeria is tested and estimated using the simulation-based Indirect inference method. It compares VAR estimates derived from the model simulations with the unrestricted VAR estimates from actual data. In conducting the indirect inference test, a Wald test on VAR estimates is applied and subsequently the test compares the distance between actual and simulated data which form a basis for either to reject or not reject the null hypothesis that the model is a good representation of the true data generating process. An important advantage of indirect inference testing procedure compared to classical methods like likelihood ratio test is that the

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[2] Investment, the change in capital, rises sharply as the new capital is installed.

unrestricted VAR model based on actual data will automatically generate an appropriate alternative hypothesis for testing the specification of the model, hence, specifying different DSGE models as the alternative hypothesis is not required. The method entails the use of empirical estimate of the small sample distribution obtained via bootstrap methods.[3] The estimation of the model is achieved by altering the structural model parameters until the closest match is obtained with the data behaviour- i.e. the Wald is minimised.

The results of the indirect inference test presented in chapter 5 show that the model can replicate the stylized facts on macroeconomic indicators of Nigerian economy; the test uses auxiliary model with output and real interest rates.

This study is the first of its kind that uses non-stationary data and applies the indirect inference methodology to investigate the effect oil cyclical fluctuations in Sub-Saharan African Countries in general and Nigeria in particular. The work also serves as an additional contribution to the existing literature on small open economy Dynamic Stochastic General Equilibrium Model (DSGE) models that focus on the propagation of shocks to oil producing economies.

The thesis is structured as follows; Chapter 1 covers an overview of the Nigerian Economy. Chapter 2 presents the relevant theoretical and empirical literature. Chapter 3 focuses on building the multisector small open economy model for Nigeria. Chapter 4 discusses the Indirect Inference Methodology. Chapter 5 presents the testing and estimation of the calibrated and estimated model as well as policy experiment Chapter 6 concludes and discusses the model's broad policy implications for Nigeria.

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[3] The significantly advantage of indirect inference testing procedure over the classical likelihood ratio test is that there is no need to specify a different DSGE models as the alternative hypothesis because the unrestricted VAR model based on actual data will automatically generate an alternative hypothesis suitable for testing of the specification of the model. The only requirement of this testing procedure is that the DSGE model generates an identified VAR. Instead of using the asymptotic distribution of the test statistics, in our case, a Wald statistic, an empirical estimate of its small sample distribution obtained by bootstrap methods is used.

1 An Overview of the Nigerian Economy

This section presents an overview of the Nigerian economy mainly the structure of the economy, policy regimes formulated by previous administrations in respect to real sector activities and response of some selected macroeconomic fundamentals to both policy induced changes and other exogenous factors for the period 1981 – 2016.

1.1 Introduction

The structure of the Nigerian economy has undergone various transformation since independence with a view of uplifting the economy to a higher and sustainable growth trajectory through diversifying the revenue base from a mono-product economy with heavy reliance on oil sector revenue to an economy with large non-oil sector income.

At independence in 1960, the economy depended on non-oil exports as main sources of foreign exchange earnings with agricultural exports and mining activities been major drivers. During that period, agricultural output dominated the non-oil exports, hence, with the discovery and exports of crude oil the economic base shifted from an agriculture-based economy to an oil-dependent economy (one commodity to another). Therefore, the stance of the economy is structured into two main sectors, namely the oil and non-oil sectors. The non-oil sector is divided into agriculture, mining/solid minerals, Services and Other activity sectors. This shift in economic base caused structural distortions as it slows down growth in the non-oil sector, increases unemployment underemployment particularly in agricultural sector been the major employer of labour which invariably decreased household's income and consumption. Several policy regimes were implemented to stimulate the output and set the country into the path of growth and development. These policies are as follows: Firstly, the enactment of medium-term "development plans" from the 1960s to 1986, which mainly meant to restructure the economy towards higher output production and employment generation. The framework emphasised the role of agriculture and industrial sector in diversifying the economic base of the country. The outcome of these development plans to a greater extent was satisfactory, even though the real Gross Domestic Product (GDP) growth rate has remained at 3.2 per cent in between 1982 - 1990 as it was in 1976-1980. The period was marked with a rapid increase in oil production and exports as well as improved performance in the agricultural and industrial sectors.

The National Development Plan of 1981-85 ended with an abysmal performance as the economy becomes stagnant with substantial fiscal deficits due to the collapse in oil price. To bring back the economy to the right track, in 1986, Structural Adjustment Programme (SAP) was introduced as a blueprint of International Monetary Fund (IMF) the programme was in response to the dwindling oil resources and macroeconomic policy distortions. The programme aimed at achieving fiscal balances and macroeconomic stability through creating robust market friendly-environment, free capital flows, foreign exchange system reform, and agricultural sector reforms (increasing need to diversify the productive base of the economy). The SAP partially achieved its objectives as an annual real GDP growth rate rose significantly from a negative 0.6 per cent in 1987 to an average of 8 per cent in 1990. However, the average real GDP growth rate fell to 1.9 per cent in 1991 -1998. The gains obtained from the reform were eroded following the increased spate of policy reversals and inconsistencies identified with the military regime, which eventually created distortions in the economy leading to decline in the GDP growth rate and other macroeconomic variables. Adverse external shocks further exacerbated the worsening economic conditions observed during that time, mainly fall in oil price and foreign debt overhang. The SAP ended abruptly without achieving the desired results, leaving the economy short of economic strategy in place for almost a decade.

With the return of democratic dispensation in 1999, many economic policies were put in place to reverse the negative trend of macroeconomic fundamentals. One of the reforms introduced was the Medium-Term Expenditure Framework (MTEP), 2003 – 2005, the programme was designed to provide a macroeconomic framework to strengthen the financial management and improve efficiency in public expenditure. In addition to MTEP, a "National Economic Empowerment Development Strategy" (NEEDS) was launched in 2004. The policy was a medium-term planning programme that focuses on economic empowerment, poverty eradication, wealth creation, promoting private enterprises and public sector reform. An appraisal of the NEEDS reveals that the policy succeeded in turning around the economy and move the real GDP to 8.3 per cent during the period 1999-2007. The abysmal performance of NEEDS programme to actualise the objectives mentioned above was attributed to infrastructural decay, high dependence of the national economy on oil exports, high imports dependency culture, and high cost of production. At the end of 2007, the programme came to an end, with little success in terms of its specific targets[4].

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[4] For the analysis in this section I sourced the data from Central Bank of Nigeria Statistical Bulletin, 2017

The new economic strategy termed vision 20-20-20 was formally introduced to push the economy to the 20th position in the world by the year 2020 through an increase in real GDP growth of double-digit as well as other strategies. Despite all these growth and development strategies that were formulated and perhaps implemented from (1982 – 2016) the structure of the Nigerian economy remained mono-cultural economy with high import dependency. The economy is also characterised with infrastructural constraints, corruption, increase poverty level, and high rate of unemployment. However, the new leadership in Nigeria that is committed to eradicating corruption in the country, the spate of corruption begins to decline, but a lot needs to be done.

This instability stems from the oil (commodity) price shocks that the country's exports are exposed to, due to the structure of the economy, which relies heavily on oil sector revenue. This volatility in oil prices has a significant negative impact on the economy as they affect households' intra/ inter-temporal consumption and labour /leisure decisions.

The Nigerian economy like any other small open oil exporting economies depends mainly on revenue from a commodity whose price is determined exogenously. The economy is more prone to business cycle volatility than other non-oil dependent small open economies. For instance, the recent fall in crude oil prices in the fourth quarter of 2014 impacted adversely on the economy through huge decline in foreign exchange receipts, negative accretion to foreign exchange reserves leading to depreciation of the Naira (Nigerian currency). Nigeria being a heavily import-dependent economy with high exchange rate pass-through to domestic prices, the depreciation of naira led to inflation through a significant increase in prices of imported finished and semi-finished goods. Also, with lower revenue that failed to match government spending, the policymakers were left with the only option of continuous borrowing from both domestic and foreign sources to finance the deficit. These developments negatively affected the output as the economy recorded negative growth rate of output for three consecutive quarters in 2016, a full-scale economic recession. The recession not only affected the aggregate demand but was also associated with supply constraints.

1.2 Nigeria's Output Real Sector

Nigeria's economy recorded accelerated economic growth considering the growth rate of GDP that picked up from the lower level trend to a higher positive output growth rate during the review period. The massive drop of oil price at the international oil market, high dependence on imported goods that in turn negatively impact on the domestic currency and worsened the balance of payment position of the economy are seen as some of the factors that significantly retard the output growth mainly from 1981 – 1990.

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The trend of the of real GDP in figure 1 showed an average growth rate stood at 3.2 per cent between 1981 – 90 then decline to an average of 1.9 per cent in 1991 – 98 despite the positive performance recorded in agriculture and services sector during that period. The trend reverses positively with the re-emergence of democratic governance in Nigeria after prolonged military regime, for instance, the real GDP growth rate increased rapidly to 8.3 per cent in 1999 - 2007 reflecting the positive impact of NEEDS and other economic reforms introduced by the regime such as MTEF. he real output decline gradually to 6.62 per cent growth rate in 2007 – 2014, the decrease was due to failure of the government to consolidate the little achievements recorded under NEEDS programme with new policies but rather the programme was terminated without provision for an alternative scheme that could replace it. The real output growth rate slumped to 0.6 per cent in 2014 – 2016, this poor performance of the economy was attributed to the sudden crush of oil prices from $110.16 per barrel to $33.37 per barrel. Being the major source of foreign exchange earnings for the economy, the level of accretion to external reserves turns negative and resulted in depreciation of the naira as expectation of further deterioration of foreign exchange became high. The depreciation of the domestic currency then triggered higher inflation that led to low economic activity, a decline in consumption, a decrease in aggregate demand and subsequently plunged the economy into recession.

Figure 1. Year-on-Year Real GDP Growth Rate, 1981 – 2016
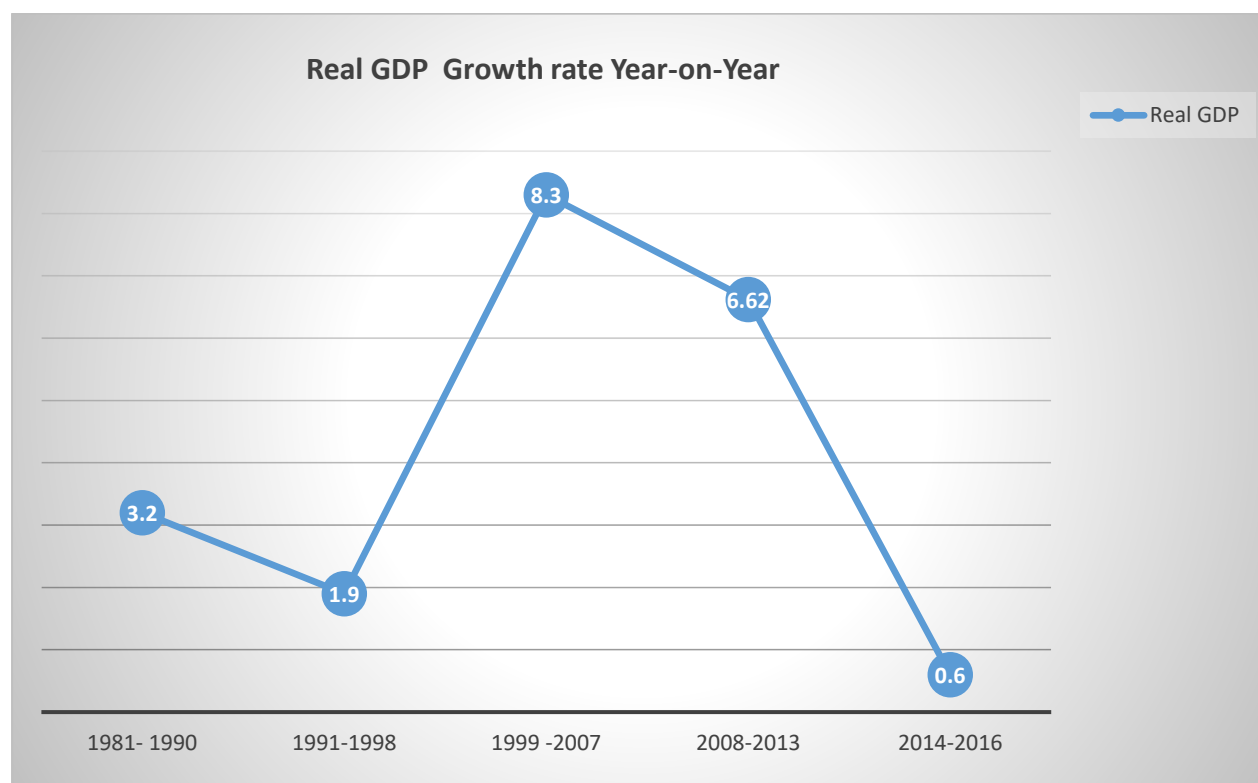
Source: (CBN 2017)

1.2.1. Real GDP Growth Rate for Oil and Non-oil Sectors, 1981 – 2014

Figure 2 shows the growth rate of real oil and non-oil GDP for the period 1981 – 2016. The oil sector is made up of the crude petroleum and gas production while the non-oil sector comprises agriculture, manufacturing, services and others. The oil sector contributed the bulk of the country's foreign exchange earnings, however, its contribution to the total aggregate real output is minimal and quite volatile.

The oil sector growth rate improved significantly with the rise in the oil prices attributed to 1991 - 1992 gulf war and maintained its dominance until 1999 when the non-oil sector rebounds in response to various government policies that aimed at diversifying the revenue base of the country to non-oil sector. The decline in oil sector's growth from (1999 – 2016) was mainly due to volatility in both oil price and oil production. The oil production had been quite erratic during that period as spate of activities of oil bunkering increased. The volatile nature of the sector's output as discussed above is based on its exogenous nature of price which is rooted to the product's demand and supply of at the international oil market. For instance, oil sector growth rate decreased from 12.4 per cent in 1984 to 2.1 percent in 1998. The sector's output resonated as its growth rate increased to about

23.90 per cent in 2003, reaching its peak in three decades only to fell drastically to -1.32 per cent in 2004.

The performance of non-oil sector was not spectacular either as it was volatile or follows similar trend of oil sector, the sector grew from 11.93 per cent in 1982 to about 15 per cent in 1988 and 7.17 per cent in 2003, the rates further crashed to -1.32 in 2014 respectively. however, from 1981-1988 the sector performed higher than oil sector despite rapid decline of the sector's output in 1984 due to change from democratic government to military regime. The suboptimal performance of the tradeable non-oil sector attributed to the sector's neglect since 1970s.

Figure 2: Real GDP Growth Rate for Oil and Non-oil Sector, 1981 – 2014
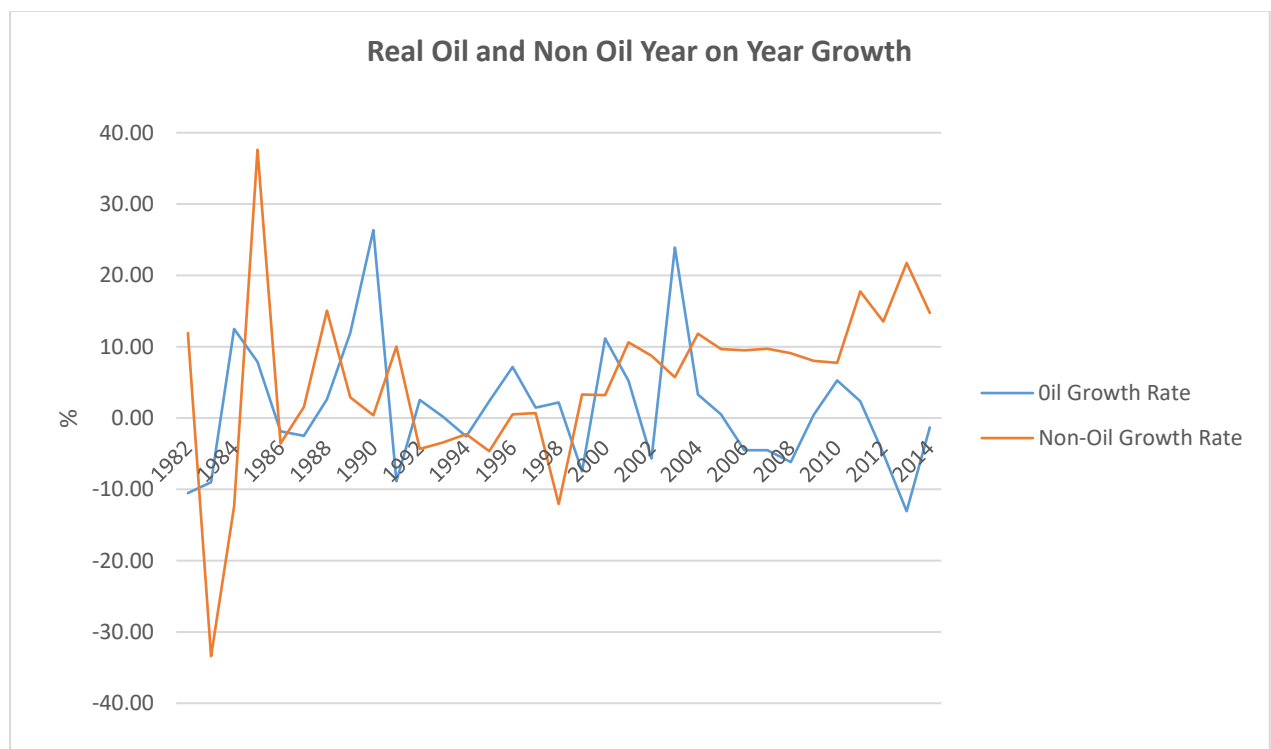
Source: (CBN 2017) and National Bureau of Statistics Nigeria (2017)

1.2.2. Real GDP growth Rate for Oil and Non-oil sectors, 2015 – 2016

Technically, an economy is said to be engulfed in recession when the GDP growth is negative for two consecutive quarters. Officially, Nigerian economy slipped into recession from second quarter of 2016, as it recorded negative domestic output growth of (0.36) and (2.06) per cent in the first and second quarters respectively. However, both real oil and non-oil GDP decreased significantly from third quarter of 2015 leading to a full-scale economic recession in 2016 from 2016 quarter

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one. The real non-oil sector growth decline from 6 per cent in first quarter 2015 to, 0.38 and 0.33 per cents in 2016 second and fourth quarters respectively. Similarly, the oil sector growth rate dropped drastically from negative (8) per cent in the first quarter 2015 to negative (17.48) and (22.01) per cent in second and third quarter 2016 (figure 3).

Moreover, the incessant decline of both real oil and non-oil growth rate in the recession period is partly due to a significant decrease in the oil production particularly in the second and third quarters of 2016. As discussed above the decline in the production is attributed to oil pipeline vandalism in by the Niger Delta Militants, oil bunkering other sharp activities (Figure 4).

Figure 3: Real GDP Growth Rate for Oil and Non-Oil Sectors, 2015 – 2016
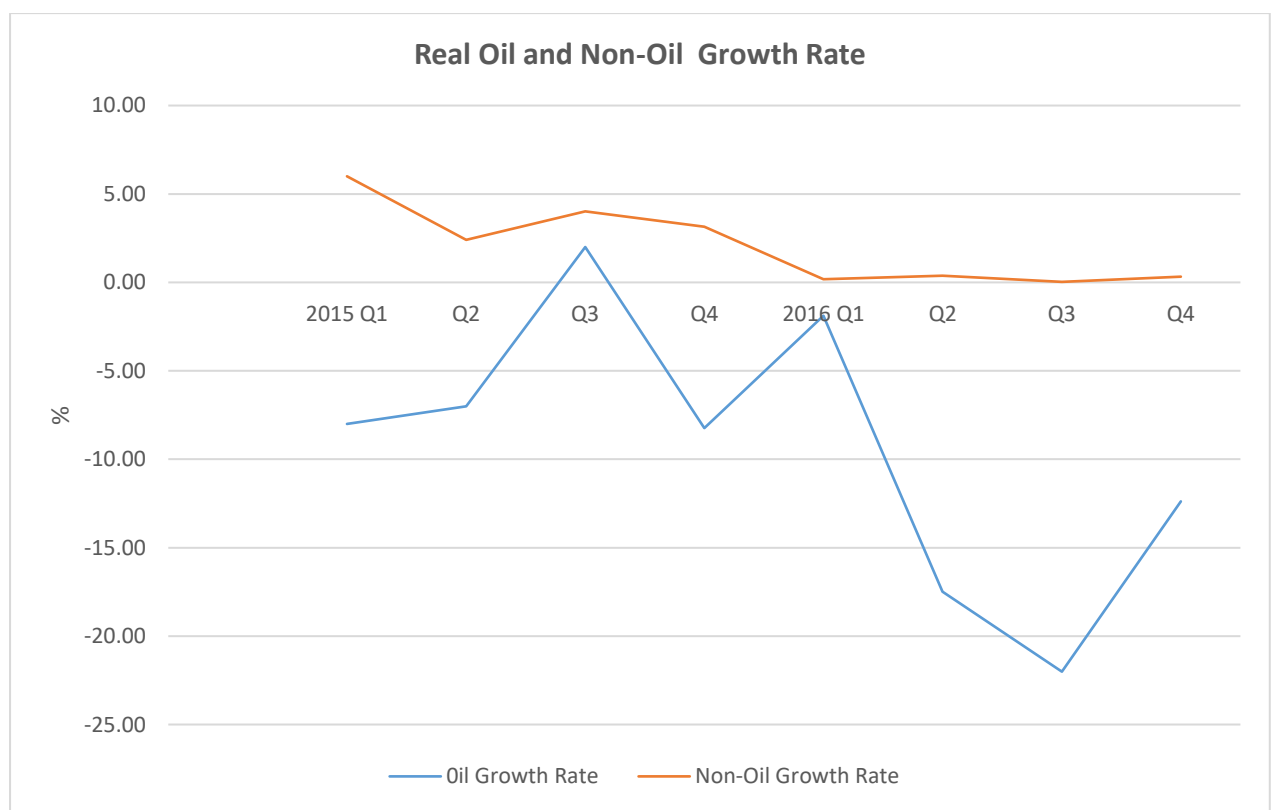
Source: National Bureau of Statistics, Nigeria (2017)

Another important factor that compounded the recession in Nigeria was the drop in the quantity of oil produced as a result of militia activities, oil-bunkering and other disruptions activities in the oil producing states: for instance, oil production dropped from 2.14 and 2.08 barrel per day in the first and fourth quarters of 2015 to 1.92 and 1.58 million barrel per day (MBPD) in the first and fourth quarters of 2016. The recession period was characterised with drastic decline in the real oil sector growth rate. For instance, the oil growth rate slumped to an all-time low of (22.01) % (year-on-

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year) in the third quarter of 2016 from a positive rate of 2% in the corresponding quarter of 2015. The decline was ascribed to fall in oil production which was estimated to be 1.833mb/day in 2016, compared to 2.13mb/day in 2015. This reduction has largely been attributed to vandalism in the Niger Delta region[5] (the oil producing states) refer to figure 4.

Figure 4: Daily Crude Oil Output in million barrel, 2015 Q1 - 2016 Q4

Oil Production (MBPD)

2015 Q1	Q2	Q3	Q4	2016 Q1	Q2	Q3	Q4
2.18	2.05	2.17	2.16	2.11	1.69	1.63	1.9
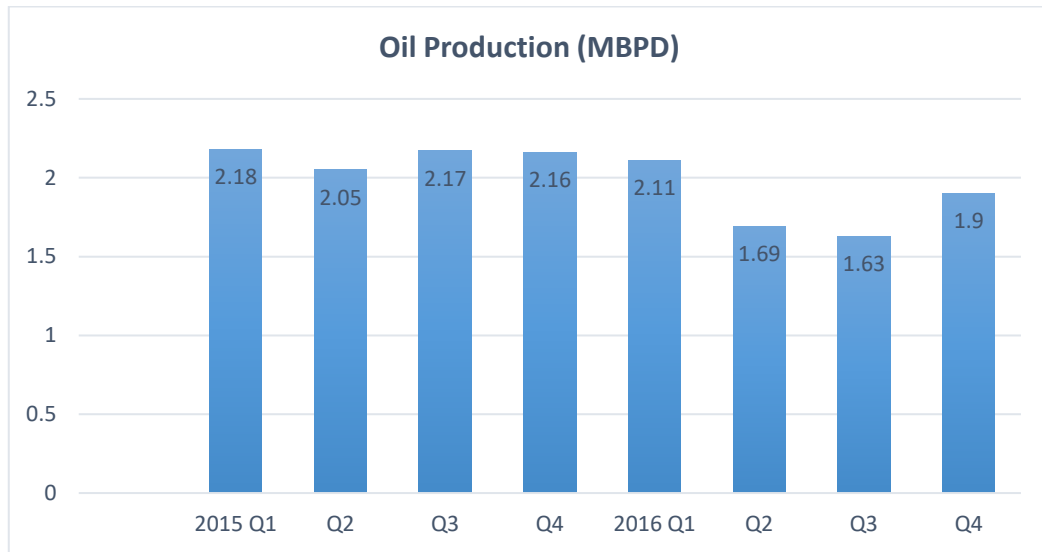
Source: Central Bank of Nigeria Statistical Bulletin CBN (2017)

 To reverse this negative business cycle trend that engulfed the Nigerian economy to desired growth trajectory during the review period, the policy makers introduced several countercyclical fiscal and monetary policies as well as unconventional intervention measures to stimulate aggregate demand and engender growth.   These growth-enhancing and development interventions include the Commercial Agriculture Credit Scheme (CACS), Real Sector Support Facility (RSSF), the Micro, Small and Medium Enterprise Development Fund (MSMED), Anchor Borrowers Programme (ABP). These programmes are not only aimed at short term remedy of the recession but rather are expected to have a long-term positive effect in transforming and diversifying the economy from oil dependent to Agricultural and industrial economy as discussed above. These interventions aimed at enhancing access to finance at less than market rates to stimulate income, consumption, and

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[5] These oil producing states in Nigeria are: Akwa Ibom, Rivers, Cross Rivers, Edo, Delta, Bayelsa, Imo, Abia and Ondo. The first six states are the Niger delta states and the remaining three are not Niger Delta states despite that they are oil producing states.

output and generate second round effect of increase in real sector growth. On their part, the fiscal authority responded to the crisis through implementation of some countercyclical fiscal policies to restore the demand and return the economy to its trajectory. Some of these fiscal operations include: disbursement of funds for different diversification and infrastructural development projects, sharing of excess crude accounts to the three tiers of governments, Federal government special bailout to states that are more vulnerable to the recession[6]as they could not to afford workers' salaries. All these fiscal operation expenditures increased the level of government spending and it is expected to stimulate income and consumption in the economy. Hence, government expenditure as a proportion to GDP increases during the recession period (figure 7). Although, numerous plans were formulated by various administration from 1982 - 1998 as encapsulated in different development plans to enhance the performance of both agriculture and manufacturing sector failed to achieve the desired outcome as they ended up with little no success mainly attributed to poor implementation and corruption of highest order in the pervades the Nigerian economy compiled from Central Bank statistical bulletin 2017.

1.2.3. Real GDP Components, 1981-2016

Figure 5 below shows the components of aggregate GDP in Nigeria with output been disaggregated into oil and non-oil sector. The non-oil sector is further subdivided into agriculture, manufacturing, services and others. The contribution of agriculture as proportion of total output increased from an average 19 percent between 1981 - 1998 and average 24.4 percent for the period 199-2016. The increase is associated with different programmes introduced to expand the sectors output. However, considering the huge unemployed labour in Nigeria, the sector could perform better with more utilisation of more labour to expand the production frontier which could stimulate the production process and hence pushing the output to its potential level.

Despite being the highest revenue generating sector for Nigeria, the oil and gas sector contribution to the total output decreased drastically from 29 percent 1982 to 8.36 per cent in 2016. The drop of the sectors contribution is mainly attributed to domestic (constraints in daily oil production by both the being an EPEC member that has to comply with the production Quota assigned to it and the activities militants in the oil producing area) and external shock mainly the volatility of oil price at the international oil market.

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[6] Nigeria practice Federal system of Government with 3 tiers of government namely; Federal (central government) States governments, and Local Government. The revenue accrued to the federation account are shared among these 3 tiers of government based on the present revenue sharing formula of 52.68, 26.72 and 20.60 accordingly. Most of the states in Nigeria depend on this revenue as their internally generated revenue is insignificant.

The share of manufacturing sector decreased from 10.22, 9.63, 7.39, per cent in 1981, 1989, 1998 to 6.4, 6.55, and 9.28 per cent in 2006, 2010 and 2016 respectively. The decline reflects the prevalence of structural problems that impedes on the sectors growth in Nigeria. The most noticeable among these problems are incessant cost of production (high cost of imported inputs due to depreciation of the Naira, rising cost of fuel as the economy is still faced with power challenges. and infrastructural degeneration, this makes the domestic manufacturers output non-competitive compared with imported substitutes goods that are relatively cheaper and thereby leaving the domestic producers with two choices of either to sell at less-than cost price or to shut down their firms. Of course, rational investor chooses the later rather than the former.

The performance of the services sector[7] in Nigeria has increased over the years. For instance, the sector's contribution which stood at 24.04, 24.89 and 27.61 in 1981, 1989 and 1998 increased to 29.47, 34.73 and to 36.91 percent in 2006, 2010 and 2016.

The contribution of other services[8] to the total output was relatively stable from 1981-2006 it stood at an average of 15 percent however, from 2009 to 2016 the sector's contribution increased to an average of 20 percent. Moreover, the incessant decline of both real oil and non-oil growth rate in the recession period is partly due to a significant decrease in the oil production particularly in the second and third quarters of 2016. As discussed above the decline in the production is attributed to oil pipeline vandalism in by the Niger Delta Militants, oil bunkering other sharp activities (Figure 4).

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[7] See footnote 4 for the breakdown of the subsectors in the services sector
[8] See these are miscellaneous services that are not captured under the services sector.

Figure 5: Nigeria's Real GDP Components, 1981-2016
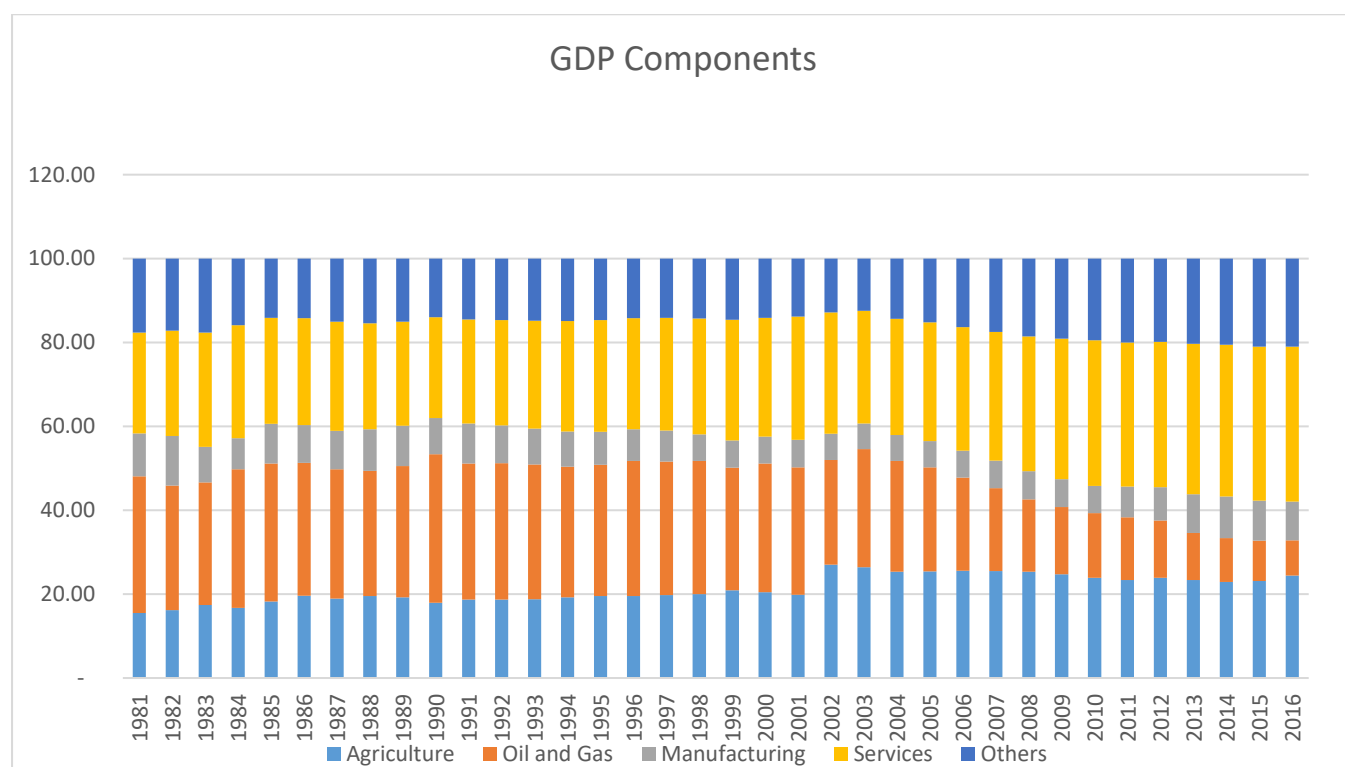
Source: Central Bank of Nigeria Statistical Bulletin CBN (2017) and National Bureau of Statistics Nigeria (Nigeria, 2017)

1.3 Government Fiscal Operations

The fiscal policy in Nigeria has been expansionary since 1992 though there were periods of low government expenditure particularly from 2014 - 2016. The government expenditure growth rate presented in figure 7 shows that the government embarked on expansionary fiscal policy over the years. Thus, federal, states and local government fiscal operations are characterised by rapid increase in expenditure reflecting increased revenue accruals to the economy. Their expenditure from 1981 and 1999 grew at an average growth rate of 0.3 percent. With the continuous expansionary fiscal policy of the three tiers of government[9] the aggregate expenditure rose astronomically from 4.2 per cent in 1999 to a peak of 8.2 per cent in 2013. On the other hand, aside the expansionary fiscal policy measures meant to stimulate growth the rise in government

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[9] The Fiscal Federalism in Nigeria constitute of the three tiers of government namely: the Federal Government, the States Government, and the Local Government.

expenditure are attributed to the constitution provision of zero federation account which stated that all revenue accrued to the federation account must be shared to the three tiers of government i.e. Federal, State and Local Governments at month end based on the existing revenue sharing formula of 52.68, 26.72 and 20.60 per cent, respectively. Theoretically, expansionary fiscal policy positively affect consumption, aggregate demand directly, aggregate output and indirectly affect net exports. In the case of Nigeria, though, the period of high expenditure corresponds to the period of high growth rate (figure 1), however, the overall balance declined steeply indicating a large fiscal deficit which are finance from both external and internal debt. Over the years it is apparent that the recurrent expenditure constituted higher percentage of government total expenditure and it is often unproductive or even diverted as the level of corruption is prevalent in the economy.

To achieve sustainability of government, finance the monetary authority (Central Bank of Nigeria) are left with no option rather than increasing its ways and means to the Federal Government beyond the stipulated limit of 5 per cent of previous government revenue. This trend of government spending is not only non-sustainable but also it undermines the monetary policy conduct and contributed to higher inflationary pressure in the economy during the review period.

Figure 6: Government Expenditure as proportion of GDP, 1981-2016

Source: Central Bank of Nigeria Statistical Bulletin (2017)

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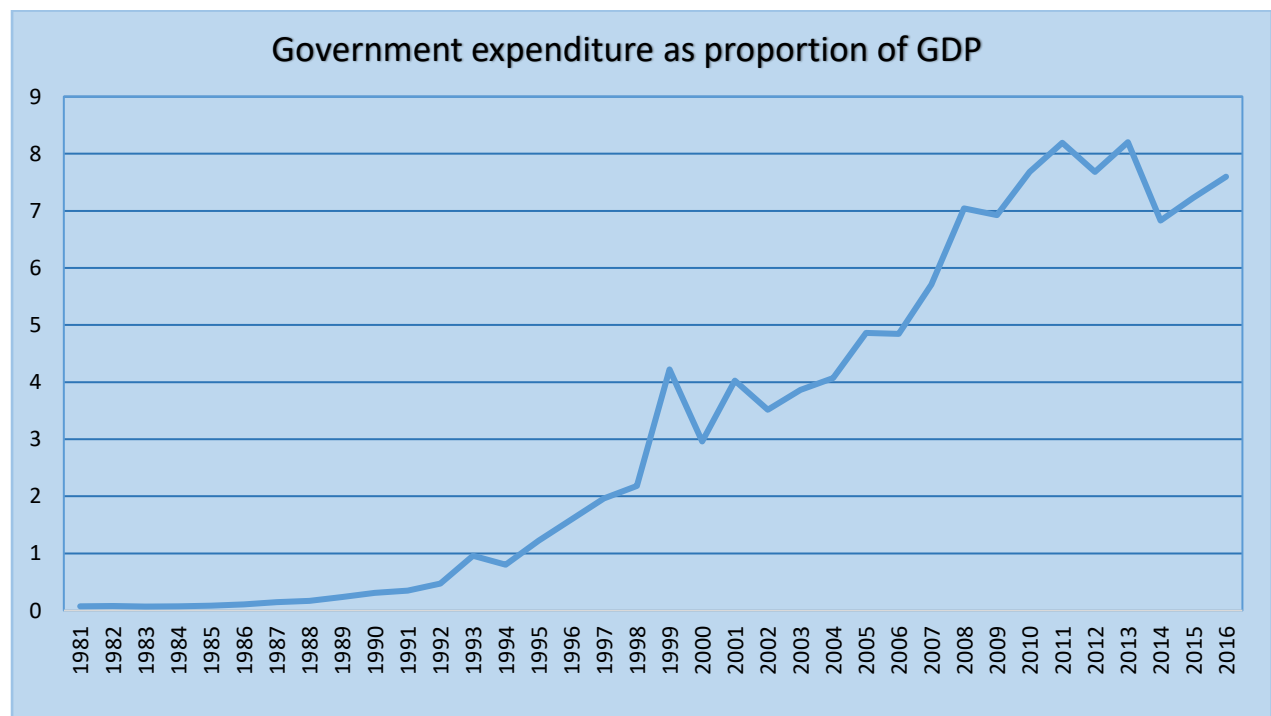
The Overall Balance (the difference between the government revenue and government expenditure) was positive and stable in 1981 - 1998, with higher revenue the trend rose steadily from 1991 but declined in 2009 before it resonated reaching a peak in 2011 and falls drastically in 2013. The overall balance for the period 2015-2016 worsened and turns negative (figure 8).

Figure 7: Government Overall Balance, 1981-2016
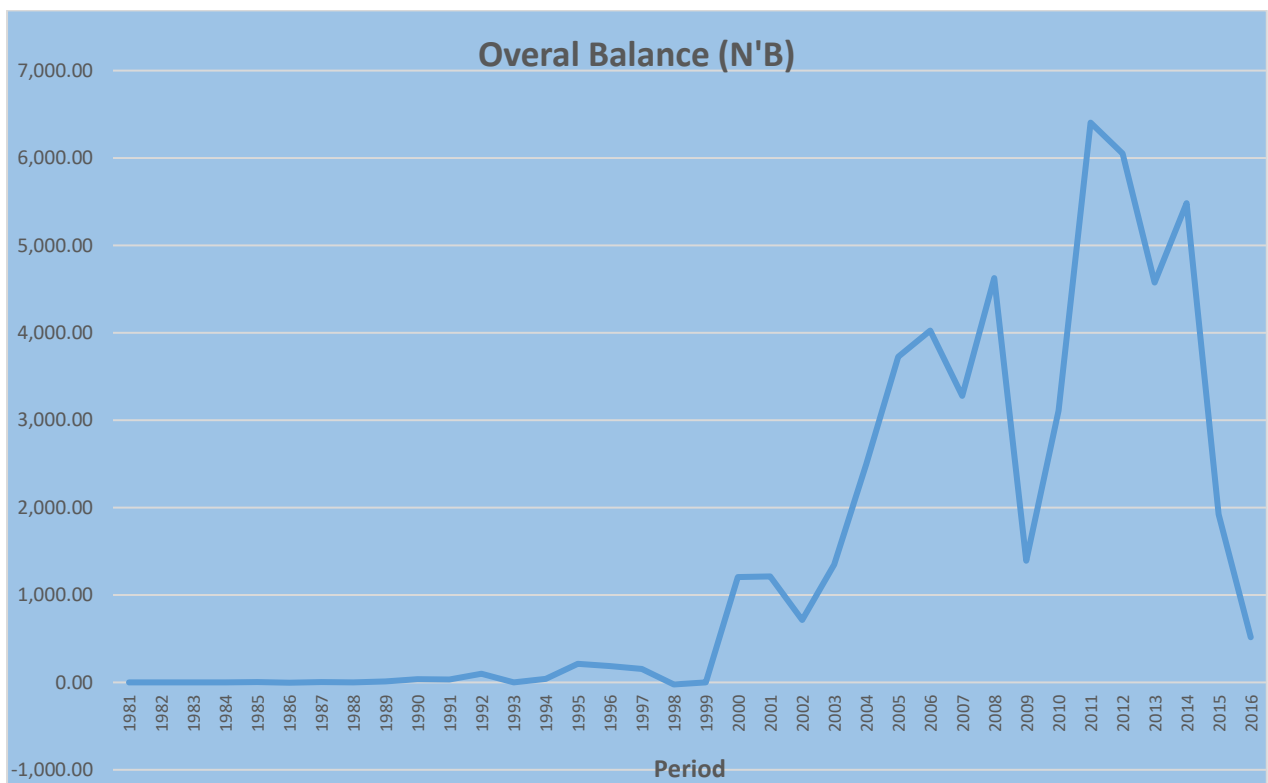
Source: Central Bank of Nigeria Statistical Bulletin (2017)

1.4 Nigeria's External Sector Performance

The Nigeria's external sector performance has been robust from 1981 – 2016 despite being a heavily import dependent economy with high exposure to external shock. Most of the key external sectors' performance indicators in the economy indicates a favourable position during the review period. Starting with the external reserves position which increases during the period largely due to increased foreign exchange inflow into the country. The importance of maintaining high external reserves for small open import dependent economy like Nigeria could not overemphasized, these includes preserving value of domestic currency; maintaining confidence in monetary and exchange rate policy management; and providing a level of confidence to the international community that the country can meet its current and future external, obligations.

Over the years, Nigeria's external reserves grew steadily reflecting the increase in crude oil prices, increased capital flows, increased investment income and improved fiscal prudence. However, owing to the volatility of oil price, the growth in the external reserves could not be sustained.

External reserves rose from US$5.52 billion in 1981 to US$28.28 billion in December 2005, peaked at an all-time high of US$62.08 billion in September 2008 before declining to US$26.99 billion in 2016. The huge accretion to external reserves between 2000 and 2008, reflected favourable developments in the oil market; including high prices, strong demand and improved domestic production. However, between 2008 and 2010 reserves declined significantly reflecting the effects of the 2008/09 Global Financial Crisis (GFC), significant production declines due to insecurity in the oil producing region and high import bills. The external reserves position from 2002 – 2016 was adequate to meet the standard six months import cover. However, the drastic fall in external reserves between 2015 - 2016 created macroeconomic instability as it triggered deterioration of balance of payment position, exchange rate depreciation, capital flight, worsened short-term external debt position, and retard economic growth. The decline in oil prices has been a key driver in the decline in foreign reserves as oil receipts represents substantial part of Nigeria's external reserves accretion (figure 9).

Figure 8: External Reserves and Oil Price, 1981 - 2016
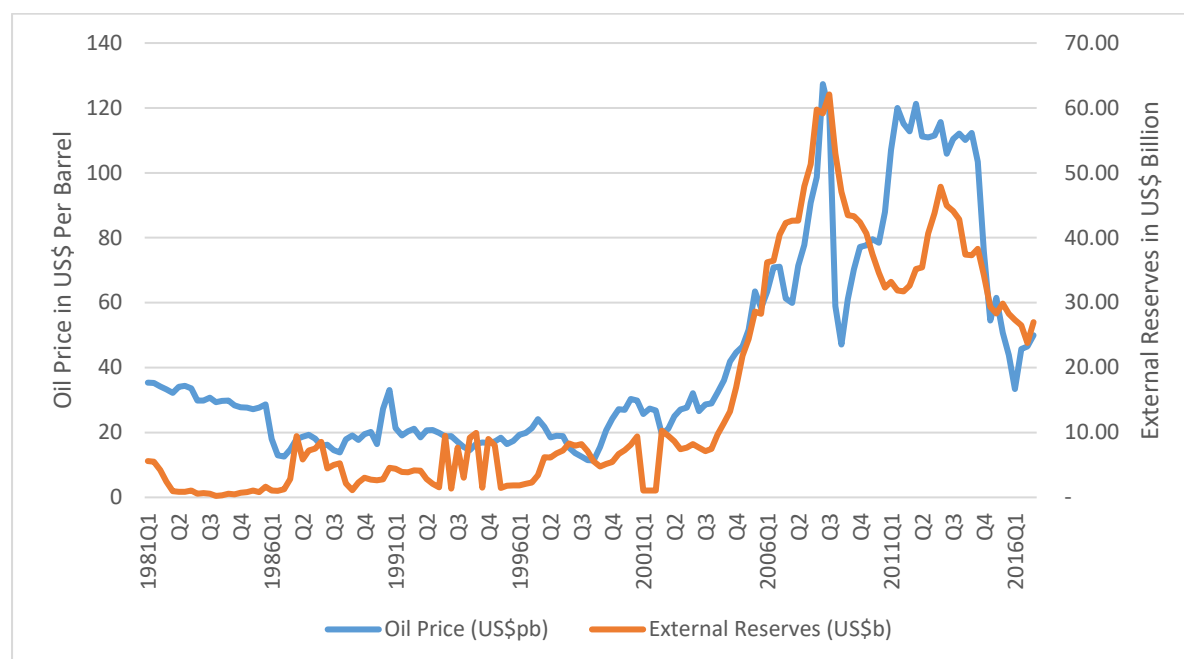
Source: Central Bank of Nigeria (CBN 2017))

1.4.1. Trend in Real Exchange Rate Movements

like any other small open economy volatility of real exchange rate is a source of concern for policy makers in Nigeria because of the notion that instability in the exchange rate creates fear of future exchange rate deterioration and hence it influence decisions of risk averse investors, discourages inflows and encourages capital outflow, inflation and generating second round effect of further depreciation of the domestic currency. The Nigerian economy has undergone various policies that aimed at stabilising the value of naira.

With the introduction of Nigeria pound currency in 1973, fixed exchange rate system was adopted for the period 1974 – 1985. As the oil boom started at that time, policy makers opted for a fixed exchange rate system to prevent currency appreciation. The currency was pegged against a basket of currencies[10] and subsequently in 1985 adopted the US dollar as the currency of intervention. However, because of inflation the naira was forced to depreciate by about 30 percent. In 1986 the Structural Adjustment Programme (SAP) was introduced with foreign exchange market been deregulated marking the beginning of flexible exchange rate regime in Nigeria; the reaction of the market to the new policy at that time was highly destabilising as naira continue to depreciate substantially by more than 100 percent. Several exchange rate policies under flexible exchange

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[10] The currency was pegged against basket of currencies such as the Canadian dollar, the US dollar, the Deutsche Mark, the French Frank, the Swiss Franc, the Dutch guilder and the Japanese Yuan.

rates were introduced to stem this fall in the rate: such as Interbank Foreign Exchange Market (IFEM) and Autonomous Foreign Exchange Market (AFEM) in 1988 and 1995 respectively. The Dutch Auction System (DAS) and Retail Dutch Auction System (RDAS) were introduced in 2002 and 2005. In spite of all these policies the naira continued to depreciate further creating panic in the market and pave way for speculations and sharp practices in the foreign exchange market. To eradicate speculations and bring about sanity in the market the Managed Floating System was introduced where the CBN intervened and supply adequate foreign exchange to meet up with the genuine demand for imports and ensure stability of the naira, this continued up to 2015 without with little success. After about a decade of managed floating exchange policy in operation without achieving a stability in the exchange rate the policy makers shift to flexible exchange rate regime which was reintroduced in 2016. Figure 10 indicates that the real exchange rate was stable for the period 1981-1999, the stability attained could perhaps be as a result of administrative peg of the naira which covered substantial part of the period. The Central Bank of Nigeria has been practising managed floating system with band for nearly 2 decades, the Bank intervene in the foreign exchange market by supplying foreign exchange meet-up the demand with a view to stabilise the domestic currency when the depreciation goes beyond the bound set. In spite of the interventions in the market by the monetary authority particularly between to 1999 – 2015, the real exchange rates was relatively not stable mainly due to speculative activities and regulation lapses, consequently in 2016 the central bank moved from managed floating to a flexible exchange rate regime to reduce speculative activities and attain stability in the exchange rate market.

Figure 9: Real Exchange Rates, 2008 - 2016
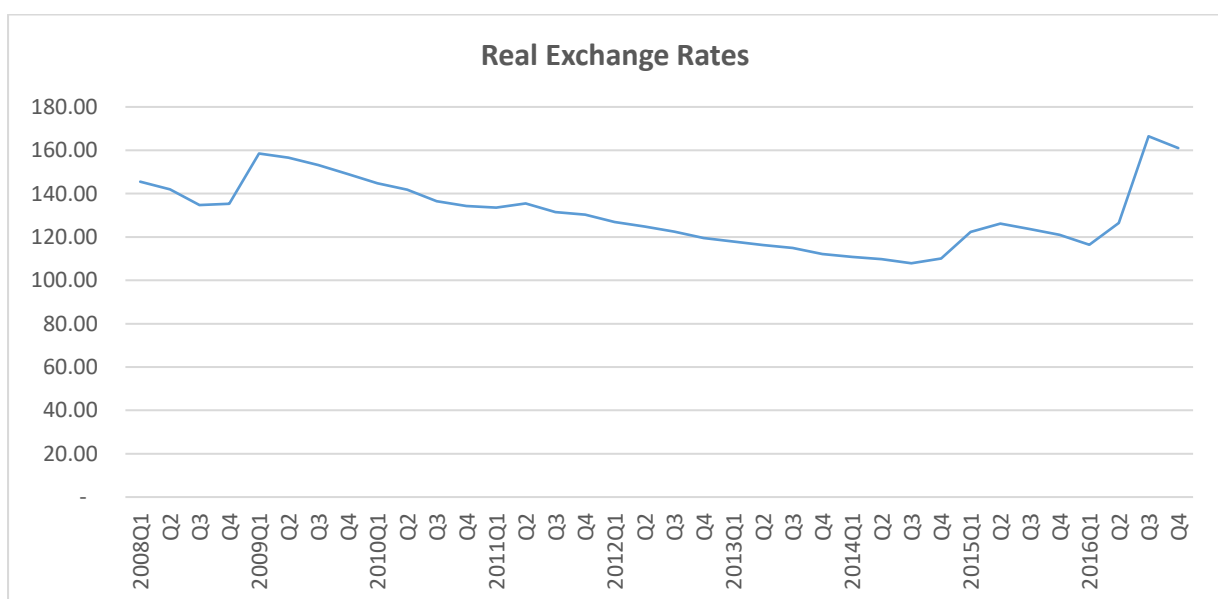
Source: Central Bank of Nigeria Statistical Bulletin CBN (2017)

Figure 10 above presents the trend in net exports and oil price from 1981 – 2016, the net exports maintained positive trend throughout the review period except for 1981, 1993, 2015 and 2016. A period of high oil price coincided with the period of high net exports. This is due to large percentage of oil share in the export basket of Nigeria forms more than 70 percent. The correlation become stronger during the 2008 financial crisis as the two variables move closely.

Figure 10: Crude Oil Price and Net Exports, 1981-2016
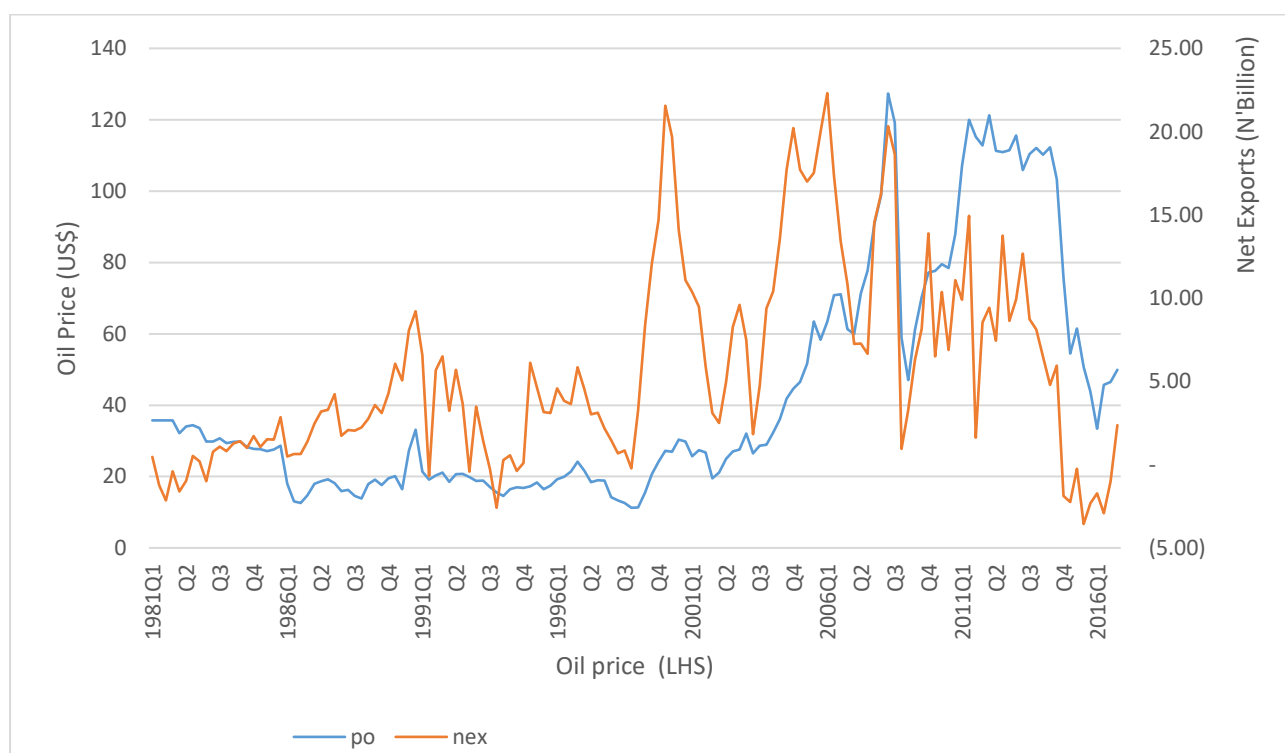
Source: Central Bank of Nigeria Statistical Bulletin CBN (2017)

On the other hand, oil price behaves in a volatile manner for instance, the price fell to US$12.6per barrel (bp) in the first quarter of 1986 from an average price of US$ 35.7bp in the first quarter of 1981 largely due to Iran crisis. The price moves upward to US$21.6bp in the first quarter of 1997 before falling drastically to US$11.3bp in the first quarter of 1999, the decrease was attributed to the Asian financial crisis. It rose significantly to a peak of US$127.4bp in the second quarter of 2008 and perhaps, in response to the global financial crisis the price collapsed to its lowest level of US$ 47.6bp in the first quarter 2009. The price slumped further to US$ US33.3bp in the first quarter of 2016 as a supply glut in the international oil market by non-OPEC members and the competition from US shale oil.

Figure 12 shows relative stability of imports to Nigeria from 1981 – 1994, however, from 1994 the trend changed as imports proportion to GDP rose significantly from 0.8 percent in 1994 to 19.1 per cent in 2011. The rise in imports reflects import dependency culture of the economy particularly for intermediate and final goods. In Nigeria, the weight of imported goods in the consumer price index (CPI) stood at about 50 per cent, this exposes the economy to a higher exchange rate pass-through. In addition, since imports are procured with foreign currency which are sourced from the central bank's reserves that put excessive pressure on the country's foreign reserves and pave way for parallel foreign exchange market with different exchange rates.

Figure 11: Imports as proportion to GDP, 1981 - 2016
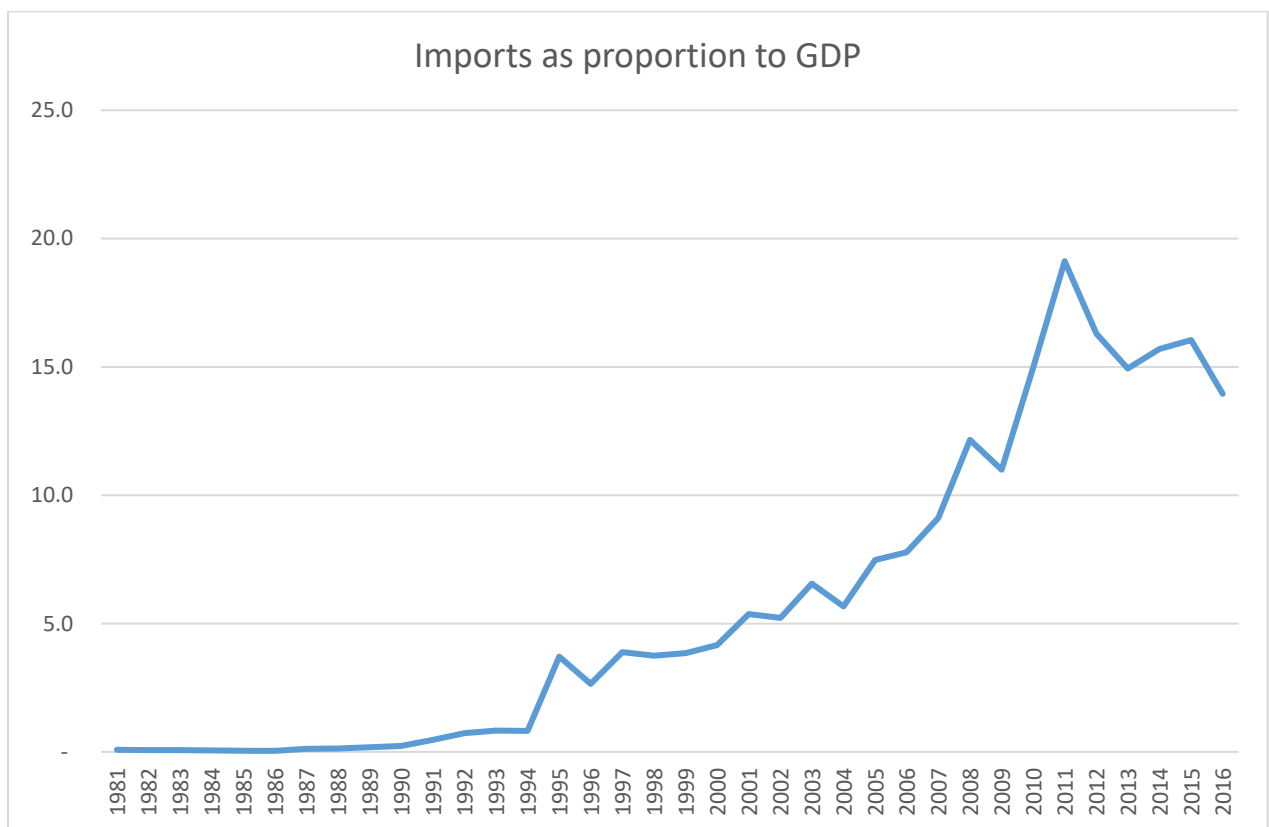
Source: Central Bank of Nigeria Statistical Bulletin (2017)

The shock impacted on the economy adversely, affecting government spending[11], and necessitating increased fiscal deficits financed from both domestic and foreign sources. It also led to falling foreign exchange receipts and negative accretion to foreign exchange reserves, with subsequent

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[11] Like most developing economies the Nigerian economy is driven largely by the public sector, as the government commands a significant proportion of resources and represents the biggest economic agent.

depreciation of the Naira[12]. Nigeria being a heavily import dependent economy with high exchange rate pass-through to domestic prices, the depreciation led to inflation, through a significant increase in the prices of imported finished and semi-finished goods. These developments negatively affected the output as the economy recorded negative growth rate of output for three consecutive quarters in 2016, a full-scale economic recession. The recession not only affected the aggregate demand but was also associated with supply constraints.

The rise in inflation rate above its target level of single digit in Nigeria has contributed immensely in exchange rate depreciation and retarding economic growth. Despite various policies implemented by the Central Bank of Nigeria to bring down inflation within acceptable bound the rates rises persistently higher except on few occasions when the rates fell within the target. Figure 13 below presents the movement in inflation rates for the period 2008Q1 – 2016Q4. The rates stood at an average of 11 percent from 2008- 2012 it declines to 8 percent on average in 2013 – 2015 before it rose significantly to 14 percent on average between 2014 – 2016.

Figure 12: Inflation Rates, 2008Q1 – 2016Q4
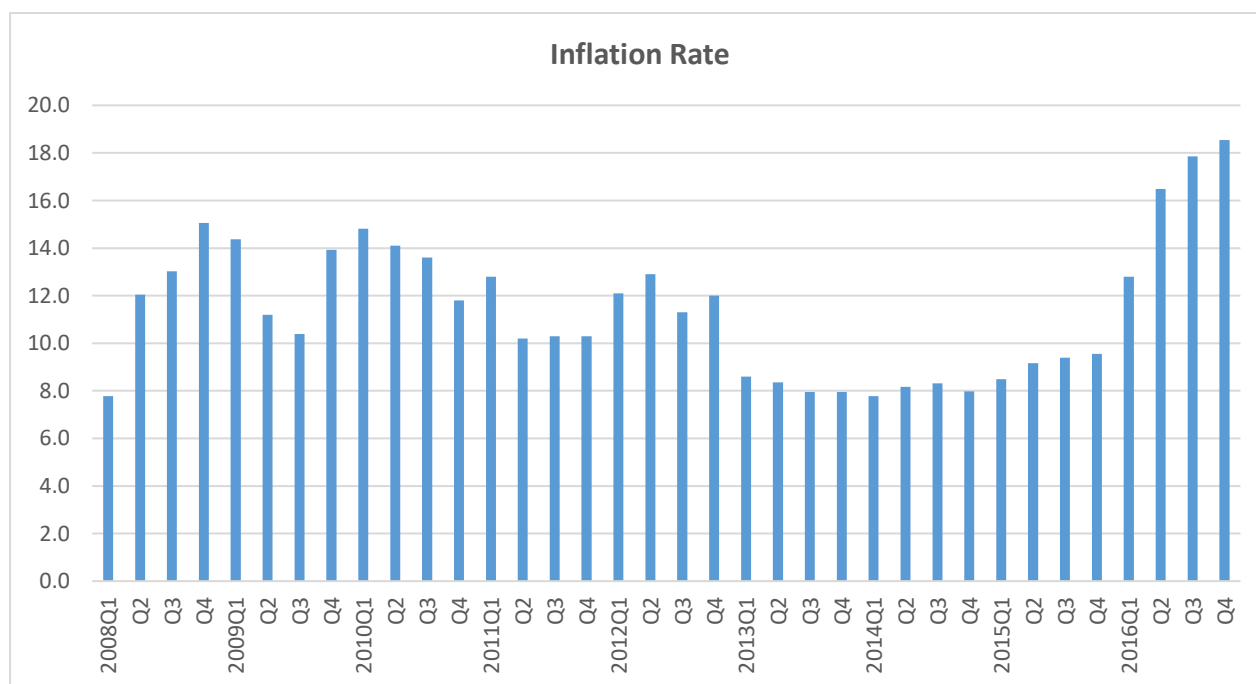
Source: National Bureau of Statistics Nigeria (2017)

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[12] Naira is the official currency of Nigeria,

2 Literature Review

2.1 The RBC model

Kydland and Prescott (1982) developed the Real Business Cycle (RBC) model, based on the (Solow 1956, 1957) growth model, which centred primarily on the role of technological change on economic growth in addition to capital per worker, as a major source of variation in output per capita. This work of Solow was limited to the production side of the economy; the consumer side was introduced by (Cass 1965; Koopmans 1965) following Ramsey (1928). Earlier work that contributed to the Kydland-Prescott development included (Lucas 1972; Lucas Jr 1975) and King and Plosser (1984)[13].

In this literature review, I refer to the results found in the context of comments and judgements made by the authors themselves for the most part. None of the empirical work used the statistical method for testing the models that I use here; indeed, most use the simple matching of different moments and do not consider any overall statistical test. I return to the issue of testing methods in a later section and do not discuss them here.

The RBC model emphasises that cyclical features (similar to observed ones) are generated from the reaction of economic agents to real rather than monetary shocks. In spite of the model's success in replicating some important regularities of the US economy, it generally failed to match the high variance in investment, total factor inputs (TFI) and GDP. Kydland (1984) explored other specification modifications that are designed to improve the match between the model and actual data. He postulates two types of labour, of differing effectiveness in production, and finds that this modification increases the variability of hours relative to output. Kydland and Prescott (1988) incorporate a variable rate of capital utilisation and show that a smaller variance is required and with this elaboration it may yield output variability that matches actual data.

To overcome the variance overestimates problem Prescott (1986) suggests that the TFP shock could be estimated better if it is approximated to a random walk with drift plus a serially uncorrelated measurement error.

The original RBC models are also unable to explain some stylised facts of the labour market. For instance, labour productivity is more volatile than real wages, hence with the relatively small

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[13] Although the seminal paper of Kydland and Prescott 1982 served as a bedrock of the RBC, however, the work of Long and Plosser (1983) was the one that brings out clearly the concept of Real Business cycle model.

volatility of wages it implies that the share of labour in aggregate income behaves counter-cyclically. In addition, the basic RBC model analyses variation in the total hours of work based on the intensive margin, rather than the extensive margin. Hence, it ignores the possibility of labour moving from some form of employment to unemployment. This imprecise explanation of the labour market has created a big gap that the proponents of RBC need to contend with. (Mankiw 1989) suggested that the intertemporal substitution of leisure is not adequate to enable business cycle work. In response to this, the model was improved to include the effects of indivisible labour supply where agents are needed to work either full-time or not work, i.e. the effect of changes in the extensive margins (Hansen 1985); Rogerson (1988) . The arguments put forward by Hansen (1985) is based on a stochastic growth model with lottery concept, such that agents either work or do not work entirely. The main findings of his work indicate that the variance in total hours generated using indivisible labour model is significantly larger than the one found in the baseline RBC model that considers intensive margins.

Merz (1995) Set-up a model that treated the labour market as frictionless and run by a Walrasian auctioneer without any recourse to unfilled vacancies. To improve the relative volatility of employment with high persistence he introduces labour market friction to replace the Walrasian labour market. With this extension he argued that the presence of trade frictions resulted in deviation of the equilibrium real wages from the labour productivity.

Andolfatto (1996) Focuses on improving the baseline model by incorporating a labour market search framework to replace the Afrasian labour market. He found that extending the model to capture labour market search improved the performance of the model as follows: firstly the model is transformed to be consistent with the stylised fact that hours fluctuate much more than wages; secondly it displays lower correlation between hours work and productivity level; thirdly the model matches the pattern of growth.

Other observations on the basic RBC model Mankiw (1989) and Plosser (1989) reveals that the RBC model overemphasises the role of the technology (productivity) shock as the only source of change in the environment. Hence, there is a need to incorporate other shocks and evaluate their impact on the model variables.

In counteracting response to these arguments put forward against the RBC model of being small, amplifying the role of productivity shock and simplified representation of reality that enable smooth simulation and quantitative validation, nominal disturbances are included to account for role of monetary shocks in the business cycle. The incorporation of money into the RBC was first

introduced by Lucas Jr and Stokey (1985) where he provide the role of money and try to move away to some extent from the neo classical "ideal world". Cooley and Hansen (1989) stressed the effects of cash advance constraints on business cycle, in other words, they assume that money is valuable because of cash in advance constraint and could have impact in the business cycle through unanticipated inflation. This comes through the inflation tax which affects the consumption level of the economy with the assumption that both investment and leisure are credit goods. The work of King and Plosser (1984) contradicts the submission of Cooley and Hansen (1989 p.4) where he opined that money is treated as outside the control of the monetary authorities. They introduced the concept of inside money-output correlation when a technology shock occurs. However, the outside money link is not incorporated and there was no quantitative validation of the model.

Various other efforts have been made to introduce nominal effects into the models, including Hairault and Portier (1995), Barro (1981) and Blanchard (1989). Furthermore, Keynesian short-run macroeconomic features have been added, such as: nominal rigidities as in Calvo (1983) staggered pricing behaviour and (Taylor 1980, 1998) wage contracts. Then also real rigidities were introduced by (Blanchard and Kiyotaki 1985; Blanchard and Kiyotaki 1987). They set up a monopolistic competition framework that bring these rigidities, mainly in form of staggered contract or menu cost into the baseline model.

Real rigidities in the labour market, through efficiency wages and risk sharing contracts, were introduced following the work of Danthine and Donaldson (1990) and risk sharing contract labour hoarding (Eichenbaum 1991; Burnside et al. 1993). These extensions of rigidities and market imperfection yields a real business cycle model that is termed as New-Neoclassical synthesis or New Keynesian modelling paradigm[14]. The first generation New Keynesian models, for instance Gordon (1982) and Taylor (1980), have upgraded the specification of the wage-price setting to incorporate the monetarist and rational expectation insight.

To provide more explanation on the real wage fluctuation the wage contract was introduced into the baseline RBC model to account for the propagation of nominal shock into the economy. These contracts imply short run nominal wage rigidity (Cho 1990; Benassy 1995).

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[14]Romer, D. 1993. The new Keynesian synthesis. *The Journal of Economic Perspectives* 7(1), pp. 5-22. Suggest that this modelling framework i.e. combining Real Business Cycle and New Keynesian model.

The incorporation of government into the RBC model was mainly to obtain adequate information on the cyclical behaviour in the economy as pointed out by Hartley et al. (1997) . The relevance of modelling government is argued by McCallum (1988).

In their work on current real business cycle theories Christiano and Eichenbaum (1992) included government spending shocks to their model. They allow government consumption shocks to influence the dynamics of labour market. Although the estimates of the augmented model were better than the prototypical real-business cycle models, however, the assumption that equates government and private consumption as perfect substitute is not realistic. The work of King et al. (1988b) incorporates government intervention in form of proportional tax rate on output.

Other studies that attempted to improve the response hours worked in the model by incorporating heterogeneity across households in the economy include (King and Plosser 1984; Kydland and Prescott 1984; King et al. 1988a) . All these studies indicate the possibility of significant downward biases in labour supply elasticities across households with different skills.

The basic RBC model was based on closed economy framework (Kydland and Prescott 1982; Long Jr and Plosser 1983). The extension was based on some irregularities on important international macroeconomic indicators as follows: firstly, high correlation between savings and investments in developed economies which was attributed to imperfect degree of capital mobility Feldstein and Horioka (1979).

Conversely , some recent theoretical work (Obstfeld 1986; Finn 1990; Mendoza 1991; Backus et al. 1992; Bec 1994) have perceived the high correlation between savings to be as a result of persistence of productivity shocks since these shocks affect both savings and investment at the same time. Secondly, the counter-cyclicality of trade balance and current account was observed accordingly (Cardia 1991; Mendoza 1991; Backus et al. 1992). Explaining the trade balance and current account behaviour Mendoza (1991) argued that "for the current account or the trade balance be counter-cyclical the pro-borrowing effect caused by an expected expansion of future output must dominate the pro-saving effect induced by an increase in current output".

Using three sector small open economy DSGE model Mendoza (1995) analysed the role of terms of trade on business cycle in some selected developing economies and seven largest industrialised economies (G7). The paper reveals that the effects of terms of trade shocks drives business cycle in these sets of countries. However, for the non-traded goods sector, the effects of terms of trade shocks do not affect the sector. The effects of terms of trade shocks on GDP and exchange rates fluctuation is about 45% to 60 %.

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Garcia-Cicco et al. (2010) Builds an Open Economy Real Business Cycle model driven by productivity shocks and using data of Mexico and Brazil he found that the model can capture the observed counter-cyclicality of the trade balance. Though the model could not explicitly explain business cycle in emerging markets however, He identified key features of the model that enhance its prediction ability as follows; firstly, the productivity shock must be sufficiently persistent and secondly that the capital adjustment cost has to be less strong.

Extending the basic RBC model to capture informality in general equilibrium framework , Roca et al. (2001) specify a RBC model by incorporating a new sector which they termed *'underground economy'*. This sector has a different technology, produces goods and services that could otherwise be produced in the formal sector or registered markets channel but are not registered. The model is specified with these two sectors therefore: individuals face two labour decisions either to get involved in registered or not and then decide on the number of hours to provide there. The trade-off between the registered and non-registered sectors is in terms of labour indivisibilities in the registered sector and wage premium in the formal sector. Households are faced with a lotteries in perfectively competitive markets in an event they choose to work in the informal sector. The benefits that the household could derive from the choice of informal sector is leisure at the cost of earning lower wage. The authors used wage premium differentials in explaining the dynamic fluctuations in response to technological shocks.

Other studies that extend the RBC model by including the informal sector include (Koreshkova 2006; Antunes and Cavalcanti 2007). These papers using money analyse the informal sector as dominated by cash transactions. Their approach shows how government can either select an implicit inflation tax or explicit tax (for instance, income tax). Hence, the two sectors, formal and informal, are differentiated based on the incidence of the two taxes.

A number of other studies have also incorporated the informal sector including (Castillo and Montoro 2008; Mattesini and Rossi 2009; Castillo and Montoro 2012). Mattesini and Rossi (2009), modeled the duality in terms of a labour market that is based on flexible wages and a unionised labour market with rigid real wages. In Castillo and Montoro (2012) both sectors have wage rigidity.

In other work, calibrated his small open economy DSGE model on sub-saharan African countries by modelling the formal sector labour as having a higher wage rate and search frictions, and an informal sector labour based on lower wages. Zenou (2008) has formal sector with a search friction and which coexists with the competitive informal sector (Batini and Nelson 2001) using a closed

economy DSGE model investigates the conduct of monetary policy with an informal sector in the context of emerging economies.

2.1.1 The Small Open Economy Model

Considering the focus of this thesis is to analyse a small open economy business cycle for Nigeria, it is worthwhile to present some literature on the small open economy for some selected countries. The literature considered in this section is not an exhaustive survey but limited only to work relevant to this thesis.

The first generation small open economy models that were extended to amend the inefficiency of the baseline model in terms of exchange rate mechanism and terms of trade for small open economy include first Mendoza (1991). Using the Canadian data, he modified the baseline RBC model by including adjustment costs to enhance the fit of the model. He examined the impact of the productivity and foreign interest rate shock on Canadian macroeconomic variables. The model was able to replicate the main features of the post war Canadian economy; particularly, the positive correlation between investment and savings, and the counter-cyclical behaviour of the trade balance and foreign assets. The model however could not replicate some other stylised facts of the Canadian economy.

Correia et al. (1995) presented a small open economy business cycle model for Portugal that includes the utility function based on the work of Greenwood et al. (1988). His findings show that the model can replicate the cyclical pattern of the Portugal economy when driven by productivity shock or shocks to terms of trade. However, the model failed to match the data when driven solely by government shocks.

Carmichæl and Samson (2002), following the work of Mendoza (1991) adjusted the model to include agency costs as a replacement of capital adjustment costs, and also asymmetric information in the small open economy DSGE model of Canada. Although the model predicted the correlation between the terms of trade and trade balance, however, it fails to replicate the countercyclical movement of the trade balance and the correlation between the terms of trade and many macroeconomic variables.

Backus et al. (1993) used a two-country model extension of Kydland and Prescott (1982) closed economy. They incorporated two new features as: first, allowing innovations in the shocks to be correlated across different countries based on the rationale that different countries experience different technological shock at different point in time. Second, allowing diffusion of the

technology shock amongst the countries, as technological change is transmitted across borders. Their results indicate that output is generally more correlated across countries than consumption. Thus, their finding was not consistent with the actual data, which was observed to be the opposite as consumption are more highly correlated across countries than output.

Feve and Langot (1996) study cyclical fluctuations in France using small open economy business cycle model. Their work shows that the macroeconomic data is consistent with that of an open economy with search and bargaining in labour market, hence the model fits the French economy stylised data.

Mendoza and Uribe (1999) examined a small open economy DSGE model of Mexico; they incorporated uncertainty in the duration of currency peg. Their model matches the stylised regularities of exchange rate-based stabilisation as follows: large real appreciation, large external deficits and recessions that occurred before the currency collapse.

Balsam and Eckstein (2001) analyse the business cycle features in Israel using a small open economy model with non-traded goods. Their results suggest that volatility of consumption can be realised by changing the main parameters (three) of the CES utility function and the share of non-traded goods in government spending, while keeping the production side constant.

Neumeyer and Perri (2005) specified a small open economy DSGE model to evaluate the role of interest rates in driving business cycles, using the data sets of some selected emerging markets countries namely; Argentina, Brazil, Korea, Mexico and Philippines. The interest rate is modelled in two ways: Firstly, it was specified as completely different from the fundamental shocks. Secondly, it was modelled as variable that is explained by the fundamental shocks. The findings of their paper indicate that modelling the interest rates based on the fundamentals shocks yield the best result and thus match the data than the first scenario where the interest rate was modelled independent of shocks. The results also show that the default risks can account for 27% of the total output variation.

In an effort to improve the fit of the basic RBC model and in particular, to replicate both the dynamics of consumption and current account, a number of studies have shown that the inclusion of habit formation in closed economy RBC model solved the problem of equity premium puzzle (Campbell and Cochrane 1999; Lettau and Uhlig 2000). These studies also reveal that with the inclusion of habit formation in consumption the response of consumption has been affected, substantially reducing level of volatility in consumption and reducing the correlation of consumption with output significantly.

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In line with this improvement recorded in the closed RBC model, Letendre (2004) extends the small open economy real business cycle model to incorporate habit formation which he argue that it could change the dynamic properties of the current account through its effects on the dynamic savings. Specifying the model with separate endogenous capital utilisation and habit formation on the Canadian data, he found that endogenous capital utilisation raises the variability of output, hours, and investment sufficiently to enable the model to fit the stylised data. In addition, the model finds that the inclusion of a shock to the foreign interest rate can improve the fit of the basic model.

In this study small open economies have been categorised into small open developing countries and small open developed countries[15]. These countries differ along various lines, for instance developing small open economies depends solely on the earnings from primary commodity exports whose price is exogenously determined, and hence this makes them highly vulnerable to external shocks. As result of this unstable price faced by these countries, their earnings are quite volatile and sometimes very low; in general, on average they are not wealthy countries. Conversely, developed small open economy countries are industrialised countries that exports industrial goods and have sound financial system to greater extent. Several studies were conducted to find out whether the business cycle is similar or different between these set of small open economies. If eventually the business cycle is different then, the model that can be used for these countries has to differ. Uribe and Schmitt-Grohé (2012) present a paper that aims at explaining business cycles in poor, emerging and rich countries. They categorised countries into poor (countries with annual PPP-converted GDP per capita of up to $3000), emerging countries (countries with annual PPP-converted GDP per capita between $3000 and $25,000) and rich countries (countries with annual PPP-converted GDP per capita greater than $25,000). Their findings reveal the following: that the business cycle in poor and emerging countries is about twice as volatile as the business cycle in rich countries; the relative consumption volatility is higher in poor and emerging countries than in rich countries; the rich country's share of government consumption is counter cyclical while in the poor and emerging countries it is acyclical.

To explain their findings, the authors asked the question: could the high volatility observed on the part of poor and emerging countries be attributed to "volatility in terms of trade, productivity shock,

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[15] Small open developing economies are mainly commodity exporting economies, they comprises up of countries that depends on agricultural goods or natural resources as their major source of revenue, whereas small open developed economies are economies that are industrialised. Also, economic fluctuation in most small developing economies has been more volatile than the developed small open economies. Another distinguishing feature is that these economies are more prone to default risks. Historically, quite a number of small open developing economies have defaulted on their debt obligation whereas the latter have not defaulted.

country risk premia or animal spirits? Or could it be associated to inefficient or precarious economic institutions that lead to poorly designed monetary and fiscal policies, political distortions, fragile financial systems, or weak enforcement of economic contracts, that tend to exacerbate the effects of changes in the fundamentals?" It seems that the second is the main explanation.

In another study carried out by Kouparitsas (2001) he examined the business cycle fluctuations between two regions: Northern economies (developed economies that export industrial goods) and southern economies (that export non-oil commodities) to ascertain the level of their correlation or otherwise. The author summarises his findings as follows that: 20% of the business cycle fluctuation in southern economies are explained by productivity shock from the northern economies.

One important literature that is highly relevant to this thesis is Kose (2002) that used a DSGE model to examine the effects of world prices on business cycle fluctuations in small open developing economies. The set-up of his model provides an avenue for interactions between world price shocks and business cycle fluctuations in both traded and non-traded sectors and interaction with many factors of production. An important landmark related to this work is the incorporation of land into the production process of the tradeable sector: as he argues, "land limits the substitution across different types of factors and reduces volatility of primary sector output. This, in turn, decreases the volatility of aggregate output, and helps the model to generate realistic volatility properties" Kose (2002 p.3). His result shows that small open developing economy is highly sensitive to the world price shocks; about 88% of the fluctuation in aggregate output is explained by world price shock. Likewise, these also accounted for about 90% of the variation in investment.

Drawing the importance of including land in small economy business cycle model, this work following Kose (2002) incorporates land as one of the factors of production in the model to reduce the aggregate volatility of output as explained in chapter 4.

Macroeconomic business cycle models often have failed to provide a financial channel in the economy. Yet, Fisher Fisher (1933) "attributed the severity of the Great depression of 1933 in part to the heavy burden of debt and ensuing financial distress associated with the deflation of 1930s". This observation on the role of financial market was also emphasized by Bernanke (1983) who examined the effect of   global financial crisis of   1930s in relation to the   financial sector. Responding to these problems identified, the standard model has undergone some modification as follows:Carlstrom and Fuerst (1997) construct a business cycle model that incorporates agency cost, to evaluate the role of agency cost in the business cycle using partial equilibrium framework.

The model works such that agency costs arise in the creation of new capital and then affect the investment supply curve. The results of the model with agency cost show the model produces a hump-shaped in output, which is consistent with much empirical work. The hump shaped output behaviour displayed by the model is attributed to the households' delay in investment decision waiting for the agency cost to be at its lowest- this may in fact be a long period after the initial shock. The paper also establishes the links between explicit models of agency costs and adjustment costs models.

Blankenau et al. (2001) examine the effect of world interest rate shocks on small open economies. They extended the baseline dynamic stochastic small open economy model by incorporating preference and depreciation shocks.

Uribe and Yue (2006) have set up a small open economy model to investigate the country spread and business cycle in emerging markets. The authors included gestation lags in the production of capital, external habit formation and working capital constraint and an information constraint. The result of the study revealed that world interest rate has a significant impact on the country interest rate (20 % of the emerging markets output is attributed to US interest rate shocks) whereas country spreads and aggregate activity respond to domestic macroeconomic variables simultaneously.

Boileau (1999) present a two country DSGE model using Canadian data; the model incorporates trade in capital goods to replicate the high volatility of net exports and terms of trade. Although the modification has improved the fit of the model, in general the results under-predict the volatility of the net exports and terms of trade.

The work of Meenagh et al. (2010) developed a small open economy business cycle model for the UK without any rigidities (price or wage rigidity) to explain the behaviour of real exchange rate. The model is driven by productivity shocks and tested using indirect inference method. Their finding reveals that two third of the variation in real exchange rate is caused by productivity shock and other exogenous shocks.

Davidson et al. (2010) developed a real business cycle to model crisis period, the model explains the pattern of non-stationary data. The model is tested with indirect inference testing method where the data from the simulated data is matched with the actual data and the results indicates that the model is capable of replicating the behaviour of the some selected macroeconomic variables such as real exchange rates, output and real interest rates. The model was then used to explain the crisis tendency with productivity shock as the driver of the economy. The result also shows the possibility

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of reoccurrence of banking crisis due to productivity created crisis if banking sector financing to those affected sectors remains high.

Using similar approach of indirect inference Onishchenko (2011) examined the small open economy DSGE model for Ukraine and found that the model is able to replicate the stylised variables of Ukrainian economy.

The role of financial friction in DSGE model could be traced to the work of Bernanke and Gertler (1989). They observed that the effect of temporary shocks through the financial transmission channel could have long lasting effects. Following this work, a lot of research work has been conducted on the role of financial friction in macroeconomics. Some of the notable literature include: Bernanke et al. (1999) developed "financial accelerator" that is based on the assumption of risk-averse household (borrower) and risk neutral entrepreneurs (lenders). The paper included credit-market imperfection in the DSGE models and explain that the inclusion of the credit market frictions into the baseline model can enhance its performance particularly in explaining the cyclical fluctuations. Their findings show that the model with credit market frictions produces a hump-shaped response, which is in line with most empirical findings. Some other models developed include (Kiyotaki and Moore 1997; Christiano et al. 2005; Brunnermeier et al. 2012). Kiyotaki and Moore (1997) incorporate collateral constraints on borrowing because of incomplete contract.

Christiano et al. (2007) in a standard DSGE model with financial markets ask: firstly "are there shocks that originate in the financial markets (i.e., 'bubbles', 'irrational exuberance') and do these contribute to business cycle fluctuations? Secondly, "Do financial markets play an important role in propagation of non-financial market shocks? Thirdly, "how, if at all, should policy react to financial market shocks"? Responding to the questions , the paper follows the work of Christiano et al. (2005) by including sticky wages and prices , adjustment costs in investment, habit formation in preferences and variable capital utilisation.

To evaluate the financial markets interaction with the aggregate macroeconomic variables the model also follows the work of Chari et al. (1995) and incorporates banking. Firstly, the results show the model fits the data for both Euro area and U.S. respectively. Secondly, financial frictions have significant impact in the amplification of the shocks (monetary policy shocks) that move output and price in the same direction. The banking sector effects on both source of shocks and in adjusting the propagation of the shocks that come from the sector is less. Thirdly, the main driving factor in the fluctuation is a shock that originates within the BGG financial friction.Carlstrom and Fuerst (1997).

More research has been carried out to incorporate the financial friction into open economy framework. Caballero and Krishnamurthy (2001) emphasise the role of collateral in borrowing where domestic firms could not get access to borrow funds from foreign lenders because of domestic country's limited international collateral.

Bianchi (2011) presented a model that is based on welfare analysis on the optimal borrowing of an individual transmits to over-borrowing at social level. Using quantitative analysis with DSGE model the paper examine the role of over-borrowing in amplifying the financial crisis and the size of the welfare losses. The findings of the paper show that macroeconomic effects of the systemic credit externality are significant. In other words, the level of externality is positively correlated with the severity of the financial crisis. The result also suggests that introducing macro-prudential regulations helps tremendously in reducing the systemic credit externality effects on the economy during a cycle. Other papers examine different forms of constraints households faced from accessing foreign loan due to lack of collateral include (Mendoza 2005; Lorenzoni 2008; Jeanne and Korinek 2010; Benigno et al. 2016).

2.1.2 Commodity Shocks and Small Open Economies

The importance of oil price shocks on small open economies has gained substantial consideration among scholars which resulted to large number of researches been conducted on the effects of oil price shock on the cyclical fluctuations of macroeconomic variables in respective economies. Most of these studies focus on the oil importing countries for instance, (Hamilton 1983; Bernanke et al. 1997; Hamilton and Herrera 2004).

These studies examined the effects of oil price shock on U.S. output and the impact of monetary policy using Vector Auto Regressive (VAR) models to decompose the effects of oil price shock on some selected macroeconomic variables from the effects generated by the endogenous monetary policy response. Their results failed to provide an insight an accurate impact of monetary policy because VAR models are atheoretical and have the problem of structural interpretations of the reduced form coefficients.

Recently there are some studies that consider the effect of oil price shock to the oil exporting countries. Oil price shock generates an income effect that significantly affects both the consumption and labour decision of the household. From the production side (firm) the shock affects the marginal cost of firms, thereby altering the pricing decisions of those firms.

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McCallum (1988) has made a case for incorporating energy into the real business cycle models as follows: "there is one prominent type of 'supply-side' disturbance that has effects across a very wide category of industries, namely, a change in the real price that must be paid for imported raw materials – especially energy." The oil price shocks of 1974, 1979 and 1986 clearly have had significant impact on the U.S. economy at the aggregate level. In addition, since the Kydland – Prescott (1982) and Hansen (1985) models have no foreign sector, such effects are treated by their analyses as 'residuals'- shifts in the production function. Such a treatment is, however, avoidable since these price changes are observed and are documented in basic aggregate data sources. Hence, it pointed out that "it is also analytically undesirable: to lump price changes together with the production function shifts is to blur an important distinction. Presumably, future RBC studies will explicitly model these terms-of-trade effects and thereby reduce their reliance on unobserved technology shocks."

Extending Hansen (1985) that discusses the importance of labour indivisibilities into the baseline RBC model Kim and Loungani (1992) also included energy into the inputs in the production function and the energy price and incorporated an exogenous shock to oil prices. Including this increased the baseline RBC model's explanatory power of output volatility by more than 13 percent. However, the model fails to match some stylised variables.

Bruno and Portier (1995) using French data attempt to replicate French business cycle for the period 1973-1989. Specifying an open economy RBC model, they included imported energy into the production function and create a choice for the domestic household between international and domestic financial assets. Carrying out stochastic simulation and second order moment comparison, the model has achieved success in bringing imperfect financial assets substitutability into the small open economy RBC model. They based their model on the assumption that oil and capital are perfect substitutes, comparing the impulse response obtained from the actual data and the estimated VAR impulse response function, Bruno and Portier (1995) concluded that the technological shock is overstated by the theoretical model.

Backus and Crucini (1999) construct a small open economy DSGE model to investigate the behaviour of real output and other macroeconomic variables in response to the oil price shock in some selected countries including Canada, using three different disturbances, namely: domestic productivity shock, foreign productivity shock and oil supply shock. Their finding indicates a strong correlation of terms of trade with real output. It also shows that the volume of trade varies over time

and across countries and hence, the relationship between relative prices and quantities is unstable as the shock differs across different times.

Blanchard and Gali (2007) investigate the performance of some selected industrialised countries in relation to the oil price shock of 1970s, concentrating on the differences across events to uncover the causes and nature of changes in the macroeconomic effects of oil shock during the period. Using structural VAR model, (large VAR and rolling bivariate VARs) the estimation results indicate the following: firstly, that at that time there must have been occurrences of other bigger shocks of different nature that had happened, however, the VAR model fails to identify these bigger shocks. Secondly, the effects of oil price have changed over time. Thirdly, these changes could possibly be attributed to the decline in real wage rigidities. Fourthly, it is also possible that these changes were due to the credibility of monetary policy or the decrease in the share of oil in both consumption and production use. The paper could not fit the stylised facts of Japan. In addition, it is observed that VAR approach could not be appropriate to for this type of study, as it could not identify those biggest shocks that coincidently happened concurrently with the oil price shock.

Kilian (2008) using a different methodology evaluate the effects of exogenous oil supply shock on macroeconomic indicators of U.S. and the oil price. The study covers the modern OPEC period, using the new approach for quantifying exogenous oil supply shocks and compares it with the conventional dummy approach. His findings reveal that exogenous oil supply shocks have significantly affected the evolution of the U.S. economy since the 1970s. In another paper (Kilian 2009) attempts to find out the dynamic effects of oil price shock as these shock may have different effects depending on the main cause of the increase in price. His findings show that the effects of the shocks, i.e. rising price of oil since 2003 was mainly driven by a rapid rise in demand. These studies of (Kilian 2008, 2009) were not based on structural model that is micro founded and hence could be mis-specified.

Recently, interest has increased in the effects of oil price shocks on the variability of endogenous macroeconomic variables in oil exporting economies. The increase in the interest in this area is attributable to the fact that these oil-exporting countries are more vulnerable to exogenous shocks and experience very high variability relative to emerging and developed economies. Although there are some studies that examine the impacts of oil price shock on different sectors of the oil exporting economies: the "Dutch disease syndrome[16]" attributes the de-industrialisation of these

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[16] Dutch disease story came from Netherland when they experienced increased revenue due to discovery of large sources of natural gas in the late 1960's, This resulted to appreciation of Dutch Florin as the Demand for their

oil /commodity exporting economies to the resource boom - Fardmanesh (1991) and Looney (1990)
. However, VARs were used in these studies, with the problems referred to above.

Medina and Soto (2005) develop a Small Open Economy DSGE Model for Monetary Policy and
Oil shocks for Chilean economy. The study specifies oil as both inputs in the production process
and part of the consumption basket of the Household. Using Bayesian methods of estimation, they
simulate the response of monetary policy and some macroeconomic variables under policy rules
operational at the central bank of Chile, to the effect of the oil price shock. The results show an
increase in oil price leads to a fall in output and inflation, with the monetary policy tightening found
to be the main cause of the contractionary effect.

Leduc and Sill (2004) carried out a quantitative analysis of oil price shocks and systematic monetary
policy and economic downturns. They modelled small open economy DSGE model based on
preferences, technology and the stochastic process that governs shocks. The study   investigates
economic variables response to oil price shocks across different monetary policy rules. Their results
show that even though it is observed that the monetary rule can increase the size of negative output
response to oil price; however, the direct effect of the oil price shocks (increase) is of high
importance. Hence, the paper suggests that the policy makers need to emphasise offsetting the
inflationary consequences of the oil price shock rather than concentrating on stabilising output.
Similar work has been done for a variety of countries: Venezuela Morales and Sáez (2007); (Arfa
2010) for France; Allegret and Benkhodja (2011) for Algeria; and Santacreu (2005) for the New
Zealand.

Some prominent papers study open economies particularly on the performance of simple policy
rules include (Batini and Haldane 1999; Dennis 2000; Ghironi 2000; McCallum and Nelson 2000;
Obstfeld and Rogoff 2000; Batini and Nelson 2001; Laxton and Pesenti 2003). The New Keynesian
framework is the central point of most of this monetary policy research. Multi-country open
economy studies include Clarida et al. (1998). and Lubik and Schorfheide (2007), both using eth
new Keynesian open economy model for a number of developed countries.

Galí and Monacelli (2005) developed a small open economy model with Calvo-staggered price
setting as a framework to examine the properties of three alternative monetary policy regimes for
small open economy namely: a domestic inflation-based Taylor rule; a CPI-based Taylor Rule; and
an effective nominal exchange rate peg. The finding reveals the existence of trade-off between

domestic currency increases causing high appreciation of their currency and thereby decreasing the manufacturing
sector outputs.

stabilisation of their relative ranking and the macroeconomic implications. The ranking of these regimes are based on the volatility for the nominal exchange rate and terms of trade, thus, inflation targeting regime which can achieve simultaneous domestic inflation target and stabilisation of both terms of trade and nominal exchange rate on one- hand and stabilisation of output gap and inflation on the other effective nominal exchange rate. Therefore, domestic inflation targeting display high volatility of the nominal exchange rate and the terms of trade. The findings also indicated that the Taylor rule that the policy makers react to domestic inflation provide higher welfare than a similar rule based on CPI-based Taylor rule.

Crucini et al. (2011) presented an important paper that attempt to find an answer for a question that has been lingering for long in macroeconomics modelling of business cycle. The question posed in his study is that, "what the driving forces of international business cycle are". Although there are quite a lot of literature that identified many driving forces of business cycle ranging from productivity shocks, oil price shocks, monetary policy shocks, fiscal shocks, news shocks, terms of trade shocks and many more, some studies regarded these variables as exogenous whereas other studies treated them as endogenous. Using a dynamic factor model to estimate and nation-specific factors in each of these specific variables on the data from G7 economies for the period 1960-2005, they found oil prices as the dominant common factor while monetary aggregates and government expenditure were found to be less important factors.

2.1.3 Review on the Dutch Disease and Sub-Saharan Africa

Recently, there has been a growing interest across the Sub-Sahara African the region on the part of policy makers and academicians to develop a business cycle model for their respective countries.
 (Loungani and Swagel 2001; Peiris and Saxegaard 2007) was believed to be the pioneer work that uses real business cycle framework DSGE for African countries.

 Peiris and Saxegaard (2007) using open economy new Keynesian DSGE model analysed the monetary policy trade-offs between alternative monetary policies rules and sources of inflation in the Mozambique. Following the (Kollmann 2002; Prati and Tressel 2006; Agénor and Montiel 2007; Adam et al. 2009; Montiel et al. 2010) they estimated a New Keynesian DSGE model of monetary policy and extend it to capture monetary policy trade-offs in low income countries, the frictions that the firms are facing in Mozambique and learning by doing. Their finding indicate that monetary policy is more effective under inflation targeting regime rather than fixed exchange rate regime.

Hove et al. (2012) carried out a study under the framework of New Keynesian DSGE model to examine the optimal monetary policy in emerging market, using data for South Africa, calibrated his model and the impulse response functions shows that the conduct of monetary policy under the CPI inflation targeting regime performs better than non-trade inflation targeting and exchange rate targeting. .

Further work on South Africa was done by Alpanda et al. (2010) specified a small open economy DSGE model with imperfect competition, nominal rigidities, habit formation , indexation and partial exchange rate pass-through. The paper seeks to find the extent of monetary policy conduct in response to variation in past interest rate, inflation and output when the central bank follows Taylor type rule. Including nine shocks into the model and estimating it using Bayesian methods, the impulse response function displayed by the calibrated model shows that the model fits the stylised macroeconomic variables of South African economy. The results also suggest that optimal Taylor rule attached more weight on inflation and output than the estimated Tylor rule coefficients, with no weight attached to exchange rate.

Batté et al. (2009) analysed a small open economy DSGE model for oil exporting country represented by Nigeria[17] and non-oil exporting country denoted by WAEMU[18]. The model incorporates money and financial constraints households (Rule-of-thumb households that faced difficulty in accessing loans). The paper examined the effectiveness of monetary regime of the currency union in response to oil price shocks under three different monetary regimes namely; fixed exchange rate, floating exchange rate with exogenous money supply and floating exchange rate with endogenous money supply. The results found that the flexible exchange rate regimes decreased consumption volatility relative to the fixed exchange rate regime. The paper suggests fixed money supply as the better regime for both economies and stressed the importance of an oil stabilisation fund in reducing the effect of oil and commodity price shocks on the economies.

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[17] In this model Nigeria, serve as a prozy for West African monetary zone (WAMZ). The main objective of WAMZ is to establish the actualisation of single currency for the West African Countries, to minimise effects of asymmetric shocks. countries which includes , Nigeria, Ghana, Gambia , Liberia and Sierra Leon

[18] WAEMU refers to West African Economic and Monetary Union, set up in 1994 with the main aim of intensifying competitiveness of the economic and financial activities of the West African Economic and Monetary Union economies. They also aims at developing an open and competitive market and a harmonised legal environment. The union has the following member countries: Benin, Burkina Faso, Ivory Coast, Mali, Niger, Senegal, Togo and Guinea- Bissau.

Policy makers of commodity exporting economics, particularly small open oil exporting economies are faced with resource curse which often referred as "Dutch disease". The negative effect of Dutch disease on macroeconomic variables has become a source of concern as it destabilises the economy.

The Dutch disease theory as postulated by Corden and Neary (1982) and Corden (1984) states that countries endowed with natural resources are associated with deterioration in manufacturing sector output (de-industrialisation) due to appreciation of their domestic country's currencies. With the rise in foreign exchange earnings as a result of high commodity exports the domestic economy foreign reserves rises which in turn led to an appreciation of the exchange rate.

Numerous studies were carried out using the data of these economies to ascertain the depth of such effect on their respective countries. Several studies were conducted to evaluate the efficacy of different intervention policies across different regimes (boom and normal) that can counteract, minimise or even insulate the economy from the negative effect of the Dutch disease. Some noticeable literature that analyses the effect of Dutch disease in their economies using different methodologies include: Sosunov and Zamulin (2007) (Acosta et al. 2009) .

(Lama and Medina 2012) established a New Keynesian small open economy model of the Canadian economy with nominal rigidities and learning by doing externality in the tradable sector. They assess the effects of stabilising exchange rate in response to Dutch disease. Their results showed that exchange rate intervention could not mitigate the effect of the Dutch disease but rather increases the volatility in macroeconomic variables. However, they found that monetary policy could be an essential instrument that can be applied to prevent an inefficient outcome from the tradeable sector during the Dutch disease period.

Benkhodja (2014) modelled the Dutch disease syndrome for Algeria using a DSGE multisector small open economy with nominal and real rigidities. The result of his calibration reveals that the effect of Dutch disease syndrome occurs after spending and resource movement in both; flexible prices and wage during wind fall and boom regime, and flexible wages and sticky prices during fixed exchange rate. He argued for flexible exchange rate regime to avoid Dutch disease syndrome.

(Mahmud 2009) investigates the effects of oil price shocks on monetary aggregate of Nigeria. His findings reveal that the oil price shock negatively impacts on number of macroeconomic variables which in turn create higher government expenditure and increased inflation rate. The study suggest that monetary policy makers need to tighten more during the period of positive oil price shock as the fiscal sector is outside the purview of monetary policy makers.

2.1.4 Nigeria

The literature on Small Open Economy DSGE model for Nigeria is increasing, mainly due to the recognition that the monetary policy could be better analysed using DSGE models.[19]   Literature on business cycle model for Nigeria are quite few, though there could be some preliminary work, or unpublished work on the subject matter. However, in this thesis only published work are referenced. Among the pioneer literature on small open economy DSGE model for policy analysis using Nigeria data include (Alege 2009; Batté et al. 2009; Edun 2013; Richard and Olofin 2013).

Alege (2009) developed a DSGE model for Nigeria to examine the sources of business cycle fluctuation in Nigeria and uses the model for policy analysis. He considers the effects of monetary supply shocks, technology shock and export supply shock on some monetary aggregates. His estimates indicate that the Nigerian business cycle is driven by both real and nominal shocks.

Olayeni (2009) set-up a small open economy DSGE model for Nigeria using bayesian approach, he examined the effect of policy shock, foreign inflation shock, terms of trade shock, foreign inflation shock and technology shock on the economy. His results show that monetary authority react to cycle but with small emphasise on the exchange rate behaviour in reaction to cycles which lead to overshooting and persistence of exchange rate. Hence, he argued that to the monetary policy makers should pursue guided exchange rate policy in a period of cycle in Nigeria.

Mordi (2013) A New Keynesian DSGE model for Nigeria covering the period 1985 – 2009 was specified and estimated using Bayesian method of estimation. The findings of the study reveal the following: firstly, high persistence of household's consumption in Nigeria as the estimated value of consumption persistence was high. Secondly, high price spell in Nigeria as firms change their prices every two quarter. Thirdly, the pass-through to prices was 25 percent per quarter and finally the cost of disinflation was estimated to be 1.32 was also very high.

Edun (2013)   calibrated DSGE model for Nigeria using Bayesian method, he analyses sources of business cycle fluctuations and evaluate the impact of the shocks to some economic variables. His findings show that there is no strong link between the export sector and rest of the economy.

The above   studies carried out using DSGE on Nigeria data used Bayesian method and did not consider oil in their work, except the DSGE model of the Research Department Central Bank of Nigeria consider oil in the modelling, however, oil was not treated as a separate sector in that model.

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[19] There are quite few DSGE models that are developed for Nigeria, but unfortunately they are either not pub are not published work because they are inconclusive and some attempt to estimate DSGE model of monetary policy for Nigeria is at advanced stage.

Therefore, this thesis improves on the existing literature on Nigeria by including oil sector in the firm sector of the model through disaggregating tradable sector into oil and non-oil tradable sectors to enable sectoral analysis of the impact of sectoral shocks on macroeconomic indicators of the economy. Secondly, in this work I applied indirect inference method of estimation and testing a joint fit of a model, detailed explanation and steps in carrying out estimation using Indirect inference is has been presented in chapter 4. Finally, this work used non-stationary data to avoid distorting the behaviour of the series in the process of differencing or filtering the data. Filtering the data could yield misleading results on the interactions of variables of interest and impact of policy. In addition, using the non-stationary data would provide a better description of the behaviour of all the variables. This is even more important when estimating a model for oil exporting economies where it is quite volatile due to the exogenous nature of the variables.

Following Meenagh et al. (2010) and extending the model to include some peculiarities of Nigerian economy, namely oil sector dependent economy as presented in the section one, above. This thesis has developed a multi-sector small open economy DSGE model for Nigeria.

The model developed in this thesis is adopted from Meenagh et al (2010) and extended to multi-sector model, Nigerian economy is an open economy though not developed like UK, however, being an open economy the model has been extended to capture some idiosyncratic features of the Nigerian economy by including tradeable oil sector in the production side of the firms. Specifically, the inclusion of oil as a separate sector aimed at enhancing our understanding of the responses of the economy to productivity shocks from different sectors of the economy.

2.2 Closing the Model

Closing a model requires stationarity condition be satisfied, considering that the steady state value is needed to solve the model and obtain the approximation solution. In this section I present alternative methods for inducing stationarity in small open economy models as discussed in Schmitt-Grohe and Uribe (2003).

Non-stationarity in small open economies arises mainly from three features namely; an exogenous subjective discount factor, an exogenous cost of borrowing in international market and incomplete asset markets. Different approaches are applied in inducing stationarity arising from any of the above stated sources. Schmitt-Grohe and Uribe identified approaches to inducing stationarity in small open economy models. The predicted business cycle of small open economy is not affected by the choice of different method of inducing stationarity, thus, irrespective of the approach applied

the outcome is similar. These approaches include: External Debt Elastic Interest Rate (EDEIR); Portfolio Adjustment Cost (PAC); Internal Debt Elastic Interest rate (IDEIR); Complete Assets Markets (CAM); Perpetual Youth Model (PYM) and Internal Discount Factor (IDF).

2.2.1 External Debt Elastic Interest Rate (EDEI)

This approach solves the non-stationary problem that emanates from the model's assumption that representative household in the home country obtain external debt at exogenous determined risk-free interest rate. Meanwhile, the household is faced with additional cost for borrowing or saving in international financial markets (due to the continuous evolvement of foreign debt). He pays higher interest rate above the prevailing world interest rate whenever he borrows, likewise, he receives interest that is lower than the prevailing saving interest rate whenever he saved. The premium he paid above the prevailing rate depend on the net level of his debt, hence, this debt premium increases with the level of indebtedness of the economy.

This method is assumed to induce stationarity of net foreign assets in the model as proposed by Schmitt-Grohe and Uribe $r_t^f = r^{\bar{f}} + \varphi\left(e^{\left(b_t^f - b^{\bar{f}}\right)} - 1\right)$.

Where r_t^f and $r^{\bar{f}}$ denotes foreign interest rate its steady state value.

With the domestic economy debt premium written as:

$$prem_t = \varphi\left(e^{\left(b_t^f - b^{\bar{f}}\right)} - 1\right),$$

Where φ and $b^{\bar{f}}$ are constant parameters with $b^{\bar{f}}$ being the steady state value of b_t^f.

2.2.2 Complete Asset Markets (CAM)

One of the important features of small open economy models is the assumption of incomplete asset markets where representative household have access to single financial assets that pays a non-state-contingent returns. In the standard small open economy household smoothen his consumption over time by saving in risk free assets, however, it does not enable him to smoothen across states. Under complete asset market model, the representative households smoothen his consumption across different states over time. To induce stationarity, this approach advocate for state-contingent asset return through replacing the assumption of incomplete asset market with that of complete asset market, which enable risk diversification and remove the endogenous random walk problem inherent in the incomplete model. Hence, the equilibrium condition of complete model as presented in by Schmitt-Grohe and Uribe (2003 p.7) is given by $U_c(c_t, h_t) = \psi_{cam}$. This equilibrium

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condition states that in the absence of external risks, domestic representative household can achieve marginal utility of consumption at all times under different contingencies. Where ψ_{cam} stochastic capturing the effect of external shock is, U_c, c_t, h_t represents Utility, Consumption and labour respectively.

2.2.3. Internal Discount Factor (IDF)

The IDF model of inducing stationarity assumes that that the subjective discount factor depends on household's level of consumption and hour worked instead of the average levels. While the EDF model depends on the average levels. The author further argued that the steady state of IDF economy is similar to that of EDF, however, the IDF model includes additional $-\eta_t$ which represent expected present discounted value of utility from period $t + 1$ onward) variable that did not feature in the EDF model .

2.2.4 Perpetual Youth Model (PYM)

PYM model is an approach of inducing stationarity in small open economy models which originates from the work of Blanchard (1985). The model assumes finite lives to attain stationarity in aggregate net foreign asset position. This assumption means that the accumulated debt of the deceased household would not be repaid, because it is a small proportion of the aggregate debt and it is deterministic as well. The work of (Cardia 1991) pointed out that stationarity could be attained by creating a wedge between the world interest rate and subjected discount factor. Uribe (2006)Uribe (2016) extends the model of Cardia (1991) by incorporating preference specification. The model also placed a premium above the prevailing interest rate. This premium is meant to cover the expected unrepaid debt.

2.2.5 Portfolio Adjustment Costs (PAC)

PAC is a model of inducing stationarity, the model assumes that households faced convex costs of holding assets different from long term level. This approach is similar to EDEIR model in terms of treatment of preference and technology. However, small open economy model with PAC is different from the EDEIR as it incorporates additional term in household's budget constrain. The role of the term is to serve as adjustment costs in the model. The interest rate on external debt determined exogenously.

2.2.6 Internal Debt Elastic Interest Rate (IDEIR)

This approach induces stationarity in similar manner with the method of (EDEIR), however, the main difference between the two approaches is that, under IDEIR the interest rate premium depends

on the household's individual debt position and thus, household internalise the effect that his borrowing decisions have on the rate of interest that he has to pay. While the EDEIR assumes that the premium depends on cross sectional average level of debt, and therefore take the country premium as exogenously given. The IDEIR model is presented as follows:

$$r_t = r^* + p(d_t)$$

Under this approach, $p(d_t)$ is the household's specific interest rate premium. In contrast with the EDEIR, that assume that specified r^* as the world interest rate and r_t is real interest rate.

2.2.7 Why the Choice of EDEIR Approach in closing the model

Following the work of (Lubik 2007) and (Seoane 2015) the choice of a particular method is highly significant as it affect the final results of the estimation, for instance, (Lubik, 2005) pointed out that, stable equilibrium exists under the EDEIR and IDEIR approaches, only if the parameter values meet some certain conditions. Simeon (2015 p.37-38) revealed that the model's results is affected when the model is calibrated on emerging market data. This is contrary the submission of Schmitt-Grohé and Uribe (2012) who postulates that all these approaches for inducing stationarity generates identical impulse response functions to a productivity shock and similar second moment predictions. Except, method of complete assets markets where the variance for consumption is relatively lower. The author argued that EDEIR generates better results compared to all the methods, for example with the deterministic model the method does not suggest a negative interest rates premium unlike IDEIR method that consider such. The testing of the model is easier done with EDEIR than be conducted by IDF and other methods. The Schmitt Grohe (2003) method of closing models have some certain draw backs, in addition to the challenges in respect to the results obtained using the method. Some of these problems include ignoring the risk aspect of the method.

3. A Small Open Economy Multisector RBC Model

This chapter presents multisector small open economy dynamic stochastic general equilibrium (DSGE) model without nominal rigidity for oil exporting economy. The model is based on open economy real business cycle model adapted from Meenagh (2010) which builds on the work of Chari et al. (2002), it is extended to capture multi-sectoral features of the Nigerian economy as in Santacreu (2005). It is assumed that each sector of the economy is faced with specific productivity shock. Modelling the economy in this form is important particularly as the Nigerian economy is characterised with large oil sector that co-exists with relatively large non-tradeable sector, hence the model would investigate the effect of respective productivity shocks on these various sectors of the economy. A stationarity of Net Foreign Assets (NFA) was imposed in the model using external debt elastic interest rate Schmitt-Grohé and Uribe (2003).

The remaining part of this chapter is organised as follows; the model is presented in (3.2), calibration and impulse response (3.3) and conclusion in (3.4) respectively.

3.1 The model

The model consists of home economy populated by identical infinitely living agents who produce output and use it for both consumption and investment purposes. The economy coexists with another, foreign economy (the rest of the world) where equivalent choices are made. The international prices, foreign interest rate and foreign demand and other variables of foreign economy are unaffected by development in home economy because these variables of the latter economy are assumed to be insignificant to affect the variables of the former.

 The model assumes a perfect competitive market of final goods with consumers having to choose between home goods and foreign goods but with some high degree of biasedness towards home goods.

The model comprises of a representative firm that seek to maximise present and future values of its profits by producing under perfectly competitive final goods market and a representative consumer that maximises his utility from consumption and leisure subject to budget and time constraints. The firm produces tradeable goods, namely, tradeable oil good and tradeable non-oil good. It also produces non-tradeable goods (domestic goods). All these three sectors of production require hiring labour, capital and land to produce their goods accordingly.

3. 1.1 Representative Household

A representative household chooses the commodity bundle for consumption (C_t) and investment. C_t , is a composite good that comprises up of domestic consumption (C_t^d) and a consumption of imported goods, (C_t^f). Agent also choses the total amount of leisure ($1 - N_t$) needed to maximise her utility. The household's consumption function may be expressed as follows:

$$U = MaxE_0\left[\sum_{t=0}^{\infty} \beta^t u(C_t, 1 - N_t)\right] \qquad 0 < \beta < 1 \tag{3.1}$$

Where E_0 expectations operator, β is the discount factor of representative household, C_t is consumption in period `t', $1 - N_t$ is the amount of leisure time in period 't'.

It is assume that a representative household has the following time-separable utility function as in (McCallum and Nelson 1999), this specification is often used in open economy literature.

$$U(C_t, 1 - N_t) = \theta_o (1 - \rho_o)^{-1}\gamma_t C_t^{(1-\rho_0)} + (1 - \theta_o)(1 - \rho_2)^{-1}\zeta_t(1 - N_t)^{(1-\rho_2)} \tag{3.2}$$

Where θ_o is the preference bias for consumption ρ_o and ρ_2 are Arrow-Pratt coefficients of relative risks aversion for consumption and leisure and γ_t, ζ_t are preference errors. The total time is normalised to one where the representative household divide his time between enjoying leisure time ($1 - N_t$) , and N_t time spent on employment (exchange of real wage).

$$N_t + (1 - N_t) = 1 \tag{3.3}$$

All the three sectors in this economy use labour inputs, hence the aggregate labour is normalised to unity as follows:

$$N_t^O + N_t^{NO} + N_t^D = N_t \tag{3.4}$$

Where N_t^O, N_t^{NO} and N_t^D denotes labour supply to tradeable oil sector, tradeable non-oil sector, and non-tradeable sector respectively. In this model, labour is assumed movable and has equal marginal utility across sectors, thus, ensuring price equalisation in the labour market.

The representative household maximises her lifetime utility in (3.1) subject to a budget constraint of the form:

$$C_t + \frac{b_{t+1}}{1+r_t} + \frac{Q_t b_{t+1}^f}{\left(1+r_t^f\right)} + q_t S_t^p \le (w_t N_t + b_t + T_t + Q_t b_t^f + (q_t + d_t)S_t^p) \tag{3.5}$$

The left-hand side of (3.5) above reflect aggregate household's expenditure on consumption (C_t), interest on maturing domestic bond (b_{t+1}), interest on maturing foreign bond (b_{t+1}^f) and acquisition of new shares (S_t^p).

The right-hand side captures the total income earned by households in form of wage earned from the labour supplied to the firms for the hours of work ($w_t N_t$), the domestic and foreign, bonds(b_t, b_t^f) as well as dividends (d_t) earned from the household's share purchased in the previous period. Households are taxed/subsidized by a lump-sum transfers in the modelled economy it is assume that there are substantial transfers in non-cash form, basically, in terms of subsidy (education, healthcare, fuel) or taxed (for instance, through excise). The variables Q_t denote real exchange rate i.e. it measures the price of foreign goods relative to general price (Consumer Price Index) in domestic economy. $Q_t = \frac{P_t^f}{P_t} . e_t$ where e_t refers to nominal exchange rate and $, w_t = \frac{W_t}{P_t}$ such that w_t refers to the real consumer wage. All the other variables are in real terms relative general price level.

The representative household maximises the expected discounted stream of utility (equations 3.1 and 3.2) subject to the budget constraints (equations 3.3 and 3.5).

The representative household's lagrangian function is given as:

$$\mathcal{L}_0 = E_0 \sum_{t=0}^{\infty} \beta^t E_t \left\{ \theta_o (1-\rho_0)^{-1} \gamma_t C_t^{(1-\rho_0)} + (1-\theta_o)(1-\rho_2)^{-1} \zeta_t (1-N_t)^{(1-\rho_2)} - \lambda_t \left[C_t + \right. \right.$$

$$\left. \left. \frac{b_{t+1}}{1+r_t} + \frac{Q_t b_{t+1}^f}{\left(1+r_t^f\right)} + q_t S_t^p - w_t N_t - b_t - T_t - Q_t b_t^f - (q_t + d_t)S_{t-1}^p \right] \right\} \qquad (3.6)$$

The first order conditions of the with respect to $C_t, 1 - N_t, b_{t+1}, b_{t+1}^f$ and S_t^p yield the following:

$$C_t: \beta^t \gamma_t \theta_o C_t^{-\rho_0} - \lambda_t \beta^t = 0$$

$$N_t: \beta^t \zeta_t (1-\theta_o) (1-N_t)^{-\rho_2} - \lambda_t w_t = 0$$

$$b_{t+1}: -\lambda_t \beta^t + \lambda_{t+1} \beta^{t+1}(1+r_t) = 0$$

$$b_t^{f+1}: -\lambda_t \beta^t Q_t + \lambda_{t+1} \beta^{t+1} Q_{t+1}\left(1+r_t^f\right) = 0$$

$$S_t^p: \lambda_t \beta^t q_t - \lambda_{t+1} \beta^{t+1} (q_{t+1} + d_{t+1}) = 0$$

$$\lambda_t: w_t N_t + b_t + T_t + Q_t b_t^f - C_t - \frac{b_{t+1}}{1+r_t} - \frac{Q_t b_{t+1}^f}{\left(1+r_t^f\right)} + q S_t^p = 0$$

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Hence,

$$C_t: \gamma_{t\theta_o} C_t^{-\rho_0} = \lambda_t \tag{3.7}$$

$$N_t: \zeta_t (1 - \theta_o)(1 - N_t)^{-\rho_2} = \lambda_t w_t \tag{3.8}$$

$$b_{t+1}: \lambda_{t+1} \beta (1 + r_t) = \lambda_t \tag{3.9}$$

$$b_t^{f+1}: \lambda_{t+1} \beta Q_{t+1} (1 + r_t^f) = \lambda_t Q_t \tag{3.10}$$

$$S_t^p: \lambda_{t+1} \beta (q_{t+1} + d_{t+1}) = \lambda_t q_t \tag{3.11}$$

Combining first order conditions (3.7) and (3.8) gives intra-temporal condition that equates to marginal rate of substitution between consumption and leisure to their price ratio (real wage) in equation (3.12) below. The condition also indicates that high real wage will results to high labour supply and increases consumption level thereby decreasing elasticity of substitution between current and future leisure.

$$\zeta_t (1 - \theta_o)(1 - N_t)^{-\rho_2} = \gamma_{t\theta_o} C_t^{-\rho_0} w_t$$

$$\frac{(1-\theta_o)}{\theta_o} \frac{\zeta_t}{\gamma_t} \frac{(1-N_t)^{-\rho_2}}{C_t^{-\rho_0}} = w_t \tag{3.12}$$

$$\frac{C_t^{\rho_0}}{(1-N_t)^{\rho_2}} = \frac{\theta_o}{(1-\theta_o)} \frac{\gamma_t}{\zeta_t} w_t \tag{3.13}$$

Using equations (3.7) and (3.9) gives Euler equation that describes intertemporal substitution in consumption. This illustrates that $\frac{1}{(1+r_t)}$ represents the additional unit of utility from consumption in period t in terms of expected consumption utility in period t+1 discounted by time preference.

$$\beta(1 + r_{t+1}) = \frac{\gamma_{t\theta_o} C_t^{-\rho_0}}{\gamma_{t+1\,\theta_o} C_{t+1}^{-\rho_0}}$$

$$\beta(1 + r_{t+1}) = E_t \frac{\gamma_t C_t^{-\rho_0}}{\gamma_{t+1} C_{t+1}^{-\rho_0}}, \text{ this can be re-written as follows:}$$

$$\frac{1}{(1+r_t)} \gamma_t C_t^{-\rho_0} = \beta E_t (\gamma_{t+1} C_{t+1}^{-\rho_0}) \tag{3.14}$$

Likewise, combining equations (3.9) and (3.10) gives the Real Uncovered Interest Rate Parity (RUIP) in equation (3.15). The RUIP condition depicts positive relationship between expected future exchange rates and current domestic interest rates, as the former increases it triggers an increase in the later. The equation also means that the real interest rate differentials is equal to the

expected change in the real exchange rate, since there is no restriction in the movement of the money into global financial markets in bonds. Nonetheless, we assume presence of barriers in the market for equity investment and such that market is incomplete.

$$(1 + r_{t+1}) = E_t \frac{Q_{t+1}}{Q_t}(1 + r_t^f) \tag{3.15}$$

Substituting (3.9) in (3.11) yields:

$$p_t = \left\{ \frac{(p_{t+1} + d_{t+1})}{(1 + r_t)} \right\} \tag{3.16}$$

Using the arbitrage condition and by forward substitution the above yields

$$p_t = E_t \sum_{i=1}^{\infty} \frac{d_{t+i}}{(1+r)^i} \tag{3.17}$$

Equation (3.17) above states that the present value of a share is simply discounted future dividends.

In this model final consumption (C_t) good is assumes to be a composite of both domestic and imported goods that are combined using Armington CES aggregator (Armington 1969), which is presented as follows:

$$C_t = \left[\vartheta \left(C_t^d \right)^{-\rho} + (1 - \vartheta) \varsigma_t \left(C_t^f \right)^{-\rho} \right]^{\left(\frac{-1}{\rho} \right)} \tag{3.18}$$

Where C_t^d and C_t^f denotes consumption of domestic and imported goods, ϑ and

$(1 - \vartheta)$ represent the weight attached to consumption of domestic and imported goods, hence, in this model it is assumed that household have biased towards consumption of domestic goods.

$\sigma = \frac{1}{1+\rho}$ measures the elasticity of substitution between domestic and imported goods (intra-temporal substitution in consumption between home and imported goods respectively). Parameter ς_t is a stochastic shock to demand for imports.

$$C_t = p_t^d C_t^d + Q_t C_t^f \tag{3.19}$$

$$\mathcal{L} = \left[\vartheta \left(C_t^d \right)^{-\rho} + (1 - \vartheta) \varsigma_t \left(C_t^f \right)^{-\rho} \right]^{\frac{-1}{\rho}} + \mu (C_t - p_t^d C_t^d - Q_t C_t^f) \tag{3.20}$$

Substituting $\left[\vartheta \left(C_t^d \right)^{-\rho} + (1 - \vartheta) \varsigma_t \left(C_t^f \right)^{-\rho} \right]^{\frac{-1}{\rho} - 1} + \left[(--)^{\frac{1}{\rho}} \right]^{(1+\rho)} = C_t^{(1+\rho)}$

Gives the following first order conditions:

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$$C_t^d : 0 = \vartheta C_t^{(1+\rho)} \left(C_t^d \right)^{-(1+\rho)} - \mu p_t^d \tag{3.21}$$

$$C_t^f : 0 = (1 - \vartheta) \varsigma_t C_t^{(1+\rho)} \left(C_t^f \right)^{(1+\rho)} - \mu Q_t \tag{3.22}$$

$$\mu : 0 = C_t + p_t^d C_t^d + Q_t C_t^f \tag{3.23}$$

Considering $\mu = 1$, if constraints bind. Thus, the relative demand for the imported goods is given as:

$$\frac{C_t^f}{C_t} = [\,(1 - \vartheta)\varsigma_t]^\sigma (Q_t)^{-\sigma} \tag{3.24}$$

The demand for domestic goods is presented as follows:

$$\frac{C_t^d}{C_t} = \left(\frac{\vartheta}{p_t^d} \right)^{(\sigma)} \tag{3.25}$$

Q is re-written as $\quad lnq = -\frac{1}{G}(lny_t^d - \psi \, lny_t) + \varepsilon_{q,t} \tag{3.26}$

3.1.2 Open Economy Consumption Relations and Clearing Conditions

In open economy models the relationship between domestic economy and rest of the world is in twofold, firstly, through consumption relation and secondly, based on the assumption of international risk sharing where representative agent have access to internationally traded securities through international financial markets.

In her quest to smoothen her consumption pattern the representative agent, consider a choice of consumption between domestic and foreign goods in her consumption demand basket.

Equation (3.24) that shows the demand for traded (foreign) goods by home residents as:

$$C_t^f = [\,(1 - \vartheta)\varsigma_t]^\sigma (Q_t)^{-\sigma} C_t$$

Thus, $im_t = [\,(1 - \vartheta)\varsigma_t]^\sigma (Q_t)^{-\sigma} C_t \tag{3.26}$

Hence, the corresponding equation for the supply of domestic traded goods (exports) relative to aggregate foreign consumption is as follows:

$$C_t^{f*} = (1 - \vartheta^F)\varsigma_t^*)^{\sigma^F} (Q_t^*)^{-\sigma^F} C_t^*$$

$$ex_t = (1 - \vartheta^F)\varsigma_t^*)^{\sigma^F} (Q_t^*)^{-\sigma^F} C_t^* \tag{3.27}$$

Where $*$, ϑ^F and σ^F denotes foreign variables, foreign equivalent to home bias parameter and the elasticity of substitution between home (domestic) and foreign goods.

In this model, the assumption of free capital flow holds therefore the sum of current account and capital account must be zero[20]. Thus, at any point in time balance of payments holds.

$$bp_t = curt + cap$$

Hence, $bp_t = 0$

Where $bp_t, curt$ and cap denote balance of payments, current account and capital account respectively.

Therefore, the net savings in period t requires the economy to have a trade surplus.

In other words, foreign bonds evolve during the period to satisfy balance of payments constraint as shown below.

$$\Delta b_{t+1}^f = r_t^f b_t^f + \frac{p_t^d ex_t}{Q_t} - im_t \tag{3.28}$$

Equation (3.28) above signifies that the domestic economy accumulates new debt to settle the interest due and the trade balance deficit. To overcome the problem of non-stationarity in this model (due to the continuous evolvement of foreign debt) external debt elastic interest rate is assumed to induce stationarity of the model as proposed by Schmitt-Grohe and Uribe (2003). Under this approach, it is also assumed that households are faced with additional cost for borrowing or saving in international financial markets. They pay higher interest rate above the prevailing world interest rate whenever they borrow likewise, they receive interest that is lower than the prevailing saving interest rate whenever they save. The level debt premium increases with the level of indebtedness of the economy.

$$r_t^f = r^{\bar{f}} + \varphi\left(e^{\left(b_t^f - b^{\bar{f}}\right)} - 1\right) \tag{3.29}$$

With the domestic economy debt premium written as:

$prem_t = \varphi\left(e^{\left(b_t^f - b^{\bar{f}}\right)} - 1\right)$, where φ and $b^{\bar{f}}$ are constant parameters with $b^{\bar{f}}$ being the steady state value of b_t^f.

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[20] It is assumed that any increase in the real net exports cum returns from foreign assets (rise in current account surplus) would be neutralised by decrease in the net foreign asset (fall in capital account).

3.1.3 The Representative Firm

The representative firm rents labour, capital inputs and land to produce homogeneous consumption goods (traded and non-traded) using a production technology that is based on constant returns to scale with diminishing marginal products of labour, capital and land. Conversely, households and government purchase these consumption goods from the firm. The production technology used is based on simple Cobb-Douglas production function described as follows:

$$Y_t^i = Z_t^i N_t^{i\alpha^i} K_t^{i\gamma^i} L_t^{1-\alpha^i-\gamma^i} \tag{3.30}$$

Where Y_t^i is aggregate output per capita, Z_t^i represent state of technology at time t, K_t^i is capital carried over from previous period $(t-1)$, N_t^i is the labour inputs required by the firm and L_t^i is the land used in the production. Where $'i'$, denotes tradeable oil sector (O), tradeable non-oil sector (NO), and non-tradeable (domestic) sector (D) also, $0 \leq \alpha, \gamma \leq 1$.

It is assumed that the chosen production technology $f(N, K, L)$ is smooth and concave and it satisfies the usual smoothness conditions. The capital evolves according to the following capital accumulation equation:

$$K_t = I_t + (1-\delta)K_{t-1} \tag{3.31}$$

Where δ is the depreciation rate and I_t is gross investment.

Therefore, the firm's profit function includes total cost of capital, labour and land inputs (for all the sectors). Hence, the profit function is given as:

$$\pi_t^i = P_t^i Y_t^i - K_t^i(r_t + \delta^i + k_t^i) - N_t^i(w_t^i + \chi_t) - L_t^i(s_t^i + \varsigma) \tag{3.32}$$

where k_t, χ_t and ς_t capture the impact of regulations on firm's use of capital, labour and land respectively. The quadratic adjustment costs take the following form, $0.5\xi(\Delta K_{t+j})^2$ where ξ denotes the adjustment costs parameter. Thus, the representative firm maximises the present discounted stream, V, of cash flows after the corporation tax (τ_t, assumed to be set at any time t, to be constant over the future) subject to the constant-returns-to-scale production technology and quadratic adjustment costs for capital.

$$\mathcal{L}_0 = E_t \sum_{t=0}^{\infty} d^t E^t \left[P_t^i Y_t^i - K_t^i(r_t + \delta^i + k_t^i) - \frac{1}{2}\xi(\Delta k_t^i)^2 - N_t^i(w_t^i + \chi_t) - L_t^i(s_t^i + \varsigma) \right]$$
(3.33)

From equation (3.32) above r_t, w_t^{i21}, and s_t^i denotes rental rate of capital, labour inputs and land usage by firms. Price (P_t) represents sectoral output prices i.e. tradeable oil sector output price (P_t^O), tradeable non-oil sector output price (P_t^{NO}) and non-tradeable sector output price (P_t^D) relative to the general price level.

The model assumes that the firm's marginal products are equal to the price per unit of inputs, as the firm's decision on choice of labour and capital and use of land is optimal. The first order conditions are:

$$N_t: \frac{\alpha P_t Y_t}{N_t} - (w_t + \chi_t) = 0 \tag{3.34}$$

$$K_t: \frac{\gamma P_t Y_t}{K_t} - (r_t + \delta + k_t) - \xi(K_t - K_{t-1}) + \xi d(E_t K_{t+1} - K_t) = 0 \tag{3.35}$$

$$L_t: \frac{(1-\alpha-\gamma) P_t Y_t}{L_t} - (s_t + \varsigma_t) = 0 \tag{3.36}$$

3.1.4 Tradeable and Non-tradeable Sectors

In this section, I model the three sectors and specify it as in Corden and Neary (1982), Corden (1984), Mendoza (1991) and Benkhodja (2014). The three sectors that made up of the economy are: oil sector tradable, non-oil sector tradable and non-tradable sector (domestic sector). It is assumed that the factors are mobile across the sectors. Hence, disaggregating the production process in to the three respective sectors (O, NO, and D) are presented in subsection (3.37) – (3.57).

3.1.5 Tradeable Oil Sector Firm

Tradeable oil sector firm produces oil, which is assumed to be traded, the output prices in this sector (oil price) and the cost of inputs required in the production (capital, labour and land) are exogenously determined[22].

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[21] The w_t in the representative firm denotes the real cost of labour to firm and it is specified as nominal wage relative to the unit value of domestic output produced, P_t^D. Conversely, the real wage in the consumer problem is the nominal wage relative to the general price level, P_t. this wedge between the two wages is based on the assumption that domestically produced goods are valued at the home price level and not on the general price level, Minford, P. and Brech, M. 2015. 15. THE WAGE EQUATION AND RATIONAL EXPECTATIONS. *Macroeconomic Analysis: Essays in Macroeconomics and Econometrics* 5, p. 434.

[22] Problem Oil firms operate in Nigeria under Joint Venture Agreement and Memorandum of Understanding (MOU) between the Federal Government of Nigerian represented by the Nigerian National Petroleum Company and Operation Companies (Shell BP, Mobil, Agip, Chevron, and ELF among others).

The production and costs of oil exploration are shared based on the Contract Sharing Agreement, the firms pay Nigerian Government tax, and royalties. Both prices of oil and inputs are exogenously determined.

Both prices of inputs and outputs of these firms are set exogenously by the international market, hence, there is no monopoly power. We assume that in addition to the regulations faced by the oil firms, they are subject to other shocks, thus, error term is maintained.

The return of oil is given by the rate of increase of real oil prices as in hoteling, this must (worldwide) equal the real rate of interest. In principle, oil can be treated as an investment asset with the same yield by producing more of it at present time and investing it, yet, production is constrained by the marginal opportunity cost of investment in domestic (non-traded sector).

$$Y_t^o = Z_t^o N_t^{\alpha^o} K_t^{\gamma^o} L_t^{1-\alpha^o-\gamma^o} \tag{3.37}$$

Where Y_t^o denotes tradeable oil sector output, Z_t^o represent state of technology for oil sector at time t, K_t^O is oil sector capital demand carried over from previous period $(t-1)$, N_t^O is the oil sector labour inputs demand by the firm and L_t^O is the land used in the production.

$$0 \leq \alpha, \gamma \leq 1,$$

$$\mathcal{L}_0 = E_t \sum_{t=0}^{\infty} d^t E^t \left[P_t^O Y_t^O - K_t^O (r_t + \delta^O + k_t^O) - \frac{1}{2} \xi (\Delta k_t^O)^2 - N_t^O (w_t + \chi_t) - L_t^o (s_t + \varsigma) \right]$$

$$N_t^O : \frac{\alpha^O P_t^O Y_t^O}{(w_t^O + \chi_t)} = 0 \tag{3.38}$$

$$L_t^O : \frac{(1-\alpha^O-\gamma^O) P_t^O Y_t^O}{(s_t^O + \varsigma_t)} = 0 \tag{3.39}$$

$$K_t^O : \frac{\gamma P_t^O{}_t Y_t^O}{k_t^O} - (r_t + \delta + k_t^O) - \xi (K_t^O - K_t^O) + \xi d (E_t K_{t+1}^O - K_t^O) = 0 \tag{3.40}$$

The above equation (3.38) could be rearranged to give tradeable oil sector labour demand as follows: $N_t^O = \frac{\alpha^O P_t^O Y_t^O}{(w_t^O + \chi_t)}$ $\tag{3.41}$

Rearranging the first order condition with respect to capital in equation (3.40) yields to a non-linear demand for capital in the oil sector as:

$$K_t^O = \frac{1}{1+d} K_{t-1}^O + \frac{d}{1+d} E_t K_{t+1}^O + \frac{\gamma}{\xi(1+d)} \left(\frac{Y_t^O}{K_t^O}\right) - \frac{1}{\xi(1+d)} (r_t + \delta) - \frac{1}{\xi(1+d)} k_t^O \tag{3.42}$$

Rearranging equation (3.39) gives tradeable oil sector land demand as:

$$L_t^O = \frac{(1-\alpha^O-\gamma^O) P_t^O Y_t^O}{(s_t^O + \varsigma)} \tag{3.43}$$

The model assumed that the oil sector land demand responds to the cycle as the land rent increases at boom thereby limiting the expansion of non-tradeable sector.

3.1.6 Tradeable Non-oil Sector Firm

Tradeable non-oil firm similarly with the tradeable oil sector firm, it produces traded goods and the prices of these goods are exogenously determined on world markets, the labour costs of firm is set by the domestic labour supply while the costs of capital are set by international conditions. This firm have no monopoly power on the price of its output and input (cost of capital labour and land) respectively.

$$\mathcal{L}_0 = E_t \sum_{t=0}^{\infty} d^t E^t \left[P_t^{NO} Y_t^{NO} - K_t^{NO}(r_t + \delta^{NO} + k_t^{NO}) - \frac{1}{2}\xi(\Delta k_t^{NO})^2 - N_t^{NO}(W_t^{NO} + \chi_t) - L_t^o(s_t + \varsigma) \right]$$

$$Y_t^{NO} = Z_t^{NO} N_t^{\alpha^{NO}} K_t^{\gamma^{NO}} L_t^{1-\alpha^{NO}-\gamma^{NO}} \tag{3.44}$$

Where Y_t^{NO} denotes tradeable non-oil sector output, Z_t^{NO} represent state of technology for non-oil sector at time t, $K_t^{\gamma^{NO}}$ denotes non-oil sector capital demand carried over from previous period $(t-1)$, N_t^{NO} is the non-oil sector labour inputs demand by the firm and L_t^{NO} is the land used in the production. $0 \leq \alpha, \gamma \leq 1$,

$$N_t^{NO}: \frac{\alpha^{NO} P_t^{NO} Y_t^{NO}}{(w_t^{NO}+x_t)} = 0 \tag{3.45}$$

$$L_t^{NO}: \frac{(1-\alpha^{NO}-\gamma^{NO})P_t^{NO}Y_t^{NO}}{(s_t^{NO}+\varsigma_t)} = 0 \tag{3.46}$$

$$K_t^{NO}: \frac{\gamma P_t^{NO}{}_t Y_t^{NO}}{K_t^{NO}} - (r_t + \delta + k_t) - \xi(K_t^{NO} - K_t^{NO}) + \xi d(E_t K_{t+1}^{NO} - K_t^{NO}) = 0 \tag{3.47}$$

Rearranging the above equation (3.45) gives tradeable non-oil sector labour demand as follows:

$$N_t^{NO} = \frac{\alpha^{NO} P_t^{NO} Y_t^{NO}}{(w_t^{NO}+x_t)} \tag{3.48}$$

Rearranging the first order condition with respect to capital in equation (3.47) yields to a non-linear demand for capital in the non-oil sector as:

$$K_t^{NO} = \frac{1}{1+d} K_{t-1}^{NO} + \frac{d}{1+d} E_t K_{t+1}^{NO} + \frac{\gamma}{\xi(1+d)} \left(\frac{Y_t^{NO}}{K_t^{NO}}\right) - \frac{1}{\xi(1+d)} (r_t + \delta) - \frac{1}{\xi(1+d)} k_t^{NO} \tag{3.49}$$

Rearranging equation (3.46) gives tradeable non-oil sector land demand as:

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$$L_t^{NO} = \frac{(1-\alpha^{NO}-\gamma^{NO})P_t^{NO}Y_t^{NO}}{(s_t^{NO}+\varsigma)} \tag{3.50}$$

Note: the model assumes that labour is movable across sectors with same wage.

3.1.7 Non-tradeable Sector (Domestic Sector)

The non-tradeable sector output is assumed to produce output that is entirely consumed domestically, also government owns all land, and the domestic sector is simply competitive sector[23].

$$\mathcal{L}_0 = E_t \sum_{t=0}^{\infty} d^t E^t \left[P_t^D Y_t^D - K_t^D(r_t + \delta^D + k_t^D) - \frac{1}{2}\xi(\Delta k_t^D)^2 - N_t^D(W_t^D + \chi_t) - L_t^D(s_t + \varsigma) \right]$$

$$Y_t^d = Z_t^d N_t^{\alpha^d} K_t^{\gamma^d} L_t^{1-\alpha^d-\gamma^d} \tag{3.51}$$

Where Y_t^D denotes non-tradeable sector output, Z_t^D represent state of technology for non-tradeable sector at time t, $K_t^{\gamma^D}$ denotes non-tradeable sector capital demand carried over from previous period$(t-1)$, N_t^D is the non-tradeable sector labour inputs demand by the firm and L_t^D is the land used in the production. $0 \leq \alpha^d, \gamma^d \leq 1$

$$N_t^D : \frac{\alpha^D P_t^D Y_t^D}{(w_t^D+\chi_t^D)} = 0 \tag{3.52}$$

$$L_t^D : \frac{(1-\alpha^D-\gamma^D)P_t^D Y_t^D}{(s_t^{NO}+\varsigma_t^{NO})} = 0 \tag{3.53}$$

$$K_t^D : \frac{\gamma P_t^D Y_t^D}{K_t^D} - (r_t + \delta + k_t) - \xi(K_t^D - K_t^D) + \xi d(E_t K_{t+1}^D - K_t^D) = 0 \tag{3.54}$$

The above equation (3.52) rearranged to give non-tradeable sector labour demand as follows:

$$N_t^D = \frac{\alpha^D P_t^D Y_t^D}{(w_t^D+\chi_t^D)} \tag{3.55}$$

Rearranging the first order condition with respect to capital in equation (3.54) yields to a non-linear demand for capital in the non-tradeable sector as:

$$K_t^D = \frac{1}{1+d}K_{t-1}^D + \frac{d}{1+d}E_t K_{t+1}^D + \frac{\gamma}{\xi(1+d)}\left(\frac{Y_t^O}{K_t^D}\right) - \frac{1}{\xi(1+d)}(r_t + \delta) - \frac{1}{\xi(1+d)}k_t^D \tag{3.56}$$

Rearranging equation (3.53) gives non-tradeable sector land demand as:

$$L_t^{NO} = \frac{(1-\alpha^{NO}-\gamma^{NO})P_t^{NO}Y_t^{NO}}{(s_t^{NO}+\varsigma)} \tag{3.57}$$

$$y_t^D = \psi(\, y_t) - \, G_t(q) + \varepsilon_{yd,t} \tag{3.58}$$

The market clearing for the sector Total domestic sector output equals total domestic sector demand

$$y_t^D = D^D \tag{3.58}$$

Where ψ, $\,G_t$ and D^D represent the elasticity of domestic sector output in the total aggregate sector output, elasticity of real exchange rate and domestic demand respectively.

(N is fixed by labour supply equation. And L is fixed exogenously. However, non-traded output is set as a share of total output.)

$$y_t^D = D^D = \psi(\, y_t) - \, G_t(q) + \varepsilon_{yd,t}$$

3.1.8 The Government

The government uses its revenues to finance its consumption expenditure[24] (G_t) which is assumed to be non-productive, the government generates its revenue through collecting rents (at rate s) on its land,[25] levying a tax rate on household's domestic and foreign corporate profits (in both oil and non-oil sector). It is assumed that all the remaining fiscal surplus/deficit are given to household in form of lump sum transfer (T). The government borrows, by issuing bonds (b_t) which pays return one period ahead (For instance, a bond issued in period t at a specific unit price is presented as b_{t+1} ,pays return $(1 + r_t$). Thus, the government budget constraint is given as;

$$G_t + T_t + b_t = s_t L + \frac{b_{t+1}}{1+r_t} \tag{3.59}$$

It is also assumed that the government does not directly affect household's decision, therefore government is modelled as an exogenous first order exogenous process.

$$lnG_t = \rho G lnG_{t-1} + \varepsilon_{g,t} \tag{3.60}$$

I re-introduce sectoral price equations to make price equals marginal cost as follows

$$lnp_t^o = \alpha^o lnw_t + lnr_t + (1 - \alpha^o - \gamma^o)lns_t + \varepsilon_{yo,t} \tag{3.61}$$

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[24] In this model the government expenditure is assumed to be non- productive and this is in line with the stylise fact of the Nigerian economy where these expenditure does not yield commensurate revenue to government rather it is meant for provision of welfare basically inform of social amenities. Another side of the story is that this government expenditure is not productive because of high level of corruption that is pervasive in most less developed economies Nigeria inclusive, therefore the money set aside for such government consumption expenditure ended up in personal accounts of government officials and their cronies.

[25] The government in Nigeria (G_t) owns all the land under the land use act of 1978.

$$lnp_t^{no} = \alpha^{no} lnw_t + lnr_t + (1 - \alpha^{no} - \gamma^{no}) lns_t + \varepsilon_{yno,t} \qquad (3.62)$$

$$lnp_t^{d} = \alpha^{d} lnw_t + lnr_t + (1 - \alpha^{d} - \gamma^{d}) lns_t + \varepsilon_{yd,t} \qquad (3.63)$$

Solving $w_t \ and \ s_t$ in equation (3.60 and 3.61) given that prices of oil and non-oil are exogenous yield equation (3.63 and 3.64) as follows:

$$lnw_t = \frac{\gamma^o}{\alpha^o} \, \boldsymbol{lnr_t} + \frac{(1-\alpha^o-\gamma^o)}{\alpha^o} lns_t - \frac{1}{\alpha^o} \, \boldsymbol{lnp_t^o} + \varepsilon_{yo,t} \qquad (3.64)$$

$$lns_t = \frac{\alpha^{no}}{(1-\alpha^{no}-\gamma^{no})} \, \boldsymbol{ln \ w_t} + \frac{\gamma^{no}}{(1-\alpha^{no}-\gamma^{no})} lnr_t + \frac{1}{(1-\alpha^{no}-\gamma^{no})} \, \boldsymbol{lnp_t^{no}} + \varepsilon_{yno,t} \qquad (3.65)$$

Equation 3.81 is rewritten as follows:

$$\boldsymbol{ln \ N_t} = \frac{\rho_0}{\rho_2} \boldsymbol{lnc_t} + \frac{1}{\rho^2} \left(1 - \frac{\vartheta}{\vartheta}\right) lnq + \varepsilon_{w,t} \qquad (3.66)$$

Now solving for lnL_t requires exogenous land supply equation:

$$lnL_t = \rho^L lnL_{t-1} + e_{L,t} \qquad (3.67)$$

In summary, the model works HOS trade model where exogenous world prices of oil and non-oil determine factor prices wages and land rent (w and s). Whereas real interest rate (r) is fixed by foreign interest rate and real exchange rate (rf and q) movement.

3.1.9 Market Clearing Conditions

Completing the model requires market clearing in each of the market, thus goods market-clearing condition is presented as follows;

For the non-traded sector market clearing $y_t^D = D_t^D$ from equation (3.58) and for the tradable sector comprising up of oil and non-oil sector

$$y_t^T = lnD^T \qquad (3.68)$$

$$NX_t = y_t^T - D^T \qquad (3.69)$$

$$lnY_t = lny^T + y_t^D \qquad (3.70)$$

Thus: $Y_t = D^D + y_t^T + D^T$;

Rearranging gives:

$$Y_t - y_t^T = D^D - D^T$$

Thus,

$$Y_t = C_t + I_t + G_t + NX_t$$

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Hence,

$$NX_t = Y_t - C_t + I_t + G_t \tag{3.71}$$

Where D_t^D denotes non-tradable demand.

The above equation states that the supply of the goods denoted in the left-hand side is equated to the right-hand side that covers the summation of demand for consumption, investment, government expenditure and net export. The equilibrium is attained through the relative price of foreign to domestic general prices Q_t that moves continuously to clear this market in effect through domestic inflation.

Note that, in the remaining markets the demand should be equal to supply to satisfy the Walras' law general equilibrium theory.

Hence, the movement of wage price yields labour market equilibrium,

$$N_t^S = N_t^D \tag{3.72}$$

This indicates that labour supply equals labour demand

Capital market clears as follows:

$$\Delta K_{t+1}^S = \Delta K_{t+1}^D \tag{3.73}$$

Signifying that the change in capital supply equals the change in capital demand by the movement in returns on capital.

Land market equilibrium is stated as follows

$$L_t^S = L_t^D \quad \text{Land rent set exogenously by government } (\bar{L} = e\_s) \text{ , therefore;}$$

$$\bar{L} = L \tag{3.74}$$

As discussed in the 3.32 land is an input in the production process, its market is cleared by the movement of land rent which is determine exogenously.

Balance of payment identity must hold at every period (t), therefore,

$$D_{t+1} - D_t = r_{t-1}D_t + IM_t Q_t - EX_t \tag{3.75}$$

This states that a change in foreign debt level denoted in the left-hand side is equated to the repayments of previous period's debt and net import. In other word, in this model the balance of payments consists of two components current account represented by the right-hand side of

equation (3.63) and the left-hand side external debt. As external debt increases, the current account must be in deficit to attain balance of payment and vice-versa.

3.2 Model Structural Shocks

The role of shocks is crucial to determination and analysing the dynamic response of a small open economy to various chosen shocks. Therefore, in this model sixteen shocks from both endogenous and exogenous variables are incorporated. The shocks obtained from the exogenous shocks include shocks to foreign consumption, foreign price, international oil price, land rent, foreign interest rate, price non-oil (world price), and government shock respectively. While the remaining shocks are residuals backed out of the structural model. The autoregressive nature of the shocks provides a key propagation mechanism for these shocks in this model. To include these shocks process as suggested by Box et al. (1970) autoregressive integrated moving average (ARIMA) . The model also assumes that stationary shocks variables including the structural residuals and exogenous variables assume level stationary or trend stationary written as ARIMA (1, 0, 0) form

$$\varepsilon_t^i = \mu_i + b_i\, t + \rho_i \varepsilon_{t-1}^i + \eta_{i,t} \tag{3.76}$$

Where ε_t^i, is the shock, with the superscript i representing corresponding shock equation, $\eta_{i,t}$ denotes $i.i.d.$ process with mean zero and t is the time trend, μ_i are the intercept and b_i, ρ_i denotes the coeffients of time trend and the autoregressive coefficients respectively.

Also, the model assumes the logarithmic of Solow residual, lnA_t is a random walk process with drift. Thus,

$$lnA_t = \mu_A + lnA_{t-1} + \eta_{i,T} \tag{3.78}$$

Where μ_A is a drift term that captures the long-run rate of growth of technological change; $\eta_{i,T}$ is serially uncorrelated innovation for productivity which generates serially uncorrelated behaviour in some important macroeconomic variables of the economy; capital, output and investment through the dynamic structure of the economy.

3.3 Log-linearized Model

The system of equations are log-linearized around steady state, with each equation been normalised on one of the endogenous variables. All the variables are expressed in natural logarithm except for variables that take negative values and or percentage (i.e. rf, rt). Thus, the behavioural equations describe in the model are presented below:

$$\ln c = lnc(+1) - \frac{\beta}{\rho_0} r + \varepsilon_{r,t} \tag{3.79}$$

$$\boldsymbol{r} = rf + q(+1) - q - phi\ bf(-1) \tag{3.80}$$

$$lnY_t^O = \alpha^O lnN_t^O + \gamma^O lnK_t^O + (1 - \alpha^O - \gamma^O)lnL_t^O + \varepsilon_{yo,t} \tag{3.81}$$

$$lnY_t^{NO} = \alpha^{NO} lnN_t^{NO} + \gamma^{NO} lnK_t^{NO} + (1 - \alpha^{NO} - \gamma^{NO})lnL_t^{NO} + \varepsilon_{yno,t} \tag{3.82}$$

$$lnY_t^D = \alpha^D lnN_t^D + \gamma^D lnK_t^D + (1 - \alpha^D - \gamma^D)lnL_t^D + \varepsilon_{yd,t} \tag{3.83}$$

$$lnY_t = \omega^O \ln Y_t^O + \omega^{NO} \ln Y_t^{NO} + \omega^D \ln Y_t^D \tag{3.84}$$

$$lnN_t^O = \alpha^O(lnP_t^O + lnY_t^O) - lnw_t + \varepsilon_{no,t} \tag{3.85}$$

$$lnN_t^{NO} = \alpha^{NO}(lnP_t^{NO} + lnY_t^{NO}) - lnw_t + \varepsilon_{nno,t} \tag{3.86}$$

$$lnN_t^D = \alpha^D(lnP_t^D + lnY_t^D)) - lnw_t + \varepsilon_{nd,t} \tag{3.87}$$

$$lnN_t = \left[\omega^O \frac{\alpha^O}{\delta^N}\right] lnN_t^O + \left[\omega^{NO} \frac{\alpha^{NO}}{\delta^N}\right] lnN_t^{NO} + \left[\omega^D \frac{\alpha^D}{\delta^N}\right] lnN_t^D \tag{3.88}$$

$$lnK_t^O = \xi_1^O lnK_{t-1}^O + \xi_2^O lnK_{t+1}^O + \xi_3^O(lnP_t^O + lnY_t^O) - \xi_4^O r_t + \varepsilon_{ko,t} \tag{3.89}$$

$$lnK_t^{NO} = \xi_1^{NO} lnK_{t-1}^{NO} + \xi_2^{NO} lnK_{t+1}^{NO} + \xi_3^{NO}(lnP_t^{NO} + lnY_t^{NO}) - \xi_4^{NO} r_t + \varepsilon_{kno,t} \tag{3.90}$$

$$lnK_t^D = \xi_1^D lnK_{t-1}^D + \xi_2^D lnK_{t+1}^D + \xi_3^D(lnP_t^D + lnY_t^D) - \xi_4^D r_t + \varepsilon_{kd,t} \tag{3.91}$$

$$lnK_t = \left[\omega^O \frac{\gamma^O}{\delta^K}\right] lnK_t^O + \left[\omega^{NO} \frac{\gamma^{NO}}{\delta^K}\right] lnK_t^{NO} + \left[\omega^D \frac{\gamma^D}{\delta^K}\right] lnK_t^D \tag{3.92}$$

$$lnL_t^O = (1 - \alpha^O - \gamma^O)(lnP_t^O + lnY_t^O) - lnS_t + \varepsilon_{lo,t} \tag{3.93}$$

$$lnL_t^{NO} = (1 - \alpha^{NO} - \gamma^{NO})(lnP_t^{NO} + lnY_t^{NO}) - lnS_t + \varepsilon_{lno,t} \tag{3.94}$$

$$lnL_t^D = (1 - \alpha^D - \gamma^D)(lnP_t^D + lnY_t^D) - lnS_t + \varepsilon_{ld,t} \tag{3.95}$$

$$lnL_t = \left[\omega^O \frac{(1-\alpha^O-\gamma^O)}{\delta^L}\right] lnL_t^O + \left[\omega^{NO} \frac{(1-\alpha^{NO}-\gamma^{NO})}{\delta^L}\right] lnL_t^{NO} + \left[\omega^D \frac{(1-\alpha^D-\gamma^D)}{\delta^L}\right] lnL_t^D \tag{3.96}$$

$$lnq = -\frac{1}{G} * (lnyd - psi * lny) + \varepsilon_{q,t} \tag{3.97}$$

$$lnbf(+1) = (1 + rf)ln\,bf + nex \tag{3.98}$$

Where NEX; this is net exports as fraction of GDP; bf is net private foreign assets as fraction of GDP.

$$lnp_t^d = \alpha^d lnw_t + lnr_t + (1 - \alpha^d - \gamma^d)lns_t + \varepsilon_{yd,t} \tag{3.99}$$

$$ln\,n_t = \frac{\rho_0}{\rho_2} lnc_t + \frac{1}{\rho_2}\left(1 - \frac{\vartheta}{\vartheta}\right) lnq + \varepsilon_{n,t} \tag{3.100}$$

$$lnw_t = \frac{\gamma^o}{\alpha^o} lnr_t + \frac{(1-\alpha^o-\gamma^o)}{\alpha^o} lns_t - \frac{1}{\alpha^o} lnp_t^o + \varepsilon_{w,t} \tag{3.101}$$

$$lns_t = \frac{\alpha^{no}}{(1-\alpha^{no}-\gamma^{no})} ln\,w_t + \frac{\gamma^{no}}{(1-\alpha^{no}-\gamma^{no})} lnr_t + \frac{1}{(1-\alpha^{no}-\gamma^{no})} lnp_t^{no} + \varepsilon_{s,t} \tag{3.102}$$

$$nex = lnY_t - 0.32(lnK_t + lnK_{t-1}) - 0.44lng_t - 0.79lnC_t \tag{3.103}$$

$$lng_t = \rho^G lng_{t-1} + e_{g,t} \tag{3.104}$$

$$lnP_t^f = \rho^{Pf} lnP_{t-1}^f + \varepsilon_{Pf,t} \tag{3.105}$$

$$ln\,P_t^O = \rho^{PO} lnP_{t-1}^O + \varepsilon_{pO,t} \tag{3.106}$$

$$lnS_t = \rho^S lnS_{t-1} + e_{s,t} \tag{3.107}$$

$$lnr_t^f = \rho^{r_t^f} lnr_{t-1}^f + \varepsilon_{rf,t} \tag{3.108}$$

$$ln\,P_t^{NO} = \rho^{NO} lnP_{t-1}^{NO} + \varepsilon_{PNO,t} \tag{3.109}$$

$$lnC_t^f = \rho^{C_t^f} lnc_{t-1}^f + \varepsilon_{Cf,t} \tag{3.110}$$

NB the terms omega- superscript (N, K, L) in (3, 88), (3.92) and (3.96) represent the total shares of N, K, L respectively in GDP.

Equations 3.84, 3.88, 3.92, 3.96 and 3.103 are identities (aggregate output, aggregate labour demand, aggregate capital demand, aggregate land demand and market clearing condition), while equations 3.104 – 3.110 describes the exogenous variables: government consumption demand, foreign prices, international oil price, land rent, foreign interest rates, price of non-oil goods and foreign consumption demand. All the equations are log-linearized around steady state values.

3.4 Calibration

This section presents a brief discussion on the calibration technique and describe the parameter values used in the model calibrated for Nigeria.

The introduction of calibration method into mainstream macroeconomics is traced to the work of Kydland and Prescott (1982) where they applied calibration on real business cycle model RBC instead of the conventional econometrics' methods of estimation. In their justification for choosing the calibration method, they argue that selection of the parameter values should reflect the specifications of the preferences and technology that are used in applied studies and that they should be those for values for which the model's steady state values are near the average values of the economy over the period being explained. Hence, one could have parameter values suitable to the economy or problem being examined. This implies that calibration is not only based on traditional econometric estimation applied to a single data set but also entails obtaining numerical values of parameters from extraneous sources of data including other previous studies. Cooley (1997) observed that "calibration is a strategy for finding numerical values for the parameters of artificial economic worlds", hence the method is based on economic theory to form a restricted general framework and then use the created framework into data. The wide use of calibration is also attributed to the strictness of conventional econometric estimation techniques like maximum likelihood method in evaluating macro econometric models.

Some of the earlier literature that attempt to incorporate the calibration methodology into the conventional macroeconomics include: (Manuelli and Sargent 1988; Gregory and Smith 1990; Hoover 1995; Hansen and Heckman 1996) they analyse the calibration method as a form of 'estimation by simulation'.

Generally, initial numerical values of parameters are chosen either from estimates on the existing literature on the modelled economy or from estimates on economies with a similar structure. The parameters considered in this study are mainly from empirical literature on small open developing countries with similar structures. For parameters that were not readily available, or their values were not found in any relevant literature from empirical literature of developing economies, parameter from small open developed economies that are consistent with these studies were borrowed, particularly from Meenagh et al (2010). In addition, parameters not found in any above discussed studies are estimated from the actual data. However, these parameters were used as starting coefficients for calibrating the model, therefore, a justification for the selection is not a major issue for concern.

Using quarterly Nigerian data for the period 1981 Q1 to 2016 Q4 to calibrate the model and the parameter choices are in line with the model's reasoning.

For the household side, the subjective discount factor, β , is set at 0.99 which indicates an annual steady-state real interest rate of 4% as in Bouakez et al. (2008) , Dib (2008) and Obeng-Odoom (2014), the value is line with literature on DSGE model. A lower discount value factor signifies higher preference of household for immediate rewards over delayed rewards and vice-versa.

The depreciation rate, is set at 0.025 or 2.5% per quarter as in Devereux et al. (2006) and as applied in some small open developing economy literature , notably Allegret and Benkhodja (2011).

Frisch Labour supply elasticity ρ_2 is set at 1.2, as in Meenagh et al. (2010). The coefficient denotes the elasticity of inter-temporal substitution of leisure, i.e. hours worked with respect to wages. The value of the elasticity determines the extent to which the labour hours are smoothen by the household in response to the change in the wage rate. With higher elasticity value labour is willing to smoothen and as the elasticity assumes lower value it means that the labour is less willing to smoothen his labour hours in response to the change in wages. Thus, with the choice of labour supply of a value of 1.2 signifies that the labour hours worked changed by same proportion in response to a unit change in wages.

The relative risk aversion coefficient ρ_0 is set at 1.0, this is in line with the (Gandelman and Hernández-Murillo 2015), estimates of risk aversion at the country level. Even though, out of the 80 countries that H-M reported in his work did not include Nigeria, but he suggests an average coefficient that could be applicable among developing countries to be about 1.1 while for developed countries, it was set at 0.88. This implies that higher intertemporal elasticity denotes that consumption growth is highly sensitive to variation in the real interest rate[26].

The value of preference bias for the home good, ϑ and its foreign equivalent ϑ^f are fixed at 0.7 apiece[27] by symmetry as in Meenagh et. al (2010).

For the production side, the production function is specified as in Cob-Douglas technology, thus, aggregated to unity. $Y_t^i = Z_t^i N_t^{i\propto^i} K_t^{i\gamma^i} L_t^{i-\propto^i-\gamma^i}$.

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[26] With choice of ρ_0 to 1.0 in this study implies that consumption responds by 0.93 to one unit change in interest rate i.e. $\dfrac{1}{\rho_0}$

[27] This value means that households assigns 70 per cent on home goods relative to imported goods, while that of preference of foreign goods is $1 - \vartheta$.

The share of labour in oil tradeable sector, α^O, non-oil tradeable sector, α^{nO} and domestic (non-tradeable) sector, α^d in the output production are set at 0.10, 0.30, and 0.6 0 respectively[28]. The values assigned are in line with Benkhodja (2014), and Dib (2008). The capital share in the three sectors is the production function are set at 0.4, 0.4, and 0.2 for oil tradeable, non-oil tradeable and domestic (non-tradeable) sectors accordingly[29]. Similarly, the share of oil sector capital γ^O, non-oil sector capital γ^{nO} and domestic sector capital γ^d takes the following values 0.6, 0.3 and 0.2 respectively. The values are assigned as oil sector is more capital intensive than non-oil and tradable sector.

As the capital demand in the three sectors are linearized and the log-linear difference capital demand equation are already presented above:

$$lnK_t^o = \xi_1 lnK_{t-1}^o - \xi_2 E_t lnK_{t+1}^o + \xi_3 lnY_t - \xi_4 r_t \,. \tag{3.4.1}$$

$$lnK_t^{no} = \xi_1 lnK_{t-1}^{no} - \xi_2 E_t lnK_{t+1}^{no} + \xi_3 lnY_t - \xi_4 r_t \tag{3.4.2}$$

$$lnK_t^d = \xi_1 lnK_{t-1}^d - \xi_2 E_t lnK_{t+1}^d + \xi_3 lnY_t - \xi_4 r_t \tag{3.4.3}$$

The fixed coefficients in the adjustment cost of capital in the oil sector, non oil sector and domestic sector are aggregated to 1 in each sector, and the aggregation of all the sectors also sum up to 1. These are set so that the adjustment cost of capital play no role at the steady state. Following Menagh et al (2010) the calibration is presented as for capital in all three sectors[30] as follows.

$$lnK_t^o = 0.51 \, lnK_{t-1}^o - o.\,47 E_t lnK_{t+1}^o + 0.02 lnY_t - \xi_4 r_t \,. \tag{3.4.4}$$

$$lnK_t^{no} = 0.51 \, lnK_{t-1}^{no} - 0.47 \, E_t lnK_{t+1}^{no} + 0.02 lnY_t - \xi_4 r_t \tag{3.4.5}$$

$$lnK_t^d = 0.51 \, lnK_{t-1}^d - 0.47 \, E_t lnK_{t+1}^d + 0.02 lnY_t - \xi_4 r_t \tag{3.4.6}$$

The weight attached to land inputs in all the three sectors (land oil, land non-oil and land non-tradable) reflect the balance of the weight attached to the two inputs (labour and capital) in all the three sectors. The parameter values and weight attached to each input in each sector reflect idiosyncratic feature of the Nigerian economy.

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[28] The weight of labour in non-tradeable sector production is set at about 70 percent, larger than the two sectors put together, this is due to dominance of the sector in terms of provision of jobs, where the majority of the teaming labour force are mainly engaged in some activities that are not directly associated to tradeable sectors of the economy.

[29] The weight of capital inputs is higher on the tradeable sectors (oil and non-oil), whereas, the non-tradeable sector capital inputs is quite low as the sector is more of labour intensive in the Nigerian economy.

[30] The capital demand equation is linearized around the moving state of K and Y. where ξ_i = is a fixed coefficient for adjustment cost.

Aggregate output is made up of oil sector output, non-oil sector output and non-tradable (domestic) sector output respectively. The summation of their weights equals to a value of unity (1).

$$lnY_t = \omega^O \ln Y_t^O + \omega^{NO} \ln Y_t^{NO} + \omega^D \ln Y_t^D \qquad (3.4.7)$$

The weight attached to oil output , ω_t^O , non-oil output, ω_t^{nO} and domestic output ω_t^d as a ratio of the aggregate output are 0.3, 0.2, and 0.5 respectively, The assinment of the weights are based on authors computation compiled from various Central Bank of Nigeria (Statistics Department,2017) and sectorial contribution to aggregate output from the National Bureau of Statistics GDP reports (Nigeria 2018).

The premium on the world interest rate (interest elasticity of debt) φ is set as 0.00742 as in Schmitt-Grohe and Uribe (2003) , this parameter plays an important role in stationarising the model and the speed of convergence to the steady state. Considering that the parameter represents additional cost above the prevailing world interest rate that the country has to incur for additional borrowing , the Nigerian economy alike is characterised with high debt which implies that the parameter value could be higher. However, in the absence of any estimates from empirical literature for Nigeria, I adapt the value as in Schmitt-grohe and Urube (2003).

The log-linearised foreign bonds is:

$$b_{(t+1)}^f = \left(1 + r_t^f\right)b^f + (NEX) \qquad (3.4.8)$$

The above condition is calibrated from the Nigerian data average for the period 1981– 2016, as $\frac{IM}{Y} = 0.42, \frac{EX}{Y} = 0.53$.

The log-linearised market clearing condition is :

$$lnNX_t = \left(\frac{\bar{Y}}{NX}\right) lnY_t + \left(\frac{\bar{C}}{NX}\right) lnC_t + \left(\frac{\bar{G}}{NX}\right) lnG_t + \left(\frac{\bar{K}}{NX}\right) [lnK_t - (1 - \delta - \gamma)lnK_{t-1}] \quad (3.3.9)$$

Where the calibration of consumption net-export ratio, government expenditure net-exports ratio are based on Nigerian data averages: $\frac{C}{NX} = 0.79, \frac{G}{NX} = 0.44$. Other starting coefficients include: capital output ratio 2.10, import output ratio 0.42, export output ratio 0.53 and Government spending output ratio 0.73. Also, $\frac{Y}{C} = 0.96$ respectively. These values yields the parameter values for $\frac{K}{C} = 2.02, \frac{IM}{C} = 0.40, \frac{EX}{C} = 0.51, ,\frac{G}{C} = 0.70$ respectively [31].

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[31] The values of kc, ext/c and imt/c are obtained by multiplying each with the initial value of y/c i.e. 1.5.

3.4.1 Initial Calibrated Parameters

Table 1 presents starting parameter coefficients and initial set of values for the residuals in each eqaution with error term, these values were set using empirical studies as discussed in section 3.0 above. However, these values are replaced with the estimated residuals in chapter 5.

Table 1: starting parameter coefficients

Parameters	Calibrated Values	Definitions
ρ_0	1.0	CRRA Coefficient (c_t)
ρ_2	1.2	CRR Coefficient (n_t)
α^O	0.1	Labour in oil sector.
α^{nO}	0.3	Labour in non-oil sector
α^d	0.6	Labour in domestic sector
γ^O	0.6	Capital in oil sector
γ^{nO}	0.2	Capital in non-oil sector
γ^d	0.2	Capital in domestic
ω_t^O	0.3	Oil sector in aggregate output
ω_t^{nO}	0.1	Non-oil sector in aggregate output
ω_t^d	0.6	Weight of domestic sector in aggregate output
$\xi_1^O, \xi_2^O, \xi_3^O, \xi_4^O$	0.51, 0.47, 0.019, 0.25	Capital equation Coefficients in oil sector
$\xi_1^{NO} \xi_2^{NO}, \xi_3^{NO}, \xi_4^{NO}$	0.51, 0.47, 0.02, 0.25	Capital equation Coefficients non-oil sector
$\xi_1^D, \xi_2^D, \xi_3^D, \xi_4^D$	0.51, 0.47, 0.02, 0.25	Capital equation Coefficients in domestic sector
σ	0.7	
ψ	0.5	Weight of Domestic sector in output in the total output
G	0.7	A policy variable that can smoothen the resource curse
ϑ	0.7	Home bias for domestic good
δ	0.25	Depreciation Rate
φ	0.00742	Premium on top of world interest rate
ϑ^f	0.7	Foreign bias for foreign good

For capital output ratio (k/y), import output ratio (imt/y) export output ratio (ext/y), g/c and y/c initial values were assigned based on the averages of Nigerian data for the period 1981 to 2016.

Table 2: Starting Rho Coefficients

	Starting values of (ρ)
ρ_g ρ_{po} ρ_{pf} ρ_{pno}	0.92, 0.90, 0.90, 0.90
ρ_{y^o} , $\rho_{y^{no}}$, ρ_{y^d}	0.85, 083,0.82
ρ_{n^o}, $\rho_{n^{no}}$, ρ_{n^d}	0.70, 0.70, 0.70
ρ_{k^o} , $\rho_{k^{no}}$, ρ_{k^d}	0.90, 0.60, 0.90
ρ_g , $\rho_{l^{no}}$, ρ_{l^d}	0.70, 0.80,0.60
ρ_{ext} ρ_{es} ρ_{en}	0.70, 0.80,0.80
ρ_{pno} ρ_c ρ_{es}	0.74, 0.90, .0.90
ρ_w ρ_{pd}	0.63, 0.90

# 3.5 Analysis of Impulse Response for Calibrated Model

The Impulse Response Functions (IRFs) describe the internal dynamics implied by the model shocks, in this work it mainly presents the effects of one-off sectoral positive productivity shocks (oil, non-oil, domestic sector) and an oil-price shock, respectively. Even though the impulse response functions of all the variables behaves as expected, however, only the variables of interest in the thesis are presented and discussed in this section while the remaining sets of impulse response functions to other shocks are attached in appendix 3.

3.5.1 Response to Tradable Oil sector productivity shock

A positive tradeable oil sector productivity shock to the economy raises the sector's output, domestic and aggregate output, however, non-oil sector's output responds negatively to the shock. As more labour, capital and land for both oil and domestic sectors are required in the production of additional output for oil and domestic sectors, household supply more labour which increased his income and in turn stimulates more consumption and aggregate demand since the interest rate rise was insignificant to generate intertemporal substitution of consumption. In respond to the rise in aggregate demand, real interest rate begun to rise higher in the second period to maintain real uncovered interest rate parity. Thus, the real exchange rate supposed to appreciates more in the short term and restored as real interest rate rises in the short but do not seemed to behave as expected also, hence the real exchange rate is expected to depreciate over time.

With more labour supply in domestic and oil sector the substitution effect dominates income effect of labour supply, hence, aggregate labour supply increased. The response of the variables reveals a crowding out effect of non-oil sector factor inputs by the oil sector and domestic sector boom.

Figure 13 . Oil Sector Productivity Shock
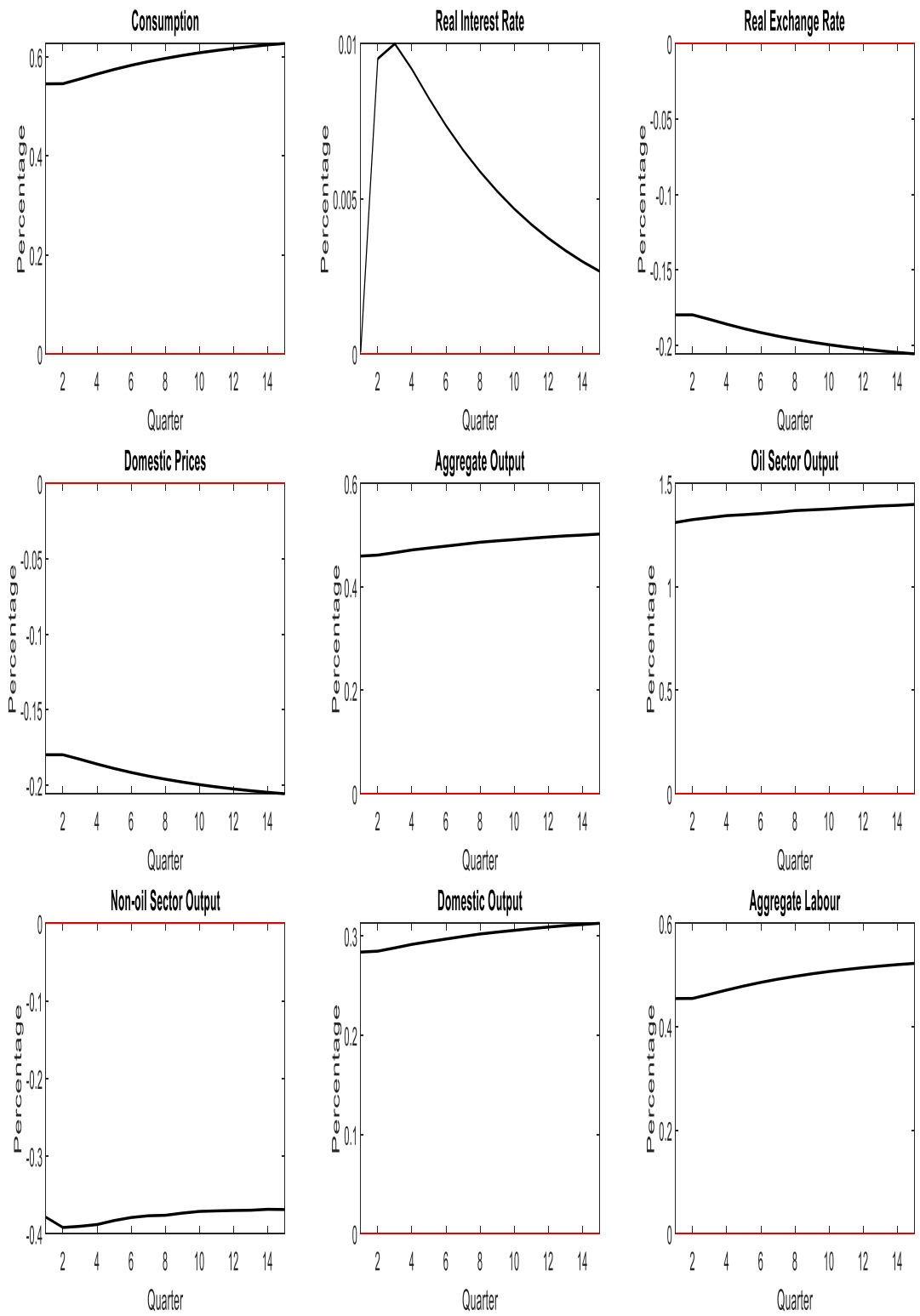
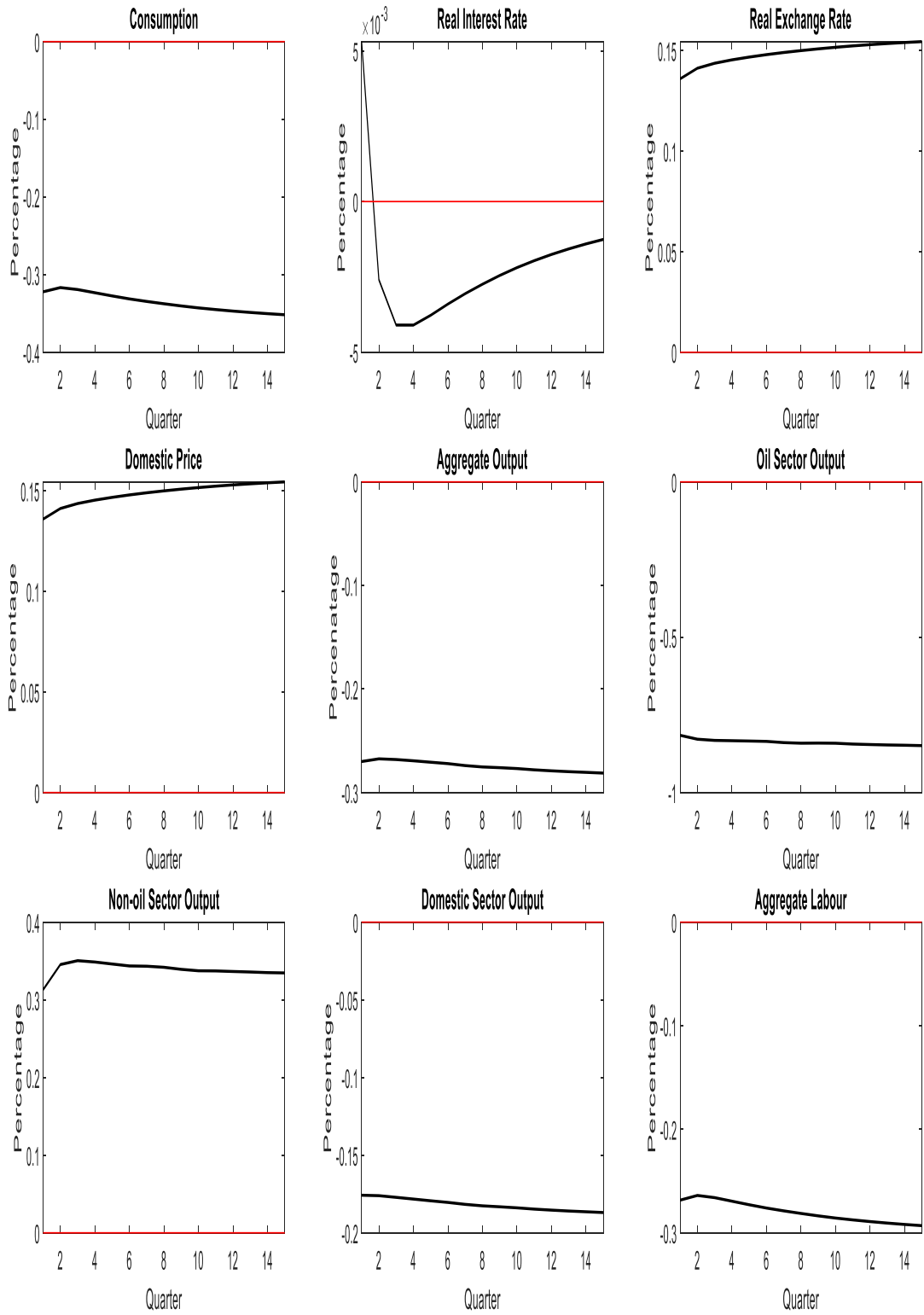### 3.5.2 Response to Non-oil sector Productivity Shocks

The response of most of the variables to non-oil sector productivity shock are distinct from that of oil sector productivity shocks even though they are both tradable sectors with their prices being exogenously determined   at international market as explained in (a). The shock increased the sector's output while oil sector, domestic sector and aggregate output decreased leading to fall in income and aggregate demand for factor inputs of the sector aside non-oil sector capital which responds positively to the shock. The fall in oil and domestic sectors output dominates the rise in non-oil sector output and that led to decline in aggregate output. With low economic activity, consumption decreased and consequently resulted to fall in income as well as expected investment. Therefore, the demand for factor inputs in oil and domestic sectors decreased while the non-oil sector inputs demand increased   though the aggregate input demand decline. Real

Typically with the real business cycle model with flexible prices, marginal productivity equals to wage, therefore with the positive productivity shock to the sector real wages rises in response to the shock to offset the income effect of labour supply, hence substitution effect dominate as both non-oil sector and aggregate labour supply increased.

The real interest rate rises to maintain real uncovered interest rate parity as in accordance with this model set-up which requires that higher real interest rate must be matched by an expected increase in real exchange rate. In other word, the real exchange rate depreciates and restored external balance.

The response of non-oil sector's output and factor inputs with corresponding fall in the oil and domestic sectors factor inputs confirms the crowding out effect between the sectors as observed in oil sector productivity shock (a) and oil price shocks (d) respectively.

# Figure 14. Non-Oil Sector Productivity Shock

3.5.3 Response to Non-Traded (Domestic Sector) Productivity Shock

A positive non-traded sector productivity shock affected domestic economy positively as the increased in the sectors output dominated the fall in tradable (both oil and non-oil) sectors output which generated a positive response of aggregate output to the shock. This supports the logic of the model that the weight of non-tradable services of the economy is higher than that of the weight of tradable sector output in aggregate output. Substitution effect dominates income effect as wages rises to counter and stimulates additional labour supply. Being a labour intensive sector, household's income increased which in turn generate more consumption and aggregate demand in general. However, the disroportionate increase in aggregate output vis-à-vis the rise in consumption led to a higher domestic price. In other word, as the aggregate demand for non-traded goods increased without a proportionate rise in nontraded supply causes inflation in the economy. To bring about market-clearing in the nontraded sector. In the short term, the aggregate supply may be slower to adjust hence the real exchange rate rises overtime that shift factor supply from traded to non-traded sector increasing the domestic output further to meetup with the domestic sector demand.

 the Impulse response function also revealed that eventhough the domestic sector capital was on the increase the decrease in tradable sectors capital (oil and non-oil) pulled down the aggregate capital demand , this also conforms with the model assumption that the domestic sector is more of labour intensive than capital intensive.

 In general, positive productivity shock to non-tradable sector raises the sector's and aggregate output , increased aggregate demand, factor inputs demand particularly labour demand, rise in real wage , domestic price and real interest rate while the real exchange rate rises in the short term to clear the sector.

Figure 15. Non-Tradeable (Domestic Sector) Productivity Shock
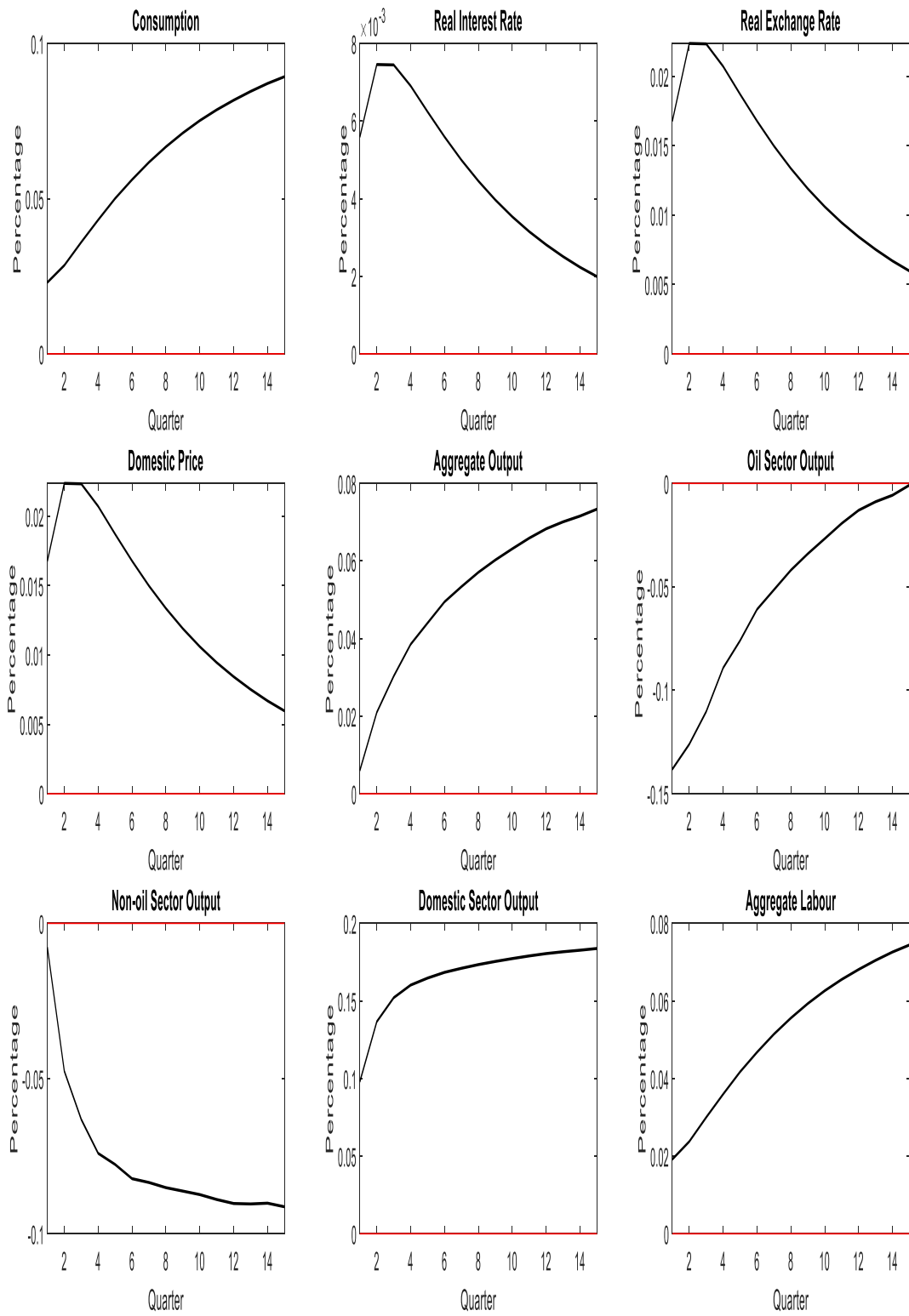
3.5.4 Oil Price Shock

Figure 11 presents response of macroeconomic variables to temporary oil price shock. The oil, domestic and aggregate output increased in response to the shock. Labour supply increased as income effect failed to dominate substitution effect. The sector being a capital-intensive, the rise in oil price trigger appetite for additional oil production and that requires an increase in factor inputs supply. Hence, real interest rate rises slowly in response to the surge in the sector's additional demand for factor inputs. Under oil price shock, the non-oil sector is crowded out by the oil sector.

The oil sector output increased tremendously higher than the increase in consumption leading to a fall in domestic price.   The real exchange rate fell (appreciates) in response to the shock as it is expected in the model since positive oil price shock comes with higher foreign exchange earnings (inflow) more than the expected outflow. As the factor inputs demand for oil sector increases the non-oil sector factor inputs decreases its factor inputs demand as the sectors' output decreases this in turn lead to decline in the aggregate capital demand.

Conversely, the substantial decline in non-oil sector capital and output suggest the presence of Dutch disease effect as widely established in empirical literature on oil and other commodity exporting economies Benkhodja (2014).

Fig 16. Response to Oil Price Shock
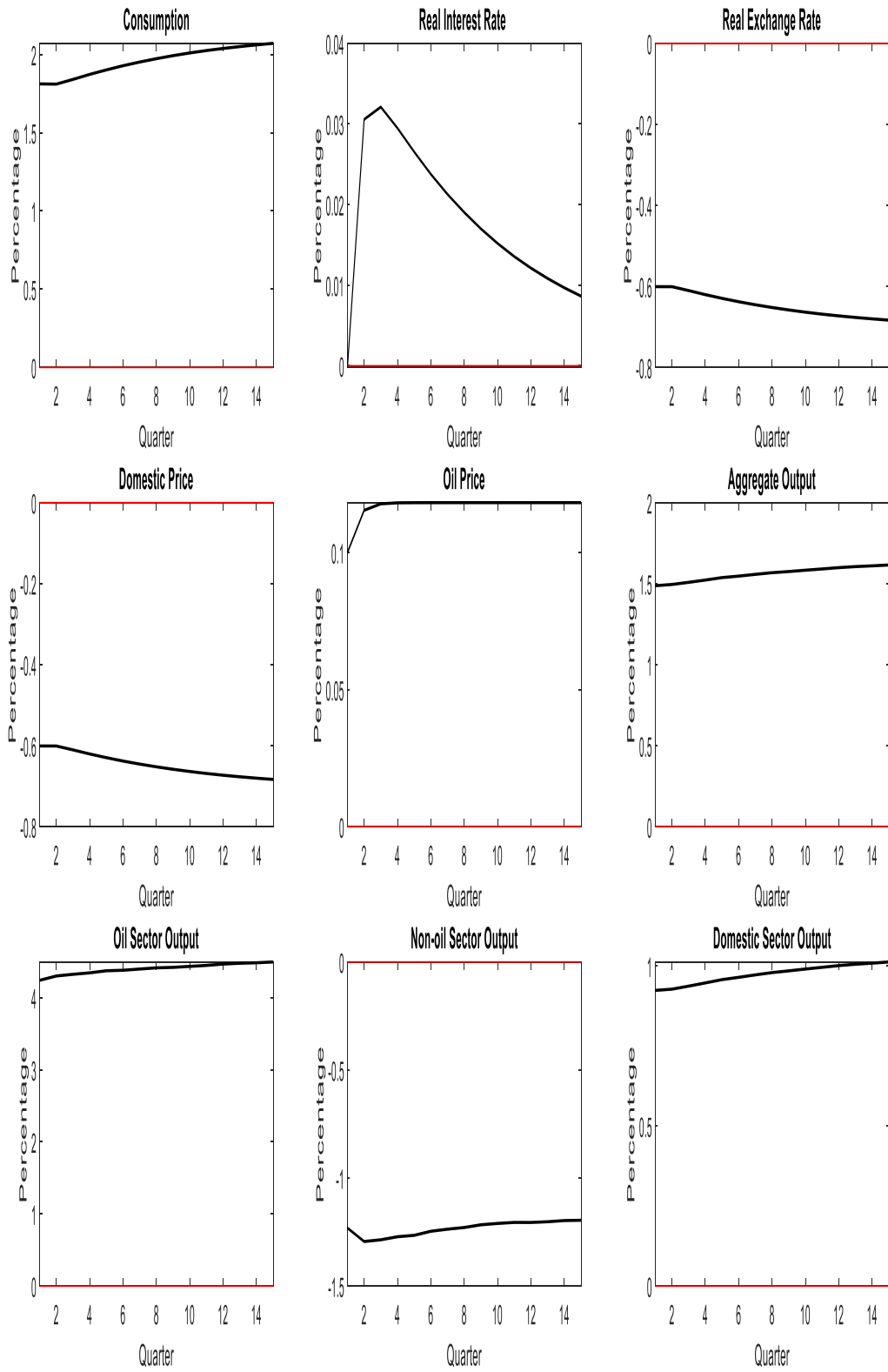
4. Methodology: Testing and estimation Using Indirect Inference

4.1 Introduction

The best approach to testing and estimation of macroeconomic models has been contentious among macroeconomists, particularly the DSGE model builders, hence the issue is still unsettled among the macroeconomist. In this chapter, I present an Indirect Inference Wald testing method to evaluate the fit of the small open economy business cycle model developed for Nigerian economy in chapter 3. The remaining part of the chapter, 4.2.0 discusses the evaluation of DSGE models, 4.3.0 highlights the working of the Indirect Inference Methodology applied in testing and estimation of the model, and 4.4.0 compares the direct and indirect inference testing methodology.

4.2 Evaluation of DSGE Model

DSGE models emanate from the vulnerability of conventional macro-econometric models to the Lucas critique, thus they cannot be used for policy evaluation. This is because they are not structural[32] Lucas, (1976).

In spite of the fact that DSGE models are micro founded and immune to Lucas critique which has placed them ahead of conventional macroeconomic models, the evaluation, and fits of these models has been contested and still contestable as it is argued that these models do not need to be calibrated but rather they should be subjected to estimation and testing Sims (1980). In an attempt to address the issue of the model evaluation, DSGE models are estimated and tested using conventional methods of testing such as Likelihood ratio test, however, that has not resolved the issue, rather, it created another problem as many models been rejected including the models perceived to be good[33].

In their quest to search for alternative methods that overcome the problem of model misspecification identified with the classical statistical methods of estimation, particularly problem associated with the maximum likelihood method, macroeconomists have developed other econometric frameworks that formalise some features of calibration method by considering

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[32] These conventional macro-econometric models are conglomeration of partial equilibrium equations rather than general equilibrium models of the economy. They lack coherent structure and mainly based on weak identifying restrictions.

[33] Sargent remarked of the early days of testing DSGE models: "…my recollection is that Bob Lucas and Ed Prescott were initially very enthusiastic about rational expectations econometrics. After all, it simply involved imposing on ourselves the same high standards we had criticized the Keynesian for failing to live up to. But after about five years of doing likelihood ratio tests on rational expectations models, I recall Bob Lucas and Ed Prescott both telling me that those tests were rejecting too many good models Evans, G. W. and Honkapohja, S. 2005. An interview with thomas j. sargent. *Macroeconomic Dynamics* 9(4), pp. 561-583.Tom Sargent, interviewed by Evans and Honkapoja (2005).

misspecification. For example DeJong et al. (1996) proposed Bayesian approach to calibration which was subsequently improved by Geweke (1999) and Canova (1994) among others. Bayesian estimation has now taken a centre stage as an alternative method to the conventional econometric methods of estimation. The Bayesian estimation methods work in such a way that it uses a standard econometric estimation method whilst at the same time limiting the range of values that the main parameters can take based on calibration. Bayesian estimations falls between calibration and classical estimation. It incorporates prior information but allows it to be uncertain, and actual data are used in combination with the prior information in a manner that reflect relative uncertainty of prior and classical estimates An and Schorfheide (2007).

As noted Tovar (2009) pointed out that the Bayesian method can address the weakness observed from the maximum likelihood based on the following reasons: that the prior reweight the likelihood such that as the likelihood reaches a peak at a point that is at odds with the prior then the marginal density of DSGE will be low. In effect, good prior can add curvature to a flat likelihood function. The proponents of the method also argue that using the Bayesian method of estimation enables the policy makers' inputs to be incorporated in terms of his knowledge of the behaviour of the economy. It is in line with this argument of including some inputs that are based on the experience of the policy maker on the historical features of macroeconomic variables in the economy into the prior distribution that Del Negro and Schorfheide (2008) suggest that prior distributor either reflect subjective views or summarises information derived from data that are not included in the estimation sample. The approach of Bayesian method in evaluation of the model is discussed in (4.2).

Despite   the advantages of using Bayesian method of estimation, the method has been widely criticised because of the following: firstly, the choice of the prior information is subjective and even if not subjective, it can distort the results if the likelihood function imposes little information.

 Kocherlakota (2007) caution that that the model could be biased if priors are introduced to achieve identification rather than introduced as auxiliary information. Other papers that discussed the identification problem associated with the Bayesian methods include Fukac and Pagan (2006) opined and Iskrev (2008).

 Secondly, Bayesian method of estimation is criticized for overreliance of posterior estimates of the structural parameter on simulation methods like MCMC, hence this invariably makes it difficult to replicate Bayesian results. Explaining this problem Fukac and Pagan (2006, p.3) highlight one prominent example of this problem that they attempt to replicate the posterior mode of Lubik and

Schorfheide (2005) but the simulated posteriors seems to be different even with millions of replications, hence this suggests a problem of replicability of Bayesian results.

With these problems attributed to Bayesian estimation method, some macroeconomists are quite sceptical about using the method in their model's estimation. Thus, another recent methodology (though it's been there for long time) presently gaining popularity is the Indirect inference method of estimation.

The method of indirect inference also identified as (the method of simulated moments) is a form of optimal calibration that parameters of both model (RBC or DSGE) and that of disturbances (shock process) is selected, as the model is simulated. In addition to matching certain moments of the data the simulated data is matched with a time series model of the observed data for instance VAR. After this stage, that could be regarded as generalisation of conventional calibration, an optimal calibration is found by selecting the parameters of the DSGE model that best match the VAR based on the observed data.

  In other words, Indirect Inference estimation attempt to find the parameter set that is closest to matching the sample data behaviour and then decides whether the set of parameters passes the test or not. Dridi et al. (2007) describe the calibration estimation method as "from specific to general"

This research adopt Meenagh et al. (2010) to test the model using Indirect Inference approach, This test reinstates the role of conventional statistical test of DSGE and originate cooperate the widely accepted economic testing methodology that could be regarded as 'Friedman utility' of tests. Friedman and FRIEDMAN (1953) pointed out that an economic model should be tested on 'as if it is true' rather than 'literal truth'. Hence, focus should be on testing DSGEs on their ability to match or mimic the important features of the actual economy of interest or the model economy that we are concern with and designed them to explain.

To summarise, the indirect inference model evaluation criteria attempt to answer the question on 'how closely can the model match the data behaviour?' It thus provides an answer on the closeness of data/s stylised facts to the model.

4.3 Indirect Inference Method

The method of Indirect inference was originally introduced by (Smith 1993) and subsequently extended by ,(Gouriéroux et al. 1993), Gourieroux and Monfort (1996) and Gourieroux and Monfort (1997), (Minford et al. 2009) and (Gouriéroux et al. 2010). Indirect inference method could be described as a simulation-based method that uses auxiliary model to match the parameters obtained from actual and simulated data. Indirect inference approach is mainly calibrated- based testing method to evaluate models match to an observed data given initial parameters. The method can be explained by a test, which is carried out to compare the unrestricted VAR estimates, that is derived from the simulated data with another unrestricted model or an alternative unrestricted VAR estimates derived from the actual data to ascertain the closeness of these two sets of estimates of parameters of auxiliary models. The estimates of the real model are expected to be close to that of simulated model, in other word, the distance of the unrestricted VAR estimates and the alternative unrestricted VAR estimates has to be minimum. The method of indirect inference also aims at finding a set of parameters values to minimise the distance, using searching method called simulated annealing algorithm.

As an evaluation method, indirect inference is approach that provides a coherent framework for judging the performance of a calibrated or estimated model. It also involves comparing the moments of the simulated data and the actual data. Hence, it is observed that comparing those moments do not provide adequate information about the closeness of the model to the actual data.

There are number of empirical work that applied the indirect inference method using different data sets from different countries for instance, (Davidson et al. 2010) estimate DSGE model for United States , (Onishchenko 2011) for Ukraine, (Raoukka 2013) uses Greece data, (Meenagh et al. 2009), (Minford 2015), (Meenagh et al. 2015), (Le et al. 2011) while the remaining papers estimates EU and UK DSGE models using indirect inference. Research conducted by (Le et al. 2011) using indirect inference method confirmed the strength of the approach having higher power of a test compared to likelihood ratio test. In a related development (Le et al. 2011) applied indirect inference test on(Smets and Wouters 2007) model with the results that shows the model fails the test.

In this regard, I applied indirect inference methodology to small open economy DSGE model of Nigeria following the procedure of conducting indirect inference test as laid down in (Minford et al. 2009; Davidson et al. 2010; Le et al. 2016). One important issue regarding this thesis is that it

is the first time that an indirect inference methodology is applied to any work on Nigeria and African countries in general.

4.3.1. Indirect Inference Test Stages

The main objective of the indirect inference testing is to get the performance of the model by comparing the coefficients from the estimated VAR from the actual data and the mean of the distributions of the estimated coefficient from the simulated data. The method is a form of Wald statistics test that measure the joint capacity of the model to fit the joint capacity of dynamic performance of the observed data. The approach is also used to find the best fitting set of structural parameters that replicates the trajectory of the behaviour of the real data. Hence, the optimal searching procedure is put within the indirect inference process and re-conducted in subsequent stages. Using auxiliary model, the test provides statistical inference that could be used to assess the model's ability to generate behaviour found in the actual data.

Using the same notation as in (Meenagh et al. 2009) for non-stationary data. The testing of the DSGE model using indirect inference could be presented as follows;

Let assume that y_t be $m \times 1$ vector with actual data where is $t = 1, \ldots \ldots T$, and let $x_t(\theta)$ be $m \times 1$ vector of simulated data, (θ) is $k \times 1$ vector of parameters of the model economy. The auxiliary model is in form of probability density function $f(y_t, \alpha)$, where α is a $q \times 1$ vector that consists of parameters of the auxiliary model with $k > q$. this follows the assumption that θ carries a particular value i.e. θ_0 which can be calibrated value or estimated value of the coefficients of the model where the two distribution are same as:

$f(x_t(\theta_0), a) = f(y_t, \alpha)$. Where α_T is regarded as estimator of α for observed data and $a_T \theta_0$ is the estimator for α with the simulated data. The mean of $a_T(\theta_0)$ is found as $\frac{1}{N} \sum_{k=1}^{N} a_T(\theta_0)$ from the sets of simulated data obtained from the bootstrapping.

Hence, the Wald statistics is written as follows:

$$WS(\theta_0) = \left(a_T - \overline{a_{T(\theta_0)}}\right)' W(\theta_0)(a_T - \overline{a_{T(\theta_0)}}) \tag{4.3.1}$$

Where $\overline{a_{T(\theta_0)}}$ denotes the arithmetic mean of the estimated parameters; $W(\theta_0) = w\left(\theta_0^{-1}\right)$ [34] is the inverse of the estimated variance-covariance matrix.

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[34] N bootstrap sample of the structural model are drawn and estimating the auxiliary VAR on each of the sample. The parameters are estimated by bootstrapping $a_{T(\theta_0)}$ in this work, a 1000 bootstrap simulations (N) has been set and the auxiliary model is estimated using ordinary least squares (OLS) method

A brief step for indirect inference testing is presented as:

Firstly, determine the structural errors of the economic model conditional on the observed data as well as θ_0. The starting point is to solve the model and obtain the structural errors ε_t. It is assumed that the errors are not normal, and the total number of the independent structural errors are assumed to be less than or equal to the total number of the endogenous variables. However, in a situation where the equations in a model do not have expectations then we can assume errors in that case and the structural errors can be calculated using actual data given the structural parameters. On the other hand, if there are expectations in any equations in the model then we calculate the rational expectation terms using the robust instrumental variables method of (McCallum 1976) and (Wickens 1982) where the lagged endogenous data are treated as an instrument, which is consistent with the auxiliary model VAR.

Secondly, construct an empirical distribution of the structural errors

The structural errors are assumed to follow AR 1 following the DSGE model specified by (Le et al 2016,). In this stage, a bootstrapping is undertaking N times to obtain to simulate N pseudo samples. Meanwhile the structural errors are estimated and obtain the coefficients.

Thirdly, set up null hypothesis and compute the Wald statistics

A null hypothesis $(a_T = \overline{a_{T(\theta_0)}})$ is set as true meaning that the dynamic behaviour of the structural macroeconomic model is not significantly different from that of the actual data. Whereas, the alternative hypothesis means the model is mis-specified. The distribution of the estimates from VARs are obtained by estimating the auxiliary VAR on all the pseudo sample. Hence, these sets of vectors represent the sampling variation implied by the structural model allowing direct estimation of its mean, covariance matrix, and confidence bounds. Often a thousand simulation is set however, in an event where the search could not yield any optimal set of parameters the simulation number is increased accordingly. Coefficients of the estimated auxiliary model are compared for both actual data and from the simulated data. The dynamic and volatility properties are captured by VAR estimates and the variance of the main variables respectively. As discussed for the model the Wald statistics is computed using the following

$$WS(\theta_0) = \left(a_T - \overline{a_{T(\theta_0)}}\right)'W(\theta_0)(a_T - \overline{a_{T(\theta_0)}})$$

While calculating individual estimates the confidence interval of 95 % is computed from their bootstrap distribution.

Lastly, test statistics comparison described as follows:

With the Wald statistics computed, the test compares the percentile of the Wald distribution at which the critical Wald statistics falls within the specified size of the test; for instance, for the model to pass the test or model fit at 5 % confidence level then the Wald statistics of the data is required to be less than the 95% confidence level, otherwise, if it is above then it falls within the rejection region. Another way of getting to the same conclusion is by using Mahalanobis

$$MD_{Norm} = (\frac{\sqrt{2WS} - \sqrt{2k-1}}{\sqrt{WS^{95th}} - \sqrt{2k-1}}) \times 1.645 \qquad (4.3.2)$$

Where k is the length of a_T (the vector auxiliary model parameter estimated on the actual data), MD_{Norm} is the 95th percentile of the standard normal distribution, WS^{95th} denotes the Wald statistics of the 95th percentile of the simulated data which is scaled by 1.645.

$\sqrt{2WS} - \sqrt{2k-1}$ represents Mahalanobis Distance with mean of 0 and standard deviation of 1.

4.3.2 Model Estimation using Indirect Inference Approach

In this section the small open economy model developed in (3.1) is estimated using indirect inference estimation with a view to minimise the distance between a given criterions of the two sets of estimated coefficients of the auxiliary model. A brief procedure for indirect inference estimation using directed Wald is presented as:

Stepe1; calculate minimum value Wald using a global optimisation simulated annealing algorithm [35] to find the parameter values within a predefined set of upper and lower bounds. "This search takes place over a wide range around the initial values with optimising search accompanied by random jumps around the space" (Liu and Minford 2014).

Step; the residuals from the model's equations are estimated for any given set of coefficients.

Step 3; these estimated residuals are fitted to equations that to greater extent represents their time series properties. For the non-stationary data, it is assumed that the residuals are trend stationary with a drift or are identified by a unit root. Conversely, for stationary data autoregressive process (1) is used.

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[35] Simulated annealing is a method for finding a solution to an optimisation problem. The method models the physical process of heating a material and then slowly lowering the temperature to ensure that the defects are minimised globally. At each iteration of the simulated annealing algorithm, a new point is randomly generated. The distance between the new point and the current, or the range of the search, is relied on a probability distribution with a scale proportional to the temperature. The algorithm avoids being caught in local minima and is able to explore globally for better solutions. https://uk.mathworks .com/discovery/simulated-annealing

Step 4; the innovations series are found using the residuals. Hence, these series are regarded as the structural shocks of the model.

Step 5; the bootstrap simulations are undertaken using the innovations series obtained, based on the null hypothesis that the model is true. When a bootstrap is set to 1000, it means that the simulation creates 1000 artificial sets. As in the case of this work, I set the bootstraps at one thousand (1000) simulation.

Step 6; for non-stationary data using a vector error correction model (VECM) the simulated series are fitted to auxiliary model. While vector autoregressive (VAR) is used for stationary model to fit the simulated series to an auxiliary model[36].

Step 7; the coefficients from each simulation apart from constant term are gathered together to form distribution that consist of the sampling properties of the coefficients of the auxiliary model.

Step 8; calculate the Wald statistics[37]for each simulation.

Step nine, estimate the Wald statistics for the auxiliary model, observed data, and compare the Wald from the observed data to the distribution of Wald using simulated data.

Step 11; using the 95th percentile (1.645), a Wald in the actual data mahalanobis is measured.

Step 12; evaluate the values of mahalanobis distance, if it falls less than the value of 1.645 implying that the null hypothesis is not rejected, implying close approximation of the model to the true data. On the other hand, if it falls outside the region then the null hypothesis is rejected.

Step 13; Collect the mahalanobis distance values and the parameter set that generated the simulated data. Repeat the process by choosing different sets of parameter values using simulated annealing algorithm. Note that the best estimate of the model parameters are the ones that generated the lowest mahalanobis distance.

4.4 Choice of Auxiliary Model

Having obtained the solution of the log-linearized DSGE model as presented in form of a vector autoregressive moving average (VARMA) or vector autoregressive (VAR) with restrictions on the coefficients.

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[36] The reduced form of a DSGE model can be represented as VAR.
[37] The Wald statistics represents the function of the estimated coefficients and variances of parameter.

Using a non- stationary data as in the case of this work, the auxiliary model whose error is stationary is created by vector error correction model (VECM). Following the work of (Meenagh et al. 2012) and (Le et al. 2015). A cointegrated VAR with exogenous variables (VARX) is selected as an auxiliary model. The exogenous variables may consist of both observable variables and unobservable variables, hence, presenting the log-linearized model in that form yield:

$$A(L)y_t = BE_t y_{t+1} + C(L)x_t + D(L)e_t \tag{4.3.3}$$

$$\Delta x_t = a(L)\Delta x_{t+1} + d + b(L)z_{t-1} + c(L)\varepsilon_t \tag{4.3.4}$$

x_t is a vector consisting of exogenous non-stationary variables with elements that may perhaps depend on the lag of z_t systematically. y_t denoted a vector of endogenous variables, e_t is a vector of iid with zero mean, A and B are coefficient matrices, L is a lag operator $z_{t-s} = L^s z_t$ and $A(L), (B)$ and e.t.c. are polynomials that have their roots outside unit cycle.

The general solution is presented as follows:

$$y_t = G(L)y_{t-1} + H(L)x_t + f + M(L)e_t + N(L)\epsilon_t \tag{4.3.5}$$

f denotes solution the vector of constants. Thus, the solution to the model has P cointegration relations.

$$y_t = [I + G(1)]^{-1}[H(1)x_t + f] \tag{4.3.6}$$

Hence; substituting $[I + G(1)]^{-1}[H(1)x_t + f]$ with $\pi_{x_t} + g$ gives

$$y_t = \pi_{x_t} + g \tag{4.3.7}$$

From (4.6) y_t can be re-written as a function of deviation from the equilibrium in the short-run

$$y_t - [\pi_{x_t} + g] = \eta_t$$

Where η is error correction term while in the long-run the solution of model is written as;

$$\bar{y}_t = \pi \bar{x}_t + g \tag{4.3.8}$$

$$\bar{x}_t = [1 + a(1)]^{-1}[d_t + c(1)\xi_t] \tag{4.3.9}$$

$$\xi_t = \sum_{i=0}^{t-1} \epsilon_{t-s} \tag{4.3.10}$$

Equation (4.7) which shows the long-run solution to x_t can be decomposed into two components $\bar{x}_t = \bar{x}_t^d + \bar{x}_t^s$, the deterministic trend part $\bar{x}_t^d = [1 + a(1)]^{-1}d_t$; and stochastic trend component

$\bar{x}_t^s = [1 + a(1)]^{-1}c(1)\xi$. Hence, the solution for y_t can be written in the form of vector error correction model (VECM)

$$\Delta y_t = -[I + G(1)]^{-1}(y_{t-1} - \pi_{x_{t-1}}) + P(L)\Delta y_{t-1} + Q(L)\Delta x_t + f + M(L)e_t + N(L)\epsilon_t \quad (4.3.11)$$

$$\Delta y_t = -[I + G(1)](y_{t-1} - \pi_{x_{t-1}}) + P(L)\Delta y_{t-1} + Q(L)\Delta x_t + f + w_t \quad (4.3.12)$$

$$w_t = M(L)e_t + N(L)\epsilon_t \quad (4.3.13)$$

The VECM is approximated by the VARX as follows;

$$\Delta y_t = -K[y_{t-1} - \pi_{t-1}] + R(L)\Delta y_{t-1} + S(L)\Delta x_t + g + \zeta_t \quad (4.3.14)$$

Since $\bar{y}_t - \pi\bar{x}_{t-1} - g = 0$, VECM can be written as

$$\Delta y_t = -K[(y_{t-1} - \bar{y}_{t-1}) - \pi(x_{t-1} - \bar{x}_{t-1})] + R(L)\Delta y_{t-1} + S(L)\Delta x_t + h + \zeta_t \quad (4.3.15)$$

The auxiliary model can be in form of either equation (4.14) or equation (4.15). Therefore equation (4.14) can be re-written as co-integrated VARX:

$$y_t = [1 - K]y_{t-1} + K\pi x_{t-1} + n + \phi_t + \delta_t \quad (4.3.16)$$

Where the error term δ_t captures the lagged difference regressors ϕ_t contains deterministic linear trend in $\bar{x}_t$ that affects both endogenous and exogenous variables.

x_{t-1} Contains unit root variables that are necessarily needed to control for the effect of past shocks on the long-run path of both endogenous and exogenous variables. Following (Meenagh et al. 2012), this work applied Directed Wald statistics that is derived from a particular aspect of the model's performance. Some selected endogenous variables of interest are used in the test to evaluate the theory that is being tested. The test has proven to explain main features and parameters of the model rather than attempting to explain the whole model parameters, which could lead to misspecification. The endogenous variables of interest in this work are output (oil sector, non-oil sector and domestic sector) real exchange rate and real interest rate.

4.5 Data

This section presents Nigerian quarterly macroeconomic data that is used in the thesis. It includes details relating to data sources, definitions and transformation carried out on respective variables. Nigerian time series quarterly data for the period 1981 quarter 1, to 2016 quarter 4 was obtained from the   (CBN 2017), National Bureau of Statistics Nigeria (2017), Abuja Geographical

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Information System, AGIS (2017), International Monetary Fund, International Financial Statistics IMF (2018), Organisation of Petroleum Exporting countries OPEC (2018). The logarithm for all the series is taken, data are scaled, seasonally adjusted and expressed in percentages.

The time series data for Gross Domestic Product (GDP) are segregated into three components namely; tradeable oil sector GDP (y^o), non-oil tradeable sector GDP (y^{no}) and (non-tradeable sector (domestic sector) GDP (y^d)[38]. The computation of GDP in Nigeria is done by the NBS and published in their quarterly reports. However, NBS data base started mainly from 1999, meanwhile, before then, the CBN was the main custodian of GDP. To allow for more flexibility in the model the study used long series data beyond 1999 as starting point, for model estimation, hence the series are sourced from both the CBN and the NBS. The data from both sources only divided the GDP to oil and non-oil starting from 2010. However, in this work I obtained the domestic sector GDP by the assigning 60 percent of the aggregate GDP to the sector while oil sector and non-oil sectors were assigned 30 and 10 percent. This is line with the economic reality in the Nigerian economy and series of discussions with the NBS and CBN Statistics Department.

The GDP data was rebased to be at year 2000, thus, from 1981 – 2016, for the purpose of this study, I used yearly series obtained from the Central Bank of Nigeria and spliced to quarterly series, using the (E-views 7) econometric package window[39].

For real interest rate (r), three-month Nigerian Treasury Bill (NTB) rate is depleted with Consumer price index (CPI).

The Real exchange rate Q_t data series is defined as relative foreign to Nigeria's consumer price levels expressed in common units, the computed data was collected from the CBN. A rise in the real interest rate denotes depreciation of the domestic currency Naira, and vice-versa.

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[38] The Activity sectors of GDP in Nigeria is made up of Agriculture; Mining and Quarrying; Manufacturing; Construction; Trade; Construction; Information and Communication; Accommodation and Food Services; Real estate; Education; Financial and Insurance; Professional, Scientific and Technical; Electricity, Gas, Steam and Waste. With each of the activity having sub-activities.

[39] The GPD series was interpolated due to the absence of quarterly data for some period, the interpolation method used Interpolation is often done to fill gaps or to convert data from one frequency to another in time series. In this work data series from high frequency are converted to low frequency data. There are various methods of interpolation as follows: Constant with sum or average matched to source data; Quadratic with sum or average to source data, Linear with first or last observation; Cubic spline with first or last observation; Chow-Lin method relates one or more high frequency target series; Denton method that minimises the proportional first difference between interpolated and high frequency. The method used in this work cubic spline because it combine quadratic, linear and polynomial interpolation. Data interpolation methods are identified uncertainty on the interpolated values.

The land rent (s) data composed up of the charges for the actual land rent, application cost and other charges. The data was scaled and approximated before taking it to the model. The oil block licence cost is also considered in arriving at the weight attached to the land rent for various sector. The collection and reliability of land data is one the of the challenges faced while carrying out the studies. The data was gathered from Abuja Geographical Information System (AGIS), after series of discussions with the Head Data and IT of the AGIS.

Foreign bonds b^f denotes the net total indebtedness of Nigeria, it is proxied by the Net Foreign Assets of Nigeria sourced from the Central Bank of Nigeria Statistical Bulletin 2017.

For the foreign interest rate r^f, and foreign price p^f proxied by US three months Treasury Bills rate and US consumer price index. The USCPI also served as price of Nigeria's non-oil exports. The Choice of the US as a proxy to world in this thesis is because substantial part of the period under study falls at the time when the US is the major trading partner of Nigeria (it is the major buyer of Nigeria's oil exports). These data are collected from Federal Reserve Bank of St. Louis (FRED 2018) . However, recently we are observing a shift in trade relationship as china is taking over the US place as a major trading partner of Nigeria.

Labour supply is calculated by subtracting the total number of unemployed work force in Nigeria (18 years and above) from the total number to arrive at the number of employed workforce in the economy. Labour force and employment data in Nigeria like in many developing economies might not reflect facts, this is because in these economies large employment is in the informal sector that are not captured in the available statistics obtained from the NBS. These informal sectors consist of firms and individuals that are not fully registered with government. All these errors fall into residual measure of productivity (TFP). Therefore, this is really another challenge that the study encountered while gathering the data.

Consumer Real Wage, I used the average wage paid to workers across the industries and depleted by the price level sourced from the CBN Statistical bulletin 2017.Consumption data comes from the household final consumption expenditure, All the data series mentioned above are collected from (Nigeria 2018) and (CBN 2017).

4.6 Filtering the Data

Substantial number of macroeconomics variables are generally not stationary as found by (1982) (Nelson and Plosser 1982). In most DSGE models these variables appear as endogenous, hence they may have growth paths that are non-stochastic trends or, in addition, stochastic trends.

Analysing and estimating these models the variables are firstly detrended or filtered (both deterministic and stochastic) to make them stationary and then the filtered series are treated as a deviation from steady state. There are quite a number of techniques used in literature to remove the trend components from the original data but the most commonly used in literature are HP filter (Hodrick and Prescott 1997) and Band Pass Procedure (Baxter and King 1999) and (Christiano and Fitzgerald 2003). The filter isolates the trend from the cyclical component by smoothening arbitrarily via two-sided moving average to obtain the trend component, the leftover series that is not smoothen is regarded as business cycle volatility. Therefore, this method decomposes time series data arbitrarily into trend and cyclical component.

Although the filtering data has been regarded as standard method of removing trend in the data, there are concern on the methods particularly HP Filtering. It has been established the HP filter distort the expectation structure of the model before and after the shock because the filter is two-sided thereby affecting the properties of the original model, as it incorporates future values of the data into current measurement of detrended data. Due to this distortion created by HP filter we could not analyse the model adjustment in response to shock, as it would relegate the effect, interpret it as a change in the process, and ignore it. In other word, it distorts the dynamic structure of the model making it difficult to be revealed. The method seems not effective in decomposing a non-stationary time series into a 'long-run potential trend' component and swings around it. Considering that some transitional periods that follow the shocks could be long, meanwhile, all these long swings could be wrongly regarded as a trend and subsequently be removed by the filter. This work uses non-stationary time series considering that filtering the data could yield misleading results on the interactions of variables of interest and impact of policy. In addition, using the non-stationary data would provide a better description of the behaviour of all the variables. This is even more important when estimating a model for oil exporting economies where the quite volatile due to the exogenous nature of the variables.

4.7 Conclusion

In this chapter the method of indirect inference is explained in detail, with all the steps involved in carrying out testing and estimation of a model. It also discusses the auxiliary model and stationarity test results of residuals. As pointed out in the previous section, the choice of this method is based on its ability to search the best parameters that reduce the distance between the actual and simulated

data using simulated annealing algorithm. It evaluates the joint significant of the parameter estimates of a model.

5. Empirical Work

5.1 Introduction

 In this chapter the model developed and calibrated in chapter three is estimated using indirect inference method, all the three productivity shocks are non-stationary, therefore, the auxiliary model could not be specified as VAR , consequently, using VECM resolve the non-stationarity problem which would have cause some of the structural equations to generate non-stationary shock (Davidson 2010). The parameters of the model are ought to be estimated, with following important variables; oil sector output (Y_t^O) , non-oil sector output (Y_t^{NO}) , non-tradeable sector output (Y_t^D)

, and real interest rate $(R_t,)$ as endogenous variables . However, due to the sensitivity of the number of endogenous variables in the auxiliary model to the model rejection I reduced the variables by picking the aggregate output (Y_t) as it is an aggregation of the three sectors output and real exchange rate to estimate the auxiliary model. After ascertaining that the model fits the data, I carried out a fiscal policy analysis. The estimation results for parameter estimates and the indirect inference test (Wald test statistics) result are presented in section 5.2 and 5.3. The impulse response functions are presented in 5.4. The error and shock process are illustrated in section 5.6 and 5.7. After ascertaining that the model fits the data a policy analysis is carried out and results presented in 5.8.

5.2 Results of Estimated Parameters

Applying the procedure of Indirect Inference Method of estimation as explained in Chapter 4, on the data for the period 1999Q1 –2016Q1. The best fit estimated coefficients were obtained from the wide search around the initial parameters using simulated annealing method. Most of the coefficients were allowed to change and search for the best sets of coefficients. The result of the estimated parameter values was mixed as some of the parameters changes significantly while others varies slightly.

From the household side, the estimated Arrow-Pratt coefficient of relative risk aversion for consumption (ρ_0) decreased tremendously by - 46.5 % suggesting less impact of real interest rate changes on consumption growth in Nigeria. However, the estimated (ρ_0) lies within the threshold of $1 - 3$ accepted measures of coefficient of risk aversion as established in literature reported by Gandelman and Hernandez-Murillo (2014) and (Lartey 2008) Dib (2008).

The coefficient of relative risk aversion for leisure (ρ_2) decreased from the starting value of 1.2 to estimated value of 0.95 signifying a fall by -20.78 %, this implies that the workers are more willing to smoothen their hours of work compared to calibrated parameter that assumes less smoothen of labour in response to wage change, the results conforms with Devereux et al (2006) and BenKhodja Tahar (2014).The estimated parameter value for preferences of domestic good (ϑ) decreased drastically by -76%, indicating domestic consumers tendencies of allocating more weight on their preferences for consuming imported goods. Domestic sector's weight in the aggregate output (ψ) varied widely from its initial calibrated value by -76.32%, meaning that the initial value assigned to the parameter was very high.

From the production side, most of the estimated parameter values varied significantly from their initial values, for instance, the weight of oil sector labour (α^O) and domestic sector labour (α^d)

decreased by -30.98% and -28.85 %   while non-oil sector labour (α^{nO})   increased by 31.74 %. The estimated values of domestic sector capital and weight of domestic sector output were assigned values higher than they required, their estimated values deviate from their initial values by -5.58% and -3.36% compared to their initial values. For the oil sector capital, though the estimated value was lower than the initial calibrated value, however, the estimated value is relatively high suggesting capital-intensive nature of oil sector that requires enormous capital investment to increase their production The estimate of elasticity of domestic tradeable sector output to total output (ψ) varies largely from initial value of 0.5 to estimated value of 0.19 a drop by almost by 76.32%.

The result of the residual in table 6 shows that the estimated residual values changed significantly as it captures the dynamic and variance of the fitted residuals of the VECM compared to the calibrated model. For ease of comparison the estimated and initial coefficients are presented side by side in table (table 5) while estimated residuals are presented in table 6.

Table 3: Result of the Estimated Coefficients

Parmeter	Calibrated	Estimated	% Change
ρ_0	1.0	0.534755	-46.52
ρ_2	1.2	0.950648	-20.78
ϑ	0.7	0.165547	-76.35
ψ	0.5	0.118379	-76.32
G	0.3	0.20704	-48
α^O	0.1	0.177933	-30.98

α^{no}	0.3	0.395224	31.74
α^{d}	0.6	0.426843	-28.85
γ^{o}	0.6	0.527907	-12.01
γ^{no}	0.2	0.283261	41.80
γ^{d}	0.2	0.188832	-5.58
ω^{o}	0.3	0.367814	22.60
ω^{no}	0.2	0.148988	-25.50
ω^{d}	0.5	0.483198	-3.36

Fixed Parameters		
$\xi_1^{O}, \xi_2^{O}, \xi_3^{O}, \xi_4^{O}$	0.51, 0.47, 0.019, 0.25	*fixed*
$\xi_1^{NO} \xi_2^{NO}, \xi_3^{NO}, \xi_4^{NO}$	0.51, 0.47, 0.02, 0.25	*fixed*
$\xi_1^{D}, \xi_2^{D}, \xi_3^{D}, \xi_4^{D}$	0.51, 0.47, 0.02, 0.25	*fixed*
ф	0.2	*fixed*
v	0.35	*fixed*
δ	0.25	*fixed*
φ	0.00742	*fixed*
ϑ^{f}	0.7	*fixed*

Table 4: Estimated Rhos

	Estimated values of (ρ)
$\rho_{y^o}, \rho_{y^{no}}, \rho_{y^d}$	0.90, 0.99, 0.31
$\rho_{k^o}, \rho_{k^{no}}, \rho_{k^d}$	0.85, 0.83, 0.87
ρ^{n}	0.92
ρ^{l}	0.84
ρ^{s}	0.16
ρ^{c}	0.86

5.3 Indirect Inference Test Results

With the best fit parameters in table 5 and 6, above using auxiliary model with output, and real interest rate as endogenous variables the model was estimated and tested, the result obtained indicates a test statistic of 1.548 and a p value of 0.05. This suggests that the model has passed the stringent Wald test. Hence, the model is able to replicate joint behaviour of real interest rate and output with other macroeconomic variables mainly real exchange rate, real wage, consumption and sectoral outputs.

Table 5: Indirect Inference Wald Test Result

Auxiliary model	T statistics	P-value	Decision
$r_t, y_t,$	1.5480	0.0570	**Accept**

The results of the Indirect Inference Wald statistics test (7) indicates that the auxiliary model with variables; real interest rate and aggregate output passed the test with T statistics of 1.548, suggesting non-rejection of the models given the critical value of 1.645 at 95 per centile. Perhaps, the auxiliary model rejection is sensitive to the number of endogenous variables in the model, hence applying few numbers of variables enhance the chances of the model passing the test.

With auxiliary model the test at 5% and describing the dynamic behaviour of output and real interest rate of the Nigerian economy, the findings is in conformity with the theoretical postulation of open economy model that consider real interest rate and output as important variables.

5.4 Impulse Response Functions for Estimated Model

In this section I presented and compare the estimated model's impulse response functions for oil sector productivity shock, non-oil sector productivity shock, domestic sector productivity shock and oil price shocks with corresponding IRFs of calibrated model presented in chapter 3.

As highlighted earlier in section 3, the impulse response functions analysed in thee work are limited to the ones that are of direct relevance to the thesis even though the impulse response functions of the other shocks behave as expected and presented in appendix 5.
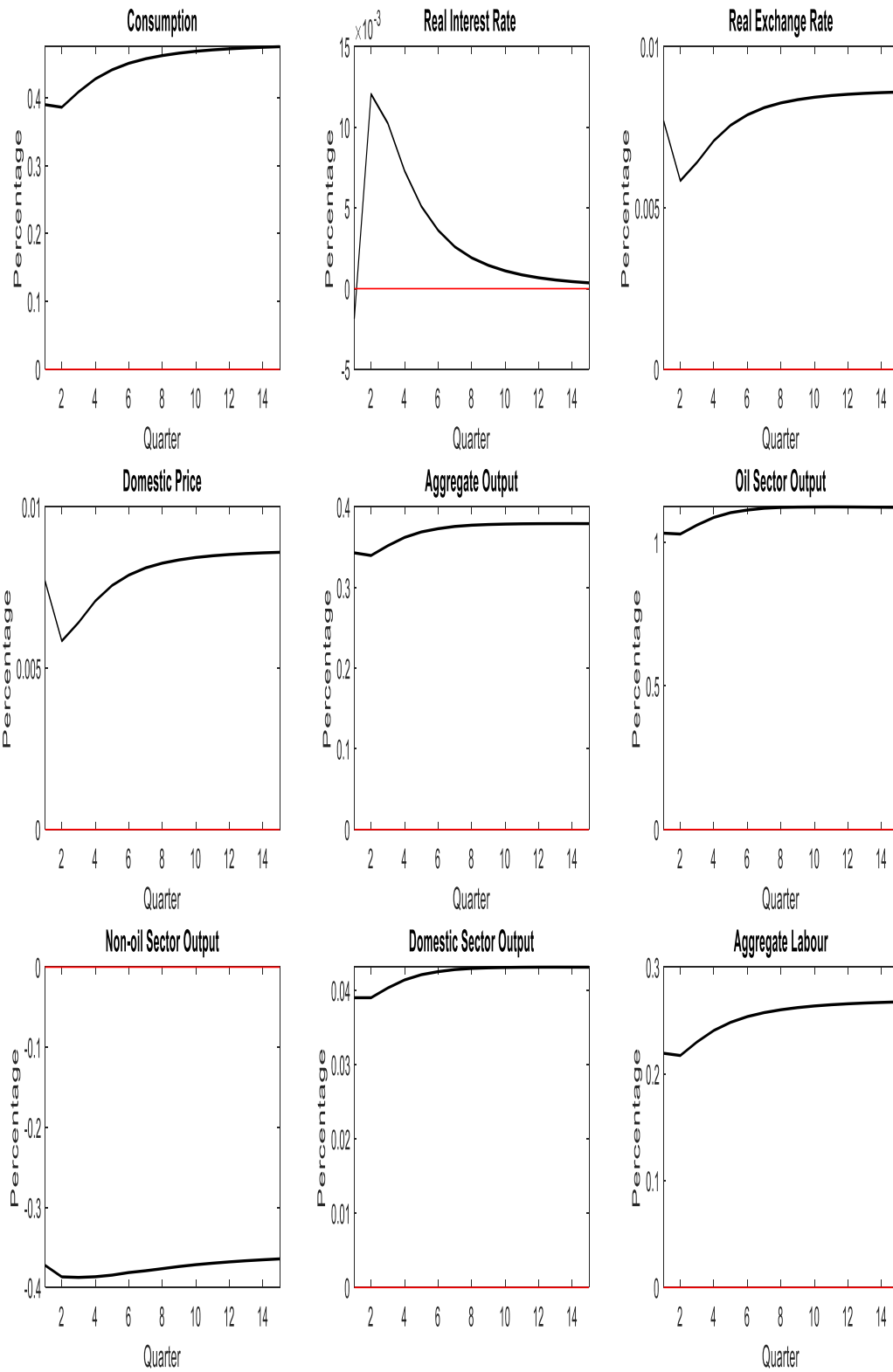
5.4.1 Response to Oil Sector Productivity Shock

 The dynamics of oil sector productivity IRFs of the estimated model (figure 16) is similar with that of calibrated model (figure 8) except the real exchange rate and domestic price that rise in the second period after initial decline**.** However, the estmated model has a dampened effect on the response of the endogenous variables to the shock as the size of the response to the shock is higher in the IRFs of calibrated model than that of estimated model. For instance, consumption responds positively in both IRFs reached 6 per cent in the calibrated model while it attained 4 per cent in the estimated model. Similarly, oil sector output, aggregate output and aggregate labour supply of the calibrated IRFs are higher than that of estimated model by about 0.3 %, 1% and 2% respectively. Conversely, domestic sector responds higher in the estimated IRFs than the calibrated IRFs by about 1%. The most interesting results is improvement in the IRFs of the estimated is the fall in the real exchange rate as in accordance with the model set-up with a positive (permanent) shock to traded productivity the short term raises demand for nontraded with no rise in nontraded supply; this causes inflation raising the real exchange rate (fall in Q) to bring about market-clearing in the nontraded sector. In the short term this will have to be largely by reducing non-traded demand as supply may be slower to adjust. Long-term current account balance also requires a rise in the real exchange rate, this shift supply out of traded into non-traded as well as some little shift of demand. Thus, the real exchange rate appreciates more in the short term than the long-term

 In general, all these little variations observed between the calibrated IRF and the estimated shows the the fit of the estimated coefficients as they are best set of coefficients that are found to pass the stringent test and enable the model to behave as expected.

However, the analyses on the responses of the endogenous variables to oil sector productivity shocks are similar with that of the calibrated model in 3.5.1 except the for the real exchange rate as discussed.

Figure 13: Tradeable oil sector productivity shock

5.4.2 Response to Non-oil Sector Productivity Shock

The IRFs to non-oil sector productivity shock of estimated model (Figure 17) below responds in the same direction but at different magnitude with that of calibrated model (Figure 9), therefore all the explanation of the response to non-oil sector productivity remains the same with that of calibration in 3.5.2, A dampened effect is observed as the IRFs rose higher than that of calibrated IRFs. For instance, IRFs from the calibrated responded higher in consumption, real exchange rate, real interest rate, oil sector output and aggrgegate output while the corresponding IRFs from estimated model respond to the shock in a lesser rate.

Figure 14: Impulse Response Function for Non-Oil Sector Productivity shock
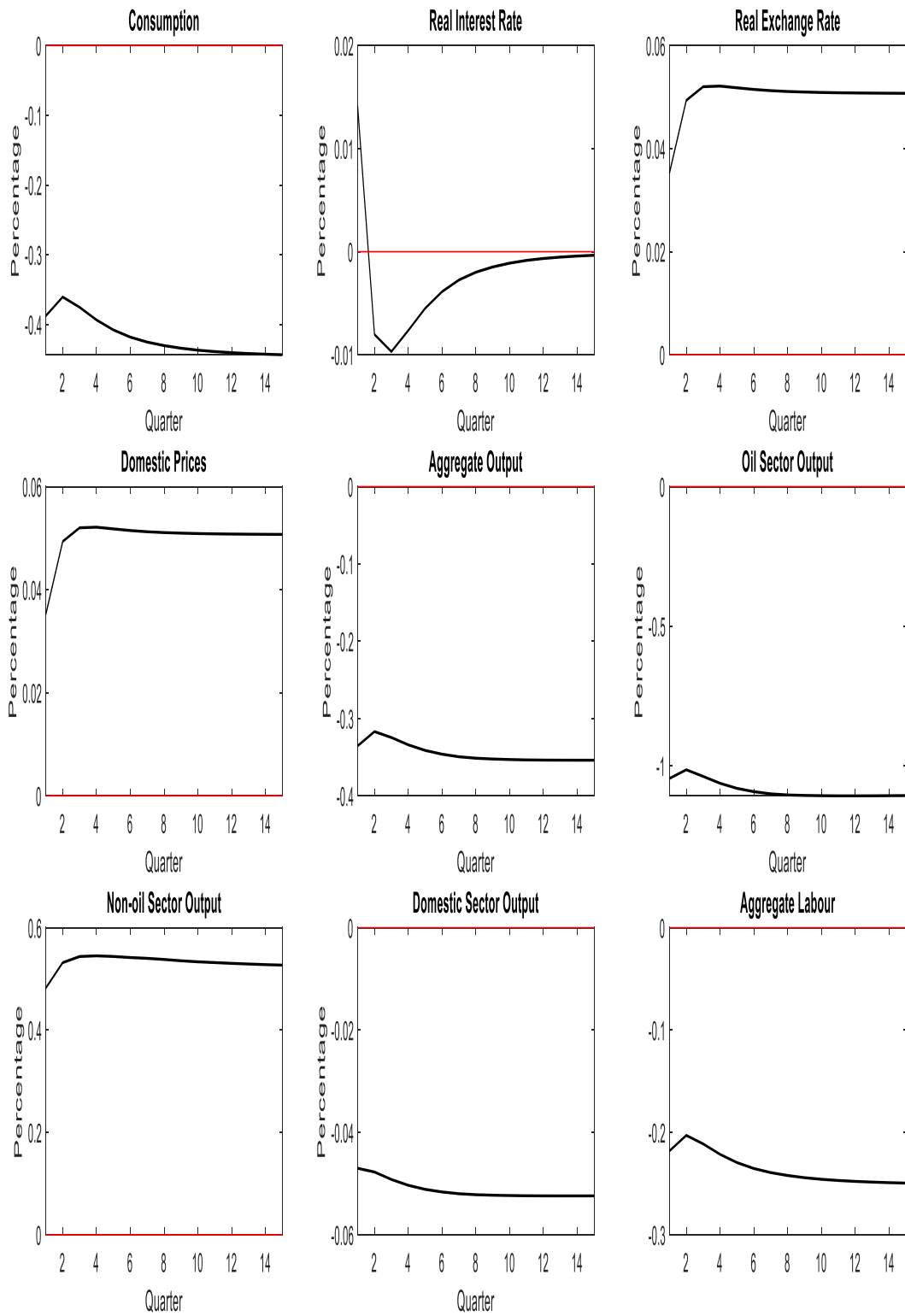
5.4.3 Response to Non-tradable Sector

The IRFs to domestic sector productivity shocks from the estimated model also similar to the corresponding IRFs from the calibrated model except the behaviour of real exchange rate that responds negatively after initial rise suggesting appreciation of the domestic currency as the domestic production increased significantly higher than the aggregate consumption in the economy, hence need for imports decline. While in the calibrated model IRFs the real exchange rate depreciated insignificantly and became persistent even after 15 quarters, thus appreciation process takes longer time. Hence, the estimated coefficients perhaps fit the model unlike the calibrated values that failed the test and didn't fit the model.

## Figure 15: Impulse Response Function for Domestic sector productivity shock
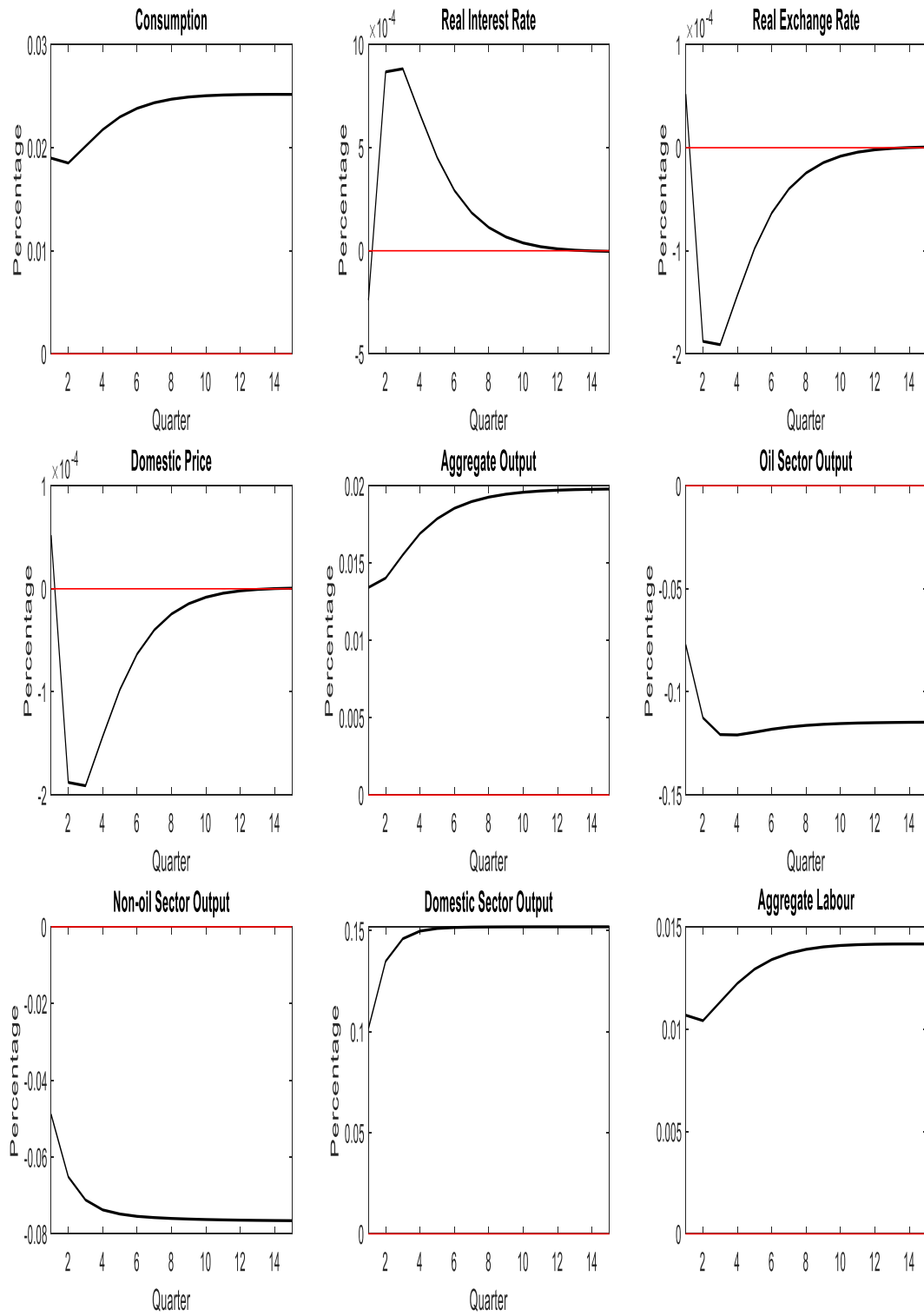
5.4.4 Response to Oil Price Shock

Oil price shocks for the estimated model generates IRFs that differs from the IRFs generated from the calibrated model, in three perspectives. Firstly, the real exchange rate in the estimated model depreciated in response to the shock suggesting absence of widely acknowledged Dutch diseases syndrome often associated with oil and other commodity exporting countries. This is contrary to the calibrated model response of real exchange rate that appreciated (figure 11) and suggests the existence of the Dutch disease. The rise in the real exchange rate is explained by high variance of estimated value of preferences for domestic good (ϑ) which decreased by about 76.35 percent from its initial calibrated value. The decrease suggests a fall in domestic consumers tendencies of allocating higher weights on domestic goods and shift for a higher preference on imported goods. Hence, this trigger higher imports which in turn result to depreciation of domestic currency. This is further supported by the oil price shocks IRFs which shows that the depreciation is intensified by low response of aggregate output and domestic sector output compared to the rise in consumption level in the economy thereby creating supply gap and that lead to increase in imports which invariably cause a depreciation of the domestic currency. For instance, an increase in consumption by 1.4 percent and disproportionate rise in domestic output by 0.13 percent creates excess demand which led to a rise in domestic price. Unlike the corresponding calibrated model IRFs that showed a fall in domestic prices due to a rise in consumption by 1.8 per cent and lesser rise in domestic sector output by about 0.8 percent which is insufficient to clear the increased aggregate demand. Therefore, this could perhaps be the main reason why the IRFs from the estimated are inconclusive in explaining the presence of Dutch disease in Nigeria.

The estimated IRFs in comparison with the calibrated IRFs exhibited a dampened effect as it reduced the magnitude of the response of all the endogenous variables in response to the oil price shock as observed (figures 5.1 - 5.3).

## Figure 16: Impulse Response Function for Oil Price Shock
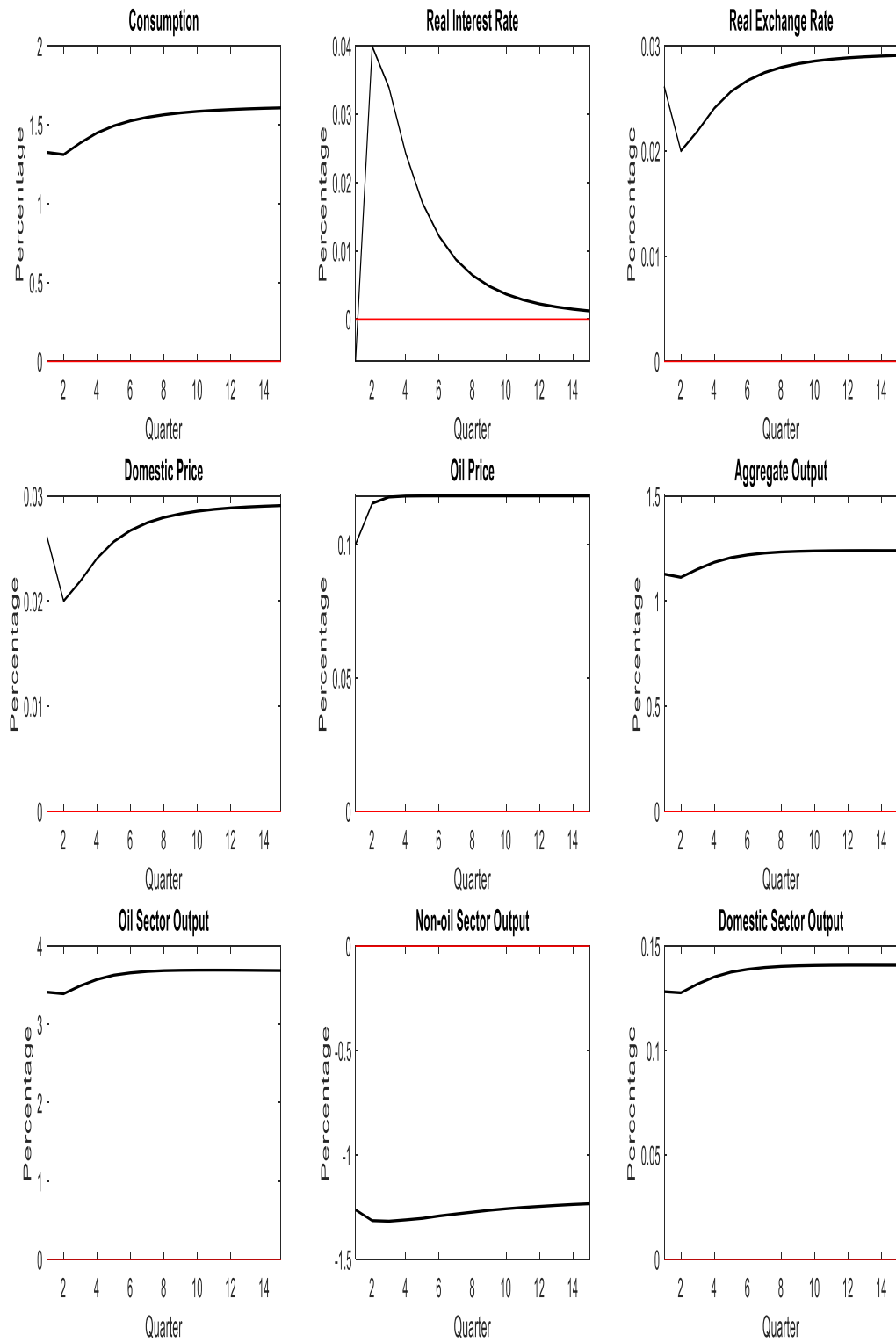
5.4.5 Other Impulse Responses

The impulse of response of non-stationary shocks to Consumption, Foreign interest rate, Capital oil sector, Capital non-oil sector, Capital domestic sector, aggregate labour, aggregate land, real wage rate are all generated, however, they are not discussed in this theses but full set of the remaining impulse responses are attached **in** the appendix 5 as they are not the focus of the study.

5.5 Error Properties

The estimated residuals are obtained from the structural errors of non-stationary data and estimated parameters. Thus, the model has twenty-four shocks from both endogenous and exogenous variables, for details on the model structural shocks see section 3.2. The endogenous shocks are residuals backed out of the structural model and all assume level stationary or trend stationary including the productivity shocks. The Figures that follow show the data, the residuals and the innovations after estimating residual processes.

Figure 17: Data
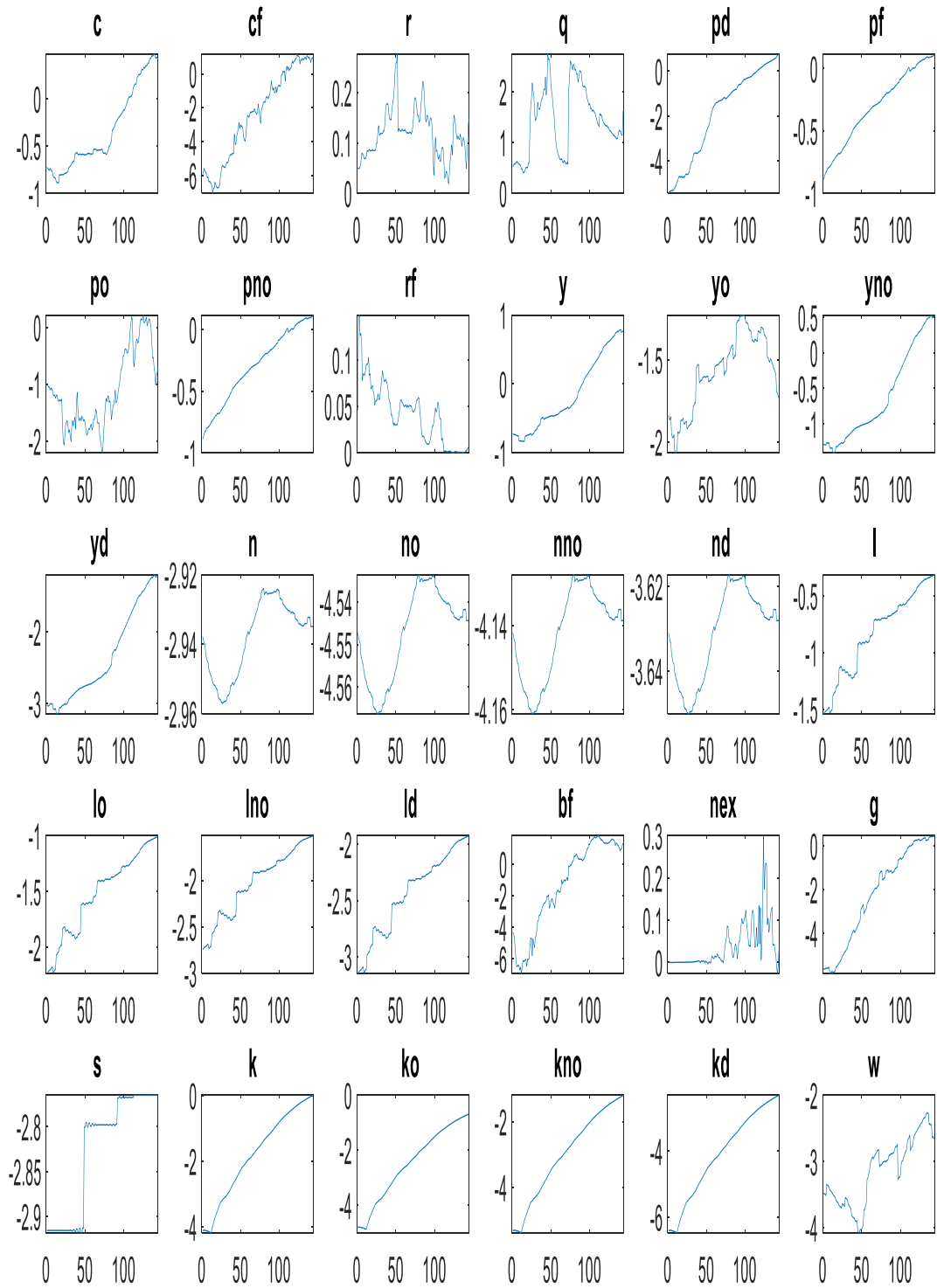
5.6 Estimating the Shock Processes

A stationarity test is conducted on the residuals and found in almost all cases strong evidence of non-stationarity, as shown in the following Table. Thus, this suggest that some or all these residual errors are non-stationary.

Table 9: ADF and KPSS coefficients on error processes

Shocks	KPSS	Conclusion
Non-oil Capital	0.763	Non-Stationary
Oil-Capital	0.869	Stationary
Domestic Capital	0.204	Non-stationary
Non-oil Output	0.102	Non-Stationary
Oil Output	1.05	Non-Stationary*
Domestic Output	0.901	Non-stationary
Labour	0.126	Stationary
Domestic Prices	0.119	Stationary
Consumption	0.186	Non-stationary
Land Rent	0.009	Non-stationary
Wages	0.241	Non-stationary

Note: The KPSS test statistic with ***, **, and* indicates a rejection stationary process at 10%, 5% and 1% level of significance

5.7 Policy Analysis

The failure of counter-cyclical automatic stabilisers to restore the economy to potential level during global financial crisis of 2008 has become a source of concern to policy makers and academicians. This necessitated the resurgence of countercyclical activist fiscal policy in United States, United Kingdom and some other developed countries after it was subdued for decades by the intriguing notion of Ricardian Equivalence Barro and Grossman (1974) which brought about scepticism about the effectiveness of fiscal policy. For instance, in the US the activist fiscal policy was implemented during and after the economic recession of 2008 inform of tax cuts, tax credit for first time home buyers, the "temporary cash for clunkers'' programme to enable the replacement of old cars with new ones, transfers to individuals and states among others. In the United Kingdom as well during the recession the policy makers pursued fiscal stimulus policies like temporary consumption tax rebate. On the other hand, developing countries responded to the recession through various fiscal policies for example in Nigeria government intervention programmes targeting individuals and states and local government inform of soft loan for small and medium enterprises, subsidy on agriculture among others.

Small open oil exporting countries[40] are often faced with extreme swings in the business cycle due to their dependence on oil exports which apparently has volatile price trend. In view of that, policy makers in these countries also explore additional discretionary government fiscal policy that are counter-cyclical and can assist to smoothen high fluctuations of the business cycle to return the economy to its potential level. Being a highly important player in the economy, government fiscal policy decisions can influence aggregate demand directly and indirectly affect net exports. Fiscal policy does not only affect aggregate demand in short, but it is often argued that it affects supply side of the economy. For instance, tax rule is crucial in investment decision, labour supply and intertemporal substitution of consumption. Furthermore, government spending on infrastructure, subsidy on agriculture, education and health can affect labour productivity[41]. Therefore, this chapter modifies the specification of government spending in chapter 3, to enable government policy decision in response to variance of output growth. Basically, this model assume that government can put in countercyclical policy coefficient "eta" such that government spending responds negatively to output growth, therefore if output growth is high government spending will

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[40] Small open oil exporting economies referred in this work are basically OPEC members but does not include oil exporting countries like Russia and Sweden.

[41] The effectiveness of tax cut, government spending and other fiscal policy measures aimed at creating boom in an economy are negated by Ricardian Equivalence who asserted that rational forward household consumption decision and aggregate demand are not influenced by government spending.

decrease and in the period of low output growth government spending increases. The increase in government spending could be in the form of government subsidy, intervention programmes, investment in research and innovation, tax credit, trader money[42], SMEs, and other governmental polices. However, in the confines of this model we proxy all these interventions in the form of a change in government spending.

The proposed fiscal policy tool work in such a way that "eta" measures how much government spending reacts to output growth. Thus, government spending increases if the growth rate is lower and decreases during the period of higher growth rate, as stated above, if we assume that government spending is more when the perceived growth rate is low then government expenditure increases while the eta would give us an insight on the extent of reaction of government spending to output growth

In carrying out fiscal policy analysis, government expenditure shocks in equation (3.59) is re-specified to include a policy parameter that could guide policy makers on the extent of interaction between government spending and output growth rate. Therefore, since the policy aims at minimising the deviation in the growth rate then the equation is re-presented as follows:

A policy coefficient η is introduced and equation (3.59) is rewritten as:

$$lnG_t = \rho GlnG_{t-1} - \eta(y(-1) - y(-2)) + \varepsilon_{g,t} \tag{5.6.1}$$

Where $y(-1)\ and\ y(-2)$ denoted previous period one and two, and η is coefficient of government fiscal policy equation.

5.7.1 Fiscal Policy Scenario Analysis

This section analyses various values of policy coefficient 'eta' in response to output growth. The policy coefficient is measure of the extent of government spending in response to deviation in the growth rate. The logic for using growth rate is because during extreme swings in business cycle output growth rate tend to deviate, therefore, the policy makers need to have a tool that they can twist to reduce the deviation. Hence, attainment of low output growth deviation required raising the policy coefficient. In this experiment the variation in output growth is measured by deviation of output growth from its natural growth rate, it can be described as a measure of how far from trend output is. As the values desired its trend the variation level decreases. In other word, if the variation of output growth rate moves towards steady state it shows that the output in the economy increases,

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therefore, the fiscal policy makers need not to increase "eta" as it is driven mainly by business cycle to desired level. On the other hand, if output variation moves far away from desired steady state it signifies a decrease in output from its potential level and that require a higher increase of "eta" by the policy makers to restore the output growth rate to its trend level. Similarly, the policy coefficients are generated by bootstrapping simulation that searched for the best values of eta that minimises the corresponding variation in output growth.

The scenario experiment as displayed in figure 20 below indicates the influence of policy coefficient (eta) in reducing the deviation of output growth rate, over a period. As policy coefficient increases the deviation of output growth became less, conversely, as eta decreases the output growth variation increases. Thus, in this experiment the model searched for the best respective values of policy coefficient (eta) required for corresponding level of growth rate. The average policy coefficient stood at 2 percent when average variance of output growth was 1.04 percent.

Furthermore, when the values for fiscal policy variable (eta) was 1.9 percent, output growth rate variation was at its lowest point of 1.06 percent, meaning that the policy makers apply higher fiscal stimulus of about 2 percent to decrease the deviation to a minimum level. Similarly, when fiscal policy coefficient eta decreases from 0.9 and 0.6 percent the corresponding growth rate deviation increased to 1.96 and 3.64 percent respectively. And when the eta dropped to 0.5 percent the growth rates variation reached its peak of 5.24 percent.

The policy variable plays a significant role in reducing high swing in output growth rate. This finding reveals that as policy coefficient decreases the output growth rate deviation increases.

Figure 22: Fiscal Policy Scenario Analysis

FISCAL POLICY SCENARIO ANALYSIS
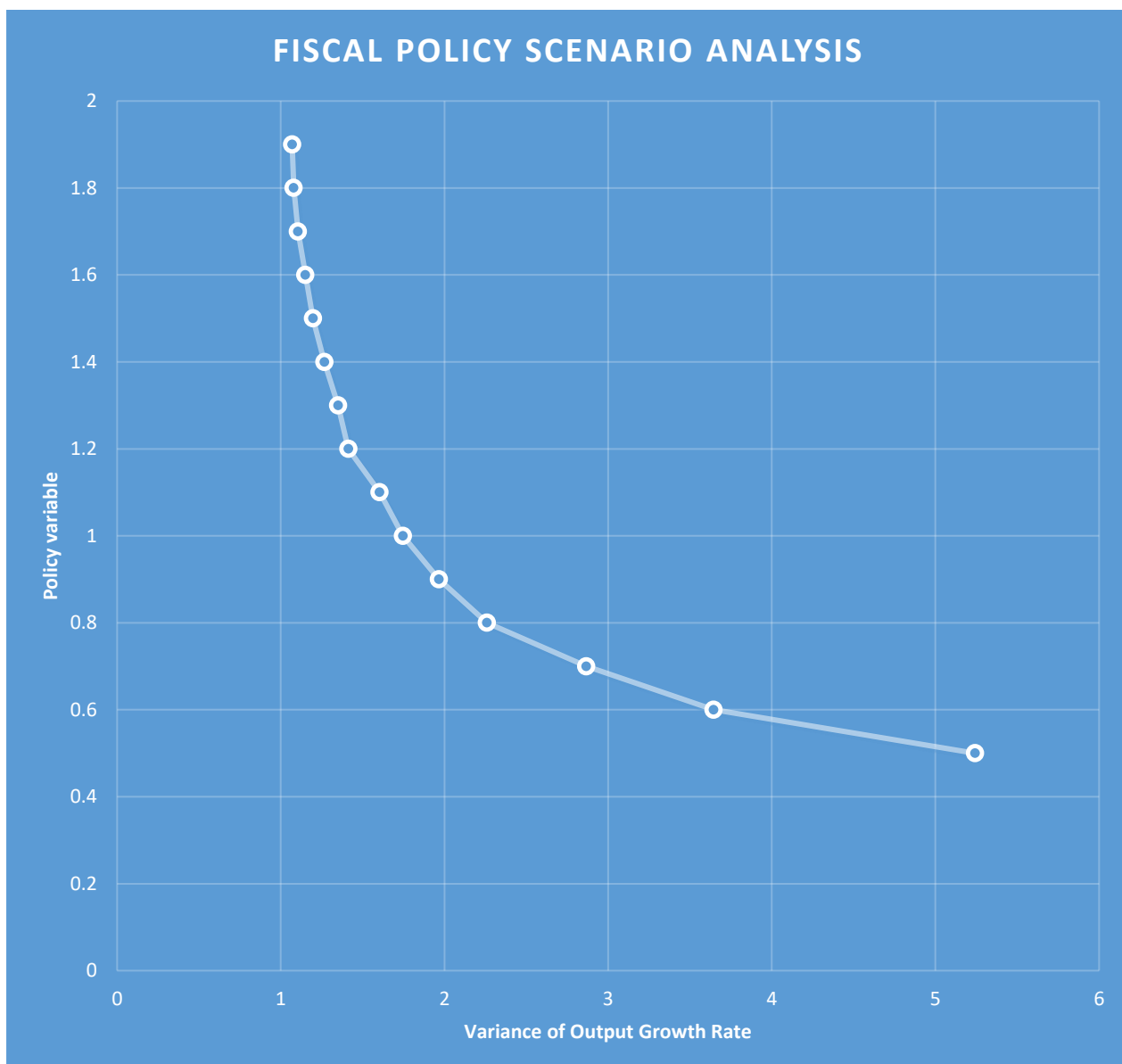
It could be argued that the value of eta and the variance of output are negative elements of cost function of a sort:

$$C = (\eta - \alpha)^2 + (\sigma^2 - \beta)^2$$

Here σ^2 is the variance of output growth. An increase in the response to output growth by the government spending is not costless as it reflects the scale and scope of response. The main effect is basically a rise in fiscal deficit which is financed either through money creation or debt issuance.

Conventional monetary policy postulates that an increase in government spending financed entirely through money creation will have inflationary consequences on the economy. This is based on the fear that it would lead to monetary expansion as implied in the link by quantity theory of money Friedman (1989) illustrated in Lucas (1980 p.1) "That a given change in the rate of change in

quantity of money will induces an equal rate in rate of inflation and an equal change in nominal interest rate". On the other hand, increased government spending financed through debt borrowing could further rises the stock of government debt, creates larger debt-GDP ratio and perhaps trigger the possibility of debt crisis in the economy. Therefore, the cost of increasing could be high, however, it is argued that "if the steady state is sufficiently inefficient, an increase in government purchases may increase welfare even if spending is wasteful" Gali (2014).

The optimal response of government therefore not unconditional even though in general it is considered as welfare enhancing. Figure 21 illustrates welfare maximising (cost minimising) combination. The ideal point as indicated in the below figure 21 is the optimal point where there is no variance of output growth and equally change in government policy variable is zero.

Figure 23: Welfare Maximising (Cost Minimising) Combination

Policy Variable (eta)

Cost

The Ideal point

Variance of output growth
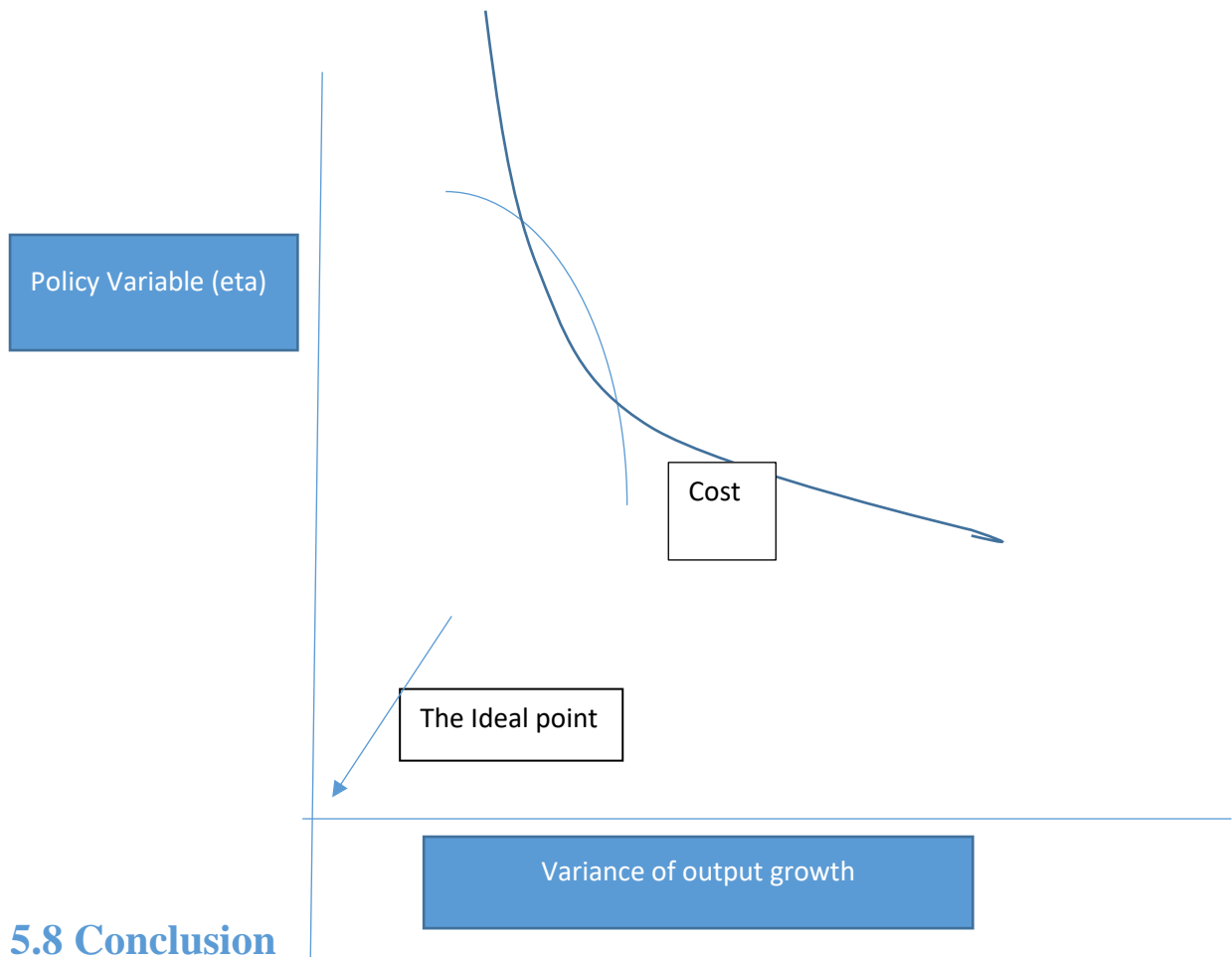
5.8 Conclusion

This section has estimated the model developed in section 3 using indirect inference estimation method, to find the best set of coefficients that fits the model. The model was re-estimated using the new sets of estimated coefficients and tested using indirect inference Wald test. The result of

the test indicated that the model has pass with a Wald statistic of 1.52. Using the estimated parameter values, impulse response functions were generated and compared with the impulse response functions from the calibrated model. To greater extent, the impulse response of the estimated models are similar with that of estimated model, particularly, the direction as expected. However, there are number of discrepancies or anomalies observed: Firstly, IRFs from the estimated model showed that oil price shock raises real exchange rate (depreciation) implying no definitive results on the existence of Dutch disease syndrome as established in IRFs from the calibrated model. Secondly, Domestic price respond positively to oil price shock in the IRFs of estimated model, this is due to small increase in domestic sector output and higher increase in consumption, therefore domestic prices increased accordingly. On the other hand, Domestic price responds negatively to oil price shock in the IRFs of calibrated model mainly because the rise in the consumption is higher than the supply of domestic sector output. This conflicting issue is one of the critical issues that would be looked at in further work. Thirdly, the estimated model's impulse response functions revealed a dampened effect on response of all the endogenous variables to the three productivity shocks and oil price shocks compared to the IRFs of calibrated model that amplifies the response.

However, in general as expected, strong similarity between the two IRFs is established and this justifies that the calibrated model possessed all the requisite properties to explain output productivity shock, oil price shock and other relevant shocks. Also, the estimated model proved to have better coefficients and fit as it generates best coefficients that pass the test and dampened the shock effect.

The last part of the section introduced policy into the model due to the in ability of counter-cyclical automatic inbuilt adjusting mechanism to restore the economy to its trend when it deviates. This has become a source of concern to policy makers and academicians in both developed and developing economies which necessitated the resurgence of countercyclical activist fiscal policy in United States, United Kingdom and some other developed countries. In view of this development, having satisfied fits the data properly, Government fiscal equation is modified to include countercyclical fiscal policy coefficient 'eta' that influences the deviation of output growth rate. The coefficient 'eta' is policy coefficient that measure the extent of government spending in response to deviation in the growth rate. Therefore, with the increase in the value of the coefficient eta when the deviation of output growth rate is high, means increase in government spending (intervention in critical real sector of the economy that directly affect production process, increase funding of health, education, agricultural subsidy) which increase output and reduce the deviation

of growth rate observed. The experiment result indicates that as deviation of output growth rate increases it requires corresponding higher fiscal stimulus to increase output growth thereby smoothen or reduce the variation. However, this comes with cost of rise in inflation if financed through money creation, and the consequences could be more damaging if financed through government borrowing as it could trigger debt crisis.

6. Summary of findings and Concluding Remarks

6.1 Introduction

This chapter provide a summary of all the results obtained in the thesis. Section 6.2 presented the model developed and calibrated, Section 6.3 Analyses and compare the impulse response functions (IRFs) of calibrated with the impulse response function of estimated model. Summary of the empirical findings from the policy experiments and its relevance to Nigerian economy is presented in section 6.4. Possible ways of future research are discussed in section 6.5, while conclusion of the chapter forms 6.6.

6.2 The Model developed for Nigeria

In this section I developed a Real Business Cycle model of a small open economy with tradeable and non-tradable sector. The model is in line of Kydland and Prescott (1982), Long and Plosser (1983) and Kose (2002), it is a multi-sector model for Nigeria that clearly disaggregate the tradable sector into oil and non-oil sectors, with domestic sector on the other hand to enable the model analyse the respond of sectoral productivity shocks and oil price shocks. In general, the model focus on the behaviour of the real sector in response to the oil price change and volatility in output. The model is driven mainly by market forces, it has been calibrated and generates impulse response functions that behaves as expected, and furthermore, it possessed and display all the properties of the standard real business cycle model. It indicates that the economy is heavily affected both in size and structure by productivity shocks to its oil, non-oil-traded, and domestic (non-traded) sector; also, by oil price shocks and oil capital shocks which have been highly volatile. Hence, the model will help tremendously, in explaining the behaviour of the Nigerian economy in response to real shocks using a general equilibrium multi-sector model. Consistent with Benkhodja (2011), Mahmud (2009) , the impulse response functions from the calibrated model reveals as expected that there is a Dutch Disease effect, suggesting that the discovery of oil has led to a substantial reduction in the size of the tradeable non-oil sector while boosting the non-traded sector.

6.3 Comparison of IRFs of Calibrated and Estimated Models

The model has been estimated using Indirect Inference Method which minimises the distance between a set of coefficients from the auxiliary model based on the model simulated data and observed data. The result of the estimated model exhibits a dampened effect on the response of endogenous variables to oil sector productivity shock, non-oil sector productivity shock and domestic sector productivity shock as well as oil price shock. The estimated model fit the data as it passes the stringent indirect inference test. Although, the IRFs of the estimated model is inconclusive about the existence of Dutch disease syndrome in Nigeria, However, the model could be used for policy analysis considering that it found the best set of parameter estimates that matched the Nigerian data and hence the model can replicate the features of the Nigerian economy. Therefore, one could ask if fiscal policy could stabilise the dynamic path of these shocks? Plainly while there is Ricardian equivalence which negates any effect by tax changes, public spending could be varied as a stabilisation tool. Furthermore, public spending itself is done in satisfaction of private agents' needs; therefore, changing its timing could worsen the satisfaction of those needs if the original timing was optimal.

However, these dynamic paths reflect private agents' optimising choices in response to shocks, whether temporary or permanent; distortions would need to be identified to justify government action. Therefore, the answer could be yes, considering that the automatic inbuilt adjusting mechanism failed to restore the economy during and after extreme swing of business cycle, a typical example for that is during the 2008 global financial crisis. This has raised concerns among policy makers and academicians and that brought about resurgence of countercyclical activist fiscal policy and unconventional monetary policies in United States, United Kingdom and some other developed countries after it was subdued for decades by the intriguing notion of Ricardian Equivalence which to some extent overstated scepticism about the effectiveness of fiscal policy.

6.4 Summary of Policy Experiment

Having accepted that the fiscal policy could stabilise the dynamic path of these shocks, in this section we relaxed the assumption of automatic stabilisers and modified the model to capture the impact of a policy variable (eta) which serve as a proxy for public spending in Nigeria.

Generally, the role of eta would even be more relevant to small open oil exporting countries for two reasons firstly; these countries are mainly developing economies operating at less than full capacity, thus, the absorptive capacity of these economies is not stretched. In other word, there are scope for expansion in an event of deviation of output growth rate from its potential without distorting other sectors of the economy. Secondly; these countries are often faced with extreme swing in business cycle due to their dependence on oil exports or other commodities which apparently have volatile price trend. In view of that, the inclusion of policy coefficient "eta" would enable policy makers explore additional discretionary government fiscal policy that are counter-cyclical and can assist in smoothening high fluctuations of the business cycle and subsequently return the economy to its potential level.

The modified model as fully discussed in Chapter 5 above was estimated to generate series of simulated variance of output growth variation and their corresponding policy coefficients values from a thousand of bootstrapping simulations carried out in the process. The modification expressed the growth rate of output as a function of policy coefficient "eta".

The result of the policy experiment indicates that an increase in the value of policy coefficient "eta" reduces the deviation of output growth rate, though it comes some cost which could be minimise. This suggest that a rise in "eta" (government spending) will smoothen output growth rate in Nigeria. The findings of the policy model is consistent with arguments put forward by   Auerbach et al.

(2010) and Galí (2014) on the efficacy of government interventions amidst turbulence period in an economy.

To the best of my knowledge this thesis is the first empirical study using small open economy model to estimate values of policy coefficients that could reduce the variation of output growth rate in Nigeria. Therefore, this study would guide the policy makers in the conducting countercyclical fiscal policy and improve welfare of Nigerian citizens.

Apparently, the finding is plausible as regards to Nigerian economy because the economy is operating at less than full employment with huge idle labour. Hence, increase in public spending on real sector of the economy will drive output and spur economic growth if the increase spending is channelled to real the sector of the economy that directly affect production process. It could as well be utilised in sectors that indirectly affects output however, these should be strictly to sectors that could affect labour productivity and in turn stimulates economic growth. Such sectors may include, health sector, education sector, and research and innovations. Public spending on these sectors will certainly enhance human capital development, raising labour productivity and ultimately increase output in the economy.

Presently, in Nigeria productivity of labour in the predominant agricultural sector is very low, this is attributed to the subsistence nature of the agriculture being practice with less meaningful value added. The agricultural sector though contributes higher to the total output of Nigeria compared to the oil sector, yet its contribution to aggregate output is decreasing with attendant effect on more unemployment and further decline in aggregate output. Therefore, more intervention programmes that will impact on the farmers productivity should be intensified[43]. Without undermining the relevance and the need for further intervention in agricultural sector of the Nigerian economy, it is highly important to transform the economic base from agriculture to manufacturing sector after several attempt by past administrations to transform the structure of the economy has failed or not implemented properly. This transformation entails about a structural shift to manufacturing sector as engine of growth. With very large population and prospects for market, if the manufacturing sector is boosted the economy stands a better chance of creating more employment, reducing dependence on import goods, promote technological development, increase private consumption and ultimately increase the aggregate output. However, this could only be feasible if public

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[43] Since the return of democracy there are numerous programmes introduce to assist the farmers to increase production but unfortunately the beneficiaries of most of this programmes are not the real vulnerable farmers, however Anchor Borrowers programme has to some extent gets to the target farmers but the programme has a lot of problems that need to be addressed which is outside the scope of the this thesis.

spending are properly utilised in providing infrastructural facilities in the economy[44] and upgrading the security system, as well as intensifying efforts in the fight against corruption. If those structures are provided, it will hopefully change present pattern of capital inflow into Nigeria from foreign portfolio to foreign direct investment which create more employment and further increase production in the economy. It will change the economy from a net importer (dumping ground for Chinese goods) to a net exporter of non-oil tradable goods.

Although, monetary sector policy makers may argue that increase in public spending may further increase excess liquidity that is already prevalent in the Nigerian banking system and eventually lead to inflation. On the contrary, public spending in real sector of developing economy if not diverted and if utilised efficiently will not be inflationary but rather deflationary in the long run, this is because with the boost in domestic sector production the supply may eventually exceeds the demand and dampened domestic prices.

6.5 Future Research

Although the Nigerian model developed in this thesis has performed wonderfully, passes the indirect inference test which is regarded as highly strict test and was applied in policy analysis to obtain best values of policy coefficients that could smoothen output variation in Nigeria. Nevertheless, this could be the beginning of the process as the model assumption could be varied countercyclical fiscal policy   mimic the behaviour of the Nigerian economy , however the model was based on so many assumptions as discussed thoroughly in chapter three, therefore should such assumptions be changed the findings may as well change. For instance, relaxing the assumption of flexible price and flexible wages would provide an avenue for introducing imperfect competition together with wage rigidity and sticky prices as in Calvo staggered prices. With this new assumption the performance of the model may change in respect to increase in aggregate demand externality due to increase in output which will in turn rise the profit and income. Consequently, the rise in profit and income will offset the negative wealth effect. Therefore, the response of the macroeconomic variables may be higher if flexible price assumption is drop and substituted with sticky prices. Hence, if the response of output is higher it will reduce the variation in output growth rate and the government policy intervention variable need no rise meaning the welfare will increase at less cost to the economy.

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[44] There were attempt by various regimes to create an enabling environment for private sector to take over as a leading indicator of the economy but to no avail, see chapter one on overview of Nigerian economy.

One important realistic assumption that could be included in the model and may vary the results is the inclusion of co-existence of Ricardian and Non-Ricardian households as in Coenen and Straub (2004) and Gali (2004) respectively. The Nigerian model developed assumed that all the households are Ricardian as such they can smoothen their consumption, they are optimising and do not have constraints in borrowing. This assumption may be too broad for developing economy where the majority of the households are and could not be able to smoothen their consumption like the Ricardian as some have to resort to borrowing for consumption and many are liquidity constraint Therefore, it could be possible that with the inclusion of Non-Ricardian households may reduce the level of consumption and in-turn requires more government intervention which as earlier stated comes with cost. Therefore, perhaps with the inclusion of Non-Ricardian in the baseline model it may increase the policy variable "eta".

The model could be elaborated by introducing Habit Formation in Consumption as it has been suggested that for most developed country data consumption is better modelled with a degree of habit formation as introduced in the work of Mehra and Prescott (1985), Smets and Wouters (2007). Therefore, it would be introduced for developing economy if the data appear to require it.

Secondly, the model could be modified to generate more supply side shocks the economy for instance, labour supply shock and wage costs shock respectively.

Finally, the inconclusive findings on Dutch Disease would be re-visited.

6.6. Possible Constraints to Policy Effectiveness in Nigeria

With prevalence of peculiar structural and administrative constraints that the Nigerian economy is facing, the effectiveness of the policy decision suggested in the thesis could be impaired. Some of these challenges are as follows: Firstly, Corruption in Nigeria like most of the developing economy is seen as a bedrock for slow growth of these economies. It has directly exacerbated poverty level, increased inequality, created distortions in the economy and undermine long-run economic growth of Nigeria. Though corruption is encompassing but in this conclusion section, it is defined as policy makers use of public office for private gain. Corruption dissuade effectiveness of any economic policy in Nigeria through deep involvement of public servants in form of extortion, influence peddling, fraud, and embezzlement using their office to perpetuate the act. The level of corruption in Nigeria has reached its highest stage which I termed "crude corruption" an issue that affect the belief of most Nigeria on the possibility of having a good policy and governance that could work and transform the economy and restore it to sustainable growth path[45]. Therefore, as stated above,

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[45] Governance in Nigeria like in many developing economies is identified with well-known problem of governance.

the findings of these thesis could be implausible if implemented amidst high corruption in Nigeria. This is because government spending would not reach the targeted real sector or the real labour as highlighted above, but rather, it would be diverted to foreign accounts of these influential policy makers, politicians and other leaders creating second round effect of corruption. This was the case since the return of democratic governance which the citizens hoped would change the fate of the economy for better, after prolonged military regime of about three decades. For instance, the successive civilian administrations since 1999 have attempted to implement many programmes aimed at creating job, poverty reduction and increase output, with billions of Naira spent[46]: National Poverty Eradication Programme (NAPEP); Millennium Development Goal Programme (MDGP) ; Subsidy Reinvestment and Empowerment Programme (SURE-P) ; the Social Investment Programme (SIP) , under this programme there are Farmer Moni, a no-interest loan scheme for farmers, Market Moni and Trader-Moni and no-interest loan scheme for small scale traders and petty traders . Unfortunately, the budgeted billions of Naira were not designed to create more employments, rather they become an instrument to further syphon of public funds in the name of job creation and poverty eradication with very little to show-up. Secondly, there is an issue of administrative capacity to execute such policies, given the heavy information requirements these issues may well mandate, even if justified, thus, the policy makers need re-training and change in their value re-orientation.

6.7 Conclusion

This chapter presented a summary of the findings for all exercises carried out in the work. The thesis has focused on developing a model on how the Nigerian economy behaves in response to real shocks using a general equilibrium multi-sector model developed for Nigeria. The impulse response functions generated from the calibrated model reveals the existence of Dutch Disease syndrome in Nigeria. The model was estimated using indirect inference method of estimation and pass the stringent Wald test for matching the data behaviour. However, the empirical evidence from the estimated model is inconclusive about the Dutch Disease syndrome. The model was modified to introduce a fiscal policy variable "eta" which serve as proxy for government spending aimed at smoothening the variation in output growth. The policy model was estimated to generate series of simulated variance of output growth variation and their corresponding policy coefficients values from a thousand of bootstrapping simulations carried out in the process. A key finding from

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[46] All the mentioned programmes are schemes introduced by government in Nigeria from 2000- 2016 to reduce poverty level i.e. NAPEP, MDGP, SURE-P, SIP Farmers moni and Traders Moni.

my analysis indicates that an increase in the value of policy coefficient "eta" reduces the deviation of output growth rate, though it came with cost in form inflation if financed through seignorage, and more costly if policy makers decided to finance eta through new debt. However, if output growth rate deviate from its efficient level then increase in eta may raise welfare higher if the increase in eta is strictly on the real sector of the economy.

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Appendix 1: Calibrated Parameters Impulse Responses to Other Shocks
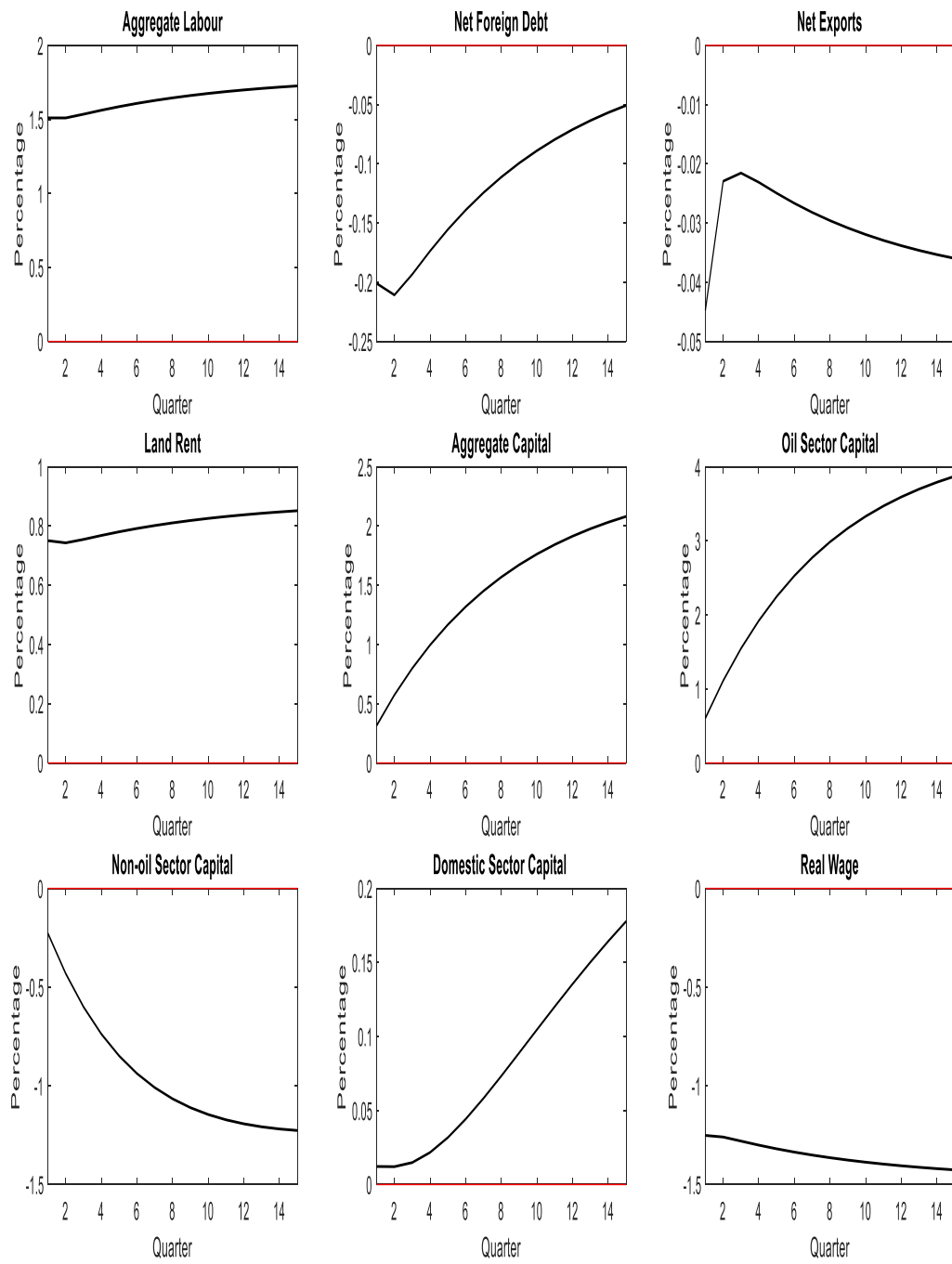
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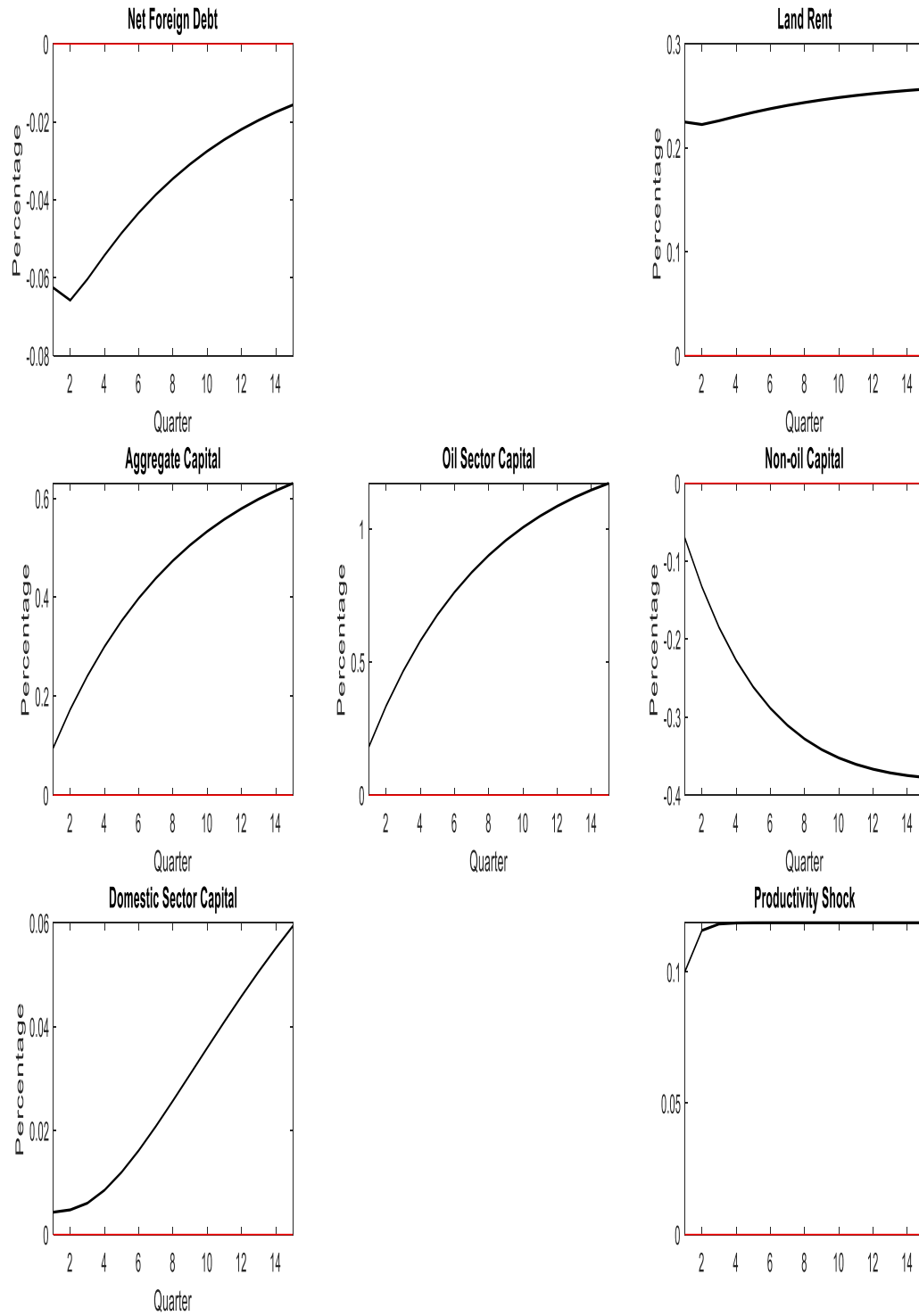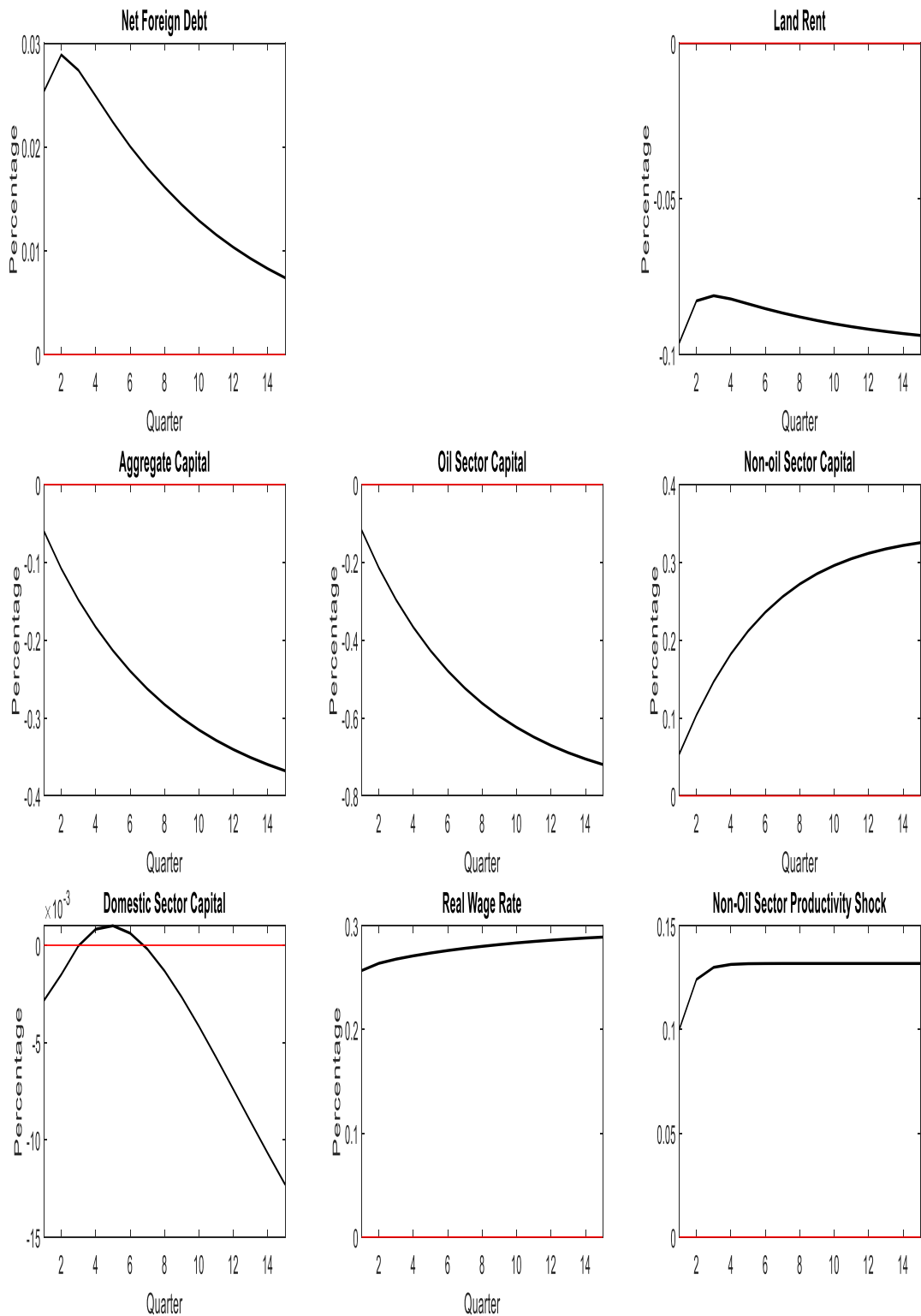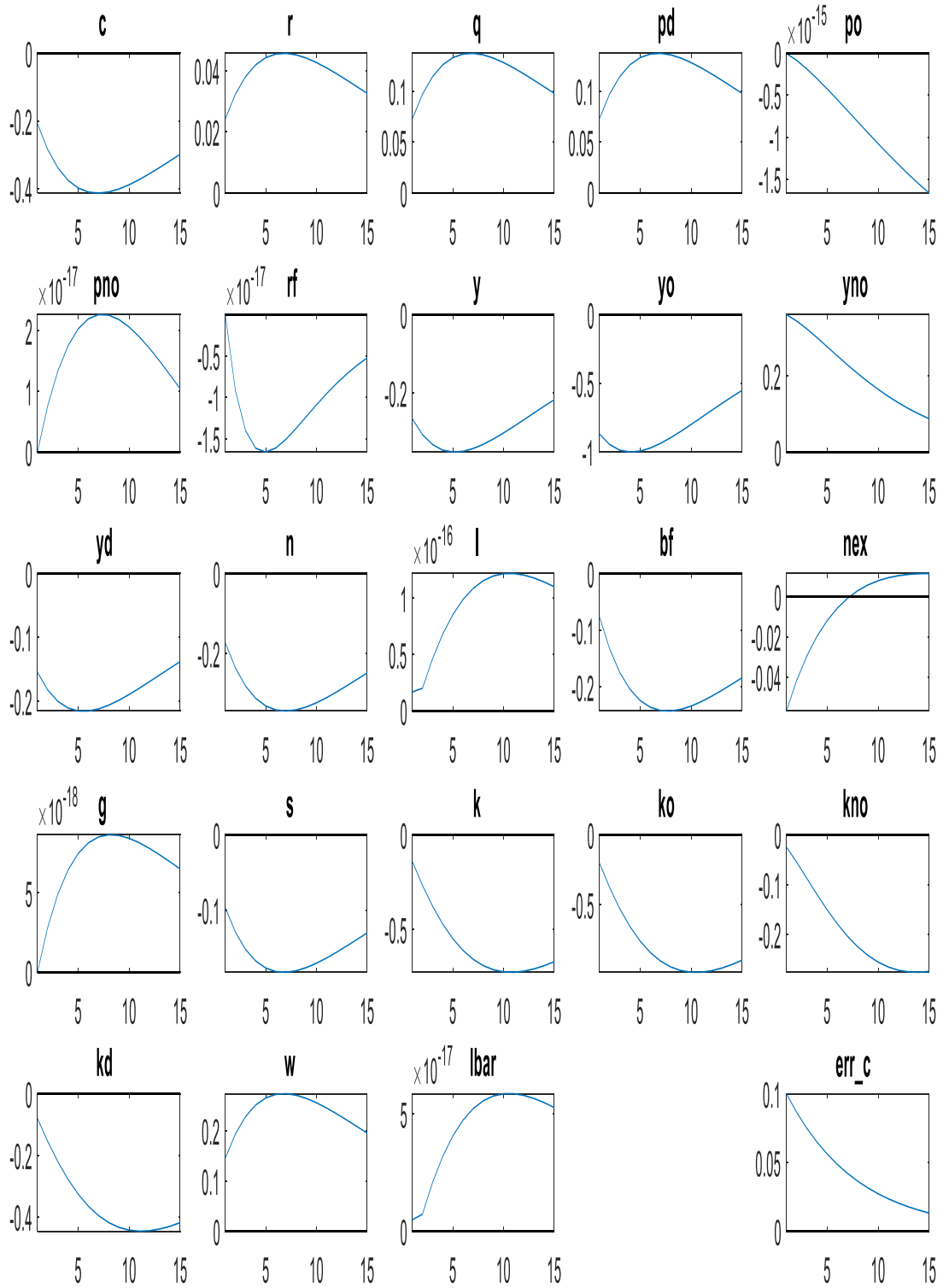
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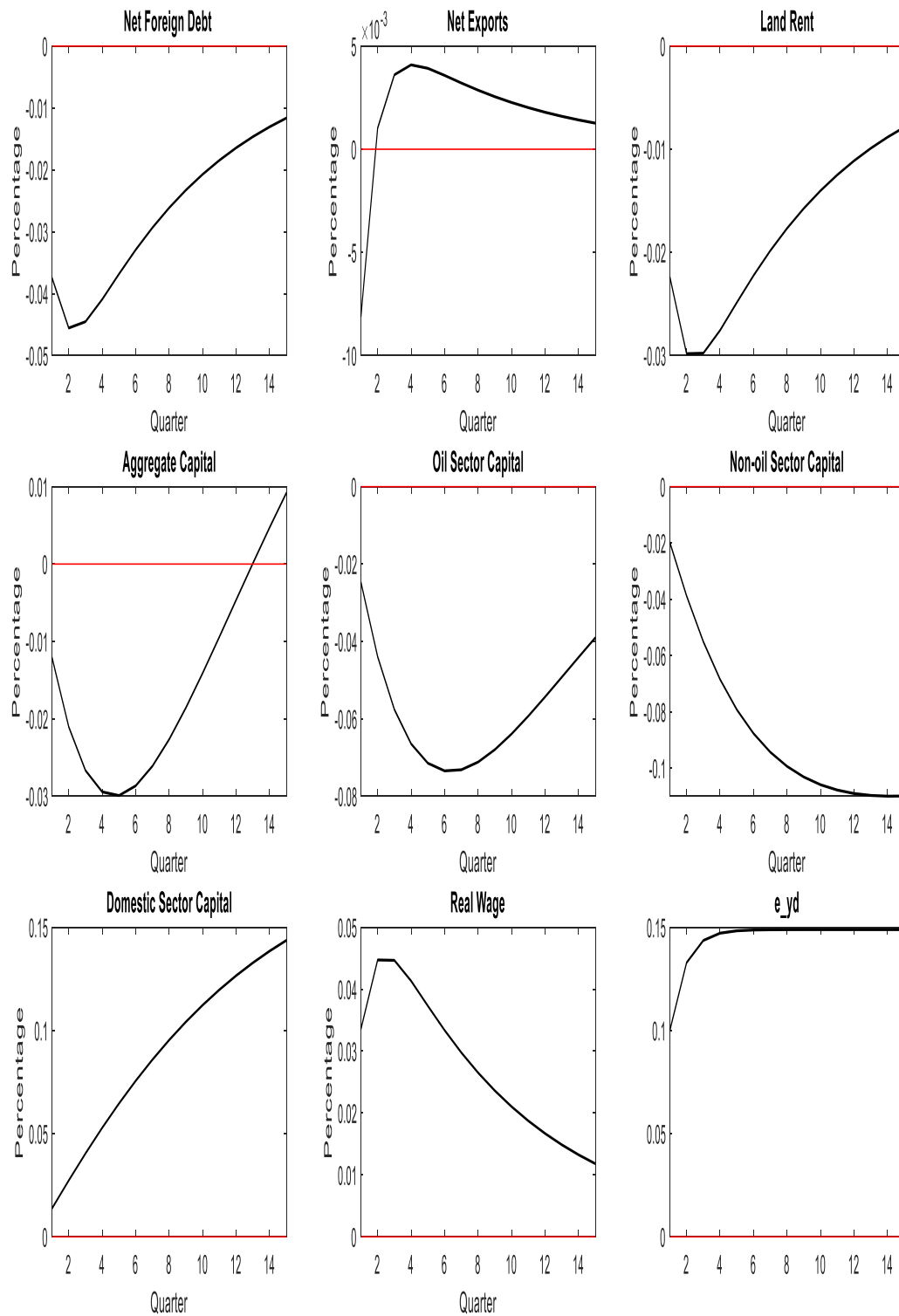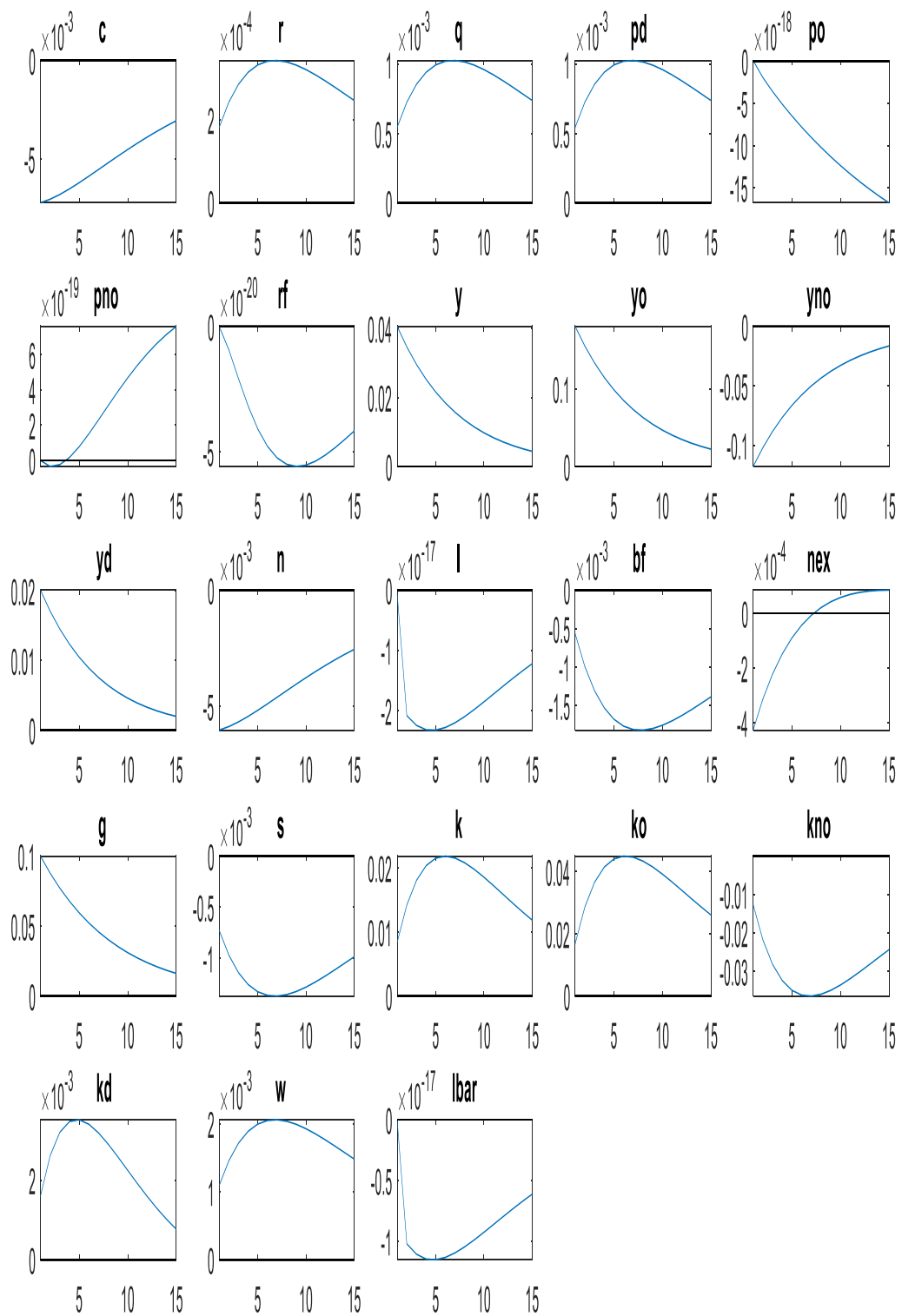
Consumption Shock
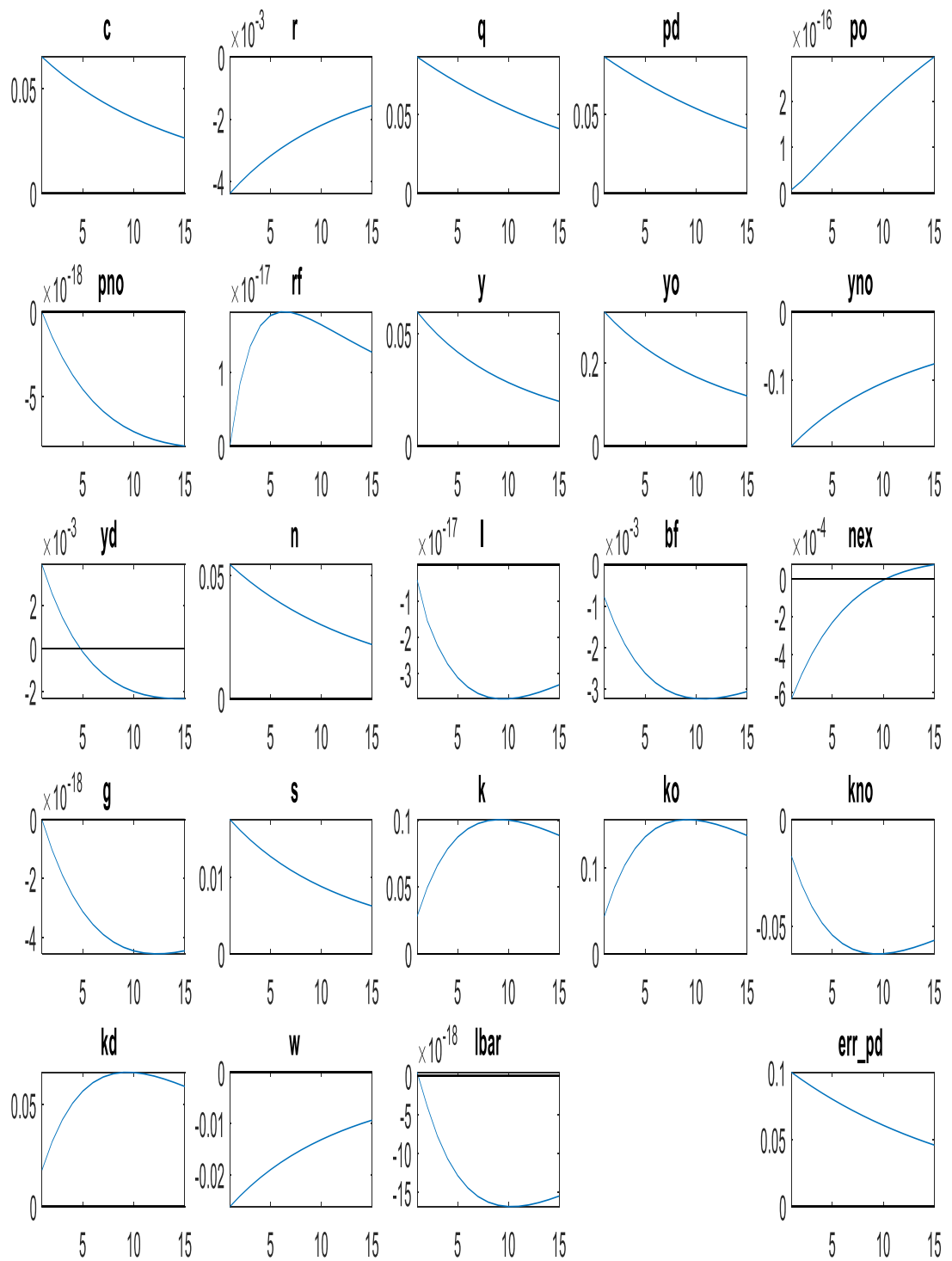
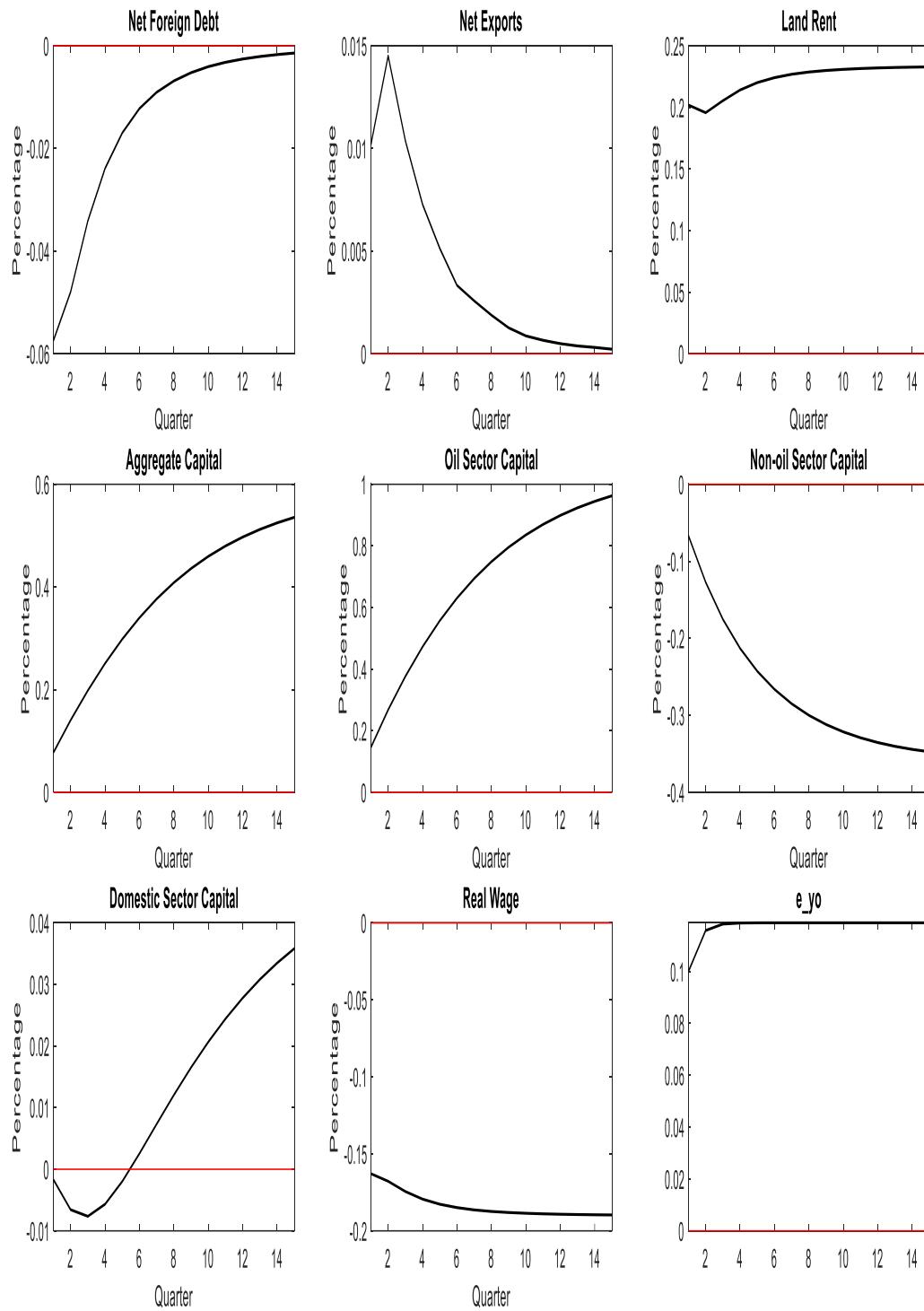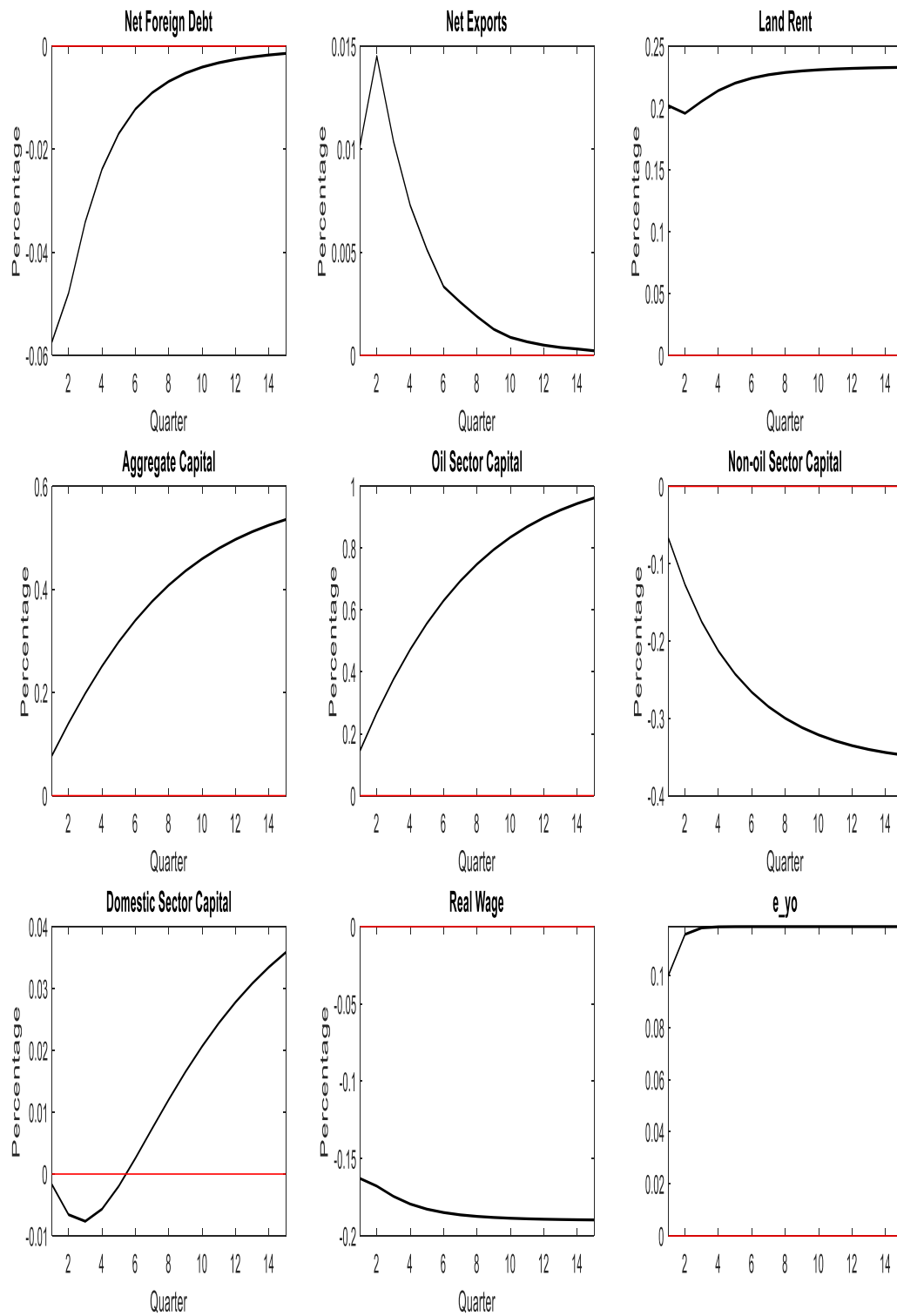Oil Sector Capital Shock
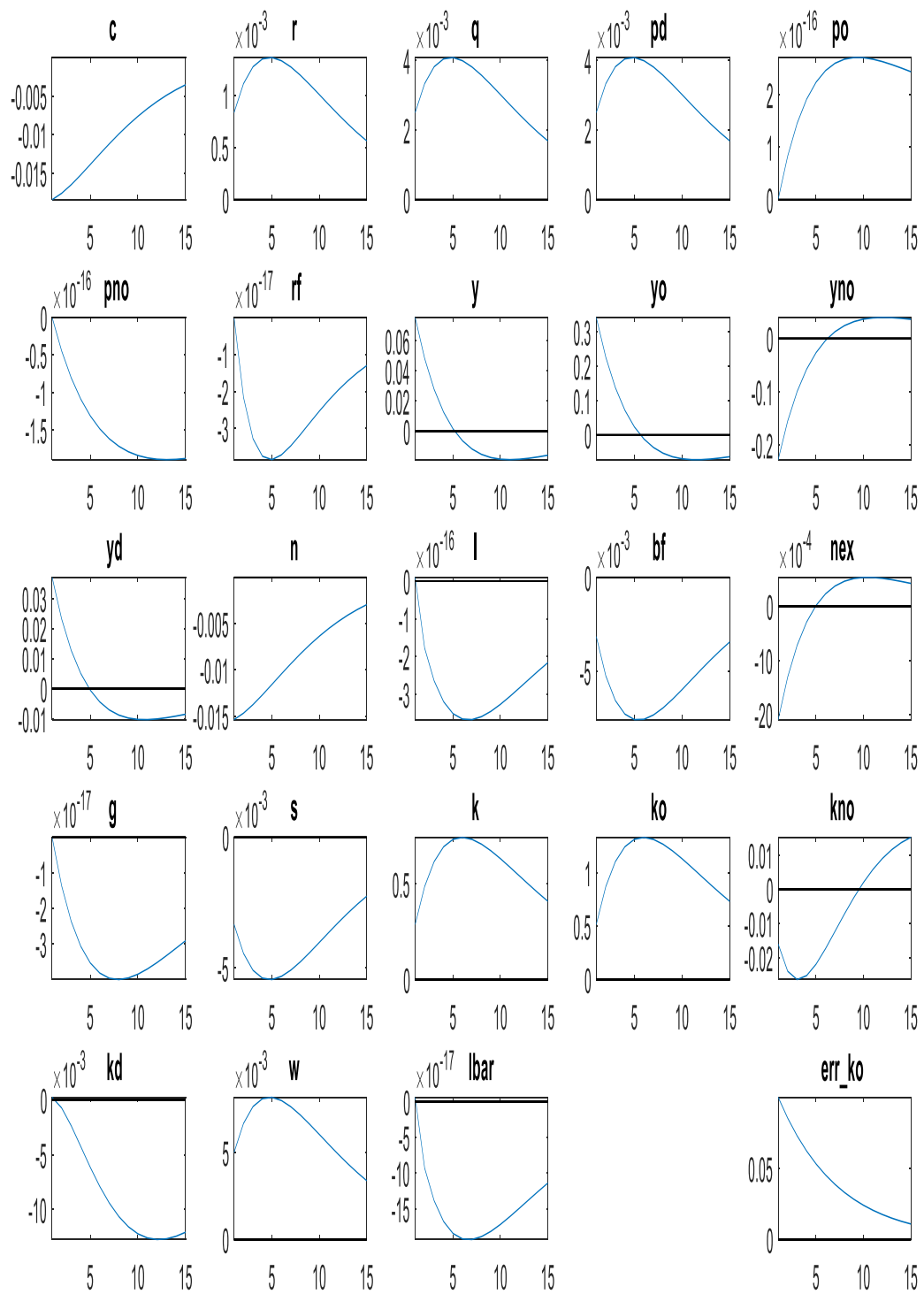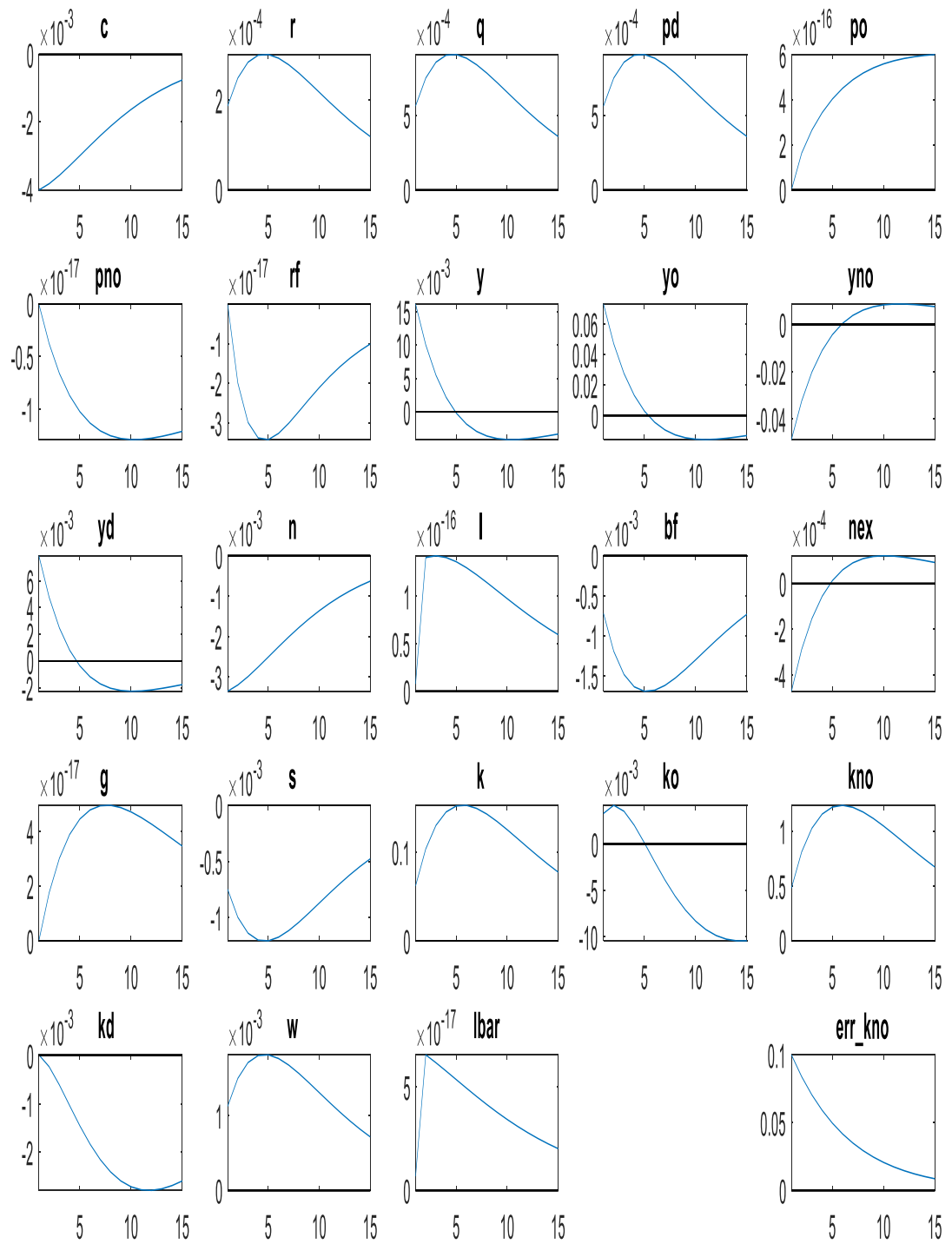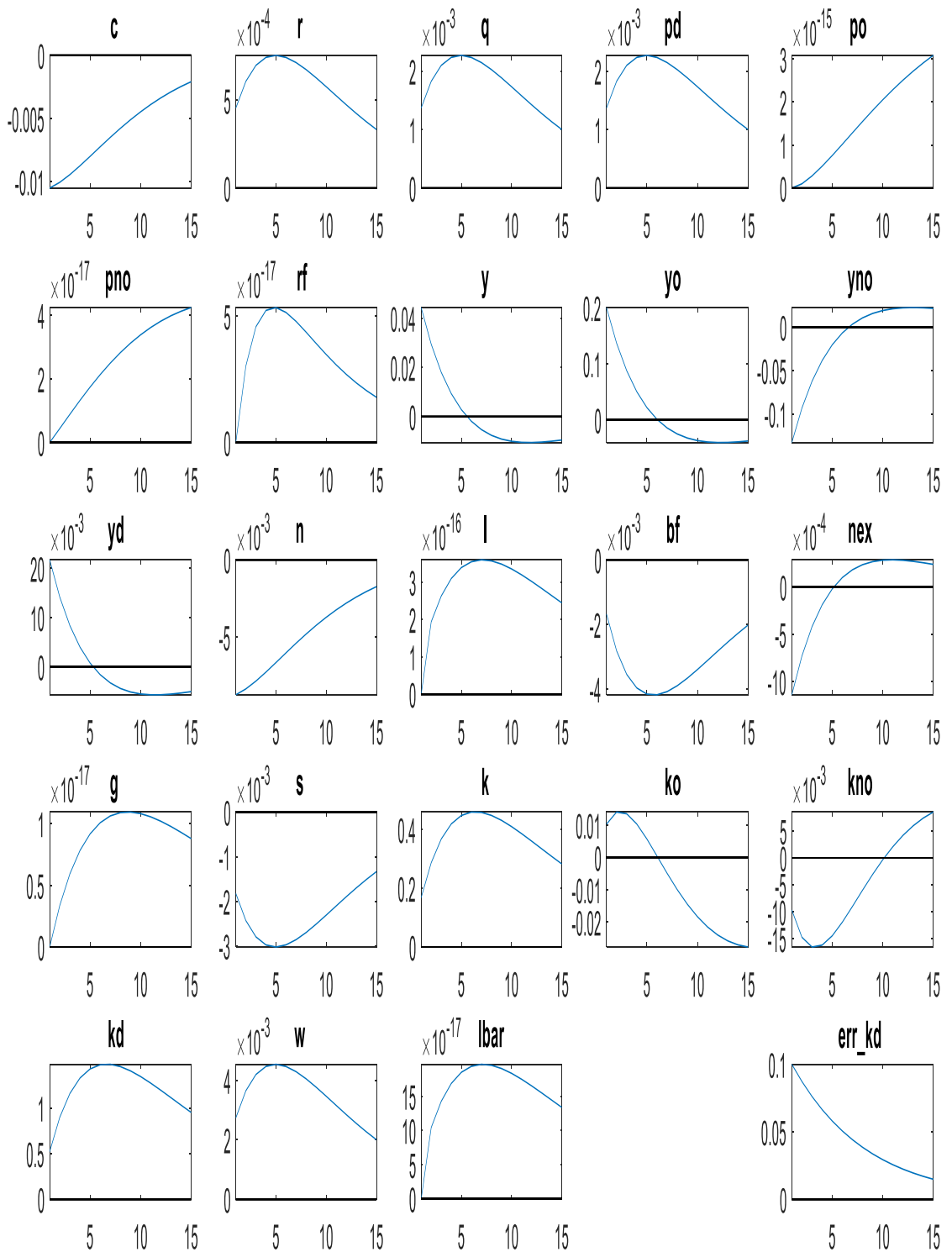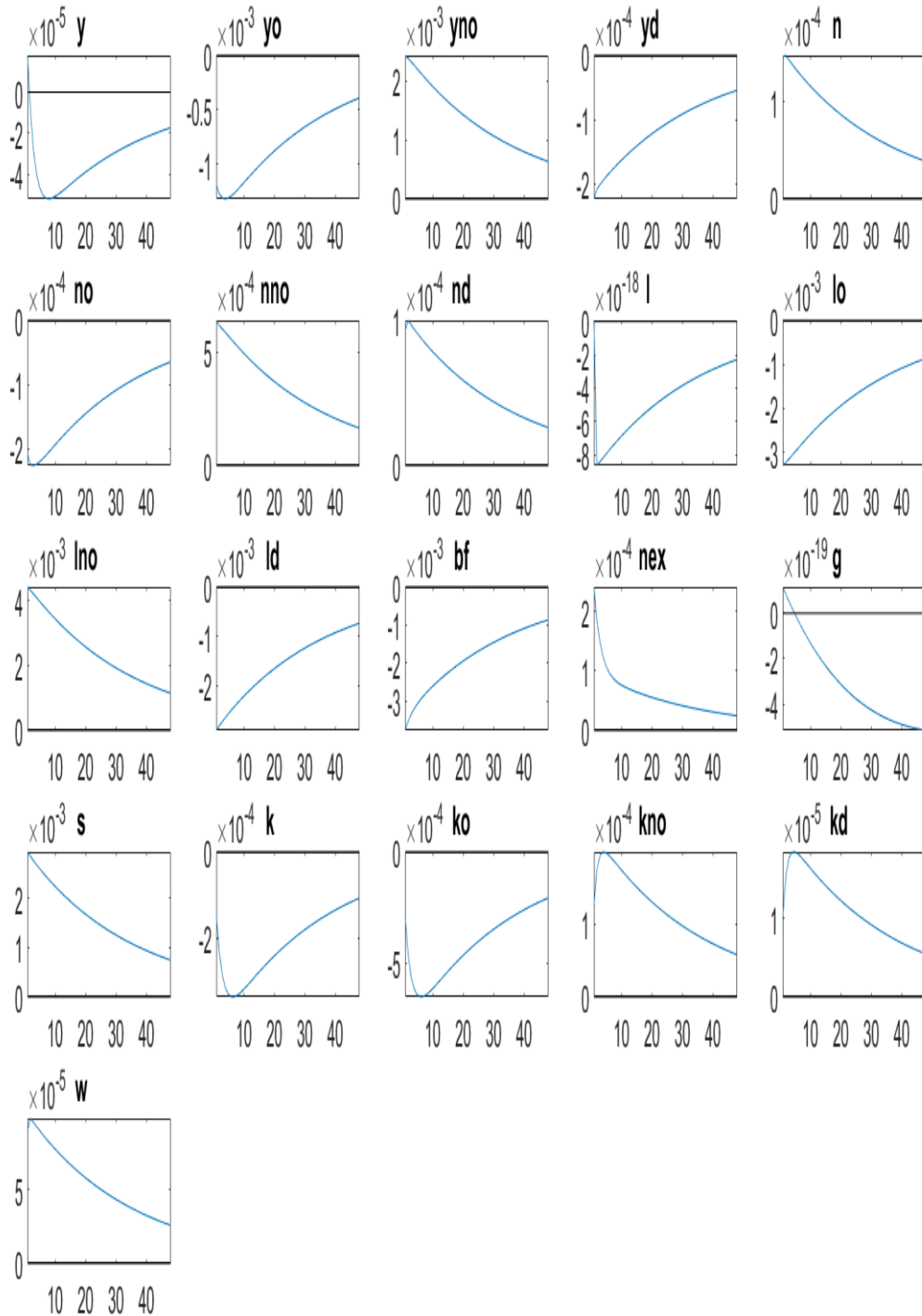
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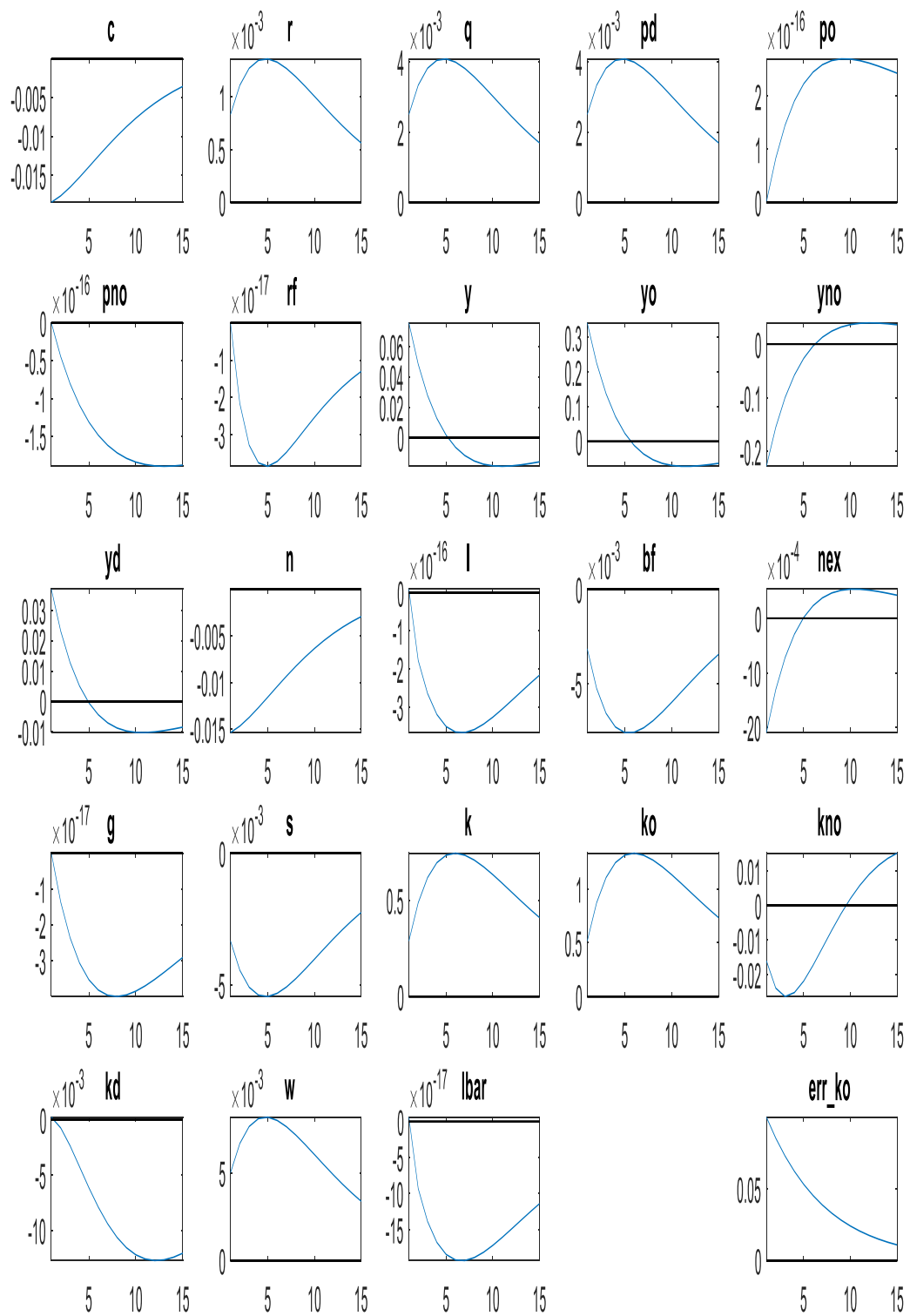
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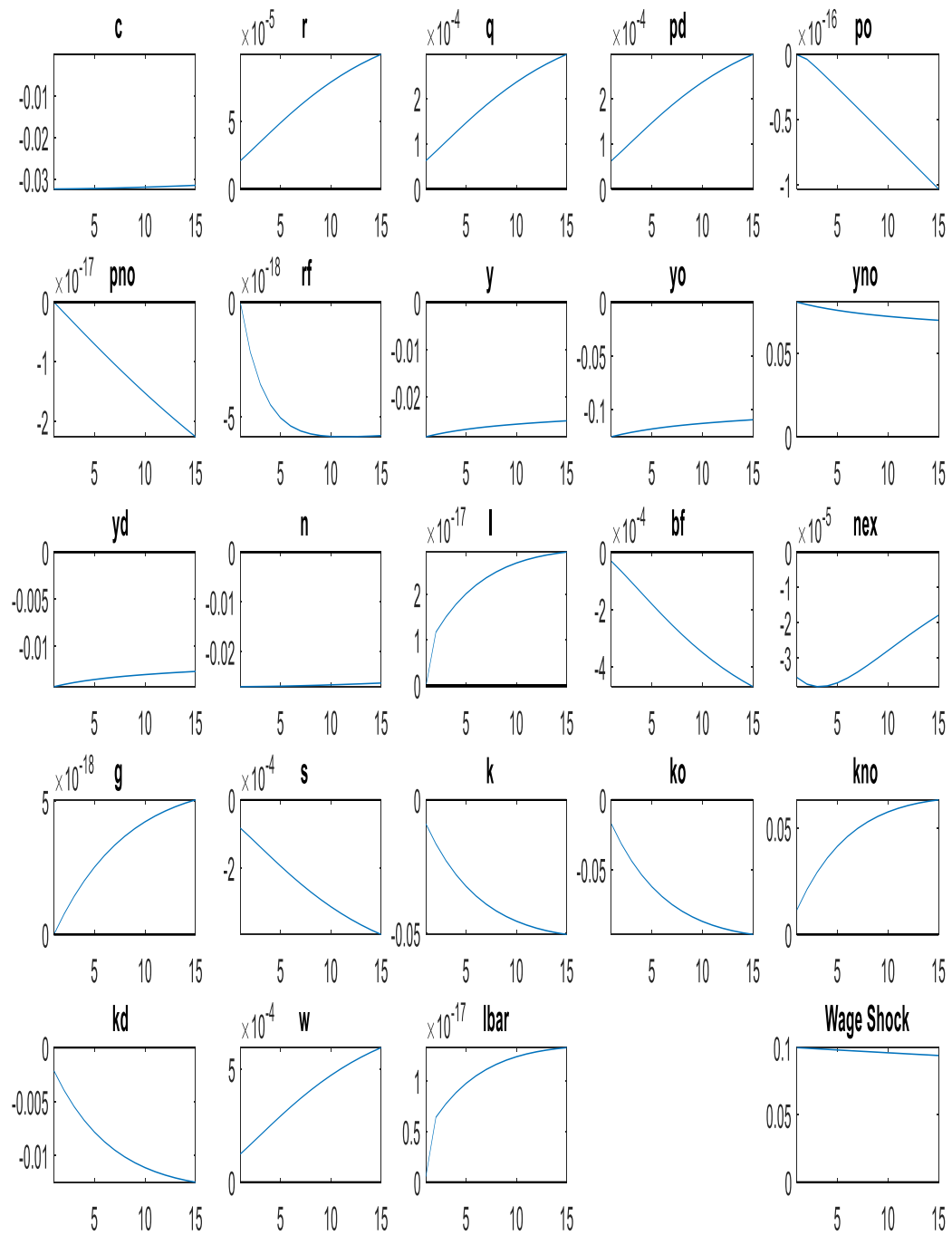
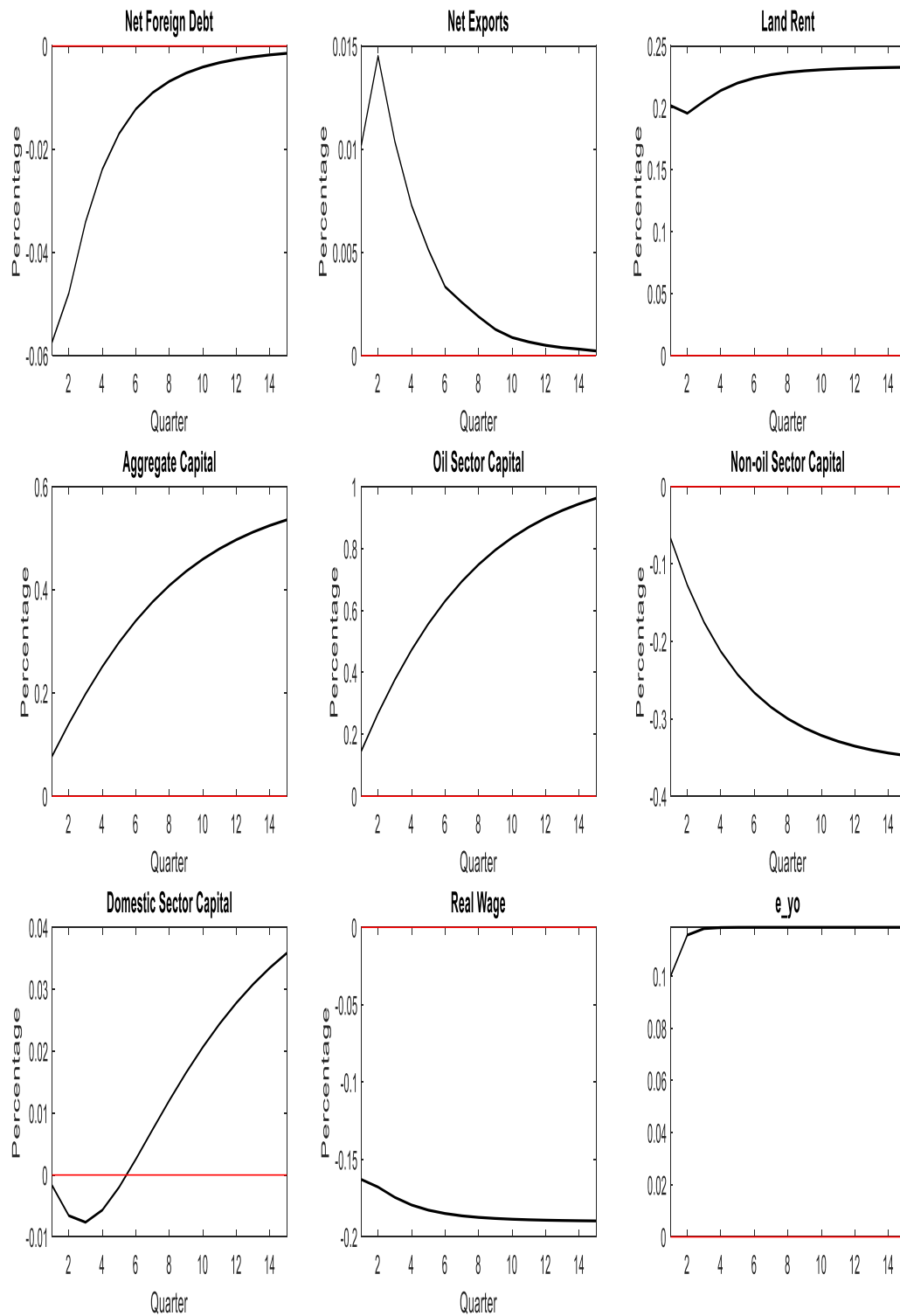# Appendix 2: Estimated Parameters Impulse Response Functions
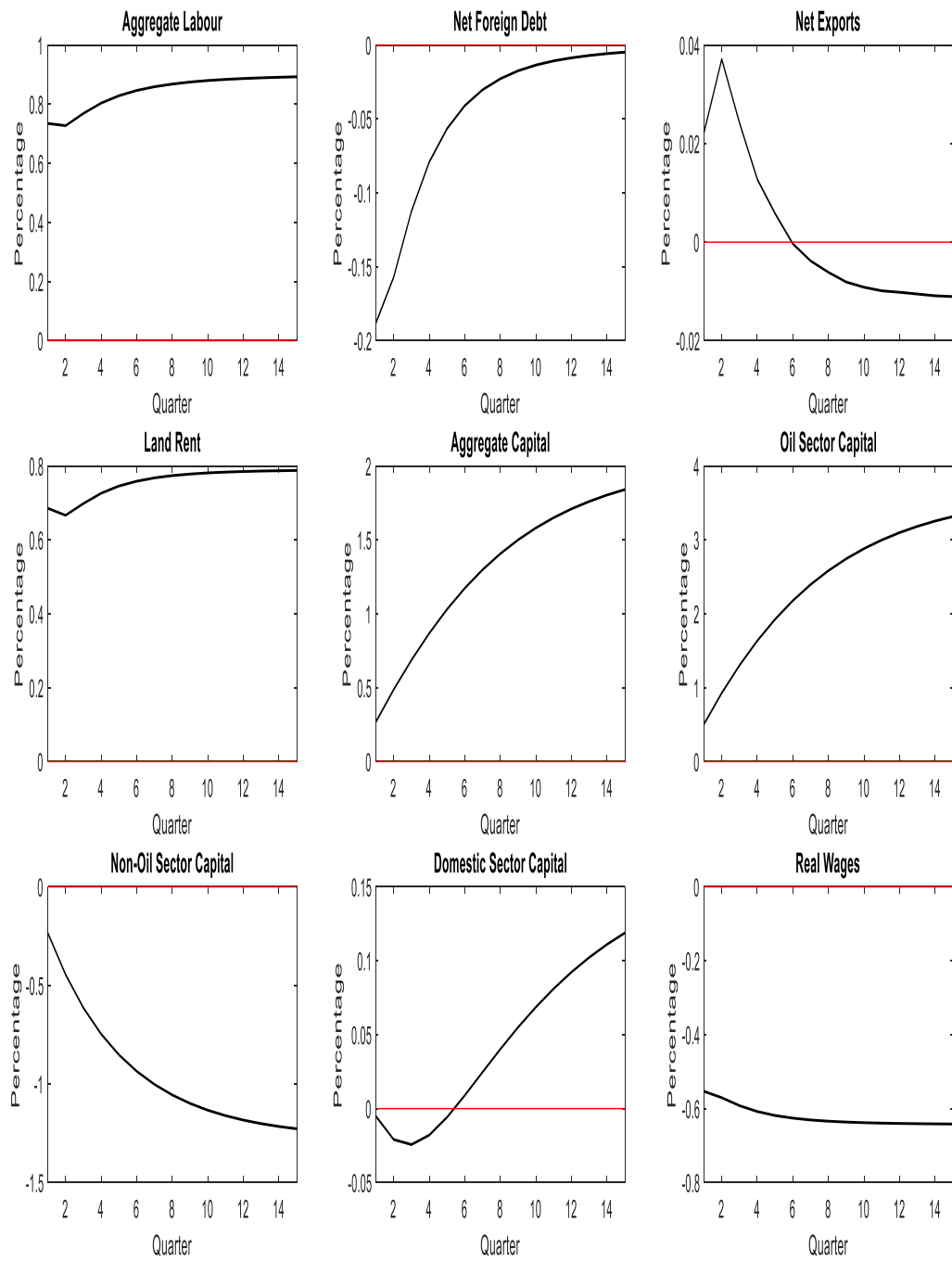
Oil Sector Productivity

Non-Oil Sector Productivity Shock

Domestic Sector Productivity Shock

Oil Price Shock

Appendix 3: Data

Symbol	Variable	Definition and Description	Sources
YO	Oil sector output	Gross Domestic Price, Oil sector Proportion	NBS
YNO	Non-oil sector (NO)Output	Gross Domestic Price, Non- Oil sector Proportion	NBS
YD	Domestic Sector (D)Output	Gross Domestic Price, Domestic sector Proportion	NBS
NO	Oil sector (O) labour	Ratio of total employment t0 18+ working population, O	NBS
NNO	Non-oil Sector Labour	Ratio of total employment t0 18+ working population, NO	NBS
ND	Domestic Sector Labour	Ratio of total employment t0 18+ working population, D	NBS
KO	Capital Oil sector	Calculated from investment data (I)	NBS
KNO	Capital Non-Oil	Calculated from investment data (I)	NBS
KD	Capital Domestic Sector	Calculated from investment data (I)	NBS[47]
LO	Land Oil Sector	Calculated using AGIS land rent schedule in Nigeria	AGIS[48]
LNO	Land Non-Oil Sector	Calculated using AGIS land rent schedule in Nigeria	AGIS
LD	Land Domestic Sector	Calculated using AGIS land rent schedule in Nigeria	AGIS
I	Investment	Investment	NBS
C	Consumption	Domestic Consumption	NBS
CF	Foreign Consumption	Foreign Consumption Demand	IFS[49]
G	Government Consumption	Government Expenditure	NBS
NEXQ	Net Exports	Exports less imports	CBN
E	Exchange Rate	Nominal Exchange Rate	CBN
Pd	Domestic Price Level	Change in Consumer Price Index	NBS
PF	Foreign Price	USA Consumer Price Index	FRED[50]
BF	Net Foreign Assets	Ratio of nominal net foreign assets (NFA) to Nominal GDP	CBN
W	Consumer Real Wage	Average wage paid to workers across the industries	CBN
r	Real Interest Rate	Nominal interest rate less inflation rate	CBN
R	Nominal Interest, Domestic	Weighted average of 3 months treasury bill rate	CBN
PO	Oil Prices	International Oil price (bonny light)	OPEC[51]
PNO	Non-Oil Prices	The USCPI is used as price of Nigeria's non-oil exports	FRED
RF	Foreign Interest Rate	US lending rate	IFS
S	Land Rent	Land Rent	AGIS

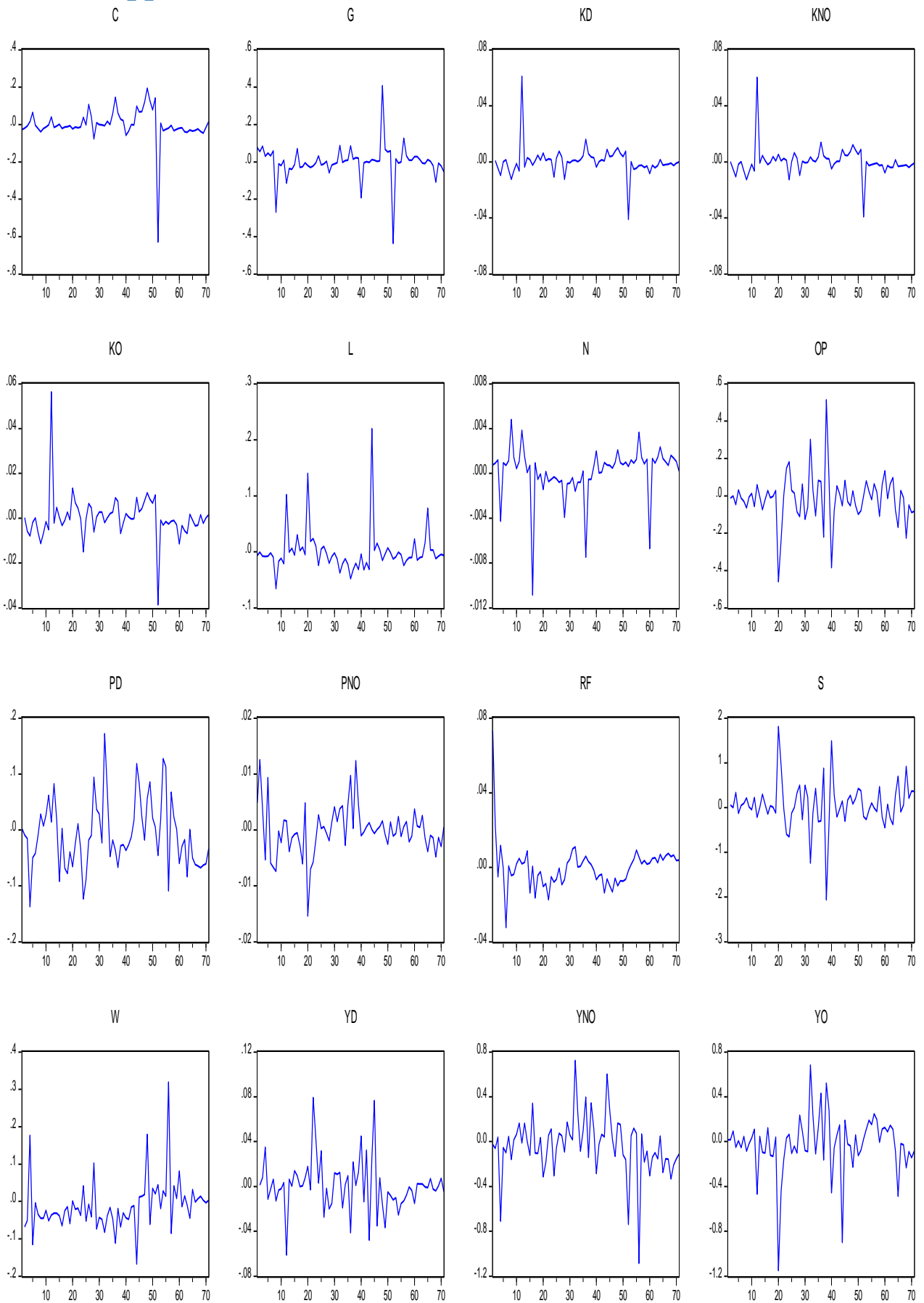
[47] National Bureau of Statistics Nigeria (NBS)
[48] Abuja Geographical information System (AGIS)
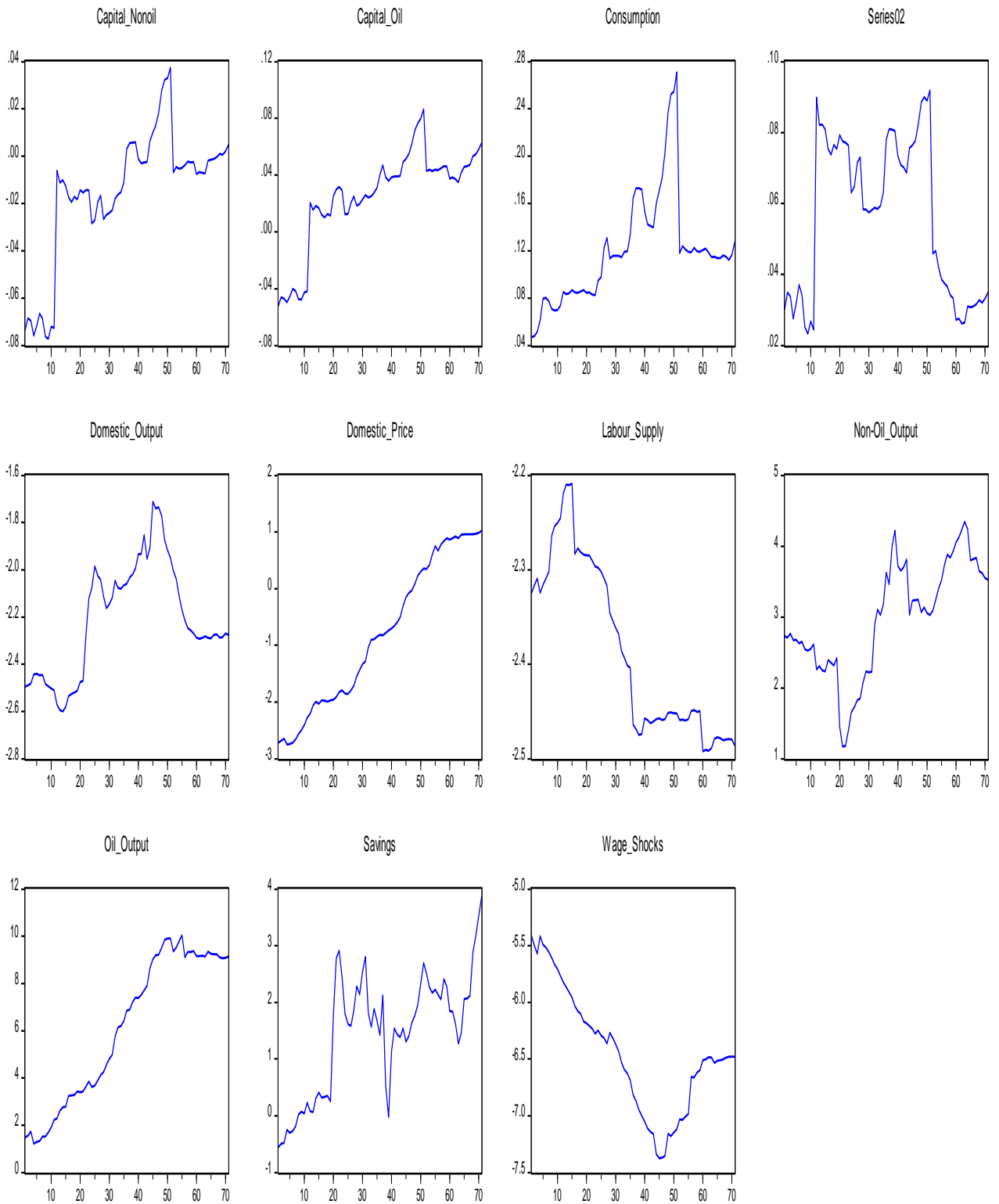[49] International Financial Statistics , IMF
[50] Federal Reserve Economic Data FRED Federal Reserve Bank of St Louis
[51] Organisation Of Petroleum Exporting Countries OPEC

Appendix 4: Innovations

Appendix 5: Estimated Residuals

Appendix 6: Glossary of Terms

(A1) Abuja Geographical Information System AGIS): AGIS is an institution that provides Geo-spatial data for Federal Capital Territory Abuja

(C1) Crude Oil Output in million barrel per day (MBPD): This is the quantity of daily crude oil produced and exported from Nigeria, being a member of Organisation of Petroleum Exporting Countries (OPEC) Nigeria has to adhere to assigned daily crude oil quota production. Often, OPEC curtail oil output to ease global glut and influence the price upward. The Nigeria's quota as at 2016 stood at two million (2,000,000) million barrel per day.

(D1) Dutch Disease Syndrome: The concept of Dutch Disease emanates from Netherlands experience with natural gas discovery. Their economy shifts from manufacturing to commodity exports as it generates higher foreign exchange to the economy and in turn led to an appreciation of the Dutch exchange rate generating second negative round effect on manufacturing sector's output competitiveness. The Dutch disease syndrome is often identified with all commodities exporting countries.

(F1) Foreign Exchange Market Policies: In Nigeria like many developing open economies are confronted with exchange rate volatility several exchange rate policies were implemented to ensure stability of domestic country's currency naira. These polices includes Interbank Foreign Exchange Market (IFEM) and Autonomous Foreign Exchange Market (AFEM) in 1988 and 1995 respectively. The Dutch auction System (DAS) and Retail Dutch Auction System (RDAS). Under these policies the central bank of Nigeria intervened in the market, supply foreign exchange in form of either wholesale or retail.

(M1) Medium Term Expenditure Framework (MTEP): the programme was designed to provide a macroeconomic framework to strengthen the fiscal management and improve efficiency in public expenditure in Nigeria.

(N1) National Bureau of Statistics (NBS): Is the office responsible for generating statistical data on macroeconomic indicators especially output and other household's data for Nigeria.

(N2) National Economic Empowerment Development Strategy" (NEEDS): is a policy introduced in Nigeria in 2004 as a medium-term planning programme that focus on economic empowerment, poverty eradication, wealth creation, promoting private enterprises and public sector reform.

(N2) Niger Delta Region: This term refers to the oil producing states in Nigeria presently there are nine states that fall into this category. The oil deposits and production vary across these states. These states received 13 percent of the total oil revenue in addition to their share as individual states in the Federation.

(O1) OPEC: Organisation of Petroleum Exporting Countries established in 1961 as an intergovernmental organisation. The main objective of the organisation is to co-ordinate and unify petroleum polices among member countries to secure fair returns on capital and stable prices for the petroleum exporting countries; efficient, economic and regular supply of petroleum to international oil market. The membership of OPEC as at 2016 stood at 14 member countries Nigeria inclusive.

GLOSSARY OF TERMS ……

(O2) Oil Bunkering: Means illegal or fraudulent oil production by some pirates particularly from within the country.

(S1) Structural Adjustment Programme (SAP): This is a programme introduced in Nigeria in response to the dwindling oil resources revenue and macroeconomic policy distortions that economy faced from 1983 – 1985, the programme was a blueprint of International Monetary Fund (IMF) launched in 1986.

(V1) Vision 20-20-20: is a new economic strategy termed that was formally introduced to push the Nigerian economy to the 20th position in the world by the year 2020 through increase in real GDP growth of double digit as well as other strategies.