Building Dynamic Stochastic General Equilibrium Models for Monetary Policy Analysis

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Dynamic Stochastic General Equilibrium (DSGE) models are powerful tools that provide a coherent framework for policy discussion and analysis. In principle, they can help to identify sources of fluctuations, answer questions about structural changes, help to forecast and predict the effect of policy changes, and perform counterfactual experiments. Against this background, this paper aims at providing an insightful discussion on DSGE models by developing a simplified version of the models to explain the behavior of key macroeconomic variables in Nigeria namely: the growth rate of gross domestic product (GDP), headline inflation, exchange rate and the monetary policy rate.

The estimated results highlight the central role of expectations in the transmission of shocks and policy impulses in DSGE models. The main lesson that we derive from the study is that management of expectations provides an effective approach to controlling inflation.

Keywords: *DSGE Models, Monetary Policy Analysis, Impulse Response Functions, Forecasting, Nigeria*

JEL Classification Numbers: *E37, E47, E50, E51, E52*

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I. Introduction

Macroeconomic models embody two important sets of hypotheses about the role of monetary policy. The first is concerned with the operation of policy, or how the policy instrument reacts to wider economic developments. This aspect of model design involves assumptions about the choice of instrument, the form of decision-rules relating instruments to objectives and the operational meaning of a 'no policy change' assumption with respect to monetary policy. The second embodies a range of hypotheses about how changes in policy-related variables influence the economy as a whole.

In the last two decades, modelling efforts had been concentrated on building

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models with little or no scope for monetary policy. This had compelled the policymakers to rely on ad-hoc models such as Mundell-Fleming that lacked adequate treatment of expectationsand stock-flow relationships. However, in recent years, considerable efforts have been put to building simple, coherent, and plausible models capable of merging empirically motivated IS/LM models with dynamic stochastic general equilibrium (DSGE) methodologies, to explain monetary policy transmission. These models, which consist of an aggregate demand (or IS) curve, a price-setting (or Phillips curve) mechanism and a policy reaction function (Taylor's rule), are built on solid microeconomic foundations and incorporates expectation variables.

This class of models is useful for the following reasons. First, they serve as a guide to policy makers to know whether an inflation target could be met in the future given the contemporaneous stance of monetary policy and the output gap or not. Second, they help in determining whether exchange rate pass-through is lower than in the past or not. Three, they help in determining sacrifice ratio (that is the amount of output to be forgone to achieve a given permanent reduction in the rate of inflation. Lastly, they shed light on the implications of following alternative policy rules.

Against this background, the goal of this paper is to provide an insightful discussion on dynamic stochastic general equilibrium models and show how they could be used as tools for monetary policy analysis. Following this introduction, section 2 provides a brief literature review covering the importance of DSGE models for monetary policy and basic structure of DSGE models, while Section 3 presents the methodology, which covers data, model set-up, its description and calibrations. Section 4 provides the results and interpretations, while Section 5 summarises, provides policy implications and conclusion.

II Brief Review of Literature and Theoretical Underpinning

II.1 Monetary Policy in DSGE Models

The importance of DSGE models in monetary policy analysis cannot be overemphasized. They provide a consistent analytical framework for conducting a positive and counterfactual historical analysis. For example, Sahuc and Smets (2007) and Christiano *et al.* (2007) propose DSGE models with multiple shocks which make it possible to interpret differences in the policies applied by the central banks as resulting essentially from the economic conditions prevailing in these banks.

Progressively, the behaviour of central banks in the analysis of monetary policy using DSGE models has been described to follow a monetary policy rule. The rule, in which the central banks are assumed to adjust the nominal interest rate, is based on several indicators, including the deviation of inflation from its target and the output gap (Taylor, 1993). It has been demonstrated theoretically that if a central bank does not adjust its monetary policy instrument sufficiently enough to respond to changes in the price level, it could cause undesirable economic fluctuations. In the same vein, it has been demonstrated that, under certain conditions, the effectiveness of monetary policy may be hindered by a loose fiscal policy and thus, the DSGE models can help in moderating these conditions and guiding policymakers to avoid the zone of economic instability (Leeper, 1991).

DSGE models can also aid the monetary authorities on how to anchor uncertainty into their decision-making processes. Central banks do this by expressing their preferences via a criterion – e.g. maximising a social welfare function just like other agents - and then hypothesise that their perception of the economy through the models is potentially subject to error that may hinder the realisation of their preferences.

II.2 A Simplified Microfoundation of DSGE Models[1]

The new Keynesian model follows the earlier rational expectations models of Lucas (1972) and Sargent and Wallace (1975) in which the role of expectations in the monetary transmission mechanism is underscored. The model also takes advantage of the powerful microeconomic foundations by building expectations into the optimizing behavior of households and firms through the real business cycle model (Kimball, 1995; Kydland and Prescott, 1982). While the policy implications of the New Keynesian model was traced out by Clarida, Gali, and Gertler (1999) and Woodford (2003), the open-economy extension, in which the exchange rate and the interest rate channel of monetary transmission operates together, was developed by Obstfeld and Rogoff (1995). Bernanke, Gertler, and Gilchrist (1999) extended the New Keynesian model to account for the balance

[1]This section benefited immensely from the work of Sbordone et.al. (2010)

sheet channel of monetary transmission.

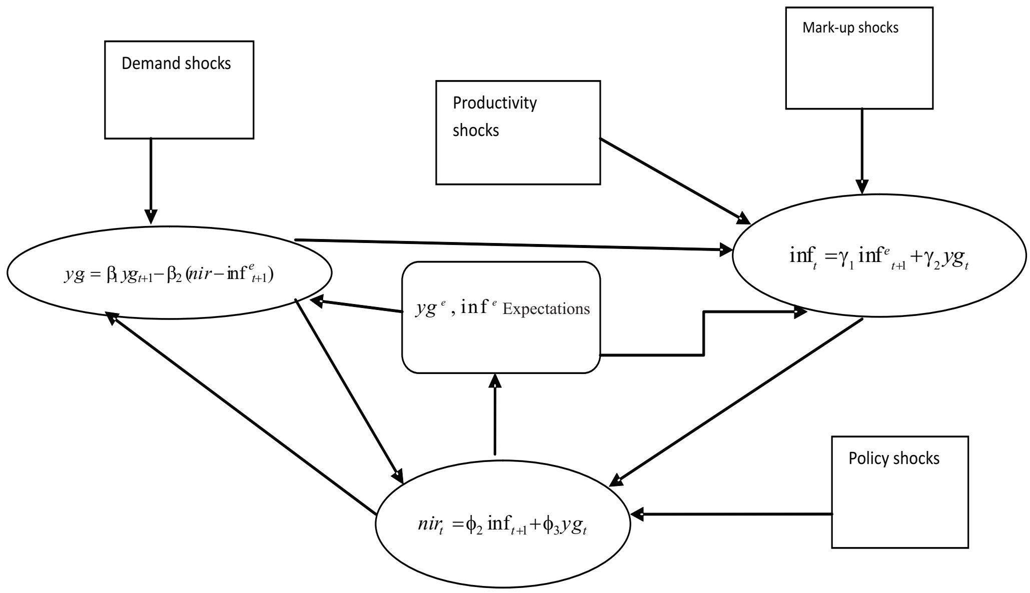
The workings of the traditional Keynesian interest rate channel within the framework of DSGE model have been discussed in the literature (Sbordone et al, 2010). The discussion focuses on the assumptions that economic agents - consumers, producers and government - always consider rational expectations in the formulation of their decisions.

Fischer (1977) and Phelps and Taylor (1977) demonstrated that anchoring the role of expectations on nominal price or wage rigidity, it is possible to reverse the impotency of policy associated with Lucas (1972) and Sargent and Wallace (1975).

The derived and simplified version of DSGE models are micro-founded and are built on the assumptions of rational expectations of the economic agents - the household, the producers/firms and the government. The interaction of these agents in the markets gives room for market clearance and the fulfillment of the "general equilibrium" condition.

Figure 1 illustrates a simplified version of the basic structure of the DSGE models consisting of three blocks - a demand block, a supply block, and a monetary policy block. The blocks contain three equations and three variables.

Figure 1: A Schematic Representation of the Basic DSGE Model



Source: Sbordone, et. al. (2010).

From the demand block, it is obvious that output (yg_t) today is linked to its expected future value (yg_{t+1}) and to the ex-ante real interest rate. From the linkage, it is obvious that when real interest rates are temporarily high, households are willing to spend less of their current incomes and firms would rather save than invest. The line connecting the demand block to the supply block reveals that the level of activity (yg_t) and expectations of future inflation (inf_e) are key input in the determination of current inflation (inf_t). The supply block shows that high level of economic activities encourages firms to raise wages so as to motivate employees to work longer hours. This action raises marginal costs and puts pressure on prices, thereby raising the current and expected inflation.

The monetary policy block is an interest rate rule for monetary policy that is similar to the type suggested by Taylor (1993). The block shows that central bank systematically adjusts the short-term nominal interest rate in response to movements in inflation and output. This description of monetary policy in terms of interest rates shows that most central banks conduct monetary policy using targets for the interest rate as opposed to any of the monetary aggregates. From the standard New Keynesian model, monetary policy works through the conventional Keynesian interest rate channel. For instance, a shock to interest rate (by reducing the monetary policy rate) reduces the short-term nominal interest rate, which transforms into a reduction in the real interest rate arising from costly or staggered price setting (Ireland, 2008). This reduction encourages consumers to increase their current consumption or spending, which raises output and price with gradual adjustment after the shock.

The role of expectations in the conduct of monetary policy and the dynamic interactions among the variables are visible in Figure 1. The figure shows that the conduct of monetary policy has a large influence on the formation of expectations and that expectations are the main channel through which policy influences the economy. This is consistent with the perception of the financial markets and the general public on the pronouncements of central banks and their likely course of action. It is also visible from the figure the existence of shocks, which creates uncertainties in the evolution of the economy. In every period, the steady states in each block are perturbed and uncertainties are injected, thereby generating economic fluctuations.

III. Methodology

III.1 Data, Model Set up and Description[2]

In the estimation of the model parameters, quarterly data spanning 1985:Q1 to 2011:Q2 is employed on seven macroeconomic indicators: domestic real output (y); foreign real output, proxied by the US real GDP (y^f); domestic headline inflation (inf); domestic interest rate (i); nominal exchange rate (s); foreign inflation rate, proxied by the US inflation (inf^f) and foreign interest rate (i^f). The data are filtered,

[2]Benefited immensely from the work of Adebiyi and Mordi (2010b)

converted into logs, then growth rates and gaps are computed.

In line with the work of JVI/IMF (2010) a reduced form new-Keynesian model is adopted. The model is made up of four basic behavioral equations- aggregate demand and supply, uncovered interest rate parity, monetary policy rule and some identities- as shown in equations 1 to 6:

$$yg_t = a_1 yg_{t-1} - a_2 mci_t + a_3 yg_t^f + \varepsilon_{ygt} \quad (1a)$$

$$mci_t = a_4 z_t + (1 - a_4) r_t \quad (1b)$$

$$inf_t = b_1 inf_{t-1} + (1 - b_1) inf_{t+1} + b_2 rmc + \varepsilon_{inft} \quad (2a)$$

$$rmc_t = b_3 yg_t + (1 - b_3) z_t \quad (2b)$$

$$s_t = e_1 s_{t+1}^T + (1 - e_1)(s_{t+1}^e + (i_t^f - i_t + prem_t)/4) + \varepsilon_{st} \quad (3a)$$

$$s_{t+1}^T = s_{t-1} + 2/4(inf^t - inf_e^f + \Delta z_e) \quad (3b)$$

$$i_t = f_1 i_{t-1} + (1 - f_1)(i_t^n + f_2 (inf_{t+1}^e - inf^T) + f_3 yg_t) + e_{it} \quad (4)$$

Identities

$$z_t = s_t + inf_t^f - inf_t \quad (5)$$

$$i_t^n = r_t^t + inf_{t+1}^e \quad (6)$$

Where yg_t is the output gap in period t, yg_t^f is the foreign output gap in period t, mci_t stands for the real marginal condition index in period t, z_t is the real exchange rate in period t defined as nominal exchange rate deflated by relative prices, and Δz_e is the change in the equilibrium real exchange rate in period t, s_t is the nominal interest rate in period t; $\inf_t$ represents inflation rate in period t, rmc_t is real marginal cost in period t, $\inf_{t+1}^e$ stands for expected inflation rate in period t, $\inf^T$ represents optimum or equilibrium inflation rate in period t, $prem_t$ stands for exchange rate premium in period t, i_t is the domestic nominal short-term interest rate in period t, i_t^f is the foreign nominal short-term interest rate in period t, i_t^n represents the natural rate of interest in period t; t-l represents the lag of relevant variables, t+i stands for the lead of relevant variables; and a, b, e and f are all parameters to be estimated.

Aggregate spending relationship corresponds to the open economy version of the traditional IS curve and is explained in equation 1. In calculating the present value of spending and wages, interest/policy rate is incorporated. The lag of output gap (yg_{t-1}) is included to give room for some degree of habit persistence in consumption or adjustment costs of investment (Pongsaparn, 2008).Considering Nigeria as a small open economy, real exchange rate gap (z_e) is included as a variable that influences economic activities through the prices of imports and exports (Adebiyi and Mordi, 2010b). The relative weight of the real interest and real exchange rates is explained by the monetary condition index (MCI) in the IS curve. Also, foreign output gap (yg^f_t), proxied by US gross domestic product, is added as a determinant of export demand. The influence of other explanatory variables such as oil prices, fiscal policy and other demand shocks are captured in the residual term.

The aggregate supply equation (the Phillips curve) is defined in Equation 2. The supply relationship incorporates the behavior of the both the domestic producers and importers (JVI/IMF, 2010). The inclusion of equation 2(b) justifies small open economies, like Nigeria, that usually have a potent exchange rate channel of monetary transmission. The equation is the real marginal cost (rmc), which is the weighted average of the output gap (domestic producers) and the gap in real exchange rate (importers) with the coefficient representing the weight of imported goods in the consumer basket (JVI/IMF, 2010). Attempt is made to model expectations to include forward and backward-looking elements. The equation shows that inflation rate is influenced not only by past inflation but also by inflation expectations, demand pressures, and external supply shocks captured by z_t. From this equation, current inflation depends on its expected future value and its own lagged value. The inclusion of the lagged term shows the persistence of the inflation - the more persistent inflation, the higher the b_1 and vice versa. The relative weight of output and real exchange rate gaps in the firm's real marginal costs is captured by b_2.

The relationship with the world is captured by the uncovered interest parity (UIP) in Equation 3. i_t and i_t^f are the domestic nominal and foreign short-term interest rates, respectively. The UIP shows the link between exchange rate and interest rates. In reaction to a depreciation of the exchange rate, for example, the monetary authority is expected to raise interest rates subsequently. With this version of the UIP, the trend values for the real exchange rate appreciation and the trend values of domestic and foreign real interest rates are bound together (JVI/IMF, 2010).

The model is closed by a policy reaction function of monetary authority in equation 4. From this equation, a monetary authority is assumed to respond to deviations of the next-period inflation from its target and to the output gap. It is assumed that credit markets transmit the changes in the policy rate into money-market rates without any hindrance.

III.2 Techniques for Estimation and Forecast[3]

Five steps are involved in the estimation and forecast of the model. First, is the preparation of the data base, which requires that the historical data are stored in the excel file (csv format). The second stage is the calibration of the specific parameter values. In the model calibrations, consideration is given to the validity of economic theory, stylized facts about the economy and observation, facts and existing empirical literature (see Table 1). The priors for Phillips curve and the IS curve estimates were obtained from the work of Adebiyi and Mordi (2010b). The parameter of output lag of 0.72 was considered appropriate by Laxton and Scott (2000). They claimed that the sum of the parameters of real interest rate and real exchange rate should be smaller than that of the output gap, largely owing to the limited effect of the interest rate and exchange rate on output because of significant lags in monetary transmission mechanism in most economies.

[3]Benefited immensely from JVI/IMF (2010)

Table 1: The Model Calibration and Parameterization

Equation	Parameter	Definition	Value	Comments	Linear Homogeneity Condition
IS Curve (Output Gap)	$yg_t = a_1 yg_{t-1} - a_2 mci_t + a_3 yg^f_t + \varepsilon_{yg}$ (1a) $mci_t = a_4 z_t + (1-a_4) r_t$ (1b)				
	a_1	Lag of output gap	0.72**	Measures output gap persistence; lies between 0.1 and 0.95	$0 < a_1 < 1$
	a_2	Marginal condition index	-0.10*	Measures the pass through from monetary condition to the real economy. It varies between -0.1 to -0.5	$-0.1 < a_2 < -0.5$
	a_3	Foreign output gap	0.12*	Measures the impact of foreign demand on domestic output; varies between 0.1 (low impact) to 0.7 (strong impact)	$0 < a_3 < 1$
	a_4	Real exchange rate gap	0.5*	Shows the relative weight of the real interest and exchange rates in real monetary condition; varies between 0.3 (open economy) to 0.8 (closed economy)	$0 < a_4 < 1$
Phillips Curve	$inf_t = b_1 inf_{t-1} + (1-b_1) inf_{t+1} + b_2 rmc + \varepsilon_{inf}$ (2a) $rmc_t = b_3 yg_t + (1-b_3) z_t$ (2b)				
	b_1	Lag of inflation rate	0.62**	Measures inflation persistence. It varies between 0.4 (low persistence) to 0.9 (high persistence)	$0<b_1<1$
	b_2	Real marginal costs	0.31**	Pass-through from real marginal cost to inflation. It measures sacrifice ratio. It varies from 0.05 to 0.4	$0<b_2<1$

	b_3	Exchange rate changes	0.70**	Ratio of domestically produced goods in the consumer basket. It varies between 0.9 and 0.5	$0<b_3<1$
Uncovered Interest parity	$s_t = e_1 s^T_{t+1} + (1-e_1)(s^e_{t+1} + (i^f_t - i_t + prem_t)/4) + \varepsilon_s$ (3a) $s^T_{t+1} = s_{t-1} + 2/4(inf^t - inf^f_e + \Delta z_e)$ (3b)				
	e_1	Lag of expected exchange rate	0.1**	e1 captures either exchange rate persistency or central bank's interventions; varies between zero to 0.9 (tight control of the exchange rate)	$0<e_1>1$
Policy Rule	$i_t = f_1 i_{t-1} + (1-f_1)(i^n_t + f_2(inf^e_{t+1} - inf^T) + f_3 yg_t) + \underline{e}_i$ (4)				
	f_1	Lag of monetary policy rate	0.70**	policy persistence, value varies from 0 (no persistence) to 0.8 ("wait and see" policy)	$0< f_1<1$
	f_2	Deviation of Inflation from potential	1.50**	Measures the weight put on inflation by the policy maker; value has no upper limit but must be always higher then 0 (the Taylor principle)	$f_2>0$
	f_3	Output gap	0.50**	measures the weight p ut on the output gap by the policy maker; value has no upper limit b ut must be always higher then 0	$f_3>0$

Note:* the values are obtained from expert judgment (see JVI/IMF Institute (2010). ** the values are obtained from Adebiyi and Mordi (2010b)

We assume all exogenous variables follow AR (1) processes (Adebiyi and Mordi, 2010). The coefficients of the AR(1) processes are set as follows: persistent shock to risk premium, 0.5; persistent shock to the real exchange rate, 0.8; GDP trends, 0.8; foreign GDP, 0.95; persistence in foreign interest rates, 0.8; speed of inflation

potential adjustment to the medium-term inflation, 0.5 (JVI/IMF, 2010).
The "steady-state" values are calibrated as follows: domestic inflation target, 10.00; foreign inflation target, 2.35; trend level of domestic real interest rate, 10.71; trend change in the real exchange rate (negative number is real appreciation), 5.11; potential output growth, 6.29; and trend level of foreign real interest rate, 1.26 (JVI/IMF, 2010).

The third step is the calibration of shocks, which is done by filling the respective databases with the shocks' values for the start point of the simulation. For simplicity, all shocks are set to 1 per cent. The fourth step is the in-sample forecast, which involves the selection of historical time series for computing the model's forecasting properties. It is essential to identify the start date of the sample, the start date for the first simulation and the end date of the known history.

The last step is the ex-ante (out-of-sample) forecast. In carrying out the out-of-sample forecast, three steps were taken into consideration: (1) obtained initial conditions from the historical data; (2) created forecasts of key equilibrium variables that were exogenous in the model, which included: the inflation target (announced by monetary authorities), potential output, and equilibrium real interest and exchange rates (by smoothing the original series and/or judgment-based assessments); and (3) ran the program to generate the forecasts by simulating the model forward. This was done by reading the model and historical data from the database (JVI/IMF, 2010).

IV. Estimation Results

A good model is not judged primarily by how well its parameters are chosen or how well the model fits the data. Rather, the adequacy of a model for policy analysis depends significantly on how well it captures the key aspects of the monetary policy transmission mechanism. For example, a good model provides reasonable estimates of: first, how long it takes a shock to the exchange rate to feed into the price level (exchange rate pass-through); second, the amount of output that must be foregone to achieve a given permanent reduction in the rate of inflation (the sacrifice ratio), and three, how the inflation rate responds to the shock in output.

IV.1 Stylized Facts

Figures 2, 3 and 4 display the nominal, real/trends and gaps variables, respectively. These figures show the trends and behavior of economic variables between 1985:1 and 2010:2. The graphs reflect various changes in economic policies, structural breaks and regime shifts. They also show the difference between actual and potential variables of interest.

Figure 2: Stylized Facts - Nominal Variables

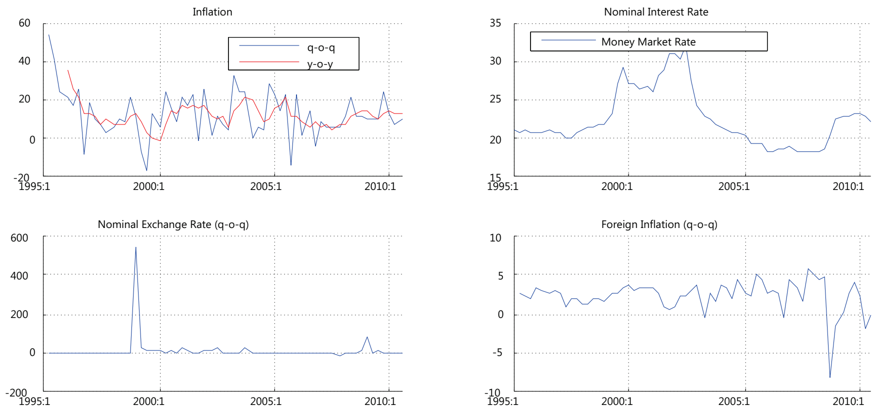


Figure 3: Real Variables and Trends

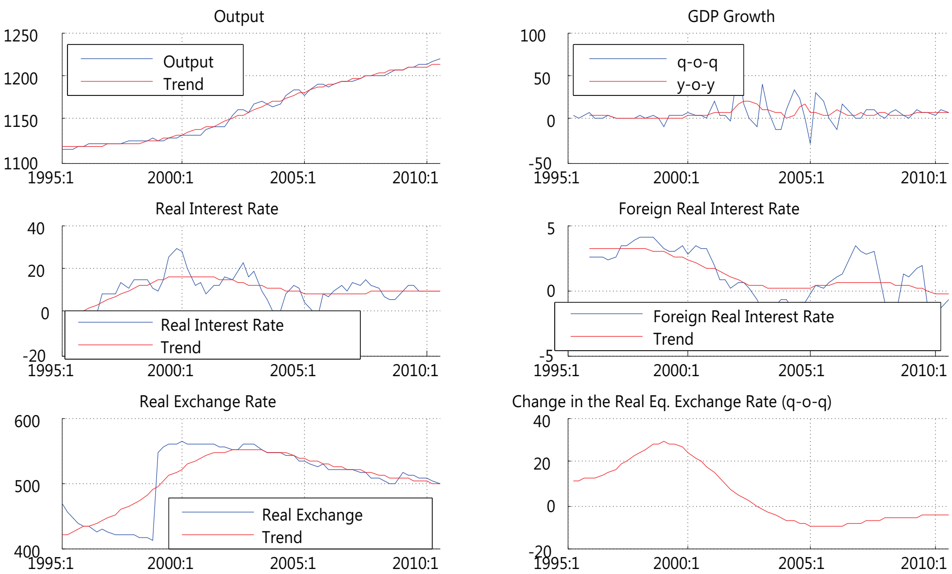


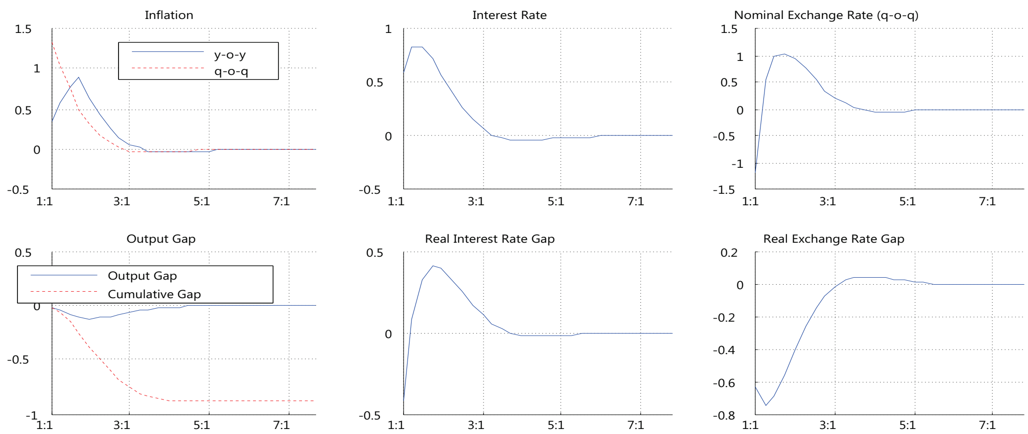
Figure 4: Gaps

IV.2 Model Properties- Impulse Response Functions[4]

IV.2.1 Response of Inflation and Output to 1% Price shock

Figure 5 shows the aggregate supply shock and illustrates the dynamic impact of inflation rate on the economy. It indicates that a positive shock to price leads to an increase in inflation rate due to the dynamics of inflation arising from both backward and forward-looking components. An increase in inflation consequently leads to an appreciation of the naira by 1.0 per cent. This causes the marginal cost of imported input to increase, thereby resulting in output reduction and fall in price. The speed of reversion to steady state, arising from the shock, was about four years (16 quarters) for most of the variables.

Figure 5: Response of Inflation and Output to 1% Price Shock

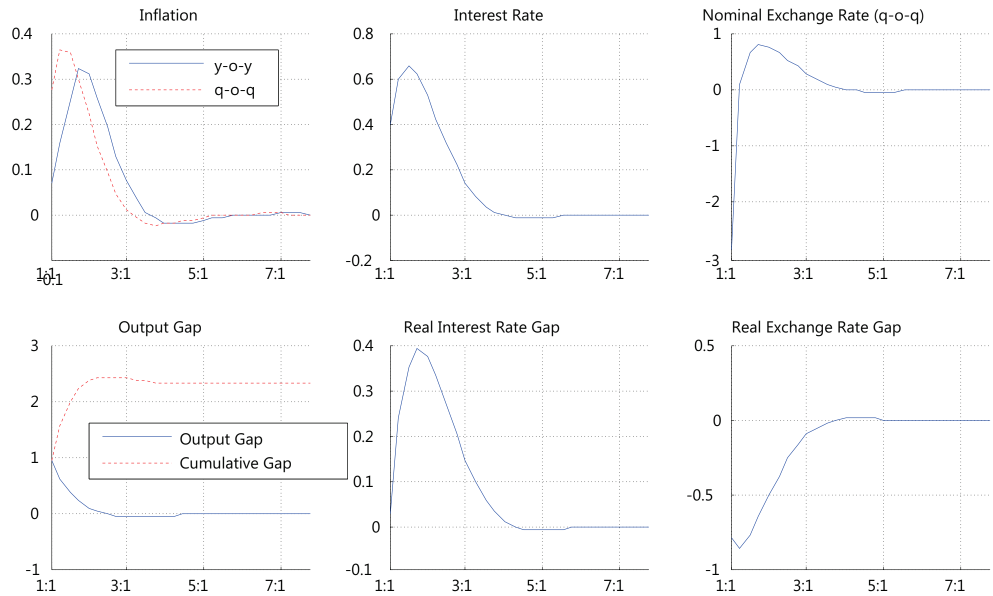


[4]The work benefited immensely from the work of Central Bank of Nigeria (2010), Adebiyi and Mordi (2010b)

IV.2.2 Response of Inflation and Output to 1% Aggregate Demand shocks

Figure 6 explains the aggregate demand shock. A 1 percent shock to aggregate demand immediately raises the year-on-year inflation by 0.08 percent, through the increase in marginal cost of input (real interest rate) by 0.05 percent, which consequently leads to an appreciation of the currency by 2.5 percent. With aggregate demand shocks, the exchange rate appreciates in response to increased policy rate in the first quarter and thereafter depreciates between year 1, quarter 1 and year 3, quarter 3 before reaching its steady state level in year 4. The erratic exchange rate behavior is due to the forward-looking component. In general, shocks to output generate disequilibrium in the economy which last for about 4 - 5 years before reverting to equilibrium.

Figure 6: Response of Inflation and Output to 1% Aggregate Demand Shock

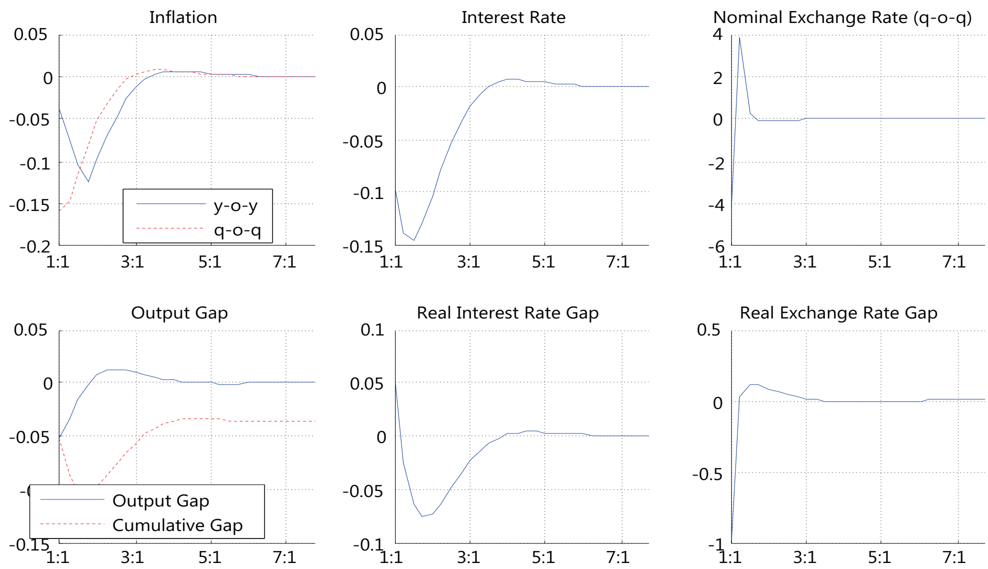


IV.2.3 Response of Output and Price to 1% Exchange Rate Shock

As shown in Figure 7, year-on-year and quarter-on-quarter inflation declined by about 0.05 and 0.15 percent, respectively, in the first quarter, while output gap falls by only 0.05 percent over the same period and thereafter rebounds to a value above its potential before it dies off in year 4 quarter 2. The effect of the nominal appreciation on output is weakened probably due to a smaller decline in domestic inflation relative to foreign ones.

Although this may suggest that a large appreciation may not be harmful to real economic activities, its impact on inflation is quite substantial. This probably reflects Nigeria's trade structure that relies increasingly on large imports of raw materials, refined oil products, and other energy products, in addition to its reliance on intermediate goods for the manufacturing sub-sector. In general, exchange rate shock increases real interest rate, which reduces output and inflation.

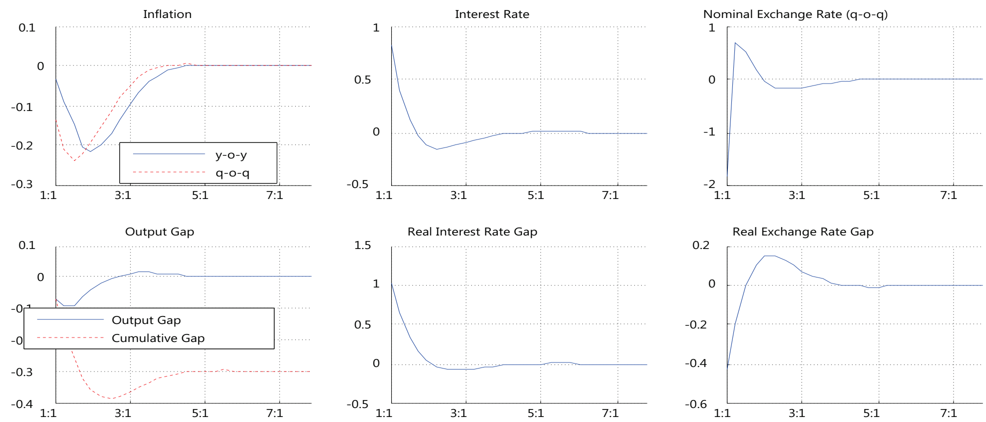
Figure 7: Response of Output and Price to 1% Exchange Rate Shock



IV.2.4 Response of Inflation and Output to 1% Interest Rate Shock

As shown in figure 8, an unanticipated tightening of monetary policy, by altering the relative returns on domestic assets vis-à-vis foreign assets, induces portfolio adjustments, which results in an appreciation of the Naira. The adjustment in the exchange rate affects inflation directly, given the cost structure of domestic output and the ratio of tradeables to non-tradeables in domestic consumption. This is complemented by the dampening effect of the constraint on aggregate demand, arising from the higher interest rates.

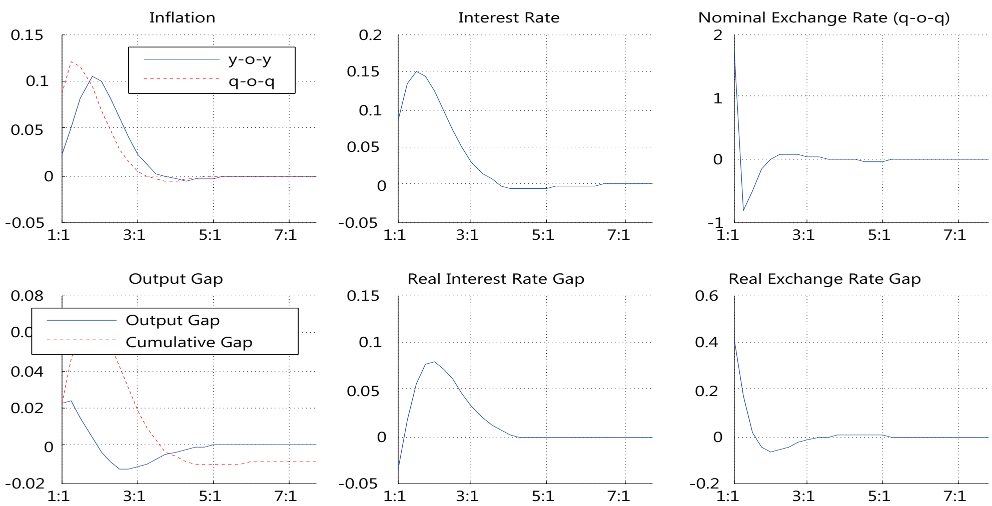
Figure 8: Response of Inflation and Output to 1% Positive Interest Rate Shock



IV.2.5 Response of Output and Price to 1 % Risk Premium Shock

Figure 9represents a shock to risk premium, which is explained by the uncovered interest rate parity equation. In the Figure, a positive shock to the risk premium leads to a depreciation of the naira immediately by 1.5 per cent. The depreciation encourages exports and discourages imports, thereby causing an immediate increase in output gap by 0.02 per cent, interest rate by 0.1 per cent and inflation by 0.03 per cent. The speed of reversion to steady state, arising from the shock, was about four years (16-20 quarters) for most of the variables.

Figure 9: Response of Inflation and Output to 1% Risk Premium Shock



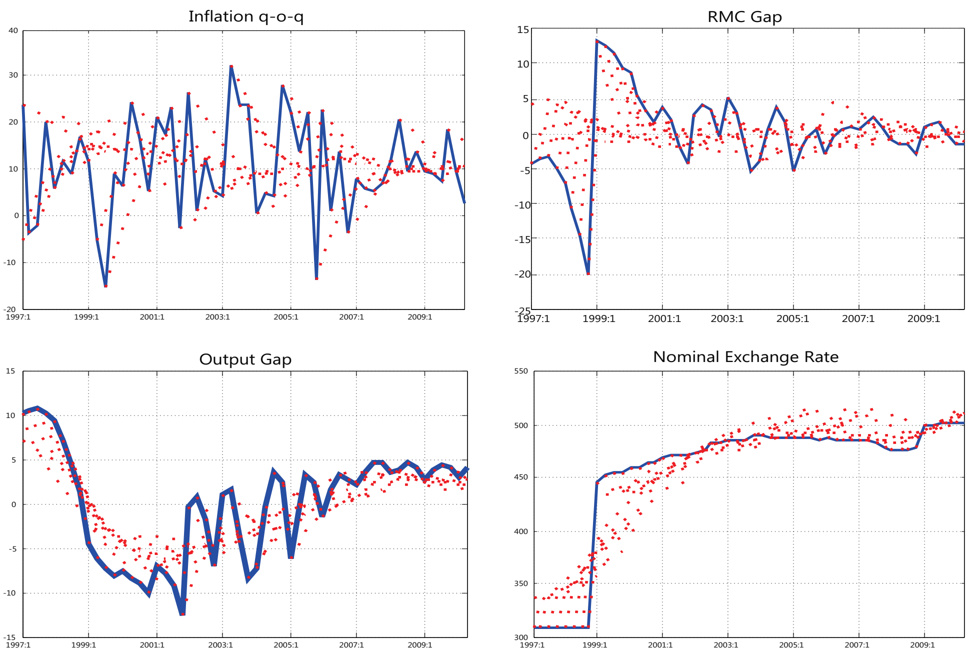
IV.3 Model Forecast

A model by itself does not make forecast. The forecast comes from some combination of several sources: forecasting models of various sorts, market expectations, judgment of senior policymakers, and, most importantly, interactions with the stakeholders (Berg et. al, 2006). The quality of forecast depends on model parameterization (calibration), data preparation and ex-post (in-sample) simulation.

IV.3.1 Recursive (in-Sample) Forecast

Recursive forecasts mean that you run the model for each quarter of the sample. The in-sample forecasts in Figures 10 are done for 8 quarters without the model being updated for actual data, except for the foreign variables (JVI/IMF, 2010).

Figure 10: In-sample Simulations



IV.3.2 Ex-ante (Out of Sample) Forecasts-Main Indicators

From Table 2, we observe that the inflation forecast converges to the targeted inflation within the transmission period of 8 quarters in 2012 with some initial fluctuation (arising from the unconditional forecast). At this point of convergence, nominal interest rate was 22 per cent. The most interesting variable was the trajectory of nominal interest rate set by the monetary authority rather than the forecast of the interest rate, which reflects the policy reaction given the past data and model structure. The values of real interest rate and exchange rate gaps show the tightness in the monetary stance to meet the inflation target and the cost of this stance in terms of real economic activities (output).

Table 2: Forecast- Main Indicators and Decomposition

Forecast - Main indicators

		2009:4	2010:1	2010:2	2010:3	2010:4	2011:1	2011:2	2011:3	2011:4	2012:1	2012:2
CPI	% y-o-y	11.2	11.3	9.8	8.5	4.6	3.2	3.9	5.1	6.5	8.1	9.5
	% q-o-q (AnnuaL)	18.9	9.8	2.9	2.5	3.1	4.2	5.7	7.3	8.9	10.3	11.4
Target	% y-o-y	9.5	9.5	9.5	9.8	9.9	9.9	10.0	10.0	10.0	10.0	10.0
Real GDP	% y-o-y	7.1	7.6	7.3	5.7	7.4	9.3	8.9	10.3	9.1	9.1	7.4
	% q-o-q (AnnuaL)	5.5	3.4	11.1		12.4	10.9	9.5	8.4	7.6	7.0	6.6
Nominal interest Rate												
Market Rate	%	23.2	23.2	22.7	18.3	16.5	16.4	17.6	19.5	21.5	23.4	23.4
Policy Neutral Rate	%	26.9	19.1	13.1	13.9	15.1	16.5	18.1	19.7	21.1	23.1	
Nominal Exchange Rate												
Naira/Dollar	% y-o-y	21.7	2.1	1.6	3.4	6.8	9.0	11.1	9.6	9.9	11.4	13.5
	% q-o-q (AnnuaL)	-2.6	-0.1	0.5	15.8	11.0	8.7	8.6	10.0	12.2	14.7	17.0
	level	150.0	149.9	150.1	156.2	160.5	164.1	167.7	171.9	177.3	183.9	191.9
Risk Premium	% of Exchange Rate	8.3	6.8	5.5	5.0	4.9	4.8	4.7	4.6	4.6	4.5	4.5
Monetary Conditions												
Real Monetary Conditions	%	3.2	8.4	12.0	8.3	6.3	5.5	5.4	5.6	5.9	6.2	6.4
Real interest Rate Gap	%	-3.7	4.1	9.6	4.4	1.4	-0.1	-0.5	-0.2	0.4	1.3	2.3
Real Exchange Rate Gap	%	-10.1	-12.7	-14.5	-12.3	-11.3	-11.1	-11.3	-11.4	-11.4	-11.1	-10.5
Supply Side Assumptions												
Real Exchange Rate Trend	% q-o-q (AnnuaL)	2.7	2.7	2.8	3.2	3.6	3.9	4.1	4.3	4.5	4.6	4.7
Real Interest Rate Trend	%	11.2	11.2	10.9	10.8	10.8	10.8	10.8	10.8	10.8	10.7	10.7
Potential GDP	% q-o-q (AnnuaL)	7.1	7.2	7.2	7.0	6.9	6.8	6.7	6.6	6.5	6.5	6.4

Forecast -Decomposition

		2009:4	2010:1	2010:2	2010:3	2010:4	2011:1	2011:2	2011:3	2011:4	2012:1	2012:2
External Development												
Foreign Output Gap	%	8.2	8.2	8.1	7.7	7.3	7.0	6.6	6.3	6.0	5.7	5.4
Foreign Inflation	% q-o-q (AnnuaL)	4.1	2.3	-2.0	-1.1	-0.4	0.1	0.6	0.9	1.3	1.4	1.6
Foreign Nominal Interest Rate	%	3.3	3.3	3.3	2.8	2.6	2.4	2.4	2.4	2.5	2.6	2.7
Output Gap Decomposition												
Output Gap	%	4.2	3.2	4.2	3.1	4.5	5.5	6.2	6.7	6.9	7.1	7.1
Output Gap Lag	PP	3.3	3.0	2.3	3.0	2.2	3.2	4.0	4.5	4.8	5.0	5.1
Real Monetary Conditions	PP	-0.3	-0.8	-1.2	-0.8	-0.6	-0.6	-0.5	-0.6	-0.6	-0.6	-0.6
Foreign Output Gap	PP	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8	0.7	0.7	0.6
Output Gap Decomposition												
Inflation	% q-o-q (AnnuaL)	18.9	9.8	2.9	2.5	3.1	4.2	5.7	7.3	8.9	10.3	11.4
Inflation Lag	PP	4.7	11.7	6.1	1.8	1.5	1.9	2.6	3.5	4.5	5.5	6.4
Inflation Expectation	PP	3.7	1.1	0.9	1.2	1.6	2.2	2.8	3.4	3.9	4.3	4.4
Real Marginal Costs	PP	-0.0	-0.5	-0.4	-0.5	-0.1	0.2	0.3	0.4	0.4	0.5	0.6
Interest Rate Decomposition												
Interest Rate	%	23.2	23.2	22.7	18.3	16.5	16.4	17.6	19.5	21.5	23.4	24.7
Interest Rate Lag	PP	16.1	16.2	16.3	15.9	12.8	11.5	11.5	12.3	13.6	15.1	16.4
Policy Neutral Interest Rate	PP	8.1	5.7	3.9	4.2	4.5	5.0	5.4	5.9	6.3	6.6	6.7
Policy Rule	PP	-1.8	-2.6	-2.1	-1.7	-0.9	-0.9	0.7	1.2	1.6	1.7	1.6

The forecast decomposition provides a breakdown of the contributing factors to the forecasts based on the relevant equations. For example, the aggregate demand (the IS curve) is a function of the past output gap, real monetary conditions, and external demand. These variables are provided in the second block of Table 1 under output gap decomposition. Similarly, the Phillips curve breakdown is enumerated in the third block (inflation factor decomposition).

All these information provide economic facts in analyzing inflation scenarios. For example, it is observed from table 2 that lag of output gap contributes significantly to output gap. The contribution increases from 3.0 per cent in 2010:3 to 5.1 per cent in 2012:2. On the other hand, the contribution of foreign output gap declines from 0.9 per cent in 2010:3 to 0.6 per cent in 2012:2. This implies that the contribution of foreign output to the Nigerian economy declines with time.

Similarly, the decomposition of inflation factor in the Phillips equation shows that the contributions of both the lag of inflation and inflation expectation increase with time. Their contributions increase from 1.8 and 1.2 per cent in 2010:3, respectively to 6.4 and 4.4 per cent in 2013:2.

V. Summary, Policy Implications and Conclusion

DSGE models are powerful tools that provide coherent framework for policy discussion and analysis. In principle, they can help to identify sources of fluctuations, answer questions about structural changes, forecast and predict the effect of policy changes, and perform counterfactual experiments (Berg, Karam and Laxton, 2006). Such features and the rapid advances in the academic literature have attracted the attention of central banks across the globe, some of which have already developed and employed these models for policy analysis and forecasting.

This paper provides an insightful discussion on dynamic stochastic general equilibrium models and show how they could be used as tools for monetary policy analysis. A simplified version of DSGE models is developed to account for the behavior of three key macroeconomic variables, namely: GDP growth, headline inflation, and the monetary policy rate. This model focuses on the nominal interest rate as the policy instrument and embodies the key principle that the role of monetary policy is to anchor inflationary expectations. It captures most of the channels through which policymakers believe monetary policy acts in a small open economy with a managed floating exchange rate regime.

The main lessons that we learnt from the empirical results are as follows. First, the responses of most of the variables to policy shocks conform to economic theory, For example, a positive shock to price leads to an increase in inflation rate due to the dynamics of inflation arising from both backward and forward-looking components. This shock consequently leads to an appreciation of the naira by 1.0 per cent, which cause the marginal cost of imported input to rise, thereby resulting in output reduction and fall in price.

Second, shocks to most of the variables generate disequilibrium in the economy, which has lasted for about 4 - 5 years before reverting to equilibrium. Third, the out-of-sample forecast indicates that the inflation forecast converges to the targeted inflation within the transmission period of 8 quarters in 2012 with some initial fluctuation and this corresponds with nominal interest rate of 22 per cent.

Fourth, the variance decomposition shows that lags of output, interest rate and inflation rate contribute significantly to their contemporaneous values. For example, the contribution of output lag to its contemporaneous values increases from 3.0 per cent in 2010:3 to 5.1 per cent in 2012:2. However, the contribution of foreign output gap to domestic output declines from 0.9 per cent in 2010:3 to 0.6 per cent in 2012:2. This implies that the contribution of foreign output (i.e. the US output) to the Nigerian economy declines over time.

Fifth, the study highlights the central role of expectations in the transmission of shocks and policy impulses in the model. It shows that the most effective approach to controlling inflation is through the management of expectations in addition to actual movements of policy instruments. Lastly, the findings explicitly reveal how models could help in structuring policy discussion and provide a framework for assessing risks and alternative scenarios.

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