A DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM (DSGE) MODEL OF EXCHANGE RATE PASS-THROUGH TO DOMESTIC INFLATION IN NIGERIA

by

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Abstract

This study employs a Bayesian framework of DSGE model to estimate the pass-through effect of exchange rate to domestic inflation in Nigeria using a quarterly data for the period 1980 to 1998. The response of inflation rate to exchange rate shock is found to be positive and statistically significant in the short run. It shows a small and incomplete pass-through of exchange rate to domestic inflation in Nigeria with almost zero in quarter 1 (0.09), rose to 0.18 in quarter 2 and declined to 0.07 and 0.01 in quarters 3 and 4, respectively. This *is lower than the findings obtained elsewhere by other authors. The low pass-through is attributed in part to the* low, stable, and predictable inflation rate arising from the improved credibility of the policy environment.

Keywords: DSGE Model, Exchange Rate Pass-through, Inflation, Nigeria

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1.0 INTRODUCTION

Developing economies, like Nigeria, have historically been reluctant to permit more than a moderate degree of exchange rate flexibility due to the fear that such variations might feed into domestic prices. The potential vulnerability of small and open economies to exchange rate pass-through into domestic prices is high and this arises from the high share of tradable goods, high import content of domestic production and exports, as well as generally high degree of integration with the global trading system.

Policy makers are concerned about the extent and speed of exchange rate pass-through into domestic prices. If pass-through is low, a variation in the exchange rate to improve the trade balance may prove impotent. The implication is that policy makers may not necessarily need to be worried about potential inflationary consequences of exchange rate fluctuations. However, in recent times, there seems to be a growing degree of disconnect between exchange rate changes and domestic consumer prices.

The degree of responsiveness of prices to movements in the nominal exchange rate - the degree of exchange rate pass-through - has significant implications for the transmission of shocks and optimal monetary policy in open economies. It is observed that flexible exchange rate facilitates relative price adjustment in the face of country-specific real shocks. Changes in the relative prices produce an expenditure-switching effect between home and foreign goods that partly offsets the initial effect of the shock. This argument is premised on the fact that the domestic prices of imported goods react to changes in nominal exchange rates. Thus, a low degree of exchange rate pass-through implies a minimal expenditure-switching, which limiting the short-run adjustment role of nominal exchange rates and hence the desirability of flexible exchange rates.

The issue of exchange rate pass-through has received much attention in the 'new open economy macroeconomics' (NOEM) literature with emphasis on dynamics stochastic general equilibrium (DSGE) models (Bache, 2007; Lane, 2001; Sarno, 2001; and Bowman & Doyle, 2003). Revently, DSGE models have become useful tools for policy analysis both in academia and in policy institutions such as central banks (Bache, 2007). The increasing popularity of these models is attributable partly to a response to the Lucas (1976) critique, which argued that possibility of parameters stability of coefficients in traditional data-based econometric becomes unlikely due to shift in policy regime. For instance, in a model with forward-looking agents, current decisions are influenced by expectations of future policies, which imply that, when policy is altered, expectations of future policies also change, which also affect current decisions. In response to the Lucas critique, therefore, it is argued that policy analysis should be premised on inter-temporal optimizing models with explicit microfoundations (Bache, 2007).

While there is a large volume of literature on DSGE analyzing different areas of economic issues in developed and emerging economies[1] few of these studies are based on the African economies and, in particular, Nigeria (Alege, 2009). In Nigeria, with the pioneering work of Olekah and Oyaromade (2007) in this area, other attempts were made by Olayeni (2009), Alege (2009), Garcia (2009) and Adebiyi and Mordi (2010). From available information, there are no DSGE models that have investigated the extent and speed of exchange rate pass-through to domestic prices using a DSGE technique. This paper, therefore, aims at filling this gap by adopting Bayesian techniques to estimate the extent and the speed of exchange rate pass-through to domestic inflation in Nigeria using a dynamic stochastic general equilibrium (DSGE) methodology.

[1] *For examples Benhabib, Rogerson and Wright (1991) conduct the study for USA; Bergoeing and Soto (2002), for Chile; Kose (1999) and Hofmaiser and Roldos (1997), for Asia; Maussner and Spatz (2005), for Germany and Christodulakis, Dimeli and Kollintzas (1999), for the European countries.*

The structure of the paper is organized as follows. Following the introduction in section 1, section 2 provides the theoretical underpinning and literature review. Framework for DSGE modeling is discussed in Section 3, while methodology, covering the data, models set-up and their description are discussed in section 4. Model estimation, using Bayesian technique and the interpretation of the prior and posterior estimates are covered in Sections 5. This is followed with the analysis on impulse response functions in Section 6. Section 7 summarizes and concludes the paper.

2.0 THEORETICAL UNDERPINNING AND LITERATURE REVIEW

Under a perfectly competitive market, marginal cost equals price. However, in an imperfectly competitive market, there is possibility of firm earning abnormal profit due to the nature of the market. In this situation, what determines the variation in markup is the degree of substitutability between domestic and imported goods and this depends on the ability of a firm to differentiate its product and segregate the market.

Market segmentation, however, is made possible when geographical location has no systematic effects on transaction prices for identical products (Oladipo, 2006). Product segmentation is geographically possible if the location of the buyers and sellers influences the terms of the transaction substantially.

A market that is integrated may not be perfectly competitive. A monopoly supplier may charge a price above marginal cost, but not able to practice price discrimination if buyers are well organized or if the products are easily transported across markets. Market power of the sellers is, therefore, greater, the lower the degree of substitutability between domestic and imported goods and lower the degree of market integration.

There is extensive literature on open–economy macroeconomics. However, there are limited studies in the specific area of full-fledged dynamic modeling on exchange rate pass-through. It is more common for studies to follow Monacelli (2005) and introduce Calvo-type importers in model specifications where agents buy goods that are produced domestically and have them sold to foreign countries, even though they face Calvo type pricing frictions and can occasionally optimally reset their prices (Calvo, 1983). A useful example, Smets and Wouters (2002) incorporate the monopolistically competitive importers into a relatively large scale open economy model. Similarly, Lubik and Schorfheide (2005), in an earlier attempt, estimate an open economy New Keynesian model via Bayesian macroeconometric method, incorporating monopolistically competitive firms in a relatively small scale DSGE model.

The results and interpretation of literature on the estimation of PCP and LCP reveal that typically, there is a lower pass-through for indices defined in terms of import prices for a limited set of manufactured goods in comparison to homogeneous ones, particularly primary products. In addition, significantly lower estimates of coefficients are reported for consumer price index (CPI) when it is used as the dependent variable compared to an import price index that is narrower, because of the associated non-tradable nature and base point retail costs. Furthermore, core-CPI measures rather than the headline measure decreases the estimates further, since the volatility in prices of raw materials are typically not included, as they are usually the imports with larger pass-through. The estimated pass-through coefficients also differ considerably across countries.

Parsons and Sato (2006, 2008) examine pass-through effects on Japanese exports in an application with highly disaggregated data. Ito and Sato (2008) study pass-through in East and Southeast Asia in the post Asian crisis period using a VAR methodology. The novelty of this paper is in the application of a model-based estimation approach to the issue of pass-through. Campa and Goldberg (2005) study exchange rate pass-through into import prices for twenty three OECD countries and the findings reveal that there is evidence in favor of partial pass-through for both producer currency pricing and local currency pricing. The paper reveals an average exchange rate pass-through (ERPT) coefficient is 0.46 in the short-run and 0.64 in the long run for import prices. Shioji, Vu and Takeuchi (2007) develop a Bayesian estimation technique to analyze of partial pass-through using the Japanese aggregate data. It was found that passthrough was incomplete on both the export and import side of the Japanese economy.

Obstfeld and Rogoff (1995, 1996) are acknowledged as the first to build new open economy macroeconomics models that incorporate preset prices in the currency units of the exporter's country referred to as Producer Currency Pricing (PCP). The model presents within the framework of a two-country model, evidence that monetary expansion of a country is always profitable to the partner country. On the other hand, Betts and Devereux (2000) develop a model with the assumption of Local Currency Pricing (LCP) which is the quotation in importer's currency and show that different price setting led to different welfare outcomes.

Oyinlola and Egwaikhode (2011) study exchange rate pass-through to different measures of domestic price in Nigeria by applying a vector error correction model. This study, by employing data of 1980 – 2008, reveals that long run relationship exists between exchange rate and domestic price level. In addition, it was shown that short run variations in exchange rate might be anticipated and thus has its impact dampened.

Oriavwote and Omojimite (2012), in their study, establish the strength and length of the relationship between exchange rate pass-through and domestic prices in

Nigeria using the Vector Error Correction Model. Applying data covering 1970 to 2009, they find that exchange rate volatility induces domestic inflation in Nigeria, and thus recommend that exchange rate volatility should be given important consideration when implementing domestic inflation management policies.

Oyinlola (2011) investigates the impact of exchange rate movements on prices of disaggregated imports in Nigeria (1980-2006) by taking trade policy into consideration. The outcome of the study reveals that exchange rate exhibits positive and more-than-complete pass-through to import prices of consumer and capital product groups, with mixed interpretations for intermediate products. Hence, depreciation of exchange rate outstrips the impact of tariff reduction on prices of some products.

Oladipo (2012), investigating sectoral exchange rate pass-through effects, reveal that sectoral dependence on imports varies across sectors and show evidence of incomplete pass-through at varying degrees across sectors. As a result, when adjustment in relative prices is dampened, it reduces considerably the incentive for consumers to switch expenditure from foreign to domestic goods. The implication is that exchange rate policy may not be the most appropriate instrument to be used in dealing with external imbalances.

3.0 FRAMEWORK OF DSGE MODELLING

Most DSGE models available in the literature have a basic structure that incorporates elements of the new-Keynesian paradigm and the real business cycle approach. The benchmark DSGE model is an open or a closed economy fully micro-founded model with real and nominal rigidities (Christiano, et al, 2005; and Smets and Wouters, 2003). In this section, effort is made to illustrate the basic elements of DSGE models from the view of 'mathematical language of economists'. These models, though simple, provide a detailed empirical description of the development of output, inflation, and the nominal interest rate in Nigeria. However, some basic features of a standard DSGE models are excluded from the model. These include: the process of capital accumulation by firms in the demand block; the detailed treatment of labor market covering the number of hours worked by each employee and the number of people at work; the exclusion of the impediment to the smooth functioning of financial markets; and the assumption that central bank can perfectly control the short-term interest rate (Sbordone et.al., 2010).

Household

3.1.1 Households and the Aggregate Demand Block[2]

In all DSGE models, negative relationship exists between the real interest rate and desired spending. Since spending comes from consumption, the negative relationship between the interest rate and demand emanates from the consumption decision of households. This decision is modeled from the optimal choice of a very large representative household which maximizes its expected discounted lifetime utility, looking forward from an arbitrary date t_0

[2] The sub-section benefited immensely from the work of Sbordone etal (2010).

$$\underset{\{X_{t_0+s,}Z_{t_0+s,}[T_{t_{0+s}}(i)]_{i\in[0,1]}\}_{s=0}^{\alpha}}{Max} \mathrm{E}_{t_0} \sum_{s=0}^{\alpha} \beta^s \left\{ b_{t_{0+s}} \left[\log\left(C_{t_0+s} - \eta C_{t_0+s-1} \right) - \int_0^1 v\left(T_{t_0+s}(i) \right) di \right] \right\}$$

subject to the sequence of budget constraints

$$P_1 Z_1 + \frac{X_1}{R_1} \leq X_{t-1} + \int_0^1 w_t(i) T_t(i)\, di,$$

for $t = t_0, t_{0+1}, \ldots, \infty$, and given $X_{t_{0-1}}$. The representative household prefers more consumption to spending longer hours at work, T_t, as described by the convexity of demand function v. The satisfaction derived from consumption is a function of not only the current but also the past consumption, with a coefficient of η. With this 'habit', a rational consumer ensures that his current consumption does not fall below his recent past consumption.

In deciding how much to consume, household consumption is obtained by working for a certain amount of hours $T_t(i)$ in each of the *i*-firms, to earn an hourly nominal wage $W_t(i)$ which is assumed to be given in deciding how much to work[3]. The household can use his earned income to purchase the final good at price P_t or save, which can come from accumulating one-period discounted government bonds X_t, with a gross rate of return of R_t between t and $t+1$.

From the time perspective t, utility in time t+1 is discounted by time-varying factor $\beta b_{t+1}/b_t$ where b_{t+1}/b_t is an exogenous stochastic process. A shock to household's impatience is represented by changes in b_{t+1}/b_t. When b_t increases

[3] In equilibrium, wage rate is determined at the level at which the supply of labor by the household equals the demand of labor by firms. The demand for labour, in turn, is a function of the need of firms to hire enough workers to satisfy the demand for their products.

faster than b_{t+1}, for instance, the household cares more about the present than the future, and, consequently, increases the current consumption relative to the future. Thus, b_{t+1}/b_t acts as a conventional *demand shock*, which influences desired consumption and saving exogenously. A persistent decrease in b_{t+1}/b_t reflects current macroeconomic condition in a country, in which households have to reduce their future savings in order to increase their current consumption. In reality, this observed change in behavior is explained by many intricate factors, including the concern of people about the future, which is the exclusive focus of this model.

Solution to the optimal problem above is provided by forming the Lagrangian function

$$L = \mathrm{E}_{t_0} \sum_{s=0}^{\infty} \left\{ \beta^s \begin{bmatrix} b_{t_0+s} \left(\log\left(Z_{t_0+s} - \eta Z_{t_0+s-1} \right) - \int_0^1 v\left(T_{t_0+s}(i) \right) di \right) - \\ \Lambda_{t_0+s} \left(P_{t_0+s} Z_{t_0+s} + X_{t_0+s} R_{t_0+s}^{-1} \right) - X_{t_0+s-1} - \int_0^1 W_{t_0+s}(i) T_{t_0+s}(i)\, di \end{bmatrix} \right\},$$

with first-order conditions

$$\frac{\partial L}{\partial X_t} : \Lambda_t = \beta \mathrm{E}_t \left[\Lambda_{t=1} \right] R_t \tag{1a}$$

$$\frac{\partial L}{\partial Z_t} : \frac{\Lambda_t}{b_t} P_t = \frac{1}{Z_t - \eta Z_{t-1}} - \eta \mathrm{E}_t \left[\frac{\beta b_{t=1} / b_t}{Z_{t+1} - \eta Z_t} \right] \tag{1b}$$

for t= t_o, t_{t+1}… ∞ and

$$\frac{\partial L}{\partial T_t(i)} : \frac{v^t\left(T_t(i) \right)}{\Lambda_t / b_t} = W_t(i) \tag{2}$$

for t= t_o, $t_{t+1}\ldots\infty$ and $\lambda i \in [0,1]$ together with the chain of budget constraints. These conditions, which yield a fully state-contingent plan for the household's choice variables, provide an answer to the question on how much to work, consume, and save in the form of bonds. It is assumed that the household is conscious of the kind of random exogenous outcomes that might influence its actions and, importantly, that it knows the likelihood with which these outcomes might occur.

Consequently, the household can form expectations about future events, which are one of the inputs in its current choices. It is assumed that these expectations are rational, which implies that expected outcomes are premised on the belief that economic agents are fully informed about the economy and the random exogenous events that hit it.

For example, equation 1 establishes optimality conditions, which shows the negative relationship between the interest rate and desired consumption. This describes the demand side of the model and is clearer in the special case of no habit in consumption (η=0). We can combine the two equations to obtain the Euler equation.

$$\frac{1}{Z_t} = \mathrm{E}_t\left[\frac{\beta b_{t+1}}{b_t}\frac{1}{Z_{t+1}}\frac{R_t}{P_{t+1}/P_t}\right] \tag{3}$$

From this Equation, desired consumption decreases as (gross) real interest rate $\left(\frac{R_t}{P_{t+1}/P_t}\right)$ increases, as anticipated future consumption falls, and as households become more impatient (b_{t+1} falls).

After some manipulation, a log-linear representation of the Euler equation (3) is shown as

$$q_t = \mathrm{E}_t q_{t+1} - \left(i_t - \mathrm{E}_t \pi_{t+1}\right) - \delta_t \tag{4}$$

where $\pi_t = \log P_t / P_{t+1}$ is the quarterly inflation rate, i $\equiv$ log R_t represents the continuously compounded nominal interest rate, $\delta_t \equiv \mathrm{E}_t \log(\beta b_{t+1} / b_t)$ is a transformation of the demand shock, and $q_t \equiv$ log Q_t stands for the logarithm of total output. Since consumption is the only source of demand for the final good, Z, it is rational to substitute consumption of the final good with its output Q, and, thus, market clearing entails $Q_t = Z_t$

In this structure, equation 4 is akin to a conventional IS equation, which shows the relationship between aggregate output, y_t and the ex ante real interest rate, $i_t - \mathrm{E}_t \pi_{t+1}$. This must exist for the final-good market to clear. However, this equation differs from the conventional IS equation because it is dynamic and forward looking in nature; it shows current and future expected variables. Specifically, it shows a relationship between existing output and the total future expected path of real interest rates as shown in equation 5. This equation reveals the channel through which expectations of future monetary policy directly affect current economic conditions.

$$q_t = -\mathrm{E}_t \sum_{s=0}^{\alpha} \left(i_{t+s} - \pi_{t+s+1} - \delta_{t+s}\right) \tag{5}$$

It should be noted that the full Euler equation is a bit more complicated than in equation 4 as a result of the nature of the consumption habit ($\eta \neq 0$). However, these more complex dynamics do not alter the qualitative characterization of the link between real rates and demand.

Equation 2, which represents the labor supply decision, is the third first-order condition of the household optimization problem. It shows that workers are willing to work more hours if firms pay a higher wage[4]. In reality, a significant increase in wages would generate a positive income effect such that workers who are currently richer as a result of the increase would curtail their labor supply significantly. Technically, workers with higher income tend to raise consumption, thereby causing marginal utility Λ_t , to fall and invariably decrease labor supply at any given wage level significantly.

Thus, labor supply schedule (in equation 2) shows the link between the wages that firms must pay to motivate workers to work a certain number of hours. With rising economic activities, however, firms are willing to pay higher hourly wages that correspond with the desire of the household to work longer hours. All these are critical to the production and pricing decisions of firms, which is the subject of our discussion in the next section.

3.1.2 Firms and the Aggregate Supply Block

In the supply block of a DSGE model, firms set their prices with consideration given to the level of demand facing them. Consequently, a positive link exists between inflation and real activity. From the microeconomic foundations perspective, firms' production structure includes a set of monopolistic *i*-firms, as

[4] Labor supply is upward sloping because v’ is an increasing function, as v is convex.

well as an *f*-firm, which simply aggregates the output of the *i*-firm into the final consumption good. This section focuses on the firms' problem with no consideration given to the *f*-firm. This is because all the pricing system occurs within the *i*-firms.

It is assumed that intermediate firm *i* hires $T_t(i)$ units of labor of type i on a competitive market to produce Q_i units of intermediate good *i* with the technology

$$Q_t(i) = K_t T_t(i) \tag{6}$$

where K_i stands for the overall efficiency of the production process and is also assumed to follow an exogenous stochastic process, whose random fluctuations over time reflect the unanticipated changes in productivity often experienced by modern economies. This process is called an aggregate *productivity shock* as it is common to all firms.

Assuming a monopolistically competitive market for intermediate goods (Dixit and Stiglitz, 1977) where firms set prices subject to the condition that they satisfy the demand for their good, we derive the demand for f-firm as

$$Q_t(i) = Q_t\left(\frac{P_t(i)}{P_t}\right)^{-\theta} \tag{7}$$

where $P_t(i)$ is the price of good i and θ_t is the elasticity of demand. With increase in the relative price of good *i*, its demand falls relative to aggregate demand by an amount determined by θ_t.

It is well established in the economic literature (Bils and Klenow, 2004; Nakamura and Steinsson, 2008) that firms alter their prices occasionally and that they do not adjust prices frequently, but rather hold them constant in some cases for long periods of time. Upon this premise, we follow Calvo (1983) assumption that in every period of time only a fraction $1-\alpha$ of firms is allowed to reset its price while the remaining proportion maintains its old price. The portion that is able to reset their price set it optimally at *t* call it $\Omega \subset (0,1)$, thereby maximizing the discounted stream of expected future profits with the belief that *s* periods from now there is a probability α^s that they will be forced to keep the price currently chosen. Based on this fact, the objective function of each of these firms is stated as

$$\underset{Pt(i)}{Max}\ \mathrm{E}_t \sum_{s=0}^{\alpha} \alpha^s \frac{\beta^s \Lambda_{t+s}}{\Lambda_1} \left\{ P_t(i) Q_{t+s}(i) - W_{t+s}(i) T_{t+s}(i) \right\}$$

for all $i \in \Omega_t$ subject to the production function in equation 6 in addition to the limitation that they must satisfy the demand for their product at every point in time.

$$Q_{t+s}(i) = Q_{t+s} \left(\frac{P_t(i)}{P_{t+s}} \right)^{-\theta_{t+s}} \tag{8}$$

for s = 0, 1… ∞ . Profits, defined as total revenue at the price chosen today, $P_t(i)Q_{t+s}(I)$, minus total costs $\mathrm{W}_{t+s}(\mathrm{i})\mathrm{T}_{t+s}(\mathrm{i})$, are discounted by the multiplier $\beta^s \wedge_{t+s} / \wedge_t$, which transforms profits in the future into a current value.

The first-order condition of this optimization problem is derived as

$$\mathrm{E}_t\sum_{s=0}^{\infty}\left(\alpha\beta\right)^s\Lambda_{t+s}Q_{t+s}P_{t+s}^{\theta_{t+s}-1}\left[P_t^*\left(i\right)-\mu_{t+s}\frac{W_{t+s}\left(i\right)}{K_{t+s}}\right]=0 \qquad (9)$$

For all $i\in\Omega_t$, where $P_t^*\left(i\right)$ denotes the optimal price chosen by firm i, $\mathrm{W}_{t+s}\left(\mathrm{i}\right)\mathrm{T}_{t+s}\left(\mathrm{i}\right)$ is the firm's nominal marginal cost at time *t*+s, and $\mu_{t+s}=\frac{\theta_{t+s}-1}{\theta_{t+s}}$ is its desired mark-up charged if prices were flexible. As rational monopolists, optimizing firms set their price as a mark-up over their marginal cost but this relationship holds given the expected present discounted value and not every period. This is because a price chosen at time t will still be in effect with probability α^s in period $\mathrm{t}+\mathrm{s}$.

Marginal cost of a firm can be rewritten such that at time $\mathrm{t}+\mathrm{s}$ is still forced to retain the price $P_t(i)$as

$$\begin{aligned} S_{t+s}\left(i\right) &\equiv \frac{W_{t+s}\left(i\right)}{K_{t+s}}=\frac{v^t\left[T_{t+s}\left(i\right)\right]}{\Lambda_{t+s}/b_{t+s}}\frac{1}{K_{t+s}} \\ &\equiv \frac{v^t\left(\frac{Q_{t+s}}{K_{t+s}}\left(\frac{P_t\left(i\right)}{P_{t+s}}\right)^{-\theta_{t+s}}\right)}{K_{t+s}\Lambda_{t+s}/b_{t+s}} \end{aligned} \qquad (10)$$

From equation 10, we use the labor supply equation in 2 to substitute for the wage as well as the production function in equation 6 and the demand function in equation 8 to arrive at a term for the labor demand $\mathrm{T}_{t+s}(\mathrm{i})$, which is equivalent for 'solving' for equilibrium in the labour market.

The equation for the desired mark-up, $\mu_{t+s}=\frac{\theta_{t+s}-1}{\theta_{t+s}}$ says that a monopolist that faces an inelastic demand charges a higher mark-up, which translates to higher price since the consumers are indifferent to price increase. This insensitivity is assumed to follow an exogenous stochastic process. A positive shock to *desired mark up, for instance,* increases the firm's market power, which invariably translates into higher prices.

Considering equation 9 together with definition of the aggregate price level as a function of newly set prices P^*_t and the past price index P_{t-1}

$$P_t \equiv \left[(1-\alpha) P_t^{*(1-\theta_t)} + \alpha P_{t-1}^{1-\theta_t} \right]^{\frac{1}{1-\theta_t}}$$

produces an estimated New Keynesian Phillips curve, which shows a connection between current inflation, future expected inflation, and real marginal cost of the type

$$\pi_t = \xi s_t + \beta E_t \pi_{t+1} + u_t \tag{11}$$

where u_t = $\xi \log u_t$ is a transformed mark-up shock and s_t= $\log(S_t/P_t)$ is the logarithm of the *real* marginal cost. The responsiveness of inflation to changes in the marginal cost, ξ , is a function of the rate of price change , α and other structural parameters as indicated by $\xi \equiv \frac{(1-\alpha)(1-\alpha\beta)}{\alpha(1+\omega\theta)}$, where $\omega \equiv \frac{v"T}{v'}$ is the elasticity of the marginal disutility of work, while θ is the average value of the elasticity of demand θ_t .

Supply block, which provides the relationship between inflation and real activity, is defined by the Phillips curve together with the expression for marginal costs in equation 11. Equation 11 shows that marginal cost is a function of the level of aggregate activity, among other factors. Higher economic activity translates to higher wages, higher marginal cost and higher inflation.

Another characteristic of the Phillips curve is that it is forward looking. By iterating equation 11 forward, we obtain

$$\pi_t = E_t \sum_{s=0}^{\infty} \beta^s \left(\xi s_{t+s} + u_{t+s}\right),$$

which reveals how current inflation depends on the entire future expected path of marginal costs and real activity. However, this path invariably depends on expected interest rates and the entire future course of monetary policy as revealed in equation 5.

3.1.3 Monetary Policy

In Equation 5, it is shown that low interest rate—current and expected—encourages more consumption of goods. However, with high demand, firms' marginal costs and prices tend to increase, thereby raising inflation. The converse holds when the interest rate is high. It should be noted, however, that short-term interest rate enters the models through the action of the monetary authority that sets the nominal interest rate. In Nigeria, this is a decision made by the Monetary Policy Committee (MPC) using various inputs from the monetary policy technical committee (MPTC), projections from several models, and the judgment of policymakers, among others. Notwithstanding the perceptible complexity of the process, Taylor (1993) has clearly shown that it could be logically demonstrated by assuming that the Central Bank of Nigeria (CBN) raises the monetary policy rate when inflation and/or output is "high" with respect to some baseline. This is an assumed behaviour in almost all segments of DSGE models, but the definition of the correct baselines is rather contentious.

In this model, therefore, it is assumed that interest rates are set based on policy rule

$$i_t = \rho i_{t-1} + (1-\rho)\left[r_t^e + \pi_t^* + \varphi_\pi\left(\pi_t^{4q} - \pi_t^*\right) + \varphi_y\left(q_t - q_t^e\right)\right] + \varepsilon_t^i \tag{12}$$

where r_t^e , π_t^* and q_t^e and are the baselines for the real interest rate, inflation, and output, respectively, and $\pi_t^{4q} \equiv \log(p_t / p_{t-4})$ is the rate of inflation over the previous four quarters. The monetary policy shock ε_t^i captures any discrepancy between the observed nominal interest rate and the value suggested by the rule. This rule implies that if inflation and output rise above their baseline levels, the nominal interest rate is raised over and above its own baseline, $r_t^e + \pi_t^*$, by values determined by the parameters φ_π and φ_y and at a speed that depends on the coefficient ρ. The higher policy rate, which is expected to persist even after output and inflation have returned to the steady state, exerts a restraining force on the economy, thereby reducing demand, marginal costs, and inflation. In this respect, π_t^* and q_t^e can be regarded as targets of monetary policy, which are the levels of inflation and output that the central bank considers consistent with its mandate.

Production of equilibrium or 'efficient' level of output could be identified as part of the central bank's objective and could be represented as q_t^e. This unobserved variable represents the prevailing level of output in the economy that is capable of eliminating all distortions. The level of activity resulting from such behavior is ideal from the view of the representative household in the model and makes it a suitable target for monetary policy. When output is at its efficient level, however, inflation is not stable, as desired by policymakers, but fluctuates due to the presence of mark-up shocks. This is the essence of the monetary policy trade-offs in the economy. Achieving the efficient level of output requires undesirable movements in inflation. In contrast, a stable inflation implies deviations from the efficient level of output. The two objectives cannot be reconciled, but must be traded-off at any particular point in time.

Related to the efficient level of output is the efficient real interest rate, r_t^e, which is the observed rate of return in an efficient economy. This implies that, when the actual real interest rate is at its efficient level and is expected to remain at that level in the future, output will also be at its efficient level as reflected by r_t^e in the definition of the baseline interest rate.

4.0 METHODOLOGY

4.1 **Model Set Up and Description**[5]

Most DSGE models available in the literature have a basic structure that incorporates elements of the new-Keynesian paradigm and the real business cycle approach. The benchmark DSGE model is an opened or a closed economy fully micro-founded model with real and nominal rigidities (see for instance Christiano, et al, 2005; and Smets and Wouters, 2003). Considering the peculiarities of Nigeria as an oil-dependent economy, the dynamic evolution of the endogenous variables of interest in the Nigerian economy, as explained in equations 13 to 16, as follows: aggregate demand equation (IS curve), aggregate supply (the Phillips curve), uncovered interest rate parity (UIP) and monetary policy reaction function (a forward-looking Taylor rule).

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

The dynamic evolution of the endogenous variables is explained in four equations covering 1990:1 – 2011. The variables are expressed in difference form as specified in equations 13 to 16:

$$yg_t = a_1 yg_{t+1} + a_{11} yg_{t-1} - a_2 mci_t + a_3 yg^f{}_t + a_5 gov_t + \varepsilon_{yg} \quad (13a)$$

$$mci_t = a_4 z_t + (1 - a_4) r_t \quad (13b)$$

$$inf_t = b_1 inf_{t-1} + (1 - b_1) inf_{t+1} + b_2 rmc + b_4 p_o + b_5 m_2 + \varepsilon_{inf} \quad (14a)$$

$$rmc_t = b_3 yg_t + (1 - b_3) z_t \quad (14b)$$

$$s_t = e_1 s_{t+1} + e_2 yg_t - e_3 res - e_4 (i_t^f - i_t) + \varepsilon_s \quad (15)$$

$$i_t = f_1 i_{t-1} + (1 - f_1)\left(i_t^n + f_2 \left(inf_{t+1}^e - inf^T\right) + f_3 yg_t + f_4 ner_t\right) + \varepsilon_i \quad (16)$$

$$pf_t = \tau_1 pf_{t-1} + \varepsilon_{6t} \quad (17)$$

$$i_t^f = \tau_2 i_{t-1}^f + \varepsilon_{7t} \quad (18)$$

$$ygf_t = \tau_3 ygf_{t-1} + \varepsilon_{8t} \quad (19)$$

$$po_t = \tau_4 po_{t-1} + \varepsilon_{9t} \quad (20)$$

$$gov_t = \tau_5 gov_{t-1} + \varepsilon_{10t} \quad (21)$$

$$res_t = \tau_6 res_{t-1} + \varepsilon_{11t} \quad (22)$$

$$m_{2t} = \tau_7 m_{2t-1} + \varepsilon_{12t} \quad (23)$$

where: yg_t is the output gap in period t; yg^f_t is the foreign output gap in period t; mci 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; Δz_e is the change in the equilibrium exchange rate in period t; s_t is the nominal interest rate in period t; gov stands for the government total expenditure; inf_t represents inflation rate in period t; rmc is real marginal cost in period t; inf^e_{t+1} stands for expected inflation rate in period t; inf^T stands for 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; po is the oil price (bonny light); M_2 stands for the broad money supply; i^f_t is the foreign nominal short-term interest rate in period t; i^n_t represent the natural rate of interest in period t; t-i represents the lagged of relevant variables; t+i stands for the lead of relevant variables; and a, b, e and f are all parameters to be estimated.

Equation 13 is an enriched version of the standard new-Keynesian Euler equation for consumption, which is theoretically linked to household utility optimization. According to the theory, household maximizes discounted stream of utility (consumption and labor supply) subjected to budget constraints (consumption expenditure and wages). In calculating the present value of spending and wages, interest/ policy rate is incorporated.

The lag of output gap (yg_{t-1}) is included in equation 13 to give room for some degree of habit persistence in consumption or adjustment costs of investment (Pongsaparn, 2008). Nigeria is a small open economy and consequently, real exchange rate gap (z) is included as a variable that influences economic activities through the prices of imports and exports. The relative weight of the real interest and real exchange rates is explained by a monetary condition index (MCI) in the IS curve. Also, foreign output gap ($y^f g$) 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 by the residual term.

Equation 14 is the inflation equation specified in the spirit of the Philips curve. 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, inflation depends on its expected future value and its own lagged value. The inclusion of the lagged term shows the existence of a short-run trade-off between output and inflation. In the specification of inflation equation, exchange rate effect on domestic prices is considered. The inclusion of the real exchange rate attempts to capture the exchange rate pass-through to domestic prices due to the openness of the economy. Domestic sources of inflation are captured by the inclusion of output gap, yg_t. The relative weight of output gap and real exchange rate gap in the firm's real marginal costs is denoted by b_2.

Equation 15 is the uncovered interest parity (UIP) equation for an open economy, like Nigeria. i_t and i_t^f are the domestic nominal and foreign short-term interest rates, respectively. In the literature, many models that assume interest parity condition do not provide enough persistence to generate a hump-shaped response of the real exchange rate after a shock to monetary policy, which is commonly found in estimated VARs (Eichenbaum and Evans, 1995; Faust and Rogers, 2003). Given the degree of openness of the Nigerian economy, it is plausible to assume that interest parity condition holds in Nigeria. Thus, nominal exchange rate depends on its lead value.

Equation 16 is the modified Taylor's rule, which explains the interest rate path for the monetary authority. From the equation, monetary authorities react immediately to the changes in the inflation and output gaps, by altering its monetary policy rate to stabilize both the nominal and real exchange rates. The exchange rate plays an important role in aggregate demand through its effects on net export and also on inflation through the pass-through effect. 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.

5.0 **EMPIRICAL METHODOLOGY**

5.1 Bayesian Estimation

This paper employs a Bayesian methodology to estimate the above structural model. Technically speaking, Bayesian estimation is a mix between calibration and maximum likelihood, which are connected by Bayes' rule. The calibration part is the specification of priors and the maximum likelihood approach enters through standard econometrics based on adjusting the model with data. This methodology has recently been used extensively in estimating complex stochastic models involving very large numbers of parameters. In such cases, it is typical to conduct the Bayesian estimation via Markov-chain Monte-Carlo (MCMC) simulation rather than the straightforward maximum likelihood estimation: this is because in most of such cases it is not possible to specify the joint distribution of parameters in an explicit manner. This paper employs the Metropolis-Hastings (MH) algorithm, which is one of the oldest among the existing MCMC sampling methods.

The basic idea of the Bayesian estimation can be summarized as follows.

$$p\left(\lambda_R \middle| K_T, R\right) = \frac{p\left(K_T \middle| \lambda_R, B\right) p\left(\lambda_R \middle| R\right)}{p\left(K_T \middle| R\right)}$$

where $p\left(K_T \middle| R\right)$ is the marginal density of the data condition on the model, $p\left(\lambda_R \middle| R\right)$ the priors density function and $p\left(K_T \middle| \lambda_R, R\right)$ is the likelihood function.

5.2 Prior Distributions of the Estimated Parameters

The starting point of the Bayesian inference is the identification of prior distribution, which describes the available information prior to observing the data used in the estimation. In the calibration of the model, we take into consideration the validity of economic theories, stylized facts about the Nigerian economy and observations, facts and existing empirical literature. Thus, we obtained the coefficients in Table 1 as follows. The Phillips curve and the IS curve estimates were obtained from the work of Adebiyi and Mordi (2010b). The estimates of output lag of 0.72 is consistent with what is found in Laxton and Scott (2000), who claim 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. We assume all exogenous variables to follow AR (1) processes (Adebiyi and Mordi, 2010).

Table 1: The Model Calibration and Parameterization

Equation	Parameter	Definition	Value	Comments	Linear Homogeneity Condition
IS Curve (Output Gap)	$yg_t = a_1 yg_{t-1} - a_2 mci_t + a_3 yg^f_t + a_5 gov_t + \varepsilon_{yg}$ $mci_t = a_4 z_t + (1 - a_4) r_t$				
	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	$\mathrm{inf}_t = b_1\mathrm{inf}_{t-1} + (1 - b_1)\mathrm{inf}_{t+1} + b_2\mathrm{rmc}_t + b_4\mathrm{p}_{0t} + b_5\mathrm{m}_{2t} + \varepsilon_{\mathrm{inf}}$ $\mathrm{rmc}_t = b_3\mathrm{yg}_t + (1 - b_3)\mathrm{z}_t$				
	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	$0<b_2<1$

				sacrifice ratio. It varies from 0.05 to 0.4	
	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	$s_t = e_1 s_{t+1} + e_2 yg_t - e_3 res - e_4(i^f_t - i_t) + \varepsilon_s$				
	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	$i_t = f_1 i_{t-1} + (1 - f_1)(i^n_t + f_2(\inf^e_{t+1} - \inf^T) + f_3 yg_t + f_4 ner_t) + \varepsilon_i$ (				
	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	1.50**	Measures the weight put on inflation by the policy maker; value has	$f_2>0$

		potential		no upper limit but must be always higher then 0 (the Taylor principle)	
	f_3	Output gap	0.50**	measures the weight put on the output gap by the policy maker; value has no upper limit but must be always higher then 0	$f_3>0$
	f_4	Changes in Exchange rate	0.25**	measures the weight put on the exchange rate by the policy maker; value has no upper limit but must be always higher then 0	$F_4>0$

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

** the values are obtained from Adebiyi and Mordi (2010)

5.3. Posterior Distributions of the Estimated Parameters

In order to sample from the posterior, random walk Metropolis-Hastings (MH) algorithm is utilized to produce 100,000 draws from the posteriors. The Estimation results are reported in Table 2 and Figure A.1 (in the Appendix). The results show the distribution used, the prior mean, the prior standard deviation, and the confidence interval.

Table 2: Prior and Posterior Distribution of the Estimated Parameters

Parameter	Description	Density	Prior Mean	Posterior Mean
a_1	Measures output gap expectation	Beta	0.35	0.29
a_{11}	Measures output gap persistence	Beta	0.65	0.74
$a_2 * a_4$	Measures impact of exchange rate on output	gamma	0.40	0.20
$a_2 * (1-a_4)$	Measures impact of interest rate on output	gamma	0.25	0.13
a_3	Measures the impact of foreign demand on domestic output	beta	0.50	0.68
a_5	Measures impact of government expenditure on output	gamma	0.20	0.27
b_1	Inflation expectation	beta	0.30	0.40
b_{33}	Measures Inflation persistence	Beta	0.65	0.74
$b_2 * b_3$	Measures sacrifice ratio	Beta	0.30	0.21

$b_2*(1-b_3)$	Measures exchange rate pass-through	beta	0.25	0.096
b_4	Measures impact of oil price (bonny light) on inflation	gamma	0.20	0.28
b_5	Measures the impact of money supply on output	gamma	0.50	0.37
f_1	Measures policy persistence	Beta	0.20	0.15
f_2	Measures the weight put on inflation by policy makers	Beta	1.50	1.45
f_3	Measures the weight put on output gap by policy makers	gamma	0.50	0.51
f_4	Measures the weight put on exchange rate by policy makers	gamma	0.25	0.23
e_1	Measures exchange rate expectation	gamma	0.50	0.52
e_2	Measures the impact of output gap on nominal exchange rate	gamma	0.20	0.12
e_3	Measures the impact of external reserves on nominal exchange rate	gamma	0.20	0.14
e_4	Measures the impact of interest rate differential on nominal exchange rate	gamma	0.50	0.48
τ_6	Measures the AR(1) of foreign (USA) price	gamma	0.40	0.32
τ_7	Measures the AR(1) of foreign	gamma	0.50	0.47

	interest rate			
τ_8	Measures the AR(1) of oil price	Beta	0.45	0.42
τ_9	Measures the AR(1) of money supply	Beta	0.55	0.51
τ_{10}	Measures the AR(1) of US GDP	Beta	0.60	0.50
τ_{11}	Measures the AR(1) of external reserves	gamma	0.60	0.55
τ_{12}	Measures the AR(1) of monetary policy rate	gamma	0.50	0.65

* Metropolis-Hastings sampling algorithm based on 100000 draws with 59% acceptation rate.

From Table 2, it is observed that monetary policy influences inflation through its effects on output and the exchange rate. The posterior estimate of the output gap, which measures the sacrifice ratio ($b_2 * b_3 = 0.21$) is not too far from the prior (0.30). This makes it possible for monetary authorities (particularly the Central Bank of Nigeria) to control inflation through output gap. Also, the impact of the exchange rate on prices ($b_2 * (1 - b_3)$ = 0.10), indicating a low and incomplete pass-through into prices (that is 10 per cent per quarter or 40 per cent per annum).

The estimated exchange rate pass-through in Nigeria (9.6%) when compared with past studies on subject indicates that exchange rate pass-through to inflation is declining in Nigeria. For example, Aliyu, Yakub, Sanni and Duke (2007) obtained an ERPT of 10.5%; Barhoumi (2007), 14.7%; Garcia (2010), 10%; Oyinlola (2011), 18-47%; CBN (2011), 0.25%; and Oriavwote and Omojimite (2012), 16%. However, these findings should be interpreted with caution since past studies on this subject vary from scope to methodology. Some used annual data, while others employed quarterly data. Apart, while some studies employed OLS technique, others used VAR and DSGE methodologies.

Notwithstanding, some reasons are attributed to the decline in exchange rate passthrough in Nigeria, which include the following. First, changes in Nigeria's monetary policy in the late 1980s and early 2000s. This has responsible for the decline in the exchange rate pass-through into Nigerian consumer prices during the last 14 years. The introduction of monetary policy rate (MPR) as an anchor rate, seems to have had a significant effect on the way the consumer price index responds to technology shocks, in relative to the way it responded in the pre-MPR rate. Second, in recent time, inflation rate in Nigeria has remained low, stable, and predictable. Inflation expectations have been well-anchored, policy credibility has been enhanced, and the persistence of inflation has been significantly reduced. Third, the propagation of exchange rate shocks is minimized and consequently exchange rate pass-through is less significant because of the increased confidence on the part of economic agents. Confidence is built on the fact that monetary authority will not allow inflation to move persistently above optimum and will anchor inflation expectations from becoming extrapolative. Lastly, ERPT seems to be declining in Nigeria due to the change in structure and the composition of trade in Nigeria. Today, the Nigerian trade is being expanded and diversified to include other emerging economies like China and Brazil, which has given the monetary authority room for flexibility.

Other empirical findings that are relevant to the study are as follows. Change in oil price has a significant impact on inflation with a posterior value of 0.28 (that is b_4=0.28), which is very close to the prior values of 0.20. This implies that a 1 percent increase in oil price would raise prices by only 0.28 the following period.

The output cost of disinflation, which is the sacrifice ratio, estimated to be is 1.21[6].

In the hybrid Phillip equation, the hypothesis that the values of forward-looking inflation expectation must be significantly below 0.50 to produce results that is consistent with data is established (Berg, Karam and Laxton, 2006). The posterior estimates show that the data provide useful information in explaining inflation behavior in Nigeria. The behavior of the economy depends critically on the value of b_1. The posterior estimates of Calvo price stickiness provide reasonable notion about frequencies of price change which is the probability of not changing price in a given quarters. The estimated values $b_1 = 0.40$ shows domestic firms re-optimize their prices in almost every one and half quarters[7], which is consistent with 0.382 obtained by Adebiyi and Mordi (2010) and the 0.57 obtained by Garcia (2009) and 0.38 by CBN (2011).

From Table 3, the posterior value (f_1 = 0.15) explains the possibility that the central bank can moderate interest rates and adjust them fairly slowly to the desired value based on the deviation of the inflation and output from equilibrium. The weight attached to inflation shows a posterior value of 1.45, which is very close to a prior of 1.50 and this supports the literature that a stable inflation rate requires a positive f_2 (Berg, Karam and Laxton, 2006). The posterior estimates for output gap and exchange rate are almost pin down by the data. The posterior mean of exchange rate (f_4) is 0.23, which indicates that monetary authority takes cognizance of exchange rate behaviour when determining the monetary policy rate. For example, if nominal exchange rate is appreciated by

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[6] Sacrifice ratio is defined as the cumulative output losses associated with a permanent one percentage point decline in inflation.

[7] This is obtained as $\frac{1}{1-b_3}$

1 per cent, maximum interest rate will decline by 23 basis points. This implies that the Taylor-type policy rule for Nigeria is a monetary policy rule that attaches weights not only to inflation and output gap, but also to exchange rate.

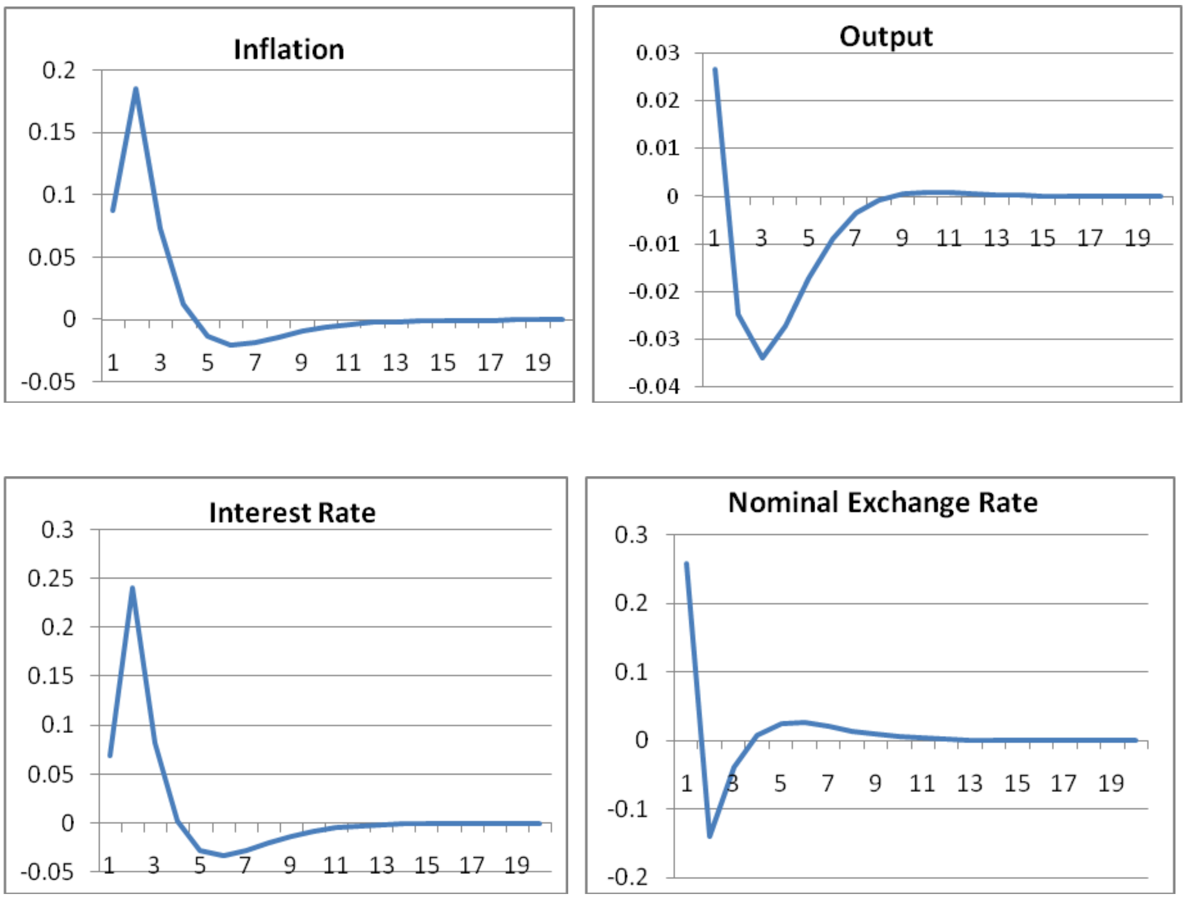
With regards to the persistence parameters of the AR(1) process, all of the parameters, except MPR, show a posterior mean smaller than the mean of the prior. This indicates that the persistence of the shocks is smaller than our prior beliefs (CBN, 2011).

6.0 PROPAGATION OF SHOCKS

From Figure 1, the response of inflation rate to exchange rate shocks is positive and statistically significant in the short run. The pass-through was almost zero in quarter 1 (0.09), rose to 0.18 in quarter 2 and declined to 0.07 and 0.01 in quarters 3 and 4, respectively. The finding shows a small and incomplete pass-through of exchange rate to inflation in Nigeria.

In the Figure also, a positive shock to the exchange rate leads to a depreciation of the naira. Depreciation encourages exports and discourages imports, thereby causing an immediate increase in output gap, interest rate and inflation. The speed of reversion to steady state, arising from the shock, was about 2- 3 years (8-12 quarters) for most of the variables.

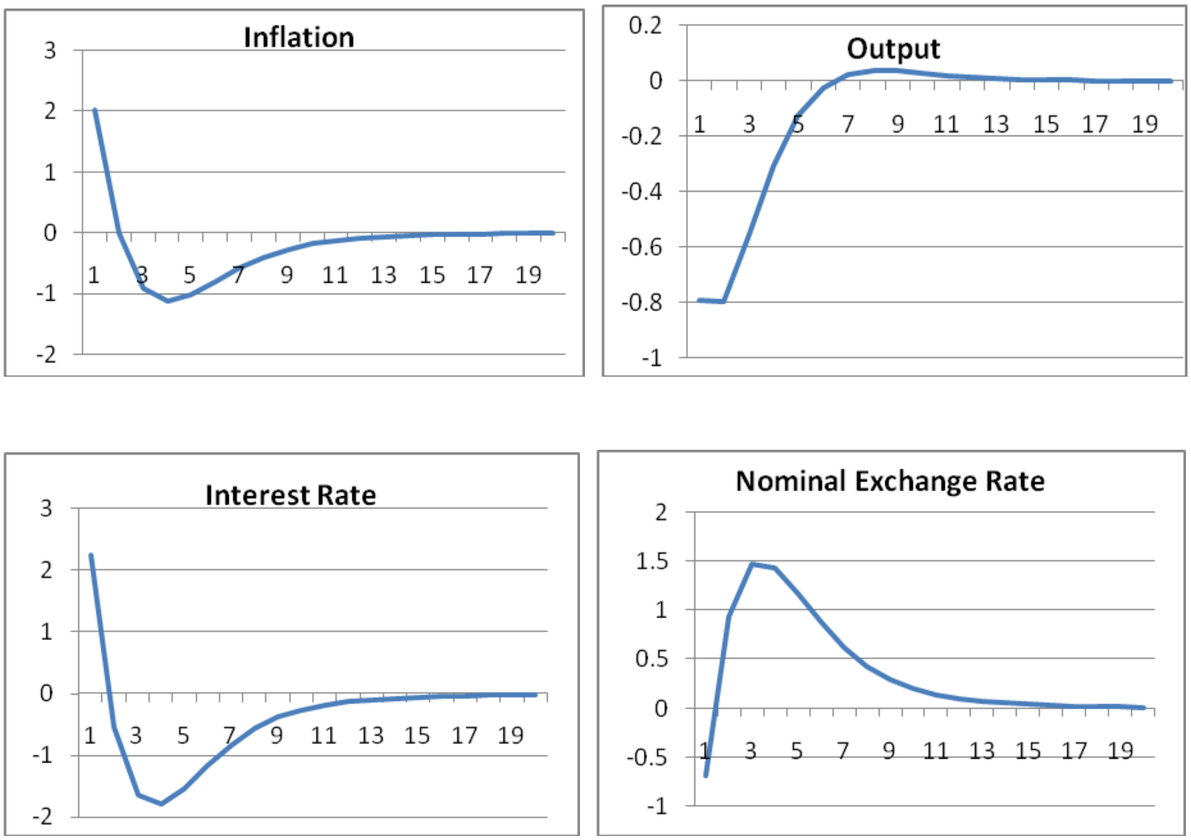
Figure 1: Response of Output and Prices to 1% Exchange Rate Shock



Source: Authors' Calculations

Supply shock as shown in Figure 2 causes an increase in inflation that causes the output gap to decline (i. e. produces a recession). This arises from the need of the monetary authority (Central Bank of Nigeria) to raise the interest rate in order to reduce inflation to its original level. As inflation declines, exchange rate depreciates due to the decrease in interest rate. Consequently, in the long run, all the variables are restored to their steady state values.

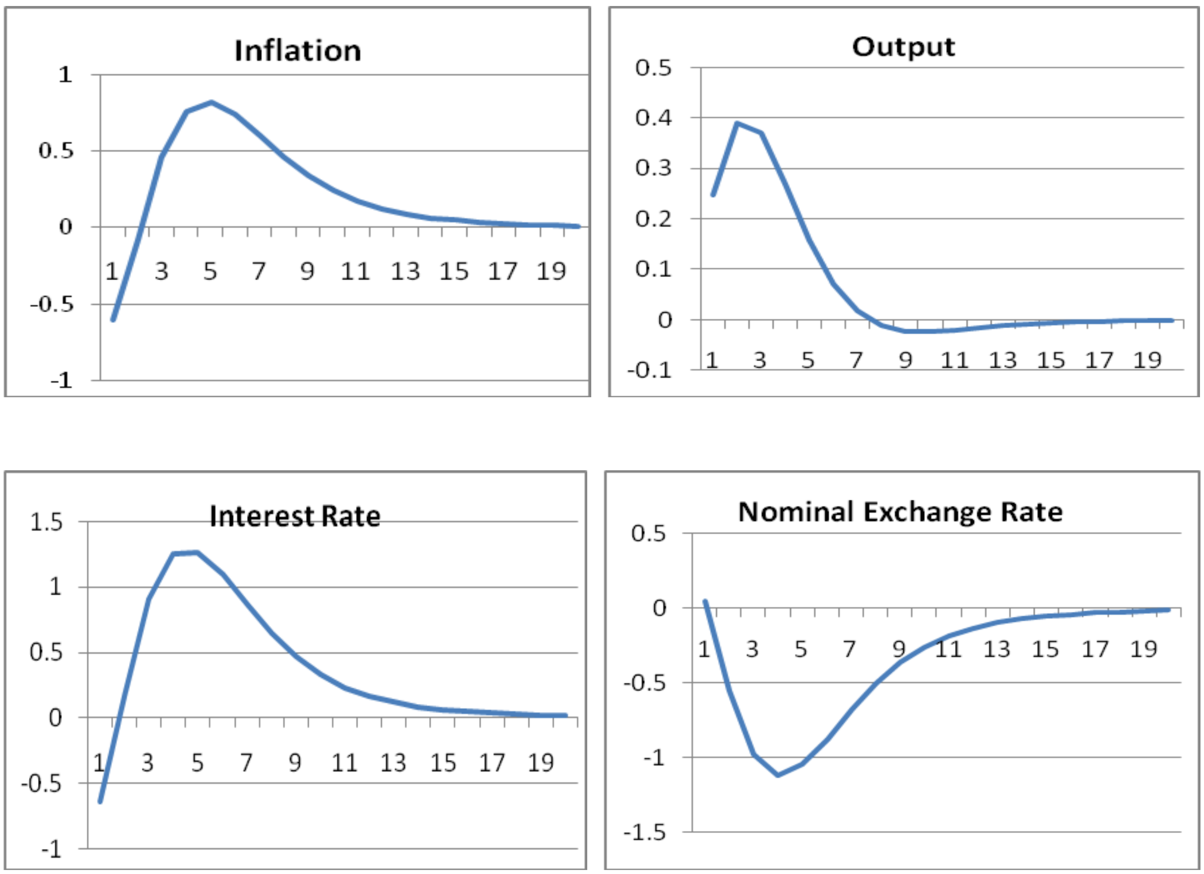
Figure 2: Response of Prices and Output to 1% Aggregate Supply Shock



Source: **Authors' calculations**

Positive shock to oil price produces an appreciation of the real exchange rate, which arises from the response of the authority to raise interest rate (see Figure 3 and equation 16). Consequently, the appreciation causes a reduction in inflation rate (equation 14a). The impact of the oil price shock on the inflation rate can be viewed from two perspectives. One, the appreciation reduces inflation rate. However, a second-round effect (though not shown here) shows that when the price of oil (bonny light) increases, foreign inflation tends to rise, which causes the domestic inflation rate to increase. Thus, the net effect is that inflation initially falls (because the positive effect of appreciation on inflation exceeds the negative impact of imported inflation), before it increases, reaches its maximum in quarter 5 and thereafter decelerate and returns to its steady state value.

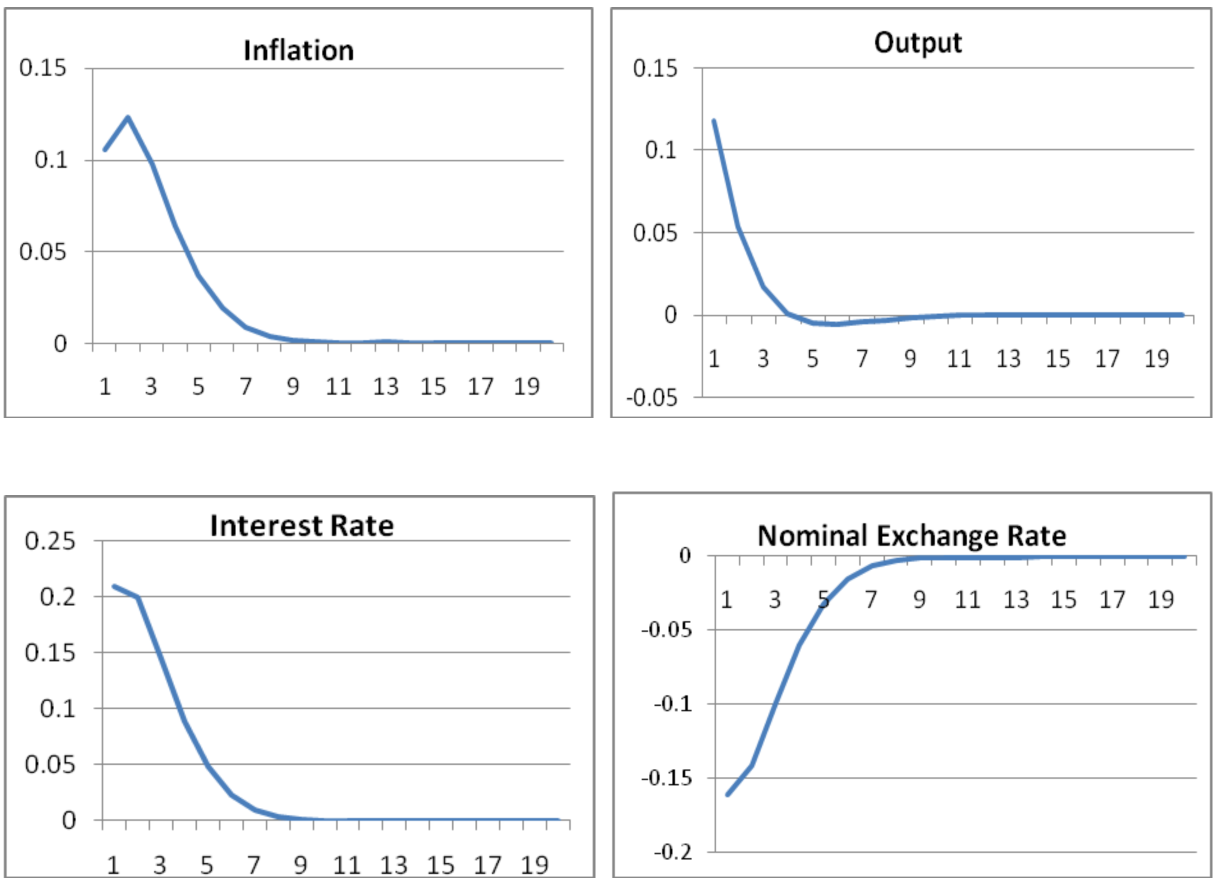
Figure 3: Response of Prices and Output to 1% Oil Price Shock



Source: **Authors' calculations**

The aggregate demand shock, which is in line with the prediction of the economic theory, produces an expansion of the economy (output) and increases in the inflation rate in the medium term (Figures 4). Increase in inflation rate raises the interest rate, which results in the appreciation of exchange rate and reduction in output gap in the medium to long run. However, in the long run, all the variables are restored to their equilibrium state values.

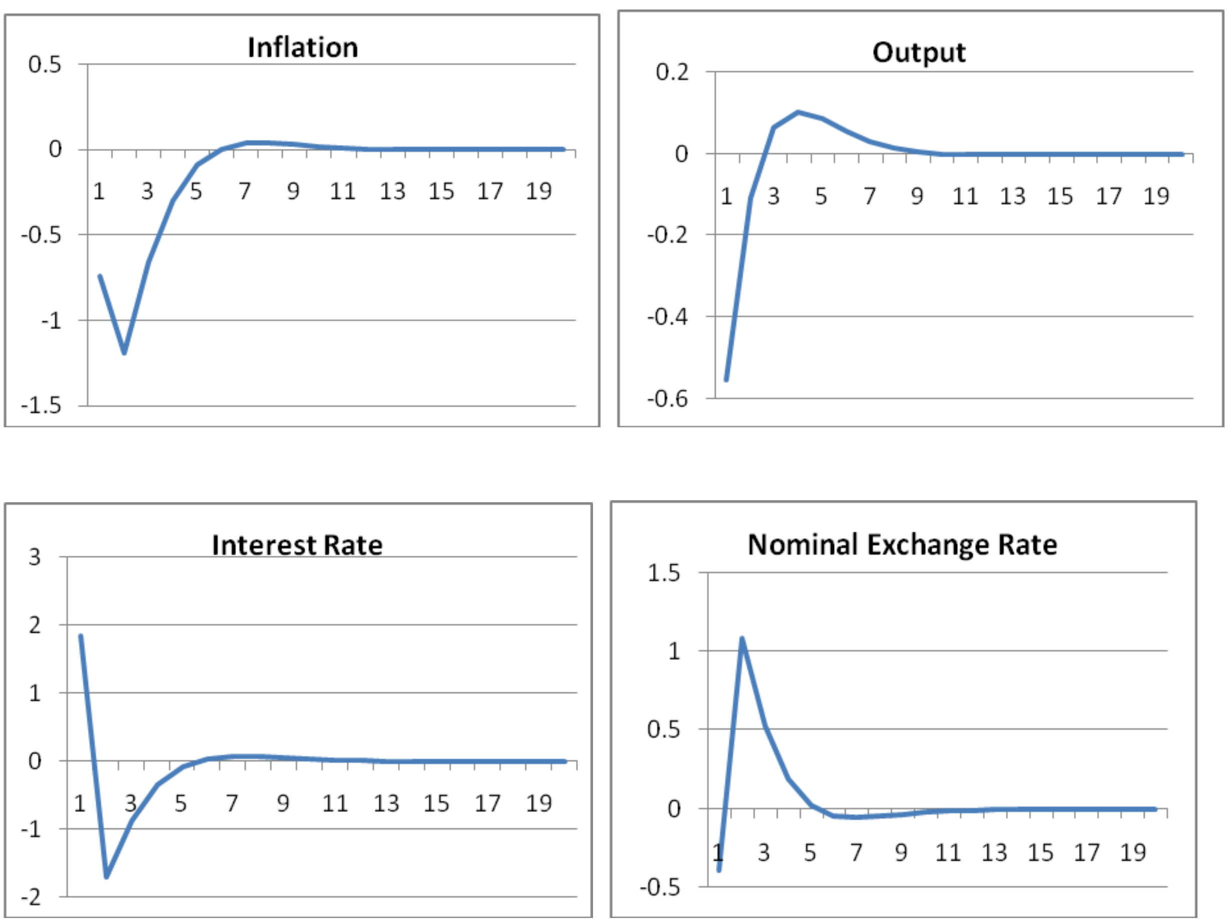
Figure 4: Response of Prices and Output to 1% Aggregate Demand Shock



Source: **Authors' calculations**

According to economic theory, a, increase in monetary policy rate (shock to interest rate) (Figure 5) is expected to decrease output gap and the inflation rate, which is consistent with our findings. This arises due to the fact that the real interest rate is negatively correlated with output gap (see equation13a), which results to a decline in the inflation rate as shown in the Phillip curve equation 14a. The existence of partial uncovered interest rate parity (that is the higher interest rate generates capital inflows that cause the Naira to appreciate as shown in equation 15) causes the shock to produce an appreciation of the Naira. Thereafter, all variables return to their steady state values because the decline in output and inflation generates a downward adjustment in the interest rate as shown in equation 16.

Figure 5: Response of Price and Output to 1% Positive Interest Rate Shock



Source: **Authors' calculations**

7.0 Conclusions

This study employs a Bayesian framework of DSGE model to estimate the pass-through effect of exchange rate to domestic inflation in Nigeria using a quarterly data for the period 1980 to 1998. The response of inflation rate to exchange rate shock is found to be positive and statistically significant in the short run. It shows a small and incomplete pass-through of exchange rate to domestic inflation with pass-through almost zero in quarter 1 (0.09), rose to 0.18 in quarter 2 and declined to 0.07 and 0.01 in quarters 3 and 4, respectively. This is lower than the findings obtained elsewhere by other authors [Aliyu, Yakub, Sanni and Duke (2007) obtained an ERPT of 0.11; Barhoumi (2007), 0.15%; Garcia (2010), 0.10; Oyinlola (2011), 0.18-0.47; CBN (2011), 0.25; and Oriavwote and Omojimite (2012), 0.16]. An improved monetary policy and enhanced credibility have probably played an important contributing role in the decline, along with significant shifts in the composition of trade and increased globalization.

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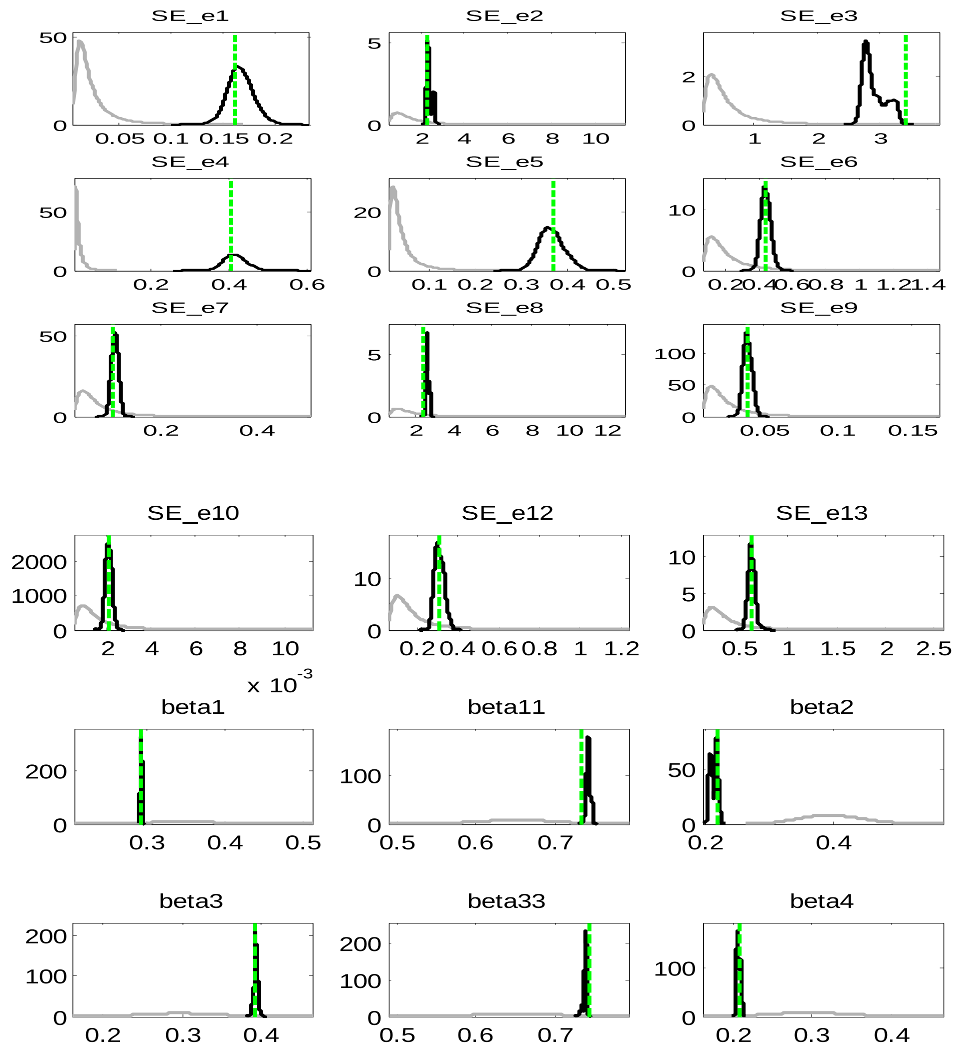
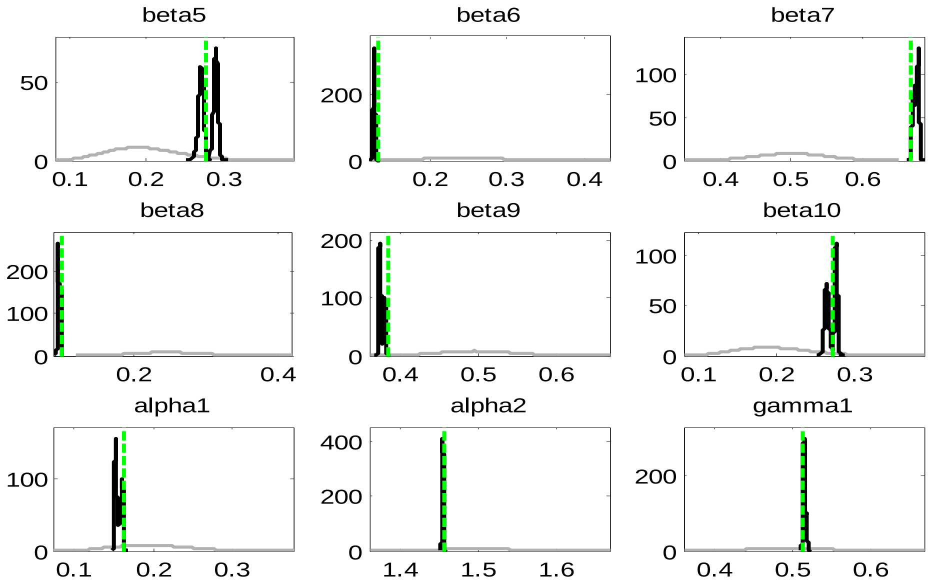
Appendix

Figure A.1: Prior and Posterior Distributions

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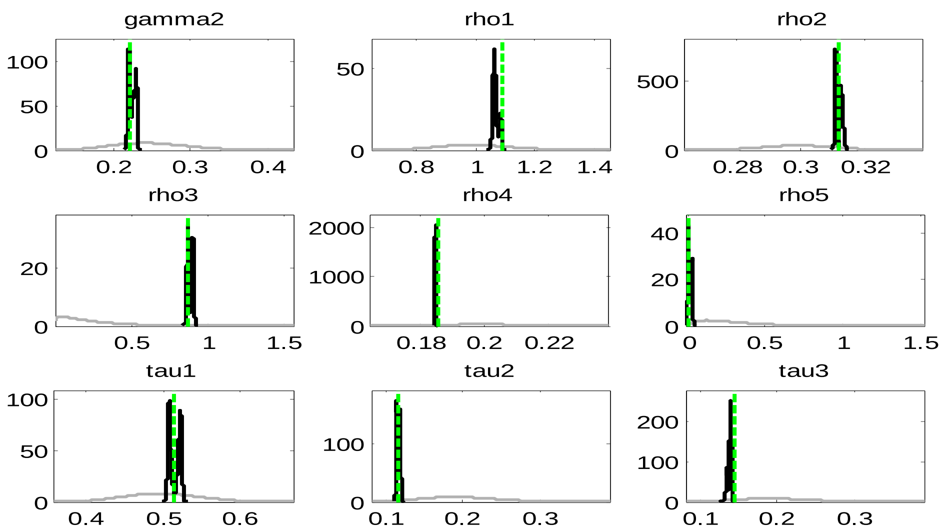
beta8
200
100
0
0.2 0.4
beta9
200
100
0
0.4 0.5 0.6
beta10
100
50
0
0.1 0.2 0.3
alpha1
100
0
0.1 0.2 0.3
alpha2
400
200
0
1.4 1.5 1.6
gamma1
200
0
0.4 0.5 0.6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0
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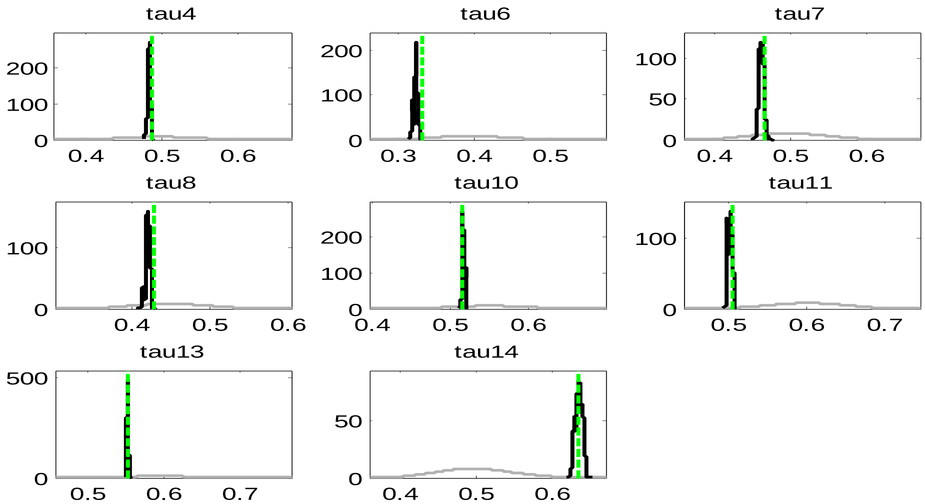
rho2
500
0
0.28 0.3 0.32
rho3
20
0
0.5 1 1.5
rho4
2000
1000
0
0.18 0.2 0.22
rho5
40
20
0
0 0.5 1 1.5
tau1
100
50
0
0.4 0.5 0.6
tau2
100
0
0.1 0.2 0.3
tau3
200
100
0
0.1 0.2 0.3


tau4
tau6
tau7
tau8
tau10
tau11
tau13
tau14