Is the Phillips curve useful for monetary policy in Nigeria?

Carlos J. García

ILADES- Georgetown University, Santiago Chile

cgarcia@uahurtado.cl

Is the Phillips curve useful for monetary policy in Nigeria?

Carlos J. García

Abstract

The objective of this article is to determine if the Phillips curve is a relevant tool to conduct monetary policy in African countries wishing to adopt an inflation-targeting regime. I choose Nigeria as a case of study because it is in the early stage of the implementation of this regime. I estimate a medium-sized model for monetary policy analysis. The model reflects a synthesis between the New Keynesian and the Real Business Cycle (RBC) approaches. Then I estimate the model by using Bayesian econometric technique in order to overcome the shortage of data availability. The study concludes that there is evidence that central banks can control the inflation rate through a Phillips curve, a Taylor rule that includes the exchange rate, and the sterilization of the resources from oil exports. Nevertheless, there are limits to the stabilization program. The same evidence suggests that it is important to implement a credible inflation-targeting regime to reduce inflation gradually, instead of abrupt stabilization attempts with high costs in lost output.

JEL codes: E31, E52, E58, O23

Keywords: Monetary policy, Phillips curve, inflation-target regime.

1. Introduction

The main objective of this article is to determine whether the Phillips curve is a relevant empirical tool for monetary policy conduct in Nigeria. The Phillips curve is in the heart of the new macro models that have helped developed economies and some emerging ones to adopt the inflation-targeting regime. Are African countries prepared to adopt this regime? Is there a Phillips curve in these economies to implement this regime as in other regions? How could the central bank manage the reserves from natural resource exports to implement an inflation-targeting regime? In this article I explore the relevance of the Phillips curve in Nigeria, one of the biggest economies in the African continent, an important oil exporter, and in the early stages of the implementation of an inflation-targeting regime.

If the Phillips curve is a relevant tool for guiding monetary policy, then the central bank of Nigeria could control the nominal interest rate and thus affect the output gap, the inflation rate, and the exchange rate. All these variables in turn affect monetary policy and so on through a kind of Taylor rule. Eventually this mechanism would result in a decreasing inflation rate toward a target, which the central bank has defined below 10%.

To measure the importance of the Phillips curve, I built a model which is sufficiently general to incorporate the basic structures observed in this economy, including a wide range of shocks that affect it. I propose an approach that has been used in many countries (including Canada, the U.K., Japan and New Zealand) and international organizations (such as the IMF) for that purpose. This combines the New Keynesian approach[1], with an emphasis on nominal and real rigidities and a role of aggregate demand in output determination, with the real business cycle tradition methods of dynamic stochastic general equilibrium (DSGE), with an emphasis on modeling with rational expectations[2] (Erceg et al.,2000; Christiano et al., 2005; Smets and Wouters, 2003, 2007; Galí 2008).

[1] Ball and Romer (1990), Mankiw and Romer (1991), and Clarida et al. (1999).
[2] See also Lucas (1976), Kydland and Prescott (1977), Sims (1980), Sargent (1981), and Prescott (1986).

The model is semi structural since it includes equations that have a direct interpretation from the economic theory such as a modern Phillips curve and the output gap interpreted as a Euler equation (Woodford, 2003). I assume that the agents have rational expectations, .i.e., expectations depend on the model's own forecasts. In other words, we assume that agents in the Nigerian economy use all available information at their disposal to calculate the expectation of some crucial macroeconomic variables such as inflation rate and exchange rate.[3]

The model is estimated by using Bayesian econometrics. This is especially well suited for economies where data availability is limited, because this allows us to exclude values in our estimations without economic sense that are usually obtained with standard econometric tools when time series data are short. The use of prior information for the parameters is a strategy that could change dramatically the quality of the estimation of macro models in developing economies and therefore avoid important policy mistakes for spurious results.

In summary, I conclude that there is empirical evidence in Nigeria that the central bank controls the inflation rate through a Phillips curve. Thus the adoption of a full-fledged inflation-targeting regime in Nigeria is quite feasible. The monetary policy transmission mechanism looks quite standard: the central bank reacts to an upsurge in the inflation rate by raising the interest rate. The reaction is strong enough to control the inflation rate Also, the central bank is relatively successful sterilizing the reserve form natural-resources exports combined with a fiscal policy that delays the impact of oil prices on the economy. But the monetary policy works by introducing a sacrifice ratio in the Nigerian economy; therefore, it is important to implement a credible inflation-targeting regime to reduce the inflation rate gradually instead of making abrupt stabilization attempts with high associated costs in lost output and employment.

---

[3] Even though the model presented in this report ignores a number of critical issues for monetary policy (a more complete description of the fiscal policy, current account determination, and the equilibrium levels for several variables), it has the advantage of relative flexibility for analysis. In addition, there is considerable scope to further develop the model, thus the model for the Nigerian economy may be extended to include full microeconomic foundations (DSGE), stock-flow dynamics, credit market restrictions, non-tradable sectors, fiscal policy, the implications for households' intertemporal savings decisions, and so on.

The study is organized as follows: Section 2 provides a detailed description of stylized facts to support the structure of the model. Section 3 presents the model and the empirical strategy, while Section 4 shows the results of the estimations; parameters and impulse response functions. Section 5 concludes.

2. Stylized Facts

In this section I present the evidence to support the theoretical structure of the model. Thus, it is very important to check whether or not some stylized facts are present in the Nigerian economy that let the central bank carry out a standard monetary policy. The first one is the existence of a stable Phillips curve, which allows it to affect the inflation rate through the output gap. The idea behind this is that the central bank can affect the demand side of the economy, which implies that the central bank is able to reduce the inflation rate via a lower aggregate demand or an actual GDP below its potential level. In fact **Figure 1** confirms this positive relationship between inflation and output gap in the Nigerian economy.

But what is the monetary transmission mechanism to control the inflation rate? **Figure 1** also shows the connection between the Monetary Policy Rate (MPR) and the output gap. It is observed that an increase in the MPR reduces the output gap in the period 1995-2007. From the IS equation, it is evident that the bridge connecting the inflation rate and the MPR is the negative link between the output gap and the MPR. This could explain the influence of the interest rate on both private consumption and investment, probably via the expansion and contraction of the credit market.

Figure 1: Inflation, GDP gap, and interest rate (MPR) in Nigeria

The next issue is how the central bank is setting the MPR. **Figure 2** shows the actual MRP and the MPR following a Taylor rule. I calibrate this rule by assuming a response for the inflation rate of 1.5 and a response of output gap of 0.5. I also assume that there is a lag of 0.7 in the MPR. As it is evident from Figure 2, the central bank follows very closely a standard Taylor rule. This shows that the complete mechanism of monetary policy in the Nigerian economy could be explained as follows: a higher level of inflation causes the central bank to raise the MPR above the inflation rate to ensure a positive real interest rate. This slows down private consumption and private investment, ultimately moderating the increase in prices.

Figure 2: MPR and the Taylor Rule in Nigeria

There is an additional issue relating to inflation stabilization in Nigeria that is important to discuss. Theoretically, the right connection in the Phillips curve is between the inflation rate and the output gap (or unemployment rate), and not for other measures of economic activity. This is also established in the Nigerian economy. For instance, **Figure 3** shows that the positive relationship between inflation and economic activity is clearly valid only for the output gap and not for output growth. Even for a same level of economic growth, we can observe a wide range of inflation rates.

Another important issue is how we can measure the output gap. Should we use the potential output as researchers do in developed economies or just a trend to indicate when there is excess demand? In **Figure 4** I show the possible discrepancy that can occur between these concepts in an economy such as Nigeria. Moreover, there is difficulty in measuring the potential output in developing economies (for instance, what is the level of capital stock?, labor force? and Total Factor Productivity?) and thus, the potential output can be inappropriate for planning monetary policy in the short run in developing countries like Nigeria. Probably all the distortions present in these economies hinder them from reaching their potential output not only in the short run but also in the long run. Therefore, the correct proxy to measure the output gap seems to be the actual GDP trend as opposed to the ideal potential output.

Figure 3: GDP gap, GDP growth, and inflation rate

Figure 4: GDP gap: potential output gap vs. output trend

Still another issue that is strongly related to monetary policy transmission in a small open economy is the impact of the exchange rate on prices. First, from the interest rate parity condition, a relationship between the interest rate and the exchange rate can be established. Under a flexible exchange rate system, a higher interest rate produces capital inflows that appreciate the exchange rate. Conversely, a lower interest rate causes capital outflows that produce a depreciation of the exchange rate. **Figure 5** shows some evidence of a negative link between the exchange rate and the interest rate in the Nigerian economy. Second, it could be that the exchange rate has a direct impact on the economy via import sector (both final goods and inputs). So an appreciation (depreciation) of the exchange rate can have a positive (negative) impact on the inflation rate. Undoubtedly all this depends on whether the pass-through coefficient of the exchange rate to inflation is high or not, which is an empirical question. For instance, a lower coefficient can moderate the impact of the exchange rate on prices due to the existence of price stickiness. **Figure 6** shows that in the Nigerian economy there is a direct relationship between the inflation rate and exchange rate depreciation.

Figure 5: Real exchange rate and interest rate in Nigeria

Figure 6: Exchange rate pass-through in Nigeria

One of the main subjects in the Nigerian economy is the role of the price of oil. But what is the real impact of this price on the inflation rate and on the monetary policy mechanism? I find at least three channels through which the oil price is affecting the inflation rate. The first one is the influence of the oil revenues on the money supply. In effect, **Figure 7** shows the positive connection between the money supply, net foreign assets (NFA) and the central bank's international reserves. Therefore, if the central bank does not sterilize, the excess supply of money can impact negatively on the inflation rate. The second channel is the influence of exchange rate on the inflation rate. **Figure 8** shows that an appreciation of the exchange rate is associated with a higher oil price. As we have observed, appreciations are also connected with lower inflation rates.

Figure 7: Net foreign asset (NFA), foreign reserve, and money

Figure 8: Real exchange rate and oil price

Nevertheless, the most difficult task was to find some prior link between the price of oil and the output gap. **Figure 9** indicates that this relationship seems to be inexistent in the Nigerian economy; even this association becomes negative for the period 1995-2001. The reason may not be unconnected with the type of fiscal policy the government implemented during these years. In fact, the **Figure 10** shows that the correlation between the oil price and the government expenditure gap is almost non-existent. This means that the government would not be transmitting temporary oil price shocks to its expenditure and therefore to the aggregate demand. However, we do not mean to say that the price of oil is not important to explain the dynamic of the level of output in the Nigerian economy. **Figure 11** shows that there is always a positive correlation between these two variables. However, the important concept for explaining the inflation rate as we said above is the output gap and not the level of GDP.

Figure 9: Oil price and output gap

Figure 10: Government spending, GDP gap, and oil price gap

Figure 11: Oil price gap and GDP

The last stylized fact is related to the lack of credibility. This can affect the power of monetary policy to control the inflation rate if expectations are not anchored. **Figure 12** indicates that the inflationary trend was not exactly constant in the period 1995-2007. Actually, this trend has fluctuated around a level of 10% of inflation. This evidence means two things for the model: first, we need to introduce a variable target into the Taylor rule; and second, the model must be able to measure the cost in terms of higher inflation and lost output of a temporary deviation of inflation from the target.

Figure 12: Inflationary trend in Nigeria

To sum up, the actual evidence indicates that the model has to consider these following elements to explain the inflation rate in Nigeria:

- The positive connection between inflation and the output gap (Phillips curve);
- An IS curve where the output gap is dependent on the real interest rate gap;
- An interest parity condition to incorporate the effect of the MPR on the exchange rate;
- A channel of transmission from exchange rate to inflation rate (pass-through coefficient); and
- The impact of the price of oil on the money supply and the exchange rate.

3. The Model

The Nigerian economy is analyzed using a medium sized "New Keynesian" macroeconomic model with rational expectations (Berg et al., 2006). The core equations in the model consist of an output gap relation; an inflation equation, an exchange rate equation, and a monetary policy reaction function. The model expresses each variable in terms of its deviation from the equilibrium (gap terms). The model emphasizes the flow dynamics of the Nigerian economy.

Thus, the first of these equations is an aggregate demand (IS curve) that relates the level of real activity to expected and past real activity, the real interest rate, and other variables to properly reflect the Nigerian economy, especially government expenditure and the oil price. The second equation is a Phillips curve that relates inflation to past and expected inflation, the output gap, the oil price, and the exchange rate. Then the third equation is the exchange rate, assuming an uncovered interest parity condition with some allowance for backward-looking expectations and a variable to measure the country risk premium. The fourth equation is a monetary rule for setting the policy interest rate as a function of the output gap, expected inflation and money supply.

I add some additional equations to capture some specific characteristics of the Nigerian economy. I let the model incorporate the money supply as an endogenous variable dependent on external reserves and net foreign assets (oil revenues). So the interest rate is partially defined by a kind of Taylor rule and for an endogenous money supply. In addition I introduce the possibility of an inflation target that depends on past inflation and influences the formation of inflationary expectations. So if this variable increases, it will push up inflation through the expectation of higher inflation. I use this as a measure of lack of credibility of the monetary policy.

Notation and Structure of the Model

The variables of the model are defined as follows:

- *ygap* is the output gap
- *rrgap* is the real interest rate gap
- *zgap* is the real exchange rate gap
- x^* denotes foreign variables
- π is inflation
- Δ is the first difference operator
- z is the real exchange rate
- *rr* is the real interest rate
- *rs* is the monetary policy rate
- $\overline{rs}$ is the equilibrium nominal interest rate
- ε denotes error terms
- βs, δs, φ, Θ, γs, θs, ζs, κs, νs, ρs, and αs are the parameters.

Output depends on aggregate demand and hence the real interest rate, as well as past and future output itself. The equation (1) can be derived from a standard Euler equation with habit persistence, which yields an equation relating the nominal interest rate to the expected paths of output and expected inflation. Moreover, the output gap also depends on specific characteristic of the Nigerian economy, all of them related to the oil industry, the weight of the government sector in the economy, and the import sector. These variables are the oil price gap (*pogap*), the real exchange rate gap, the government expenditure gap (*gregap*) and the foreign interest rate gap (*rrgap**).

$$\begin{aligned} ygap_t &= \beta_1 ygap_{t+1} + \beta_{11} ygap_{t+1} + \beta_2 rrgap_t + \beta_3 rrgap_t^* + \beta_4 zgap_t \\ &+ \beta_6 gregap_t + \beta_7 pogap_t + \varepsilon_t^1 \end{aligned} \quad (1)$$

I assume that government expenditure depends on the oil price gap, the exchange rate gap, and the output gap. The first two variables are associated with the oil industry and the foreign sector, respectively. I introduce the output gap to measure the impact of economic activity on government revenues.

$$gregap_t = fiscal_2 pogap_t + fiscal_3 zgap_t + fiscal_4 ygap_t + \varepsilon_t^2 \quad (2)$$

Inflation depends on expected and lagged inflation, the output gap, the exchange rate gap, and the oil price.

$$\pi_t = \alpha_1 \pi_{t+1} + (1-\alpha_1)\pi_{t-1} + \alpha_2 ygap_t + \alpha_3 \Delta z_t + \alpha_4 \pi_t^* + \varepsilon_t^3 \quad (3)$$

This equation indicates how monetary policy affects inflation rate. First, monetary policy influences inflation through its effects on output and the exchange rate. In other words, the coefficients of the output and exchange rate gaps must be greater than zero. Otherwise, monetary policy would have no effect on inflation.

A common problem with many models that assume interest parity condition is that they typically 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 (see, e.g., Eichenbaum and Evans, 1995; Faust and Rogers, 2003). We suppose that the interest parity condition holds partially and the real exchange rate depends on a lag of itself. Two additional variables are included—the oil price and *ygap*—to measure the effect of the country risk premium on the exchange rate. Consistently with the empirical evidence, the idea here is that these variables measure occasionally the perception of foreign investors about the Nigerian economy.

$$z_t = \gamma_1 z_{t-1} + (1-\gamma_1)\left(z_{t+1} - \left(rr_t - rr_t^*\right)\right) + \gamma_2 pogap_t + \gamma_4 ygap_t + \varepsilon_t^4 \qquad (4)$$

I assume that the monetary policy instrument is based partially on some short-term nominal interest rate, and that the central bank sets this instrument in order to achieve a target level for inflation, π^T. It may also react to deviations of output from the equilibrium. Nevertheless, central banks also use sometimes as the monetary policy instrument the money supply; thus, the nominal interest rate depends on the money supply as well. To do that, I use money demand to obtain the interest rate in terms of money supply.

$$\begin{aligned} rs_t &= epsilon_1 rs_{t-1} + (1-epsilon_1)\left(grama_1\left(\overline{rs} + epsilon_2\left(\pi_t - \pi_t^T\right) + epsilon_3 ygap_t\right)\right) \\ &+ (1-epsilon_1)\left(+(1-grama_1)\left(\left(\frac{1}{tau_3}\right)\left(tau_2 y - (m_t - p_t)\right)\right)\right) \\ &+ grama_2 zgap_t + grama_3 \Delta z_{t-1} + \varepsilon_t^5 \end{aligned} \qquad (5)$$

In addition, I consider in equation (5) that the interest rate also responds to the real exchange rate. Accordingly, if domestic currency appreciates in real terms, the central bank of Nigeria decreases the interest rate with the aim of offsetting the appreciation (fear of floating). We can measure the same phenomenon by replacing the exchange rate by the level of intervention of the central bank in the currency market, which is measured by the divergence between the official rate and the rate in the black market. In order words, as this difference gets larger, the central bank decides to change the interest rate to encourage capital flows, thereby moderating the difference between the two markets.

Let us assume that central bank decides to increase money supply when international reserves also increase. Equation (6) formalizes this assumption, where the parameter θ determines the level of sterilization of the central bank. If the central bank makes a decision of sterilizing completely the increase in the reserves, θ is equal to zero; otherwise θ is between 0 and 1 .

$$\Delta m_t = \theta\left(\Delta res_t\right) + \varepsilon_t^6 \qquad (6)$$

Let international reserves depend on, among others, the oil price, the exchange rate, the output gap, and net foreign assets (equation 7). I add an equation to explain net foreign assets in terms of the difference between the domestic and the foreign interest rate.

$$\Delta res_t = money_1\left(\Delta po_t\right) + money_2\left(\Delta z_t\right) + money_3\left(ygap_t\right) + money_4\left(\Delta nfa_t\right) + \varepsilon_t^7 \qquad (7)$$

$$\Delta nfa_t = money_5\left(\Delta po_t\right) + money_6\left(\Delta z_t\right) + money_7\left(rr_t - rr_t^*\right) + \varepsilon_t^8 \qquad (8)$$

Credibility issues

We introduce the credibility issues by endogenising the inflation target (equation 9) in the formation of inflationary expectations.

$$\pi_t^T = \rho\pi_{t-1}^T + (1-\rho)(\pi_{t-1} - \pi_{t-1}^T) \qquad (9)$$

In other words, if the parameter ρ is equal to one, the inflation target is constant. Otherwise, the inflation target also depends on the difference between the past inflation rate and the past inflation target. So in this latter case, the central bank accommodates a higher rate of inflation by setting also a target higher for the next period. This accommodation will produce lack of credibility if the inflation target is introduced directly in the expectations of the inflation rate. Thus we need to adjust all the equations of the model involving expectation of the future inflation rate. The changes are the following:

$$ygap_t = \beta_1 ygap_{t+1} + \beta_{11} ygap_{t+1} + \beta_2\left(rrgap_t - \phi_1\pi_t^T\right) + \beta_3 rrgap_t^* + \beta_4 zgap_t + \beta_6 gregap_t + \beta_7 pogap_t + \varepsilon_t^1 \qquad (1)'$$

$$\pi_t = \alpha_1(\pi_{t+1} + \phi\pi_t^T) + \left(1-\alpha_1\right)\pi_{t-1} + \alpha_2 ygap_t + \alpha_3\Delta z_t + \alpha_4\pi_t^* + \varepsilon_t^3 \qquad (2)'$$

$$z_t = \gamma_1 z_{t-1} + \left(1-\gamma_1\right)\left(z_{t+1} - \left(rr_t - \phi_3\pi_t^T - rr_t^*\right)\right) + \gamma_2 pogap_t + \gamma_4 ygap_t + \varepsilon_t^4 \qquad (4)'$$

$$\Delta nfa_t = money_5\left(\Delta po_t\right) + money_6\left(\Delta z_t\right) + money_7\left(rr_t - \phi_4\pi_t^T - rr_t^*\right) + \varepsilon_t^8 \qquad (8)'$$

The ϕ parameters quantify the relevance on the inflationary expectations of a central bank's departure from a constant inflation target. Positive values of each parameter signify an increase in expectations and then more inflationary pressures.

For the sake of simplicity, all the equilibrium values to calculate the gaps (output, interest rate, inflation, and exchange rate) were estimated by using the Hodrick-Prescott filter.

Finally, I represent the foreign sector of the United States and the price of oil. I assume as exogenous variables (AR process) the output gap, the Fed fund rate, and the international oil price.

4. Econometric Methodology: Bayesian Econometrics

The model is estimated by Bayesian econometrics, which is a mix between calibration (economic intuition) and maximum likelihood. The calibration part is the specification of priors, and the maximum likelihood approach enters through standard econometrics based on adjusting the model with data. Thus priors can be seen as weights on the likelihood function in order to give more importance to certain areas of the parameter subspace according to economic intuition. This is especially well-suited for economies such as Nigeria where data availability is limited and therefore priors for parameters are helpful in setting the parameters of the model by excluding values without economic sense for lacking of proper data for the econometric estimation.

On the one hand, the priors are described by a density function of the form

$$p\left(\theta_A | A\right)$$

Where A indicates a specific model, θ_A represents the parameters of model A, $p(\bullet)$ is the probability density function.[4] On the other hand, the likelihood function describes the density of the observed data, given the model and its parameters:

$$L\left(\theta_A | Y_T A\right) \equiv p\left(Y_T | \theta_A, A\right)$$

Where Y_T are the observations until period T. In order to obtain $p\left(\theta | Y_T\right)$, the posterior kernel density, I use the Bayes theorem:

[4] Such as a normal, gamma, shifted gamma, inverse gamma, beta, generalized beta, or uniform function

$$p\left(\theta_A \left|Y_T, A\right.\right) \propto p\left(Y_T \left|\theta_A, A\right.\right) p\left(\theta_A \left|A\right.\right) \equiv \kappa\left(\theta_A \left|Y_T, A\right.\right)$$

This is the equation that will allow us to rebuild all posterior moments of interest.[5]

5. Results

5.1 Estimated parameters

The results for all parameters of the model are presented in the Appendix. I focus on this section in the equations that measure essentially the monetary policy transmission mechanism through the Phillips curve to control the inflation rate.

Table 2 shows the estimation of the Phillips curve. The priors for the estimation are in line with the estimations in other countries. The estimated effect (prior) of the output gap on the inflation rate is lower than our prior (alpha2). Nevertheless, it exists and gives the central bank an important tool to control inflation via the output gap. In other words, there is a Phillips curve that allows the central bank to stabilize the economy taking advantage of some level of price stickiness in the economy.

Another interesting result is that in the Nigerian economy 57% (=1-alpha1) of the agents set the actual inflation by considering their past inflation. This backward-looking characteristic of the economy implies that the inflation rate shows a high level of inertia and therefore it may be difficult for policy makers to reduce the inflation rate.

Also, the impact of the exchange rate on prices is smaller than our prior (alpha 3), indicating that the pass-through coefficient of the exchange rate to the inflation rate is quite low. In addition and consistently with this last result, the influence of foreign inflation (alpha4) is only 0.15. This takes place even though imports are an important sector in the Nigerian economy; I believe that all these results are indicating that the prices in the Nigerian economy are sticky downward rather than flexible.

Inset Table 2: Parameters estimated for the Phillips curve

The second set of results is shown in **Table 3,** containing the parameters estimated for the IS curve. This table indicates for the second time that the Nigerian economy

[5] In the appendix I explain in detail the econometric procedure.

displays a high level of inertia (beta11=0.91). Practically, the actual output gap is not affected by the expectations about the future trajectories of the interest rate, the exchange rate, etc. (beta1=0.0063). Nevertheless, what influences the output gap are the actual values of the domestic and foreign real interest rate gaps (beta2 and beta3). The other variables, namely the government expenditure gap (beta4), the oil price gap (beta5), and the exchange rate gap have a nil impact on the output gap (beta6). Thus, this gives the central bank some level of control of the inflation rate by changing the aggregate demand through the interest rate. But this impact is only limited and it can take many quarters due to the high inertia in the output gap.

Insert Table 3: Parameters estimated for the IS curve

Regarding the parameters involved in the determination of the interest parity condition (**Table 4**), we have that this condition holds only partially. The posterior mode for gamma1 indicates that the exchange rate depends only on 50% of the expectations about the future trajectory of the difference between the domestic and the foreign interest rate. Regarding the impact of the other variables on the exchange rate, we have that the oil price gap (gamma2) and the output gap (gamma4) have some small effect on the exchange rate. This result is consistent with all the previous evidence that in the Nigerian economy the inertia is an important element to explain the dynamic of many macroeconomic variables.

Insert: Table 4: Parameters estimated for the Interest Parity Condition

Next in the monetary policy rule, I find (see **Table 5**) that the central bank most of the time is following a Taylor rule very closely (gamma1=0.95). So the central bank is responding to the inflation rate (epsilon2=1.33) and the output gap (epsilon3=0.34) in a very standard manner. On the contrary, the central bank used very moderately the money supply to affect the interest rate in the period 1995-2007. Other interesting results indicate that the output elasticity of the money demand is close to 1 (tau2) and the interest rate elasticity of money demand is 0.29 (tau3). We do not find any evidence that the central bank is using the interest rate to intervene the exchange rate market (gamma2 and gamma3 are close to zero). However, from all these results, the central bank is very conservative when changing the interest rate. Thus, our estimation indicates that the actual interest rate depends on a 0.98% (epsilon1) of changes in its own lag.

Insert Table 5: Parameters estimated for the Monetary Policy Rule

Another important issue related with the monetary policy rule is the level of sterilization of the international reserves that the central bank carried out in the period 1995-2007. **Table 6** indicates that the central bank sterilized most of the time the reserves that came from the oil revenues. Thus, the parameter theta, which can take values between 0 and 1 (one being no sterilization and zero complete sterilization), has a posterior of only 0.1. This result is also consistent with the previous evidence that the central bank is using almost all the time a Taylor rule to implement monetary policy in the Nigerian economy.

Insert: Table 6: Parameters estimated for the Money supply

Finally, the last important issue is about the credibility of the monetary policy in the Nigerian economy. To do so, we repeat the equation for the Phillips curve and the equation for the inflation target of Section III. I mention in that section that if ρ is smaller than one the inflation target is not constant. Moreover, if ϕ is greater than zero, agents are introducing changes in the inflation target into the expectation formation, indicating a lack of credibility of the monetary policy, i.e., they expect a higher inflation due to changes in the inflation target.

$$\pi_t = \alpha_1(\pi_{t+1} + \phi\pi_t^T) + (1-\alpha_1)\pi_{t-1} + \alpha_2 ygap_t + \alpha_3\Delta z_t + \alpha_4\pi_t^* + \varepsilon_t^3$$

$$\pi_t^T = \rho\pi_{t-1}^T + (1-\rho)(\pi_{t-1} - \pi_{t-1}^T)$$

Table 7 shows that the inflation target has been very stable in the last ten years in Nigeria (rho=0.98); however, small changes in the inflation target have some effect in the formation of inflationary expectations (phi=0.13). Thus, the departure of a constant inflation target has some important consequences. So, if the central bank increases its inflation target temporarily, it will cause a temporary but very persistent increase in the rate of inflation.

Insert: Table 7: Parameters estimated for the Phillips curve and the dynamic of the inflation target

5.2 Impulse response functions

First, the monetary shock (**Figure 13**) is consistent with what the economic theory predicts to stabilize the economy (Woodford, 2003).[6] After the increase in the monetary policy rate (*rs*), there is a decrease in the output gap and the inflation rate. This happens because the real interest rate has a negative effect on the output gap (see equation 1) and then this brings about a decline in the inflation rate (see equation (3), Phillips curve). This shock also produces an appreciation (in nominal and real terms) of the Naira because the uncovered interest rate parity holds partially, i.e., the higher interest rate generates capital inflows that appreciate the Naira (see equation 4). Then, subsequent to the shock all variables tend to return to their equilibrium values. This takes place because the decline in output and inflation triggers a downward adjustment in the interest rate (see equation 5).

Insert Figure 13 MPR shock

Therefore, an increase of 200 bsp causes a reduction in the inflation rate of up to 2% after two years. This is evidence of the high degree of price stickiness present in Nigeria, as in many other economies. The reduction in the output gap is about 0.6% (annually) after two years with a real appreciation in the exchange rate of 20%. In other words, the monetary policy transmission works by introducing a sacrifice ratio in the Nigerian economy. For instance, if the central bank decides to reduce quickly the inflation rate by 10%, the output gap will drop by -3.0%. In addition, the policy is effective in a horizon of up to two years. Consequently, it is advisable to implement a credible inflation-targeting regime to reduce the inflation rate gradually and avoid output costs.

Figure 14 shows what happens if the central bank raises the inflation target temporarily. The estimation indicates that an increase in the inflation target of 3.6% (historical variance of the inflation target) has important effects in the economy. The inflationary expectations affect quickly the inflation rate, which goes up to 2.0%. Historically after these episodes, the central bank returns to its stabilization policy by raising the interest rate. This change in the monetary policy has a direct impact on economic activity. The increase in the interest rate brings about a contraction in aggregate demand which in turn reduces the output gap and decreases the inflation rate in a horizon of two years. As

[6] Each shock corresponds to an increase of one standard deviation.

the Figure 17 shows, the departure from a constant inflation target of 3.6% has a cost implication on the output gap (that is, reducing the output gap up to 0.7%) .

Insert Figure 14 Inflation Target shock

Figure 15 shows the impulse response function for a shock in the interest rate parity condition. This allows to measure directly the impact of a pure exchange rate shock on the inflation rate. An exchange rate shock of approximately 18% increases the inflation rate by around 1.8%. Therefore, the exchange rate pass-through in the Nigerian economy is around 0.1 (=1.8/18) and occurs in the first two quarters approximately. The moderate response in the inflation rate is due not only to the high inertial in the inflation rate but also to the reaction of the central bank to increases the interest rate. These two effects go in the same direction: a lower output gap that weakens aggregate demand and real appreciation that finally reverse the risk premium shock.

Insert Figure 15 Risk Premium shock

The oil price shock (**Figure 16**), produces a very moderate expansion in the output gap (see equation 1). The response of the authority is to increase interest rate (see equation 5), that triggers an appreciation in the exchange rate; consequently, this appreciation pushes down the inflation rate (equation 3). However, all variables tend to return to their equilibrium values when the oil price shock disappears. The main important effect of the oil price shock is an appreciation of the real exchange rate. The impact of the oil price shock on the inflation rate is not strong because there are two opposing factors at work. First, the appreciation of the exchange rate that pushes down the inflation rate as **Figure 16** shows. But there is a second-round effect that is not incorporated in the **Figure 16**. When the price of oil goes up, foreign inflation also increases, pushing up the domestic inflation rate (see **Figure 17)**.

Insert Figure 16 Oil Price shock

Insert Figure 17 Foreign Inflation shock

Finally, demand and supply shocks in the Nigerian economy are in line with the prediction of the economic theory (**Figures 18-19**). The demand shock produces an expansion of the economy (output) and increases in the inflation rate in the medium term as expected. On the contrary, the supply shock causes an increase in inflation that causes a recession. This materializes as the central bank must raise the interest rate to reduce inflation to its original level.

Insert Figure 18 Demand shock

Insert Figure 19 Domestic Inflation shock

5. Conclusions

I develop a semi-structural dynamic general equilibrium model to understand how monetary policy is working in the Nigerian economy. This model is based on the Phillips curve and captures most of the channels through which policymakers believe monetary policy to influence a small open economy with a managed floating exchange rate. The model was estimated with Nigerian quarterly data between 1995 and 2007, to replicate some true facts.

The estimation confirms that the central bank in the Nigerian economy can control the inflation rate through a Phillips curve. Moreover, there is an IS curve, an interest parity condition to incorporate the effect of the MPR on the exchange rate, a channel linking the exchange rate to the inflation rate (pass-through coefficient), and a well-defined monetary policy rule. Thus the adoption of a full-fledged inflation-targeting regime in Nigeria is quite feasible and it could be a good example for other African economies

The monetary policy transmission mechanism acts like this: the central bank reacts to an upsurge in inflation by raising the interest rate. This reaction is strong enough to produce an increase in the real interest rate gap, which in turn diminishes the output gap. Finally, the inflation rate tumbles through a Phillips curve.

In other words, monetary policy transmission works by introducing a sacrifice ratio in the Nigerian economy. For instance, if the central bank decides to reduce quickly the inflation rate by 10%, the output gap will narrow by -3.0%. In addition, our estimates indicate that the policy is effective in a horizon of up to two years. Consequently, it is preferable to implement a credible inflation-targeting regime to reduce the inflation rate gradually. I also find that a departure from a constant inflation target has important costs in terms of lost output, and that the pass-through coefficient of the exchange rate to the inflation rate is around 0.1 in Nigeria.

Appendix

Bayesian Econometrics

To get the posterior kernel I need to estimate the likelihood function $p\left(Y_T \middle| \theta_A, A\right)$ of the model. I express the model as linear to calculate easily the log-likelihood function. A model with rational expectations can be written in this form:

$$\mathrm{E}_t\left\{f\left(y_{t+1}, y_t, y_{t-1}, u_t\right)\right\}=0,$$

and the solution is an equation of the type that we call the decision rule

$$y_t = g\left(y_{t-1}, u_t\right).$$

This can be rewritten in the following linear manner:

$$\hat{y}_t = g_y\left(\theta\right)\hat{y}_{t-1} + g_u\left(\theta\right)u_t$$

$$y_t^* = M\bar{y}\left(\theta\right) + M\hat{y}_t\left(\theta\right) + \eta_t$$

$$\mathrm{E}_t\left(\eta_t\eta_t^{'}\right) = V\left(\theta\right)$$

$$\mathrm{E}_t\left(u_t u_t^{'}\right) = Q\left(\theta\right),$$

where $\hat{y}_t$ represents all the endogenous variables in deviations from the steady state, $\bar{y}$ is the vector of steady-state values, u_t are exogenous variables, and θ is the vector of parameters to be estimated. The first equation is the decision rule expressed in lineal terms, but the second equation expresses a relationship among the true endogenous variables that are not directly observed $\hat{y}_t$ and the endogenous variables that are observed, y_t^*. Both variables are related through an error term η_t.

The next step is to estimate the likelihood of the system. Notice that, if all endogenous variables are observed, the previous system is a VAR model with a standard log-likelihood function (see Hamilton, 1994). Second, if a group of the endogenous variables are not observed, we need to use a Kalman filter recursion to derive the log-likelihood. The only condition to be considered is that the number of observed endogenous variables has to be equal to the number of the shocks (see Hamilton, 1994). The result is the following log-likelihood function:

$$\ln L\left(\theta \middle| Y_t^*\right) = -\frac{Tk}{2}\ln\left(2\pi\right) - \frac{1}{2}\sum_{t=1}^{T}\left|F_t\right| - \frac{1}{2}v_t' F_t^1 v_t \, ,$$

where F_t and v_t come from the Kalman filter procedure or a simple VAR if all variables are observed. Then the log posterior kernel can be expressed thus:

$$\ln \kappa\left(\theta \middle| Y_t^*\right) = \ln L\left(\theta \middle| Y_t^*\right) + \ln p\left(\theta\right) .$$

The next step is to get the posterior distribution. To do that through the Metropolis-Hastings algorithm:

1. Choose a starting point θ^0 that is the posterior mode
2. Draw a proposal θ^* from a jumping distribution $J\left(\theta^* \middle| \theta^{t-1}\right) = N\left(\theta^{t-1}, c\Sigma_m\right)$ where Σ_m is the inverse of the Hessian computed at the posterior mode.
3. Compute the acceptance ratio $r = \dfrac{\kappa\left(\theta^* \middle| Y_T\right)}{\kappa\left(\theta^{t-1} \middle| Y_T\right)}$
4. Finally, accept or discard the proposal θ^* according to the following rule, and update, if necessary, the jumping distribution:

$$\theta^t = \begin{cases} \theta^* \ \ \textit{with} \quad \textit{probability} \quad \min\left(r,1\right) \\ \theta^{t-1} \qquad\qquad \textit{otherwise} \end{cases}$$

In practice, the model for the Nigerian economy was estimated with two programs. The first one obtains the starting point that is the posterior mode considering 1,200 draws in the Metropolis Hastings algorithm. After that a second program carries out a second simulation of the Metropolis Hastings algorithm considering 250,000 draws to obtain the final results.

Acknowledgments

This research was conducted while García was visiting scholar in the Central bank of Nigeria, for whose hospitality he is grateful. I thank Charles N.O. Mordi, Abwaku Englama, and Adebiyi Michael Adebayo for very useful comments and discussion. Especially I want to thank to Professor Eddy Ndekwu for interminable conversations about monetary policy in Nigeria during our tea time. Also I thank to Solange De Vidts for her support during my visit in Nigeria. All remaining errors are the author's own.

References

Ball, L. and D.H. Romer (1990) 'Real Rigidities and the Nonneutrality of Money', *Review of Economic Studies*, 57(April): 183–203.

Berg, A., P. Karam and D. Laxton (2006) 'A Practical Model-Based Approach to Monetary Policy Analysis: A How-To Guide', *International Monetary Fund Working Paper,* 06/81 (Washington: International Monetary Fund).

Christiano, L.J., M. Eichenbaum and C.L. Evans (2005) 'Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy' *Journal of Political Economy*, 113(1): 1–45.

Clarida, R., J. Galí and M. Gertler (1999) 'The Science of Monetary Policy: A New Keynesian Perspective', *Journal of Economic Literature*, 37(4): 1661–707.

Eichenbaum, M. and C. Evans (1995) 'Some Empirical Evidence on the Effects of Shocks to Monetary Policy on Exchange Rates', *Quarterly Journal of Economics,* 110: 975– 010.

Erceg, C., D. Henderson and A. Levin (2000) 'Optimal Monetary Policy with Staggered Wage and Price Contracts', *Journal of Monetary Economics*, 46(2): 281–313.

Faust, J. and J. Rogers (2003). 'Monetary Policy's Role in Exchange Rate Behavior', *Journal of Monetary Economics*, 50: 1403–24.

Galí, J., (2008) *Monetary Policy, Inflation, and the Business Cycle*. Princeton University Press.

Hamilton, J. (1994) *Time Series Analysis*. Princeton University.

Kydland, F. and E.C. Prescott (1977) 'Rules Rather Than Discretion: The Inconsistency of Optimal Plans', *Journal of Political Economy*, 85(3): 473–91.

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

Mankiw, N.G. and D. Romer (1991) *New Keynesian Economics,* Cambridge: MIT Press.

Prescott, E. (1986) 'Theory Ahead of Measurement', *Federal Reserve Bank of Minneapolis Quarterly Review*, Fall: 9–22.

Sargent, T. (1981) 'Interpreting Economic Time Series', *Journal of Political Economy*, 99(2): 213–48.

Sims, C. (1980) 'Macroeconomics and Reality', *Econometrica*, 48(1): 1–48.

Smets, F. and R. Wouters (2003) 'An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area', *Journal of the European Economic Association*, 1(5): 1123–75.

Smets, F. and R. Wouters. (2007) 'Shocks and Frictions in U.S. Business Cycles: A Bayesian DSGE Approach', *American Economic Review*, 97(3): 586–606.

Woodford, M. (2003) *Interest and Prices: Foundations of a Theory of Monetary Policy*. Princeton: Princeton University Press.

Tables

Table 1: Parameters estimated for the Phillips curve

	Prior	Posterior	Distribution
alpha1	0.50	0.43	beta
alpha2	0.10	0.06	gamm
alpha3	0.15	0.06	gamm
alpha4	0.20	0.20	gamm

Table 2: Parameters estimated for the IS curve

	Prior	Posterior	Distribution
beta1	0.05	0.0063	beta
beta11	0.95	0.9163	gamm
beta2	0.05	0.0317	gamm
beta3	0.05	0.0314	gamm
beta4	0.05	0.0003	gamm
beta6	0.05	0.0028	gamm
beta7	0.05	0.0003	gamm

Table 3: Parameters estimated for the Interest Parity Condition

	Prior	Posterior	Distribution
gamma1	0.50	0.50	beta
gamma2	0.20	0.03	gamm
gamma4	0.05	0.07	gamm

Table 4: Parameters estimated for the Monetary Policy Rule

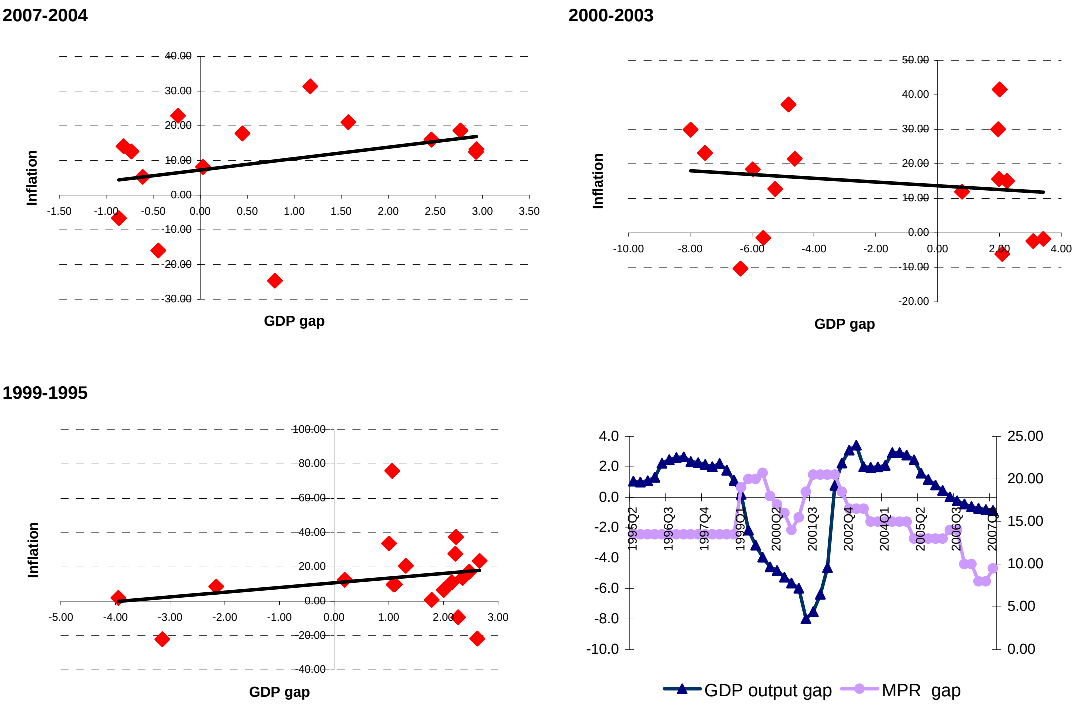
	Prior	Posterior	Distribution
epsilon1	0.75	0.98	beta
epsilon2	1.50	1.33	beta
epsilon3	0.50	0.34	gamm
grama1	0.75	0.95	beta
grama2	0.05	0.00	gamm
grama3	0.05	0.01	gamm
tau2	1.00	1.06	gamm
tau3	0.15	0.29	gamm

Table 5: Parameters estimated for the Money supply

	Prior	Posterior	Distribution
theta	0.30	0.10	beta

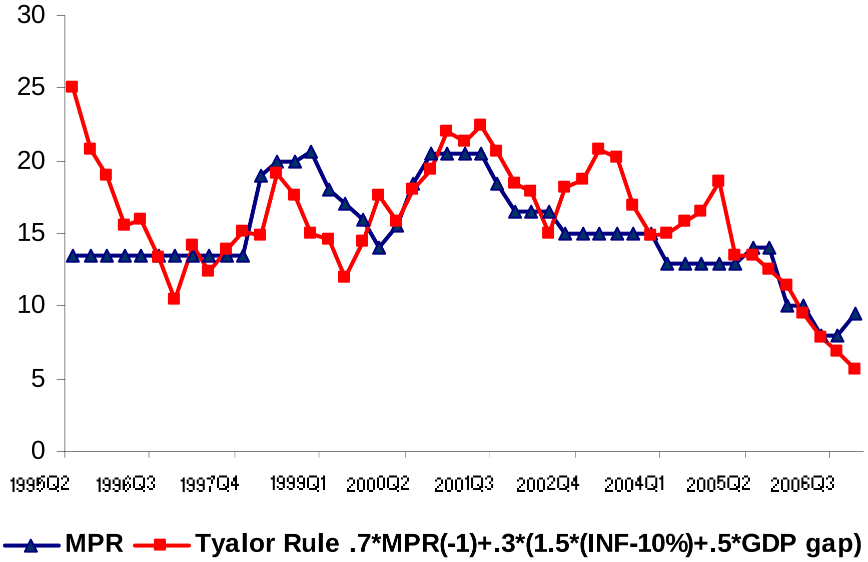
Figures

Figure 1: Inflation, GDP gap, and interest rate (MPR) in Nigeria



Source: CBN

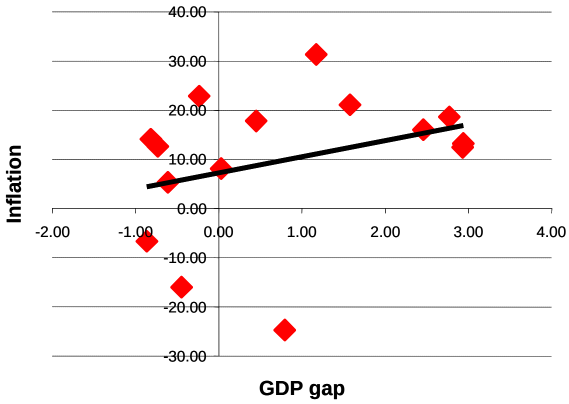
Figure 2: MPR and the Taylor Rule in Nigeria

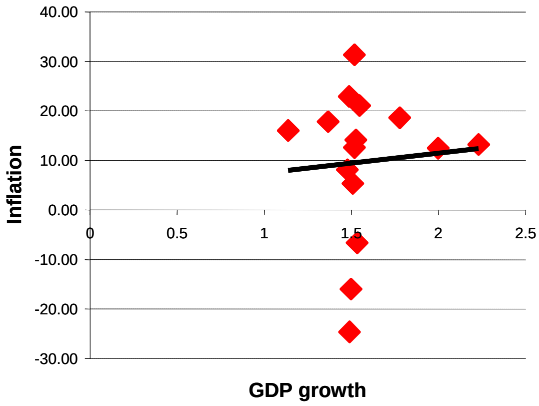


Source: CBN and author's calculations

Figure 3: GDP gap, GDP growth, and inflation rate

2004-2007





Source: CBN

Figure 4: GDP gap: potential output gap vs. output trend

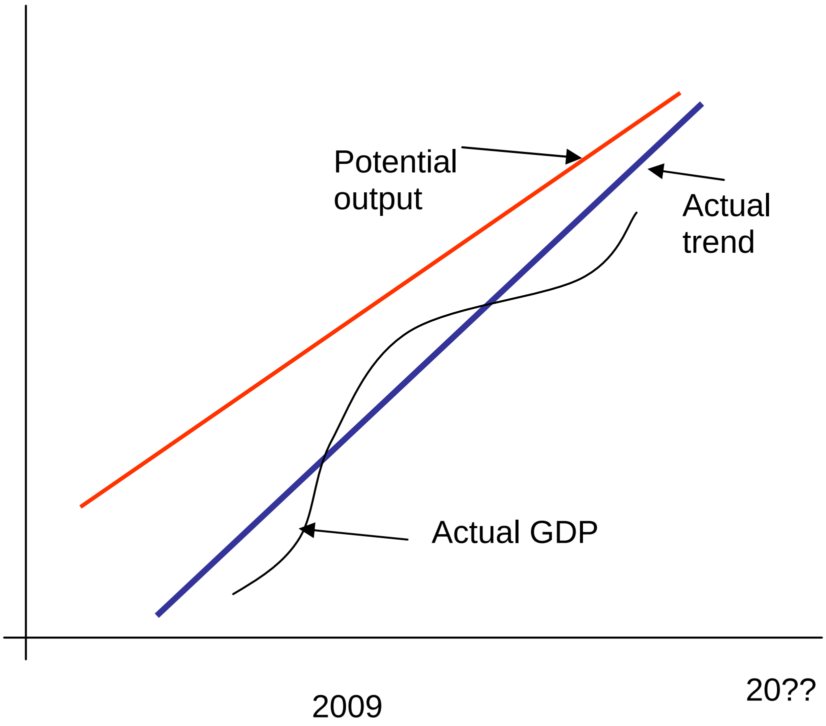
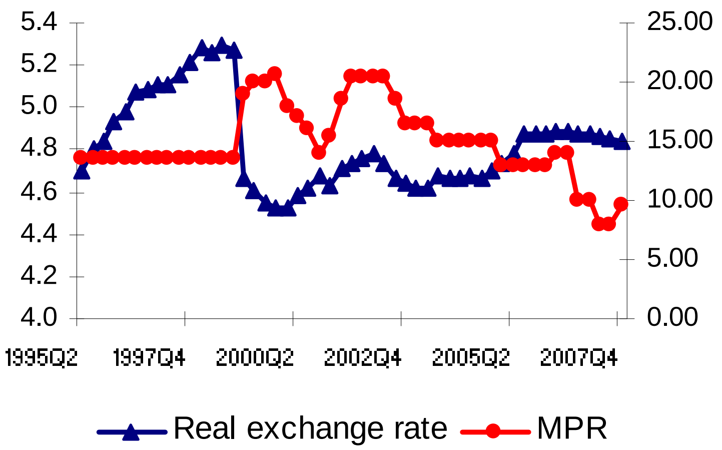
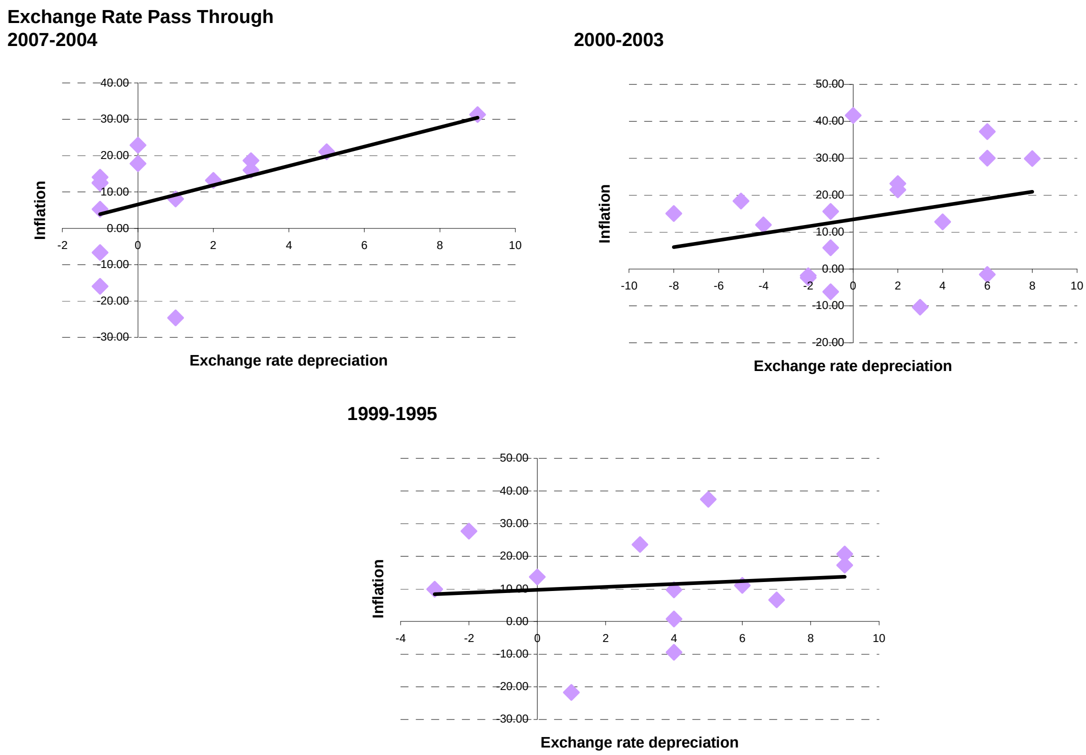


Figure 5: Real exchange rate and interest rate in Nigeria



Source: CBN

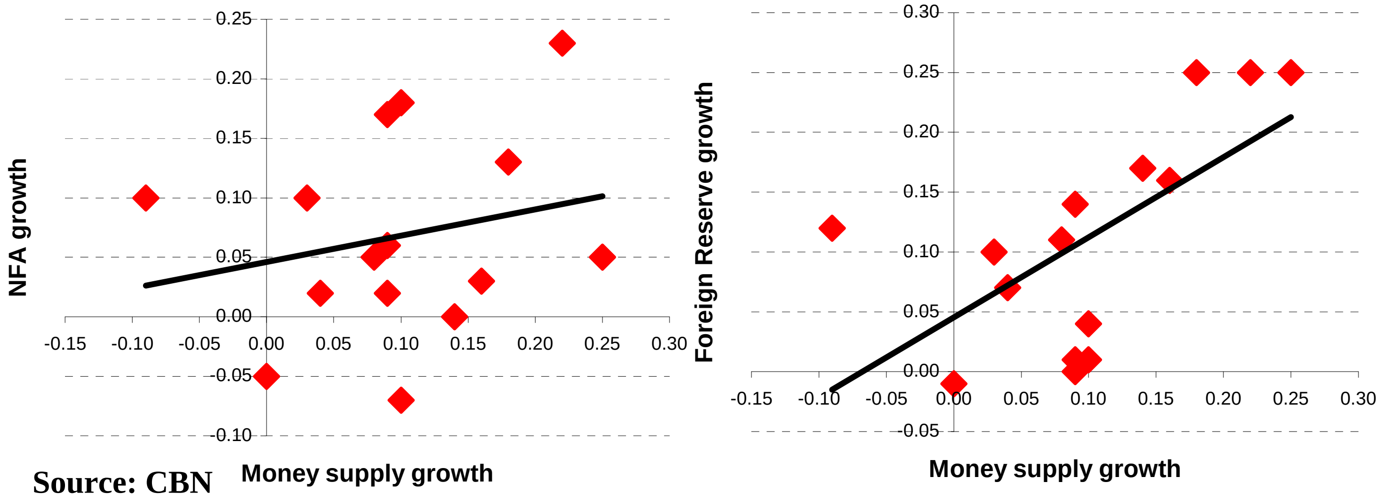
Figure 6: Exchange rate pass-through in Nigeria



Source: CBN

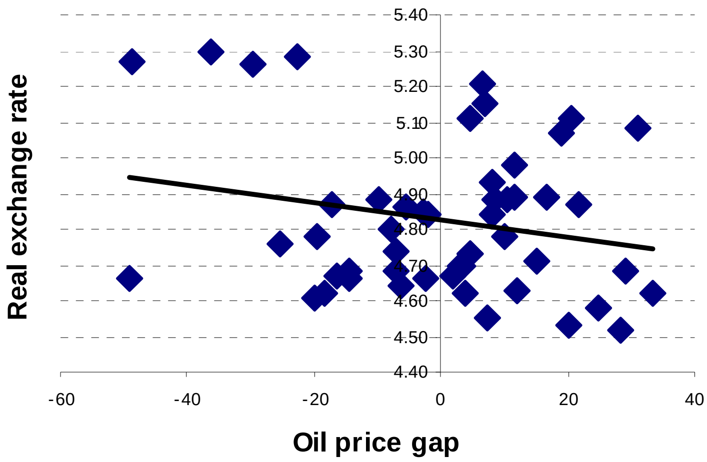
Figure 7: Net foreign asset (NFA), foreign reserve, and money

2001-2007



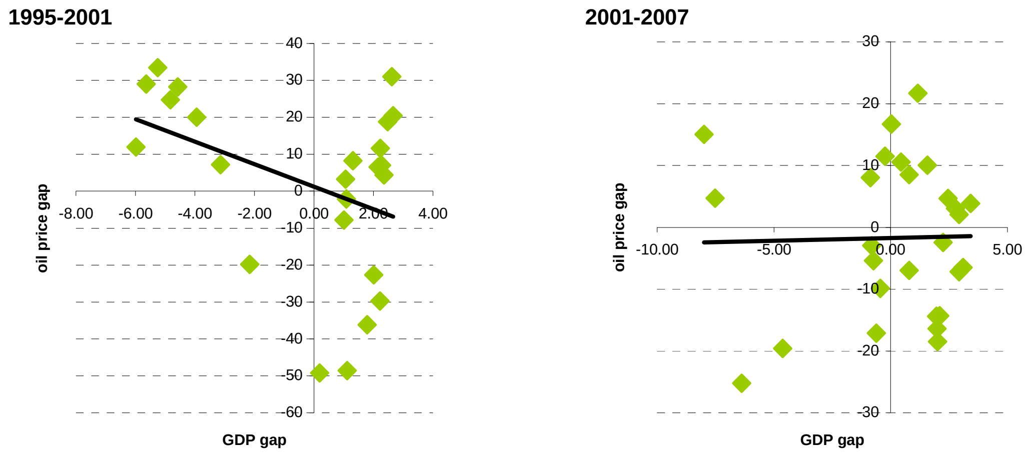
Source: CBN

Figure 8: Real exchange rate and oil price



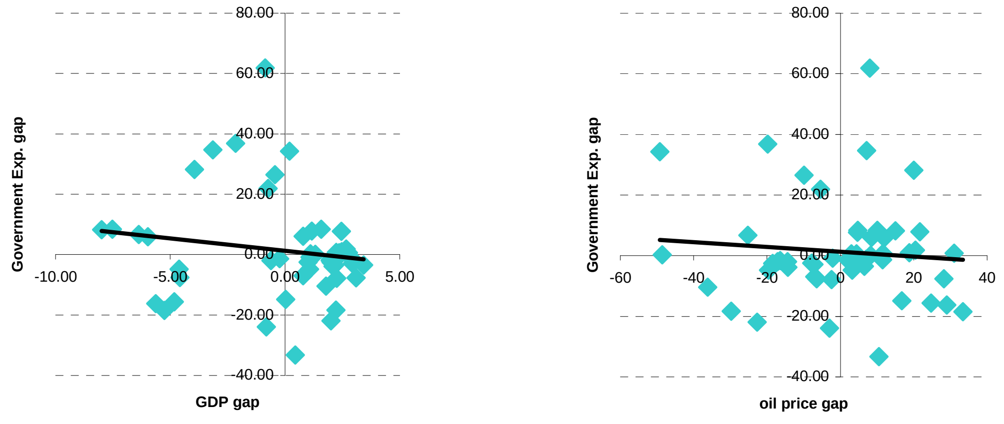
Source: CBN

Figure 9: Oil price and output gap



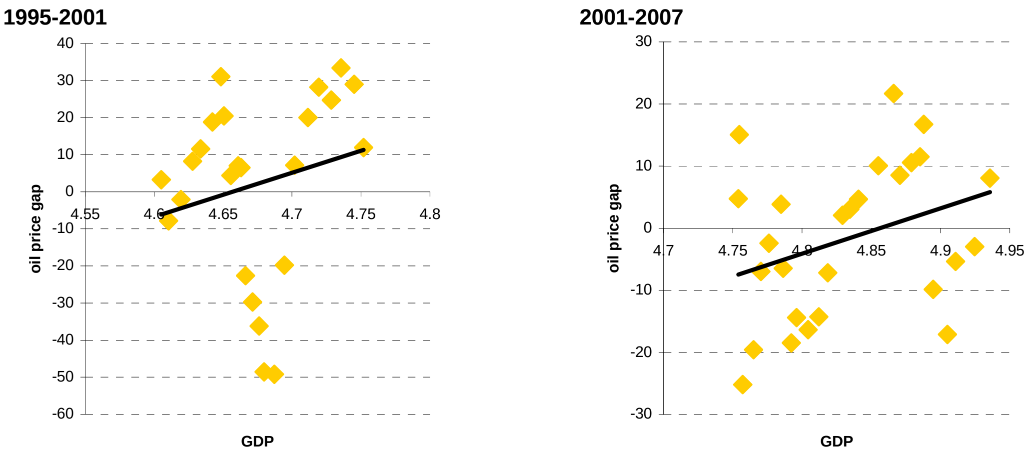
Source: CBN

Figure 10: Government spending, GDP gap, and oil price gap



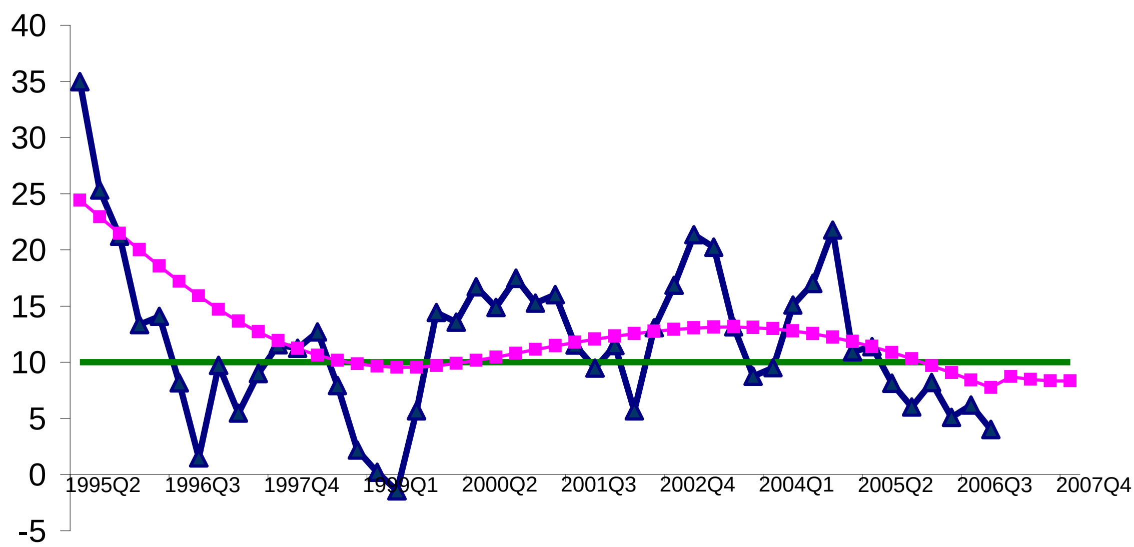
Source: CBN

Figure 11: Oil price gap and GDP



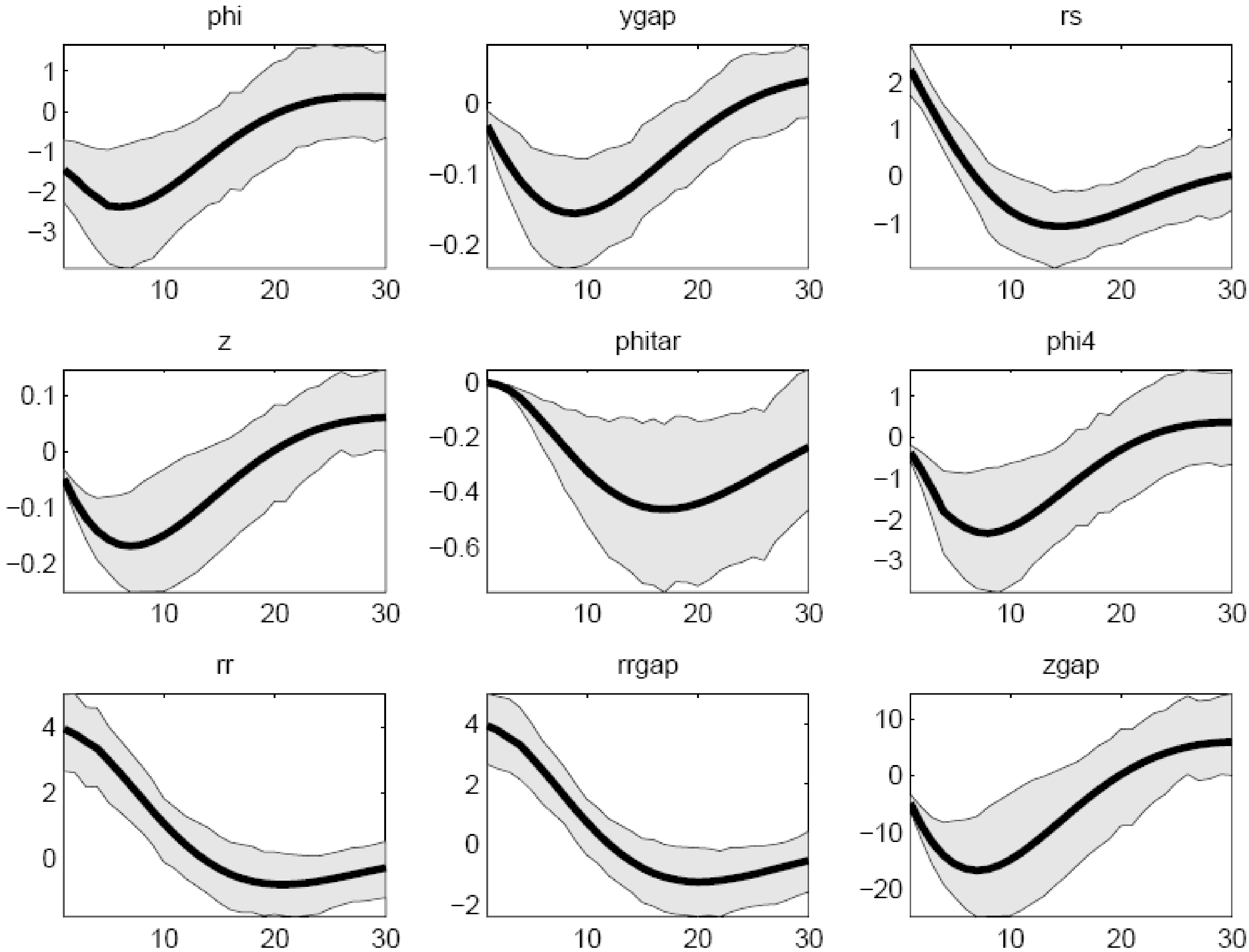
Source: CBN

Figure 12: Inflationary trend in Nigeria



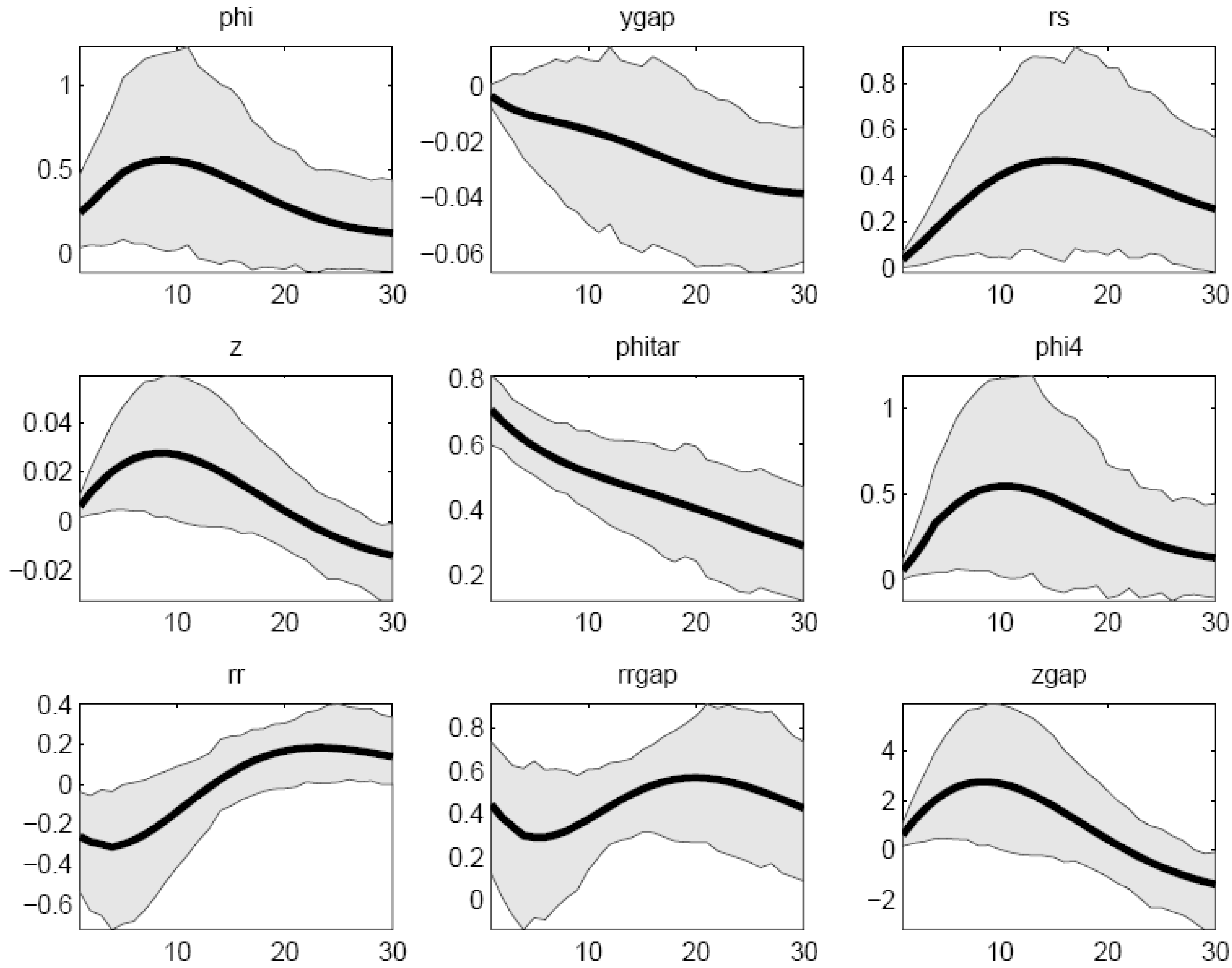
Sources: CBN and author's calculations

Figure 13 Impulse response function: Monetary policy shock



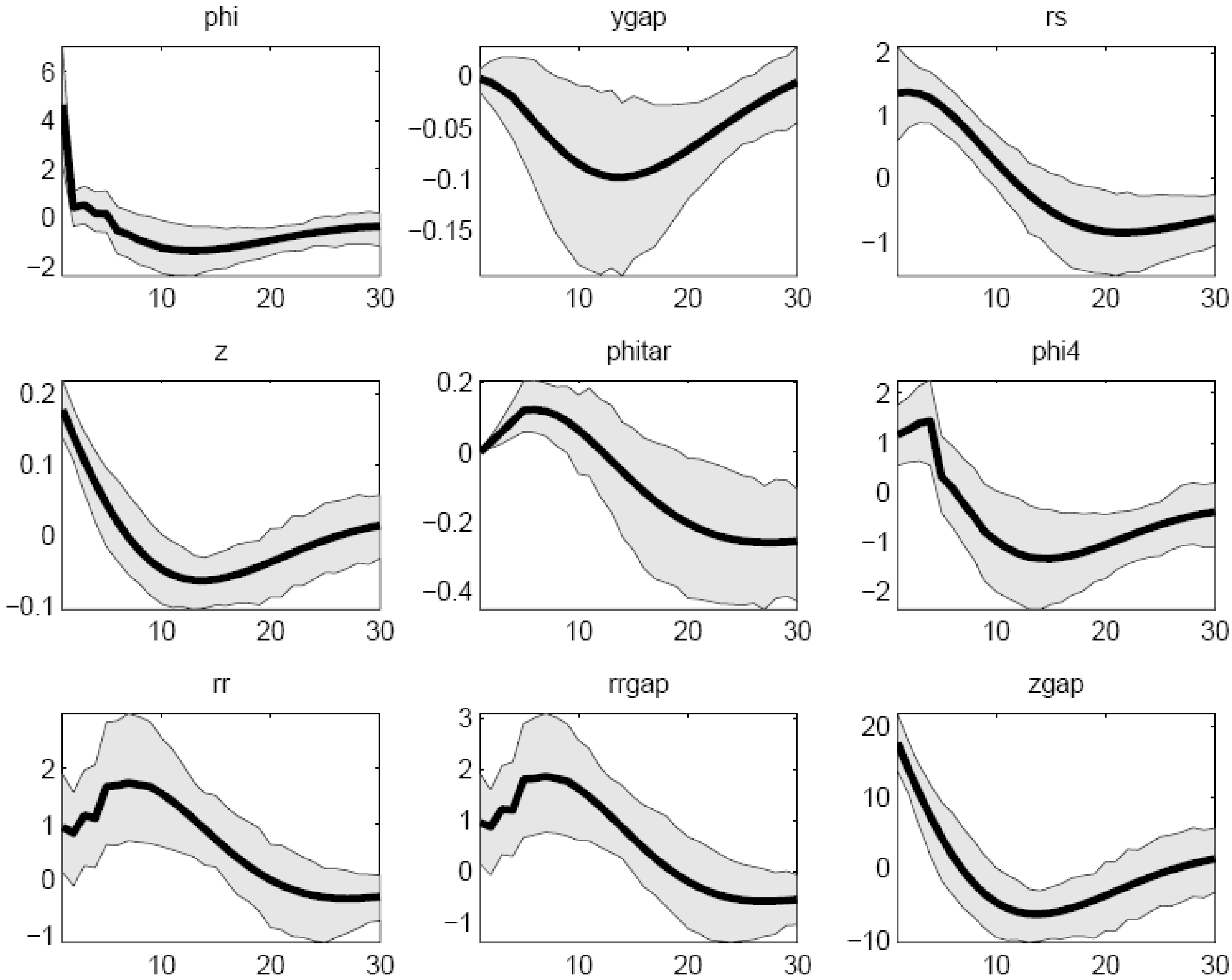
Source: **Author's calculations**

Figure 14 Impulse response function: Inflation target shock



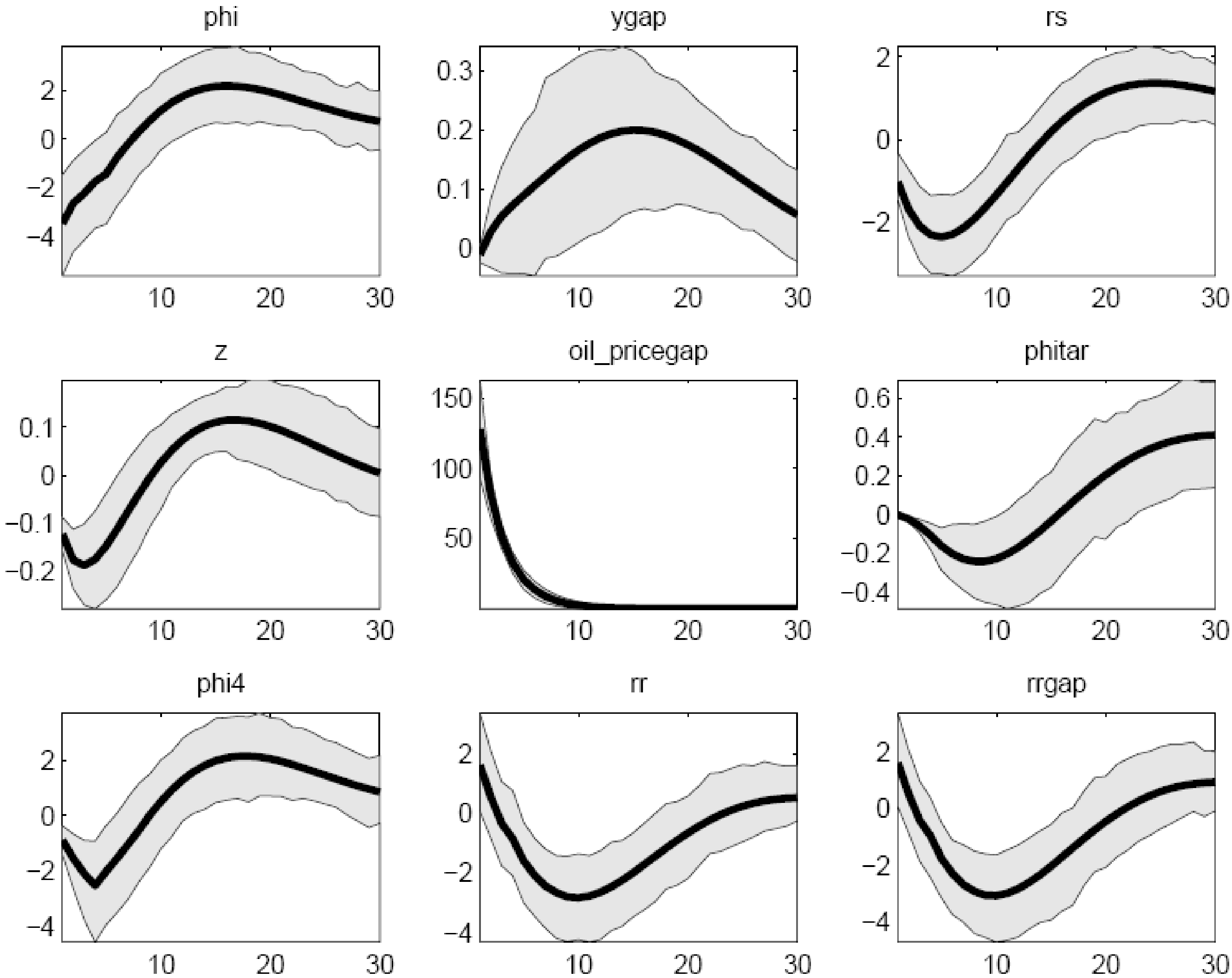
Source: **Author's calculations**

Insert: Figure 15 Impulse response function: Risk premium shock



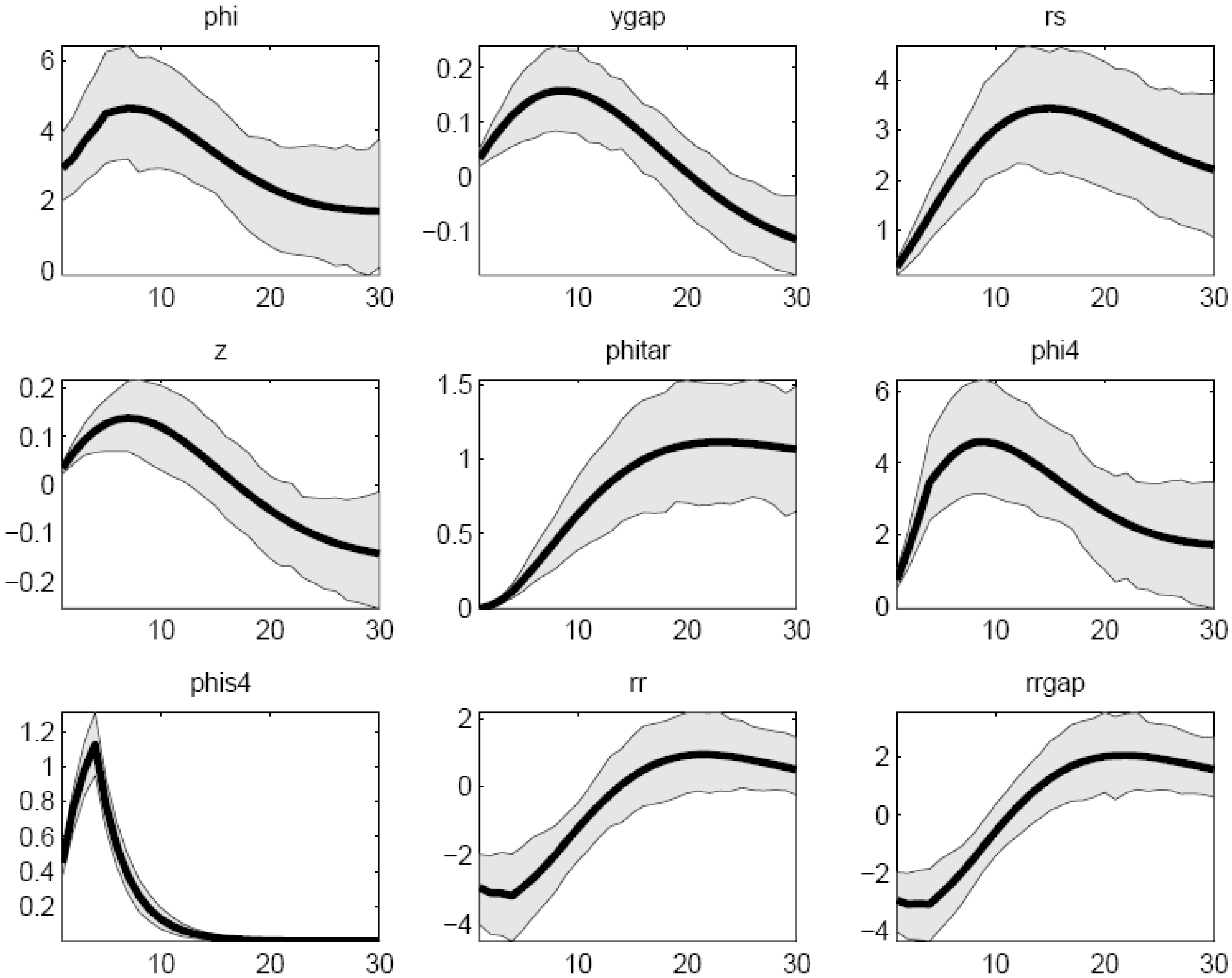
Source: **Author's calculations**

Insert: Figure 16 Impulse response function: Oil price shock



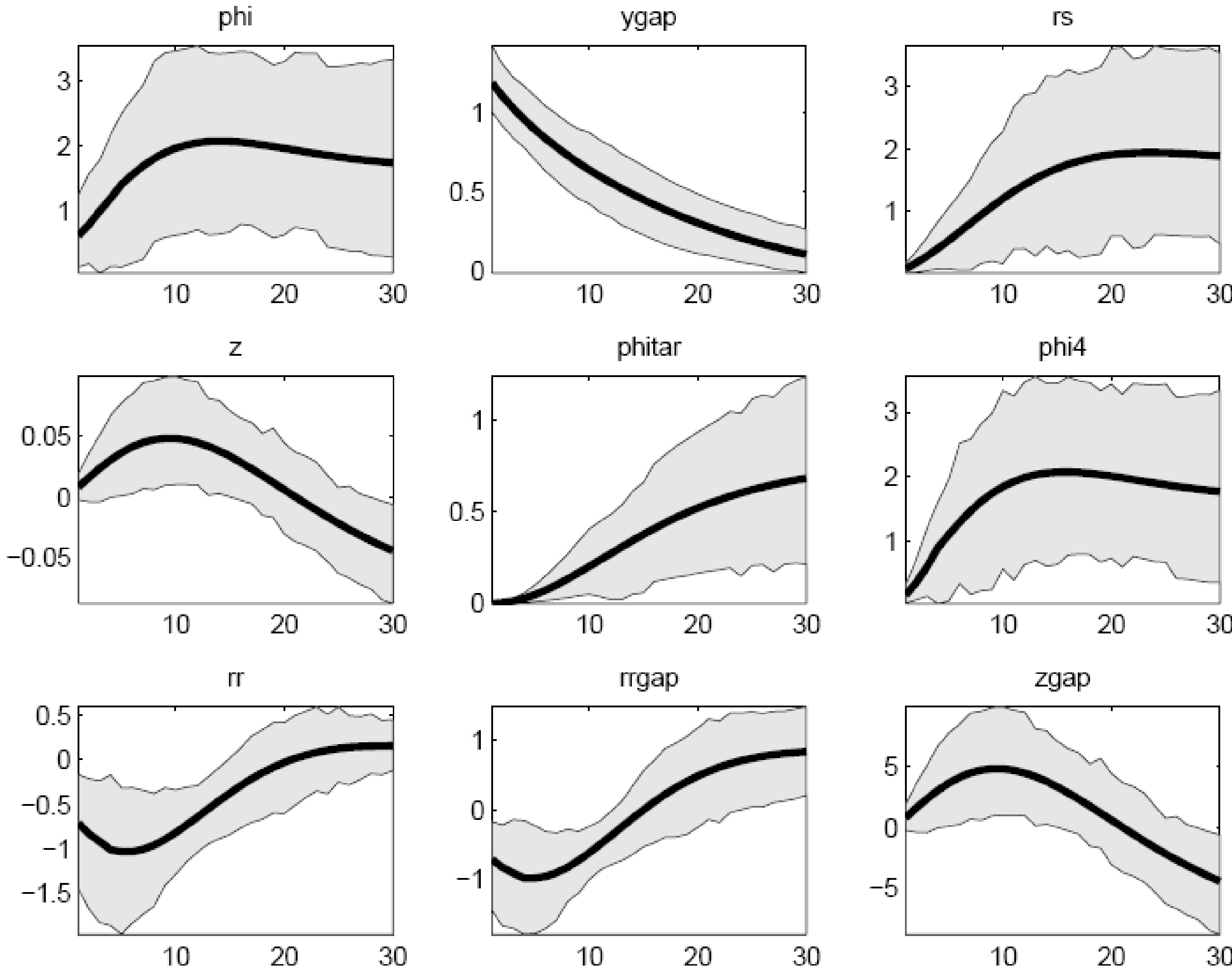
Source: **Author's calculations**

Insert: Figure 17 Impulse response function: Foreign inflation shock



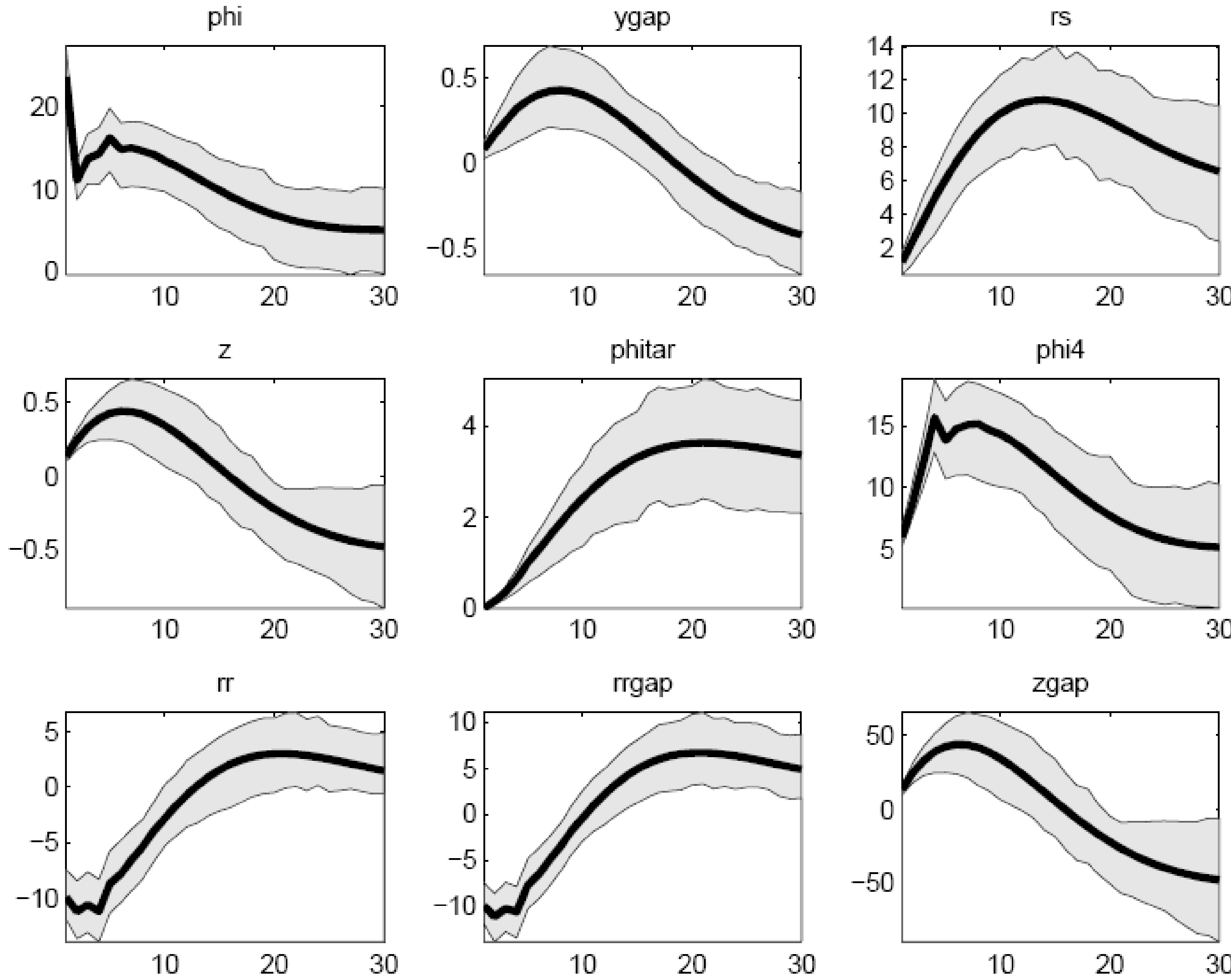
Source: **Author's calculations**

Insert: Figure 18 Impulse response function: Demand shock



Source: **Author's calculations**

Insert: Figure 19 Impulse response function: Supply shock



Source: **Author's calculations**