A Small Open Economy DSGE Model for an Oil Exporting Emerging Economy

Iklaga, Fred Ogli

University of Surrey

f.iklaga@surrey.ac.uk

Presented at the 33rd USAEE/IAEE North American Conference,
October 25 - 28, 2015, Pittsburgh, USA

October 28, 2015
Overview

1. Research agenda
   - Modelling Strategy
   - Current Work

2. Models
   - Standard SOE DSGE Model
   - Augmented SOE DSGE Model
   - Policy

3. Model Calibration and Results
   - Calibration
   - Simulated Results
   - Preliminary Estimates

4. Conclusions
   - Moving ahead
Modelling Plan

- Develop a micro-founded DSGE model ‘fit for purpose’ for an Oil Exporter
  - Incorporate important features peculiar to emerging economies
  - From standard SOE NK DSGE to SOE NK DSGE model with Oil production sectors, Endogenous Fiscal Policy, and Informal and Formal Sectors
  - Estimate model via Bayesian-Methods with priors from related research and data
  - Undertake quantitative analysis.
- Assess the welfare implications with various policy rules, particularly focusing on the policy responses to oil price developments
Questions:

- Do the new features improve the fit of the model?
- Are the DSGE estimates informative about the Nigerian economy?

Estimate and analyse to:

- Validate model
- Assess statistical properties
- Analyse impulse response functions
Current paper: develops an open economy model with financial frictions, oil production sector and endogenous fiscal policy

Model Calibrated to fit the stylize facts of typical SOE oil exporter


Papers on the Informal Economy: a survey [Batini et al.(2010b)] and a study of monetary policy and the informal economy

Related paper: [Anand et al.(2010)], Bergholt [2014]
Some Stylized Facts

- **Nigerian Economy**
  - Total GDP: USD521.8 billion
  - Oil Exports/Total Exports: 91.6 per cent (OPEC, AR)
  - OIL/GDP: 33 per cent (1980-2014)
  - Size of Informal Sector: 58 per cent
Some Stylized Facts...

As highlighted in [Sen and Kolli(2009)], [Rada(2009)] and more recent work by [Fox (2015)] some broad characteristics of the informal sector are:

- **Size:** 50 per cent of GDP 90 per cent workforce
- **Ownership:** usually by individual or household enterprises
- **Output:** marketable goods and services
- **Bookkeeping:** No complete accounts
Modelling in stages

- Objective is to build up model in stages
- Model 1: A standard Open economy NK model calibrated to fit the stylized facts of the Nigerian Economy
- Model 2: Model 1 plus non-Ricardian households, oil production sector and endogenous fiscal policy
- Model 3: Add informal sector with labour market frictions
At the core is an "RBC model" with:

Representative households optimize its intertemporal utility-maximizing choice of consumption and labour supply over time subject given budget constraints.

Firms producing output according to a production technology and choose labour and capital inputs to maximize profits.

- Labour, output and financial markets clear.
- Add investment adjustment costs.
- Add monopolistic competition in retail market and price stickiness.
- Add Macroeconomic policy via a monetary policy rule.
Households

Households Euler equations and marginal utilities:

\[
\frac{1}{R_{n,t}} = \beta E_t \left[ \frac{\Lambda_{C,t+1}}{\Lambda_{C,t} \Pi_{t+1}} \right]
\]

\[
\frac{W_t}{P_{C,t}} = \frac{\Lambda_{L,t}}{\Lambda_{C,t}} = -\frac{\Lambda_{h,t}}{\Lambda_{C,t}}
\]

\[
\Lambda = \frac{(C(1 - \chi))^{(1 - \rho)}(1 - h)^{\rho}}{1 - \sigma_c} - 1
\]

\[
\Lambda_{C} = (1 - \rho)(C(1 - \chi))^{(1 - \rho)(1 - \sigma_c) - 1}((1 - h)^{\rho(1 - \sigma_c)})
\]

\[
\Lambda_{L} = -\rho(C(1 - \chi))^{(1 - \rho)(1 - \sigma_c)(1 - h)^{\rho(1 - \sigma_c) - 1}}
\]
Firms

- Firms maximize profits:

\[
Y_{t}^W = (A_t h_t)^{\alpha} K_t^{1-\alpha}
\]
\[
Y_t = (1 - c) Y_t^W
\]

\[
K_{t+1} = (1 - \delta) K_t + (1 - S(X_t)) I_t
\]

\[S', S'' \geq 0 ; S(1 + g) = S'(1 + g) = 0\]

\[
X_t = \frac{I_t}{I_{t-1}}
\]

\[
S(X_t) = \frac{\phi I}{2} (X_t - 1)^2
\]

\[
\frac{P_{I,t}}{P_{C,t}} = Q_t (1 - S(X_t) - X_t S'(X_t)) + E_t \left[ \frac{Q_{t+1} S'(X_{t+1})}{(R_t)} \frac{I_{t+1}^2}{I_t^2} \right]
\]
Additional frictions

- non-Ricardian households

\[ \Lambda = \frac{(C_2(1 - \chi))^{(1-\varphi)}(1 - h)^{\varphi})^{1-\sigma_c} - 1}{1 - \sigma_c} \]

\[ \Lambda_{C_2} = (1 - \varphi)(C_2(1 - \chi))^{(1-\varphi)(1-\sigma_c)-1}((1 - h)^{\varphi(1-\sigma_c)}) \]

\[ C_{1,t} = \frac{W_t h_t}{P_t} = Wage \quad Income \]

\[ C_t = \lambda C_{1,t} + (1 - \lambda) C_{2,t} \]
Oil production sector

- Oil price is assumed to follow a random walk without a drift as estimated in Hamilton (2009),

\[ \log p_t^{O^*} = \log p_{t-1}^{O^*} + \varepsilon_t^{p_o}, \]

- For simplification resource production in the model is financed by capital \( \varphi \) investments in oil sector, which follows an AR(1) process,

\[ \log \varphi_t^* = \rho_\varphi \log \varphi_{t-1}^* + \varepsilon_t^\varphi, \]

where both shocks follow the process \( \varepsilon_t^{p_o,\varphi} \sim i.i.d.N(0, \sigma_{p_o,\varphi}^2) \)

- Resource capital evolves according to

\[ K_t^O = (1 - \delta^O) K_{t-1}^O + \varphi_t^*. \]
Oil production sector

- Oil production takes the form a simplified Cobb-Douglas production technology without labour input:

\[ Y_t^O = z_t^O (K_{t-1}^O)^{\alpha^O}, \]

where \( z_t^O \) is resource TFP which follows an AR(1) process,

\[ \log z_t^O = \rho_{zo} \log z_{t-1}^O + \varepsilon_{zo}^t, \]

\( \varepsilon_{zo}^t \sim i.i.d. N(0, \sigma_{zo}^2) \) is the oil production technology shock.
Monetary Policy

\[
\begin{align*}
\log\left( R_{n,t}/R_n \right) &= \rho_r \log\left( R_{n,t-1}/R_n \right) + (1 - \rho_r) \left( \theta_\pi E_t [\log \Pi_{t+1}] / \Pi \right) \\
&\quad + \theta_s \log S_t / S) + \epsilon_{r,t+1}
\end{align*}
\]
Fiscal Policy

- Resource production proceeds depend on $\tau_t^O$ a proxy for both royalties and profit taxes and paid each period as
  \[ T_t^O = s_t \left[ \tau_t^O p_t^O y_t^O \right] \]

- Government budget constraint is given by
  \[ g_t = t_t^O + d_t + R_{t-1} d_{t-1}, \]

  where $g$, $t$ and $d$ are real variables deflated by output.

- Fiscal rule
  \[ d_t = \rho_g d_{t-1} + \epsilon_t^d \]
Model Structure

Structure2.png

Formal Sector

Informal Sector

Labour Market (F)

Oil Sector

Oil Tax

Government

Ricardian Households

Non-Ricardian Households

Labour Market (I)

Wholesale Firms (F)

Intermediate Goods

Retail Firms (F)

Capital Producers

Final Goods (F)

Final Goods (I)

Entrepreneurs

Intermediate Goods

Wholesale Firms (I)

Rest of the World

SOE DSGE for Oil Exporter

Iklaga, Fred Ogli (CIMS)
# Calibration

<table>
<thead>
<tr>
<th>Calibrated parameter</th>
<th>Symbol</th>
<th>Value for Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discount factor</td>
<td>$\beta$</td>
<td>0.975</td>
</tr>
<tr>
<td>Depreciation rate</td>
<td>$\delta$</td>
<td>0.025</td>
</tr>
<tr>
<td>Risk aversion</td>
<td>$\sigma$</td>
<td>2.00</td>
</tr>
<tr>
<td>Consumption habit</td>
<td>$h_C$</td>
<td>0.70</td>
</tr>
<tr>
<td>Calvo prices</td>
<td>$\xi$</td>
<td>0.75</td>
</tr>
<tr>
<td>Labour share</td>
<td>$\alpha$</td>
<td>0.60</td>
</tr>
<tr>
<td>Preference parameter</td>
<td>$\varrho$</td>
<td>0.61</td>
</tr>
<tr>
<td>Substitution elasticity (H/F goods)</td>
<td>$\mu$</td>
<td>1.50</td>
</tr>
<tr>
<td>Investment substitution</td>
<td>$\rho_I$</td>
<td>0.50</td>
</tr>
<tr>
<td>Risk premium elasticity</td>
<td>$\chi_B$</td>
<td>0.50</td>
</tr>
<tr>
<td>Substitution elasticity (Others)</td>
<td>$\zeta$</td>
<td>0.50</td>
</tr>
</tbody>
</table>
## Calibration

<table>
<thead>
<tr>
<th>Calibrated parameter</th>
<th>Symbol</th>
<th>Value for Nigeria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proportion of RT consumers</td>
<td>$\lambda$</td>
<td>0.23</td>
</tr>
<tr>
<td>Risk premium - scaling</td>
<td>$\kappa_B$</td>
<td>1.00</td>
</tr>
<tr>
<td>Interest rate smoothing</td>
<td>$\rho_{rh}$</td>
<td>0.50</td>
</tr>
<tr>
<td>Feedback from expected inflation</td>
<td>$\theta_{ph}$</td>
<td>2.00</td>
</tr>
<tr>
<td>Feedback from exchange rate</td>
<td>$\theta_{sh}$</td>
<td>0.50</td>
</tr>
<tr>
<td>Imported investment share</td>
<td>$i_{is_{import}}$</td>
<td>0.15</td>
</tr>
<tr>
<td>Imported consumption share</td>
<td>$c_{is_{import}}$</td>
<td>0.10</td>
</tr>
<tr>
<td>Exported investment share</td>
<td>$i_{is_{export}}$</td>
<td>0.02</td>
</tr>
<tr>
<td>Exported consumption share</td>
<td>$c_{is_{export}}$</td>
<td>0.23</td>
</tr>
</tbody>
</table>
Theoretical Moments

<table>
<thead>
<tr>
<th>Standard Deviation</th>
<th>Output</th>
<th>Inflation</th>
<th>Interest rate</th>
<th>Exchange rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>NK SOE</td>
<td>2.1383</td>
<td>1.2682</td>
<td>0.5049</td>
<td>2.9086</td>
</tr>
<tr>
<td>NK SOE OIL</td>
<td>1.8510</td>
<td>0.8821</td>
<td>0.5552</td>
<td>3.6825</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Autocorrelations (1)</th>
<th>Output</th>
<th>Inflation</th>
<th>Interest rate</th>
<th>Exchange rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>NK SOE</td>
<td>0.7142</td>
<td>0.3692</td>
<td>0.7348</td>
<td>0.7016</td>
</tr>
<tr>
<td>NK SOE OIL</td>
<td>0.9071</td>
<td>0.6565</td>
<td>0.7214</td>
<td>0.6656</td>
</tr>
</tbody>
</table>

**Table:** Selected Second Moments
Figure: IRFs Technology Shock
Figure: IRFs Foreign Shock
Figure: IRFs Mark-up Shock
Figure: IRFs Government Spending Shock
Data and measurement Equations

\[
\begin{bmatrix}
GDP_t \\
\log(CPI_t - CPI_{t-1}) \\
3MDR_t/4 \\
REER_t
\end{bmatrix}
= 
\begin{bmatrix}
\log \left( \frac{Y_t}{Y} \right) \\
\log \left( \frac{\Pi_t}{\Pi} \right) \\
\log \left( \frac{1+R_{n,t}}{1+R_n} \right) \\
\log \left( \frac{REER_t}{REER} \right)
\end{bmatrix}
\]
<table>
<thead>
<tr>
<th></th>
<th>SOENKFF</th>
<th>SOENKFOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Spending</td>
<td>2.2775</td>
<td>8.7923</td>
</tr>
<tr>
<td>Technology</td>
<td>12.089</td>
<td>17.531</td>
</tr>
<tr>
<td>Mark-Up</td>
<td>1.0415</td>
<td>1.0395</td>
</tr>
<tr>
<td>UIP</td>
<td>1.0376</td>
<td>1.0381</td>
</tr>
<tr>
<td>Foreign Interest Rate</td>
<td>1.5958</td>
<td>1.5958</td>
</tr>
<tr>
<td>Foreign Inflation</td>
<td>6.2066</td>
<td>6.688</td>
</tr>
<tr>
<td>Foreign Consumption</td>
<td>11.996</td>
<td>1.0426</td>
</tr>
<tr>
<td>Foreign Investment</td>
<td>1.7189</td>
<td>1.719</td>
</tr>
<tr>
<td>Foreign MUC</td>
<td>6.3031</td>
<td>6.1422</td>
</tr>
<tr>
<td>Monetary Policy</td>
<td>3.7737</td>
<td>3.4547</td>
</tr>
</tbody>
</table>

**Figure**: Standard deviation of I.I.D. Shocks
<table>
<thead>
<tr>
<th>AR(1) coefficient</th>
<th>SOENKFF</th>
<th>SOENKFOIL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Spending</td>
<td>0.9273</td>
<td>0.9885</td>
</tr>
<tr>
<td>Technology</td>
<td>0.7952</td>
<td>0.5521</td>
</tr>
<tr>
<td>Mark-Up</td>
<td>0.4999</td>
<td>0.4997</td>
</tr>
<tr>
<td>Foreign Interest Rate</td>
<td>0.8458</td>
<td>0.8537</td>
</tr>
</tbody>
</table>

**Figure**: Standard of I.I.D. Shocks
Work-in-progress

- Policy implications: how should monetary policy respond to oil price shocks in Nigeria
- Incomplete exchange rate pass-through more realistic
- Add informal sector and do the policy analysis to complete the project
  Model 1: A standard SOE NK model
  Model 2: SOE NK model with financial frictions and Oil
  Model 3: SOE NK model with financial frictions, Oil and informal sector
The End