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Macroeconomic Management on Becoming an African Oil Exporter

Oliver Morrissey and Lars Spreng

ABSTRACT

This paper provides analysis of the macroeconomic management implications of becoming an exporter of oil, taking the case of Ghana and applying to Uganda as a prospective exporter. The paper proceeds in two steps. First, we construct a Dynamic Stochastic General Equilibrium (DSGE) model of a primary commodity exporting developing country calibrated to Ghana and Uganda and simulate the impulse response to shocks to the oil price and oil production. Second, using parameters from the DSGE model to obtain priors for parameter values, we use a Structural Vector Autoregressive (SVAR) with monthly data over 2001 to 2019 to estimate the response to oil shocks as an importer for both countries and as an exporter for Ghana after 2010. The DSGE results suggest that although an oil price shock generates appreciation and initially output falls, there are reductions in interest rates and inflation and ultimately output increases. The larger the oil sector the greater the appreciation and inflationary effects, but output rises more quickly and there are larger increases in wages and taxes. The SVAR results for Ghana when exporting suggest an initial depreciation in response to an oil price shock, with a reduction in inflation, but the immediate negative output response slowly turns positive (and becomes consistent with the DSGE). When Ghana and Uganda are importers, oil price shocks generate appreciation, mild inflation and interest rate reductions, so although output declines initially it rises after a year and this persists. The analysis suggests that the adoption of inflation targeting, in conjunction with an improved monitoring of macroeconomic developments, has mitigated the effects of oil price shocks on domestic variables in Ghana and Uganda.

JEL Classification: F31, F35, O11, O55

Keywords: Oil, Exchange Rates, DSGE, SVAR, sub-Saharan Africa (Ghana, Uganda)

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Outline

The Authors

Morrissey – Professor of Development Economics, CREDIT and School of Economics, University of Nottingham (oliver.morrissey@nottingham.ac.uk – corresponding author); Spreng –Post-Graduate Student (lars.spreng@cass.city.ac.uk).

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1 INTRODUCTION

This paper provides analysis of the macroeconomic effects of an 'SSA-type' economy switching from being an importer of oil to exporting oil through a comparison of Ghana and Uganda. Following the discovery of oil off the coast, Ghana moved into production and became an exporter of crude in 2011 (but continued to import refined oil) and therefore provides a test case for switching effects. Uganda has discovered oil in the Western region and may become an exporter in the future; the high cost of building a pipeline has been the major constraint and projections of a global shift away from fossil fuels (given the need to address climate change) production may not be commercially viable. Nevertheless, the paper provides projections of the macroeconomic effects of becoming an oil exporter and includes analysis of the effects of shocks to the oil price as an importer.

The paper proceeds in three steps. First, we construct a Dynamic Stochastic General Equilibrium (DSGE) model of a primary commodity exporting developing country calibrated to Ghana and Uganda and simulate the impulse response to shocks to the oil price and oil production (section 2). Second, using a Structural Vector Autoregressive (SVAR) model with monthly data for 2001:1 to 2019:2 (with the split at 2010:12) we estimate empirical impulse responses to oil price shocks (Section 3). Comparing the SVAR estimates for the pre and post-exporting periods allows an assessment of the macroeconomic effects of switching, and the DSGE predictions can be compared to the estimates for the period as an exporter. Finally, we use an SVAR for Uganda with monthly data over 2006:1 to 2019:3 to estimate the response to oil shocks as an importer (Section 4). These are compared to the first period estimates for Ghana to assess similarity and judge if the Ghanaian experience is a useful guide for Uganda. The analysis is informative on the macroeconomic effects of oil shocks in Ghana and Uganda.

Although it is common in the literature to begin with the SVAR impulse responses to illustrate the macroeconomic effects of oil price shocks and then use a model to explore the reasons (e.g., Blanchard and Galí, 2010), we reverse the order for two reasons. First, and most important, the DSGE model is used to generate priors for parameters to use for Bayesian identification of the SVAR, Second, the DSGE model is intended to generate predictions for the effects of oil price shocks that can be empirically tested with the SVAR for Ghana. Furthermore, SVAR estimates are provided for Ghana as an importer (to compare with Uganda) and as an oil exporter. The concluding discussion considers theoretical and policy interpretations of the results from the two approaches (especially the few cases where they differ), specifically the relevance of inflation targetting (adopted in Ghana in 2007 and in Uganda in 2011).

2 A DSGE FRAMEWORK FOR OIL EXPORTS

New-Keynesian DSGE models have become the standard tool in the literature to investigate theoretically the effects of macroeconomic shocks for advanced and developing economies. We motivate our empirical analysis by assessing oil price and production shocks in a DSGE framework which we calibrate to fit the economies of Ghana and Uganda and derive the DSGE (theoretical) impulse responses. By calibrating the DSGE model, the model parameters can be used as prior modes in empirical analysis to assess if and how the theoretical results differ from the empirical impulse responses.

Dagher, Gottschalk and Portillo (2012) is a closely related paper as they investigate the short-run impact of oil windfalls using a DSGE model, also calibrated to Ghana. Although the basic structure of their model is similar to ours, there are important differences as their aim is to analyse the impact of revenue windfalls associated with oil, and simulate alternative policy responses, whereas we are primarily concerned with the impact of an oil price shock and generating priors for parameters in the SVAR. Given the interest in simulating alternative policy responses, Dagher *et al* (2012) incorporate a richer characterisation of the Central Bank, which has operational targets and rules for inflation and the accumulation of reserves, and a fiscal rule for the sovereign wealth fund.

Model Outline

The DSGE model is an adaptation of Medina and Soto (2007) for Chile, so we only provide a brief summary and indicate the changes made. To allow for heterogeneity in consumers the economy is populated by a share of (1-λ) Ricardian and λ non-Ricardian (subsistence or informal sector who consume all their current income and do not invest in asset markets) consumers, with λ = 70% for Uganda and 60% for Ghana. The remaining 30% (40%) Ricardian consumers are standard dynamic optimisers who smooth intertemporal consumption and own domestic firms. This accounts for the slightly higher standard of living in Ghana. Agents preferences exhibit habit formation and their consumption bundle contains a share α_c = 1.5% of oil,[1] so that 1-α_c is the core consumption bundle. Wage stickiness is introduced by assuming households are monopolistic suppliers of labour (search frictions are not incorporated).

There are different types of firms. One type rents out capital goods assembled using home and foreign investment to intermediary producers, with investment adjustment costs à la Christiano, Eichenbaum, and Evans (2005). The intermediate producers operate in a monopolistically competitive market and use a share γ_c = 0.5% of oil in their production function. The firms supply the domestic as well as the world market at differentiated prices, and Calvo price stickiness leads to two New-Keynesian Phillips Curves. The intermediate inputs are used by competitive final goods producers who sell their products domestically and abroad. Imports are modelled through monopolistic retailers that import varieties and resell them to competitive firms producing final goods (the foreign goods) that can be consumed by households or used in the production of new capital goods. This introduces price stickiness because the importing firms adjust the prices of their varieties infrequently (Calvo pricing) due to their monopoly power. This set up ensures that the model exhibits local-currency price stickiness which leads to incomplete short-run exchange rate pass-through (ERPT) to import prices thereby reducing expenditure-switching effects.

The commodity sector (copper) in Medina and Soto (2007) is replaced by an oil sector, the production of which is exported entirely and not used domestically. This is a plausible assumption, as domestic consumers and firms are likely using imported refined oil products. Similar to Dagher *et al* (2012) oil is not modelled as the export sector so oil production can be treated as a windfall gain. We do not distinguish between prices for the two types of oil. As oil is a part of firms' production function and households' consumption basket, oil price shocks directly affect both but oil production shocks do not. The oil sector does not use inputs; hence oil production shocks are a windfall gain. The government owns a share χ = 50% of the oil sector and we assume the revenue is paid into a sovereign wealth fund (SWF) included in the model, assuming the government can access $\vartheta = (1.04^{0.25} - 1)$ per cent of the fund per quarter.[2]

[1] This may be an underestimate as Nyanzi and Bwire (2018) report that in 2010 oil accounted for about 3% of final consumption spending in Uganda.

[2] Although the calibration is based on observed annual data and growth rates, the log-linear DSGE model is constructed for percentage changes in quarters, hence the conversion from annual to quarterly rates. The IRFs give percentage deviations from the initial steady-state of the variables.

The SWF evolves according to:

$$SWF_t = \vartheta(1 - i_{t-1}^{*})SWF_{t-1} + \chi p_{o,t}\, y_{o,t} \quad (1)$$

$p_{o,t}$ is the world price of oil converted to domestic currency and $y_{o,t}$ is local oil production (oil revenue is invested at the world interest rate).

After implementing the SWF, the government budget constraint takes the following form:

$$\frac{e_t B_{G,t}^{*}}{(1+i_t^{*})\Theta\frac{e_t B_t^{*}}{P_{Y,t}Y_t}} + \frac{B_{G,t}}{1+i_t} + \frac{SWF_t}{P_{Y,t}Y_t(1+i_t^{*})} = e_t B_{G,t-1}^{*} + B_{G,t} + T_t + \frac{SWF_{t-1}}{P_{Y,t}Y_t} - P_{G,t}G_t \quad (2)$$

Where $(1+i_t^{*})\Theta\frac{e_t B_t^{*}}{P_{Y,t}Y_t}$ is the interest rate of public assets in foreign currency, e_t is the exchange rate, $B_{G,t}$ are government bonds held by domestic agents, $B_{G,t}^{*}$ are government bonds held by foreign agents, $P_{Y,t}Y_t$ is GDP at market prices, T_t are tax revenues, and G_t is government consumption. The government spends on home and foreign goods. Medina and Soto (2007) use a structural balance fiscal rule which is meant to avoid excessive fluctuations in government expenditure coming from transitory movements in fiscal revenues, i.e. the oil revenue is largely saved. The central bank follows a standard Taylor rule and after implementing the SWF the structural balance rule is:

$$\frac{P_{G,t}G_t}{P_{Y,t}Y_t} = \left\{\left(1 - \frac{1}{(1+i_{t-1}^{*})\Theta_{t-1}}\right)\frac{e_t}{e_{t-1}}\frac{e_{t-1}B_{G,t-1}^{*}}{P_{Y,t-1}Y_{t-1}}\frac{P_{Y,t-1}Y_{t-1}}{P_{Y,t}Y_t} + \tau\frac{\bar{Y}}{Y_t} + \vartheta\frac{SWF_{t-1}}{P_{Y,t}Y_t} - \frac{B_{S,t}}{P_{Y,t}Y_t}\right\} e^{\zeta_{G,t}} \quad (3)$$

The calibrated model parameters are in Appendix Table A1. Several observed parameters are similar for Ghana and Uganda. The steady-state net export/GDP ratio, NX_Y, is roughly -10% for both countries. Government expenditure/GDP, GH_y is set to 10% and the current account/GDP ratio, CCq_y, is -5% in both countries. The inflation target (π_c) differs considerably: 5% for Uganda; the Bank of Ghana defines a target in the range 8-10% and as inflation has been consistently high, we set it at 10%. The population (labour force) growth rate is also higher in Ghana, n = 5% compared to 3.3% in Uganda. Labour productivity growth, g_y, is 7% in Ghana and 5% in Uganda. The size of the oil sector, Ys_y, is set at the average share of oil production in GDP for Ghana since 2010 (5%), and χYs_y is the steady state SWF level relative to GDP. The steady state real interest rate is 4% in Uganda and 5% in Ghana, and recall we assume there are fewer non-Ricardian households in Ghana (60%, versus 70% in Uganda).

We specify the following shock processes for oil production and oil prices:

$$p_{o,t} = \rho_{prs}^{*} * p_{o,t-1} + \epsilon_{o,t} \quad (4a)$$

$$y_{o,t} = \rho_{y_s} * y_{o,t-1} + \epsilon_{o,t} \quad (4b)$$

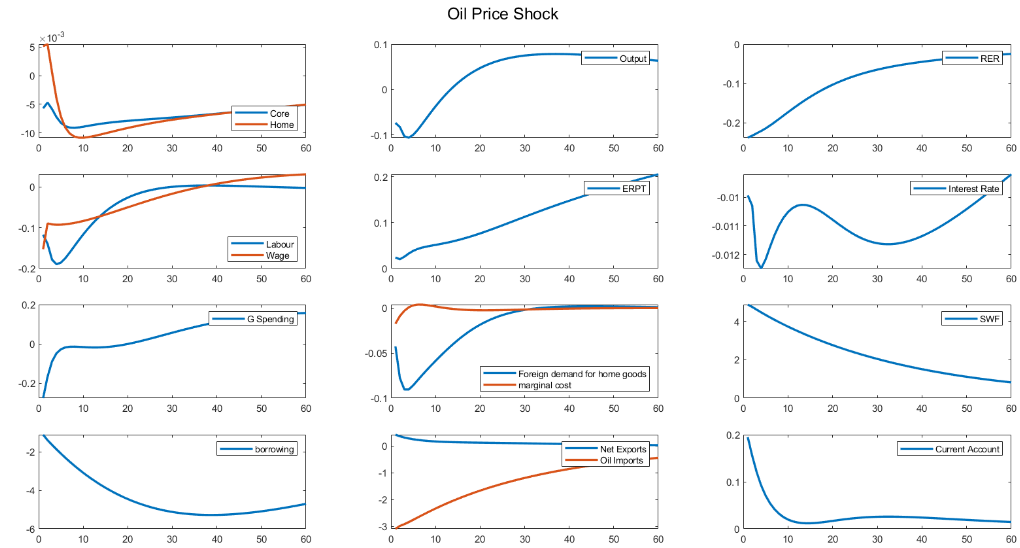
where $\rho_{y_s} = 0.77$ and $\rho_{prs}^{*} = 0.97$. We assume a one standard deviation shock of magnitude 12 for oil prices and 4.51 for oil production.

Impulse Response Functions

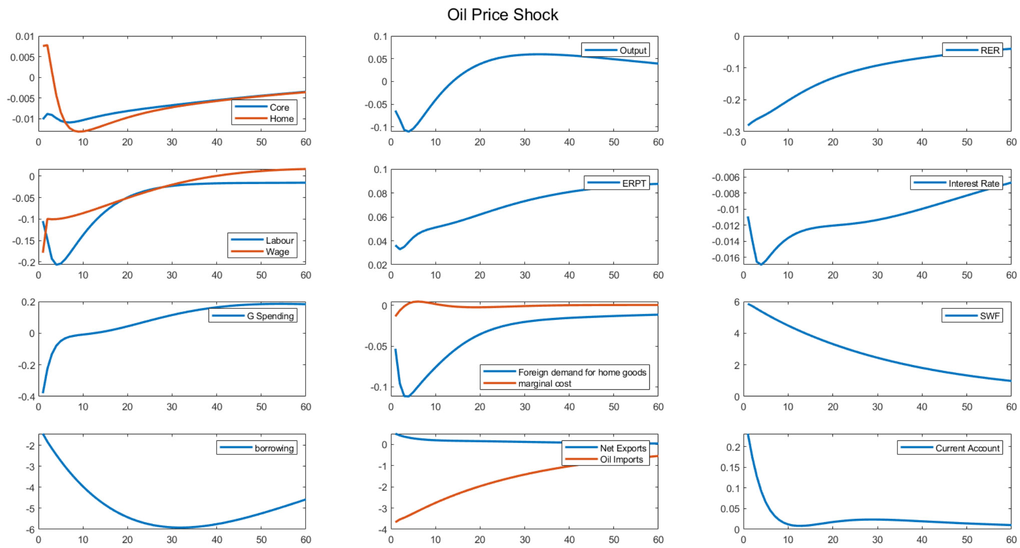
Figure 1 depicts the impulse response function to an oil price shock, and Figure 2 the responses to an oil production shock (a decline in RER corresponds to appreciation). Panel (a) shows the results for Uganda, panel (b) for Ghana. The findings are very similar for both countries.

Figure 1: Impulse response to Oil Price Shock (DSGE)

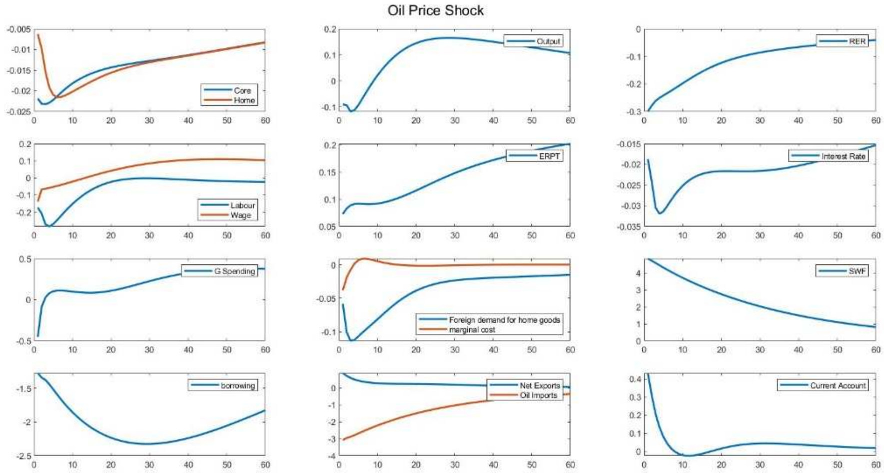
(a) Uganda



(b) Ghana



(c) Uganda, larger oil sector



Note: Impulse responses estimated from the DSGE model. Note that RER is defined such that a decline represents a currency appreciation.

The impulse response show that the Bank of Ghana cuts interest rates by more (than Bank of Uganda), and core as well as domestic inflation show a higher deviation from steady state. This reflects the fact that inflation in Ghana has been higher and more volatile. We observe a negative deviation of core (and domestic) inflation that is highly persistent. Simultaneously, the currency appreciates after the oil price shock, reducing import-price inflation. This channel outweighs the effect of the shock on marginal costs brought about by higher wages and the increased production cost (Medina and Soto, 2007). The latter impact output together with the fact that households must reallocate a larger fraction of their consumption expenditure to oil. This effect is stronger in Ghana. Due to the exchange rate appreciation, the demand for foreign goods by domestic agents falls – the impulse response exhibits a hump-shape as ERPT is incomplete in the short-run. As was to be expected, the SWF increases in value. Recalling that the government can access parts of the funds volume accumulated in previous periods, government spending dips initially but rises for an extended period after the first quarter which likely offsets negative output effects to some extent. Notably, spending rises slightly more in Ghana. At the same time, under the Structural Balance rule, the government uses its new fiscal leeway and reduces its outstanding debt.

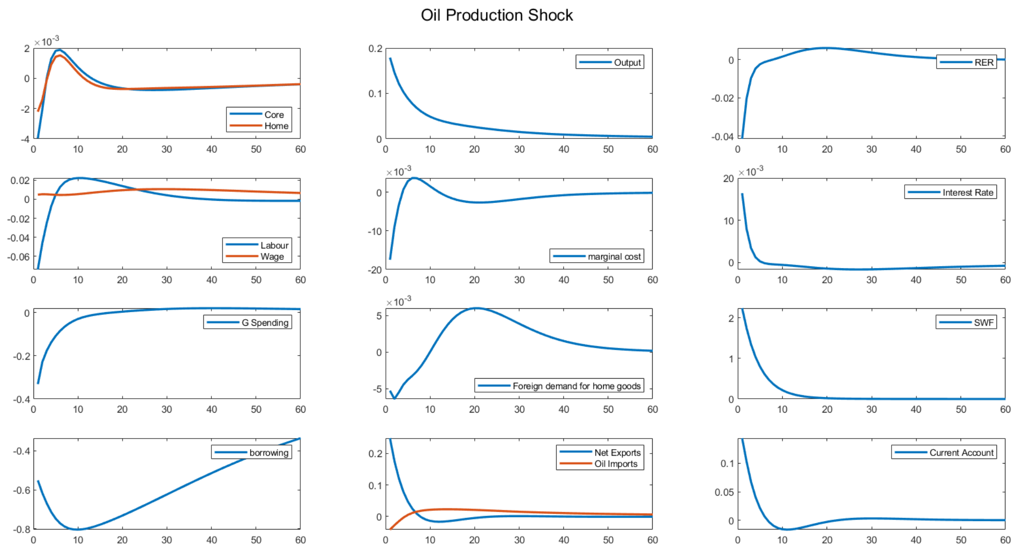
We compute a measure of ERPT following Forbes, Hjortsoe, and Nenova (2018), i.e. we divide the response of inflation by the exchange rate. The ERPT is positive in the sense that shocks are passed through with the same sign. However, the exchange rate deviations are only passed through by 10% in initial years. Subsequently, as the deviation from steady state becomes smaller, the pass-through increases slowly.

These results depend on the size of the oil sector (assumed for Uganda). Should Uganda's oil sector amount to a greater fraction of GDP, the effect of the price shock will be less adverse. To visualise the impact of this calibration, we conduct the same simulation but change the size of the oil sector to 10% of GDP given that Uganda's GDP is considerably lower than Ghana's. Panel (c) plots the corresponding impulse response functions. We observe a slight increase in deflation due to an amplified exchange rate appreciation which triggers expenditure-switching by more. Notably, the output effects are less severe: it takes considerably less time for output to rise again with higher, long-lasting effects. The effect on wages is more positive and the increased tax income allows higher spending.

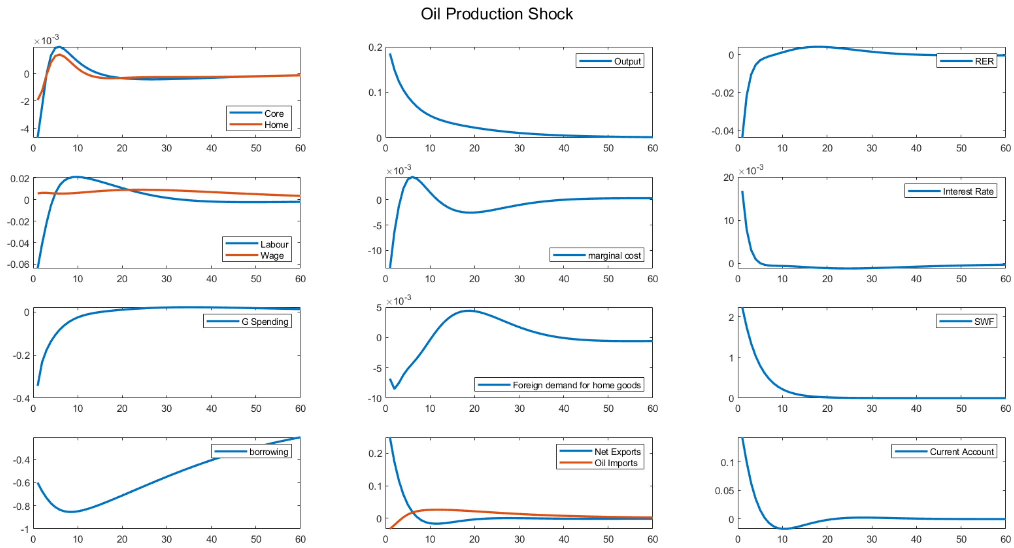
The effects of an oil production shock are more short-lived due to their lower persistence (Figure 2). The phase of exchange rate appreciation fades out after approximately one year. In conjunction with negative pressure on marginal costs, this leads to a mildly lower inflation rate. As the exchange rate appreciation ends, the increasing marginal costs dominate and we observe higher inflation rates. The shock to oil production is reflected in higher net exports and an increasing current account. Output rises and interest rates increase slightly. The government saves the extra revenue and reduces borrowing.

Figure 2: Impulse response to Oil Production Shock (DSGE)

(a) Uganda



(b) Ghana



Note: Impulse responses estimated from the DSGE model. Note that RER is defined such that a decline represents a currency appreciation.

3 Empirical Identification Strategy

To identify the effects of oil price shocks for Ghana, we estimate two different models, one for the period 2001m1 until 2010m12 and one for 2010m12 until 2019m2, to capture that Ghana became an oil exporter from 2011. Splitting the sample allows us to better compare the impact of oil price shocks whilst accounting for regime shifts. For the period of 2001m1-2010m12, we estimate the following structural system of equations:

$$\begin{aligned} p_{o,t} &= \mathbf{b_t^o} * \mathbf{x_{t-1}} + \epsilon_{o,t} \\ y_t &= \alpha_1 * p_{o,t} + \alpha_2 * \pi_t + \alpha_3 * e_t + \alpha_4 * i_t + \mathbf{b_t^y} * \mathbf{x_{t-1}} + \epsilon_{y,t} \\ \pi_t &= \beta_1 * p_{o,t} + \beta_2 * y_t + \beta_3 * e_t + \mathbf{b_t^\pi} * \mathbf{x_{t-1}} + \epsilon_{\pi,t} \\ e_t &= \gamma_1 * p_{o,t} + \gamma_2 * y_t + \gamma_3 * \pi_t + \gamma_4 * i_t + \mathbf{b_t^e} * \mathbf{x_{t-1}} + \epsilon_{e,t} \\ i_t &= \delta_1 * y_t + \delta_2 * \pi_t + \delta_3 * e_t + \mathbf{b_t^i} * \mathbf{x_{t-1}} + \epsilon_{i,t} \end{aligned} \tag{5}$$

We define the output gap[3] as $y_t = g_{y,t} - \bar{y}$, where $g_{y,t}$ is the monthly year-on-year growth rate of the Composite Index of Economic Activity (CIEA), and $\bar{y}$ is the average (steady state) growth

[3] Given the definition of the output gap an increase represents growth so the terms output and output gap are used interchangeably.

rate between 2001 and 2011. The output gap is driven by all variables in the system; even though Ghana did not export oil before 2011, firms still utilised refined oil – a feature we also account for in our DSGE estimation – therefore oil price shocks can still have implications for growth. Our Phillips Curve takes into account that Ghana is an open economy and inflation, π_t, depends not just on the forcing variable but also the exchange rate and oil prices.[4] The monetary policy equation given in reduced form is not a classical Taylor rule (as in the DSGE model), because Ghana did not adopt inflation targeting until 2007 (Bleaney, Morozumi and Mumuni, 2020). Hence, we allow for the possibility that the Bank of Ghana reacts to exchange rate changes contemporaneously. We exclude contemporaneous oil price responses, as Ghana was not exporting oil before 2011. In the second period, Ghana had already adopted inflation targeting. We explicitly account for this regime shift and assume that the Bank of Ghana follows a stricter approach than before by adhering to a Taylor rule. That is, we incorporate a smoothing parameter (ρ) into the interest rate equation and exclude the contemporaneous response to exchange rate shocks. Consequently,

$$i_t = (1-\rho)\delta_1 * y_t + (1-\rho)\delta_2 * \pi_t + \mathbf{b}_t^i * \mathbf{x_{t-1}} + \epsilon_{i,t} \tag{6}$$

The role of the smoothing parameter (ρ) in this setting will be explained in further detail below. Both systems can be written in structural VAR form as $\mathbf{A}\,\mathbf{x_t} = \mathbf{B}\,\mathbf{X_{t-1}} + \boldsymbol{\epsilon}_\mathbf{t}$ with the corresponding reduced form $\mathbf{x_t} = \boldsymbol{\Phi}\mathbf{X_{t-1}} + \boldsymbol{\eta}_\mathbf{t}$, where $\boldsymbol{\Phi} = \mathbf{A^{-1}B} = \mathbf{HB}$, $\boldsymbol{\eta}_\mathbf{t} = \mathbf{H}\boldsymbol{\epsilon}_\mathbf{t}$, $\mathbf{x_{t-1}} = [\mathbf{x}'_{\mathbf{t-1}}, \mathbf{x}'_{\mathbf{t-1}}, \ldots, \mathbf{x}'_{\mathbf{t-l}}]'$, $\mathbb{E}[\boldsymbol{\eta}\boldsymbol{\eta}'] = \mathbf{HDH}'$, and $\mathrm{x_t} = [p_{o,t}, y_t, \pi_t, e_t, i_t]'$.

Bayesian Inference

Li *et al* (2019) emphasise the problems that arise when traditional short-run SVAR identification approaches, relying on strong exclusion criteria, are applied in the analysis of low-income countries.[5] In particular, they focus on the recursiveness assumption introduced by Christiano, Eichenbaum, and Evans (2005). We account for their criticism and make use of the Bayesian VAR methodology introduced in Baumeister and Hamilton (2015), who note that even supposedly uninformative priors, such as the Haar prior, will affect the results. As a solution, they propose a new algorithm, the novelty of which is that it draws from the structural rather than the reduced from. This allows us to incorporate the prior information we have about each structural coefficient. That is, we impose a distribution on each coefficient which allows us to identify the model without imposing harsh exclusion restrictions. Where we are certain about the sign of a coefficient, we truncate the distribution at zero to keep the empirical specification closer to the economic relationships implied by theory whilst acknowledging the prevailing uncertainty.

The joint prior for our model takes the form $p(\mathbf{A}, \mathbf{B}, \mathbf{D}) = p(\mathbf{A})p(\mathbf{D}|\mathbf{A})p(\mathbf{B}|\mathbf{A}, \mathbf{D})$ where $p(\mathbf{A})$ contains the information about the structural coefficient, $p(\mathbf{D}|\mathbf{A})$ is the prior for the structural error variance, $p(\mathbf{B}|\mathbf{A}, \mathbf{D})$ the prior for the lagged structural coefficients. The hyperparameters for the last two priors are the same as in Baumeister and Hamilton (2015). Recalling that a posterior distribution is defined as $p(\boldsymbol{\theta}|\mathbf{X_t}) \propto p(\mathbf{X_t}|\boldsymbol{\theta})p(\boldsymbol{\theta})$. It follows that the joint posterior distribution for the VAR is $p(\mathbf{A}, \mathbf{B}, \mathbf{D}|\mathbf{Y_t}) = p(\mathbf{A}|\mathbf{Y_t})p(\mathbf{D}|\mathbf{A}, \mathbf{Y_t})p(\mathbf{B}|\mathbf{A}, \mathbf{D}, \mathbf{Y_t})$.

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[4] Forbes (2018) highlights the importance of international factors in the inflation process.

[5] It is worth noting that Li *et al* (2019) are also particularly concerned that SVAR estimates of monetary transmission in low-income countries are imprecise, if not misleading, because they typically rely on annual data. Our analysis goes some way to address this concern by using monthly data (which limits the variables included).

Structural Coefficients and Prior Information

For the first system we have

$$\mathbf{A} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \alpha_1 & 1 & \alpha_2 & \alpha_3 & \alpha_4 \\ \beta_1 & \beta_2 & 1 & \beta_3 & 0 \\ \gamma_1 & \gamma_2 & \gamma_3 & 1 & \gamma_4 \\ 0 & \delta_1 & \delta_2 & \delta_3 & 1 \end{bmatrix} \quad (7)$$

Whereas in the second system,

$$\mathbf{A} = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ \alpha_1 & 1 & \alpha_2 & \alpha_3 & \alpha_4 \\ \beta_1 & \beta_2 & 1 & \beta_3 & 0 \\ \gamma_1 & \gamma_2 & \gamma_3 & 1 & \gamma_4 \\ 0 & (1-\rho)\delta_1 & (1-\rho)\delta_2 & 0 & 1 \end{bmatrix} \quad (8)$$

As a source of prior information, we use the DSGE model outlined above by approximating a plausible location for the prior mode from the log-linearised equations. As a prior distribution, we impose a t-distribution with scale 0.3 and 3 degrees of freedom, following Baumeister and Hamilton (2015). This ensures our priors span over plausible ranges whilst ensuring a high degree of thickness in the tails (Table 1).

Table 1: Modes of Prior Distributions (SVAR)

System 1														
Coefficient	α_1	α_2	α_3	α_4	β_1	β_2	β_3	γ_1	γ_2	γ_3	γ_4	δ_1	δ_2	δ_3
Mode	0.01	0.19	0	-1	0	0.027	0.037	1	-0.027	-1	1	0.75	0.25	0
Sign	?	?	?	-	?	+	?	?	?	?	?	+	+	?
System 2														
Coefficient	α_1	α_2	α_3	α_4	β_1	β_2	β_3	γ_1	γ_2	γ_3	γ_4	δ_1	δ_2	ρ
Mode	0.01	0.19	0	-1	0	0.027	0.037	1	-0.027	-1	1	1.5	0.5	0.5
Sign	?	?	?	-	?	+	?	?	?	?	?	+	+	+

Note: All variables in the system are measured in per cent so the mode corresponds to prior % effect. Most values are small as we are using monthly data.

We remain fairly agnostic regarding sign restrictions but ensure that rate hikes do not increase output, the forcing variable raises inflation, and monetary policy does not respond to inflationary pressures by lowering interest rates. In addition, we have no specific prior information from our theoretical model regarding the contemporaneous response of output to exchange rate shocks and the reaction function of monetary policy regarding exchange rate shocks. However, we think that in each case hard exclusion restrictions are unwarranted. Hence, we choose to centre the prior distribution of the coefficients around zero but assign high probabilities to both positive and negative values. The DSGE model provides us with useful information regarding several of the other parameters. While we do not solve the model manually, rearranging some of the equations gives us enough information to centre the prior such that it encompasses the range of plausible values. For example, when combining the two Phillips Curves and the marginal cost function, we obtain a coefficient for the effect of oil prices on inflation, β_1, that corresponds to $\frac{\kappa_{H_D}}{1+\beta\chi_{H_D}}\frac{P_O O_H}{MC_{r_H} Y_H}$,[6] however, with our calibration this is very close to zero and hence we centre the distribution of β_1 accordingly.

Regarding the exchange rate, we centre the prior distributions around values implied by interest rate parity. The mode for the response of the exchange rate to movements in the forcing variable is taken from the DSGE model as $\gamma_C \frac{\kappa_{H_D}}{1+\beta\chi_{H_D}}$ by using the exchange rate equation, the Phillips Curve and the composition of the core price index. Combining equations 35 and 21 in Medina and Soto (2007) gives $\frac{\vartheta\chi\frac{P_S Y_S}{P_Y Y}}{1-\frac{P_G G}{P_Y Y}}$ as a location parameter for α_1 equivalent to 0.01 (the effect of the oil price on output). We assume that output responds to an interest rate increase (α_4) of one standard deviation with a decline around -1%. By rearranging the Structural Balance rule and combining it with the equation for core inflation, we approximate the mode for inflation on output (α_2) as 0.19 corresponding to

$$\left(\frac{T_p}{P_Y Y} + \vartheta\frac{\chi P_S Y_S}{P_Y Y} + \left(1 - \frac{1}{\Theta(1+i_t^*)}\right)\frac{B_G}{P_Y Y}\frac{1}{(1+\pi^*)(1+g_y)(1+n)} + \frac{P_G G}{P_Y Y}\right)\left(\left(1 - \frac{1}{\Theta(1+i_t^*)}\right)\frac{B_G}{P_Y Y}\frac{1}{(1+\pi^*)(1+g_y)(1+n)}\right)^{-1}.$$

As a mode for β_2 we choose the coefficient on the forcing variable in the domestic Phillips Curve multiplied by the home-bias in consumption $\gamma_C \frac{\kappa_{H_D}}{1+\beta\chi_{H_D}}$. It follows from interest rate parity that the reverse is the mode for γ_2. Regarding β_2 we combine the exchange rate equation with the Phillips Curve on imported goods and multiply the coefficient with the fraction of foreign goods in inflation to obtain $(1-\gamma_C)\frac{\kappa_F}{1+\beta\chi_F}$ and a mode of 0.027. Assuming complete ERPT as a prior, a plausible mode for γ_1 is 1. The reduced form monetary policy equation in (5) has $\delta_1 = (1-\rho)\phi_1$ and $\delta_2 = (1-\rho)\phi_2$ implying modes from the DSGE calibration of 0.75 (δ_1) and 0.25 (δ_2).

For the second system, under inflation targeting equation (6) the prior mode for the smoothing parameter ρ is 0.5, giving a mode for output sensitivity (δ_1) of 1.5 and inflation sensitivity (δ_2) of 0.5. The other parameters remain unchanged. Baumeister and Hamilton (2018) incorporate a simple way of imposing long-run prior beliefs on the central bank's reaction function into their 2015 algorithm. More specifically, let $\mathbf{b_5}$ be the vector of lagged structural coefficients in the monetary policy equation. We follow Baumeister and Hamilton (2018) and impose that the third element of $\mathbf{b_5}$ should be close to ρ. Although we do not aim to identify monetary shocks, this should improve our identification in light of the findings of Li *et al* (2019), who note that SVARs based on short-run restrictions often fail to identify monetary transmission in LIC.

In addition, we impose $\det(\mathbf{A}) > 0$.[7] Furthermore, let $\tilde{\mathbf{H}} = \operatorname{adj}(\mathbf{A})$ (recall = $\mathbf{A^{-1}} = \mathbf{H}$). Then

$$\xi = \frac{\tilde{h}_{25}}{\tilde{h}_{55}} = \frac{\alpha_4 + \alpha_3\gamma_4 + \alpha_2\beta_3\gamma_4 - \alpha_4\beta_3\gamma_3}{1 - \alpha_3\gamma_2 - \beta_3\gamma_3 - \alpha_2\beta_3\gamma_2 - \alpha_3\beta_2\gamma_3 - \alpha_2\beta_2}$$

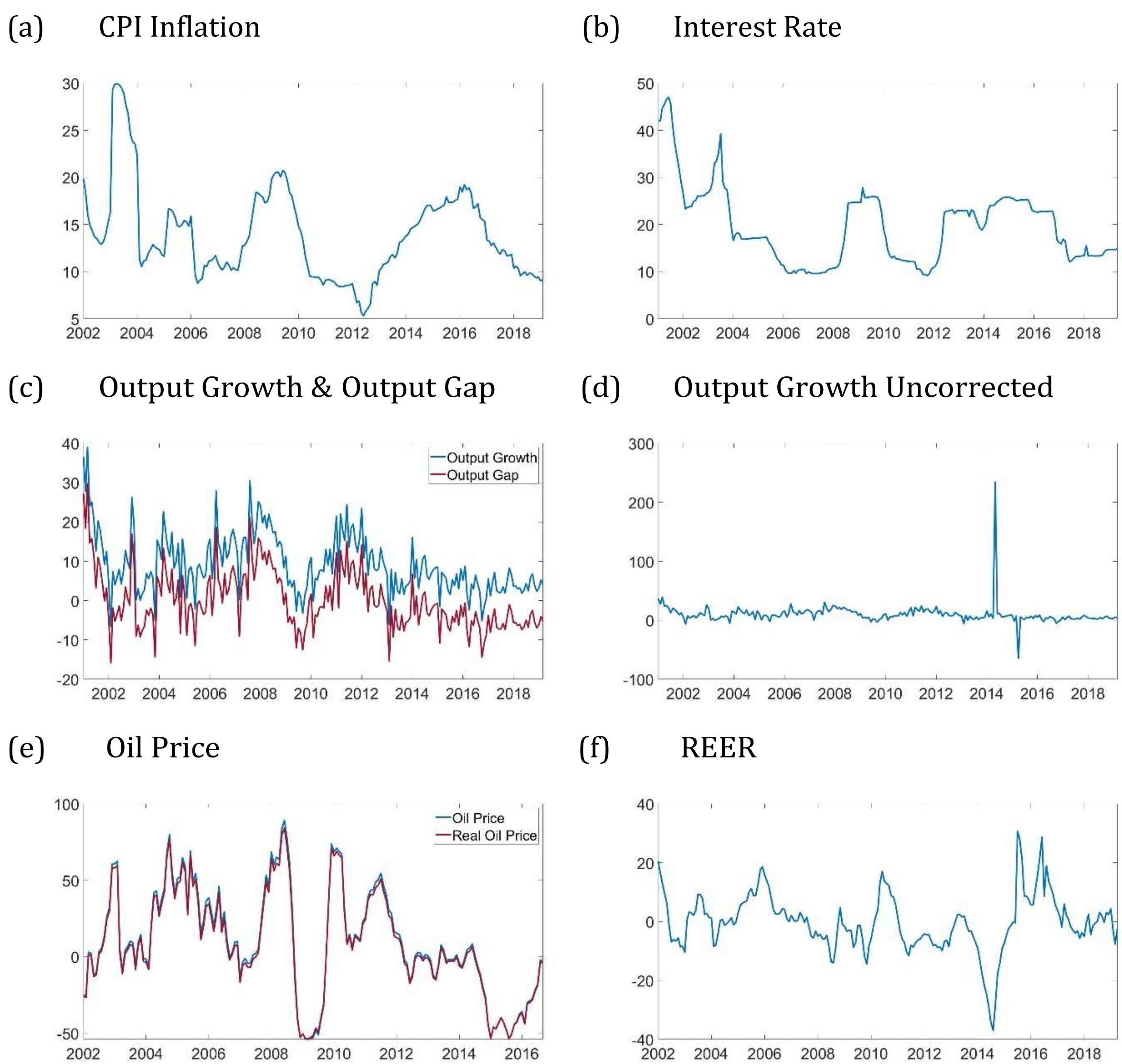
6 Medina and Soto (2007) provide the equations; note that we define the steady state of the SWF as χY_S.

7 Baumeister and Hamilton (2018) emphasis the implications should the sign of the determinant remain ambiguous.

is the response of output to a 1% interest rate increase. We impose the asymmetric t-distribution proposed in Baumeister and Hamilton (2018) on ξ as it reflects our belief that output is more likely to respond negatively to interest rate shocks. We centre this distribution around -0.5 and give it a negative skew. The scale parameter and degrees of freedom are chosen to be 0.3 and 3. Thereby, we incorporate additional information on the interaction of the structural coefficients, which leads to them not being independent of one another. Let the set of structural coefficients be $\boldsymbol{\theta}$. Then $\log(\mathrm{p}(\mathbf{A})) = \log(\mathrm{p}(\boldsymbol{\theta})) + \log\left(\mathrm{p}(\det(\mathbf{A}))\right) + \log(\mathrm{p}(\xi))$.

The additional prior information we impose ensures proper identification of the effects. In particular, the fact that we incorporate our prior knowledge of the structural coefficients means that we do not necessarily need to impose sign restrictions. Hence our agnosticism towards the latter — we only include sign restrictions where we are certain about the qualitative effects based on commonly agreed results in the literature.

Figure 3: Data Plots for Ghana (2002:1 to 2019:2)



4 DATA AND ESTIMATION

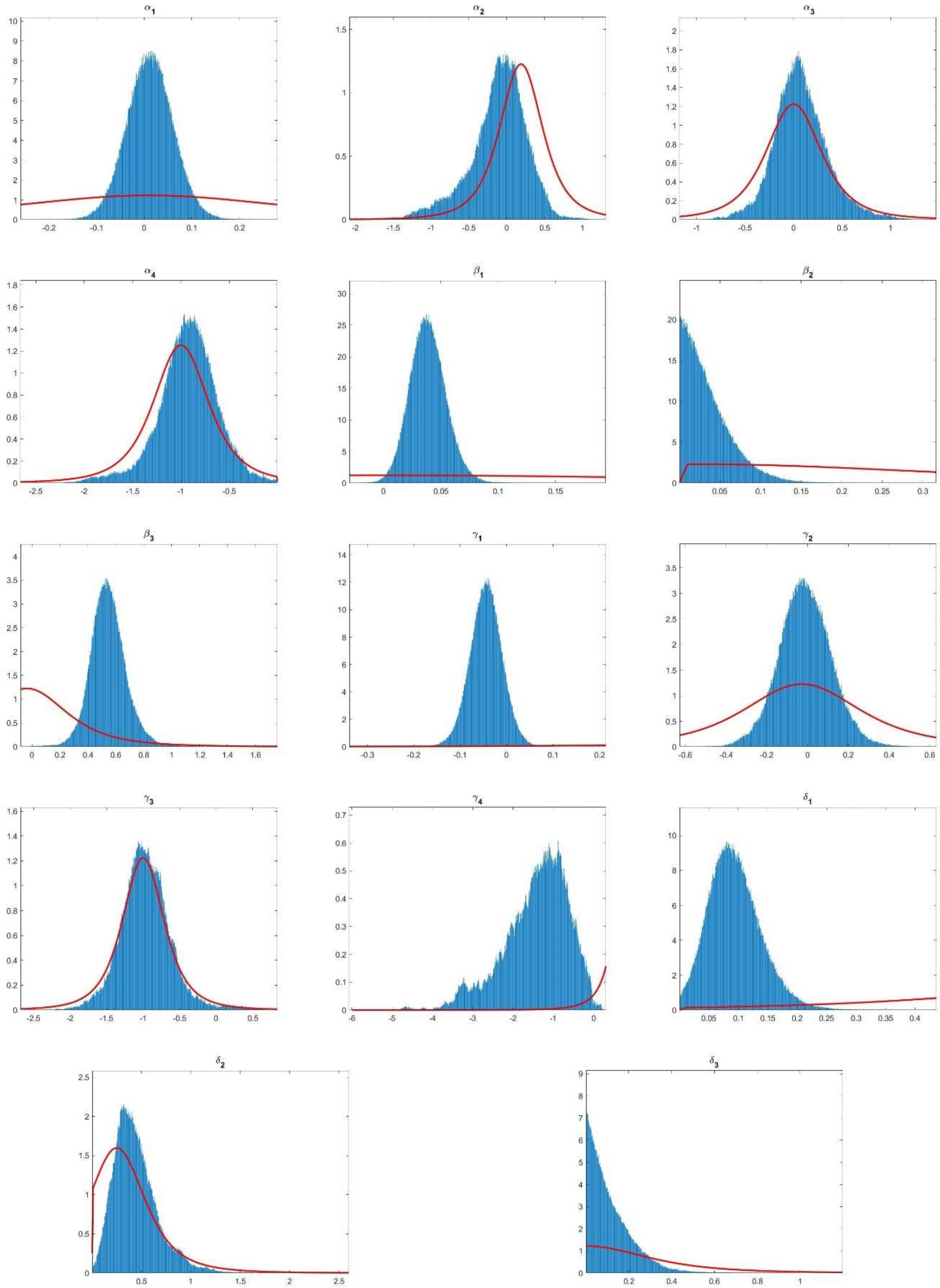
The dataset for Ghana starts in 2001m1 and ends in 2019m2. Figure 3 shows the different time series between 2002 and 2019, as the first 12 months are used for computing the growth rates of the variables. The first panel shows year-on-year CPI inflation as reported in the IMF IFS database. Ghana experiences very high levels of inflation with considerable volatility and persistence. Panel (b) shows the three-month Treasury-Bill rate obtained from the Bank of Ghana. Unsurprisingly, interest rates are also high, and currently above 10%. To measure the output gap, we use the Composite Index of Economic Activity (CIEA) computed by the Bank of Ghana (BoG) who provided the growth rates of the index on a monthly basis. Panel (d) shows that there are two abnormally high observations in the index due to data revisions that lead to changes in the levels. To avoid distorting our results, we replace the two observations by linear interpolation. This gives us the output growth measure reported in Panel (c) (blue line). We define the output gap as output growth minus the average growth rate in the respective sample. Panel (c) plots the oil price in blue and the real oil price in red. The latter is defined as the nominal oil price deflated by US CPI inflation, following, for example, Kilian (2009), Baumeister and Hamilton (2019), or Gupta and Modise (2013). Both variables are retrieved from the IMF IFS database. Due to the high volatility of oil prices, the difference between the two measures is small. The REER is taken from Bruegel (Darvas, 2012). We observe high fluctuations in the exchange rate that increase in the period considered in the second system.

Ghana Pre-Oil Exporting Period

Figure 4 shows the prior and the posterior distributions of the structural parameters; in general the priors are informative (very few are flat). The coefficient of oil price effects on output (α_1) is centred very tightly around zero, close to the mode of 0.01. Contrary to our priors, the coefficient on the exchange rate (γ_1) is likely to be negative; the coefficient for inflation (β_1) is non-zero, distributed around 0.3 with a slightly positive skew; and for the effect of interest rate changes on the exchange rate (γ_4), the distribution is negative with a high variance. Although there are revisions of our prior expectation (implying a gain in information), most coefficients are distributed in accordance with our prior expectations.

To assess the propagation of oil price shocks, we draw a sample $\{\mathbf{A}, \mathbf{B}, \mathbf{D}\}_{+=S+1}^{2S}$ of size $S = 2 * 10^6$ using the algorithm of Baumeister and Hamilton (2015). Figure 5 presents the impulse response functions. The solid blue line corresponds to the posterior median, the dashed red line to the 68% posterior credibility interval, and the blue dashed line to the 95% posterior credibility band. It can be seen in Panel (a) that, with 95% probability, an oil price shock leads to an exchange rate depreciation, followed by an appreciation after 4-6 months (in the SVAR, an increase in REER corresponds to an appreciation). With 68% likelihood we will observe a decline between 2.2% and 6.8% in the month after the shock, and an appreciation between 2.5% and 9% after three quarters. We conclude that, with very high posterior probability, oil price shocks were followed by a period of increased exchange rate volatility. Panel (b) shows that, with at least a 68% chance, we observe about eight months of mild inflation ranging between 0% and 3.5%, followed by a fall in inflation after a year which is smaller in magnitude and vanishes after 3 years. Disinflation is consistent with the currency appreciation which decreases inflation stemming from imports, and with DSGE evidence of reduced marginal cost pressures.

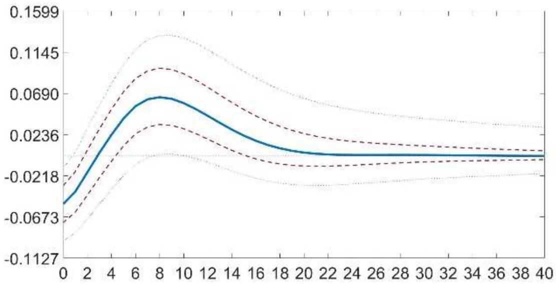
Figure 4: Prior and Posterior Distribution of Coefficients (Ghana 2002-2010)



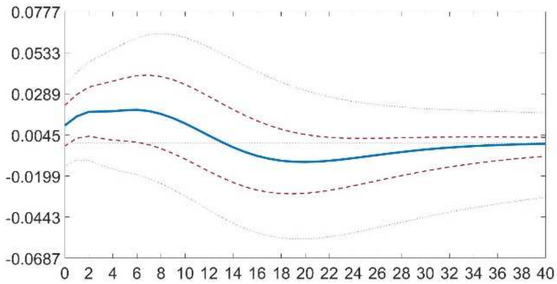
Note: Posterior distribution represented by blue bars, prior distribution by red lines.

Figure 5: Impulse Response to Oil Price Shock (Ghana, first period, importer)

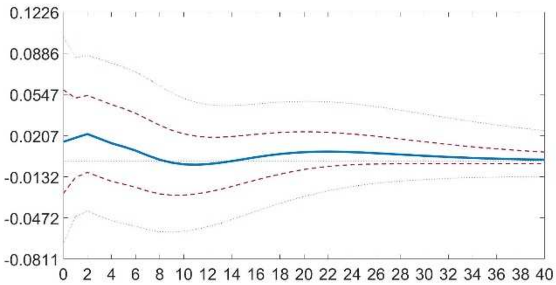
(a) REER



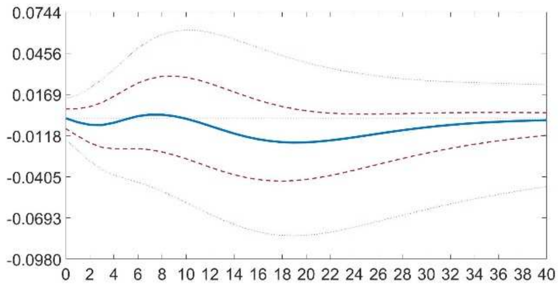
(b) CPI



(c) Output Gap



(d) Interest Rate



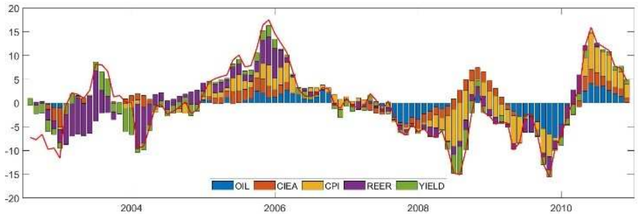
Note: Solid blue line represents posterior median, dashed red lines 68% credibility band, dashed blue lines 95% credibility bands. In the SVAR, a decrease in REER corresponds to a depreciation.

In Panels (c) and (d) of Figure 5, the responses of output and interest rates are more ambiguous; the output gap is likely to close while interest rates are likely to go down after 2.5 years. However, for the latter the 95% credibility bands are relatively wide. From these impulse responses, it can be deduced that the REER exhibited the largest fluctuations with the highest posterior credibility. During this period, Ghana did not export oil but nevertheless, oil price shocks could have affected the export industry's competitiveness through an exchange rate channel.

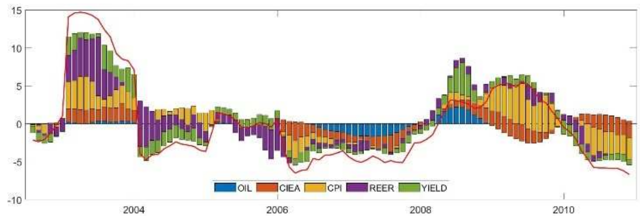
To investigate this in further detail, we consider the historical decomposition of the shocks which is shown in Figure 6. In the early years (to 2007) exchange rate dynamics were the major source of REER movements (panel a); oil price shocks (and inflation) were a considerable driver of downward exchange rate movements after the financial crisis (late 2007 to end 2009) and contributed to the positive exchange rate variation in 2006 and 2010. The exchange rate was a major factor in inflation up to 2006 (panel b) and oil price shocks were a factor during the crisis years (2007-08). Output dynamics were by far the major driver of the output gap. The output gap and inflation were important for interest rate fluctuations, consistent with most monetary policy rules (panel d), and the exchange rate contributed to higher rates until about 2005.

Figure 6: Historical Decomposition of Oil Price Shock (Ghana, importer)

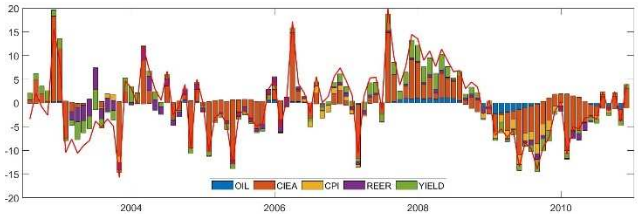
(a) REER



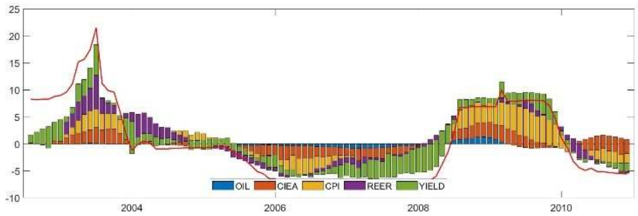
(b) CPI



(c) Output Gap



(d) Interest Rate



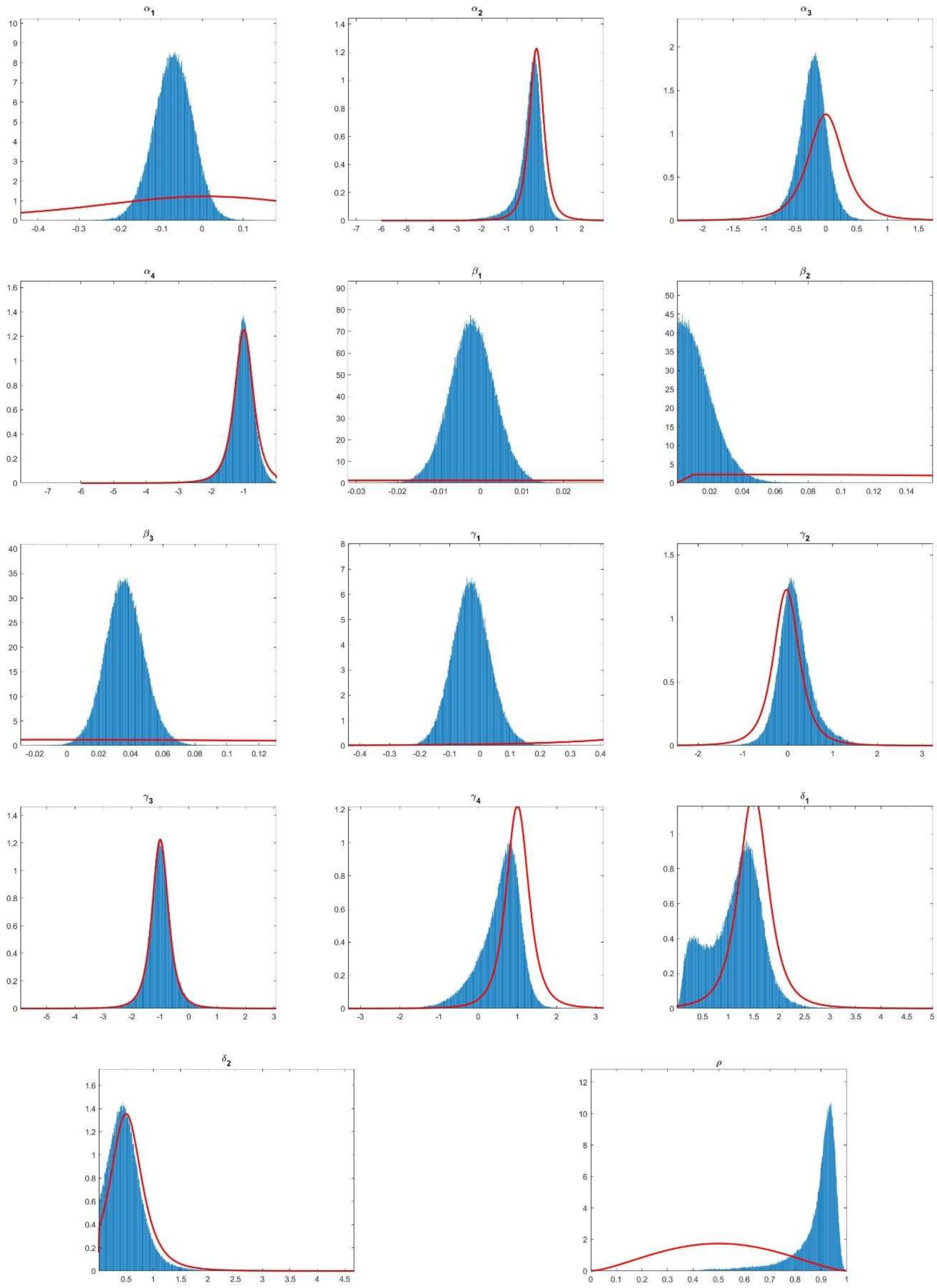
Note: Bars represent historical contribution of each variable to structural variation.

Ghana Oil Exporting Period

Figure 7 shows the prior and posterior distributions of the structural coefficients for the second system, estimated for 2011-19. In comparison to the first period, note that δ_1 and δ_2 have different definitions and priors; some posterior distributions differ, although most posteriors are consistent with our priors. The coefficient for the impact of oil prices on output (α_1) has become more negative, and further from the prior, and that on δ_1, the reaction of the interest rate to the output gap, has shifted right and is much closer to the mode of 1. The other two oil price coefficients are similar, although the effect on inflation (β_1) is now densely distributed around zero while the variance of the distribution for the impact on the REER (γ_1) is greater. The coefficients in the REER equation are broadly similar, but the distribution for the effect of output (γ_2) is much wider (and the mode appears positive rather than -0.027) while the effect of the interest rate (γ_4) has shifted to the right and closer to 1 (the prior in Table 1). In the inflation equation, the distribution for output (β_2) has shifted to the left (further from 0.027 mode) as has the distribution for the REER (β_3) moving closer to the prior mode (0.037). Nevertheless, the consistency with our priors suggests that a Taylor rule is a good approximation for MP reaction function.

Figure 8 shows the impulse responses of the second system, when Ghana was exporting oil. The trajectory of the REER is less precisely estimated but is negative with 68% posterior credibility with a high probability for over two years of deflationary pressures after the shock. Compared to the DSGE results, this is puzzling as one expects appreciation; a possibility is that the empirical estimates combine the effects of exporting crude whilst importing refined oil. Inflation declines, by a median estimate of about 2% after two years; the empirical result of mild deflation corresponds to our theoretical findings, although appears greater in magnitude.

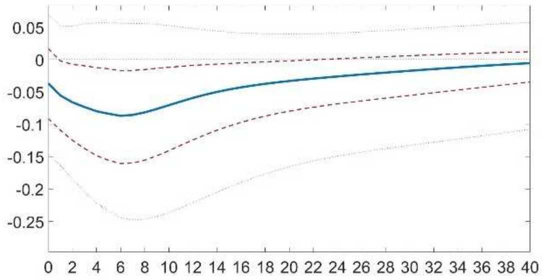
Figure 7: Prior and Posterior Distribution of Coefficients (Ghana, 2011-2019)



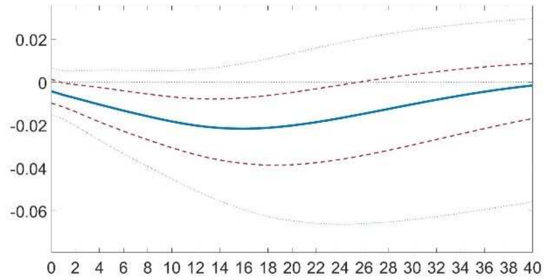
Note: Posterior distribution represented by blue bars, prior distribution by red lines.

Figure 8: Impulse Response to Oil Price Shock (Ghana, exporter)

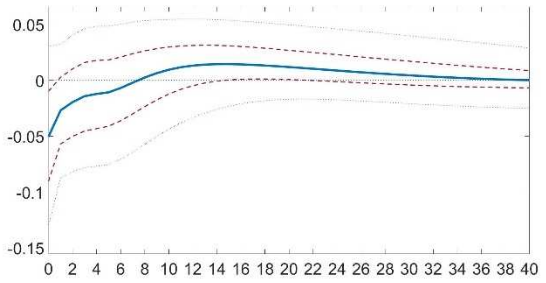
(a) REER



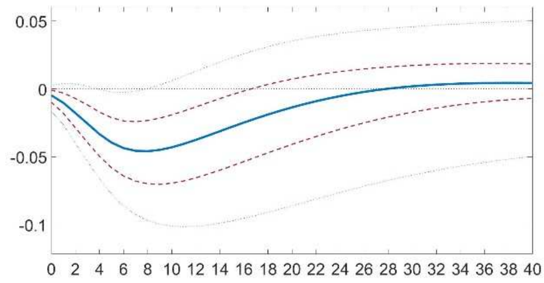
(b) CPI



(c) Output Gap



(d) Interest Rate



Note: Solid blue line represents posterior median, dashed red lines 68% credibility band, dashed blue lines 95% credibility bands.

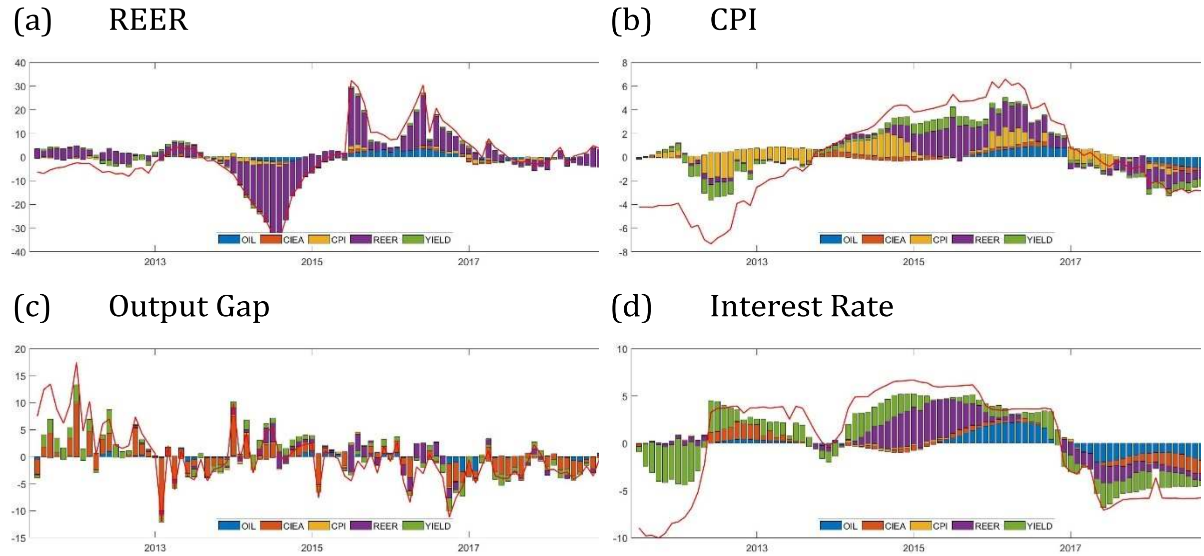
Figure 8 also shows a negative output response in the early periods after the shock that slowly turns positive. After one year, we see an increase in the output gap with 68% credibility. This is consistent with our DSGE model, but the effects in the latter are more adverse. Possible explanations for this quantitative difference are that (i) oil makes up a lower portion of consumption, (ii) oil is a less important production factor, or (iii) the oil sector is less significant for the actual economy. Furthermore, it is possible that the oil sector is underweighted in the CIEA. Finally, we can be very certain that interest rates fall for 8 quarters after an oil price shock – most likely to counteract the negative output effects. Again, the hump-shaped response of monetary policy is in accordance with our DSGE evidence. The decline ranges from close to zero to 10% with 95% probability. Except for the exchange rate results, the qualitative consistence with our theoretical model is reassuring. The empirical findings indicate that the adverse effects of oil price shocks can be contained and even turn positive in the long-run.[8]

The historical decomposition (Figure 9) shows that oil price shocks explain a considerable fraction of interest rate variations (and lesser share on inflation variation) after 2015. This contrasts with the earlier period despite the strict monetary policy rule. The effects on output are still small, as observed in the preceding period. Oil prices are the only component that

[8] In a robustness analysis real oil prices (calculated as the nominal price minus US CPI) were used and the IRFs are very similar. Figure 3 panel (c) shows the series are almost identical.

contribute to variations in the REER in addition to the exchange rate dynamics (which are the dominant factor). In 2014, and the years afterwards, the portion attributed to oil prices was consistently higher than 1%, and close to 3% in 2016. At the start of this period, there was first a sharp decline in global oil prices followed by a slower incline from 2016. This coincides with the effects oil price shocks had on CPI inflation, although they were much lower in magnitude. The high volatility in this period appears to be an important factor for explaining exchange rate, inflation, and interest rate movements.

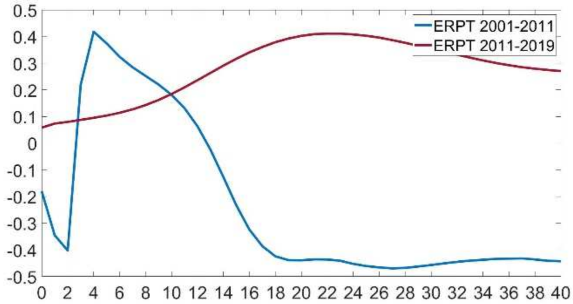
Figure 9: Historical Decomposition of Oil Price Shock (Ghana, exporter)



Note: Bars represent historical contribution of each variable to structural variation.

To provide further comparison with the non-exporter period, we compute the measure of exchange rate pass-through (ERPT) introduced in Forbes *et al* (2018). That is, we take the ratio of the impulse response function of inflation over that of the exchange rate. Figure 10 shows in blue the result for the first period and in red the results for the second period. During the former we observe a more volatile ERPT that switches from negative (i.e. an appreciation corresponds to disinflation/deflation) to positive (i.e. an appreciation corresponds to inflation). After 2011, the ERPT is a lot less volatile, positive, and lower in absolute terms. Our sample contains years of highly fluctuating oil prices after the financial crisis and from 2014 onward. Yet, we only see an increase in the average annual contribution of oil price shocks to interest rate fluctuations compared to the first system. With regards to the REER and the output gap, both have not exceeded their pre-exporter levels, and when considering inflation, their contribution declined. Taking all these findings together, we conclude that the adoption of inflation targeting, in conjunction with an improved monitoring of macroeconomic developments, has mitigated the effects of oil price shocks on domestic variables. That is not to say oil price shocks became negligible, but our findings rather imply their effects will not be severe if the BoG has a clear targeting strategy (given the design and effectiveness of other institutions).

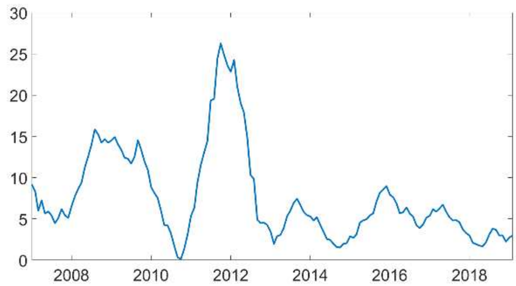
Figure 10: Exchange Rate Pass-Through (Ghana)



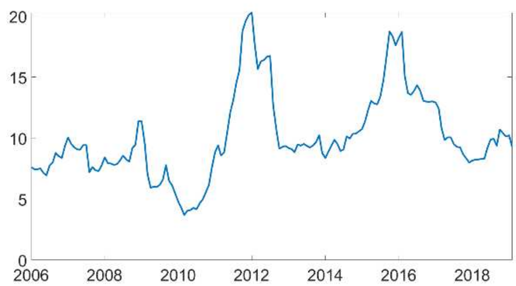
Whilst we do not have data to reliably assess the effects of oil production shocks, the consistency of our empirical results with the DSGE analysis indicates that the theoretical model is indeed an insightful counterfactual. The DSGE impulse responses suggest that the oil windfall is a profitable future pathway for the country that leads to output gains and entails positive effects on the current account.

Figure 11: Data Plots for Uganda (2007:1 to 2019:2)

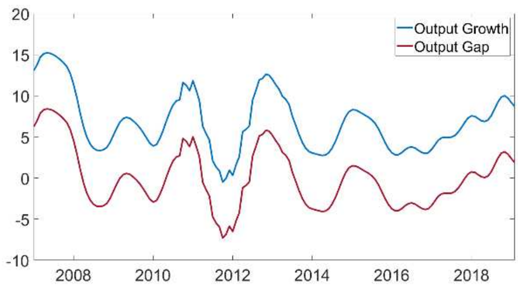
(a) CPI



(b) Interest Rate



(c) Output Gap and Growth



(d) REER

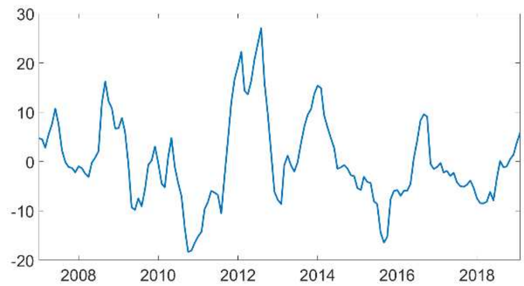
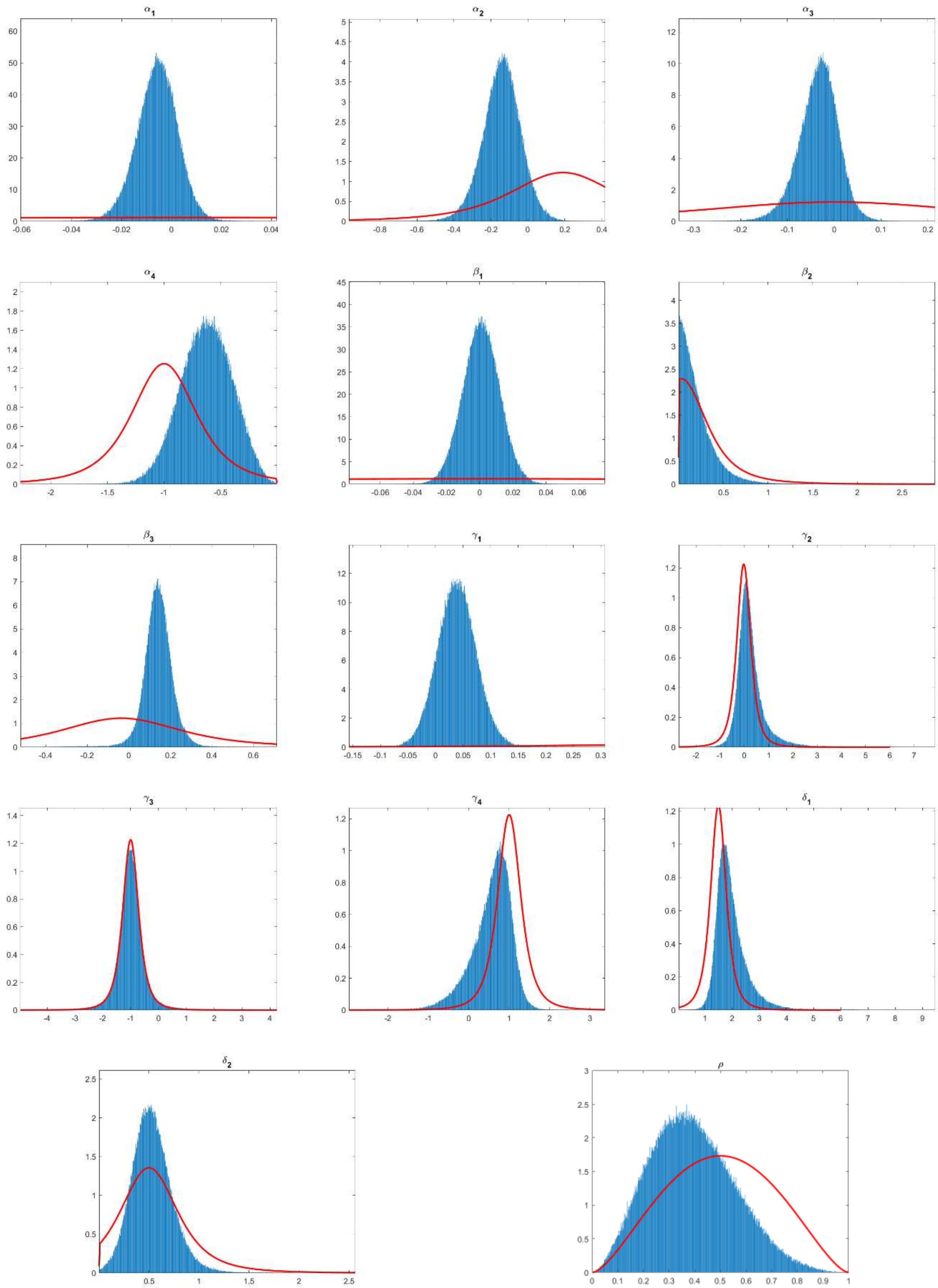


Figure 12: Prior and Posterior Distribution for Uganda (2007-2019)



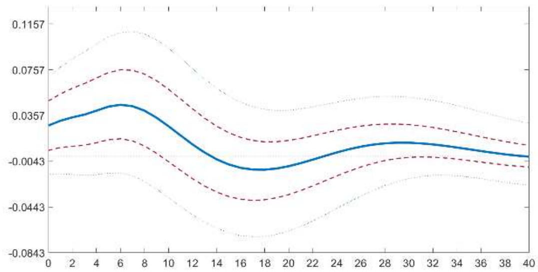
Note: Posterior distribution represented by blue bars, prior distribution by red lines.

Estimates for Uganda

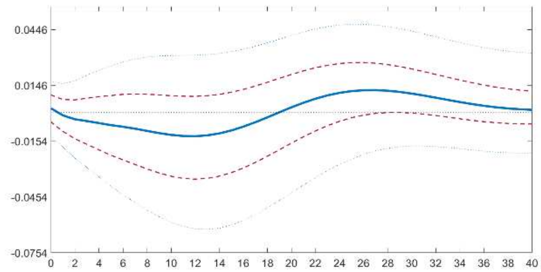
As Uganda is not an oil exporter, we conduct similar analysis for Uganda to compare with the first period for Ghana. This indicates if pre-oil exporter effects are similar and helps to assess if the DSGE and oil exporter results for Ghana are likely to be a useful guide. We use similar data from 2006m1 until 2019m2, noting that the sample period differs slightly from our analysis of Ghana's economy, due to data availability. Again, as we use growth rates, the sample used in the estimation starts in 2007. Uganda adopted inflation targeting in 2011 so the SVAR estimates are based on the second system with equation (6).

Figure 13: Uganda: Impulse Response to Oil Price Shock

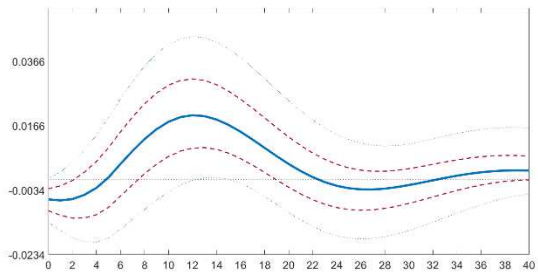
(a) REER



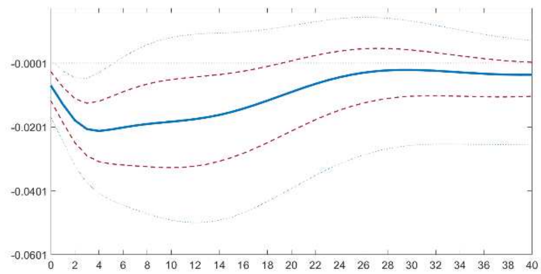
(b) CPI



(c) Output Gap



(d) Interest Rate

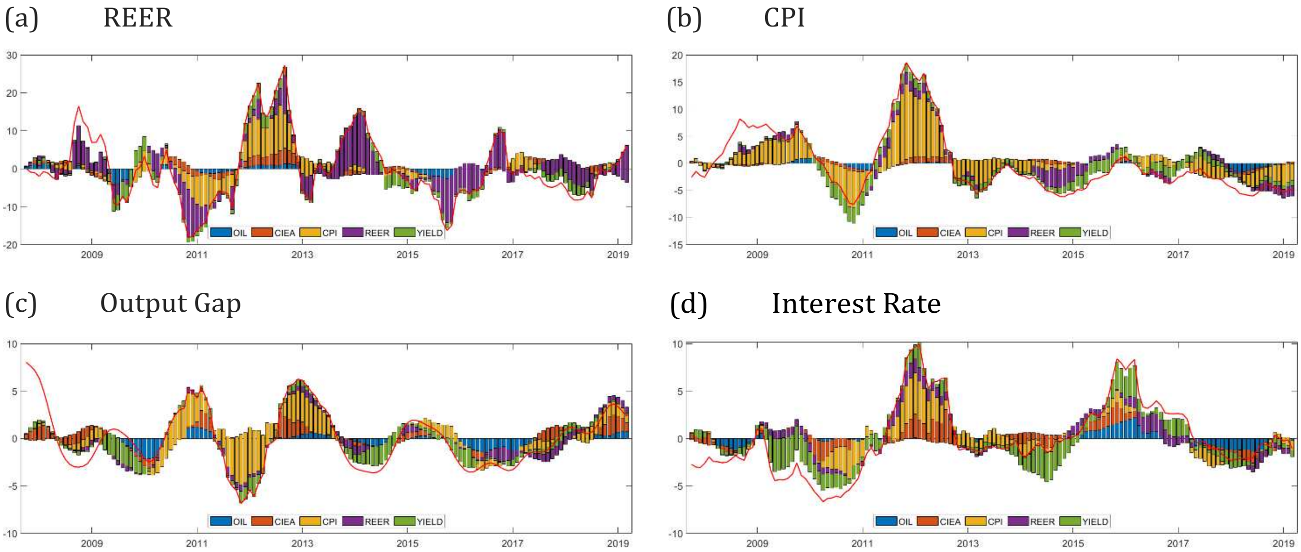


Note: Solid blue line represents posterior median, dashed red lines 68% credibility band, dashed blue lines 95% credibility bands.

Figure 12 shows the prior and posterior distributions which exhibit some notable differences compared to Ghana. For example, the mode of the smoothing parameter is located below 0.5 and the distribution exhibits a positive skew. Furthermore, the coefficient on the forcing variable in the Phillips Curve is a lot closer to our prior expectation. The coefficients of oil price effects on output (α_1) and inflation on output (α_2) are centred to the left of zero, contrary to our prior expectation (of positive modes), while the other coefficients for output are consistent with prior expectations. The coefficient on the exchange rate (γ_1) is likely to be positive but he effect of output on the exchange rate (γ_2) is centred to the right of zero, contrary to the prior mode of -0.027; the coefficient on interest rate changes (γ_4) has a largely positive variance (not inconsistent with the prior mode of 1). However, most coefficients are distributed in accordance with our prior expectations, particularly coefficients for the effects on inflation.

Contrary to the Ghanaian pre-exporting period, we observe an immediate exchange rate appreciation in Uganda with high probability up until 10 months after the initial shock (Figure 13). The appreciation reaches about 4% after two years and persists for three years. The trajectory in the following periods is less precise, but fluctuations are similar to Ghana. The response of inflation is imprecisely estimated but likely to be slightly negative initially but eventually inflation increases. We observe a clear response of output (panel c); following an initial small decline, the output gap rises with 95% probability after a year, increasing by a median 1.5% after one year (with a non-negligible probability of another decline). Interest rates fall after the shock but the effect is weak. Uganda's economy shows a higher propensity for fluctuations after an oil price shock than observed for Ghana.

Figure 14: Uganda: Historical Decomposition of Oil Price Shock

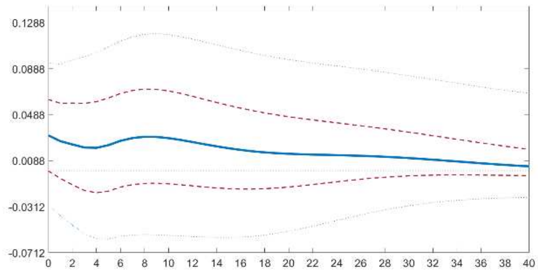


Note: Bars represent historical contribution of each variable to structural variation.

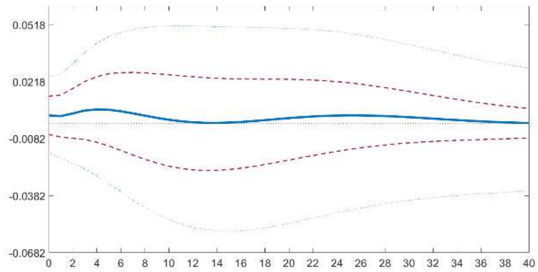
The historical decomposition (Figure 14) shows that oil price shocks had a considerable negative contribution to output fluctuations after the financial crisis and around 2017, however, they played no role in the periods of the highest output fluctuations between 2010 and 2014. They also contributed largely to interest rate movements after the crisis and towards the end of the sample. Conversely, they only played a minor role in exchange rate and inflation movements. Indeed, the latter explain the largest fractions of shocks to all variables before 2013. This highlights again the role of inflation targeting as a possible explanatory factor behind the lower contribution of inflation shocks to the overall variation in the other variables.

Figure 15: Impulse Response to Oil Price Shock (Uganda, 2011-19)

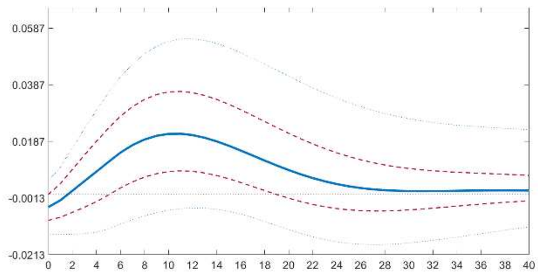
(e) REER



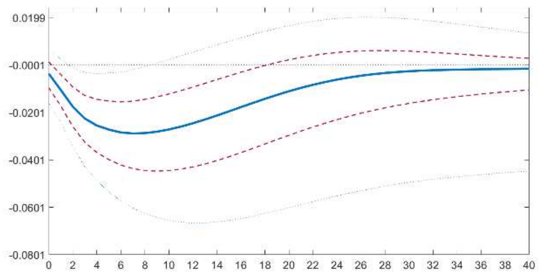
(f) CPI



(g) Output Gap



(h) Interest Rate



Note: Solid blue line represents posterior median, dashed red lines 68% credibility band, dashed blue lines 95% credibility bands.

Figure 16: Exchange Rate Pass-Through (Uganda)

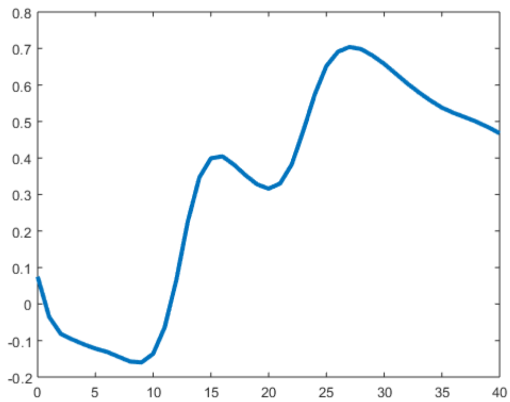


Figure 15 estimates the SVAR over 2011-2019, corresponding to the period when Ghana was an exporter (to capture the different world prices at that time) and to the adoption of inflation targeting in Uganda. The impulse response functions are similar to Figure 13, although appreciation and inflation effects are smaller whereas the increase in output is slightly greater. Finally, Figure 16 shows that after an initial negative effect, ERPT increases significantly over time – from about 10% after one year to almost 70% after two years. This is in marked contrast to Ghana where ERPT rose to 40% after a few months but then declined rapidly. The increasing ERPT in Uganda is consistent with the long-run increase in inflation.

5 CONCLUSIONS

This paper provides analysis of the macroeconomic effects of an 'SSA-type' economy switching from being an importer of oil to exporting oil through analysis of the case of Ghana. Following the discovery of oil off the coast, Ghana moved into production and became an exporter of crude in 2011 (but continued to import refined oil) and therefore provides a test case for switching effects. Uganda has discovered oil in the Western region and may become an exporter in the future; the high cost of building a pipeline has been the major constraint and projections of a global shift away from fossil fuels (given the need to address climate change) production may not be commercially viable. We include analysis for Uganda so the paper provides projections of the macroeconomic effects of becoming an oil exporter and includes analysis of the effects of shocks to the oil price as an importer.

The paper proceeds in three steps. First, we construct a DSGE model of a primary commodity exporting developing country calibrated to Ghana and Uganda and simulate the impulse response to shocks to the oil price and oil production. Second, using a structural VAR (SVAR) model with monthly data for 2001:1 to 2019:2 (with the split at 2010:12) we estimate empirical impulse responses to oil price shocks. Comparing the SVAR estimates for the pre and post-exporting periods allows an assessment of the macroeconomic effects of switching, and the DSGE predictions can be compared to the estimates for the period as an exporter.

Although an oil price shock is expected to lead to an appreciation for an exporter, as in the DSGE model, the SVAR results for Ghana as an exporter reveal a depreciation of the REER of 5-10% over two years accompanied by deflationary pressures. The REER depreciation may have been because the export price shock was offset by the shock to imports of refined oil. It may also have been due to (unmodeled) policy responses: Dagher *et al* (2012) show that expenditure smoothing or reserve accumulation can reduce the appreciation effects of an oil windfall. The decline in inflation (by about 2% after two years) is consistent with the almost 5% reduction in interest rates for two years after the shock. Bleaney *et al* (2020) show that the Bank of Ghana responded to upward inflationary shocks by increasing real interest rates, even if this was not successful in reducing the above target rates of inflation.[9] The historical decomposition is consistent with the muted effect of inflation targeting as oil price shocks had a greater effect on interest rate variations than on inflation variation, at least after 2015 (coinciding with a year of declining global oil prices. The SVAR estimates suggest interest rates were reduced in the face of deflationary shocks and this may have been more effective; although the shock has an initial negative output effect, this turns (mildly) positive after about two years, reflecting the response of monetary policy. The empirical findings indicate that the adverse effects of oil price shocks can be contained and even turn positive in the medium term.

Finally, we use an SVAR for Uganda with monthly data over 2006:1 to 2019:3 to estimate the response to oil price shocks as an importer. These are compared to the first period estimates for Ghana. The analysis is informative on the macroeconomic effects of oil shocks in Ghana and Uganda. When Ghana was an importer (2001-2010 in the SVAR, so mostly without inflation targeting)) an oil price shock leads to an exchange rate depreciation, followed by an appreciation after 4-6 months; oil price shocks were followed by a period of increased exchange rate volatility. Disinflation is consistent with the currency appreciation which decreases inflation stemming from imports.

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[9] Following the adoption of inflation targeting in 2007, inflation remained some 50% above the relatively high 8-10% per annum target over 2007–2017 (on average, actual inflation was 13%). This should not be interpreted as a failure of inflation targeting as monetary policy appeared to be appropriate. A possible reason for persistent high inflation was the failure of the Bank of Ghana to reduce inflation expectations, which remained above the official target (Bleaney *et al* 2020, p140), perhaps in conjunction with weak fiscal policy.

The impulse response functions for Uganda in the SVAR estimates over 2007-19 and 2011-19 (when Uganda had adopted inflation targeting) are similar for both periods. The appreciation and inflation effects are smaller during 2011-19: an appreciation reaching around 3% in the first year, and a very small (median) increase in inflation (compared to a slight fall for the whole period). There is a slightly greater increase in output, but in both cases it is about 1.5% in the first year, associated with a slightly larger fall in inflation (but again in both case around a median 3% within one year). The results for 2007-19 are similar to those observed for Ghana when an importer (prior to 2011) except that in Uganda inflation falls slightly; Uganda's appreciation is less, the rise in output after a year is stronger, and there is a more consistent (albeit small) decline in interest rates. These results differ from the usual expectation for net oil importing countries is that large oil price shock will lead to a fall in output and increase in inflation (Peersman and Van Robays, 2012). In Uganda, and to a lesser extent Ghana, the initial decline in output is short-lived and output rises after a year; although there is mild inflation in Ghana, Uganda experiences mild deflation or a very small increase (note that inflation has typically been markedly higher in Ghana).

Our findings do differ from previous analysis for Uganda. Nyanzi and Bwire (2018) estimate a three variable SVAR with real world oil price, Ugandan real GDP and CPI using quarterly data over 1999q3 to 2015q2. They find that an oil shock is associated with a fall in real output, mostly within the first year (consistent with our result but greater in magnitude). In contrast to our results, the decline in output persists. Whereas we find a mild deflation, or slight increase in CPI for 2011-19, and only observe a rise in inflation in the long-run, they find an immediate increase in CPI that peaks after a year. However, consistent with our historical decomposition, Nyanzi and Bwire (2018) find that oil price shocks have a marked influence on output fluctuations after about a year but are unimportant for variations in CPI. There are many possible reasons for different results as the sample periods, SVAR specification and identification strategy are very different. It may be the case that Nyanzi and Bwire (2018) are less able to identify monetary transmission using quarterly data, as argued in Li *et al* (2019), whereas our use of monthly data with Bayesian updating of priors derived from the DSGE captures the impact of inflation targeting since 2011.

The DSGE results suggest that if Uganda becomes an exporter, adverse initial effects of an oil price shock can be contained without adverse medium-term effects, and adoption of inflation targeting plays a role (at least in mitigating effects of currency appreciation). Although an oil price shock generates appreciation and initially output falls, there are reductions in interest rates and inflation and ultimately output increases. The larger the oil sector the greater the appreciation and inflationary effects, but output rises more quickly and there are larger increases in wages and taxes. The SVAR estimates for Ghana when exporting differ in the sense of suggesting a shock leads to depreciation initially (but ultimately appreciation), but interest rates and inflation decline so that output recovers and increases after an initial decline. Consistent with the DSGE, Ghana appeared to be able to manage the effects of shocks.

References

Baumeister, C. and J. Hamilton (2015), Sign restrictions, structural vector autoregressions, and useful prior information, *Econometrica*, **83**(5): 1963--1999.

Baumeister, C. and J. Hamilton (2018), Inference in structural vector autoregressions when the identifying assumptions are not fully believed. Re-evaluating the role of monetary policy in economic fluctuations, *Journal of Monetary Economics*, **100**: 48–65.

Baumeister, C. and J. Hamilton (2019), Structural Interpretation of Vector Autoregressions with Incomplete Identification. Revisiting the Role of Oil Supply and Demand Shocks, *American Economic Review*, **109**(5): 1873–910.

Blanchard, O. and J. Galí (2010), The Macroeconomic Effects of Oil Price Shocks: Why are the 2000s so Different from the 1970s?, chap 7 in J. Gali and M. Gertler (eds) *International Dimensions of Monetary Policy*, University of Chicago Press for NBER (pp 373–421) [www.nber.org/books/gert07-1]

Bleaney, M., A. Morozumi and Z. Mumuni (2020), Inflation Targeting and Monetary Policy in Ghana, *Journal of African Economies*, **29**(2): 121-145 [doi: 10.1093/jae/ejz021]

Christiano, L., M. Eichenbaum and C. Evans (2005), Nominal rigidities and the dynamic effects of a shock to monetary policy, *Journal of Political Economy*, **113**(1): 1-45.

Dagher, J., J. Gottschalk and R. Portillo (2012), The Short-run Impact of Oil Windfalls in Low-income Countries. A DSGE Approach, *Journal of African Economies*, **21**(3): 343–72.

Darvas, Z. (2012) 'Real effective exchange rates for 178 countries: a new database', *Working Paper 2012/1*. Department of Mathematical Economics and Economic Analysis, Corvinus University of Budapest.

Forbes, K. (2018), Has Globalisation Changed the Inflation Process, *BIS Working Papers 791*.

Forbes, K., I. Hjortsoe and T. Nenova (2018), The shocks matter. Improving our estimates of exchange rate pass-through, *Journal of International Economics*, **114**: 255–75.

Gupta, R. and M. Modise (2013), Does the source of oil price shocks matter for South African stock returns? A structural VAR approach, *Energy Economics*, **40**: 825–31.

Kilian, L. (2009), Not All Oil Price Shocks Are Alike. Disentangling Demand and Supply Shocks in the Crude Oil Market, *American Economic Review*, **99**(3): 1053–69.

Li, B., C. Adam, A. Berg, P. Montiel and S. O'Connell (2019), Structural VARs and the Monetary Transmission Mechanism in Low-Income African Countries, *Journal of African Economies*, **28**(4): 455-478. [doi: 10.1093/jae/ejz005]

Medina, J. and C. Soto (2007), The Chilean Business Cycles through the Lens of a Stochastic General Equilibrium Model, Santiago: *Central Bank of Chile Working Paper 457*.

Nyanzi, S. and T. Bwire (2018), The Macroeconomic Responses to Petro Shocks for Uganda, mimeo, Bank of Uganda Research Department.

Peersman, G. and I. Van Robays (2012), Cross-country differences in the effects of oil shocks, *Energy Economics* **34** (5): 1532–1547

APPENDIX TABLE A1: DSGE PARAMETERS

σ_L	inverse elasticity of labour supply	2.5	standard value
h	habit formation	0.65	estimate of Medina and Soto. (2007), similar to literature, e.g. Adolfson et al, 2008); Havranek et al, 2017)
φ_L	Calvo probability in nominal wages	0.82	Wages reset every 5.5 quarters on average, assumption
ξ_L	indexation of nominal wages	0.44	Medina and Soto (2007)
η_C	intra-temporal elasticity of foreign and domestic consumption	0.89	Based on Tokarick (2010) estimates of import demand elasticities in Uganda
θ_I	intra-temporal elasticity of investment	12	standard value (e.g. Dagher et al, 2012; Berg et al. 2010a, 2010b)
S_I	investment inertia	1.48	assumption
φ_{H_D}	Calvo probability in domestic price (home goods)	0.75	prices sticky for one year, standard Berg et al. (2010a); Zeufack et al. (2018)
ξ_{H_D}	indexation of domestic price (home goods)	0.40	Medina and Soto (2007)
φ_{H_F}	Calvo prob. in foreign price (home goods)	0.5	prices sticky for 6 months, plausible value for global price stickiness; Gorodnichenko and Weber (2016) for US
ξ_{H_F}	indexation of foreign price (home goods)	0.31	Medina and Soto (2007)
φ^*	Calvo probability in price of imported goods	0.66	prices sticky for 3 quarters. Slightly higher rigidity compared to world
ξ^*	indexation of price of imported goods	0.28	slightly lower than world market
ω_C	elasticity substitution oil (consumption)	0.3	Medina and Soto (2007), low value
ω_H	elasticity substitution oil (production)	0.3	Medina and Soto (2007), low value
$\phi_{i,1}$	Taylor rule smoothing parameter	0.75	standard
$\phi_{\pi,1}$	Taylor rule inflation sensitivity	1.5	standard
$\phi_{y,1}$	Taylor rule output sensitivity	0.5	standard
η^*	intra-temporal elasticity foreign demand	0.7	assumption
q	elasticity of external borrowing premium	0.01	irrelevant
ϱ_{Y_S}	commodity production shock persistence	0.77	assumption
ϱ_{prs}	oil price shock persistence	0.97	assumption
σ_C	intertemporal elasticity of substitution	1	log-utility
s_L	elasticity of substitution (labour)	12	standard
α_C	share of oil in the consumption basket	0.015	assumption
s_H	elasticity of substitution (home goods)	12	standard
s_F	elasticity of substitution (foreign goods)	12	standard
η_H	share of labour in production	0.7	standard Cobb-Douglas

δ_I	depreciation rate	$1.06^{0.25}$- 1	Bu (2006)
γ_H	share of oil in production of home goods	0.005	assumption
θ_H	elasticity of substitution (labour-capital)	1	standard Cobb-Douglas
NX_Y	steady state net export / GDP ratio	-0.1	matches data
GH_Y	government expenditure/GDP ratio	0.1	matches data
Ys_Y	share of oil production in GDP	0.05	matches data
CCq_Y	steady state current account / GDP ratio	-0.05	matches data
γ_C	share home goods in core consumption	0.7 (0.6)	National Accounts
γ_I	share of home goods in investment	0.25	assumption
sd_{proF}	oil price standard deviation	12	assumption
λ	share of non-Ricardian households	0.7 (0.6)	assumption
g_y	domestic labour productivity growth	$1.05^{0.25}$-1 ($1.07^{0.25}$-1)	matches data
π_C	domestic steady state inflation target	$1.05^{0.25}$-1 ($1.10^{0.25}$-1)	Central Bank target
n	domestic labour force growth	$1.033^{0.25}$-1 ($1.05^{0.25}$-1)	matches data
g_y*	foreign steady state GDP growth	$1.03^{0.25}$-1	matches average world GDP growth
n*	foreign labour force growth	$1.1^{0.25}$-1	average world population growth
π*	foreign steady state inflation	$1.03^{0.25}$-1	Matches average world inflation
r	steady state real interest rate	$1.04^{0.25}$-1 ($1.05^{0.25}$-1)	matches data
i*	foreign steady state nominal interest rate	$1.02^{0.25}$-1	Similar to Fed funds rate
β	discount factor	0.9951	standard
ϑ	amount government can withdraw from fund	0.1	assumption

Note: Calibration based on annual rates converted to quarters; parameters in parentheses are for Uganda if different from Ghana.

The calibrated model parameters in Table A1 are mostly standard in DSGE, calculated for Ghana and Uganda (in parentheses), or from Medina and Soto (2007). Assumed (unobserved) values are taken from the existing literature and observed values are calibrated to fit historical averages. In contrast to Dagher *et al* (2012) for Ghana we assume that a smaller share of agents are dynamic optimisers (40% against 60%), but this would not affect our results.

Additional References (for calibration)

Adolfson, M., S. Laséen, and J. Lindè (2008), Empirical Properties of Closed- and Open-Economy DSGE Models of the Euro Area, *Macroeconomic Dynamics*, **12**(1): 2–19.

Berg, A., J. Gottschalk, R. Portillo, and L. Zanna (2010), The Macroeconomics of Medium-Term Aid Scaling-Up Scenarios, Washington, DC: *IMF Working Paper 10/160*.

Berg, A., T. Mirzoev, R. Portillo and L. Zanna (2010) The Short-Run Macroeconomics of Aid Inflows: Understanding the Interaction of Fiscal and Reserve Policy, Washington, DC: *IMF Working Paper, 10/65*.

Bu, Y. (2006), Fixed capital stock depreciation in developing countries: Some evidence from firm level data. *Journal of Development Studies*, **42**(5): 881–901.

Gorodnichenko, Y, and M. Weber (2016), Are Sticky Prices Costly? Evidence from the Stock Market, *American Economic Review*, **106**(1): 165–99.

Havranek, T., M. Rusnak and A. Sokolova (2017), Habit formation in consumption: A meta-analysis, *European Economic Review* **95**: 142–67.

Tokarick, S. (2010), A Method for Calculating Export Supply and Import Demand Elasticities, Washington, DC: *IMF Working Paper 10/180*.

Zeufack, A., A. Kopoin, J-P. Nganou, F. Tchana and L. Kenoe (2018), Optimal Allocation of Natural Resource Surpluses in a Dynamic Macroeconomic Framework, Washington, DC: *World Bank Policy Research Working Paper 7910*.