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DOES THE DSGE MODEL FIT THE SUDAN ECONOMIC DATA?

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Abstract

This paper examines the possibility for Sudan to build a small open-economy, dynamic stochastic general equilibrium (DSGE) model. The model consists of 14 equations estimated by the Bayesian technique using the data from five variables for the period 1960-2017, which are the real money supply, the inflation rate, the output gap, the real exchange rate and the interest rate. Results indicate that the Sudan's central bank (CBS) is practicing less radical change in the formulating monetary policy, and is achieving slight progress in combating inflation and fostering economic growth. The nominal interest rate and the general price level have the same effect on the terms of monetary policy. The relationship between inflation and real marginal cost is weak. However, the position of interest rate in monetary policy is weak compared with the exchange rate. Finally, a one-point reduction in nominal interest reduces the output gap by 3%. The shock of inflation has the greatest effect on the endogenous variables, followed by shock to the consumer preference, real money supply, and finally shock to the general level of prices.

Keywords: *Economic growth; Inflation; Monetary policy; Output gap.*

INTRODUCTION

Notwithstanding the recognition by governments, academics, and especially central banks around the globe, of the DSGE as the main tool for analyzing and forecasting the economy, the central bank of Sudan (CBS) and the rest of the economy have not yet been in uses. The CBS formulates four policies:

(1) Monetary and credit policy through Islamic bonds, the legal reserve requirement; the profit margins liquidity ratio & the last resort market for inter-banks;

(2) The foreign exchange policy which admitted the fixed-rate regime from the establishment of the CBS in 1960 to September 1978, and which has since shifted to the managed floating exchange rate regime;

(3) The monetary policy implemented by the Sudanese pound between 1960 and 1992 shifted to dinar between 1992 and 2005 and again to pound up to now; and

(4) Banking policy on the stability and efficiency of the banking and financial institutions (CBS, 2018).

Standard econometric approaches typically directed the analysis, predicting monetary and fiscal policy. More than ten macroeconomic models have been built with different objectives for the Sudan economy. Nonetheless, the government did not use them to formulate economic policies. Therefore developing a small scale DSGE model could be beneficial as a policy analysis and forecasting directional device. To my knowledge, only one Ph.D. student builds such a model for assessing monetary policy and dynamics in Sudanese economy, This paper assigns section two to the literature review, section three to the model specification, section four theoretical background, results will be presented in section & discussion in section five and concludes the paper in section six.

LITERATURE REVIEW

In practice of the real business cycle economy the basic DSGE model was developed (Sisay, 2001). The 1980s witnessed the introduction of DSGE models as an alternative to the standard macroeconomic models, pioneered by Kydland and Prescott (1982), who transformed the way macroeconomics was studied. Long and Plosser (1983) built up a heterogeneous demand for money and provided the cycle labor wedge with micro-foundation. Calvo and Caluntbia (1983) studied the macroeconomic effects of the nominal and non-synchronous non-revision prices. Hansen's (1985) growth model tried to reduce the weakness of Kydland and Prescott's failure to account for phenomena on the labor market. The effects were a significant fluctuation in working hours and comparative fluctuations in productivity DSGE has some advances since 1995 and the popular "first" formal DSGE model that Smets and Wouters (2002) have implemented. Gali and Gretler (1999) linked the real marginal cost (ratio of wage rates to total labor product) and the new Phillips curve to explain inflation with forward-looking actions.

In setting the macroeconomic climate of the typical Sub Saharan Africa (SSA) economy, Sisay (2001) critically evaluated and analyzed the basic components of the open economy New-Keynesian model. Rabanal and Rubio-Ramiresz's (2003) European Area model was used to compare four versions of the New-Keynesian sticky-price model. Hodge & Stuart (2008), Adolfson et al. (2005), used the Bayesian estimation method to build a model for Euro-zone. Peiris and Saxegaard (2007) evaluated monetary policy tradeoffs in low-income countries for Mozambique showing that the peg exchange rate is less successful. Olekah and Oyaromade (2007)

built a small Nigerian economic model to evaluate monetary policy. Hodge & Stuart (2008) have built a small Australian economy structural model that achieves a competitive model with benchmark forecasting models. Gelain and Dmitry (2009) put together Estonia's DSGE model with an emphasis on the interest rate. Samya and Poghosyan present and estimate DSGE to the Jordanian economy and predict a small open market model.

In the utility function of the user, the model includes nominal and actual rigidities, imperfect competition, and habit formation. Shirbini and Mahrous (2014) showed that Tanzania's bank committed to strict monetary policy that does not radically change and has succeeded in controlling the inflation rate. Bayomi (2016) combined theory and empirics considering DSGE's discontent which resembled difficulties in moving them out of balance, and the failure to explain the current recession which, in turn, complicates fiscal policy analysis. Linardi (2016) built a small open market, dynamic general equilibrium stochastic (DSGE) model using Brazil's inflation target economic data. Rasaki (2017) developed and estimated a model for the Nigerian economy using the Bayesian technique of a small open economy, DSGE model. Boukhelofa (2018) has been successful in capturing the dynamics of Algerian economic data with three main results: aggregate demand causes business cycle government spending plays a significant role in the fluctuation of output; government spending policies are procyclical.

THEORETICAL BACKGROUND

Daney (2015) said that the DSGE models are capable of using current data, replicating business cycles, environmental issues, and natural resources. Households consume the companies' agricultural, industrial, and service products, which in turn work with the monetary sector through interest rate and monetary aggregates. Through inflation, international investment, and the current account, the monetary sector interrelates with the external market. All of the sectors listed work alongside market frictions and prices. Eventually, using expenditure, taxation, and debt, the fiscal sector deals with the household, external economy, and the market. Linear differential equations are ideal for calculation of DSGE models since most of the relationships are representations of rational expectation equation.

Barnett and Ellison (2005) aim to give the DSGE a deeper framework and knowledge. They started by maximizing consumer utility using total differentiation of current consumption about previous marks negative multiplication of discount factor with the first derivative of past utility about current utility, the addition of budget constraints

yields the ratio of the past interest rate plus one to current interest rate plus one. The general solution leads to the Euler consumption equation, known as the dynamic IS curve. The analytical models employ different sets of endogenous variables, for example, Gali and Monacelli (2005) compare real wages to the demand predicted, the real interest rate the inflation expected. The domestic price level and CPI inflation are then both functions of the consumer price index and the effective terms of trade; besides, the effective terms of trade are the nominal real exchange rate. The domestic price level and CPI inflation are then both the function of the consumer price index and the effective terms of trade; also, the effective terms of trade relates to the nominal and real exchange rate. The condition of market-clearing links output with consumption by private, government, and terms of trade.

Rubio-Ramirez (2005) set output, to be the function of the nominal interest rate, the preference shifter shock, the price level, and the elasticity of intertemporal substitution. The output is a function relates to technology shock, and the number of hours worked; the real marginal cost depends on the nominal wage and the capital share of output. The marginal rate of substitution between consumption and hours is a function of output and hours worked, in addition to a shock. Berg et al., (2006) built a small model in which output depends on the real interest rate, the real exchange rate, and the past and future output itself; output is associated to the real interest rate, the real exchange rate, and the past and future output itself. Lubik and Schorfheide (2006) rest on Phillips-curve as a solution to firms' price-setting, where inflation depends on international relative price movement, interest rate relates to the expected exchange depreciation and inflation. The output is affected by demand and relative prices.

Berg et al., (2012) model has three production sectors: non-traded goods, (non-resource) traded goods and a natural resource. It includes the households' decision, the firms, and the state of the economy, including predetermined capital, bond, and a resource fund, the realization of shocks at t, and agents' expectations. Rasaki (2017) ties consumption with past and expected future consumption, real interest rates, exchange rates, and real balances. The output gap will be affected by demand, exports, and imports; net exports will depend on international output, output gap, and real exchange rate; output will be determined by the state of technology and employment level. Real marginal cost is a function of current and the past output gap, real money balances, nominal and real exchange rate, current and foreign output, price level, and state of technology; inflation is determined to be expected and past inflation rate, real marginal cost, and shock. The nominal exchange rate governed by the expected exchange rate, the deviation between the domestic and foreign interest rates, the oil price, and foreign debt. The evolution of external debt shows an inverse relationship with oil prices, negative dependence on domestic output, and positive dependence on

foreign output, foreign interest rate, and real exchange rate; interest rate is a positive function of the current exchange rate, negative on expected future exchange rate.

DSGE Model for Sudan

The Rubio-Ramirez (2005) model is the basis of our model, from which 9 out of 14 equations are used. i.e. (1-5) 10 (12-14); then the model expanded to include the effective exchange rate, export prices, international demand, and trade terms taken from Berget al., (2005), and Gali & Monacelli (2005). The author has so gained from Barnett and Ellison's research (2005). Equation (2) is the IS curve derive from Euler equation of consumers found in the work of Barnett and Ellison (2005).

The model contains behavioral equations as follows:

(1) Household consumption (pc_t) depends on the expected consumption, the past consumption, interest rate (r_t) deviation from inflation ($infl_t$), real money supply (m_t), foreign consumption (f_t), and interest shock. Smoothing consumption optimizing the lifetime utility function of identical households subject to budget constraints bring about the dynamic IS curve known as the Euler equation for consumption

(2) Real monetary policy depends on the demand for labor (l_t), the deviation of current consumption from its past value.

(3) The output gap (y_t) is a function of the expected output (y_{t+1}), and the real interest rate (r_t) minus expected inflation ($infl_{t+1}$), plus the expected consumer preference (g_{t+1}) minus the technology shock (a_t).

(4) Real wages ($w_t - p_t$) are related to lagged wages (w_t), inflation ($infl_t$), and change in wages (dw_t).

(5) Wage change (dw_t) is affected by expected change in wages ($w_t - p_t$) and real wages; wages rise when the output above the trend i.e. rise with the output gap

(6) Real marginal cost relates to real wages ($w_t - p_t$), amount labor required to produce one unit of output, and the price markup cost λ.

(7) The general price level (p_t) is affected by the consumer price, the export price (xp_t), and the real marginal cost (mc_t); firms are divided into two groups: price setters (current price: myopic price (constant mark-up k over marginal cost) and desired price at t+1) and non-price setter (past price). Narrow-minded (Myopic)

(8) The monetary policy condition (mci_t) combines real interest rate (r_t), and the real effective exchange rate (x_t).

(9) The real money supply is a function of the nominal interest rate (i_t), and the real effective exchange rate (x_t).

(10) The growth rate of consumer price is a function of expected inflation, real marginal cost (mc_t), and the price markup cost λ.

(11) The nominal interest rate (r_t) is related to its lagged value, the inflation rate, the output gap, and the shock to nominal interest rate (ms_t). The real interest rate measured as ($i - \pi_{t+1}$). In the situation of excess supply, against excess demand, the bond is above the equilibrium interest rate. The principal determinants of demand and supply curve changes are the expected inflation (Fisher effect). The amount of bonds increases during the expansionary economic cycle, as well as the income leading to an increase in the interest rate as opposed to recession scenario. The theory of liquidity preference postulates that an inverse relationship exists between the interest rate and money via the opportunity cost of keeping money. The central bank therefore controls the money supply.

(12) The nominal effective exchange rate (e_t) is a function of foreign consumption (f_t), the terms of trade (s_t), and a shock (v_t).

(13) The technology shock (a_t) is supposed to follow an autoregressive process.

(14) The consumer preference (g_t) shock is supposed to follow an autoregressive process.

$c_t = \alpha*pc_{t+1} + \beta*pc_{t-1} - \gamma*(r - pi_{+1}) + \delta*m_t - \varepsilon*f + ms_t;$

$mrs_t = \eta*n_t - (c_t - c_{t-1})/(1-\zeta/\alpha);$

$y = y_{t+1} - \theta*(r_t - pi_{+1} + g_{t+1} - a_t);$

$w_t - p_t = w_{t-1} - pi + dw_t;$

$dw_t = dw_{t+1} + \iota*(w_t - p_t);$

$mc_t = (w_t - p_t) + 1/\zeta*(l_t - y_t - \lambda);$

$p_t = \kappa + xp_t + mc_t;$

$x_t = \lambda*s_t + j_t;$

$mci_t = \mu*(i_t - pi_t) + (1-\mu)*x_t;$

$m_t = \nu*i_t + \xi*x_t + u_t;$

$r_t = o*r_{t-1} + (1 - o)*(\pi*pi_t + \varrho*y_t) + ms_t;$

$e_t = \pi*f_t + (1- \alpha)*s_t + v_t;$

$pi_t = \sigma*pi_{t+1} + \tau*(mc_t + \lambda) + q_t;$

$e_t = \upsilon*f_t + (1- \alpha)*s_t + v_t;$

$a_t = \chi*a_{t-1} + j_t;$

$g_t = \omega*g_{t-1} + z_t;$

Data

The observed variables are output gap - the difference between the actual output of an economy's actual output and its potential output percentage points (y), the percentage points of private consumption-income (c), the nominal interest rate (r), the real money supply (m), the nominal effective exchange rate (e), and the general price level (p). The Sudanese Central statistical Bureau offers all variables. The sample covers 1960-2017. The unobserved variables are real exchange rate (x), the inflation rate (π), the marginal rate of substitution between consumption and hours worked, the marginal cost (mc), and the nominal wage (w). Exogenous variables are the terms of trade (s), the demand for labor (l), the nominal interest rate, and the export price. Shocks are the interest rate shock (ms) - non-systematic part of the monetary policy, the technological shock (a), the price markup shock (lambda), the shock to the nominal effective exchange rate (v), and the shock to the consumer preference (z).

Empirical Results

Calibration

The model parameter calibration is based on four sources: parameter values selected from the Statistics Bureau in Sudan, estimates from EViews and Standard DSGE models (Rubio-Ramirez, 2005; Gali & Monacellli, 2005; Berg et al., 2006; Schorfheide, 2007). Choosing prior shapes: beta distribution fits percentage and proportions, gamma distribution is applied to variables that are always positive and have distorted distributions. Uncertain quantities are used inverse gamma. The uniform distribution defines an experiment where there is an arbitrary outcome that lies between certain boundaries.

Metropolis-Hastings sampling algorithm in Dynare-Matlab toolbox calculates posterior distributions and related posterior statistics of the DSGE model.

Table 1 displays very small differences between the values of prior mean and posterior mode. Table 2 shows the principal results of the estimated model are as follows: The previous consumption (habit formation) affects current consumption by 70%. In terms of negative sign and magnitude, the prior of output gap yields a very near steady-state value as opposed to the initial value. The change in real wages is almost 1% per year pointing toward wage stickiness.

TABLE 1. PRIOR MEAN AND POSTERIOR MODE

Coefficient	Associated Variable	Prior Mean	Posterior Mode
Consumption Equation (1)			
Alpha α	Expectations of future consumption	0.472	0.4969
Beta β	Lagged consumption (beta elasticity of intertemporal substitution)	0.700	0.7000
Gamma γ	Nominal interest rate – inflation rate	0.300	0.2916
Delta δ	Real money supply	0.300	0.5293
Epsilon ε	Foreign consumption	0.800	0.8000
Marginal Rate of Substitution between Consumption and Hours Equation (2)			
Eta η	Labor Supply (Eta is the inverse elasticity of labor supply with respect to real wage)	0.5	0.5000
Zeta ζ	Current consumption minus lagged consumption	0.800	0.7996
Output Gap Equation (3)			
Theta θ	nominal interest rate – expected inflation + expected consumer preference – current consumer preference	0.030	0.0303
Change in Wages Equation (4)			
Iota ι	The real wages	0.01	0.0112
General Price Level Equation (5)			
Kappa κ	Constant	0.5	0.5
Real Effective Exchange Rate Equation (6)			
Lambda λ	Terms of trade	0.500	0.5000
Monetary Policy Condition Equation (7)			
Mu μ	Nominal interest rate – price level	0.3	0.3000
Real Money Supply Equation (8)			
Nu ν	Nominal interest rate	0.060	0.0524
Xi ξ	Real effective exchange rate	1.530	1.5230
(Taylor Rule) Nominal Interest Rate Equation (9)			
Omicron	Lagged real interest rate	0.9	0.8661
Pi π	Inflation rate (Pi is the long-run of monetary authority to inflation)	3.00	3.3010
Rho ϱ	Output gap (Rho is the long-run of monetary authority to output gap) mean	2.5	2.4988
Inflation Rate Equation (10)			
Sigma σ	Expectations of future inflation	0.800	0.8165
Tau τ	Marginal Cost + Price Markup shock (lambda)	0.036	0.0 966
Nominal Effective Exchange Rate Equation (11)			
Upsilon υ	Foreign consumption	0.100	0.1013
Technology Shock Equation (12)			
Chi χ	lagged technological shock	1.53	1.4873
Consumer Preference Shifter Shock Equation (13)			
Omega ω	lagged consumer preference	0.9	0.8932
Wage Growth Equation (14)			
Beta β	Expectations of future wage growth	0.472	0.3442
Kappa k	Marginal rate of substitution minus real wages	0.5	0.5
Alpha α	Degree of wage indexation	0.700	0.7000

Steady-State Results

TABLE 2. INITIAL AND STEADY-STATE

Variable	Symbol	Initial Value	Steady-state
Consumption	C	0.77	0. 553082
Marginal rate of substitution between consumption and labor	mrs	0	0.145
Output-gap	y	-0.685	-0.680113
Nominal interest rate	r	3.049	0. 695776
Real money supply	m	0.18	0.25684
Inflation rate	pi	0.22	0. 695776
Nominal wage growth	dw	0.1	0. 695776
Nominal effective exchange rate	e	4.7	0. 07432
Real effective exchange rate	x	0.013	0. 0.1325
Monetary policy condition	mci	0.022	0. 09275
General price level	p	0.22	1.38764
Nominal wages	w	2	1.38764
Marginal cost	mc	0.1	0. 587642
Required labor force to produce one unit of output	n	0.29	
Interest rate shock - non-systematic part of the monetary policy	ms	0.01	
Foreign price level - foreign goods	f	0.3	
Export price	xp	0.3	
Shocks attached to the inflation rate	q	0.1	
Shocks attached to nominal effective exchange rate	v	0.01	
Shocks attached to real money supply	u	0.01	
Shocks attached to technology	z	0.1	
Terms of trade	s	0.065	
Technological shock	a	0.1	0
Consumer preference	g	0.5	0

Transmission Mechanisms

A shock of 1% in the consumption and nominal interest rate on the hand, and real money supply on the other hand, causes all endogenous variable to gradually decrease for except the output gap which takes a hump shape and wages growth that has an upward trend.

Historical Smoothed Variables

The simulated DSGE model's estimate parameters very well follow the actual values of all endogenous variables except for inflation rate, which oscillates around actual values in a narrow band.

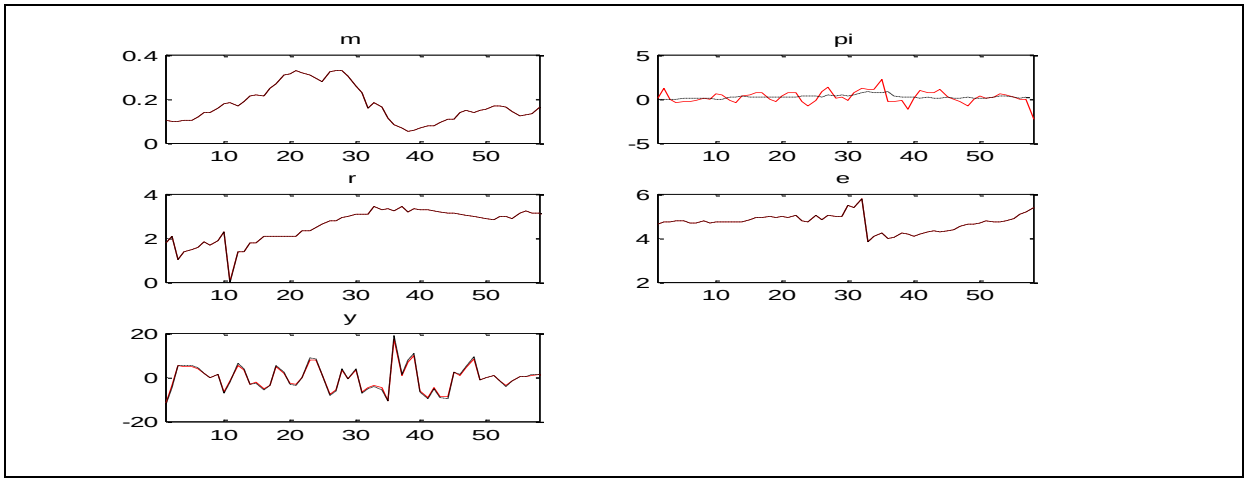

FIGURE 1. HISTORICAL SMOOTHED VARIABLES

Variance Decomposition

The shock *q* attached to the inflation rate has the largest effect on the endogenous variables with an average 43%, followed by shock z attached to attached to the consumer preference by an average 27%, trailed by 15% average of *ms* shock attached to consumption, & nominal interest rate, then the average effect of shock *u* attached to real money supply reached 12%, and finally an average of 2.6% is the shock *xp* attached to the general price level.

TABLE 3. VARIANCE DECOMPOSITION

	ms	xp	Z	U	Q
C	15.92	2.67	23.81	10.17	47.44
Y	16.35	3.04	24.37	10.41	45.84
R	16.23	2.70	23.90	10.21	46.97
M	10.88	1.81	39.11	16.70	31.50
Pi	16.02	2.77	24.13	10.31	46.77

DISCUSSION

The Sudan DSGE model's salient features are its success in matching consumer share to GDP (Euler equation), output gap, general prices, and wages to the actual values. The continuity factor for consumption habit is 0.7. The inverse marginal rate of substitution between consumption and labor is 0.145.

Results of Taylor rule show that the estimated value of the coefficient attached to the lagged interest rate (omicron) is 0.8, indicating a less radical change in the monetary policy of the CBS.

The frequent reduction in the value of Sudanese pound has been feeding inflation and causing a continuous increase in production costs in the main sectors of the economy, i.e. agriculture and manufacturing are mainly dependent on imported raw material. With regard to the output gap equation, a nominal interest reduction of one unit increases the output gap by 3%.

Because the value of the attached equation (Marginal Cost + Price Markup shock + lambda) is 0.09, implying a slight positive relationship between inflation and marginal cost. This finding is consistent with the Sudan's situation because Islam considers interest rates are banned.

The money supply equation shows that the coefficients of interest rate and exchange rate are 0.06 and 1.53 respectively pointing to the poor position of interest rate in monetary policy formation, while exchange rate has a profound effect.

CONCLUSION

This is an effort to build dynamic general stochastic equilibrium. The model's structure is based primarily on Rubio-Ramirez model (2005), Berg et al., (2006), and Gali & Monacelli (2005). For estimation the model uses Bayesian technique. Annual data are available for the share of GDP consumption, output gap, money supply, real effective exchange rate. In addition to the Sudanese Central Statistical Bureau, the sources of priors are above mentioned models, subjective assumptions that estimate stable state values to be as close to initial values as possible, and estimation of some parameters through EViews. Since the rank is verified and there is a close relationship between priors and posteriors as well as the good match between the actual and smoothed variables, the attempted can be considered successful.

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