

Monetary-fiscal policies interactions and optimal rules in Egypt

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Abstract

Purpose – This paper aims to estimate a New Keynesian small open economy dynamic stochastic general equilibrium (DSGE) model for Egypt using Bayesian techniques and data for the period FY2004/2005:Q1-FY2015/2016:Q4 to assess monetary and fiscal policy interactions and their impact on economic stabilization. Outcomes of monetary and fiscal authority commitment to policy instruments, interest rate, government spending and taxes, are evaluated using Taylor-type and optimal simple rules.

Design/methodology/approach – The study extends the stylized micro-founded small open economy New Keynesian DSGE model, proposed by Lubik and Schorfheide (2007), by explicitly introducing fiscal policy behavior into the model (Fragetta and Kirsanova, 2010 and Çebi, 2011). The model is calibrated using quarterly data for Egypt on key macroeconomic variables during FY2004/2005:Q1-FY2015/2016:Q4; and Bayesian methods are used in estimation.

Findings – The results show that monetary and fiscal policy instruments in Egypt contribute to economic stability through their effects on inflation, output and debt stock. The monetary policy Taylor rule estimates reveal that the Central Bank of Egypt (CBE) attaches significant importance to anti-inflationary policy and (to a lesser extent) to output targeting but responds weakly to nominal exchange rate variations. CBE decisions are significantly influenced by interest rate smoothing. Egyptian fiscal policy has an important role in output and government debt stabilization. Additionally, the fiscal authority chooses pro-cyclical government spending and counter-cyclical tax policies for output stabilization. Again, past values of the fiscal instruments are influential in the evolution of the future fiscal policy-making process.

Originality/value – A few studies have examined the interaction between monetary and fiscal policy in Egypt within a unified framework. The presented paper integrates the monetary and fiscal policy analysis within a unified dynamic general equilibrium open economy rational expectations framework. Without such a framework, it would not be easy to jointly analyze monetary and fiscal transmission mechanisms for output, inflation and debt. Also, it would be neither possible to contrast the outcome of monetary and fiscal authorities commitment to a simple Taylor instrument rule vis-à-vis optimal policy outcomes nor to assess the behavior of monetary and fiscal agents in macroeconomic stability in context of an active/passive policy decisions framework.

Keywords DSGE, Economic stabilization, Monetary and fiscal policy, Optimal rules

Paper type Research paper



1. Introduction

The Egyptian Government launched a comprehensive reform program in 2014 to rebuild confidence in the economy after two consecutive uprisings in 2011 and 2013. The goal of the program was to strengthen macroeconomic performance by introducing a set of monetary and fiscal policy reform measures (World Bank, 2015). Monetary reform included the Central Bank of Egypt's (CBE's) decision to liberalize the Egyptian pound in November 2016. The primary goal of the fiscal reform program was to trim the budget deficit and improve the structure of government spending without jeopardizing economic growth [GOE (Government of Egypt), 2015].

Coordination between macroeconomic policies is essential for achieving the objectives of the program. Recently, examining the monetary and fiscal policy mix has become important in view of government attempts to stimulate growth, control inflation, overcome fiscal budget problems and maintain the drive toward more CBE independence. Hence, the main objective of this paper is to study the dynamic interactions between monetary and fiscal policies in Egypt during the period 2004/05-2015/16, assess their contribution to macroeconomic performance and craft insights of an integrated optimal policy framework for inciting economic stability.

A few studies have examined the interaction between monetary and fiscal policy in Egypt within a unified framework (Panizza, 2001; Hassan *et al.*, 2014 and Abdel-Haleim, 2016). None of these studies, however, has integrated the analysis within a unified dynamic general equilibrium open economy rational expectations framework. Without such a framework, it would not be easy to jointly analyze monetary and fiscal transmission mechanisms for output, inflation and debt. Neither would it be possible to contrast the outcome of CBE and fiscal authority commitment to a simple Taylor instrument rule *vis-à-vis* optimal policy outcomes; nor to assess the behavior of monetary and fiscal agents on macroeconomic stability in context of an active/passive policy decisions framework[1].

To overcome these limitations, the present study extends the stylized micro-founded small open economy New Keynesian dynamic stochastic general equilibrium (DSGE) model, proposed by Lubik and Schorfheide (2007), by explicitly introducing fiscal policy behavior into the model (Frassetto and Kirsanova, 2010 and Çebi, 2011). The model is calibrated using quarterly data for Egypt on key macroeconomic variables during FY2004/2005:Q1-FY2015/2016:Q4, and Bayesian methods are used in estimation. The estimates of the simple Taylor rule and optimal simple rule (OSR) generally indicate that CBE pursues an anti-inflationary policy. Recent success of the CBE in achieving its inflation target has positively contributed to macroeconomic stability despite accumulated government debt and growing budget deficit[2].

In particular, the Taylor rule reaction function estimates reveal that the CBE attaches significant importance to inflation and output targeting while responding weakly to nominal exchange rate variations. Besides, CBE tends to adopt a counter-cyclical policy as an instrument for monetary stabilization. The analysis reveals that monetary policy decisions reflect a significant degree of interest rate smoothing, which may render CBE policy responses overtly transparent and anticipated. A large smoothing coefficient suggests that – *ceteris paribus* – the monetary authority adjusts its policy instrument gradually from period to period. Generally, central banks tend to smooth changes in interest rates owing to uncertainty about the economy, which may lead the monetary authority to respond cautiously until the economic situation became clearer and less uncertain. Another justification is the fear of instability in the financial market that may induce considerable changes especially for countries suffering from large debts. Interest rate smoothing can also be related to the transparency and credibility of the central bank. Central bankers may

choose to adopt small and persistent changes in interest rate over an extended period of time rather than large and transitory changes to realize higher economic stability (Clarida *et al.*, 2000 and Srouf, 2001).

On the fiscal front, the results suggest a sizable level of policy inertia, indicating that past values of the fiscal instruments (government spending and taxes) are influential in the future evolution of the fiscal policy making process in Egypt. The results further disclose that while fiscal policy involving government spending is pro-cyclical, it is counter-cyclical when implemented through income taxes. The analysis demonstrates that fiscal policy plays an important role in government debt and output stabilization, especially when income taxes are used as a policy instrument. The behavior of the fiscal authority toward debt stabilization suggests that the Egyptian Government adopts a Leeper (1991) passive fiscal policy. According to Leeper (1991), active/passive policy is defined according to policy responsiveness to a shock in public debt. Characterizing the behavior of monetary/fiscal authority as active or passive depends on the constraints and restrictions that the specific authority faces. An active authority, primarily, focuses on realizing its targets without regard neither to the budget deficit position nor the behavior of current and past variables controlled by the passive authority. Alternatively, the passive authority opts to generate sufficient revenues to balance the budget deficit based on a decision rule that is a function of the current position of public debt.

Alternatively, the OSR results recommend moderate response to inflation compared with analogous Taylor rule estimates. They also suggest that the monetary authority targets exchange rate variations. The OSR estimates disclose virtually muted response to output. Hence, the monetary authority would not want to account for output fluctuations when optimally setting its operational target.

The optimization results recommend that government should heavily target debt stabilization. In that case, the fiscal agent would adhere to a passive policy in the Leeper sense. When there is a rise in fiscal debt, adopting a Leeper passive monetary stance would support the consolidation of the fiscal balance, though probably accompanied with higher inflationary pressure. However, if the CBE adopts an active policy, then the fiscal debt stabilization policy may be restrained by monetary policy. Additionally, the OSR findings reveal that the fiscal authority should moderately target output stabilization and underscore the merits of pro-cyclical government spending in Egypt (i.e. higher expenditures during a boom and lower in periods of recession). Such pro-cyclicality may be interpreted in context of the structure of the Egyptian Government budget. The substantial share of fixed expenses in total expenditure is likely to limit the government ability to implement an independent fiscal policy, as those expenditures represent outcomes of earlier decisions that are not easily adjustable in the short-run without triggering economic imbalances (Gavin *et al.*, 1996). Moreover, the OSR findings are inclined towards a counter-cyclical income tax policy. Because tax revenues are under fiscal authority control, the government has the flexibility to counter-cyclically interfere by raising (cutting) taxes during booms (recessions) to restore stability and reduce adverse effects on the fiscal budget, especially during economic downturns. Finally, the findings reveal that the smoothing coefficients derived from Taylor instrument rules are more gradual and persistent in comparison with analogous estimates from the OSR scenarios, suggesting that the OSR advocates immediate sizeable responses to shocks rather in contrast with slower and weaker Taylor-type responses, which may help monetary/fiscal authorities to quickly achieve policy targets (Srouf, 2001).

The rest of the paper is organized as follows. Section 2 presents an overview of the Egyptian economy. Section 3 outlines the basic structure of the DSGE model for Egypt.

Section 4 describes the data and choice of priors and presents the Bayesian estimates of the model. Section 5 analyzes optimal monetary and fiscal policy implications based on the OSR model. Section 6 concludes. The model equations are portrayed in the [Appendix](#).

2. Overview of Egyptian macroeconomic performance

Since the mid-2000s, the Egyptian economy has faced repercussions of socioeconomic and political changes that took place on both the international and domestic sides. The global financial and world food prices crises disrupted the Egyptian economy in the second half of 2008 leading to a slowdown in economic activity and a decline in the relatively high rates of economic growth that prevailed in previous years. Moreover, social and economic disturbances owing to the two consecutive uprisings in 2011 and 2013 adversely affected the performance of the economy.

The average annual growth rate averaged approximately 6.4 per cent during 2005-2008 reaching 7.2 per cent by the end of the period. In 2009, real GDP growth started to decline reaching a record low of 1.8 per cent in the aftermath of the 2011 revolution. Foreign reserves fell about 50 per cent within the period December 2010-December 2011, reaching US \$15.5bn in 2012 (allowing only for a borderline three months imports cover). The average annualized CPI inflation was about 10 per cent during 2005-2008, reaching a peak of 23 per cent in August 2008 owing to the global financial crisis. The annualized inflation rate stabilized around 9.7 per cent from 2011 until the devaluation of the Egyptian pound in November 2016. Besides, the government debt to GDP ratio averaged 83.4 per cent during 2008-2017, fluctuating between a record low of 73.3 per cent in 2009 and an all-time high of 101.2 per cent in 2017.

To promote economic activity and control the budget debt, the Egyptian Government launched a comprehensive reform program in 2014. The program aimed to strengthen macroeconomic performance by stimulating output growth, promoting price and debt stabilization and improving the business and investment climate ([World Bank, 2015](#)). The reform program involved a set of monetary and fiscal reform measures. The monetary measures essentially included the CBE decision to liberalize the Egyptian pound in November 2016. The move toward a floating exchange rate regime significantly contributed to the elimination of distortions in the domestic-foreign currency market and put an end to the parallel exchange rate system. It has also helped in accumulating foreign currency reserves.

The primary goal of the fiscal reform program was to reduce government debt, trim the budget deficit and improve the structure of government spending without jeopardizing economic growth [[GOE \(Government of Egypt\), 2015](#)]. On the revenue side, the fiscal policy reform measures included adjustment of the tax system, e.g. introducing a value added tax. Alternatively, on the expenditure side, the government's fiscal consolidation program aimed at restraining the growth of government wages and compensation bill through selected policy intervention measures. The fiscal authority has started incremental reductions in energy subsidies by applying fuel and electricity pricing reforms, thereby allowing the government to redirect expenditures towards priority areas such as education, health, infrastructure and social protection programs [[GOE \(Government of Egypt\), 2015](#); [World Bank, 2015](#) and [Ministry of Finance \(MOF\), 2016](#)].

The economic reform program has attempted to strengthen macroeconomic performance by playing an important role in, gradually, restoring trust in the Egyptian economy. The initial signs of economic improvement and recovery are marked by developments in key economic indicators. The annual GDP growth reached 4.2 per cent in 2016/2017 (surpassing the IMF forecast of 3.5 per cent). The first quarter of the current fiscal year 2017/2018 has

registered a 5.2 per cent growth in real GDP compared to its analogue (3.4 per cent) in 2016/2017. The unemployment rate witnessed a gradual decrease during the fiscal year 2016/2017, reaching 11.9 per cent in 2016/2017:Q3, in contrast to 12.6 per cent during the same quarter in the previous year. Alternatively, in the aftermath of the recent floatation of the Egyptian pound, the value of the Egyptian currency registered an unprecedented decrease with the exchange rate hovering above EGP 18 per 1 USD by the end of March 2017 in comparison with EGP 8.78 just eight months earlier [CBE (Central Bank of Egypt), 2016/2017]. Pass-through effects associated with the devaluation of the Pound contributed to the significant increase in the annual CPI inflation, which reached a peak at 34.2 per cent in July 2017 versus 14.8 per cent in the previous year [Ministry of Finance (MOF), 2017].

On the upside, exchange market reforms resulted in a net increase in international reserves that rose considerably by more than 185 per cent from a low of US\$13.4bn in March 2016 to US\$38.2bn in January 2018, equivalent to 8.2 months of imports cover. In addition, to curb high inflation, the CBE has implemented successive increases in the overnight interbank rate. The annual inflation started to decline gradually reaching 13.6 per cent by August 2018.

Concurrent implementation of monetary and fiscal policy adjustments necessitates appropriate interaction between those policies to motivate stable output growth, manageable budget deficit and acceptable levels of inflation in Egypt. Accordingly, coordination between macroeconomic policies is essential for achieving the objectives of the reform program.

3. A dynamic stochastic general equilibrium model for Egypt with monetary and fiscal policies

This study extends the stylized small open economy DSGE model by Lubik and Schorfheide (2007) – based on the seminal work of Galí and Monacelli (2005) – by formally introducing fiscal policy behavior within the modeling structure (Fragetta and Kirsanova, 2010 and Çebi, 2011). Hence, it would be possible to analyze policy interactions and simultaneously evaluate the role of fiscal and monetary strategies in stabilizing the Egyptian economy.

The DSGE construct specifies a linear rational expectation model that consists of four main types of economic agents: households, firms, central bank and government. The micro-foundations for the model are based on households that maximize an intertemporal utility function subject to a budget constraint. Monopolistically competitive profit maximizing firms produce differentiated goods and determine prices, within a New Keynesian framework, according to a Calvo sticky price-setting mechanism (Çebi, 2011). Monetary and fiscal agents' reactions follow conventional Taylor-type rules. The behavior of individual agents is guided by dynamic optimality and market clearing conditions.

The linearized DSGE model for Egypt is composed of seven equations (depicted in Appendix). The first equation defines an intertemporal IS (demand) curve derived from a representative individual household optimization problem that describes output as a function of real interest rate. The IS equation relates the evolution of domestic output to its expected value, technology growth, real interest rate, future realizations of changes in terms of trade and government spending and world output.

On the supply side, firms set prices optimally; and their price-setting behavior is derived from maximization of future discounted profits assuming staggered pricing à la Calvo. The firm's optimal price strategy is approximated by a forward-looking open economy New Keynesian Phillips Curve describing the dynamic evolution of inflation in terms of current and expected inflation, marginal cost, current and future terms of trade and a cost push shock.

Monetary policy is simulated using a Taylor rule that assumes CBE (monetary authority) adjusts its policy instrument in response to inflation, output, exchange rate and a stochastic shock. The Taylor rule accommodates inertial (interest rate smoothing) effects. A nominal exchange rate equation illustrates domestic competitiveness against the rest of the world. It relates inflation, nominal exchange rate change, terms of trade and world inflation shocks.

The fiscal block is defined by two Taylor-type functions: government spending and taxes that also allow for fiscal smoothing. The reaction functions permit the fiscal authority to adjust its spending and tax policies in response to (past) output and nominal debt stock. Fiscal policy decisions are influenced by government spending and tax shocks. Apart from their policy relevance, the fiscal Taylor rules offer a straightforward way to examine the cyclicity of fiscal policy. For instance, an expansionary fiscal policy stimulates the economy via increasing government spending and/or tax cuts. Hence, a positive relation between past output and government spending implies pro-cyclical fiscal policy. In contrast, a positive relation between past output and income tax indicates a counter-cyclical policy. Analogously, a positive output coefficient in the monetary equation implies counter-cyclical monetary policy responses (Takáts, 2010).

The fiscal block is complemented by a government solvency constraint expressed in terms of a nominal debt stock equation. The debt equation is represented by a government budget constraint where the future debt stock is a function of real debt stock, deviation between taxes and output and government deficit weighted by the ratio of steady state consumption to debt as shares of GDP (Muscatelli and Tirelli, 2005 and Çebi, 2011).

The model includes seven endogenous variables (output, inflation, nominal interest and exchange rates, fiscal spending and taxes and nominal budget deficit) each corresponding to one of the seven equations described above. The model is closed with four additional AR(1) (autoregressive) equations describing the stochastic evolution of terms of trade changes, world output, world inflation and technology. Each AR equation includes an exogenous stochastic shock. Thus, the model is driven by three policy (interest rate, government spending and tax) and four exogenous shocks (Appendix).

4. Model estimation

4.1 Data description

The estimation horizon spans the period from FY2004/2005:Q1 to FY2015/2016:Q4. The initial sample period promptly precedes CBE launching a corridor system to control monetary policy and adopting the overnight interbank rate as a new operational target [CBE (Central Bank of Egypt), 2010][3]. The DSGE model is calibrated using quarterly data on seven observable variables: real GDP growth, domestic CPI inflation, nominal exchange rate growth, terms of trade growth, interbank overnight policy rate, government spending and income taxes as shares of GDP. With the exception of terms of trade, the exogenous variables in the model are non-observable (latent).

The output (real GDP) and inflation series are the annualized quarterly percentage real GDP and CPI growth rates, respectively. The monetary policy instrument is represented by the annualized quarterly overnight interbank interest rate. The model includes two fiscal instruments: nominal government spending and income tax shares to nominal GDP. Owing to deficiency of Egyptian import and export price statistics, the study proxies changes in foreign terms of trade by fluctuations in the real exchange rate (with reference to the USD). Government expenditure and GDP at constant prices are obtained from the Ministry of Planning, Monitoring and Administrative Reform [Ministry of Planning, Monitoring and Administrative Reform (MOP), 2017]. Nominal exchange rate and CPI indexes for Egypt and the USA are retrieved from the IMF-IFS [IMF (International Monetary Fund), 2017].

Quarterly overnight interbank rate and individual income tax data are acquired from the [CBE \(Central Bank of Egypt\) \(2017a\)](#). All the observable series are tested and corrected for seasonality and demeaned prior to estimation.

4.2 Prior selection

The paper implements Bayesian estimation techniques, which require choice of appropriate priors and specification of probability distributions for the estimated parameters. Rather than adopting priors from other countries, the prior selection scheme in this paper mainly considers the realities of the Egyptian economy construed from information rooted in historical pre-sample data and previous studies for Egypt and from economic theory. The distribution density, its domain and the first (mean) and second (standard deviation, SD) moments for the priors of the parameters are portrayed in [Table I](#)[4].

The Taylor policy rule coefficients for inflation, output and exchange rate (ψ_1 , ψ_2 and ψ_3 , respectively) follow a Gamma distribution with prior mean 1.75 for ψ_1 and 0.40 for ψ_2 and ψ_3 . The inflation coefficient prior is on the high side (in comparison with the value 1.5 commonly associated with the Taylor rule) based on earlier findings for Egypt that underscore CBE's inclination towards an assertive (quasi-)inflation targeting regime[5]. The policy priors for output and exchange rate imply weaker reactions in contrast with the inflation coefficient ([Taylor, 1999](#) and [Moursi and El Mossallamy, 2010](#)). To avoid arbitrarily influencing the interest rate smoothing parameter estimate with tenuous opinion, the prior mean for ρ_R is set at 0.5 and is permitted to vary widely, thus allowing the data to freely determine the estimate ([Fragetta and Kirsanova, 2010](#) and [Çebi, 2011](#)).

Coef. ter.	Description	Density	Range	Mean	SD
σ	Inv. intertemporal substitution elasticity in cons.	Normal	$(-\infty, +\infty)$	3.00	1.50
α	Trade openness	Beta	[0,1]	0.33	0.05
φ	Inv. labor supply elasticity wrt real wage	Normal	$(-\infty, +\infty)$	2.00	1.00
Ψ_1	Taylor rule inflation coefficient	Gamma	[0, $+\infty$)	1.75	0.75
Ψ_2	Taylor rule output coefficient	Gamma	[0, $+\infty$)	0.40	0.20
Ψ_3	Taylor rule exchange rate coefficient	Gamma	[0, $+\infty$)	0.40	0.20
θ	Degree of price stickiness	Beta	[0,1]	0.50	0.25
ρ_R	Interest rate smoothing coefficient	Beta	[0,1]	0.50	0.20
ρ_a	Technology growth smoothing coefficient	Beta	[0,1]	0.80	0.10
ρ_q	Terms of trade smoothing coefficient	Beta	[0,1]	0.50	0.10
ρ_g	Government spending smoothing coefficient	Beta	[0,1]	0.50	0.15
ρ_τ	Tax smoothing coefficient	Beta	[0,1]	0.50	0.15
ρ_{π^*}	World inflation smoothing coefficient	Beta	[0,1]	0.50	0.10
ρ_{y^*}	World output smoothing coefficient	Beta	[0,1]	0.80	0.06
g_y	Gov. spending coefficient on past output	Normal	$(-\infty, +\infty)$	0.3	0.05
τ_y	Tax coefficient on past output	Normal	$(-\infty, +\infty)$	0.3	0.05
g_b	Gov. spending coefficient on debt stock	Normal	$(-\infty, +\infty)$	-0.3	0.05
τ_b	Tax coefficient on debt stock	Normal	$(-\infty, +\infty)$	0.3	0.05
σ_R	SD of interest rate shock	InvGamma	[0, $+\infty$)	0.40	4.00
σ_A	SD of technology shock	InvGamma	[0, $+\infty$)	1.00	4.00
σ_q	SD of terms of trade shock	InvGamma	[0, $+\infty$)	1.88	0.49
σ_g	SD of gov. spending shock	InvGamma	[0, $+\infty$)	2.00	4.00
σ_τ	SD of tax shock	InvGamma	[0, $+\infty$)	1.00	4.00
σ_{π^*}	SD of world inflation shock	InvGamma	[0, $+\infty$)	0.60	4.00
σ_{y^*}	SD of world output shock	InvGamma	[0, $+\infty$)	5.00	4.00
σ_π	SD of mark-up shock	InvGamma	[0, $+\infty$)	4.00	4.00

Table I.
Prior distributions

The prior mean of the trade openness parameter (α) is centered around 1/3, conforming to the average share of total Egyptian imports in GDP during the pre-sample period 1980-2001. The standard deviation of α is tightly set at 0.05 reflecting confidence in the prior value. The structural parameters σ and φ are purportedly distributed normally, with first and second moments centered around (3.0, 1.5) and (2.0, 1.0), respectively (Çebi, 2011).

Firms in developing countries typically tend to adjust price and wage expectations more frequently – in comparison with developed countries – wing to relatively high levels of inflation (Almeida, 2009). This study stipulates that Egyptian firms adjust prices and wages more frequently than annually. It is assumed that the average duration of fixed price contracts is half a year. Hence, the first moment of the degree of price stickiness (Calvo) parameter is set equal 0.5 with a standard deviation of 0.25, implying a loose prior.

Analogous to the monetary smoothing coefficient, the prior means for ρ_g and ρ_τ in the fiscal Taylor rules are set at the middle of the interval [0,1]. The literature suggests that fiscal feedback is usually small (Kirsanova and Wren-Lewis, 2011). In absence of a priori knowledge about the (absolute) size of the fiscal coefficients on lagged output and debt, a small value (0.3) with standard deviation of 0.05 is chosen for all four coefficients g_b , τ_b , g_y and τ_y . The sign of the debt stock parameters τ_b and g_b are determined according to expectations about fiscal authority commitment to debt stabilization. It is anticipated that an increase in debt stock would be accompanied by a contractionary fiscal policy involving reduction in government spending and/or increase in taxes (Çebi, 2011). Moreover, the signs of the output coefficients in the fiscal rules (Table I) imply pro-cyclic government spending policy (i.e. increasing government expenditures is expansionary) and counter-cyclical income tax policy (i.e. positive tax shock is contractionary).

The autoregressive parameters priors for ρ_q and ρ_{π^*} are set conservatively at the middle of the interval [0,1] while prior means for technology growth and world output (ρ_A and ρ_{y^*} , respectively) that typically exhibit persistence are set equal 0.8[6]. Again standard deviations for those parameters accommodate loose priors.

Three parameters in the model are calibrated. The ratio of private consumption to gross domestic debt (\bar{C}/\bar{B}) is fixed at its average value (0.82) during the pre-sample period 2001/02-2003/04 [CBE (Central Bank of Egypt), 2017a]. The discount factor (0.99) is parametrized based on an estimate of the steady state real interest rate for Egypt (approximately 4 per cent) during 2001-2006 (Moursi *et al.*, 2007). The elasticity of substitution between domestic and foreign goods is fixed at unity (Fragetta and Kirsanova, 2010). The first and second moment priors for the standard deviation of all the exogenous shocks in the model are chosen in line with comparable studies for Egypt (Moursi and El Mossallamy, 2010). The second moments are selected to ensure that the priors are in general sufficiently not informative (Table I).

4.3 Estimation results

Bayesian methods have become increasingly popular in estimation of DSGE models. Their advantage over classical methods mainly resides in their ability to synergize both data based (likelihood function) and non-data based information included in the prior distributions of parameters (Fernández-Villaverde and Rubio-Ramirez, 2001 and Smets and Wouters, 2003). The DSGE system of equations for Egypt is solved using conventional state-space and Bayesian methods.

The likelihood function and the priors are firstly combined to obtain the posterior distributions for the structural parameters. The Kalman filter technique is used to provide inferences about non-observable variables and to numerically evaluate the likelihood function and the posterior mode conditional on the estimated parameters. Bayesian

estimation is then implemented by summarizing the information included in the likelihood function through allocating prior distributions to the estimated parameters. The Metropolis-Hastings (M-H) algorithm is utilized to draw a sequence based on 500,000 Monte Carlo Markov Chain samples with two distinct parallel chains from the posterior distribution of the model and to evaluate the numerical maximization of the posterior distribution. Upon convergence of the algorithm, the Markov chain draws are used, after discarding the initial 50 per cent iterations as burn in, to estimate the posterior distribution moments of the model parameters (Juillard, 2014 and Griffoli, 2013).

Table II portrays the Bayesian estimates of the DSGE model. Together with the posterior mean point estimates, the table reports a 90 per cent confidence intervals and the acceptance rates for each Markov Chain. The acceptance rates – virtually equal the ideal 25 per cent – establish the viability of the M-H algorithm solution and confirm that the solver did not run into difficulties during application (Griffoli, 2013).

Table II shows that the estimated posterior means of the policy parameters are significantly different from prior values, thereby substantiating that they draw on important information from the data[7]. The inflation response ψ_1 exceeds one in accord with the Taylor principle required to ensure model stability (Vieira *et al.*, 2016)[8]. The large estimate of ψ_1 (>3.0) implies that the monetary authority pursues an aggressive anti-inflation policy to achieve its primary objective of maintaining price stability [CBE (Central Bank of Egypt), 2017b].

	Prior mean	Posterior mean	90% Confidence interval		Prior SD
			LB	UB	
θ	0.50	0.11	0.00	0.23	0.25
ψ	2.00	2.17	1.30	3.01	1.00
σ	3.00	2.73	1.62	3.73	1.50
ρ_R	0.50	0.84	0.75	0.93	0.20
Ψ_1	1.75	3.01	1.86	4.16	0.75
Ψ_2	0.40	0.95	0.40	1.49	0.20
Ψ_3	0.40	0.07	0.01	0.12	0.20
ρ_g	0.50	0.82	0.72	0.93	0.15
g_y	0.30	0.29	0.21	0.37	0.05
ρ_y	0.30	0.26	0.17	0.35	0.05
g_b	-0.30	-0.29	-0.38	-0.21	0.05
τ_b	0.30	0.26	0.17	0.34	0.05
ρ_τ	0.50	0.84	0.74	0.95	0.15
ρ_A	0.80	0.78	0.67	0.89	0.10
ρ_{y^*}	0.80	0.94	0.90	0.98	0.06
ρ_q	0.50	0.18	0.10	0.26	0.10
ρ_{π^*}	0.50	0.37	0.24	0.49	0.10
α	0.33	0.33	0.24	0.42	0.05
σ_π	4.00	2.77	1.09	4.57	4.00
σ_A	1.00	0.37	0.25	0.47	4.00
σ_{π^*}	0.60	3.93	3.24	4.62	4.00
σ_{y^*}	5.00	4.15	1.70	6.97	4.00
σ_R	0.40	0.20	0.11	0.29	4.00
σ_g	2.00	0.55	0.45	0.63	4.00
σ_τ	1.00	0.14	0.12	0.15	4.00
σ_q	1.88	2.53	2.13	2.91	0.49
Acceptance (%)			25.33; 25.04		

Table II.
Estimation results

With an estimated value of $\psi_2 = 0.95$, CBE apparently attaches substantial importance to output targeting. In contrast, the response of CBE to exchange rate variance is not quite as intense. The posterior mean for ψ_3 reveals that the CBE responds to a nominal depreciation with a monetary tightening equal 7 per cent of the initial percentage-point exchange rate. Moreover, interest rate smoothing considerably influences CBE policy decisions ($\rho_R = 0.84$) [9].

The estimates of the policy parameters are qualitatively consistent with empirical DSGE literature. According to [Lubik and Schorfheide \(2007\)](#), the inflation response parameter ψ_1 typically falls between 1.84-2.49 while ψ_2 and ψ_3 range from 0.15-0.29 and 0.07-0.24, respectively. Except for a higher output response [10], the estimates seem in line with previous findings characterizing monetary policy in Egypt ([Moursi and El Mossallamy, 2010](#)).

All the fiscal policy parameters are statistically significant ([Table II](#)). The large values of the lagged fiscal coefficients for government spending and taxes ($\rho_g = 0.82$ and $\rho_\tau = 0.84$) emphasize the influential role of policy smoothing in the evolution of fiscal strategies in Egypt. As $g_y > 0$, government spending is pro-cyclical (increases during booms and falls in recessions). Such pro-cyclicality is a common feature in developing countries, which is frequently attributed to credit supply problems that occur in periods of economic downturn ([Kaminski et al., 2004](#)). Moreover, pro-cyclic government spending could be intensified when a bulk of the government budget is composed of fixed expenses that the fiscal agent cannot directly adjust in the short-run e.g. wage bill and interest payments in the case of Egypt ([Panizza, 2001](#)).

The positive correlation between (past) output and income tax ($\tau_y > 0$) denotes a counter-cyclical fiscal policy. As tax revenues are under the fiscal authority's control, the government has the flexibility to interfere by cutting (raising) taxes during recessions (booms) to stabilize the economy by stimulating the economic activity during a downturn period and restraining it during an upturn.

[Table II](#) portrays the posterior mean estimates for the feedback coefficients of debt stock in the government spending (-0.29) and income tax (0.26) rules. The significance of both estimates confirms the importance of the debt stabilization motive in the conduct of fiscal policy. The positive sign of τ_b shows that a rise in debt stock induces the fiscal agent to raise taxes to stabilize debt. Alternatively, $g_b < 0$ implies that an increase in debt is accompanied by contractionary fiscal policy that reduces government expenditure. Accordingly, the fiscal authority in Egypt seems to embrace a passive policy in the [Leeper \(1991\)](#) sense. This means that the fiscal authority is required to generate sufficient revenues – by adjusting taxes and/or government spending – to balance the budget deficit while restricted by the monetary authority behavior. Thus, the fiscal decision rule is a function of current public debt position.

Finally, the trade openness estimate ($\alpha = 0.33$) exceeds the actual share of Egyptian imports in GDP (27 per cent). A higher level of openness may reflect stronger effects of nominal exchange rate on prices. As exchange rate movements affect domestic inflation through import price changes, higher trade openness implies stronger exchange rate pass-through effects on inflation as the economy becomes more vulnerable to international price shocks. Though statistically identified, the relation between the prior and the posterior estimate of α reveals that openness may not be driven by the data, especially, that the estimated posterior mean is close to its prior value, thereby supporting that it does not draw on important information from the data. The Calvo parameter (θ) implies that the average length of contracts is kept constant for a tad over one quarter. Hence, firms resort to adjust prices frequently owing to economic volatility ([Smets and Wouters, 2003](#)).

4.4 Posterior transmission dynamics

Bayesian impulse response functions (IRFs) are displayed in a graphical matrix (Figure 1). The IRFs describe the dynamic effects of stochastic shocks on endogenous variables in the model at the posterior mean of the parameter estimates. Figure 1 depicts the mean response (solid line) of the endogenous variables flanked by 90 per cent upper and lower confidence intervals (dotted lines). In each plot, the y-axis expresses deviations from the steady state owing to a shock and the x-axis represents a time horizon spanning 40 quarters. That horizon is sufficient for all variables to return to steady-state values following a shock, thus providing further validation for stability of the model solution.

The first row in Figure 1 depicts the effects of a positive monetary shock on endogenous variables. The tight confidence bands assert statistical significance of the estimated responses. As expected, a contractionary monetary shock reduces both output and inflation. Higher interest rate increases the cost of debt services, which raises real government debt. Accumulation of debt stock induces the fiscal authority to implement a tight stabilization policy (i.e. increase income tax and reduce government spending) to offset the increase in debt. These responses are naturally consistent with the posterior point estimates of the fiscal Taylor rules (Table II). Furthermore, except for inflation, responses of the selected variables require a relatively extended period to dissipate, implying a sizable degree of persistence in the monetary policy shock transmission mechanism.

An increase in government spending normatively induces a rightward shift in the IS curve driving up nominal interest rate, output and prices. Figure 1 shows that the increase in output and interest rate arising from a positive government spending shock dissipates within almost eight quarters. The increase in inflation upon impact seems statistically insignificant. This limited effect on inflation may result from the opposing effect of higher interest rates on prices. Fiscal expansion increases government deficit owing to the positive response of fiscal debt to a government spending shock. The effect is further magnified by the impact of increasing debt interest payments caused by the rise in the level of nominal interest rate. To finance debt service payments, the fiscal authority responds by raising taxes. The effects on debt and taxes persist for some time after the shock.

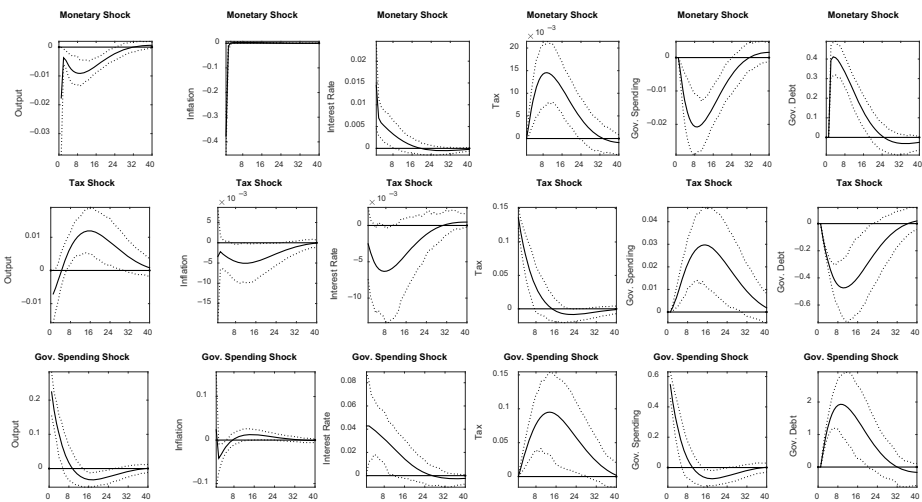


Figure 1.
IRF to policy shocks

Tight fiscal policy (a positive tax shock) considerably curbs government debt through raising tax revenues, which promote increases in government spending. For the first year and half or so (six quarters), the positive income tax shock entails counter-cyclical policy exhibiting contractionary effects. The counter-cyclicity is reversed as the increase in government spending associated with higher fiscal revenues dynamically outweighs the negative tax effects and propels growth (Figure 1). The diagram also illustrates that a tax shock has no statistically significant effect on monetary policy and consequently does not affect domestic inflation.

So far the paper has focused on analyzing the behavior of monetary and fiscal policies using Taylor instrument rules. In the following section, policy reaction functions are reformulated within an OSR optimization setting.

5. Optimal monetary and fiscal policy analysis

Several papers including Bache *et al.* (2010) study the conduct of monetary policy within a general equilibrium framework under two alternative modeling formulations. The first formulation examines monetary policy reaction functions with simple instrument rules; the second (OSR) focuses on gauging monetary policy objectives by optimizing an intertemporal loss function to derive an optimal policy rule. Bache *et al.* (2010) contrast estimates derived from each of those formulations using a DSGE model for Norway. They find that the two monetary policy specifications lead to similar policy responses. The following results show this is not the case for Egypt.

5.1 Bayesian optimal simple rule estimation

It is stipulated that monetary and fiscal authorities are committed to an OSR by minimizing a weighted intertemporal quadratic loss function, which quantifies welfare losses that occur when the volatility of the selected target variables increases. The specification of the loss function, therefore, varies depending on the chosen target variables and on weights assigned to each of those variables (Adjemian *et al.*, 2014).

In this study, the loss function comprises both monetary and fiscal policy targets. The monetary authority is presumed to minimize the weighted average of the variances of three target variables: inflation, output and exchange rate. The loss function introduces a penalty on excessive fluctuations in the overnight policy rate. Moreover, fiscal authority targets debt and output stabilization while controlling for extreme government spending and income tax movements. The choice of elements of the weighting matrix multiplied by the set of target variables entering the OSR maximand is a function of the preferences that characterize different policy strategies of the monetary and fiscal agents. The study proposes three (hypothetical) combinations of weights for the OSR simulations corresponding to different preference mixes of monetary and fiscal agents.

Table III depicts the target variables weights for the three scenarios. The first (Scenario I) assigns equal weights for monetary and fiscal policy targets, allowing central bank to consider inflation and other target variables. In this case, the monetary authority is said to be committed to flexible rather than strict inflation targeting (Svensson, 1997). With flexible inflation targeting, it would be possible to maintain moderate levels of exchange rate volatility, thus permitting analysis of the impact of monetary policies directed at stimulating economic growth via enhancing investment incentives. Scenario II (III) suggests moderately high (low) weights for monetary relative to fiscal targets in comparison with Scenario I.

The OSR problem involves minimizing a loss function consisting of the weighted sum of (unconditional) finite variances of the deviation of the selected target variables from the steady state subject to a linear law of motion derived from the first order approximation of

the equilibrium conditions represented by the DSGE model (Adjemian *et al.*, 2014 and Vieira *et al.*, 2016)[11]. A subset of the DSGE model parameters, namely the monetary and fiscal policy coefficients, is selected for optimization. The OSR computation is performed via a numerical optimization algorithm[12].

The optimal policy parameters and corresponding loss function estimates for each scenario are reported in Table IV. The OSR estimates confirm that the inflation coefficients satisfy the Taylor principle ($\Psi_1 > 1$). Because the estimates of Ψ_1 range from 1.42 to 2.08, the scenarios generally suggest that it is better for the monetary authority to moderately target inflation. The magnitude of the inflation coefficient depends on policy preferences. Assigning relatively bigger weights for monetary compared to fiscal targets (Scenario II) gives higher priority to inflation targeting ($\Psi_1 = 2.08$). However, all the OSR estimates of Ψ_1 are fairly lower than the posterior inflation coefficient derived from the Taylor rule (3.01).

In contrast with a rather high output coefficient estimate in the Taylor rule ($\Psi_2 = 0.95$), the OSR discloses an almost muted response to output in the three scenarios: monetary authority will not significantly respond to output fluctuations when formulating an optimal policy (Table IV). A possible reason for the subdued OSR output feedback response is that successful inflation stabilization by the monetary authority may itself lead to output stabilization. Hence, CBE does not account for output fluctuations when optimally setting the operational target (Vieira *et al.*, 2016)[13].

The OSR scenarios reveal that the monetary authority could be better off if it were to target exchange rate variations. As shown in Table IV, the OSR exchange rate coefficients

Table III.
Preferences weights
for monetary and
fiscal targets

Weights	Policy scenarios		
	Scenario I	Scenario II	Scenario III
ω_π	1.0	1.0	0.5
ω_y	1.0	1.0	0.5
ω_e	1.0	1.0	0.5
ω_R	1.0	1.0	0.5
ω_B	1.0	0.5	1.0
ω_τ	1.0	0.5	1.0
ω_g	1.0	0.5	1.0

Table IV.
Policy parameters
and loss functions for
OSR scenarios

	Posterior mean*	Scenario I	Scenario II	Scenario III
Ψ_1	3.01	1.53	2.08	1.42
Ψ_2	0.95	8.24×10^{-05}	2.04×10^{-04}	1.89×10^{-05}
Ψ_3	0.07	0.55	1.05	0.34
τ_y	0.26	0.20	0.39	0.14
τ_b	0.26	3.17	1.78	4.23
g_y	0.29	0.37	1.14	0.08
g_b	-0.29	-1.18	-0.46	-5.61
ρ_R	0.84	0.42	0.53	0.39
ρ_g	0.82	0.22	0.47	0.08
ρ_τ	0.84	0.01	0.01	0.01
Loss Function		37.32	35.16	20.16

Note: *DSGE simple Taylor rule point estimates (see Table 2)

(Ψ_3) are markedly larger – ranging from 0.34 to 1.05 – compared with the analogous Taylor rule estimate (0.07). Scenario II reflects the biggest exchange rate response (1.05) because of relatively bigger monetary policy weights.

The OSR estimates show that the fiscal authority heavily targets debt stabilization. Table IV illustrates that optimal values of τ_b range from 1.78 to 4.23, while optimal g_b levels fall between -0.46 and -5.61 . Despite considerably larger reactions implied by the OSR parameters *vis-à-vis* fiscal Taylor rule estimates, the direction of corresponding OSR and Taylor rule responses remains the same, i.e. government spending (income tax) response is negatively (positively) associated with positive debt shocks. Assigning bigger weights for income tax (relative to monetary) targets accentuates the fiscal authority tendency to adjust taxes to balance the intertemporal government budget. Hence, according to the OSR scenarios, optimal Egyptian fiscal behavior is consistent with a Leeper (1991) passive policy. In case of an increase in fiscal debt, a passive Leeper monetary stance would support the consolidation of the fiscal balance and promote economic growth, accompanied though with higher inflationary pressure. Alternatively, if CBE were to adopt an active policy, then the fiscal debt stabilization policy may get restrained by the discretionary effects of monetary policy. Hence, in view of what is mentioned above concerning active monetary policy, prevailing public debt would not preclude CBE in adjusting its policy instrument to gain price stability. Alternatively, the passive fiscal authority is dominated by the monetary authority behavior and is obliged to finance the government budget deficit.

The OSR findings reveal that the fiscal authority moderately targets output stabilization, especially when assigning relatively higher weights to output variability in the objective function (Scenario II). Table IV shows that the optimal income tax response to output (0.39) in Scenario II exceeds the analogous posterior mean (0.26) estimated under the Taylor rule equation. This pattern is more pronounced when government spending is used as a fiscal instrument.

The pro-cyclicality of government spending is a common feature in many developing countries adopting a fiscal Taylor rule (Gavin and Perotti, 1997). The optimal fiscal rule estimates reported in Table IV provide supporting evidence. The positive estimates of g_y suggest that optimized government spending in Egypt is pro-cyclic, increasing during a boom and falling in periods of recession. Kaminski *et al.* (2004) attribute pro-cyclicality of fiscal policy in developing countries to credit constraints that arise during bad times. In periods of recession, instead of stabilizing the economy by promoting economic activity through fiscal stimulus, countries cut government expenditure as they confront difficulties in borrowing, especially if they suffer from high interest payments and accumulated budget deficit. Lack of international financing during periods of downturns may lead to a rise in interest rate owing to the increase in the risk premium of the country.

Analogous to previous results, pro-cyclicality of government expenditure in Egypt is captured by the OSR. The substantial share of fixed expenses in total expenditure limits government capacity to implement an optimal independent fiscal policy, as these expenses represent outcomes of earlier decisions that are not easily adjustable without prompting economic imbalances (Gavin *et al.*, 1996). The average wage bill and interest payments in Egypt hovered around 25 and 28 per cent, respectively, during the period 2014/15-2016/17.

The OSR estimates demonstrate counter-cyclicality of income taxes, $\tau_y > 0$ (Table IV). As tax revenues are under the fiscal authority's control, optimal fiscal strategies recommend

that government interfere by collecting higher taxes during booms and cutting taxes during recessions to maintain stability and lessen adverse effects on budget deficit during economic downturns.

Finally, the Taylor rule results imply that both monetary and fiscal decisions are excessively transparent to the extent that may limit their effect on strategic policy outcomes if rational economic agents build predictable future policies into the decision mechanisms. The OSR scenarios emphasize that monetary and fiscal agents should depend less on policy smoothing. Table IV shows that the optimal smoothing parameters (ρ_R , ρ_g and ρ_τ) – ranging from 0.39 to 0.53 – are much less than the analogous estimates obtained from the monetary and Taylor-type fiscal rules (0.82-0.84), suggesting that the OSR supports immediate substantial responses to shocks.

6. Conclusion

The paper uses a New Keynesian DSGE model for the Egyptian economy to assess the interactions and contribution of monetary and fiscal policies to economic stabilization. The study uses Taylor-type rules and an OSR to explore the economic outcomes of monetary and fiscal authority commitment to different policy instruments. The DSGE model is calibrated using quarterly data for the period FY2004/2005:Q1-FY2015/2016:Q4 and the structural policy parameters are estimated using Bayesian techniques.

The results show that monetary and fiscal policy instruments (interest rate and government spending and taxes, respectively) in Egypt contribute to economic stability through their effects on inflation, output and debt stock. The monetary policy Taylor rule estimates reveal that CBE attaches significant importance to anti-inflationary policy and (to a lesser extent) to output targeting but responds weakly to nominal exchange rate variations. CBE decisions are significantly influenced by interest rate smoothing, which render its policy overtly transparent and anticipated i.e. insufficiently effective.

Egyptian fiscal policy has an important role in output and government debt stabilization. The results show that the fiscal authority opts for debt stabilization according to a [Leeper \(1991\)](#) passive policy. This means that the fiscal authority adjusts its policy instruments in response to public debt (i.e. it increases taxes and/or reduces government expenditures to counterbalance budget deficit). Additionally, the fiscal authority chooses pro-cyclical government spending and counter-cyclical tax policies for output stabilization. Again past values of the fiscal instruments are influential in the evolution of the future fiscal policy-making process.

Optimal policy parameter estimates based on an OSR suggest it would be better if CBE moderately responds to inflation and targets exchange rate variations. However, monetary authority will not accommodate output fluctuations when optimally setting its operational target. Furthermore, the OSR supports adopting a [Leeper \(1991\)](#) passive fiscal stance that (in contrast with monetary policy) moderately targets output stabilization. In the OSR optimization mode, government spending in Egypt exhibits a pro-cyclical pattern that could be attributed to the substantial share of fixed expenses in total expenditure, which limit the ability of the government to implement fiscal policy adjustments that are independent of past decisions without prompting economic imbalances. As tax revenues are readily under the fiscal authority control, optimal government policy should consider implementing a counter-cyclical tax policy to stabilize the economy and reduce fiscal budget

pressures during economic downturns. Finally, the OSR scenarios emphasize that the monetary and fiscal agents should limit dependence on policy smoothing.

Notes

1. According to [Leeper \(1991\)](#), a policy is active/passive conditional on its reaction to public debt shocks.
2. CBE has announced its commitment to 13% ($\pm 3\%$) inflation target ([CBE, 2018](#)).
3. The corridor system was introduced in June 2005 to manage monetary policy by imposing a ceiling and a floor on the overnight rate in order to control inflationary pressure ([CBE, 2010](#)).
4. The choice of prior densities imposes size restrictions on the first moment of the parameters. Gamma and inverse Gamma distributions restrict the mean to be positive, Beta distribution restricts it to fall between zero and one and normal distribution allows for a non-bounded mean ([Almeida, 2009](#)).
5. The complete set of requirements for inflation targeting have not yet been installed in Egypt.
6. See [Moursi and El Mossallamy \(2010\)](#) for Egypt and [Lubik and Schorfheide \(2007\)](#) for international evidence.
7. Formal tests (not reported) show that all the parameter estimates are statistically identified, indicating that the model fits the observed data well.
8. The Taylor principle states that one percentage point increase in inflation leads the monetary authority to raise nominal interest rate by more than one percentage point, which guarantees that the real interest rate increases when inflation rises ([Taylor, 1999](#)). Since a rise in real interest rate reduces output and leads to lower inflation, the Taylor principle ensures economic stability by precluding inflationary spirals.
9. Empirical evidence suggests that the interest rate smoothing parameter typically ranges from 0.7-0.9 ([Lubik and Schorfheide, 2007](#)).
10. [Moursi and El Mossallamy \(2010\)](#) find smaller output response (0.21) in Egypt during the period 2002-2008, suggesting less concern about output in comparison with inflation targeting.
11. Stationarity of the endogenous variables ensures that variances are finite.
12. The Matlab toolbox Dynare ([Adjemian et al., 2014](#)) is used to solve the OSR numerical optimization problem.
13. [Schmitt-Grohé and Uribe \(2007\)](#) study optimal monetary and fiscal policy rules within a business cycle model. They find that an optimal interest rate rule with an inflation coefficient exceeding unity and a small output coefficient promote welfare gains.

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Appendix

The DSGE model equations are presented below. Description of parameters not defined in this Appendix is listed in [Table I](#):

1. IS curve

$$y_t = E_t y_{t+1} - E_t \Delta g_{t+1} - \frac{1}{\sigma_\alpha} (R_t - E_t \pi_{t+1}) - \frac{(1 + \varphi)}{\sigma_\alpha + \varphi} (1 - \rho_a) A_t - \frac{\alpha}{\sigma_\alpha} E_t \Delta q_{t+1} - \frac{\alpha \varphi (\omega - 1)}{\sigma_\alpha + \varphi} (1 - \rho_{y^*}) y_t^* \quad (1)$$

where $\sigma_\alpha = \frac{\sigma}{1-\alpha(2-\alpha)(1-\sigma\eta)}$ and $\omega = \sigma\eta + (1-\alpha)(\sigma\eta - 1)$, η is the elasticity of substitution between domestic and foreign goods, Δ is the first difference operator, output $y_t = \ln(Y_t/\bar{Y}) = y_t - \bar{y}$ (\bar{y} is the steady state value of y_t), g_t is government spending, R_t is nominal interest rate, π_t is domestic inflation, q_t denotes terms of trade and y_t^* and A_t represent world output and technology processes, respectively (Lubik and Schorfheide, 2007).

2. New Keynesian Phillips Curve

$$\pi_t = \beta E_t \pi_{t+1} + \alpha \beta E_t \Delta q_{t+1} - \alpha \Delta q_t + \lambda [(\sigma_\alpha + \varphi)(y_t - \bar{y}_t) - \sigma_\alpha g_t + \tau_t] + \epsilon_t^\pi \quad (2)$$

where \bar{y}_t is potential output: $\bar{y}_t = \frac{(1+\varphi)}{(\sigma_\alpha + \varphi)} A_t - \frac{(\sigma - \sigma_\alpha)}{(\sigma_\alpha + \varphi)} y_t^*$, λ is the slope of the New Keynesian Phillips curve: $\lambda = \frac{(1-\beta\theta)(1-\theta)}{\theta}$, marginal cost = $(\sigma_\alpha + \varphi)(y_t - \bar{y}_t) - \sigma_\alpha g_t + \tau_t$, τ_t denotes income taxes and ϵ_t^π is a cost-push shock.

3. Monetary policy Taylor rule

$$R_t = \rho_R (R_{t-1} - R_{t-1}^n) + (1 - \rho_R) (\Psi_1 \pi_t + \Psi_2 (y_t - \bar{y}_t) + \Psi_3 \Delta e_t) + R_t^n + \epsilon_t^R \quad (3)$$

R_t^n is natural interest rate: $R_t^n = \frac{(1+\varphi)\sigma_\alpha}{\sigma_\alpha + \varphi} (\rho_a - 1) A_t + \frac{\alpha\varphi(\omega-1)}{\sigma_\alpha + \varphi} (\rho_{y^*} - 1) y_t^*$ and ϵ_t^R is a monetary policy shock (Cebi, 2011).

4. Exchange rate equation

$$\pi_t = \Delta e_t + (1 - \alpha) \Delta q_t + \pi_t^* \quad (4)$$

where e_t is nominal exchange rate and π_t^* is a world inflation shock.

Fiscal Taylor-type rules

5. Government spending

$$g_t = \rho_g g_{t-1} + (1 - \rho_g) [g_y (y_{t-1} - \bar{y}_{t-1}) + g_b b_t] + \epsilon_t^g \quad (5)$$

6. Taxes

$$\tau_t = \rho_\tau \tau_{t-1} + (1 - \rho_\tau) [\tau_y (y_{t-1} - \bar{y}_{t-1}) + \tau_b b_t] + \epsilon_t^\tau \quad (6)$$

where b_t is nominal debt stock and ϵ_t^g and ϵ_t^τ are government spending and tax shocks, respectively.

7. Fiscal solvency constraint

$$b_{t+1} = R_t + \frac{1}{\beta} \left[b_t - \pi_t + (1 - \beta)(\tau_t - y_t) + \frac{\bar{C}}{\bar{B}} (g_t - \tau_t) \right] \quad (7)$$

where \bar{C} and \bar{B} are steady state consumption and debt to GDP ratios, respectively.

$$\Delta q_t = \rho_q \Delta q_{t-1} + \epsilon_t^q \quad (8)$$

$$y_t^* = \rho_{y^*} y_{t-1}^* + \epsilon_t^{y^*} \quad (9)$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \epsilon_t^{\pi^*} \quad (10)$$

$$A_t = \rho_A A_{t-1} + \epsilon_t^A \quad (11)$$

where ϵ_t^q , $\epsilon_t^{y^*}$, $\epsilon_t^{\pi^*}$ and ϵ_t^A are exogenous shocks for terms of trade, world output, world inflation and technology, respectively.

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