MONETARY POLICY RESPONSE TO EXCHANGE RATE MOVEMENTS: THE CASE OF EGYPT

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Abstract

The primary objective of this paper is twofold. First, it examines the design and conduct of monetary policy in Egypt. Second, it verifies whether “fear of floating” induces the Central Bank of Egypt to regularly resort to policy amendments as a means of smoothing exchange rate fluctuations. Consequently, the study provides an assessment of the credibility of the CBE commitment to floating the pound and evaluates the extent to which exchange rate movements are taken into consideration when formulating monetary policy. Both issues are addressed in the context of a dynamic stochastic general equilibrium (DSGE) model that simulates the performance of monetary policy in Egypt within a SOE setting characterized by a flexible exchange rate, perfect capital mobility and an inflation targeting mechanism described by a generic Taylor-type interest reaction function.

ملخص

يتمثل الهدف الرئيسي من هذه الورقة في تحليل تصميم وأداء السياسة النقدية في مصر، والتحقق فيما إذا كان "الخوف من التعويم" يدفع البنك المركزي المصري إلى القيام بتعديلات منتظمة في السياسات كوسيلة لتمهيد التقلبات في سعر الصرف. وبالتالي، تتناول الورقة بالتقييم مدى مصداقية التزام البنك المركزي المصري بتعويم الجنيه، ومدى مراعاة التحركات في سعر الصرف عند وضع السياسة النقدية. وتتناول الدراسة هذين الأمرين في سياق نموذج توازن عام عشوائي ديناميكي يحاكي أداء السياسة النقدية في مصر في إطار اقتصاد صغير مفتوح يتسم بسعر صرف مرن، وحرية كاملة لانتقال رأس المال، وآلية لاستهداف معدل التضخم توضحها دالة عامة من نوع تايلور تحدد استجابة سعر الفائدة.

1. INTRODUCTION

During most of the period from the early 1990s until 2003, maintaining price stability and stabilization of the exchange rate remained more or less the primary objectives of monetary policy in Egypt. These objectives were seen as essential for sustaining appropriate levels of investment and promoting economic growth. Other occasionally conflicting goals including controlling liquidity growth, raising foreign competitiveness, promoting exports and establishing confidence in the national currency were presumed as secondary policy targets at the time. The high inflation rates that came about in the aftermath of the liberalization (de jure, a free float) of the Egyptian pound at the end of January 2003 prompted the Central Bank of Egypt (CBE) to proclaim price stability and low inflation rates—without jeopardizing sustainable high rates of output growth—as the primary and overriding monetary policy objective.[1] By mid-2005, the CBE adopted the overnight interest rate on interbank transactions in lieu of excess bank reserves as the main operational instrument. To manage the policy instrument within the new monetary regime, the CBE established an operational framework known as the corridor system with a ceiling and a floor for the overnight interest rates on lending from and deposits at the CBE, respectively. An important issue that as yet remains unresolved concerns the role of the exchange rate in the new monetary policy framework.

The debate is still open concerning the role of the exchange rate in the formulation of monetary policy under inflation targeting with a flexible exchange rate regime (Taylor 2001). While the recent theoretical open economy monetary models could find no substantial role for the exchange rate in policy management, the relation between exchange rate movements and policy decisions—identified by the response of the central banks short-term policy instrument to exchange rate fluctuations—is empirically debatable.[2] Clarida, Gali, and Gertler (1998) illustrated using structural estimation of inflation forecast based monetary policy rules for the US, Japan and selected European countries that although the exchange rate has a rather small policy effect in terms of magnitude, that effect is statistically significant. Lubik and Schorfheide (2003, 2007) estimated the parameters of a generic Taylor-type reaction function

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[1] Despite the liberalization of the pound in 2003, Moursi, El Mossallamy and Zakareya (2007) suspected that the CBE has maintained exchange rate stability as one of its key objectives until 2005 but provided no concrete evidence to support their argument.

[2] For example, Clarida, Gali, and Gertler (2001) show that the real exchange rate is irrelevant to monetary decisions owing to the proportionate relation between the terms of trade and the output gap.

derived from a small open economy (SOE) dynamic stochastic general equilibrium (DSGE) modeling framework. Their estimates disclose that while the Bank of Canada and the Bank of England seem to target the exchange rate, the central banks of Australia and New Zealand do not. Adopting the same micro-founded modeling framework, Caputo and Liendo (2005) concluded that the Chilean central bank has not consistently offset misalignments induced by exchange rate fluctuations. In contrast, following Clarida, Gali, and Gerlter (1998), Caputo (2005) derived contradictory evidence suggesting that the Central Bank of Chile may have systematically responded to exchange rate movements. This evidence is in line with the main findings obtained by Calvo and Reinhart (2002) who demonstrated—using a sample of 39 developed and developing countries over the period January 1970-November 1999—that the monetary authorities have routinely absorbed exchange rate fluctuations through interest rate policy adjustments.

The primary objective of this paper is twofold. First, we examine the design and conduct of monetary policy in Egypt. Second, we verify whether “fear of floating” induces the CBE to regularly resort to policy amendments as a means of smoothing exchange rate fluctuations. Consequently, we are able to assess the credibility of the CBE commitment to floating the pound and evaluate the extent to which exchange rate movements are taken into consideration when formulating monetary policy. Both issues are addressed in the context of a model that simulates the performance of monetary policy in Egypt within a SOE setting characterized by a flexible exchange rate, perfect capital mobility and an inflation targeting mechanism described by a generic Taylor-type interest reaction function (Taylor 2001).[3] The Taylor rule adjusts the policy instrument in response to inflation and output as well as exchange rate movements. Within that framework, it is possible not only to test the role of the exchange rate in the policy rule—i.e., exchange rate targeting—but also to examine the stochastic behavior and relations between domestic and foreign variables, evaluate the impact of world inflation, output and terms of trade shocks on interest rate and other key macroeconomic variables and identify the policy reactions of the monetary authority to

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[3] Egypt does not have in place a formal inflation targeting regime or an explicit inflation target, though occasionally there have been official announcements of a comfortable annual headline inflation rate in the range between 6-8 percent. The actual inflation rate during the last few years hovered well above the upper threshold of that range. The government implicitly revised its headline inflation target upward by announcing a target *core* inflation rate between 6-8 percent in the aftermath of the recent world price increases and the global financial crisis in 2007 and 2008. Moursi, El Mossallamy and Zakareya (2007) and Moursi, El Mossallamy (2009) show that while the perquisites for inflation targeting are not yet met in Egypt, the CBE policy decisions can be approximated by a Taylor-type decision function.

accommodate changes in the international variables, e.g., business cycle fluctuations induced by foreign shocks (Lubik and Schorfheide 2007).

We take up the stylized new Keynesian DSGE rational expectations construct framed by Lubik and Schorfheide (2003, 2007) for a SOE as a template to model the behavioral dynamics of monetary policy and the key aggregate variables in the Egyptian economy and to estimate the policy formula parameters during the period 2002-2008. The main advantage of Lubik and Schorfheide's approach is that it allows estimating the parameters of the policy function from within a structural multivariate macroeconomic model. Hence, it is possible to consider the cross-equation restriction effects between the structural—including the policy—parameters and the decision rules of the different agents in the economy while maintaining the independence of the non-policy coefficients that characterize the economy from monetary policy (Lubik and Schorfheide 2007; Taylor 2001; Caputo and Liendo 2005). We follow Bayes procedure proposed by Lubik and Schorfheide (2007) for the estimation of the model.

Our findings show that the estimated policy coefficients and other structural parameters fit the data reasonably well. The results disclose that the CBE adopts an aggressive inflation targeting policy by offsetting deviations of output from its expected value. A posterior odds test suggests that the CBE does not regularly react to foreign exchange movements, thus, refuting the case for exchange rate targeting. We find that policy decisions reflect a significant degree of interest rate inertia, which render monetary responses overtly transparent. The analysis highlights the important role monetary policy has to play—via different transmission channels—in the Egyptian economy. The results show that the response of output and inflation to policy changes are statistically significant and of the correct sign (no puzzles encountered). The introduction of prior beliefs about the reality of the Egyptian economy in the likelihood function—in terms of restrictions imposed on the structural coefficients—seems instrumental in attaining the expected price and output responses.[4]

The rest of the paper is structured as follows. Section 2 gives a brief overview of the specification of the SOE structural DSGE macroeconomic model estimated on the data for Egypt. In Section 3, we describe the data and the choice of priors and present the Bayesian estimates for the structural parameters. Section 4 evaluates the implied behavioral dynamics

[4] Vector autoregression (VAR) and structural VAR models used to measure monetary policy in Egypt were unable to circumvent the puzzling price and output responses (Moursi, El Mossallamy and Zakareya 2007, 2008).

of the estimated model, identifies the main policy drivers and formally tests whether the CBE considers the nominal exchange rate when formulating monetary policy under alternative assumptions concerning the specification of the real exchange rate. Section 5 concludes. The appendix includes additional information in graphical and tabular format.

2. Overview of the Model

We adopt the now all too well known micro-founded structural DSGE modeling framework proposed by Lubik and Schorfheide (2003, 2007) based on the seminal work of Gali and Monacelli (2005). Lubik and Schorfheide's stylized framework has been used extensively for policy analysis in various developed and developing countries including US, Canada, New Zealand, UK, Chile, Portugal, Nigeria and Mozambique (Lubik and Schorfheide 2007; Caputo and Liendo 2005; Almeida 2009; Richard 2009; Peiris and Saxegaard 2007). Thus, we present only a brief overview of the model with the details kept to a minimum, just sufficient for the reader to logically follow the results.

The model consists of four single equations (1-4) and four autoregressive (AR) processes (5-8) that drive the evolution of the exogenous variables in the system. There are eight variables in the model; four are endogenous (output, nominal interest rate, inflation and nominal exchange rate). The remaining variables—terms of trade, world output, technology growth and world inflation—are considered exogenous. All the variables are expressed as deviations from the steady state. The model includes four policy and nine non-policy parameters as well as five stochastic shocks including the policy shock ε_t^R. The definitions, restrictions and relations between the different variables, parameters and shocks in the model are portrayed below.

Open Economy IS Curve

$$y_t = E_t y_{t+1} - [\tau + \alpha(2-\alpha)(1-\tau)](R_t - E_t \pi_{t+1}) - \alpha[\tau + \alpha(2-\alpha)(1-\tau)] E_t \Delta q_{t+1} + \alpha(2-\alpha)\frac{1-\tau}{\tau} E_t \Delta y^*_{t+1} - E_t A_{t+1} \quad (1)$$

Endogenous variables

y_t: domestic output; R_t: nominal interest rate; π_t: inflation rate

Exogenous variables

q_t: terms of trade; y_t^*: world output; A_t: technology growth

Non-policy *parameters*

τ: coefficient of relative risk aversion; α: import share (degree of openness)

Operators

E_t: conditional expectations operator based on information up until time t;

Δ: first difference operator

Open economy new-Keynesian Philips Curve (NKPC):

$$\pi_t = \beta E_t \pi_{t+1} + \alpha\beta E_t \Delta q_{t+1} - \alpha \Delta q_t + \frac{k}{\tau+\alpha(2-\alpha)(1-\tau)}[y_t - \bar{y}_t] \quad (2)$$

Exogenous variables

$\bar{y}_t$: potential output

Non-policy parameters

κ: NKPC slope coefficient; β: discount factor

Inflation equation

$$\pi_t = \Delta e_t + (1-\alpha)\Delta q_t + \pi_t^* \quad (3)$$

Endogenous variables

e_t: nominal exchange rate

Exogenous variables

π_t^*: world inflation

Policy rule

$$R_t = \rho_R R_{t-1} + (1-\rho_R)[\psi_1 \pi_t + \psi_2 (y_t - \bar{y}_t) + \psi_3 \Delta e_t] + \varepsilon_t^R \quad (4)$$

Policy parameters

ρ_R: interest rate smoothing parameter; ψ_1, ψ_2, ψ_3: Taylor rule inflation, output, exchange rate coefficients

Shocks

ε_t^R: monetary policy shock

Stochastic shock processes

$$\Delta q_t = \rho_q \Delta q_{t-1} + \varepsilon_t^q \tag{5}$$

$$y_t^* = \rho_{y^*} y_{t-1}^* + \varepsilon_t^{y*} \tag{6}$$

$$\pi_t^* = \rho_{\pi^*} \pi_{t-1}^* + \varepsilon_t^{\pi^*} \tag{7}$$

$$A_t = \rho_A A_{t-1} + \varepsilon_t^A \tag{8}$$

Non-policy parameters

ρ_q, ρ_{y*}, $\rho_{\pi*}$, ρ_A: terms of trade, world output, world inflation and technology growth smoothing coefficients

Shocks

ε_t^q, $\varepsilon_t^{y^*}$, $\varepsilon_t^{\pi^*}$, ε_t^A: terms of trade, world output, world inflation and technology growth shocks.

The forward-looking open economy IS equation (1) links the cyclical evolution of domestic output to the expected values of domestic output and technology growth. The behavioral dynamics of output are governed by the *ex-ante* real interest rate and the values of future realizations of changes in the terms of trade and world output, whose influence on domestic production is regulated by the convolutions α and τ (import share and elasticity of intertemporal substitution, respectively) to account for the inter- and intra-temporal consumption smoothing effects of foreign trade as well as relative risk aversion and habit formation.

Equation (2) is the SOE expectational NKPC that explains the dynamic evolution of the inflation rate. It reduces to the closed economy NKPC with Calvo-type purely forward-looking price expectations when α equals zero (Gali and Monacelli 2005). The inflation rate is specified as a function of the future realization of prices loaded by the discount factor (β). It is also driven by the output gap ($y_t - \bar{y}_t$), where $\bar{y}_t = \frac{-\alpha(2-\alpha)(1-\tau)y_t^*}{\tau}$ is the potential output in the absence of nominal rigidities. The output gap affects the rate of inflation through the slope of the NKPC (given the values of α and τ) and the deviation of the discounted realization of the future change in the terms of trade from its contemporaneous value whose loading is α.

The purely forward-looking orientation of the open economy NKPC is motivated by both theoretical and empirical considerations. From a theoretical perspective, the nonstructural nature of indexation to past inflation rules out the role of inflationary inertia and price staggering in structural relations. The theoretical evidence is corroborated by the empirical findings derived from studies in which the inflation target changes over time (Benati 2008; Cogley and Sbordone 2008; Castelnuovo 2009). Moreover, using a closed economy DSGE model for Egypt, Moursi and El Mossallamy (2009) point out to the low level of persistence of inflation indicated by the small estimates of the CPI price indexation coefficient.

Equation (3) defines the difference between domestic and world inflation rates—under purchase power parity (PPP)—in terms of the appreciation or depreciation of the nominal and real exchange rate fluctuations loaded by 1-α (Richard 2009). When the world inflation shocks are treated as unobservable (latent), π_t^* may pick up the effect of possible deviations from PPP (Lubik and Schorfheide 2005, 2007).

The monetary reaction function (equation 4) denotes a Taylor-type rule described by the short-term interest rate. It defines the policy response of the central bank as a weighted average of interest rate inertia, the inflation and the output gaps and exchange rate fluctuations.

The remaining four AR(1) equations (5)-(8), which characterize the exogenous processes that drive the terms of trade, world output, and inflation and technology growth subject to the relevant innovations, close the model (Lubik and Schorfheide 2003, 2007).

3. PRIOR SELECTION AND EMPIRICAL ESTIMATION

In this section, we present a description of the observable variables employed in the estimation of the parameters of the model and the priors chosen for calibration. The posterior parameters are presented along with a sketch of the empirical Bayesian estimation procedure and some basic diagnostics for evaluating the numerical solution algorithm and the statistical results and their sensitivity to selected priors.

3.1. Data

With the exception of the terms of trade, the exogenous variables in the model—world output, inflation and productivity growth and potential output—are non-observable (latent). The model was calibrated using monthly observations—mainly retrieved from the IMF-IFS 2009 CD-ROM—spanning the sample period January 2002-July 2008 on output, inflation, the policy instrument, nominal exchange rate and terms of trade changes. The output series was obtained as the month-to-month percentage real GDP per capita growth—derived by temporally disaggregating the corresponding annual real GDP per capita series—scaled by a factor of 100.[5] Inflation was measured as the annualized percentage rate of change of the monthly CPI. The policy instrument was denoted by the annualized monthly overnight interest rates on interbank transactions (CBE unpublished). Because the quality of Egyptian statistics on import and export prices is rather dubious, we identify the changes in the terms of trade by fluctuations in the real exchange rate. The nominal exchange rate was defined in Egyptian pounds per US dollar and the terms of trade were represented by the percentage change in the real exchange rate (with reference to the dollar). All the series were tested for seasonality (none detected) and demeaned prior to estimation.

3.2. Choice of Prior

The Bayesian procedure employed in estimation requires the specification of the prior probability distribution for each structural parameter. The choice of priors reflects our a-priori convictions, which were derived from historical evidence (based on pre-sample data) and previous research. Relevant size and sign restrictions on the different parameters were imposed by trimming the domain of the distribution and selecting plausible ranges for the priors (Lubik and Schorfheide 2007). We started by estimating a benchmark model, presuming no restrictions on the response of the CBE to exchange rate fluctuations i.e., the unrestricted policy rule, $\psi_3 \geq 0$. An alternate restricted version of the model—calibrated presuming $\psi_3 = 0$—was estimated later on to test the null hypothesis that the CBE does not

[5] We employ Litterman's (1983) procedure—implemented in Quilis (2004) Matlab toolbox—for temporal disaggregation (TD) of the annual real GDP per capita during the period 1988-2008. Besides the trend, the TD procedure exploits six high frequency indicator variable series correlated with the level of economic activity, namely, oil price (UK Brent), real exports, real imports, real money balances (M1), real quasi-money and real exchange rate. For lack of more suitable deflators, the nominal exports, imports, M1, and quasi-money series were deflated by the CPI (IMF-IFS 2009).

react to exchange rate movements against the exchange rate targeting alternative. The distribution density and its domain as well as the first and second moments for the priors of the different parameters in the model are depicted in Table 1.

The output, inflation and exchange rate policy parameters (ψ_1, ψ_2 and ψ_3, respectively) follow a gamma distribution. Their prior means and standard deviations are in line with the values reported by Taylor and used in earlier studies for Egypt (Lubik and Schorfheide 2003, 2007; Caputo and Liendo 2005; Taylor 2001; Moursi and El Mossallamy 2009). It has been argued that recently, monetary policy in Egypt habitually implied a strong inclination to smooth changes in nominal interest rates (Moursi, El Mossallamy and Zakareya 2007, 2008; Moursi and El Mossallamy 2009). The strong effect of the interest rate inertia manifests the CBE's "look before you leap" stance especially during the past 4-6 years hinged on shelving policy changes until newly emerging market information was completely assimilated in order to ensure stability and avoid undesirable perturbations in the money market. We use a beta distribution for ρ_R with mean 0.6—a bit higher in comparison with analogous priors proposed in the literature for other countries—and a relatively low standard deviation of 0.2.

Table 1. Prior Distributions

	Density	Range	Benchmark	
			Mean	Stdev
ψ_1	Gamma	$[0, +\infty)$	3.00	0.50
ψ_2	Gamma	$[0, +\infty)$	0.25	0.10
ψ_3	Gamma	$[0, +\infty)$	0.25	0.10
ρ_R	Beta	[0,1]	0.60	0.20
α	Beta	[0,1]	0.30	0.10
r	Gamma	$[0, +\infty)$	2.50	1.00
k	Gamma	$[0, +\infty)$	0.21	0.10
τ	Gamma	[0,1)	0.50	0.20
ρ_q	Beta	[0,1)	0.24	0.05
ρ_A	Beta	[0,1)	0.24	0.10
ρ_{y^*}	Beta	[0,1)	0.80	0.10
ρ_{π^*}	Beta	[0,1)	0.70	0.15
σ_R	InvGamma	$\mathbb{R}^+$	1.00	4.00
σ_q	InvGamma	$\mathbb{R}^+$	2.00	4.00
σ_A	InvGamma	$\mathbb{R}^+$	1.50	4.00
σ_{y^*}	InvGamma	$\mathbb{R}^+$	1.50	4.00
σ_{π^*}	InvGamma	$\mathbb{R}^+$	1.50	4.00

Notes: Table displays prior mean, standard deviation (Stdev) and domain range for gamma, beta and inverse gamma distributions and the upper and lower bounds of the support for the uniform distribution.

Since the model is parameterized with reference to the (annualized) steady state real interest rate (r)—rather than the discount factor—we need to set its prior. Moursi, El Mossallamy and Zakareya (2007 2008) estimated the average steady state real interest rate approximately equal to 4. Considering both the prevailing high rates of inflation in Egypt and CBE's expansionary tendencies, we have chosen a (gamma) distribution for the coefficient r with a smaller prior mean of 2.5. This value is in accord with the analogous prior reported for different developing and developed economies. The corresponding discount factor of approximately 0.998 is fairly standard in the literature.[6] We chose a relatively wide domain for r by specifying a standard deviation of 1.0 to allow for a considerable degree of generality about the information available on real interest rates in Egypt.

Moursi and El Mossallamy (2009) predicted a low value for the slope coefficient of the Philips curve (κ). Consequently, we set the prior mean of κ below the usual value (around 0.5) reported for other countries in the literature (Lubik and Schorfheide 2003; Caputo and Liendo 2005). However, because Moursi and El Mossallamy's a priori prediction of κ is excessively low (.01), we centered the prior mean of the NKPC slope at 0.21 with a standard deviation of 0.10 to be as uninformative as possible, letting the data free to indicate its value.

The prior first moment of α was determined according to the average share of total Egyptian imports in GDP during the period 1980-2001 (30 percent). Its standard deviation was 0.10, echoing the confidence in the prior mean estimate. Alternatively, in the absence of reliable information on relative risk aversion—the key determinant of the intertemporal elasticity of substitution between foreign and domestic goods—we loosely centered the prior mean and standard deviation at values coherent with the literature (0.50 and 0.20, respectively).

Excluding the monetary policy innovation (ε_t^R), all the exogenous shocks evolve according to an autoregressive process AR(1). The priors for the autoregressive parameters ρ_q and ρ_{y*} were estimated using regression analysis on historical pre-sample period data. The prior mean and standard deviation for the terms of trade were set in alignment with the estimates obtained from an AR(1) regression of the (demeaned) monthly change in real exchange rate series during the period 1995-2000. The prior moments for foreign output were specified by fitting an AR(1) for the ratio of the foreign to domestic output series measured as

[6] $\beta = e^{-r/1200}$.

the proportion between Egypt and the US real GDP growth in per capita terms.[7] The selection of the prior distribution for the rest of the world inflation shock (ρ_{π^*}) and the technology growth smoothing parameter (ρ_A) were drawn from the empirical work of Caputo and Liendo (2005). Finally, all the measurement errors—assumed to be independently distributed inverse gamma—were borrowed from Caputo and Liendo (2005). The prior means (centered between 1.0-2.0) and standard deviations (chosen equal 4.0 to be sufficiently uninformative) of those innovations are reported in Table 1.

3.3. Bayesian Estimation Results

The data and priors described above were used to get the posterior distribution of the policy and non-policy parameters of the model for Egypt using Bayesian econometric techniques.[8] Following Schorfheide (2000), An and Schorfheide (2005) and Lubik and Schorfheide (2003, 2007), the prior beliefs about the structural coefficients are first described by a density function. Then the observed data are used to update the likelihood function conditional on the model parameters and specification. The prior density and the likelihood function together characterize the posterior density and, consequently, the marginal data density—conditional on the model—from which the posterior moments, the propagation mechanisms for the structural shocks (impulse responses), the relative importance of the structural innovations (variance decomposition) and forecasts can be derived (Griffoli 2007). The marginal density can be used for computing hypotheses tests about different parameters in the model. The likelihood function was generated with the Kalman filter and the (un-normalized) posterior density was simulated with the Metropolis-Hastings (M-H) Monte Carlo sampling method.

A set of visual diagnostic tests is utilized to evaluate the statistical integrity of the Bayesian estimation procedure. At the outset, we plot the (log) posterior density (grey curve) for values around the computed mode (vertical dotted line)—obtained from the maximum likelihood optimization procedure—for each parameter. Successful convergence of the optimizer is denoted when mode is at the maximum of the posterior distribution (Griffoli 2007). Figure A1 reveals that the optimizer has not run into numerical difficulty. The diagram also portrays the (log) likelihood kernel depicted by the black curve. There is no information

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[7] The foreign and domestic per capita real GDP series were expressed in purchasing power parity (Heston, Summers, and Aten 2009). The AR(1) regression employed annual data from 1982-2000 and the series were demeaned prior to the estimation.

[8] Bayesian estimation is conducted using the matlab toolbox Dynare (Juillard 2004).

in the data for the parameters whose log likelihood kernel is flat lying above the log posterior curve. Except for the case of the steady state real interest rate, the diagram illustrates that the data are informative for all the estimated parameters.

The sensibility of the M-H simulations is examined using the univariate Monte Carlo Markov Chain (MCMC) diagnostics charts displayed in Figure A2 for each coefficient. The horizontal axis in each chart represents the number of M-H iterations and the vertical axis measures the parameter moments. Three measures are reported for the different parameters: an 80 percent confidence interval around the parameter mean (interval), the variance (m2) and the third moment (m3). For each measure, the charts portray light grey and black lines measuring the parameter vectors within and between chains, respectively. The sensibility of the M-H algorithm requires that the simulations are similar within and across the chains. In that case, both lines should display little variability and converge (Griffoli 2007). The diagram shows—probably with the exception of the world output measurement error and to a lesser extent the intertemporal elasticity of substitution—that the moments for all the parameters of the model appear stable and convergent. The multivariate MCMC tests demonstrated in Figure A3 are analogous to the univariate tests; they represent, however, an aggregate measure of stability and convergence based on the eigenvalues of the variance covariance matrix of the coefficients (Juillard 2008; Griffoli 2007). The multivariate MCMC diagnostics support the plausibility of the M-H optimizer solution.

To complement the above validation checks, Figure A4 juxtaposes the prior (grey) and posterior (black) distributions for the parameters of the model. The vertical (light grey) line in each chart identifies the posterior mode from the numerical optimization simulations. Probably with the exception of the terms of trade, technology and world inflation innovations and to some extent the exchange rate targeting and import share parameters, the prior and posterior distributions are fairly close. The plotted posterior distributions do not appear to deviate substantially from normality and the optimization mode is quite similar to the posterior mode indicating that both the data and the selected priors are generally informative about the parameters.

Finally, Figure A5 illustrates the estimated smoothed shocks. The horizontal axis in each plot denotes the length of the sample period. Visual inspection supports the consistency of the expected path of the shocks with the realized estimates of the innovations, demonstrated by the clustering of the smoothed shocks estimates around zero.

The posterior parameter mean and 5th and 95th percentiles—corresponding to the posterior distributions portrayed in Figure A3—estimated by M-H sampling are reported in Table 2. The table also presents the values of the marginal likelihood calculated with both the Laplace approximation and the harmonic mean estimator as well as the average acceptation rate used for evaluating the performance of the M-H algorithm. The statistical indicators found in Table 2 support the reasonableness of our prior distribution choices and the plausibility of the M-H simulations (see footnote to Table 2).

Table 2. Posterior Estimation Results

	Policy rule $\psi_3 \geq 0$			**Alternative $\psi_3 = 0$**		
	Mean	**5%**	**95%**	**Mean**	**5%**	**95%**
ψ_1	2.57	1.76	3.42	2.02	1.28	2.73
ψ_2	0.21	0.07	0.34	0.21	0.08	0.34
ψ_3	0.05	0.01	0.08	0	-	-
ρ_R	0.80	0.70	0.89	0.67	0.53	0.82
α	0.04	0.02	0.06	0.04	0.02	0.06
r	2.49	0.91	4.03	2.48	0.92	3.98
k	0.20	0.05	0.35	0.34	0.12	0.55
τ	0.29	0.15	0.43	0.34	0.18	0.48
ρ_q	0.29	0.21	0.38	0.28	0.20	0.36
ρ_A	0.07	0.02	0.11	0.05	0.01	0.08
ρ_{y^*}	0.79	0.70	0.88	0.79	0.70	0.88
ρ_{π^*}	0.44	0.30	0.58	0.55	0.40	0.69
σ_R	0.52	0.44	0.61	0.52	0.43	0.61
σ_q	5.07	4.43	5.74	5.08	4.41	5.76
σ_A	5.82	5.03	6.59	5.74	4.99	6.49
σ_{y^*}	4.45	0.80	8.35	4.32	0.67	8.07
σ_{π^*}	9.09	7.90	10.27	9.09	7.87	10.29
Marginal likelihood						
Harmonic	-1337.15			-1328.15		
Laplace	-1337.87			-1325.81		
Acceptance	0.23,0.23,0.23, 0.22,0.23			0.25,0.26,0.24, 0.24,0.24		

Notes: Mean and 5th and 95th percentiles for posterior distributions are obtained using the M-H sampling algorithm employing 150,000 draws with 5 parallel chains. All the reported estimates are based on the last 75,000 draws from each chain. The maximized log-likelihood function is represented by the log of the Laplace approximation and the Harmonic Mean i.e., the marginal data density (Lubik and Schorfheide 2007). Acceptance shows the average acceptation rate in each chain. The ideal acceptance rate is 25 percent. The reported acceptation rates across the parallel chains, which provide a numerical evaluation of the performance of the M-H algorithm, are relatively stable across blocks.

Tables 1 and 2 show that most of the parameters are data driven as indicated by the marked differences between the posterior estimates and their prior values. The long run real interest rate, the NKPC slope parameter and the foreign output persistence parameters, however, seem highly influenced by the prior values.

4. Policy Analysis

This section presents the estimated coefficients and discusses the implied dynamic behavior derived from the model. We examine the policy relevance of the different parameter estimates, evaluate the response of the key macroeconomic variables in the economy to selected exogenous shocks and test the reaction of the CBE to exchange rate movements.

4.1. Estimation Results

The posterior Bayesian estimates and confidence intervals of the structural policy response parameters (ψ_1, ψ_2, ψ_3 and ρ_R) for the unrestricted version of the model ($\psi_3 \geq 0$) are presented in Table 2. Our findings show that the CBE has maintained a firm anti-inflation position with the estimated posterior coefficient of ψ_1 exceeding 2.5. The estimated value of ψ_2=0.21 reveals a somewhat lenient policy concern about output gap targeting at least in comparison with the policy response to inflation. Moreover, the estimate of ψ_3 (0.05) is indicative of a considerably weak response to nominal exchange rate fluctuations. In general, the posterior means of the three estimated policy coefficients are considerably different from their assumed priors, confirming that they draw on important information from the data. The posterior estimate of ρ_R with an average of 0.80 reveals a significantly high degree of interest rate smoothing. This result is in line with previous findings describing the dynamics of interest rate inertia in Egypt (Moursi, El Mossallamy, and Zakareya 2007, 2008; Moursi and El Mossallamy 2009). Tables 1 and 2 discloses a meaningful difference between the posterior mean of the smoothing parameter and the prior implying predominance of the a priori convictions about the magnitude of ρ_R.

The foreign trade openness parameter (α=0.04) is considerably lower than the observed share of imports in GDP. Lubik and Schorfheide (2007) argue that such a situation can arise when the estimation procedure attempts to select a value for α that reconciles the volatilities in inflation and the terms of trade related by the inflation equation (3) while obeying the cross-coefficient restrictions imposed by the IS and NKPC equations 1 and 2, respectively. The real exchange rate in the inflation equation is loaded by (1-α). Consequently, the low posterior estimate of openness implies the reconciliation between inflation and the terms of trade—given the restrictions—is satisfied when most of the volatility in the real exchange rate is transmitted to domestic price movements. In addition, the low openness solution suggests that the nominal exchange rate would have a relatively weaker effect on domestic prices—all other things constant—because of the increased importance of real exchange rate variances, in which case the CBE would not be compelled to adopt strict nominal exchange rate targeting. The CBE, therefore, would compensate for the weak foreign exchange targeting by resorting to more aggressive inflation targeting. The low openness solution, therefore, manifests the model's interpretation of the economy's attempt to circumvent the perils of persistent and volatile foreign relative price shocks.

The long-term real interest rate estimate of 2.49 percent suggests that the parameter is largely driven by the prior, which seems reasonable in the Egyptian case where the real interest rate—in many instances—turns negative so much so that the behavioral assumptions underlying the intertemporal choices of producers and consumers and the optimal price setting decisions by domestic firms implied by the model become inconsistent with the data. To make sense, the estimation solution is coerced to position the mean value of r as well as the slope of the NKPC (κ) in the neighborhood of the prior value, overriding the information embodied in the data. This prevents the discount factor from overshooting and upholds a stable relation between domestic inflation and the expected foreign to domestic price ratio, on one hand, and between inflation and deviations of output from its potential level, on the other hand, as denoted by equation 2. In addition, we note that the reported confidence interval for r spans a wide range from a mean real interest rate as low as 0.91 percent up to 4.03 percent. We note that the upper boundary of that interval is consistent with the steady state estimate of r derived in previous studies for Egypt (Moursi, El Mossallamy, and Zakareya 2007, 2008).

The foreign output persistence coefficient is also motivated by the prior. Nevertheless, because the posterior distribution is more concentrated relative to the prior, it is sensible to construe that ρ_y* is driven to a reasonable extent by the data at hand (Lubik and Schorfheide 2005, 2007).

The posterior mean for the coefficient of relative risk aversion (τ) diverges from the assumed prior. The elasticity of intertemporal substitution (τ^{-1}) is around 3.45. This value is noticeably higher than the analogous estimates for the UK, Canada, Australia and New Zealand (Lubik and Schorfheide 2005) and a tad above the value reported by Caputo and Liendo (2005) for Chile.

Table 3. Variance Decomposition

	Output	Inflation	Interest rate	Exchange rate
Policy	0.240	0.248	0.161	0.001
Terms of trade	0.016	0.012	0.011	0.208
Technology	0.214	0.034	0.010	0.000
World output	0.517	0.688	0.817	0.004
World inflation	0.013	0.018	0.002	0.787

The variance decomposition estimates—portrayed in Table 3—are useful to gauge the importance of each of the five structural shocks for the fluctuations in the endogenous variables. The table underscores the exposure of the Egyptian economy to (latent) foreign output shocks. Domestic output, CPI inflation and the nominal interest rate volatility are mainly driven by the world output innovations (51.7, 68.8 and 81.7 percent, respectively).[9] While the contribution of monetary policy shocks to GDP (24 percent) is relatively large, technological innovations are responsible for a small share (21.4 percent) of the movements in domestic output in comparison with corresponding estimates in the literature. Since inflation is largely driven by foreign output shocks and—to a lesser extent—by policy innovations (with a combined effect of approximately 94 percent) there is little room left for the impact of the real exchange rate, world inflation and technology shocks. The exchange rate movements are dominated by foreign price innovations, which account for over 78 percent of its variability. Thus, if foreign inflation shocks are taken as an error measuring deviations from PPP, the model would be capable of explaining about 21 percent of the Egyptian exchange rate fluctuations. In such case, the policy shocks are accountable for only 0.10 percent of the variance in the nominal exchange rate. The share of variance in the policy variable and in domestic output induced by movements in the terms of trade is small. Similarly, technical innovations do not have a substantial role in driving inflation and the nominal interest and exchange rates.

Table 2 reports the persistence and volatility posterior estimates for the structural innovations. The estimates for all the stochastic shocks, save technology growth, exhibit moderate persistence. The autocorrelation coefficients for import price inflation and terms of trade volatility are 0.44 and 0.29, respectively. It is reasonable to assume in an open economy,

[9] Lubik and Schorfheide (2007) point out that the exaggerated contribution of world output shocks to interest rate volatility might result from model misspecification, whereby the latent process picks up the impact of foreign interest rate fluctuations.

there are more channels for the propagation of shock impulses, thereby dampening the mean estimates of the degree of persistence. The persistence of foreign output shocks is significantly high averaging at 0.79. This does not represent an excessive level of persistence warranting concerns about the presence of a unit root since the posterior distribution's 95th percentile for that shock (0.88) is appreciably less than 0.93 (Almeida 2009). Alternatively, the information supported by the data show that technology growth exhibits an extremely low level of persistence (0.07). The estimated posterior mean volatility of technology shocks measured by σ_A (5.82) is markedly high both in absolute and relative terms as suggested by the prior. Egypt's increasing dependence on foreign markets for high tech commodities, inadequate human capital and labor skills and intermittent spillover effects of foreign direct investment (maybe with the exception of selected service sectors, e.g., tourism, financial, banking, etc.) are probably major contributors to the unsteady growth of technical progress particularly in the industrial sector. The highest degree of volatility is associated with foreign inflation shocks (9.09). Its effect is restrained by moderate degree of persistence (ρ_{π^*}=0.44), which together with the low level of openness safeguards against too much exposure of the Egyptian economy to relative foreign price shocks.

4.2. Policy Dynamics and the Impact of Shocks

The posterior impulse response functions (IRFs) illustrated in Figure 1 show the dynamic effect of positive exogenous shocks on the observable endogenous variables in the model. The diagram reveals that all the variables returned to their steady-state value after the shock, confirming the stability of the solution of the model.

In general, the IRFs do not seem to imply puzzling responses. Adopting a tight monetary policy results in the contraction of output and lowering the rate of CPI inflation that in turn leads to an appreciation of the domestic currency. The decrease in money supply emanating from a contractionary monetary policy raises the nominal interest rate as shown in Figure 1.

The enhancement in the terms of trade increases the level of domestic output, provoking an appreciation of the Egyptian pound. The appreciation induces a reduction in the level of inflation to accommodate the improvements in the terms of trade and GDP. It also induces the monetary authority (CBE) to lower the interest rate. The expansionary monetary policy reinforces the output growth.

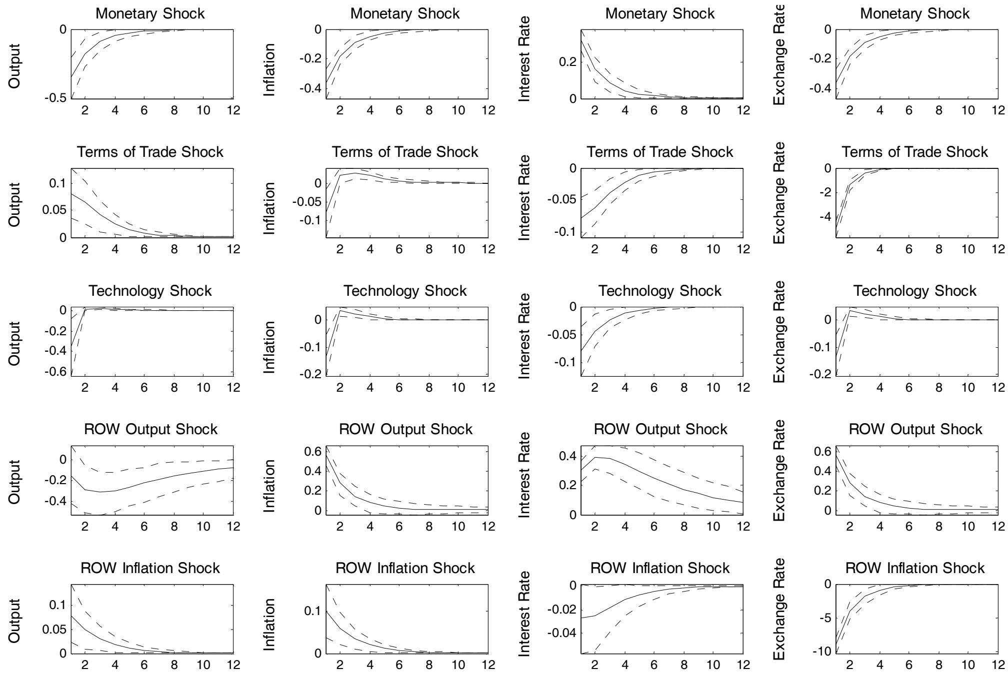
A stationary productivity enhancement reduces the marginal costs of production for domestic goods leading the level of domestic inflation to decline. Lower domestic prices spell higher relative prices of imported and foreign goods. Consequently, for a given value of relative risk aversion, the domestic currency appreciates to thwart a decrease in the preference parameter (below the estimated τ=29 percent) and excessive exportation owing to the rise of relative prices of foreign goods.[10] The appreciation of the pound brings on an excess supply of output that the monetary authority tends to absorb by relaxing policy, thus reinforcing the expansionary effect of the technological innovation on the economy with further fall of domestic prices. We have seen in the previous section, however, that technology shocks exhibit low levels of persistence and explain little of the variability in the endogenous variables in the model. The IRFs for the technology shocks depicted in Figure 1 reflect these findings.

The increase in world output has an adverse effect on domestic production that intensifies inflationary pressure.[11] Following the argument in the previous paragraph, the higher domestic prices result in a depreciation of the exchange rate to accommodate a given foreign import share. The CBE raises the interest in response to the depreciation, intensifying the contractionary effect on the economy. With a similar reasoning, innovations in relative world prices trigger an appreciation of the Egyptian pound and an increase in domestic prices. As the value of the pound rises, the CBE lowers nominal interest rates, augmenting the expansionary effect of the shock on output.

[10] The analysis holds for values of τ less than 1, implying domestic and foreign goods are substitutes (Lubik and Schorfheide 2007).

[11] Again this is implied by τ<1.

Figure 1. Impulse Response Posterior Mean (-) and 90% Posterior Confidence Interval (--) to One Standard Deviation Shocks



4.3. Evaluating Response to Exchange Rate Movements

To test whether the CBE targets exchange rate, the model is re-estimated while closing the foreign policy transmission channel (policy rule ψ_3=0), keeping the values of all the other priors unchanged. The diagnostic tests for the maximum likelihood procedure and the M-H sampling solver of the restricted model are satisfactory and similar to the comparable tests of the benchmark estimation.[12] Table 2 reports the alternative posterior mean and probability interval for the different parameters. With few exceptions (inflation targeting and smoothing coefficients, slope of the Phillips curve and degree of relative risk aversion parameter), the posterior estimates under the two policy rules ($\psi_3 \geq 0$ and ψ_3=0) are qualitatively similar. The alternative policy rule suggests less aggressive inflation targeting. The posterior mean of the interest rate inertia coefficient is now smaller (0.67) but still indicative of a considerable degree of policy smoothing. The slope of the NKPC increases under the alternative policy rule and this is accompanied by a drop in the intertemporal elasticity of substitution from 3.45 to 2.94. The loading of the output gap in the Phillips curve is a function of the NKPC slope coefficient adjusted for the preference parameter and the degree of openness. The removal of

[12] Available from the authors upon request.

the foreign exchange policy channel amplifies the effect of the output gap on inflation via the increase in the slope (from 0.20 to 0.34) and the adjusted slope (from 0.58 to 0.87) of the Phillips curve as implied by equation (2). The increased sensitivity of inflation to output gap variations leads to a stronger anti-inflationary and output targeting stance as indicated by the increased loadings—$(1-\rho_R)\psi_2$ and $(1-\rho_R)\psi_1$, respectively—from 0.04-0.07 and 0.51-0.67, correspondingly.

In general, the variance decomposition estimates do not differ—from a qualitative standpoint—between the unrestricted and the restricted versions of the model. However, the elimination of the exchange rate policy channel raises the share of foreign output shocks in GDP fluctuations at the expense of a lower contribution of technological innovations in domestic output movements.

Finally, the IRFs of the two models are similar with one exception. Because of the elimination of the foreign exchange targeting channel in the policy rule, the innovations in π^* would be completely absorbed by the nominal exchange rate while leaving all the values of the other endogenous variables intact (Lubik and Schorfheide 2007).

Table 4. Posterior Odds Test for Exchange Rate Targeting

	Log Marginal data densities		Posterior odds
	H_0	H_1	
H_0: ψ_3=0 vs. H_1: $\psi_3 \geq 0$	-1328.15	-1337.15	8103.08

Table 4 reports the posterior odds ratio for testing the null ψ_3=0 against the alternative hypothesis $\psi_3 \geq 0$. As shown in the table, the marginal data density of the unrestricted model is 9.00 smaller on a log scale implying an excessive odds ratio. We, therefore, unequivocally reject reasonable chances that the CBE policy responds to fluctuations in the exchange rate. This result does not preclude the possibility of the CBE intervention in the market for foreign exchange. However, our findings suggest it is less likely such intervention is induced through the exchange rate policy targeting mechanism.

4.4. Implication of Real Exchange Rate Fluctuations

The above findings show the mean posterior estimate for the import share coefficient is unduly low (0.04) both in absolute terms and in comparison with its prior value (0.30). The volatility in the domestic prices during the period under consideration is quite high and cannot be explained to a reasonable extent by the (full) pass-through effect from the nominal exchange rate. We have argued that the low estimate of the import coefficient (α) is suitable to allow the fluctuations in the terms of trade to sufficiently supplement the nominal exchange rate changes in accounting for the sizable variability in the domestic prices, while obeying the cross-equation restrictions imposed primarily on κ and τ by the IS and the NKPC relations. Meanwhile, the variance in the real exchange rate is also relatively large. The high real exchange rate volatility might not have permitted κ and τ to sufficiently adjust to accommodate the high levels of inflation. Consequently, our results might be misleading if the errors in the measurement of the real exchange rate (not an unlikely happening given the quality of Egyptian data) are responsible for a significant fraction of the volatility in the terms of trade or for unwarranted deviations from the PPP stipulation.

To deal with those concerns, the same model is re-estimated treating the terms of trade as a latent variable. Tables 5-6 reproduce the posterior means and confidence intervals for the benchmark and alternative policy rules, the variance decomposition and the odds ratio of the exchange rate targeting hypothesis test after including the terms of trade as unobservable in the model.

Table 5. Posterior Estimation Results with Latent Terms of Trade

	Policy rule $\psi_3 \geq 0$			Alternative $\psi_3=0$		
	Mean	**5%**	**95%**	**Mean**	**5%**	**95%**
ψ_1	2.21	1.45	2.93	1.93	1.28	2.58
ψ_2	0.36	0.14	0.57	0.29	0.11	0.46
ψ_3	0.08	0.03	0.14	0	-	-
ρ_R	0.77	0.67	0.87	0.67	0.53	0.81
α	0.25	0.17	0.33	0.29	0.18	0.40
r	2.48	0.94	4.01	2.49	0.91	4.01
k	0.13	0.04	0.23	0.22	0.07	0.37
τ	0.56	0.26	0.84	0.50	0.30	0.69
ρ_q	0.30	0.20	0.40	0.27	0.18	0.37
ρ_A	0.09	0.04	0.14	0.07	0.02	0.11
ρ_{y^*}	0.86	0.74	0.97	0.88	0.80	0.97
ρ_{π^*}	0.35	0.18	0.52	0.41	0.23	0.58
σ_R	0.53	0.45	0.62	0.53	0.44	0.61
σ_q	2.94	1.73	4.06	2.32	1.21	3.38
σ_A	5.99	5.14	6.80	5.88	5.08	6.65
σ_{y^*}	1.32	0.38	2.38	1.17	0.41	1.97
σ_{π^*}	4.73	4.04	5.42	5.02	4.27	5.72
Marginal likelihood						
Harmonic		-1019.45			-1012.33	
Laplace		-1020.55			-1012.91	
Acceptance		0.32,0.32,0.32, 0.32,0.32			0.32,0.32,0.32, 0.32,0.32	

Notes: See Table 2.

Table 6. Variance Decomposition with Latent Terms of Trade

	Output	**Inflation**	**Interest rate**	**Exchange rate**
Policy	0.234	0.228	0.370	0.003
Terms of trade	0.096	0.591	0.207	0.179
Technology	0.091	0.013	0.012	0.000
World output	0.569	0.153	0.404	0.002
World inflation	0.011	0.014	0.007	0.817

Table 7. Posterior Odds Test for Exchange Rate Targeting with Latent Terms of Trade

	Log marginal data densities		**Posterior odds**
	H_0	**H_1**	
H_0: $\psi_3=0$ vs. H_1: $\psi_3 \geq 0$	-1012.33	-1019.45	1236.45

Table 5 reveals some fundamental differences between the estimates obtained presuming latent terms of trade in comparison with the previous results displayed in Table 2. While the posterior mean of α—under the policy rule $\psi_3 \geq 0$—still remains smaller than its prior value, it is now significantly larger at a value of 25 percent. Moreover, the factor loading of the output gap in the inflation equation decreases (reaching 0.17) as the posterior estimate of the slope of the Phillips curve becomes smaller and the degree of relative risk aversion turns higher. As expected, despite increased openness, the posterior estimates suggest lower terms of trade and foreign output and inflation volatility. These results are confirmed by the variance decomposition estimates listed in Table 6. The share of world output shocks in inflation and nominal interest rate movements plummeted with the increased openness. The economy, however, in this case is more exposed to real exchange rate shocks as evident from the higher contribution of the terms of trade innovations to inflation and interest rate fluctuations.

Despite these differences, the model dynamics indicated by the IRFs (not displayed) obtained assuming latent terms of trade are virtually unaffected. More important, Table 7 displays the posterior odds for exchange rate targeting derived using the estimation results for the alternative policy rule portrayed in Table 5. The odds ratio test still remains in line with our earlier policy result, refuting reasonable chances that the CBE responds to exchange rate movements through policy amendments.

5. Conclusion

We implement the Lubik and Schorfheide's (2005, 2007) small open economy forward-looking DSGE modeling framework to examine the policy response of the CBE to exchange rate fluctuations. Although Egypt does not adopt a formal policy targeting strategy, evidence from earlier studies suggests the monetary conduct of the CBE can be approximated by a Taylor-type targeting function. Our findings show that the CBE has recently adopted a strong anti-inflationary policy and has also resorted to output targeting. Conversely, our tests show the CBE has not systematically reacted to shocks in the market for foreign exchange via policy adjustments. Besides, the CBE opts for considerable interest rate smoothing. This result is in line with earlier evidence obtained for Egypt.

The model estimates the contribution of policy, terms of trade, technical growth, world output and import price changes to variations in the key policy and non-policy macroeconomic variables in Egypt. Apparently, world output shocks contribute significantly to the variation in GDP, domestic inflation and interest rates. Technological shocks have moderate influence on changes in output but do not seem to contribute much to inflation, interest rate and nominal exchange rate variance. Our findings also disclose that real interest rates have marginal impact on domestic business cycle fluctuations. This result, however, may be attributed to the simple dynamics embodied in the model used for estimation, which ignores the role of capital accumulation, world asset market imperfections and intersectoral differences (Lubik and Schorfheide 2007).

We examined the impact of different exogenous shocks on key macroeconomic variables. The estimated impulse response functions are in line with the literature and do not indicate puzzles. Relaxing monetary policy has an expansionary output effect and raises domestic prices. Similarly, technological growth shocks result in higher levels of output and an appreciation of the Egyptian pound leading to a reduction in the nominal interest rates thereby reinforcing GDP growth. Nevertheless, our findings show the expansionary impact of technological progress in Egypt is rather limited. Alternatively, world output and relative foreign price shocks have a strong effect on the economy. A positive foreign output shock lowers domestic production and depreciates the Egyptian pound leading to higher interest rates and inflation. In contrast, a rise in the import prices raises output, appreciates the currency, lowers interest rates and raises domestic prices.

Finally, we have demonstrated that increased foreign trade openness changes the structural parameters but does not affect the dynamic behavior of the different variables in the economy. Neither does it have an effect on the CBEs decision to alter its policy variable in response to nominal exchange rate fluctuations.

APPENDIX

Figure A1. Mode Check

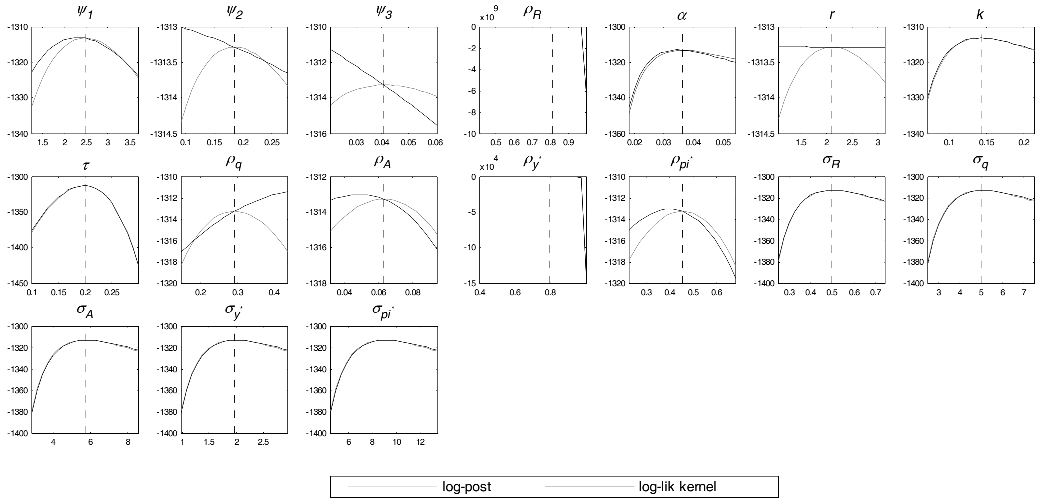


Figure A2. Univariate Diagnostics

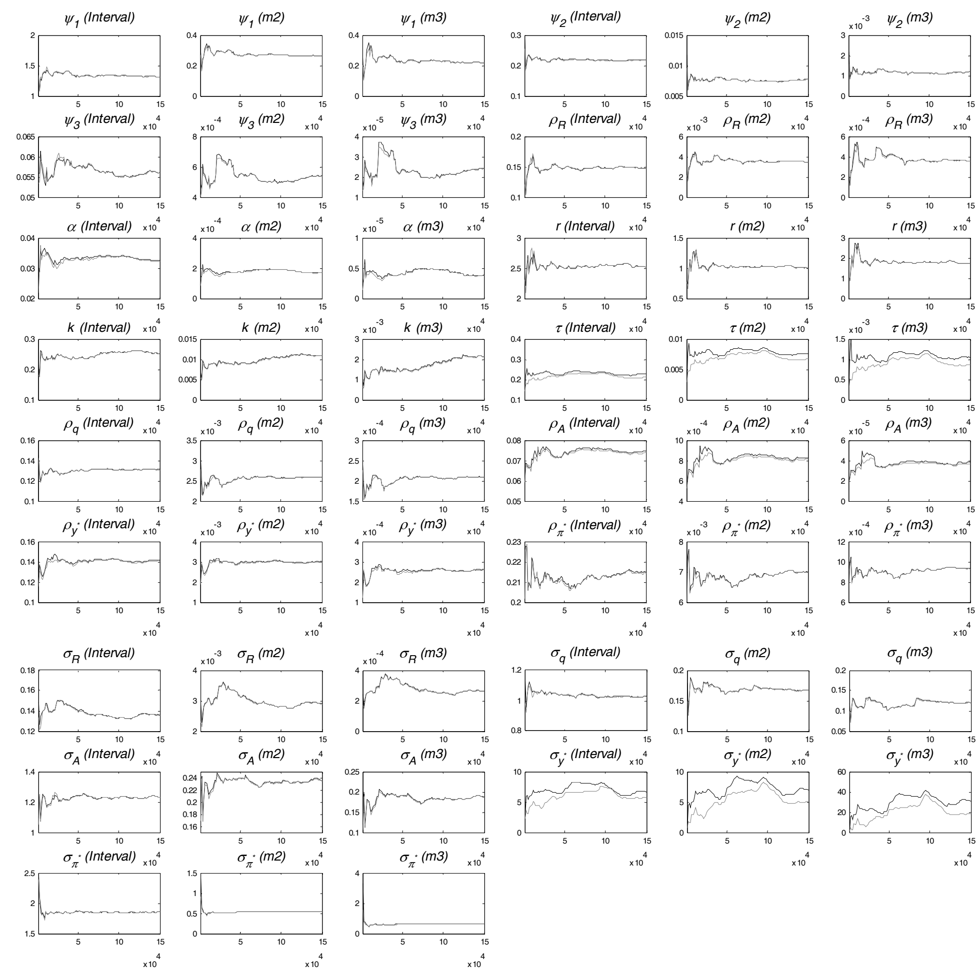


Figure A3. Multivariate Diagnostics

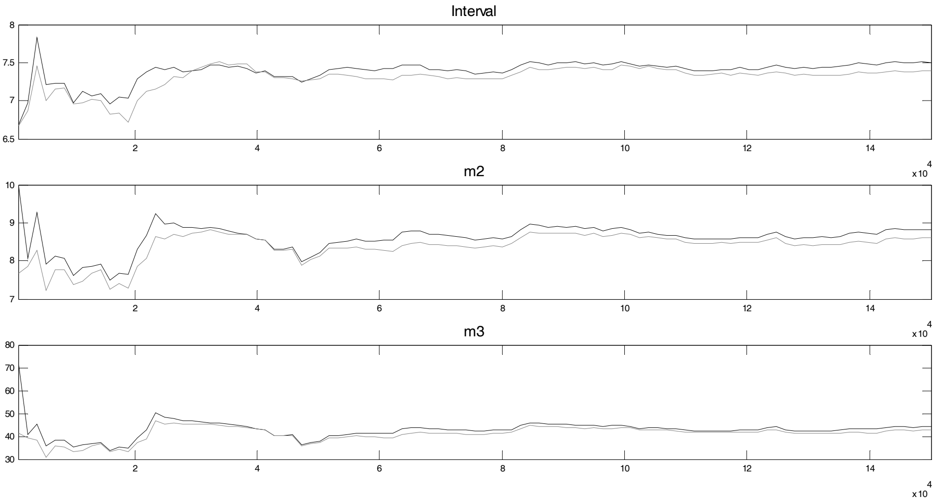


Figure A4. Comparison between Prior and Posterior Distributions

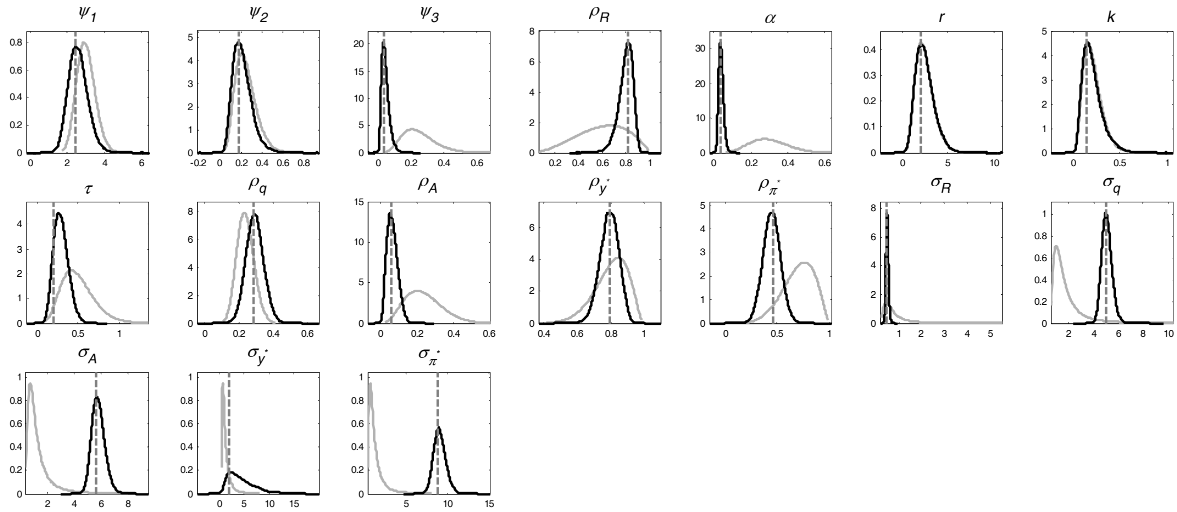
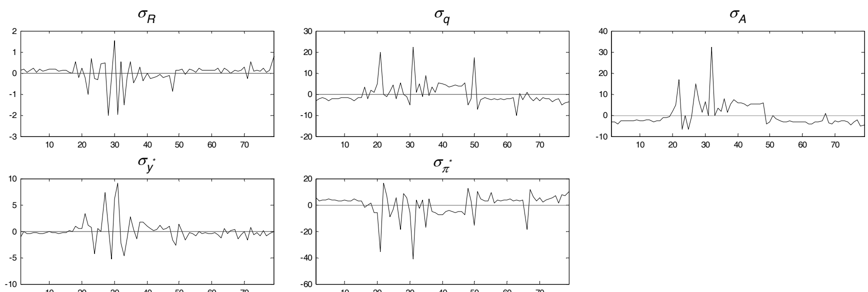


Figure A5. Smoothed Shocks



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