WP/11/108

# IMF Working Paper

# Estimating a Small Open-Economy Model for Egypt: Spillovers, Inflation Dynamics, and Implications for Monetary Policy

*Elif C. Arbatli and Kenji Moriyama*

INTERNATIONAL MONETARY FUND

 WP/ 11/108

## IMF Working Paper

Middle East and Central Asia Department

# Estimating a Small Open-Economy Model for Egypt: Spillovers, Inflation Dynamics and Implications for Monetary Policy

**Prepared by Elif C. Arbatli and Kenji Moriyama[1]**

Authorized for distribution by Ralph Chami

May 2011

## Abstract

This paper estimates a small open economy model for Egypt to analyze inflation, output dynamics and monetary policy during 2005–2010. The interest rate channel is found to be relatively weak in Egypt, complicating the use of interest rates as the immediate target of monetary policy. However, the paper also finds a significant level of persistence in the policy rate, making monetary policy pro-cyclical. More active use of interest rate policy, measures to improve domestic debt markets and a gradual move towards inflation targeting can help support a successful disinflation strategy for Egypt.

JEL Classification Numbers: E17, E37, E52, F41

Keywords: Small open economy model, monetary policy, transmission mechanism

Authors' E-Mail Address:earbatli@imf.org, kmoriyama@imf.org



[1] The authors are grateful for helpful comments from Alan MacArthur, Hassan Al-Atrash, and participants in the seminar held at the Central Bank of Egypt in January 2011.

Contents Page

Appendixes

# I. INTRODUCTION

Since mid 2005, Egypt, like many other emerging market economies, went through a significant economic reform process characterized by increasing real and financial linkages with the rest of the world and the transition towards inflation targeting in the conduct of monetary policy. Studying the transmission of shocks in main trading partners' economic activities and global interest rates to the Egyptian economy has been increasingly important from a policy perspective. In addition, Egypt's planned transition to an inflation targeting regime implies that it will be important to make inflation forecasts and policy simulations within a consistent macroeconomic framework that incorporates the conduct of monetary policy and key monetary transmission mechanisms that are estimated or calibrated for Egypt.

Motivated by the above two key developments, this paper incorporates a small open economy model for Egypt into the IMF's Global Projection Model (GPM). This extended model, also called GPM+, is the first step in conducting forecasts and policy analysis in an estimated model for Egypt that is also consistent with the IMF's global economic projections. This paper describes the application of GPM+ to Egypt and draws interesting conclusions regarding spillovers and the transmission of global shocks and inflation dynamics, as well as implications for monetary policy.

The GPM is the main quarterly projection model used in the research department of the IMF that encompasses 6 main blocks: United States, Euro Area, Japan, Emerging Asia, Latin America and other countries.[2] The GPM is used to study the transmission of country-specific and global shocks and make projections that are based on a common global environment, taking into account spillovers among regions. It was recently extended to include a canonical small open economy (GPM+) that is assumed to take as given the developments in the different regions of GPM and hence can be thought of as a satellite model that is linked to the bigger GPM model. Although there are no feedback effects from the small open economy to the rest of GPM—a reasonable assumption as long as a small open economy is analyzed, this model offers a consistent framework to study the effects of global economic developments in relatively small open economies such as Egypt. The GPM+ was first applied to the Indonesian economy as described in Andrle et. al. (2009), which also provides a summary of the greater GPM project and future planned extensions.

From a modeling perspective, the GPM+ features five reduced-form behavioral equations that describe movements in the output gap, unemployment, inflation, nominal interest rate and the exchange rate, in addition to several identities that describe the evolution of equilibrium interest rate, output and unemployment. The equations in the model are comparable to the reduced form versions of Dynamic Stochastic General Equilibrium (DSGE) models developed in the academic literature such as in Gali and Monacelli (2005)[3] and adopted in many central banks around the world for policy analysis and projections.

[2] See Carabenciov et. al. (2008) for a detailed summary of the evolution of GPM, Canales-Krijenko et. al. (2009) for its extension to Latin America, and Andrle et al. (2009) for its extension to Indonesia.

[3] The reduced form equations are somewhat different in that GPM incorporates some lagged effects, especially in the Philips Curve, to capture inflation indexation and backward looking expectations.

However, the fact that its equations are expressed in reduced form implies that it is not possible to use GPM+ to study the effects of structural changes. Rather, the GPM+ should be interpreted as a very useful tool to understand past developments, assess the effects of external shocks and make policy simulations. Central banks in Canada, Norway and Chile use GPM together with other types of models for projections and policy analysis. Several country teams at the IMF have also incorporated GPM+ into their forecasting and policy analysis toolbox.

Main findings of the paper are summarized as follows:

- The output gap in Egypt has increased during 2005–2008, reflecting a depreciated exchange rate and a positive external demand. The output gap shrank sharply in 2009, with the global financial crisis as external demand declined and monetary policy remained tight. The estimated gap has been somewhat negative but not statistically significant since the middle of 2009;
- Response of the output gap in Egypt to the foreign output gap is relatively small, which is consistent with the relatively strong growth performance of Egypt during the recent global crisis. This could reflect the structure and composition of Egypt's exports and also the lack of strong financial linkages with advanced countries;
- The estimated Phillips curve indicates that supply shocks and expected inflation (including inflation inertia) components are main determinants of inflation;
- Increased foreign real interest rate has positive effect on the output gap in Egypt, mainly through real depreciation;
- Interest rate channel of monetary policy transmission mechanism appears weak which is in line with Mashat and Billmeier (2007);
- Egypt has high inertia in its nominal interest (policy) rate which causes real interest rates to be pro-cyclical, magnifying economic fluctuations;
- Increasing the response of nominal interest rate to inflation and the output gap is desirable for the CBE to reduce fluctuations in inflation and the output gap;
- After a large devaluation in 2003, the CBE has anchored inflation expectations until the end of 2007 mainly through the exchange rate channel;

The paper is organized as follows: the next section provides a brief description of relevant recent macroeconomic developments in Egypt. The following section describes the extension of GPM to a small open economy and in particular to Egypt. Section IV discusses the data, the estimation strategy (a Bayesian-like method called regularized maximum likelihood) and the parameter estimates. Section V presents the estimated main variables in the model—the output gap, the Phillips curve, and the nominal interest rate rule (the Taylor rule)—and the estimated impulse responses, concentrating in particular on the response to external demand shocks to study spillovers and the response to domestic interest rate shocks to study the monetary transmission mechanism. Section VI conducts some policy simulations and drives conclusions for the conduct of monetary policy going forward. Conclusion will be briefly presented in the final section.

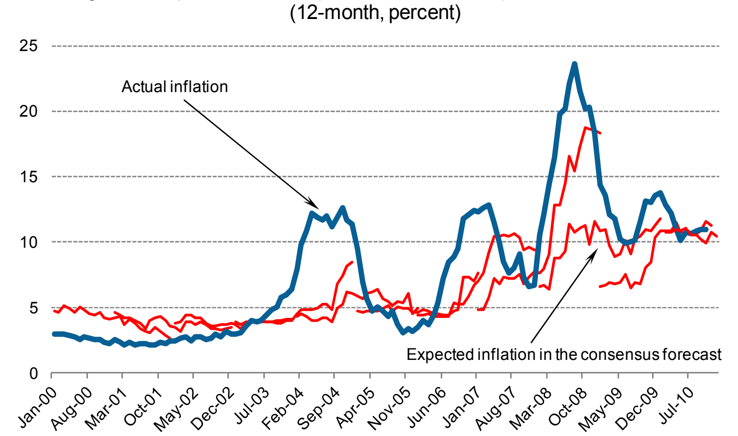
## II. Macroeconomic Developments and Monetary Policy in Egypt

Egypt's long-run growth performance during 1980–2000 was strong compared to the average of emerging market economies, although it was well below the high-growth emerging market economies in Asia (Enders 2007). Growth in Egypt has accelerated in step with the implementation of a series of reforms since 2004, including tariff reduction, tax administration and public expenditure management, exchange rate unification, and business environment improvements (e.g., lower fees and processing time, cuts in corporate tax rates and other tax incentives for foreign direct investment).[4] However, high growth rates during this period had not resulted in a substantial decline in unemployment rate and poverty. The decomposition of output growth (production side and expenditure side GDP data) and the growth accounting exercise[5] suggest the following as the main drivers of Egypt's strong growth during FY2004/05–07/08:

- Strong external demand prior to the global financial crisis;
- Improved competitiveness of Egypt supported by the productivity gains as a result of a series of structural reforms since 2004 and an undervalued exchange rate after the significant devaluation of the Egyptian pound in 2003,[6] and
- Strong capital (FDI) inflows, due to improved return of capital in Egypt and favorable financial conditions in world markets.

While growth in Egypt declined after the Lehman shock to below 5 percent (year-over-year) from an average 7 percent prior to the crisis, Egypt weathered the global financial crisis relatively well compared to other emerging market economies with similar income levels, due, in part, to relatively low credit growth in Egypt prior to the crisis—a proxy for increased financial vulnerabilities during the boom in the literature—and less sensitivity of Egypt's exports to global downturns (IMF 2010).

Figure 1. Expected Inflation (Consensus Forecast) and Actual Inflation (12-month, percent)




Inflation (12-month) in Egypt since 2007 appears to have a gradual increasing trend with several double digit inflation episodes: for example, the first spike in 2004 mainly reflected the pass-through effect of the huge devaluation of the Egyptian pound in 2003; the second spike in 2006–07 was due to an avian flu outbreak and

[4] For details, see IMF (2007) and Enders (2007).

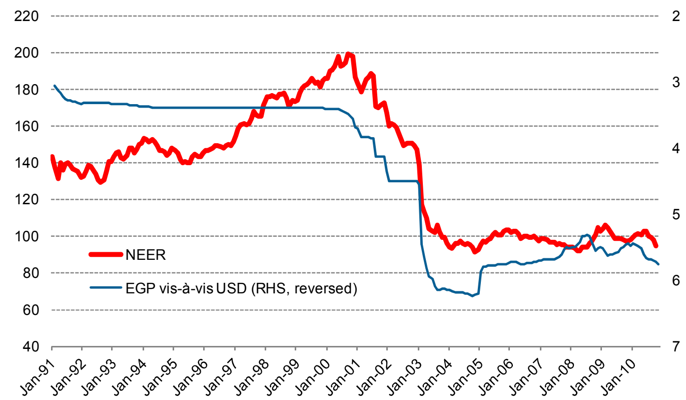
[5] In the growth accounting exercise, capital stock is estimated following the Perpetual Inventory Method, with 5 percent depreciation rate and 33 percent of the share of capital. Using different parameters, however, does not change the main findings of the analysis, where human capital is estimated following Collins and Bosworth (1996).

[6] See IMF (2010).

world commodity prices increase; and the third one (2008) was caused by the increase in world commodity prices. The expected inflation proxied by the inflation projections in the Consensus Forecast after 2007 has been substantially higher than that before 2007 (Figure 1), implying that recent spikes in inflation might have been feeding into a higher expected inflation, due partly to rigidities and distortions in price and wage settings.

Since the large devaluation of the Egyptian pound in early 2003, Egypt's exchange rate—both effective term and vis-à-vis the U.S. dollar—has been stable (Figure 2).

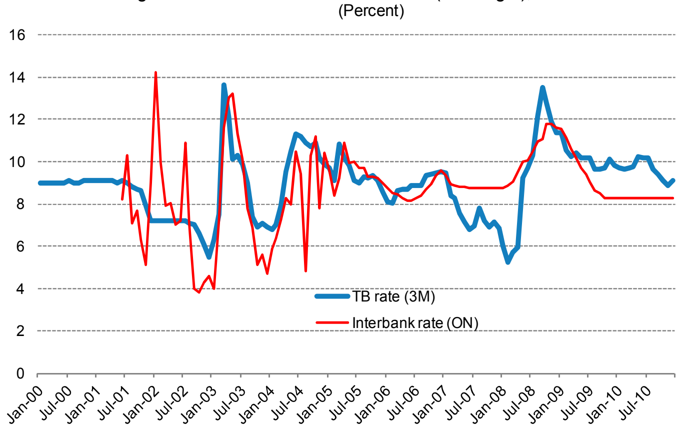
Figure 2. Effective Exchange Rate and Exchange Rate vis-a-vis US Dollar, 1991-2010
(Index values: 2005 =100 for NEER, National currency per USD)




Until 2005, the CBE's operational target for its monetary policy was excess reserves of banks, and growth in M2 was the intermediate target. Since then, the CBE began to move toward inflation targeting (Al-Mashat and Billmeier 2007), although it has not officially announced to adopt it. Institutional measures which have been implemented by the CBE include establishing the Coordinating Council on Monetary Policy headed by the Prime Minister, the Monetary Policy Committee (MPC), and the Monetary Policy Unit within the CBE, and releasing a Monetary Policy Statement on the CBE's external web-site after each MPC meeting. The operational measures include introducing an interest rate corridor by the CBE and central bank notes as the primary instrument for liquidity management through open market operations, and developing models to forecast inflation. The CBE launched its core inflation index in October 2009, to capture the more persistent trend of underlying inflation by separating the noise and short-run fluctuations.[7]

Overnight interbank rate on average appears to move more smoothly since 2005, consistent with the change in the CBE's policy framework, relying more on open market operations (Figure 3). Three month treasury bills (T-bills) rate seems to have tracked the overnight interbank rate, although when the economy faced strong capital inflows, it has tended to decline relative to the overnight interbank rate (for example, 2007

Figure 3: TB Rate and Interbank Rate (Overnight), 2000-2010
(Percent)




[7] See "The Core inflation Measure," a CBE's brochure on the core inflation.

and early 2008, and after July 2010). The latter observation may imply that most capital inflows have so far gone into short-term fixed income securities.

## III. DESCRIPTION OF THE MODEL

This section highlights key components of the GPM+: output gap evolution (IS curve), real interest rate parity with risk premium, inflation dynamics (the Phillips curve) and monetary policy (the Taylor rule), while the details of the model are outlined in Appendix I. The GPM+—a small open economy model—is linked to the rest of the word through three key exogenous variables: external demand captured by the foreign output gap, real world interest rate and real world equilibrium interest rate. All of these variables are given as a weighted average of the variables estimated for the six main blocks in GPM, where Egypt's trade shares are used as weights.

The domestic output gap is assumed to have forward and backward looking elements —reflecting habit formation in the household's expenditure—and depend on the gap in the short-term interest rate ($r_{t-1}$), the real effective exchange rate gap ($z_{t-1}$)[8] and the foreign output gap ($y_{f,t}$).[9] The evolution of the output gap—IS curve— is given by:

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t+1} - \beta_3 r_{t-1} + \beta_4 z_{t-1} + \beta_5 y_{f,t-1} + \varepsilon_t^y$$

The real effective exchange rate (an increase in the exchange rate means depreciation) is determined endogenously via a version of the real interest parity condition with risk premium, where the future expected exchange rate has both forward and backward looking components:

$$4*(Z_{t+1}^e - Z_t) = (R_t - R_{f,t}) - (\overline{R}_t - \overline{R}_{f,t}) + \varepsilon_t^{Z-Z^e}, \text{ where } Z_{t+1}^e = \phi Z_{t+1} + (1-\phi) Z_{t-1}.$$

Change in the real exchange rate depends on the real interest rate gap differentials and $\varepsilon_t^{Z-Z^e}$ which is interpreted as the risk premium for financial assets in Egypt.

Inflation dynamics in GPM+ are governed by a standard hybrid New Keynesian Philips curve equation that links current inflation to future expected inflation ($\pi_{t+1}$), the lagged inflation ($\pi_{t-1}$) capturing both the indexation of price setting to past inflation and the backward looking component of inflation expectations, the lagged output gap ($y_{t-1}$) and the change in the real effective exchange rate ($\Delta Z_t$) to reflect pass-through effects.

$$\pi_t = \lambda_1 \pi_{t+1} + (1-\lambda_1)\pi_{t-1} + \lambda_2 y_{t-1} + \lambda_3 \Delta Z_t + \varepsilon_t^{\pi},$$

---

[8] The real effective exchange rate gap is given by $z_{t-1} = \sum_j \omega_j \, z_{j,t-1}$ where $\omega_j$ are the weights of different bilateral exchange rates. These weights are calculated using the trade shares of Egypt with the different regions that exist in GPM. Currently the shares are: United States (0.14), EU (0.33), Japan (0.05), Emerging Asia (0.13), LA (0.02), others (0.33).

[9] The foreign output gap is a weighted average of the output gaps of the small open economy's main trading partners ($y_{f,t-1} = \sum_j \omega_j \, y_{j,t-1}$).

The change in the real exchange rate is determined by the change in nominal exchange rate and the inflation differential between Egypt and its trade partners: $\Delta Z_t = \Delta S_t - \pi_t + \pi_t^*$. A higher estimate of the parameter for the lag of inflation $(1-\lambda_1)$ implies higher inflation persistence and will be one of the key parameters of interest, since when $1-\lambda_1$ is large, inflation is more persistent and disinflation requires higher cost of increased unemployment (i.e., the positive sacrifice ratio).

While Egypt currently does not have an announced inflation target, the central bank communicates in its monetary policy announcements that it has a comfort zone that covers the 6–8 percent range.[10] Therefore, the model can include short term nominal interest rates $(I_t)$ given by a monetary policy rule that incorporates interest rate smoothing, and responds to the output gap and the deviation of expected inflation from its target ($\pi^{Tar}$) similar to a Taylor type rule, where the target is assumed to follow an exogenous random walk process and is simultaneously estimated within the model.

$$I_t = \gamma_1 I_{t-1} + (1-\gamma_1)[\overline{R}_t + \pi 4_{t+3} + \gamma_2(\pi 4_{t+3} - \pi_{t+3}^{Tar}) + \gamma_3 y_t] + \varepsilon_t^I$$

where $\pi 4$ is the model consistent expected inflation derived from the Kalman filter, $\overline{R}_t$ is the natural rate of interest and the policy rate used in the paper is the central bank's deposit rate.

In GPM+, the central bank can affect inflation through two channels: interest rate channel and exchange rate channel. The interest rate channel is captured by the coefficient of the real interest rate gap in the evolution of the output gap (the IS curve). The exchange rate channel operates through its direct effect on the output gap but also through the pass-through effect in the Phillips curve.

## IV. The Data, The Selection of Priors, and the Parameter Estimates for Egypt

### A. The Data and Estimation Method

The paper uses data on unemployment, seasonally adjusted real GDP, the overnight interbank rate, the nominal and real effective exchange rates and finally the CPI index (The data source and availability over the sample are described in more detail in Appendix II). The benchmark sample period is 2005: Q3 through 2010: Q2 counting that the CBE decided to adopt the interest rate corridor as its operational target in June 2005 and announced its intention to move toward an inflation targeting regime. Change in monetary policy framework suggests a structural shift in the parameters of the model. Also, focusing on this period should give the additional benefit of excluding the effects of the large devaluation of the pound in early 2003 from the sample.

The GPM+ is estimated using regularized maximum likelihood which is a simple Bayesian-like technique that combines the priors of the econometrician with the likelihood of the model based on data. The relative weights of the priors versus the data can be adjusted for

[10] This model assumes that the bank's target and policy rule is known and that it is credible.

different parameters to reflect the different levels of confidence that one may have for the priors. A detailed description of the estimation methodology is presented in Appendix III.

## B. The Selection of Priors and Identification

As in many Dynamic Stochastic General Equilibrium (DSGE) models with a large number of estimated parameters, identifying parameters is an important task. The regularized maximum likelihood method allows one to specify priors for all estimated parameters which ensures that the likelihood is smooth, greatly improving the numerical solution algorithm. These priors are certainly important for final estimates, especially when the identification is weak due to the structure of the model or when the data is not as informative about a certain set of parameters.

In GPM+, the key behavioral equations are based on gaps (of output, unemployment, real interest rates etc.), however, in contrast to many DSGE models, a stochastic law of motion for equilibrium output, unemployment, real interest rate, real exchange rate and inflation (or inflation target) are also specified and estimated within GPM+. Although this gives an important flexibility to GPM+, it also requires a more serious consideration of identification. For example, the parameter that determines the effect of the exchange rate gap on the output gap cannot be identified if the equilibrium exchange rate (and hence the exchange rate gap) is not pinned down. Therefore, it is necessary to impose tight priors on certain parameters (or use direct calibration) to achieve identification. Under standard methods for estimating DSGE models, the data would be first filtered and then fed into the model, effectively identifying equilibrium values of key variables by choosing an appropriate filtering technique (sort of a hard prior).

Our choice of priors, presented in Table 1, is based on previous applications of the GPM+ to other emerging market countries, the results of a previous study by Moursi and Mossallamy (2009) which estimates a DSGE model for Egypt, as well as basic calibration exercises based on data for Egypt. For instance, the prior means for the unemployment block parameters, parameters in the output gap equation and the Philips Curve are mainly adopted from the priors and estimates in Kriljenko el. al. (2009). We used the estimates in Moursi and Mossallamy (2009) to guide our priors for the parameters in the monetary policy rule. Some parameters such as the steady-state inflation target and the steady-state real interest rates are not estimated but simply calibrated using sample averages. The particular assumptions made about these parameters are reported in Table 2. The structural shocks in the model are assumed to be distributed independently and have a normal distribution. They are also assumed to be uncorrelated with each other and across time. The posterior estimates of the standard deviations of structural shocks have for the most part moved substantially away from the initial priors towards similar posterior modes under different initial priors. We choose small and tight priors for the standard deviations of the two shocks to potential output to reflect our notion of a relatively smooth potential output.

## C. Estimated Parameters

The estimates of key parameters (priors and posteriors) are presented in Table 1: the evolution of the output gap (IS curve), the Phillips curve, and interest rate rule (Taylor rule), all of which are critical for the dynamics of inflation and the output gap. Comparison of the IS curve and interest rate rule between Egypt and several emerging market economies, taken from past studies using GPM, is presented in Table 4.

First, the estimated parameters in the output gap evolution (IS curve) suggest that the relative size of the backward looking component to the forward looking component is about 3, implying that the habit formation of expenditure (especially, household consumption) has significant effects on the output gap dynamics. While the relative weight of the backward looking component, the coefficient for real exchange rate and for foreign output gap in Egypt are similar to other countries, the estimated coefficient for the real interest rate gap in Egypt is significantly smaller—less than one half on average—than other countries. The smaller coefficient for the real interest rate gap in the IS curve indicates weaker interest rate channel in the monetary policy transmission mechanism, since the central bank needs to move its policy rate more actively to achieve required output gap change to affect inflation in the Phillips curve. This observation is in line with the findings in Al-Mashat and Billmeier (2007).

Second, the estimated Phillips curve suggests that the forward looking component is slightly more dominant than the backward looking part in Egypt compared to other emerging market economies: the weight of the forward looking component is about two-third for Egypt, whereas the median is about 0.55. A more forward looking Phillips curve is in fact desirable for monetary policy to achieve its inflation target with a smaller impact on output. However; if monetary policy is not very responsive to inflationary shocks (as in the case of Egypt); a more forward looking Phillips curve can exaggerate the inflationary impact. A large coefficient for the output gap in the Phillips curve for Egypt compared to other countries appears somewhat reflecting larger volatility of inflation in Egypt than in other countries.

Third, the estimated nominal interest rate rule indicates that the coefficient for the lag of nominal interest rate in Egypt is higher than in other countries. This implies that the nominal interest rate in Egypt has responded less to inflation than other countries, at least in the short-run, leading the real interest rate to be pro-cyclical. Therefore, interest rate policy has not helped stabilize inflation. Rather, non-interest rate channel have been mainly used to mitigate inflationary pressures and anchor inflation expectations.

Table 3a reports the root mean squared forecast errors for real GDP growth, nominal interest rate and inflation. The one year ahead forecast error for annual growth is slightly higher than one percent, whereas for annual inflation it is slightly higher than 5.5 percent. The model forecast errors for growth and interest rates are comparable to previous applications of GPM (e.g. to Latin America (Kriljenko et. al., 2009) and Indonesia (Andrle et. al., 2009), but for inflation it is significantly higher. One factor that can explain the difference at least for Indonesia is the fact that Andrle et. al. (2009) uses the core inflation measure which implies that the volatility of inflation is probably lower than in the other studies. Nevertheless, these results suggest that there is room for improving the performance of the model in capturing inflation dynamics which can be addressed in future work.[11]

## V. Output Gap, Inflation and Interest Rate Dynamics, Impulse Responses and Variance Decomposition

This section presents historical developments of the estimated main macroeconomic variables—the output gap, inflation decomposition, and nominal interest rate—and their impulse responses to exogenously given shocks: foreign output gap shock; foreign interest rate shock; monetary policy shock; and the pass-through effect of the exchange rate to inflation, based on the estimated GPM+ in the previous section. It also reports the variance decomposition of key variables abased on parameter estimates and the estimated variances of structural shocks in the model.

### A. Estimated Dynamics of Main Variables: Output Gap, Inflation, and Nominal Interest Rate Implied by the Estimated Taylor Rule

The estimated output gap in Egypt has been somewhat negative since the middle of 2009, although it is not statistically different from zero (Figure 4). The positive output gap widened since 2005, driven by the undervalued exchange rate as well as a favorable external environment (Figure 5). Since the outset of the global crisis, however, the gap declined sharply and turned into negative due to the weak external demand and the increased real interest rates. Recent sharp real appreciation began to negatively affect the output gap since the beginning of 2009, in line with the exchange rate assessment in IMF (2010, 2011).

Figure 4. Output Gap Estimated by the GPM+
(Deviation from the potential output, percent, confidence interval = two standard deviation)

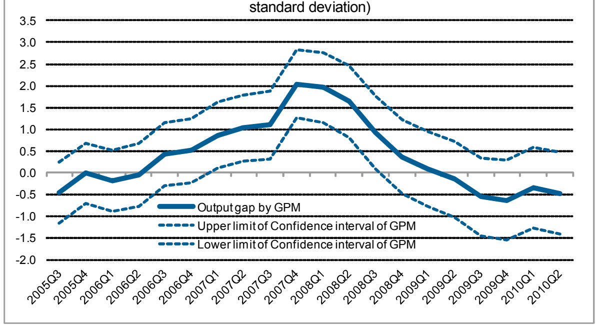
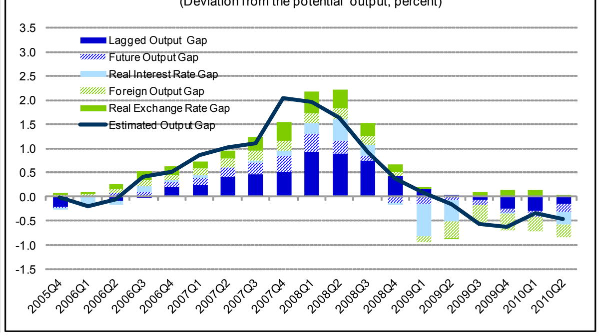



Figure 5. Estimated Output Gap and its Decomposition by the GPM+
(Deviation from the potential output, percent)




Supply shocks and inflation inertia have been the main determinants of inflation dynamics in Egypt. The estimated Phillips curve appears on average explaining inflation developments in Egypt well, while large supply shocks have played a significant role, especially during the surge in 2008 and 2009 (Figure 6). Inflation inertia also plays an important role and may make the cost of disinflation bigger in Egypt. Exchange rate appreciation has somewhat helped mitigate inflationary pressures, consistent with the pass-through effect.

---

[11] In future work, we would like to incorporate the effects of administered prices and commodity prices (especially food) into the model.

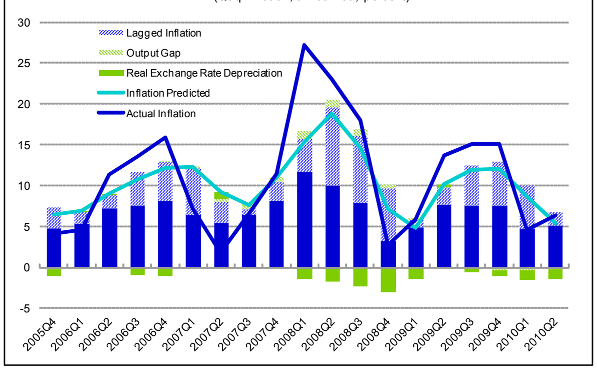


Figure 6. Estimated Phillips Curve and Inflation Decomposition by GPM+
(Qoq inflation, annualized, percent)

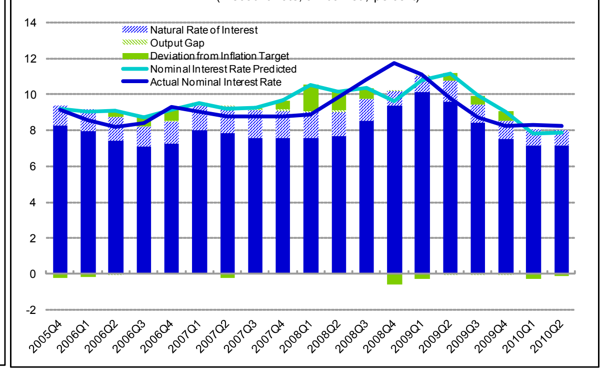


Figure 7. Estimated Taylor Rule and Policy Rate Decomposition by GPM+
(Discount Rate, annualized, percent)

Inertia is the main determinant of the nominal interest rate, while the output gap and inflation (deviation from the target) has played relatively limited role to affect nominal interest rate (Figure 7). Inertia has prevented monetary policy from responding timely to inflationary pressures: for example, the responses of monetary policy to a spike in commodity prices in early 2008 and the global financial crisis were even more delayed than that implied by the estimated Taylor rule, which already incorporates a significant level of persistence.

## B. Impulse Responses

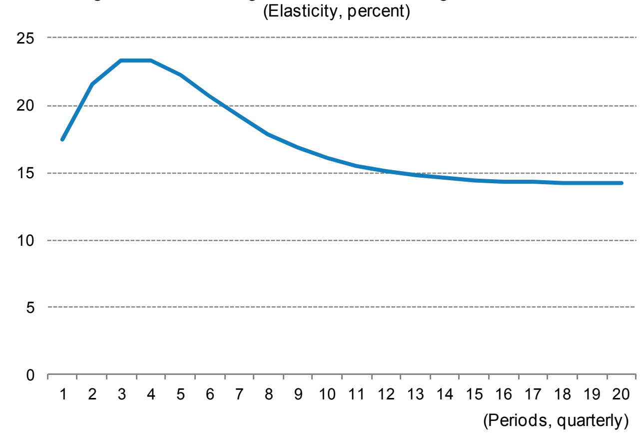
Figure 10 plots the impulse responses of main variables to a foreign output gap shock, intending to capture spillovers of external shocks, in particular, shocks in Europe which is Egypt's main trading partner. Increased external demand widens the output gap in Egypt. Despite the positive output gap, current and future expected exchange rate appreciation makes inflation negative during the first couple of periods by the pass-through effect. Nominal interest rate gradually increases and hits its peak about 7 periods after the shock, reflecting the positive output gap and increased inflation after period 2. The inertia of the nominal interest rate, however, makes the real interest rate negative in the short-run (from period 2 to 5) but positive in the medium term. While the negative interest rate makes monetary policy pro-cyclical, the latter positive real interest rate increases the size of appreciation of the exchange rate, since the real interest rate parity indicates that the current real exchange rate is given as the present value of the real interest rate gap differentials between Egypt and its trade partners.

Impulse responses to a change in foreign interest rate intend to capture interest rate shocks in advanced countries (Figure 11). Since the interest rate parity depends on the foreign interest rate gap, a foreign real interest rate increase should have impact similar to a decline in the equilibrium foreign real interest rate which should mainly be affected by output growth, fiscal balance and public debt in the advanced economies. In the context of the current economic conditions in the advanced economies, there are two potential interest rate shocks: additional monetary policy stimulus like additional quantitative easing and increased equilibrium real interest rate due to deteriorated fiscal position.

A positive shock in foreign real interest rate would depreciate the Egyptian pound. The depreciated exchange rate increases the output gap and inflation through the pass-through effect. While nominal interest rate reacts to the increased output gap and inflation, its inertia makes the real interest rate negative during the first couple of periods after the shock and monetary policy pro-cyclical, further increasing the output gap and inflation.

Impulse responses to a positive monetary policy shock are highlighted in Figure 12. One standard deviation increase in nominal interest rate (about one percent) would appreciate the exchange rate of the Egyptian pound by 2–3 percentage points, and create negative output gap of about 0.4 percentage points in the short run. Exchange rate appreciation and negative output gap would cause a decline in the price level (negative inflation) which lasts nearly 10 periods. Negative inflation would increase real interest rate and cause further exchange rate appreciation and decline in output gap.

Figure 8. Pass-through Rate of the Exchange Rate to Inflation
(Elasticity, percent)




The pass-through effect of the exchange rate on inflation is given by the impulse response of inflation to a one standard deviation shock to the equilibrium level of real exchange rate, which also implies a shock to the level of the nominal exchange rate assuming no change in foreign inflation. The estimated pass-through in Egypt is relatively low compared to estimates for other EMEs. The estimated elasticity is 0.23 at its peak within one year (Figure 8), consistent with the results by Rabanal (2005) which follows the method in McCarthy (1999) and found that the pass-through is somewhere between 6–27 percent depending on the model specification. Rabanal (2005) suggests that the low pass-through could be due to the high share of administered prices in Egypt's CPI index.

## C. Variance Decomposition

We compute the variance decomposition for key real variables to assess the relative contribution of different shocks (Table 3b). According to the model estimates, variation in output growth in Egypt is driven mainly by demand shocks (26 percent), monetary policy shocks (27 percent) and shocks to the equilibrium real interest rate (28 percent). This certainly reflects the estimated variances of the structural shocks in the model. Shocks to the nominal interest rate (surprise policy shocks) and the equilibrium real interest rate are large; reflecting to some extent differences between model implied interest rate path, based on the estimated Taylor rule, and the actual path of the policy rate. Although the interest rate channel is weak, the magnitude of the policy rate shocks lead to the allocation of a significant part of output growth variation to interest rate shocks. This is also apparent during 2008–2009, when the model based Taylor rule calls for a faster reduction in policy rates than what actually took place, suggesting a positive (i.e. pro-cyclical) policy rate shock, reinforcing the decline in output growth. Monetary policy shocks also explain a significant share of variations in real interest rate, real exchange rate appreciation and the real exchange rate gap. External shocks (foreign real interest rates and foreign demand shocks) have a relatively more significant contribution to real exchange rate movements and only explain 3–4 percent of the variation in output growth or the output gap.

## VI. Applications of the GPM+: Monetary Policy Implications

This section presents an application of GPM+ to monetary policy analyses.[12] In particular, given the estimated parameters of GPM+, the section first computes the optimal monetary policy (nominal interest rate) responses to shocks, where 'optimal' policy reaction means minimizing the loss function (present value of the weighted sum of the variance of inflation and the output gap), and then simulates the path of main macroeconomic variables with different monetary policy reaction functions to the shocks added to the system. While, as mentioned in the introduction, the IS curve and the Phillips curve in the GPM are reduced form instead of derived from optimization, the specification of the nominal interest rate rule (the Taylor rule) is a typical one in the literature of DSGE models and is independent from the optimization of households and firms. Therefore, sensitivity analysis of the parameters in the Taylor rule should not affect the parameters in the IS curve and the Phillips curve.

### A. Optimal Monetary Policy

There are two types of "optimal monetary policy," both of which minimize the objective function defined as the weighted average of the quadratic form of inflation and the output gap subject to the estimated model[13]:

- ***The Ramsey optimal policy (the social planner's solution)***: the policy should minimize the present value of the weighted average of the quadratic form of inflation and the output gap, given the estimated behavioral equations other than the Taylor rule in the GPM+; and
- ***The optimal policy rule***: the rule should minimize the weighted average of the variance of inflation and the output gap, given all of the estimated parameters other than coefficients for inflation and the output gap in the Taylor rule in the GPM+.

By its construction, the optimal monetary policy rule is a special case of the Ramsey optimal policy with further assumptions: (i) the discount factor is one (i.e., no discount rate), and (ii) the social planner must change interest rate following the Taylor rule. Although the optimal policy is a theoretical concept and thus it is not realistic that the central bank can follow it in the real world, the optimal policy analysis still gives useful insights on how the central bank should react to shocks added to an economy.

The estimated Ramsey optimal policy indicates that the central bank needs to take quick and front-loaded responses to shocks. Panels 4 and 5 highlight the impulse responses of main variables with the Ramsey optimal policy against temporary and persistent demand shocks,

---

[12] In this section, GPM+ is rewritten so that all variables are defined as deviation from the steady state because of computational capacity of Dynare.

[13] See Gali (2008) for an idea of the optimal monetary policy.

where the discount factor is 0.98 (8 percent of the annual discount rate) and the weight of the output gap is 6 in the objective function, where the model consistent variance of inflation is nine times as large as that of the output gap. The Ramsey policy raises interest rate quickly and significantly—and thus makes the exchange rate appreciate (negative sign indicates appreciation in the GPM+)—right after the shock in order to completely remove the inflationary demand pressures, sharp contrast to the responses of the estimated Taylor rule.

The optimal policy rule also requests much larger response of interest rate to inflation and the output gap than the estimated Taylor rule. Table 5 presents the estimated optimal monetary policy rule (response of nominal interest rate to inflation and the output gap) with different weights for the output gap in the objective function. As expected, the response of nominal interest rate with the optimal rule is substantially larger than that implied by the estimated Taylor rule, similar to the Ramsey optimal policy

The optimal monetary policy rule could provide another insight on the allocation of monetary policy transmission over the interest rate and the exchange rate channels. If the central bank follows the optimal policy rule, such policy should efficiently combine the interest rate and the exchange rate channels to minimize the weighted sum of the variance of inflation and the output gap, given the estimated behavioral equations in the GPM+. For example, if the increased interest rate can reduce inflation through the smaller output gap more than through the pass-through effect and the price effect of the external demand by exchange rate appreciation, the central bank should use the interest rate channel more actively, implying more volatility in the interest rate than the exchange rate.

Figure 9. Relative Size of the Standard Deviation of Real Interest Rate to Real Excange Rate withDifferent Transmission Level
(Proxied by the coefficient of Real Interest Rate in IS curve, Based on the Estimated GPM)

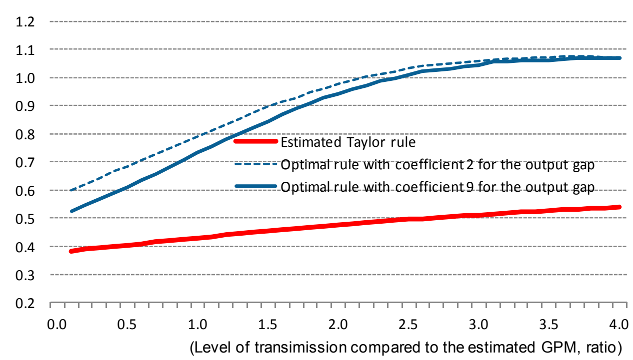



Figure 9 plot the relative size of the standard deviation of the real interest rate to the real exchange rate with different coefficients of the real interest rate in the IS curve, intending to capture the effectiveness of the interest rate channel ("two" in the horizontal axis in the figures indicates that the coefficient is twice as large as the estimated one). Stronger interest rate channel—proxied by the larger coefficient for the real interest rate in the IS curve—should make the central bank use the interest rate channel more extensively than the exchange rate, leading to the larger volatility of the real interest rate relative to the real exchange rate. The relative size of volatility with the optimal policies is substantially larger than that with the estimated Taylor rule for all range of the coefficient of real interest rate (a proxy for interest rate channel), suggesting that the CBE has used the exchange rate channel to anchor inflation expectation more actively than the interest rate channel and therefore there is much room for the CBE to use the interest rate channel in the future.

## B. Policy Scenario Simulations

This subsection quantitatively investigates the impact of shocks to main macroeconomic variables with the estimated Taylor rule and the optimal interest rate rule (with coefficient 6 for the volatility of the output gap derived in the previous subsection), where all variables are re-defined as deviation from the steady state. The shocks added to the model economy are summarized in Appendix IV.

**Capital inflows shock** (temporary), proxied by combination of a positive demand shock and a decline in the risk premium in the real interest rate parity (Figure 15).

Increased capital inflows would result in real appreciation with the estimated Taylor rule. If the central bank follows policies resisting to nominal appreciation to avoid further deterioration in competitiveness, such policies would result in higher inflation. This observation is consistent with the hypothesis derived in the previous section: because of the weak transmission mechanism of the interest rate channel, the central bank needs to rely more on the exchange rate channel to contain inflationary pressures caused by increased capital inflows. In this context, monetary policy response to increased capital inflows without allowing exchange rate appreciation would send a very contradicting message to the private sector.

**Adopting inflation targeting monetary policy framework**

Adopting inflation targeting appears to help anchor inflation expectations, where the central bank announces the adoption of inflation targeting in period 1, assuming that its policy commitment is credible, where the path of the assumed inflation target is presented in the right top chart in Figure 16. With inflation targeting, inflation declines to the target prior to the changes in the target level, suggesting that inflation expectations are well anchored in the forward looking monetary policy framework (Figure 16).

The real interest rate is negative during the first couple of periods to create exchange rate appreciation expectation. The real exchange rate depreciates first before it appreciates. Similar story holds for the periods prior to the reduction in the target inflation (period 25–30). This observation is also consistent with the hypothesis that the central bank uses exchange rate channel more actively to contain inflationary pressures, reflecting the weak interest rate channel of monetary policy transmission.

**Supply shocks to the Phillips curve**

Figure 17 highlights the responses of main variables to supply shocks. The central bank still relies on the exchange rate channel more than the interest rate channel, as indicated by the initial depreciation with the estimated Taylor rule with shocks (green line). On the other hand, real exchange rate does not depreciate first with the optimal policy rule with inflation targeting, reflecting its larger response of interest rate to inflation. The real interest rate with the optimal policy rule turns to positive after period two, responding to the increased inflation. The positive real interest rate makes the output gap and the need for the central bank to use the exchange rate channel to reduce inflation smaller than in other scenarios.

This observation implies that increased response of interest rate to inflation and output gap —i.e., more countercyclical monetary policy—helps the central bank reduce its reliance on the exchange rate channel to anchor inflation expectations.

**Delay in tightening monetary policy to capital inflows and supply**

Panels 9 and 10 highlight the effects of delaying tightening monetary condition when an economy faces capital inflows (Figure 18) or supply shocks (Figure 19). The panels clearly show the costs of delaying monetary policy reaction to inflationary pressures. Intuitively speaking, since the central bank needs to create more appreciation expectation to contain additional inflationary pressures due to the delay, exchange rate needs to depreciate more, leading to higher inflation through the pass-through effect, the price effect of foreign demand, and the negative real interest rate. Such mechanism is stronger with supply shocks in which the central bank cannot exploit rate appreciation pressures as in a capital inflows case.

Similar to the supply shocks scenario, the spike in inflation with the optimal policy rule is smaller than the estimated Taylor rule, reflecting less required appreciation to contain the additional inflationary pressures. This is mirror image of more active response of interest rate to inflationary pressures, contributing to anchor inflation expectations less relying on the exchange rate channel.

## VII. Conclusions and Policy Implications

This paper tried to investigate spillovers, the output gap and inflation dynamics, and implications for monetary policy in Egypt based on the estimated small macroeconomic model. First, the paper applied the extended version of the Global Projection Model (GPM) developed by the Research Department at the IMF and then estimated the developments of the output gap, and the decomposition of the Phillips curve and nominal interest rate based on the estimated model.

Second, the paper presented the responses of the model economy to exogenously given shocks such as the foreign output gap shock, foreign real interest rate shock, and nominal interest shocks by the central bank. The first two impulse responses should help capture the spillovers of the shocks in foreign countries, in particular the advanced countries.

Third, the paper conducted simulations based on the estimated model to study economy's response to shocks under different policy frameworks and in particular, the paper tries to highlight the impact of the adoption of inflation targeting framework.

The main findings of the paper are summarized as follows:

- After positive output gap during 2005–08, reflecting a depreciated exchange rate and a positive external demand, the gap shrank sharply in 2009, with the global financial crisis. The estimated gap has been somewhat negative but not statistically significant since the middle of 2009;

- The estimated Phillips curve indicates that supply shocks and expected inflation (including inflation inertia) components are main determinants of  inflation;
- Increased foreign real interest rate has positive effect on the output gap in Egypt, mainly through real depreciation;
- Interest rate channel of monetary policy transmission mechanism appears weak;
- Egypt has high inertia in its nominal interest (policy) rate which causes real interest rates to be pro-cyclical, magnifying economic fluctuations;
- Increasing the response of nominal interest rate to inflation and the output gap is desirable for the CBE to reduce fluctuations in inflation and the output gap;

Needless to say, there is much room in the paper to be improved further. For example, the paper focuses only on the period from Q3 2005 to Q2 2010, after the implementation of new monetary policy framework, suggesting that the estimated model may be distorted by the global financial crisis and the policy responses to it, since GPM+ does not include fiscal and financial sectors. Analysis based on the more detailed model with additional sample period after Q2 2010 is a very promising topic for future study.

## REFERENCES

Al-Mashat, Rania and Andreas Billmeier (2007): "Monetary Transmission Mechanism in Egypt," IMF Working Paper 07/285.

Andrle. Michal, Charles Freedman, Roverto Garcia-Saltos, Danny Hermawan, Douglas Laxton and Haris Munandar (2009): "Adding Indonesia to the Global Projection Model," IMF Working Paper 09/253.

Canales-Kriljenko, J., C. Freedman, R. Garcia-Saltos, M. Johnson, and D. Laxton (2009): "Adding Latin America to the Global Projection Model," IMF Working Paper 09/85.

Carabenciov, I., I. Ermolaev, C. Freedman, M. Juillard, O. Kamenik, D. Korshunov and D. Laxton (2008a): "A Small Quarterly Projection Model of the U.S. Economy," IMF Working Paper No. 08/278.

Carabenciov, I., I. Ermolaev, C. Freedman, M. Juillard, O. Kamenik, D. Korshunov, D. Laxton, and J. Laxton (2008b): "A Small Quarterly Multi-Country Projection Model," IMF Working Paper No. 08/279.

Carabenciov, I., I. Ermolaev, C. Freedman, M. Juillard, O. Kamenik, D. Korshunov, D. Laxton, and J. Laxton (2008c): "A Small Quarterly Multi-Country Projection Model with Financial-Real Linkages and Oil Prices," IMF Working Paper No. 08/280.

Collins, S. and B. Bosworth (1996): "Economic Growth in East Asia: Accumulation versus Assimilation," *Brookings Papers on Economic Activity* 2: 135–203.

Enders, Klaus-Stefan (2007): "Egypt—Searching for Binding Constraints on Growth," IMF Working Paper No. 07/57.

Gali, Jordi (2008): *Monetary Policy, Inflation, and the Business Cycle*, Princeton University Press, Princeton, New Jersey.

Gali, Jordi and Tommaso Monacelli (2005): "Monetary Policy and Exchange Rate Volatility in a Small Open Economy," *Review of Economic Studies*, 72, 707–734.

International Monetary Fund (2007): *Arab Republic of Egypt*, 2007 Article IV Consultation Staff Report, Washington, D.C.

International Monetary Fund (2010): *Arab Republic of Egypt*, 2010 Article IV Consultation Staff Report, Washington, D.C.

International Monetary Fund (2011, forthcoming): *Arab Republic of Egypt*, 2011 Article IV Consultation Staff Report, Washington, D.C.

McCarthy, J., (1999): "Pass-Through of Exchange Rate and Import Prices to Domestic Inflation in Some Industrialized Economies," BIS Working Paper No. 79.

Moursi, Tarek Abdelfattah and Mai El Mossallamy (2009): "Monetary Policy Analysis with New Keynesian Models for Egypt," Mimeograph, IDSC.

Rabanal, Pau (2005): "Exchange Rate Pass-Through," Chapter I in *Selected Issues* for Egypt, IMF Country Report 05/179.

Table 1. Priors and Estimates for Key Variables

| Parameter | Equation: Description | Prior | | Posterior | |
|---|---|---|---|---|---|
| | | Mode | Dispersion | Mode | Dispersion |
| alpha1 | Unemployment gap: lag of unemployment gap | 0.8 | 0.1 | 0.774 | 0.103 |
| alpha2 | Unemployment gap: output gap | 0.3 | 0.03 | 0.296 | 0.033 |
| beta1 | Output gap: lag of output gap | 0.5 | 0.05 | 0.453 | 0.057 |
| beta2 | Output gap: lead of output gap | 0.2 | 0.03 | 0.164 | 0.033 |
| beta3 | Output gap: real interest rate gap lagged | 0.2 | 0.03 | 0.079 | 0.041 |
| beta4 | Output gap: real exchange rate gap lagged | 0.05 | 0.005 | 0.047 | 0.006 |
| beta5 | Output gap: real foreign output gap lagged | 0.1 | 0.01 | 0.093 | 0.012 |
| gamma1 | Nominal Interest Rate: lag of nominal interest rate | 0.7 | 0.1 | 0.865 | 0.058 |
| gamma2 | Nominal Interest Rate: deviation of inflation from target | 1.3 | 0.1 | 1.273 | 0.117 |
| gamma3 | Nominal Interest Rate: output gap | 0.3 | 0.1 | 0.31 | 0.108 |
| lambda1 | Inflation: expected inflation | 0.5 | 0.1 | 0.647 | 0.071 |
| lambda2 | Inflation: lag of output gap | 0.5 | 0.1 | 0.479 | 0.078 |
| lambda3 | Inflation: real exchange rate depreciation | 0.15 | 0.05 | 0.091 | 0.037 |
| phi | Expected real exchange rate: weight of forward looking component | 0.5 | 0.1 | 0.596 | 0.056 |
| rho | Equilibrium Real Interest Rate: steady state real interest rate | 0.1 | 0.01 | 0.104 | 0.013 |
| tau | Growth Rate of Equilibrium Output: steady state growth rate | 0.5 | 0.1 | 0.501 | 0.109 |
| betaf | Foreign output gap: lag of foreign output gap | 0.8 | 0.1 | 0.855 | 0.077 |
| rhobarf | Real equilibrium interest rate (foreign): steady state real interest rate | 0.5 | 0.1 | 0.098 | 0.064 |
| rhof | Real interest rate (foreign): steady state real interest rate | 0.5 | 0.1 | 0.177 | 0.142 |
| pief_ss | Steady state foreign inflation (level) | 2 | 0.1 | 2.025 | 0.137 |
| rhopief | Foreign Inflation: steady state foreign inflation | 0.5 | 0.1 | 0.423 | 0.07 |
| growth_ss | Steady state growth rate of potential output | 5 | 0.5 | 5.926 | 0.326 |
| *Standard Deviation of Shocks* | | | | | |
| std_RES_LGDP_BAR | Level shock to potential output | 0.05 | 0.02 | 0.092 | 0.024 |
| std_RES_Y | Shock to output gap | 0.5 | 0.1 | 0.478 | 0.081 |
| std_RES_G | Growth shock to potential output | 0.05 | 0.02 | 0.097 | 0.023 |
| std_RES_UNR_GAP | Shock to unemployment gap | 0.5 | 0.2 | 0.287 | 0.084 |
| std_RES_UNR_BAR | Shock to equilibrium level of unemployment | 0.5 | 0.1 | 0.557 | 0.08 |
| std_RES_PIE | Shock to inflation | 1 | 0.2 | 3.135 | 0.15 |
| std_RES_RR_BAR | Shock to real equilibirum interest rate | 1 | 0.1 | 1.768 | 0.104 |
| std_RES_RS | Shock to nominal interest rate | 1 | 0.2 | 0.99 | 0.155 |
| std_RES_PIETAR | Shock to inflation target | 0.5 | 0.2 | 0.325 | 0.082 |
| std_RES_RR_DIFF | Shock to uncovered interest parity (risk premium shock) | 1 | 0.2 | 1.861 | 0.208 |
| std_RES_LZ_BAR | Shock to equilibirum level of real exchange rate | 1 | 0.2 | 2.629 | 0.13 |
| std_RES_YF | Shock to foregin output gap | 1 | 0.2 | 0.987 | 0.096 |
| std_RES_RRF_BAR | Shock to foreign equilibrium real interest rate | 0.5 | 0.2 | 0.154 | 0.019 |
| std_RES_RRF | Shock to foreign real interest rate | 0.25 | 0.2 | 0.52 | 0.06 |
| std_RES_PIESTR | Shock to foreign inflation rate | 0.5 | 0.2 | 1.413 | 0.096 |

Table 2. Calibrated Parameters

| Parameter | Description | Value |
|---|---|---|
| alpha3 | Persistence in the growth rate of equilibrium unemployment | 0.5 |
| rr_bar_ss | Steady-state value of equilibrium real interest rate | 3 |
| rrf_bar_ss | Steady-state value of equilibrium real interest rate (foreign) | 2 |
| std_RES_UNR_G | Standard deviation of shocks to the growth rate of equilibrium unemployment | 0.04 |

Table 3a. Root Mean Squared Errors

| Parameter | 1Q Ahead | 4Q Ahead | 8Q Ahead |
|---|---|---|---|
| *Egypt* | | | |
| Real GDP Growth (y-o-y) | 0.77 | 1.23 | 1.00 |
| Nominal Interest Rate | 0.62 | 1.09 | 1.45 |
| Inflation (y-o-y) | 1.73 | 5.59 | 5.70 |
| *Indonesia* | | | |
| Real GDP Growth (y-o-y) | 0.58 | 1.30 | 1.05 |
| Nominal Interest Rate | 0.71 | 2.00 | 2.56 |
| Inflation (y-o-y) | 0.47 | 1.75 | 1.94 |
| *Latin America* | | | |
| Real GDP Growth (y-o-y) | 0.50 | 1.42 | 1.30 |
| Nominal Interest Rate | 0.89 | 2.58 | 2.16 |
| Inflation (y-o-y) | 0.70 | 2.41 | 1.05 |

Note: RMSEs for Indonesia are from Andrle et. al (2009) and the sample period is 2000Q1-2
RMSEs for Latin America are from Kriljenko et. al. (2009) and the sample period is 2004Q1

Table 3b. Variance Decomposition (% of Variation Accounted by Different Shocks)

| | Growth (y-o-y) | Output Gap | Real Interest Rate | Real Exch. Rate Appreciation (y-o-y) | Real Exchange Rate Gap |
|---|---|---|---|---|---|
| Output Gap Shock | 26 | 18 | 1 | 2 | 3 |
| Philips Curve Shock | 7 | 7 | 10 | 8 | 10 |
| Nom. Int. Rate Shock | 27 | 31 | 36 | 31 | 25 |
| Equilib. Real Int. Rate Shock | 28 | 29 | 45 | 30 | 21 |
| Equilib. Real Exchange Rate Shock | 2 | 4 | 2 | 12 | 13 |
| Foreign Real Interest Rate Shock | 3 | 4 | 2 | 8 | 10 |
| Foreign Output Gap Shock | 3 | 3 | 0 | 3 | 13 |
| Others | 4 | 4 | 3 | 6 | 6 |

Table 4. Estimated Parameters of the Selected Variables in the GPM+ for Egypt

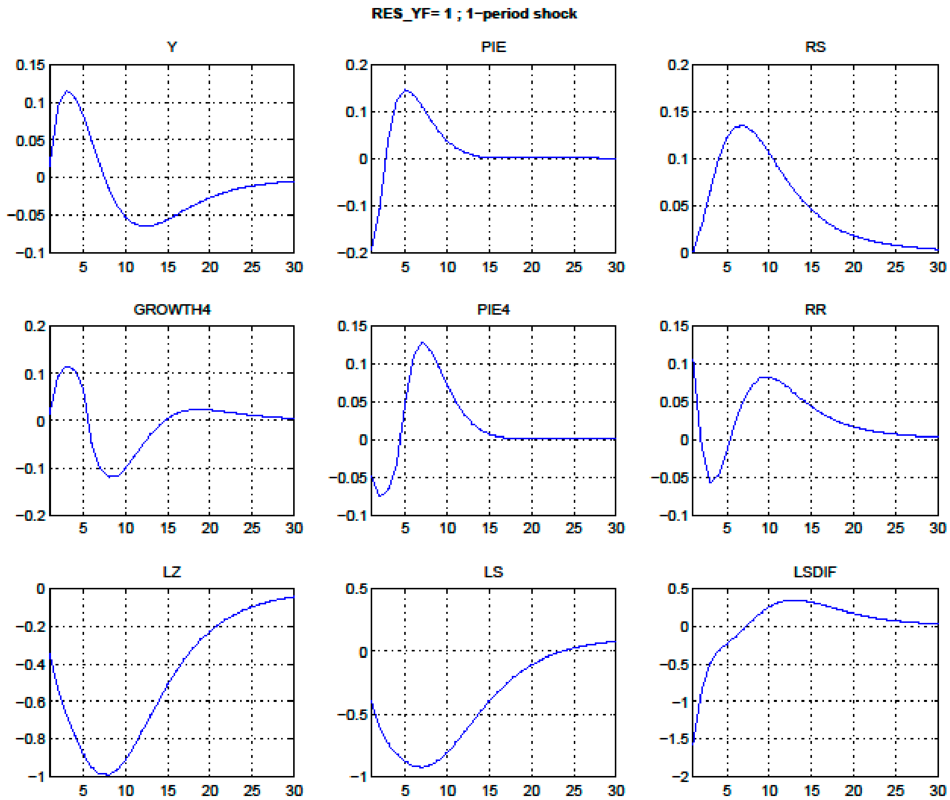
| | Output Gap Equation | | | | | Philips Curve | | | Nominal interest rate | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gap(-1) | Gap(+1) | Real interest | Real FX rate | Foreign demand | Inflation(+1) | Gap | FX rate | Interest rate (-1) | Inflation | Gap |
| **Egypt** | **0.453** | **0.164** | **0.079** | **0.047** | **0.093** | **0.647** | **0.479** | **0.091** | **0.865** | **1.273** | **0.310** |
| Indonesia | 0.428 | 0.149 | 0.164 | 0.035 | 0.178 | 0.270 | 0.209 | 0.107 | 0.628 | 1.384 | 0.186 |
| Latin America | 0.488 | 0.180 | 0.162 | 0.050 | 0.189 | 0.573 | 0.233 | 0.149 | 0.622 | 1.224 | 0.189 |
| Brazil | 0.366 | 0.143 | 0.129 | 0.049 | 0.110 | 0.589 | 0.198 | 0.276 | 0.774 | 1.149 | 0.150 |
| Chile | 0.389 | 0.155 | 0.154 | 0.049 | 0.098 | 0.564 | 0.168 | 0.298 | 0.735 | 0.908 | 0.176 |
| Columbia | 0.650 | 0.231 | 0.106 | 0.050 | 0.259 | 0.397 | 0.158 | 0.098 | 0.695 | 1.005 | 0.183 |
| Mexico | 0.720 | 0.273 | 0.121 | 0.049 | 0.189 | 0.532 | 0.255 | 0.094 | 0.725 | 1.064 | 0.143 |
| Peru | 0.425 | 0.179 | 0.159 | 0.051 | 0.127 | 0.618 | 0.196 | 0.286 | 0.771 | 1.133 | 0.178 |

Source: Canales-Krijenko et. al. (2009) and Andrle et. al. (2009)

Table 5. Estimated and Optimal Taylor Rule
(Based on the estimated GPM, 2005/06-2009/10)

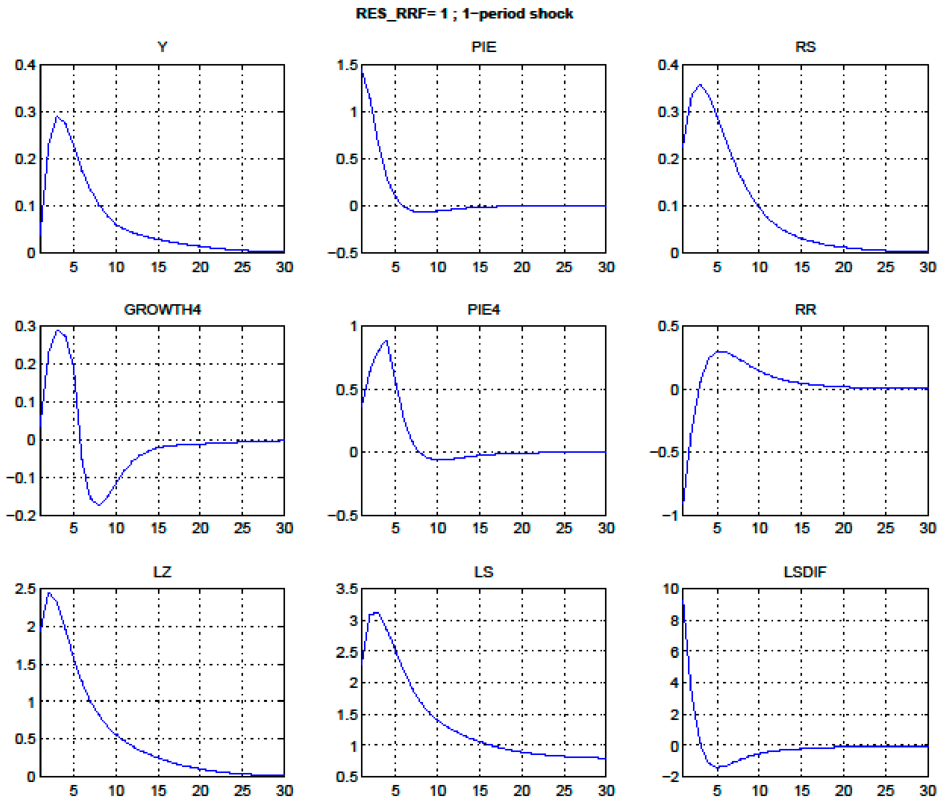
| Coefficient for the outptut gap | Optimal response of interest rate to | | Variance of | |
|---|---|---|---|---|
| | Inflation | Output gap | Inflation | Output gap |
| 1 | 51.5 | 17.7 | 0.00088 | 0.00020 |
| 2 | 23.2 | 11.0 | 0.00097 | 0.00012 |
| 5 | 13.1 | 9.4 | 0.00106 | 0.00008 |
| 10 | 10.3 | 10.5 | 0.00111 | 0.00007 |
| 15 | 10.8 | 11.2 | 0.00112 | 0.00007 |
| *Estimated Taylor rule* | 1.3 | 0.3 | 0.00144 | 0.00016 |

Figure 10: Impulse Responses to Foreign Output Gap Shock



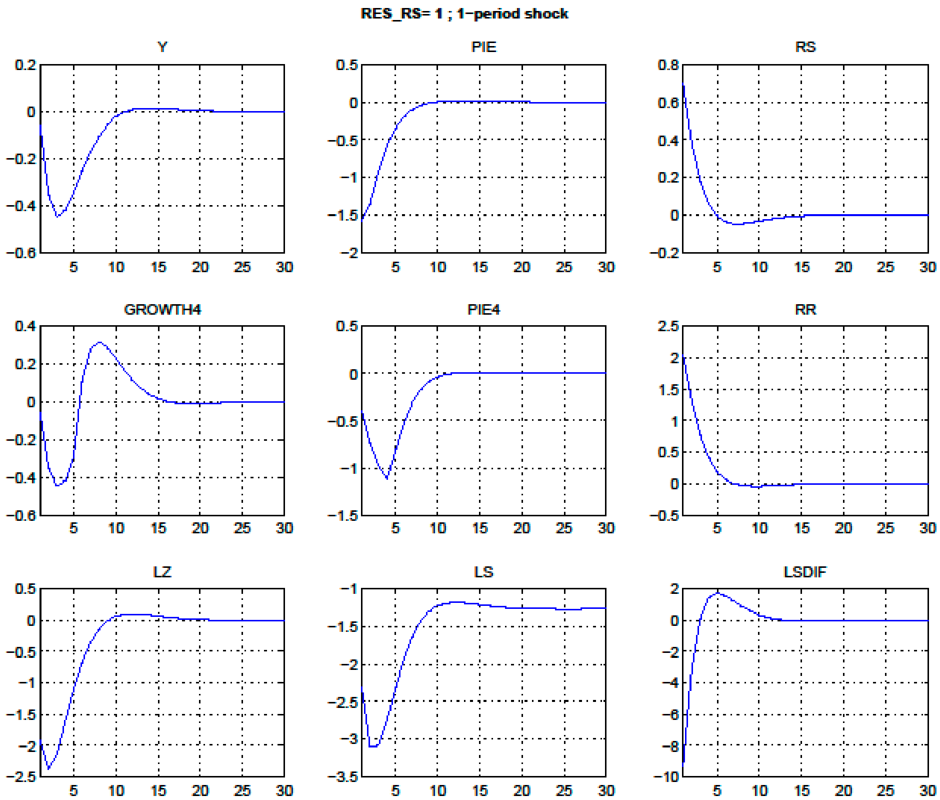

Note: Y (output gap), PIE (inflation), RS (nominal interest rate, policy rate), GROWTH4 (annual growth rate), PIE4 (y-o-y annual inflation rate), RR (real interest rate), LZ (real effective exchange rate), LS (nominal effective exchange rate), LSDIF (annualized nominal depreciation, positive values indicate a depreciation).

Figure 11: Impulse Responses to Foreign Real Interest Rate




Note: Y (output gap), PIE (inflation), RS (nominal interest rate, policy rate), GROWTH4 (annual growth rate), PIE4 (y-o-y annual inflation rate), RR (real interest rate), LZ (real effective exchange rate), LS (nominal effective exchange rate), LSDIF (annualized nominal depreciation, positive values indicate a depreciation).

Figure 12: Impulse Responses to Nominal Interest Rate




Note: Y (output gap), PIE (inflation), RS (nominal interest rate, policy rate), GROWTH4 (annual growth rate), PIE4 (y-o-y annual inflation rate), RR (real interest rate), LZ (real effective exchange rate), LS (nominal effective exchange rate), LSDIF (annualized nominal depreciation, positive values indicate a depreciation).

Figure 13. Impulse Responses of Main Variables to Temporary Demand Shock

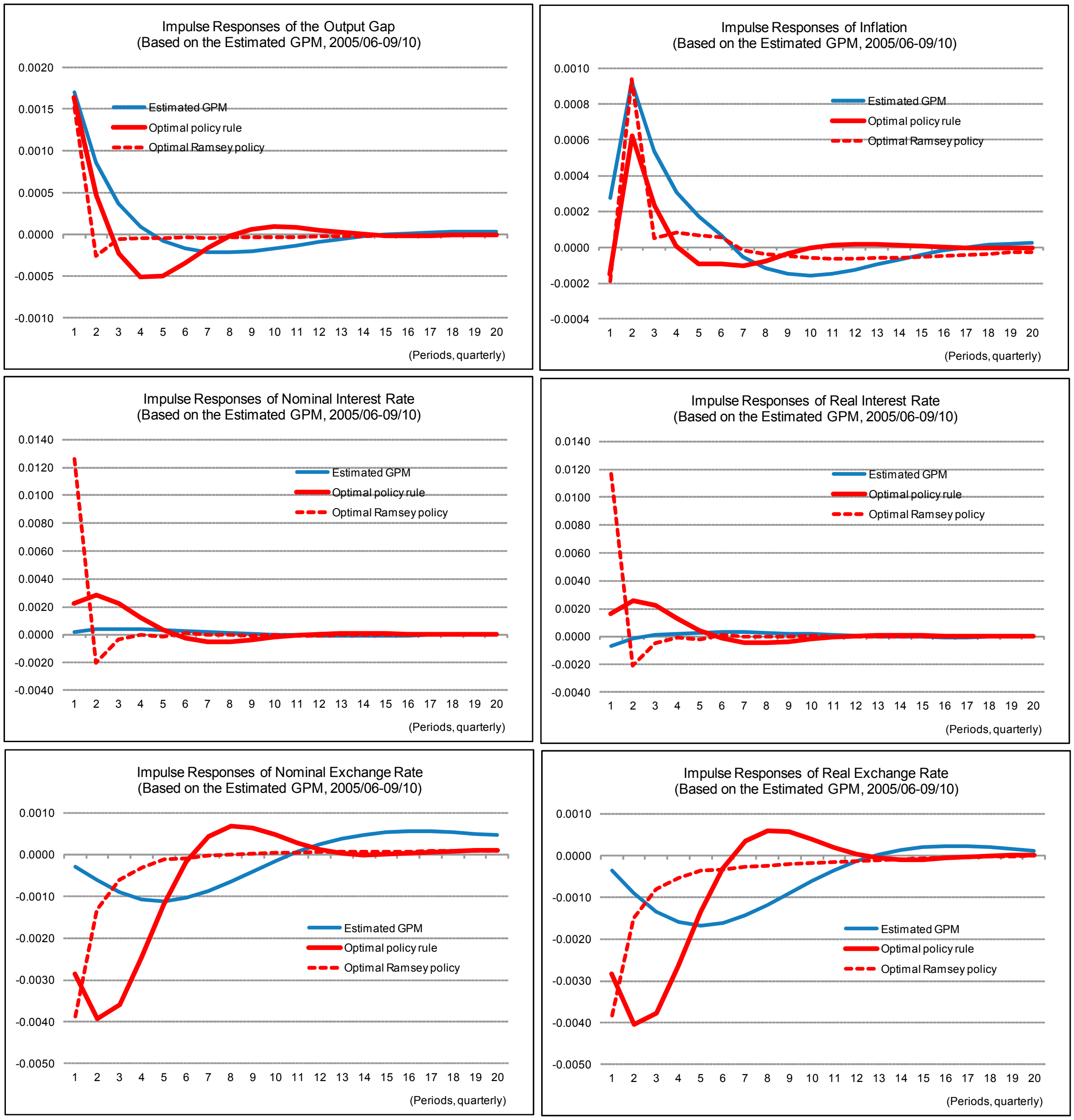


Figure 14. Impulse Responses of Main Variables to Persistent (Foreign) Demand Shock

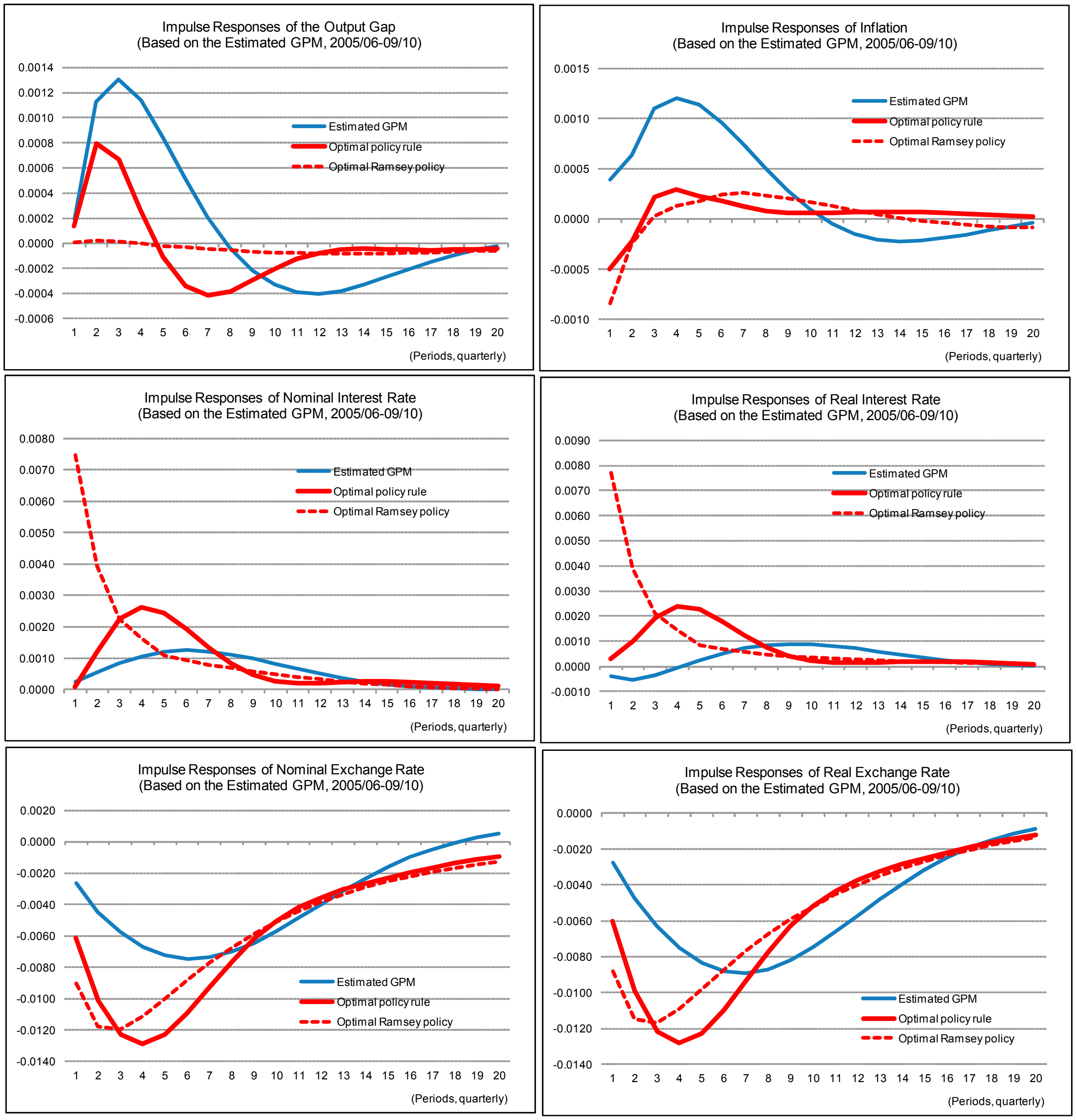


Figure 15. Simulated Responses of Main Variables with Capital Inflows Derived from the Estimated GPM

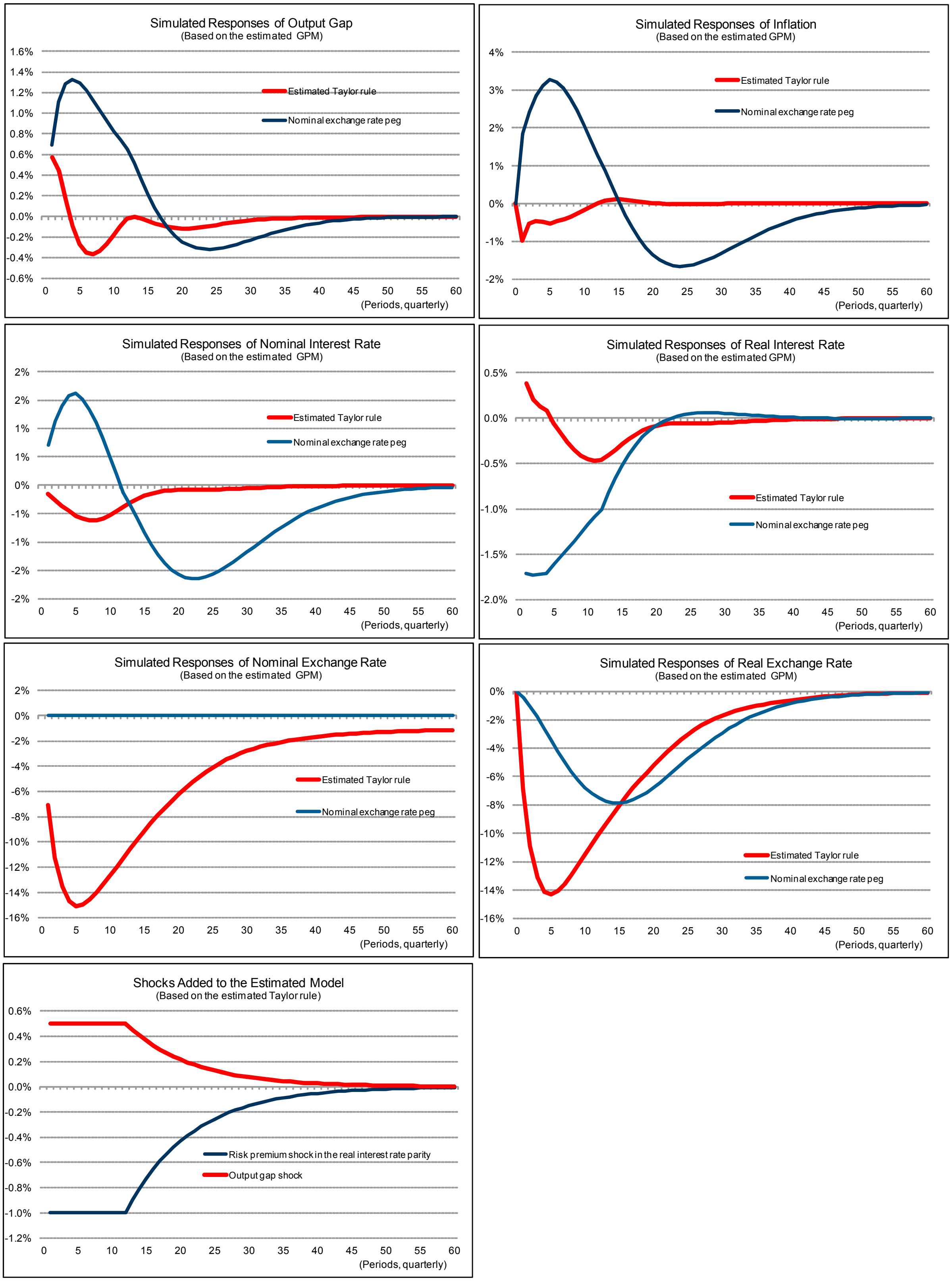


Figure 16. Simulated Responses of Main Variables with Inflation Targeting from the Estimated GPM

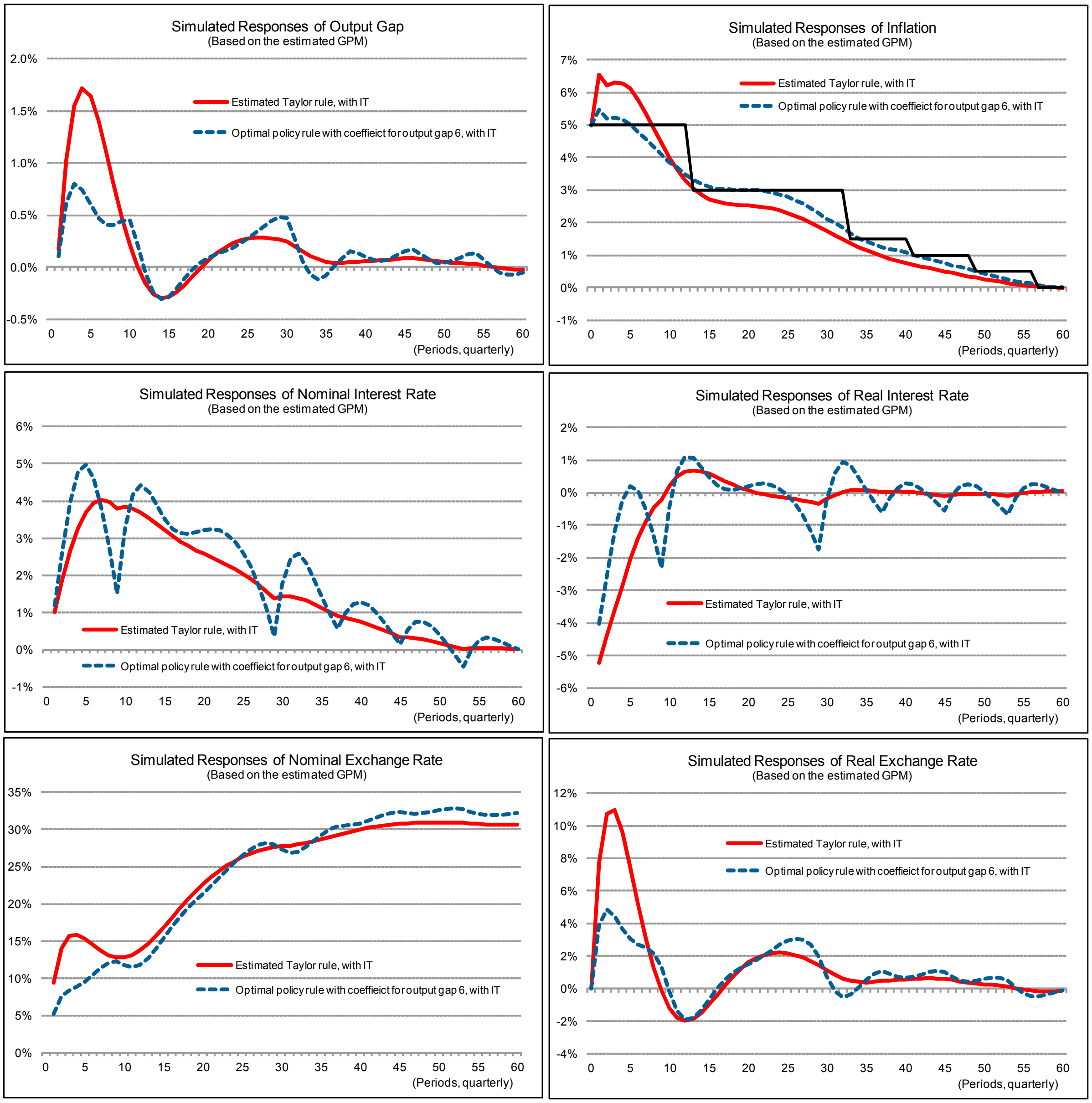


Figure 17. Simulated Responses of Main Variables to Supply Shocks Derived from the Estimated GPM

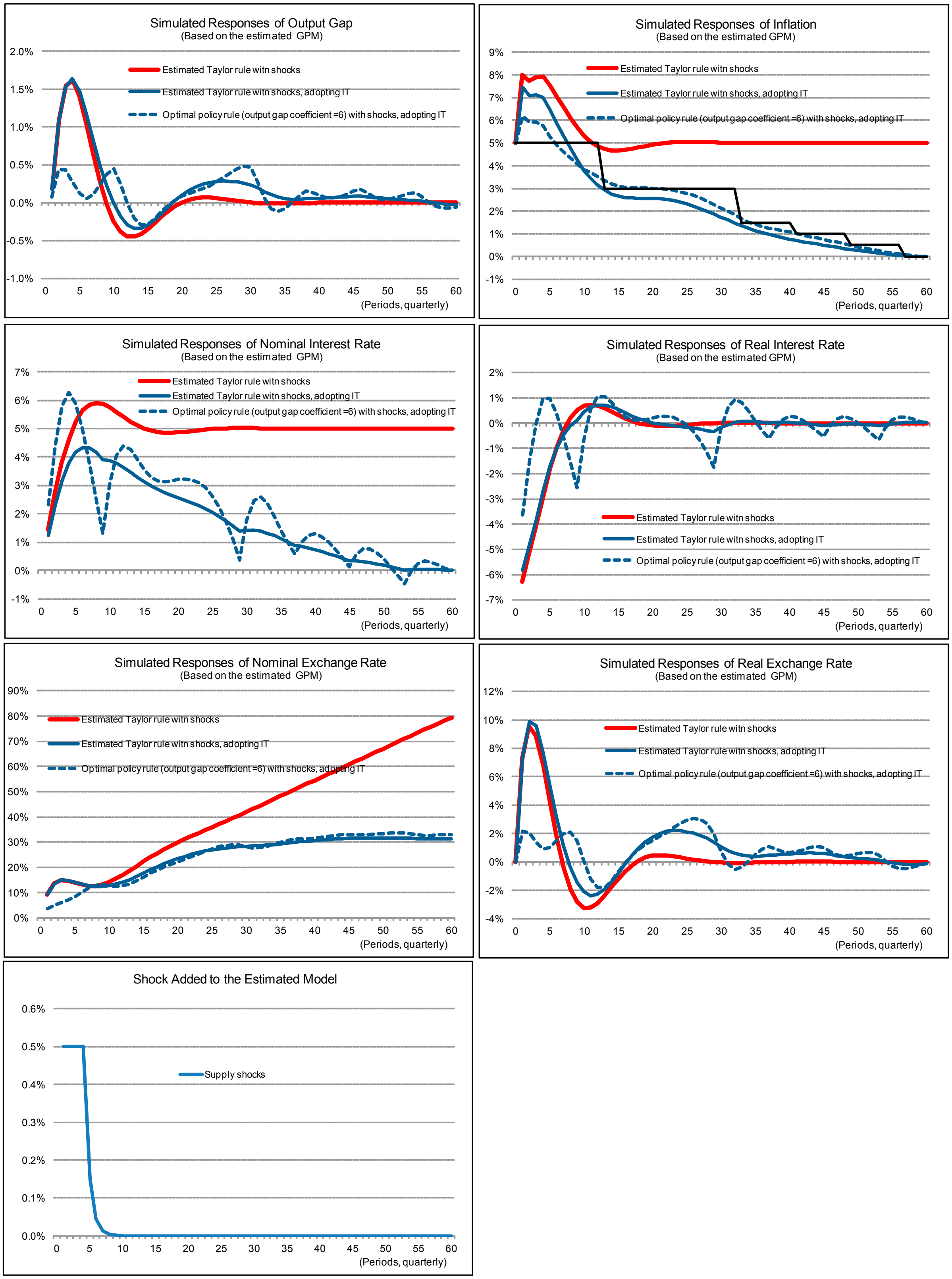


Figure 18. Simulated Responses to Capital Inflows and Delaying Tightening Derived from the Estimated GPM (Part I)

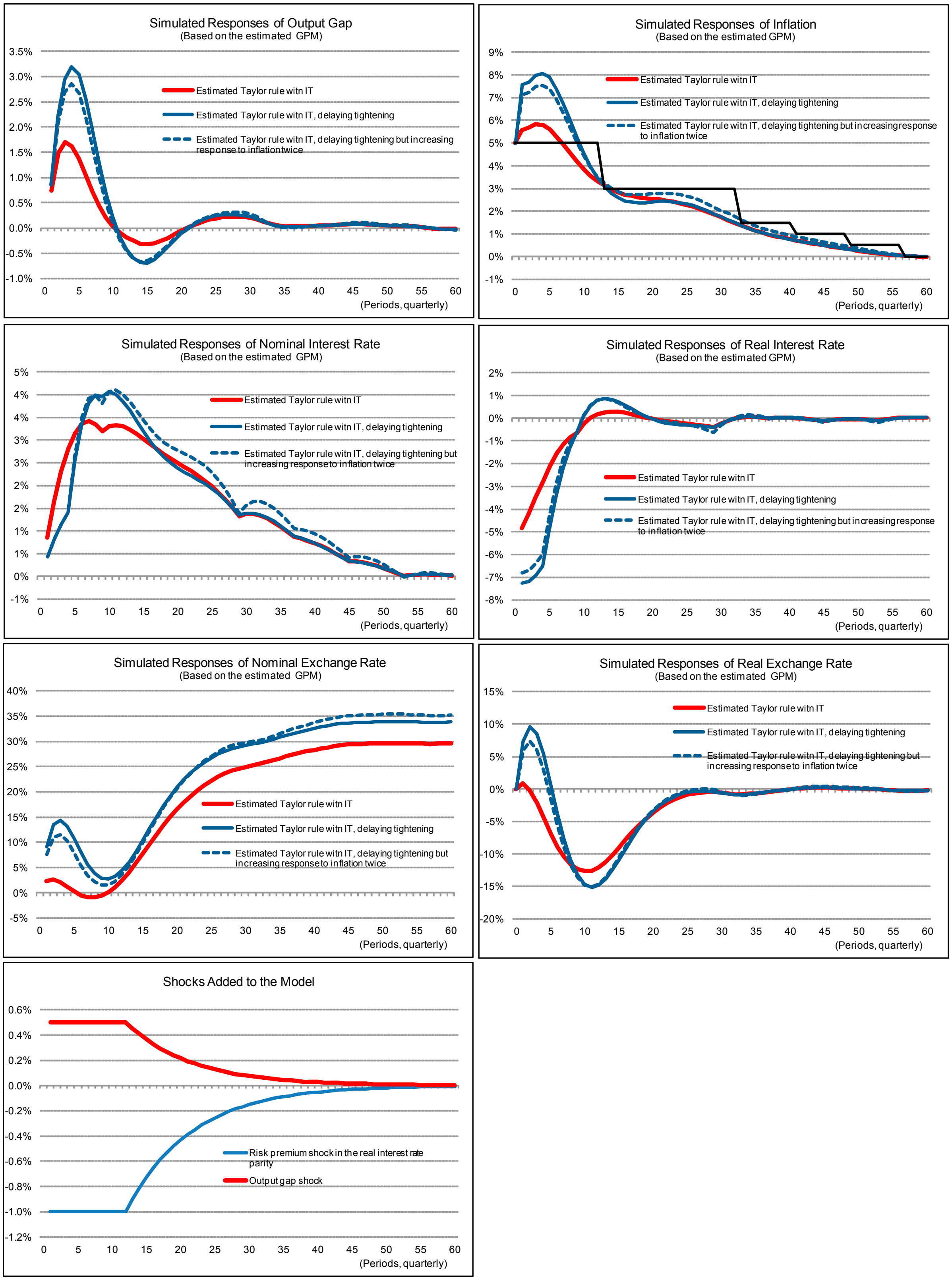
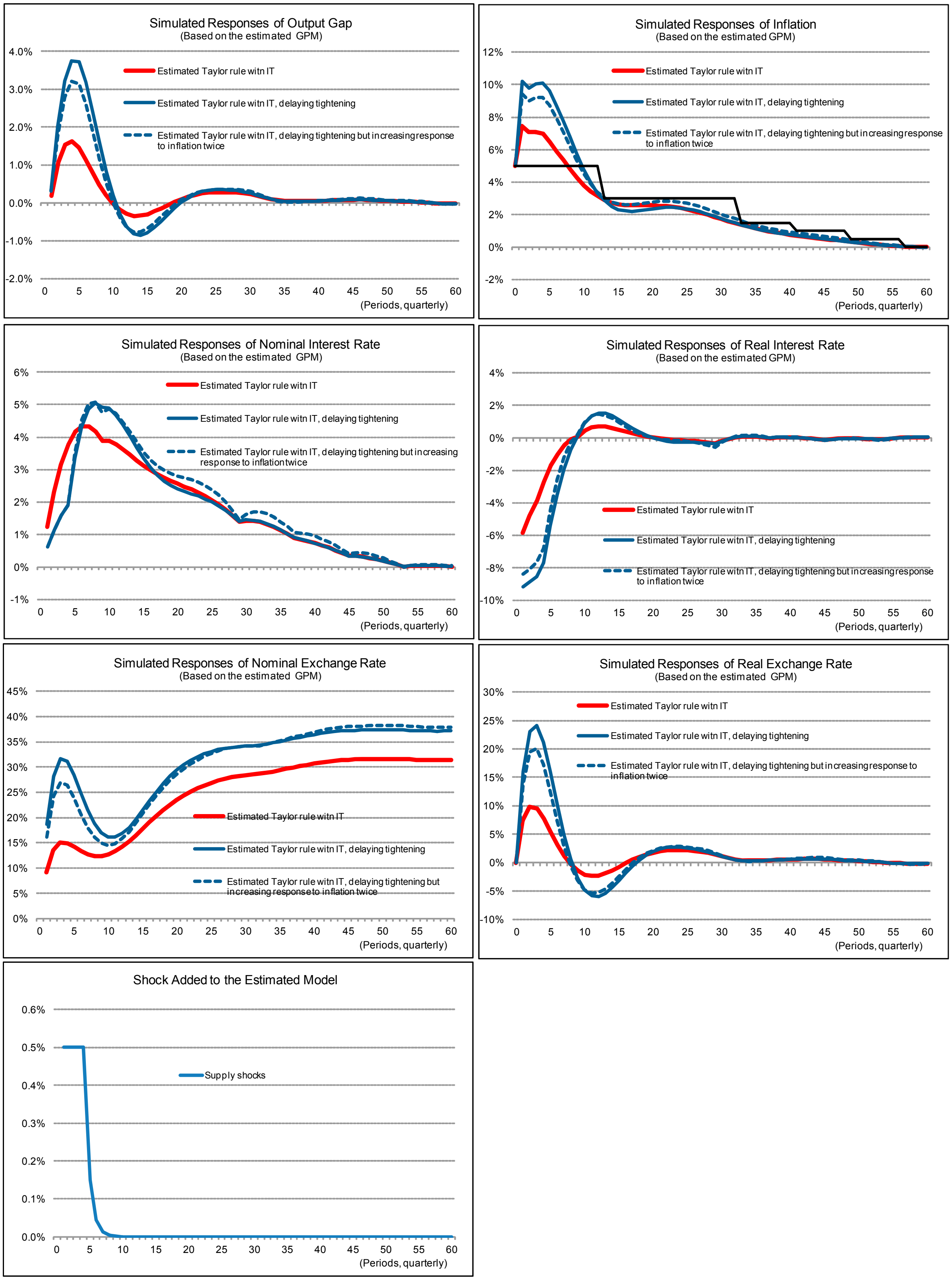


Figure 19. Simulated Responses to Supply Shocks and Delaying Tightening Derived from the Estimated GPM (Part II)



## APPENDIX I. COMPLETE MODEL EQUATIONS FOR GPM+

This appendix describes the full GPM+ model including the evolution of potential output and the equilibrium levels of the real effective exchange rate, real interest rate and unemployment rate. All of the variables in capital letters refer to levels of the variables (usually expressed in natural logarithm and in the case of unemployment and interest rates in terms of percentage points) whereas small letters refer to the gap of the variable from its equilibrium level measured in percentage points.

**Output block:**

The level of real output is denoted by $LGDP_t = 100 * \ln(GDP_t)$ and the output gap ( $y_t$ ) is defined as the difference between $LGDP_t$ and the potential level of output $\overline{LGDP}_t$ :

$$y_t = LGDP_t - \overline{LGDP}_t .$$

The output gap is assumed to depend on its own lead and lag, the real interest rate gap, the real effective exchange rate gap and the foreign output gap (IS curve):

$$y_t = \beta_1 y_{t-1} + \beta_2 y_{t+1} - \beta_3 r_{t-1} + \beta_4 z_{t-1} + \beta_5 y_{f,t-1} + \varepsilon_t^y ,$$

$$\overline{LGDP}_t = \overline{LGDP}_{t-1} + G_t / 4 + \varepsilon_t^{\overline{LGDP}} ,$$

$$G_t = \tau g_{ss} + (1-\tau) G_{t-1} + \varepsilon_t^G \text{, and}$$

$$z_t = Z_t - \overline{Z}_t .$$

**Unemployment block:**

Dynamics of the unemployment rate is governed by the dynamic version of Okun's law.

$$u_t = U_t - \overline{U}_t ,$$

$$u_t = \alpha_1 u_{t-1} + \alpha_2 y_t + \varepsilon_t^u ,$$

$$\overline{U}_t = \overline{U}_{t-1} + G_t^U + \varepsilon_t^{\overline{U}} ,$$

$$G_t^U = (1-\alpha_3) G_{t-1}^U + \varepsilon_t^{G^U} .$$

**Phillips curve:**

$$\pi_t = \lambda_1 \pi_{t+1} + (1-\lambda_1) \pi_{t-1} + \lambda_2 y_{t-1} + \lambda_3 \Delta Z_t + \varepsilon_t^\pi$$

**Real exchange rate block:**

$$4 * (Z_{t+1}^e - Z_t) = (R_t - R_{f,t}) - (\overline{R}_t - \overline{R}_{f,t}) + \varepsilon_t^{Z-Z^e} \quad \text{where } Z_{t+1}^e = \phi Z_{t+1} + (1-\phi) Z_{t-1}$$

**Nominal exchange rate:**

$$\Delta Z_t = \Delta S_t - \pi_t + \pi_t^*$$

**Policy rule:**

$$I_t = \gamma_1 I_{t-1} + (1-\gamma_1)[\overline{R}_t + \pi 4_{t+3} + \gamma_2(\pi 4_{t+3} - \pi_{t+3}^{Tar}) + \gamma_3 y_t] + \varepsilon_t^I$$

**Inflation target:**

$$\pi_t^{Tar} = \pi_{t-1}^{Tar} + \varepsilon_t^{\pi^{Tar}}$$

**Real interest rate:**

$$R_t = I_t - E_t \pi_{t+1}$$

**Real interest rate gap:**

$$r_t = R_t - \overline{R}_t$$

**Real equilibrium interest rate:**

$$\overline{R}_t = \rho \overline{R} + (1-\rho)\overline{R}_{t-1} + \varepsilon_t^{\overline{R}}$$

**Real equilibrium exchange rate:**

$$\overline{Z}_t = \overline{Z}_{t-1} + \varepsilon_t^{\overline{Z}}.$$

**Foreign demand:**

$$y_{f,t} = \beta_f y_{f,t-1} + \varepsilon_t^{y_f}$$

# APPENDIX II. DATA SOURCES

Table 6 - Data Source and Description

| Data Series | Description | Source | Availability |
|---|---|---|---|
| Real GDP (LGDP) | Quarterly average, seasonally adjusted and in logs | Central Bank of Egypt | 2005Q3-2010Q2 |
| CPI (LCPI) | Quarterly average, seasonally adjusted and in logs | Central Bank of Egypt | 2005Q3-2010Q3 |
| Unemployment Rate (UNR) | | CAPMAS, Egypt | 2005Q3-2010Q4 |
| Nominal Interest Rate (RS) | Overnight Interbank Rate, quarterly average | Central Bank of Egypt | 2005Q3-2010Q5 |
| Real Effective Exchange Rate (LZ) | Based on INS trade weights | INS Database, IMF | 2005Q3-2010Q6 |
| Nominal Effective Exchange Rate (LS) | Based on INS trade weights | INS Database, IMF | 2005Q3-2010Q7 |
| Real Foreign Interest Rate (RRF) | Based on GPM estimates for the 6 main blocks and Egypt's trade shares | GPM Historical Estimate (September 17, 2010) | 2005Q3-2010Q8 |
| Real Foreign Equilibirum Interest Rate (RRF_BAR) | Based on GPM estimates for the 6 main blocks and Egypt's trade shares | GPM Historical Estimate (September 17, 2010) | 2005Q3-2010Q9 |
| Foreign Output Gap (YF) | Based on GPM estimates for the 6 main blocks and Egypt's trade shares | GPM Historical Estimate (September 17, 2010) | 2005Q3-2010Q10 |

## APPENDIX III. ESTIMATION METHOD

The GPM+ is estimated using a method called regularized maximum likelihood whereby the standard likelihood of the model based on the vector of parameters ($\theta$) and the data ($Y$) is amended with a penalty term $p * \tau_i$ that reflects the weight of the econometrician's priors which is given by $\bar{\theta}_i$. The parameter estimates are calculated by maximizing the following expression:

$$\max_{\theta} \log L(\theta, Y) - p \sum_i \tau_i (\theta_i - \bar{\theta}_i)^2$$

such that $\theta_i \in [\theta_i^L, \theta_i^H]$.

This method can therefore be interpreted as a simple Bayesian technique where all the priors are assumed to have a normal distribution with mean $\bar{\theta}_i$ and variance $\frac{1}{p\tau_i}$. The estimates are truncated above and below as necessary to impose certain restrictions on the parameter space as specified by $[\theta_i^L, \theta_i^H]$. We use $p = 0.01$ for the results reported in this paper, where $p = 0$ corresponds to the maximum likelihood estimation.

## APPENDIX IV. SHOCKS ADDED TO THE ESTIMATED GPM+ IN THE SIMULATIONS

Socks added to the estimated system are as follows.

- ***Capital inflows***: Increased capital inflows is proxied by (i) a final demand increase by 0.5 percentage points (equivalent to 2 percentage points annually) as a share of GDP from period 1 to 12 and a gradually decline to zero after that (following AR(1) with coefficient 0.9), and (ii) a temporary decline in the sovereign spreads by 100 bp from period 1 to 12 and a gradual decline to zero after that following the same autoregressive process as the output gap shock;
- ***Adopting inflation targeting***: Inflation (from the steady state) before the announcement is set at 5 percent, counting the facts that (i) the cross country studies on inflation suggests that long-run target of inflation for Egypt should be somewhere between 2 and 5 percent and (ii) current inflation is about 10 percent. After the announcement, the central bank commits to keep its inflation target at 5 percent until $12^{th}$ period (3 years). After that, it reduces the target to 3 percent until period 32. After period 33, the central bank reduces its target by 0.5 percentage points every two years (however, choice of the initial inflation does not matter as long as it is positive), incorporating a gradual decline in the target in the countries adopting inflation targeting monetary policy framework in the past;
- ***Supply shocks in the Phillips curve***: Given 5 percent initial inflation, a half percentage point shock to inflation from period one to four and a gradual decline after that, following AR(1) with coefficient 0.3, are assumed, consistent with the estimated residuals in the Phillips curve in the GPM+; and
- ***Delaying monetary policy tightening:*** this is characterized by a half of the increase in the nominal interest rate in periods one to four compared to that implied by the scenarios of capital inflows and supply shocks.

Variables are assumed to be in the steady state before period one, unless specially mentioned. Since the estimated output gap is close to zero (at least not significantly different from zero), this assumption does not appear totally unrealistic. However, changing the initial real exchange rate level does not affect the main conclusions presented in the paper.