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Modelling monetary transmission in less developed emerging markets: the case of Tunisia

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Abstract

This paper exploits a case study of a country belonging to a group of less developed emerging markets (LDEMEs). This group has features which challenge standard New-Keynesian (NK) assumptions. These are: underdeveloped and shallow financial market, uncompetitive labour market, informal economy, weak institutions, problematic central bank independence, state ownership and controls, monetary policy targeting multiple variables. To overcome problems which might arise from using standard models, the paper proposes a complex strategy of modelling monetary transmission in LDEMEs: (i) SVARs which reflect the central bank's simultaneous recourse to multiple policy instruments and targets, and (ii) NK structural models, which capture such features as an immature financial market, exchange rate interventions, and price subsidies. This way, a range of possible reactions of basic macroeconomic variables to monetary policy instruments is obtained. Such approach, combining multiple econometric techniques, reduces uncertainty concerning specification, parameters and equilibria.

Keywords: LDEMEs, monetary transmission, SVAR, structural models

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1. Introduction

Less developed emerging markets (LDEMEs) are frequently modelled with the use of standard assumptions of New Keynesian (NK) and DSGE models, e.g. Peiris and Saxegaard (2007) for Mozambique, Ben Aïssa and Rebei (2012) for Tunisia. There are, however, two problems with this approach. The first one is specification: LDEMEs have a bunch of special features which put a question mark on the use of conventional models. Good examples are: the role of government and quality of institutions, eclectic monetary policy, an underdeveloped financial sector, where credit risk analysis is replaced by a requirement of collateral considerably limiting access to credit or non-competitive labour markets. Secondly, the estimation of NK models as a system is performed under a presumption that a steady state exists. This may not be true, as LDEMEs are subject to many structural changes (Tovar 2008; Rummel 2012). For instance, in Tunisia, the revolution of 2011 seemingly changed not only the relation between capital and labour, but also the behaviour of the labour force.

Governments in LDEMEs usually control a considerable part of prices from the consumer basket, especially foodstuffs, fuels, and energy. Likewise, controls may affect interest rates and loans in the banking sector: floors and ceilings on some rates are not unusual, as well as allocation of loans to the preferred sectors. Furthermore, state-owned banks, having explicit or implicit guarantees and privileges may distort credit channel operation (Kishan, Opiela 2000). Capital controls aimed at avoiding excessive volatility of exchange rates and loss of competitiveness put another question mark on the usually adopted assumption of uncovered interest rate parity (UIP). Only recently, Benes et al. (2013) have developed a NK model featuring sterilized interventions in a genuine emerging market economy and modelled interventions as an independent instrument operating alongside interest rate policy.

Many LDEMEs have weak institutions resulting in the state capture, corruption, and high ratios of non-performing loans (NPLs). State capture may weaken competition and negatively impact the effectiveness of monetary transmission, whereas corruption induces banks to more risk taking (Chen, Jean, Wu 2014). Furthermore, *de facto* central bank independence may be problematic. That erodes central bank credibility and has a negative impact on expectations of private agents.

Monetary policy in LDEMEs happens to be eclectic and has *de facto* multiple other targets besides inflation, like trade competitiveness or banking sector stability. The latter is particularly important for these suffering from a big portfolio of NPLs. Inflation may play a subordinate role in the policy rule, since administrative price controls leave less space for the monetary policy. Many LDEMEs resort to non-standard monetary policy instruments, like reserve requirements. This may change the usual effects of the monetary transmission: if an increase in the reserve requirements, i.e. monetary tightening, results in lower deposit rates, it may lead to higher instead of lower consumer demand and prices.

In LDEMEs, a considerable scale of informal economy and shadow labour market cushions the impact of interest rates on wage rates, aggregate demand, and inflation (Castillo, Montoro 2012). Monetary transmission is weaker in countries with a shadow financial sector, because some parts of the economy are excluded from the impact of the central bank. Usually, formal and informal financial sectors are complementary, but there is empirical evidence showing that in some circumstances interest rates in formal and informal financial sectors may change in the opposite directions, frustrate monetary policy, and its impact on the economy (Ngalawa, Viegi 2013).

Finally, consumption in standard NK models is based on the Euler equation. However, as pointed by Rummel (2012), in LDEMEs consumption may be insensitive to the real interest rate. Empirical evidence is mixed. Mukherjee and Bhattacharya (2011) provide evidence on the dependence of private consumption on a real deposit rate and conclude that for a panel of Middle East and North Africa countries (Egypt, Jordan, Lebanon, Morocco and Tunisia) the real deposit rate does not have a direct impact on consumption. However, it seems to affect consumption indirectly, in step with a growing level of financial development.

All in all, different economic structures and monetary policies challenge the standard NK models and may result in responses of macroeconomic variables to monetary policy shocks diverging from these obtained for mature market economies.

There exist models adjusted for LDEMEs (e.g. Agénor, Montiel 2007; Agénor, El Aynaoui 2010) – they do have such features as, *inter alia*, underdeveloped financial markets, where credit is the only source of external financing, the interest rate is used as a policy instrument but monetary authorities recourse also to reserve requirements and intervene in foreign exchange markets. Another example is a DSGE model in Peiris and Saxegaard (2007), where monetary policy rules allow for a use of various instruments, including reserve requirements; there are interventions in the foreign exchange market, and the modelled country obtains foreign aid. However, in many cases, the use of adjusted models is limited by data availability. Hence, building a model for a generic LDEME needs inclusion of at least the most important non-standard features and, at the same time, maintaining a necessary parsimony which is implied by a poor data environment.

To overcome at least some of these problems, the present paper suggests a complex way of proceeding with analyses and modelling monetary transmission in the LDMEs, treating Tunisia as a genuine small trade-open LDEME. We start from the stylized facts which provide a broad assessment of the distance between the modelled economy and theoretical assumptions. Then, we use structural vector autoregressive models (SVARs) to examine the stylized facts in a more rigorous way. The responsiveness of the economy to monetary policy instruments as well as lags and strength of the monetary transmission are of our particular interest. We show the weakness of the short-term interest rate, the dominance of the exchange rate and the perverse impact of the reserve requirement. We note a small, short-lived impact of the interest rate on consumer prices; the effect is ascribed to the impact of rapidly reacting cost of mortgage credit, which is usually extended to households at a variable rate. We do not find any impact of the interest rate on industrial production which is a proxy for the real sector activity. The exchange rate has a more clear-cut impact on prices, output and credit to the economy. Then we pass on to building two more informative NK models, which would be able to capture stylized facts obtained from SVARs. For example, we adjust the exchange rate equation to gauge capital controls and interventions in the foreign exchange market. Limited reliance of firms on banking credit and a low degree of financial inclusion of households is captured by the backward--lookingness of the IS curve and the Phillips curve. Two models give us a range of possible reactions. We compare our models with a standard NK model, i.e. a model which is not equipped with features specific for LDEMEs. The latter displays high responsiveness of output and prices to the interest rate and a low one to the exchange rate, which is clearly inconsistent with the findings from SVARs.

The paper proceeds as follows: Section 2 broadly overviews stylized facts, Section 3 presents SVAR models and selected impulse response functions (IRFs). Section 4 shows structural models. Section 5 concludes.

2. Overview of stylized facts

Over 2000–2010 GDP in Tunisia grew at an average rate of 4.5%.[1] The European financial crisis stifled demand for its exports and negatively affected investment. Economic growth fell from 4.3% in 2008 to 3.3% in 2009–2010. Social unrest of 2011 exacerbated the slowdown. As a result, the economy deviated significantly from its pre-crisis and pre-revolution performance. Before 2009–2011, GDP was hit by the global slowdown of 2001 and the terrorist attack on tourists in 2002.

A breakdown of total value added shows a dominant role of market services and industry (47% and 17% in 2010, respectively). Tunisia depends heavily on foreign demand, in particular that of the euro area. Trade openness amounts to 90% of GDP (Institut National de la Statistique). Financial openness is low due to capital controls. Foreign investors have a limited access to the short-term debt market. Foreign exchange deposits are allowed solely for exporters, importers, and non-residents.

Tunisia has been introducing market-oriented reforms since late 1980s, nonetheless the state still plays a significant role. It controls about 36% of consumer price index, employs 13% of the active labour force[2] and has an important role in wage negotiations. Three state-owned banks account for 37% of banking sector assets.

Financial sector is underdeveloped in spite of a relatively high ratio of financial assets to GDP (111% in 2012). It is dominated by banks (banking sector assets / GDP amounted to 90% in 2012). Banks are burdened with a sizable portfolio of NPLs (about 14% of assets in 2012), which are mostly due to the administrative allocation of loans to the privileged sectors (tourism). Loans are concentrated in big enterprises and tend to be extended on the basis of collateral. The main recipients of loans to the economy are services and industry. Outstanding credit to services is by 65% larger than credit to the industrial sector, Banque Centrale de Tunisie (2012). Credits are usually extended at variable rates (85%), whereas deposits are mostly raised at fixed rates – more than 80% (Mouha 2014). Finally, there is no efficiently working securities market.

Figures showing financial inclusion are mixed: on the one hand, just 27% of adults have an account at a financial institution, but on the other hand, 10.7% have an outstanding mortgage at a financial institution. For Poland the respective figures are 78% and 14.6% (World Bank 2014). A considerable ratio of those having a mortgage credit may result in a greater responsiveness of consumer demand and prices to the interest rate than expected for a generic LDEME.

The size of the informal economy is large, 30% (as a share of formal – officially measured – GDP (IMF 2011). More than one third of employment in the private sector is informal. Before 2011 there was a significant state capture. Firms connected to the president of the state outperformed their competitors in terms of output, employment, market share, profits and growth. Sectors in which they were active were disproportionately subject to authorization requirements and restrictions on FDI (Rijkers et al. 2014).

Tunisia's monetary policy has been eclectic, with elements of exchange rate and monetary targeting. The former was to preserve trade competitiveness, the latter to control inflation. Up to 2001 Tunisia followed the exchange rate rule. Since then it used *de jure* managed float, but *de facto* crawling peg, with 3–3.3% of annual real depreciation with respect to the euro. An important element of the

1 All data on GDP, its growth and breakdown come from Institut National de la Statistique and Banque Centrale de Tunisie.

2 This is sharply down from about 20% at the end of the 1990s as a result of market-oriented reforms (see Bardak et al. 2006).

monetary policy was interest rate stabilization and smoothing. Central bank tended to replace increases of the interest rate with reserve requirement to avoid deterioration of the loan portfolio of banks. Being the aim per se, the interest rate stability led the central bank to provide liquidity the banking sector demanded. This undermined the usual effects of reserve requirement tightening. However, after the revolution of 2011, the central bank decided to abandon reserve requirement and moved on to using the interest rate as its primary instrument. Nonetheless, even then, the central bank tended to lose its independence and was unable to increase the interest rate.

Over 2000–2011 inflation was reasonably low, though it displayed a clear-cut upward trend. It got more pronounced after the revolution of 2011, when the economy was hit by a negative supply shock. Strikes, curfew, and rising uncertainty led to an outflow of foreign capital and increased production costs. A following drop in investment demand as well as contraction in tourism made monetary and fiscal authorities apply expansionary policies: lower reserve requirement and interest rate, higher public expenditures. Increase in consumer demand for basic foodstuffs from migrants fleeing from Libya additionally fuelled inflation.

Inflation persistence has been moderate in spite of wage contracts based on past inflation. It means that shocks to inflation fade away and do not affect permanently its level. Persistence measured as the number of times that inflation crosses a time varying mean, considered to be the long--term inflation level (Marques 2004),[3] is close to a value characteristic for the absence of persistence in the case of headline inflation, and moderate in the case of core inflation. An alternative measure, a sum of autoregressive coefficients, ρ, brings similar conclusions (Table 1). To obtain ρ we start with the autoregressive representation of inflation, where p is the order of autoregression:

$$y_t = \alpha_t + \sum_{j=1}^{p} \beta_j y_{t-j} + \varepsilon_t$$

which can equivalently be written as:

$$\left(y_t - \mu_t\right) = \sum_{j=1}^{\rho} \delta_j \Delta\left(y_{t-j} - \mu_{t-j}\right) + \rho\left(y_{t-1} - \mu_{t-1}\right)$$

where μ_t is the mean and $\rho = \sum_{j=1}^{p} \beta_j$.

Moreover, quarter-on-quarter inflation, either headline or core (non-food non-energy) tends to be stationary or trend-stationary (Table 2).[4] Thus, there is some intrinsic persistence in core inflation, most probably due to wage indexation.[5]

[3] To obtain a time varying mean we use Hodrick-Prescott filtering.

[4] However, trend stationarity may be easily confused with I(1) processes, and therefore stationarity tests as an indicator of persistence should be treated with caution.

[5] For more information on stylized facts see Przystupa, Wróbel (2015).

3. Monetary transmission: SVAR models

3.1. Identification dilemmas

Eclectic monetary policy, multiplicity of policy instruments (liquidity management, the interest rate, the exchange rate, the reserve requirement), and their changing role over time make the choice of a unique "true" instrument problematic, and the identification of a true monetary policy shock non--trivial. Moreover, owing to factors distorting transmission, such as administrative controls of prices and retail interest rates, high concentration of loans and a significant shadow labour market, even a "true" monetary policy shock may have an impaired impact on the real economy and therefore be easily discarded, for example, cost channel previewed in LDEMEs by Agénor and Montiel (2007) may induce non-standard price reactions. There is also some vagueness concerning the behaviour of the exchange rate due to capital controls. The exchange rate may either appreciate after a positive shock to the interest rate, depreciate, or stay flat. The first is true if after monetary tightening domestic investors tend to sell equities and buy treasuries. Then prices of equities would fall attracting foreign investors. Depreciation, in turn, may occur if foreign investors expect a deterioration in fundamentals and sell equities. Finally, both effects may offset.

In the same vein, reserve requirement increases, which are expected to reduce aggregate demand and prices through lower liquidity and credit supply, may bring an opposite effect (Agénor, Montiel 2007; Glocker, Towbin 2012a). Using a small open-economy with sticky prices, financial frictions and the banking sector subject to legal reserve requirements, Glocker and Towbin (2012a) show that the overall macroeconomic effect of reserve requirement changes is ambiguous and depends on the relative strength of depositors' and borrowers' reaction. Namely, an increase in the reserve requirement raises the cost of deposits for the banking sector reducing banks' demand for deposits. As a result, banks lower deposit rates. If a central bank employs the reserve requirement but targets the interest rate, then it must supply more liquidity to the banking system (monetary base will adjust). With reserves remunerated below the market rate, banks may rise loan rates. Thus, monetary policy will affect a spread between deposit and loan rates. Lower deposit rates expand consumption, while higher loan rates restrain investment. The scale of overall reaction depends on the semi-elasticity of spending to the respective interest rates.

Alternatively, resources can be reallocated and the reserve requirement increase may lead to higher prices of other financial or non-financial assets, like real estate. This can additionally expand consumption through the wealth effect. To restore equilibrium loan rates should rise. In fact, however, they may remain flat or fall. The former occurs if, as aforementioned, the central bank targets the interest rate and is therefore ready to flexibly provide banks with funds at a policy rate. The loan rate should remain unaffected if deposits and loans from the central bank are perfect substitutes or if banks are non-risk averse (Agénor, Montiel 2007; Glocker, Towbin 2012a). A reason for the loan rates to fall is the positive impact of higher prices on the value of collateral (Agénor, El Aynaoui 2010).

Furthermore, macroeconomic effects of using reserve requirements depend on the weight of bank lending as a source of external funds and on the degree to which lending can be easily substituted with other sources of financing.

Taking into account all these features, identification of monetary policy shocks just on the basis of the expected shape of response functions, as in Uhlig (2005), may be not valid. For LDEMEs, to obtain "true" monetary policy innovations, it would be more appropriate to rely on the identification of the monetary policy rule. By imposing excluding restrictions in classical SVAR models and sign restrictions in the Bayesian SVAR models on a systematic part of monetary policy and leaving the remaining equations non restricted, it is possible to disentangle systematic and non-systematic impact or to separate demand and supply shocks affecting banks' reserves. The former idea has been suggested in Arias et al. (2015), while the latter exploited by e.g. Strongin (1995).

We use elements of both methods. We rely on the analysis of monetary policy procedures and of supply and demand for reserves. Firstly, we impose excluding restrictions to gauge monetary policy rules for the interest rate, the exchange rate and liquidity, and estimate a SVAR with classical methods. Secondly, we redo the exercise using zero and sign restrictions. We restrict money market variables, while prices, output, credit to the economy and the exchange rate remain unrestricted. We compare the results and determine which reactions can be considered as "true" responses to monetary policy shocks.

3.2. Models and identification

Our VAR models contain three and sometimes even four monetary policy instruments, therefore for the sake of clarity we use the notation suggested by Favero (2001), where variables are divided into two groups: non-policy and policy variables. Thus, we consider the following model:

$$A\begin{pmatrix} Y_t \\ M_t \end{pmatrix} = C(L)\begin{pmatrix} Y_{t-1} \\ M_{t-1} \end{pmatrix} + B\begin{pmatrix} v_t^Y \\ v_t^M \end{pmatrix} \tag{1}$$

where Y_t and M_t are vectors of macroeconomic non-policy and policy variables, matrix A describes contemporaneous relations between the variables, $C(L)$ is a matrix of finite-order lag polynomial and $v \equiv \begin{pmatrix} v^Y \\ v^M \end{pmatrix}$ is a vector of structural shocks to the non-policy and policy variables.

VAR models are estimated as the reduced form of the underlying structural model:

$$\begin{pmatrix} Y_t \\ M_t \end{pmatrix} = A^{-1}C(L)\begin{pmatrix} Y_{t-1} \\ M_{t-1} \end{pmatrix} + B\begin{pmatrix} u_t^Y \\ u_t^M \end{pmatrix} \tag{2}$$

where u is a vector of VAR residuals (*NID*), with full variance-covariance matrix Σ.

The relation between the residuals and structural shocks is:

$$A\begin{pmatrix} u_t^Y \\ u_t^M \end{pmatrix} = B\begin{pmatrix} v_t^Y \\ v_t^M \end{pmatrix} \tag{3}$$

We use VARs with the following representation: Y_t is a vector of three endogenous non-policy variables, all in natural logarithms: the manufacturing output (y_t), consumer prices (cpi_t) and the volume of credit to the economy (cr_t). Thus, each time $Y_t' = [y_t, \quad cpi_t, \quad cr_t]$. In contrast to Y_t, M_t i.e. a vector of endogenous policy variables and varies across models. It contains a short-term interest rate (tmm_t), the nominal effective exchange rate ($neer_t$), either excess or total reserves of banks ($exres_t$ or tr_t), depending on the model, and the reserve requirement ratio on sight deposits (rrr_t).[6] The nominal effective exchange rate and banks' reserves are in natural logarithms. Thus, we have $M_t' = [tmm_t, \quad neer_t, \quad exres_t]$ in Model I.1, $M_t' = [tmm_t, \quad neer_t, \quad tr_t]$ in Model I.2, and $M_t' = [tmm_t, \quad neer_t, \quad tr_t, \quad rrr_t]$ in Model II.

Total reserves are calculated as M0 – cash in circulation, while excess reserves as M0 – cash in circulation – reserve requirement. Reserves measure banking sector liquidity, excess reserves do not include the effects of reserve requirement changes. In general, higher reserves enable banks to extend more loans. In addition, we have a vector of exogenous variables containing industrial output in the euro area, short-term Euribor and Libor rates to pin down close trade relationships with the EU and a possible impact of foreign interest rates on the exchange rate. We use three dummy variables: for the financial crisis in 2008, for the revolution in 2011, and for the significant credit write-off at the beginning of the healing process in the banking sector (January 2001), as well as the linear trend. All variables have a monthly frequency. SVAR estimations have been performed on a sample spanning January 2000 – December 2013. The models satisfy the stability condition.

Owing to real and nominal rigidities we keep a block recursive structure between slowly moving real sector variables and monetary policy variables. Instead of using the standard Cholesky factorization, whose implied assumptions match the Tunisian monetary policy to a limited extent, we employ a more country-specific non-recursive decomposition with over-identifying restrictions. Comparing with the simple Cholesky factorization, non-recursive decomposition brings more structure to VAR models and allows a simultaneous reaction between money, the short-term interest rate and the exchange rate. Since changes in banks' reserves are due to a mixture of demand and supply shocks, we impose a set of restrictions to disentangle them.

The first six variable setting, i.e. Model I.1, has the following ordering $[y_t, \quad cpi_t, \quad cr_t, \quad tmm_t, \quad neer_t, \quad exres_t]$. In the non-recursive decomposition of the same model (Figure 2), beside the aforementioned assumptions concerning output and prices we presume that demand for loans depends on output, prices and the interest rate; the interest rate may contemporaneously respond to output and prices, but we do not expect statistically significant estimates since interest rate policy was passive over long periods. The exchange rate is assumed to be controlled by the central bank with the aim to preserve price competitiveness, i.e. the exchange rate responds contemporaneously solely to price developments. The exchange rate policy is allowed to affect banking sector reserves. Finally, the supply of reserves depends contemporaneously on loans to the economy, which reflects that the central bank targeted credit and monetary aggregates. This set of assumptions allows for feedbacks in the monetary sector and for liquidity management and exchange policy to have different targets (Table 3). We repeat the estimation using total reserves instead of excess reserves (Model I.2). The set of restrictions on the A and B matrix for Models I.1–I.2 is therefore as follows:[7]

6 We are not in possession of data on the weighted average of the reserve requirement and the effective required reserve.
7 In the Model I.3 excess reserves are replaced by total reserves.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & \alpha_{34} & 0 & 0 \\ \alpha_{41} & \alpha_{42} & 0 & 1 & 0 & 0 \\ 0 & \alpha_{52} & 0 & 0 & 1 & \alpha_{56} \\ 0 & 0 & \alpha_{63} & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^{y} \\ u_t^{cpi} \\ u_t^{cr} \\ u_t^{tmm} \\ u_t^{neer} \\ u_t^{exres} \end{bmatrix} = \begin{bmatrix} v_t^{y} \\ v_t^{cpi} \\ v_t^{cr} \\ v_t^{tmm} \\ v_t^{neer} \\ v_t^{exres} \end{bmatrix} \quad (4)$$

The non-zero coefficients α_{ij} in (4) indicate that variable j affects variable i instantaneously, e.g. α_{21} is the instantaneous impact of output on prices. The assumptions embodied in (4) over-identify the system (for a just-identification $n(n-1)/2$ restrictions are needed, where n is the number of variables in the system). In (4) we have six over-identifying restrictions. The test of over-identifying restrictions is placed over the respective figures of impulse response functions.

Identification of shocks to reserve requirement is more tricky. The simultaneity problem is more acute than in the previous setting of six variable VARs, since now three monetary policy instruments: the interest rate, the exchange rate, and reserve requirement affect banks' nominal reserves. Moreover, the model is larger, which reduces the degrees of freedom. The impact of the reserve requirement is usually examined with the use of SVAR models with sign restrictions, but the literature is scarce. The underlying reason is straightforward: this instrument is basically not in active use in developed economies. There are just a few papers concerning emerging markets, especially in Latin America that use the reserve requirement if, for some reasons, there is a need to tighten monetary policy, but there is a considerable risk that increased interest rate would lead to an undesired exchange rate appreciation. Glocker and Towbin (2012) have built a SVAR for Brazil. Then, a similar model has been applied for Peru by Perez-Forero and Vega (2014).

In this paper, however, to preserve comparability with our previous estimates, we start the identification of the reserve requirement shocks with a classical SVAR with a non-recursive decomposition (Model II.1) and only afterwards we pass on to the sign restrictions (Model II.2). In the non-recursive decomposition we use the same set of excluding restrictions as for the six variable models and add other necessary ones for the reserve requirement. We have ordered reserve requirements just after the interest rate and before the exchange rate and total reserves. We have assumed that the reserve requirement ratio depends contemporaneously on credit to the economy and the short-term interest rate. It may contemporaneously affect the exchange rate and total reserves. Total reserves are allowed to react contemporaneously with the reserve requirement. Thus, restrictions in the respective matrices A and B are as in (5). Once again, the system has 6 over-identifying restrictions. The test of over-identifying restrictions is placed over the respective figures of IRFs.

$$\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ \alpha_{21} & 1 & 0 & 0 & 0 & 0 & 0 \\ \alpha_{31} & \alpha_{32} & 1 & \alpha_{34} & 0 & 0 & 0 \\ \alpha_{41} & \alpha_{42} & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \alpha_{53} & \alpha_{54} & 1 & \alpha_{56} & \alpha_{57} \\ 0 & \alpha_{62} & 0 & 0 & 0 & 1 & \alpha_{67} \\ 0 & 0 & \alpha_{73} & 0 & \alpha_{75} & \alpha_{76} & 1 \end{bmatrix} \begin{bmatrix} u_t^{y} \\ u_t^{cpi} \\ u_t^{cr} \\ u_t^{tmm} \\ u_t^{rrr} \\ u_t^{neer} \\ u_t^{tr} \end{bmatrix} = \begin{bmatrix} v_t^{y} \\ v_t^{cpi} \\ v_t^{cr} \\ v_t^{tmm} \\ v_t^{rrr} \\ v_t^{neer} \\ v_t^{tr} \end{bmatrix} \quad (5)$$

In the analysis of impulse response functions, the reaction of total reserves to the contractionary reserve requirement shock is of key importance: if total reserves increase, then the shock may be considered as the "true" reserve requirement shock.

The next part of this chapter provides the aforementioned estimations with sign restrictions and verifies the robustness of the results from Model I (a six-variable setting) and Model II (a seven variable setting). This is a less structured approach than the one used before, where we have imposed zero restrictions on model coefficients. For the assumed structure of the model, the results obtained from the classical SVARs, either just-identified or over-identified, are unambiguous. However, if these assumptions change, the results may change as well. SVARs with sign restrictions are not susceptible to this flaw (see also Kapuściński et al. 2016). This is particularly important in the analysis of economies where the monetary policy was subject to changes or where there is considerable uncertainty about the economic model.

SVAR models with sign restrictions allow to impose a co-movement of variables suggested by the economic theory. We restrict solely the policy variables, i.e. we are agnostic about the non-policy variables. We do not want to restrict them excessively, since our aim is to examine how they behave after the monetary policy shock. We base on Uhlig's (2005) "pure sign restrictions" and additionally employ zero restrictions to impose lagged responses of output and prices to monetary policy shocks.

In Model I.3 disturbances to demand for banks' reserves not driven by development in output, prices and credit are referred to as exogenous shocks to demand for reserves. They can emerge e.g. from a shift in banks perception of risk affecting their propensity to extend loans or result from a new way of refinancing (e.g. capital market development). Exogenous supply shocks should be due to the non--systematic part of the monetary policy. Demand and supply shocks to banks' reserves are identified by a positive or negative co-movement of reserves and the interest rate (Table 4). To identify a monetary policy shock we set the total reserves as positive for a two-month interval and the interest rate to be negative (the liquidity effect). The orthogonal demand shock is identified by imposing a positive sign on banks reserves and the interest rate. In both cases, output and prices are restricted to zero at impact, other variables are allowed to react at once.

In Model II.2 the identification of the reserve requirement shock is obtained in a way similar to Glocker and Towbin (2012b). We assume that a positive shock to the reserve requirement raises demand for total reserves. The interest rate, loans and the exchange rate are left unrestricted. The exchange rate innovation is identified as the orthogonal shock. Under the floating regime a typical exchange rate shock is the one resulting from risk premium disturbances. However, the BCT highly managed the exchange rate (see Section 2), therefore our trial to extract such a shock would not be supported by data. Under the managed float, the exogenous exchange rate shock, i.e. the shock unrelated to current economic developments, can result, for example, from an unexpected need to depreciate the national currency. This in turn can be due to a negative shift in demand for tourist services, or a failure to roll over the outstanding foreign debt. Thus, we assume that the central bank intervenes to depreciate domestic currency: it offers a higher price of foreign currencies and buys them from the banking sector. This increases liquidity, which is sterilized through open market operations. We restrict the interest rate not to fall. Other variables are left unrestricted, our aim is to verify the impact of the exchange rate shock on output, prices and credits. We keep only impulse response functions which simultaneously satisfy restrictions identifying two respective shocks. A total of 1000 successful draws are used to construct impulse responses. We show the impulse response functions in the figures including the lines of the posterior median and statistical confidence bands, i.e. the 16th and the 84th percentiles of the estimated posterior distribution of the obtained impulse response functions.

3.3. Results from SVARs

Many reactions to monetary policy shocks are insignificant at standard levels of statistical inference (Figures 2–4). Confidence intervals are wide, which reflects the weakness of monetary transmission. Non-recursive VAR models have been over-restricted, but the restrictions are not rejected (for Model I.1). There is a strong support for the existence of the exchange rate pass--through and of the impact of the exchange rate on credit. The credit drop following exchange rate appreciation may result from a lower demand from services, especially tourist services, which heavily depend on the exchange rate and are one of the most intensive credit absorbers. Evidence of exchange rate influence on output is weaker, especially from decompositions obtained from classical, non-recursive SVARs, where it is only close to the statistical significance threshold. However, results from sign restrictions suggest that it exists. Weak reactions of manufacturing to the exchange rate may be due to intra-corporate trade.

Liquidity supply shocks impact loans and output. A positive shock to banks' reserves in non--recursive decompositions increases loans but also the interest rate, which indicates that innovations to reserves supply and demand may not have been well disentangled. This flaw is eliminated by sign restrictions. The latter show also a small, short-lived price effect, which is significant only at impact and results mostly from the imposed interest rate drop.

Liquidity demand shock (Model I.3) does not impact macroeconomic variables: a higher interest rate prevents prices and output from rising. With no capital inflows, it leaves the exchange rate untouched.

In all settings interest rate shocks do not exert any impact on industrial output, which reflects its weak dependence on banking credit. Neither do they affect the exchange rate. However, interest rate shocks seem to play a role in credit and inflation developments. The CPI reaction is short-lived and small, nonetheless statistically significant, supporting our conclusion of a moderate degree of inflation persistence. In response to the interest rate shock loans tend to fall, suggesting that the CPI drop may result from weaker demand (less new loans). Weaker demand may also result from a reaction of households burdened with outstanding mortgage credit – there is some evidence that in the US and UK, in response to an interest rate change, consumers adjust their spending significantly, especially on durable goods (Cloyne et al. 2016). Households in Tunisia may react in a similar way. At odds to the usual timing pattern, interest rate impacts inflation before the exchange rate. However, the preponderance of variable loan rates may justify the rapid reaction of consumer demand and prices.

The reserve requirement ratio shock (Model II) does not reduce credit to the economy, there is even some expansion of lending, suggesting that monetary authorities were lax in the liquidity provision, probably to preserve interest rate stability. Importantly, we obtain almost the same result from the non--recursive decomposition and from sign restrictions. There is practically no increase in the interest rate (TMM): sign restrictions show the point estimate of just 1.8 basis points and the result is statistically insignificant, while the respective impulse response function from the non-recursive decomposition stays flat at zero. We do not observe price increases which could result from lower deposit rates and larger consumer spending. There is a slight increase in output and exchange rate appreciation, the former observed only if sign restrictions are applied, whereas in the non-recursive decomposition this effect is not statistically significant. The appreciation of the exchange rate, visible in the impulse responses functions obtained from both models, is counterintuitive. However, we suspect that capital inflows related to the privatization process could be the underlying reason. If, in fact, there was larger consumer spending due to lower deposit rates, then the appreciation could restrain prices from rising.

What emerges from impulse responses is that monetary policy affects prices and to a lesser degree output through the exchange rate. The liquidity channel is operative but dampened by the exchange rate appreciation. We ascribe this effect to expectations of better fundamentals which induce inflow of FDI and capital to the stock exchange. The interest rate channel seems to operate partially. In contrast to prices, its impact on the real sector is nil, at least when manufacturing output approximates real sector activity. A plausible explanation is small dependence on bank loans and a significant role of the informal employment which, besides agriculture, is concentrated in manufacturing (food, wood, metals). The reserve requirement channel does not operate in the usual way. The underlying reason is the central bank's readiness to provide sufficient liquidity to smooth the interest rate. There are no signs of the cost channel.

4. Structural New Keynesian models

4.1. Specification

Structural models must confront not only the problem of country-specific features, e.g. multiple monetary policy targets and instruments, capital controls and interventions in the foreign exchange market, degree of nominal and real rigidities, but also uncertainty of parameters and equilibria. Model specification is additionally limited by data availability and reliability.[8]

We have built two simple NK structural models. Model A is more backward-looking, reflecting underdeveloped financial markets and wage indexation to lagged inflation. The exchange rate is related to fundamentals rather than to interest rate disparity. The model is estimated equation by equation with classical methods (OLS, GMM) and partially calibrated on the basis of SVAR results; equilibria have been obtained outside the model (HP filters). Model B, with built-in trends reflecting the supply side of the economy and with AR processes which close the model, allows for getting equilibria inside the model and enables the identification of non-observable variables. The model is based on the global projection model, GPM (Carabenciov et al. 2013) and it is estimated with Bayesian methods overcoming the short sample problem (2000 Q1 – 2012 Q4) and giving a possibility to implement the SVAR results. In particular, Model B allows for exchange rate interventions, both direct and indirect (moral suasion). With this aim in mind we smooth the exchange rate shock by calibrating its standard error. Both models employ public spending, which is a source of price subsidies. In Model B, public spending serves also as a proxy for a risk premium in the exchange rate equation. To evaluate the role of country--specific factors we compare reactions obtained from Models A and B to a standard GPM with no such features and with flat priors.

The models include consumers, domestic and foreign producers, the central bank, the banking sector and the government. Interactions among agents are standard for this type of models (e.g. Argov et al. 2007) beside four exceptions:

[8] There is no quarterly data on national accounts, employment and retail interest rates.

1. Consumers save by buying solely domestic assets owing to capital controls.

2. Only exporters and importers may buy foreign assets. For them, the allocation of savings between the domestic and foreign market depends on the interest rate differential, expected exchange rate changes and the risk premium.

3. Banks can allocate consumer savings to loans or securities, but due to the lack of an efficient secondary market, bonds are either traded over the counter or held up to maturity. Therefore, the central bank has a limited impact on longer rates through expectations. Banks' assets portfolios are relatively rigid, their reactions to changes in demand for loans may be sluggish; transaction costs are high.

4. Government sector spending stipulated by law has a constant share in GDP, the remaining part depends on cyclical factors.

In the GPM and Model B, economic processes are driven by shocks. They have economic interpretation, contrary to residuals in the standard gap models. In the GPM, the number of shocks is equal to the number of equations and the economic meaning of a shock is similar to that of residuals, whereas in Model B the number of shocks exceeds the number of equations. This makes it possible to employ shocks to unobservable variables.

Model A has two variables more than Model B – the loan rate, which is endogenous and exogenous world energy prices. The additional interest rate reflects the role of credit to the economy in the monetary transmission. An extension relating retail interest rates to the reserve requirement ratio would be possible in Model A, but since Tunisian data series on deposit rates is problematic, this block could operate only partially and finally has not been employed.

World energy prices capture cost push inflation. The labour market in both models is represented by the output gap. If wages behave in line with the product market, i.e. if they are pro-cyclical, the output gap could reflect cost pressures. This may not be the case of Tunisia due to its wage bargaining system and indexation to past inflation. Thus, models may fail to explain inflation driven by supply shocks other than energy.

Both models use a short-term interest rate as a sole policy instrument, although they might have been supplemented with the reserve requirement, as e.g. in Blagrave et al. (2013). In Model A, an extension relating retail interest rates to the reserve requirement ratio is possible, but owing to the lack of data on deposit rates, this block would operate only partially. The most important argument against plugging the reserve requirement into the models was the aforementioned claim of the monetary authorities discarding this instrument from the monetary policy toolkit. Thus we keep a standard setting with the interest rate although it might cause a poorer fit to past data. In contrast to the reserve requirement, we introduce the exchange rate into the policy rule (GPM, Model B) as we think that the central bank will continue interventions in the foreign exchange market.

4.2. Model A and Model B. Comparison to the core GPM

The models have four blocks: the IS and the Phillips curves, exchange rate equation and the monetary policy rule. Real variables are specified as gaps, i.e. differences between their actual values and potentials. The former can be affected by demand factors, the latter represent the supply side of the economy.

The IS curve (output gap y_t):

$$y_t = \alpha_1 E_t y_{t+1} + \alpha_2 y_{t-1} + \alpha_3 (i_t - E_t \Delta p_{t+1} - r_t^*) + \alpha_4 (e_t^r - e_t^{r^*}) + \alpha_5 y_t^{eu} + \alpha_6 g_t + \varepsilon_t^y + \varepsilon_t^{Y^*} + \varepsilon_t^{r^*} \quad (6)$$

$$r_t^* = \alpha_{31} r_{t-1}^* + \alpha_{32} (\Delta Y_t^* - \Delta Y_{t-1}^*) + \varepsilon_t^{r^*} \quad (7)$$

$$\Delta G_t = \alpha_{51} y_t + \alpha_{52} \Delta Y_t + \varepsilon_t^G + \varepsilon_t^y \quad (8)$$

$$\Delta G_t^* = \alpha_{53} Y_t^* + \varepsilon_t^{G^*} \quad (9)$$

$$g_t = \Delta G_t - \Delta G_t^* + g_{t-1} \quad (10)$$

where:

i – a short-term nominal money market rate,
r^* – natural interest rate,
ΔY, ΔY^* – dynamics of GDP and potential GDP respectively,
p – domestic prices,
p^w – foreign prices,
ΔG, ΔG^* – dynamics of public expenditure and potential public expenditure respectively,
g – the gap of the public expenditure,
X – net exports,
e – the nominal exchange rate,
e^r – the real exchange rate,
e^{r*} – the equilibrium exchange rate,
y^{eu} – the output gap in the euro area,
ε – a shock.

The Phillips curve

We examine a hybrid New Keynesian Phillips curve for an open economy, by which inflation is a function of three factors: first, the next period's expected inflation rate ($E_t \Delta p_{t+1}$), extended by the empirically observed persistence of inflation (backward looking inflation Δp_{t-1}, as in Fuhrer and Moore 1995); second, real marginal costs, approximated by the output gap (y_t), as in Woodford (2003); and third, the real exchange rate (as in Woodford 2003), understood in this equation as the logarithms of: the contemporaneous nominal exchange rate (e_t) plus foreign prices p_t^w. Then, the behaviour of inflation depends on the slope of the Phillips curve.

$$\Delta p_t = \beta_1 E_t \Delta p_{t+1} + \beta_2 \Delta p_{t-1} + \beta_3 y_t + \beta_4 (e_t + p_t^w) + \varepsilon_t^s \quad (11)$$

The real exchange rate

The exchange rate is modelled in real terms because a direct relationship between the real exchange rate, real interest rates and economic fundamentals can be derived from the Taylor rule. Also, theory points that the international trade is driven by differences in factor productivity, relative prices and technological gaps. They are carried over by the exchange rate deflated by measures of costs or prices.

$$e_t^r = \delta_1 E_t e_{t+1}^r + \delta_2 e_{t-1}^r - \delta_3((i_t - \Delta p_t) - (i_t^w - \Delta p_t^w)) + \delta_4 y_t + \delta_5 \varepsilon_t^e \tag{12}$$

$$e_t^{r^*} = \delta_6 y_{t+1} + \delta_7 y_{t+1}^{eu} + \varepsilon_t^{r^*} \tag{13}$$

The Taylor rule

$$i_t = \lambda_1 i_{t-1} + (1-\lambda_1)((r^* - \Delta p_t^*) + \lambda_2(\Delta p_t - \Delta p_t^*) + \lambda_3 y_t) + \lambda_4(e_t^r - e_t^{r^*}) + \varepsilon_t^i \tag{14}$$

In the GPM model ΔY^* is formed by the state space model and y_t^{eu}, p_t^w as autoregressive processes.

Differences in equation specifications between the models are shown in Table 4 in the column titled “Remarks”. However, they cannot fully explain differences in parameters. The significant part of differences arises due to the method of estimation: GMM in model A, Bayesian in model B and the GPM. In turn, parameters of model B and the GPM may differ due to the priors used – flat in the latter and informative, set up on the basis of information coming from the VAR analysis, in the B model (Figures 5 and 6). As an example we chose the exchange rate equation since the exchange rate plays a crucial role in the Tunisian economy.

In the case of the exchange rate, the specification of the equation is the most important. However, it is worth noting with respect to priors in model B that the use of information derived from the VAR analysis improves the quality of the parameter estimates and also confirms the correctness of parameters in the VAR models. Basic results obtained from estimations are presented in Tables 4–6. Figures 9–10 depict the reactions of the output gap and inflation (y/y) to the interest rate and exchange rate changes (Model A) or shocks (GPM, Model B).

In line with SVAR results, responses of Models A and B suggest that monetary policy transmission operates mainly through the exchange rate (impact on relative prices), while the core GPM points to the interest rate channel in spite of a low level of financial sector development and passive interest rate policy. This is also in contrast with literature on emerging markets. Furthermore, the exchange rate equation makes GPM responses unrealistically large.

Differences in reactions between Models A and B reflect the uncertainty concerning both equilibria and model specification. We treat them as a possible array of reactions. In the case of LDEMEs, which are vulnerable to numerous shocks, variables reflecting risk factors may be unstable. We propose therefore one model which approximates risk with fundamentals and another one which makes the approximation using the current macroeconomic policy. If, for example, the expected reduction of the reference rate results in some outflow of short-term capital, the depreciation will be immediate and strong, but secondary effects will be relatively small (Model B), while in a situation where short-term capital outflow is corrected by an inflow of investment, due to good fundamentals, the reaction will be much weaker, and return to equilibrium more slowly (Model A).

5. Conclusions

Less developed emerging market economies have a bunch of features which makes them different from mature market economies and undermine many assumptions of New Keynesian (NK) models.

Using a complex approach we have identified the characteristics of the Tunisian economy, which served us as an example of a genuine LDEME. We have first exploited two types of SVAR models, a classical one, with a non-recursive identification scheme, and one with sign restrictions. The results obtained from these two different econometric techniques have been fairly similar. They have shown that at least for the data set available on a monthly basis, the exchange rate has a better proved impact on output and prices than the interest rate. We have observed a small, quick, and short-lived impact of the interest rate on prices, which we attribute to the effect of a prevalence of mortgage credits for households, extended mostly at variable rates, on consumer demand. Reserve requirements, which have been used by the central bank with the aim of curbing excessive expansion of loans, seem to have been inefficient; moreover, after 2011 this instrument was abandoned and the central bank reduced its toolkit to the interest rate and the exchange rate.

On the basis of SVAR results we have built two NK small structural models with country-specific features, e.g. nominal rigidities, an underdeveloped financial market, government policy of price subsidies, capital controls, and interventions in the foreign exchange market. Model specification has been a compromise between our aim to exploit country-specific elements and poor data environment, especially on a quarterly basis. Results from SVAR models have allowed a more precise setting up of priors in the Bayesian estimations (Model B), which resulted, among others, in a suggestion of a considerable role of the exchange rate in the monetary transmission. A standard NK model without these characteristics, with flat priors, shows the leading role of the interest rate channel, which stands in opposition to stylized facts and SVAR results.

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Appendix

Table 1

Inflation persistence, headline and core inflation, q/q

	2000 Q2 – 2013 Q4 ρ	**2000 Q2 – 2013 Q4** γ	**Lags**
CPI	0.24 (1.64)	0.64	1
Core inflation	0.67 (6.50)	0.80	1

Note: t-statistics in parentheses.

Table 2

Ng-Perron (2001) unit root test, headline and core inflation, q/q

Variable	**MZa**	**MZt**	**MSB**	**MPT**
CPI headline[#]	-15.1425**	-2.73824**	0.18083**	1.66883
CPI core[##]	-26.7692**	-3.61988**	0.13523	3.63157

** significant at 1%, [#]with constant, [##]with trend and constant.

Table 3

Identification of innovations with sign restrictions, Model I.2 and Model II

Shock	**Variable**						
	y_t	cpi_t	cr_t	tmm_t	$neer_t$	tr_t	rrr_t
				Model I.2			
Total reserves supply	0	0	?	↓	?	↑	–
Total reserves demand	0	0	?	↑	?	↑	–
				Model II			
Reserve requirement	0	0	?	?	?	↑	↑
NEER depreciation	0	0	?	0 or ↑	↓	↑	?

Table 4

Main equations: Model A, GPM, Model B

<table>
<tr><th rowspan="2" colspan="2">Parameter</th><th colspan="3">Model</th><th rowspan="2">Remarks</th></tr>
<tr><th>A</th><th>GPM</th><th>B</th></tr>
<tr><td rowspan="7">IS curve (output gap)</td><td>α_1</td><td>–</td><td>0.13</td><td>0.16</td><td rowspan="7">Output gap block – differences among the models:
1. Natural interest rate (r_t^*) estimated as a state space model in GPM while r_t^* is related to potential GDP in the B
2. Equilibrium exchange rate ($e_t^{r^*}$) follows a random walk in GPM while $e_t^{r^*}$ is related to domestic and foreign output gap in the B model
3. Government expenditure (a source of subsidies and a risk premium for the exchange rate). In both A and B models it is related to the output gap. Absent in GPM
4. In model B ε_t^y determines demand shock and the sum $\varepsilon_t^{Y^*} + \varepsilon_t^{r^*}$ can be interpreted as a supply shock; $\varepsilon_t^{Y^*}$ – a shock to the potential GDP – relates to the TFP, while $\varepsilon_t^{r^*}$ – a shock to the natural interest rate – relates to the marginal productivity of capital; $\varepsilon_t^{Y^*}$ can be interpreted as a shock related to labour productivity, allowing for a cost-pushed inflation under a negative supply shock
5. Low (α_3) reflects weakness of the interest rate channel comparing to the exchange rate (α_4)</td></tr>
<tr><td>α_2</td><td>0.60[(a)]</td><td>0.64</td><td>0.66</td></tr>
<tr><td>α_3</td><td>-0.05[(b)]</td><td>-0.07</td><td>-0.04</td></tr>
<tr><td>α_4</td><td>-0.17[(c)]</td><td>0.10</td><td>0.16[(d)]</td></tr>
<tr><td>α_5</td><td>0.14</td><td>0.22</td><td>0.28</td></tr>
<tr><td>α_6</td><td>0.03</td><td>–</td><td>0.13</td></tr>
<tr><td>Shocks</td><td>–</td><td>ε^y</td><td>$\varepsilon^y + \varepsilon^{Y^*} + \varepsilon^{r^*}$</td></tr>
<tr><td rowspan="6">Phillips curve</td><td>β_1</td><td>0.25</td><td>0.62</td><td>0.29</td><td rowspan="6">1. In B: $\varepsilon_t^s + \varepsilon_t^e$ – shock to inflation (price shock ε_t^s) is amplified by ε_t^e – shock to the real exchange rate (through a relatively high (0.23) exchange rate pass--through)
2. Core GPM gives too high a coefficient for inflation expectations</td></tr>
<tr><td>β_2</td><td>0.66</td><td>0.38</td><td>0.71</td></tr>
<tr><td>β_3</td><td>0.08</td><td>0.09</td><td>0.06</td></tr>
<tr><td>β_4</td><td>-0.20</td><td>0.06</td><td>0.23</td></tr>
<tr><td>β_5</td><td>0.03[(e)]</td><td>–</td><td>–</td></tr>
<tr><td>Shocks</td><td>–</td><td>ε^s</td><td>$\varepsilon^s + \varepsilon^e$</td></tr>
</table>

[(a)] All parameters are significant at p-value < 10%.
[(b)] Difference between loan rate deflated by the current inflation and natural interest rate.
[(c)] Increase = appreciation.
[(d)] Tunisia's foreign trade is highly concentrated, thus we use the exchange rate and euro area output gap as proxies of net exports.
[(e)] β_5 – world energy prices.

	Parameter	Model A	Model GPM	Model B	Remarks
Real exchange rate	δ_1	0.60	0.73	0.57	1. A: Fundamentals (δ_4) are represented by the lagged output gap. Owing to data limitations and lags in data dissemination, economic agents are expected to consider past economic situation when deciding on capital flows. The role of interest rate disparity is almost nil (δ_3). The estimated equation: $e_t^r = 0.6\cdot e_{t+1}^r + 0.4\cdot e_{t-1}^r + 0.03\cdot(i_t^r - i_t^{reu})\cdot 0.07\cdot y_{t-1}$ 2. GPM: The real UIP with the real interest rate disparity replaced by the respective gap: $4\cdot(-0.27\cdot e_t^r + 0.73\cdot r_{t+1}^r) = ((i_t^r - i_t^{reu}) - (i_t^{r*} - i_t^{reu*})) + \varepsilon_t^e$ 3. B: The real UIP in line with a concept of the interest rate disparity (not disparity gap) with the added risk factor determined by the change of g_t. Coefficient (0.44) at ε_t^e reflects exchange rate smoothing (interventions). $0.6\cdot\varepsilon_t^g$ shows unexpected change in the government expenditure amplifying the exchange rate shock. $4\cdot(-0.43\cdot e_t^r + 0.57\cdot r_{t+1}^r) =$ $= 0.74\cdot(i_t^r - i_t^{reu}) + 0.05\cdot g_t + 0.44\cdot\varepsilon_t^e + 0.6\cdot\varepsilon_t^g$
	δ_2	0.40	0.27	0.43	
	δ_3	0.03	0.25	0.19	
	δ_4	0.07	–	0.02	
	Shocks	–	ε^e	$0.15\cdot\varepsilon^g + 0.11\cdot\varepsilon^e$	
Taylor rule	λ_1	0.90	0.91	0.79	We allow for a direct impact of the exchange rate on the interest rate (λ_4) in GPM and B. In B we introduce the exchange rate shock (ε^e) which may interact with the interest rate shock (ε^i).
	λ_2	1.35	1.23	1.35	
	λ_3	0.50	0.44	0.43	
	λ_4	–	0.17	0.19	
	Shocks	–	ε^i	$\varepsilon^i + \varepsilon^e$	

Table 5
Estimation results (main equations)

Parameter		Model									
		A		GPM				B			
		para-meter	t-stat	prior mean	mode	t-stat	prior	prior mean	mode	t-stat	prior
IS curve (output gap)	α_1	–	–	0.20	0.13	1.62	beta	0.20	0.16	1.77	beta
	α_2	0.60	est/cal	0.60	0.64	7.87	beta	0.60	0.66	11.60	beta
	α_3	-0.05	est/	-0.10	-0.07	1.68	gamma	-0.10	-0.04	5.87	gamma
	α_4	-0.17	cal1.63	0.20	0.10	2.06	normal	0.20	0.16	1.83	normal
	α_5	0.14	1.55	0.30	0.22	1.60	normal	0.15	0.13	1.75	normal
	α_6	0.03	1.88	–	–	–	–	0.30	0.28	18.32	beta
Phillips curve	β_1	0.25	3.76	0.45	0.62	7.84	beta	0.25	0.29	2.51	beta
	β_2	0.66	5.11	–	0.38	–	$(1-\beta_1)$	–	0.71	–	$(1-\beta_1)$
	β_3	0.08	4.83	0.10	0.09	4.05	beta	0.10	0.06	5.87	beta
	β_4	-0.20	est/	0.10	0.06	2.55	normal	0.20	0.23	2.28	normal
	β_5	0.03	cal1.73	–	–	–	–	–	–	–	–
Real exchange rate	δ_1	0.60	est/cal	0.50	0.73	54.88	beta	0.50	0.57	27.83	beta
	δ_2	0.40	est/cal	–	0.27	–	$(1-\delta_1)$	–	0.43	–	$(1-\delta_1)$
	δ_3	0.03	16.10	1·¼	0.25	calibr.	–	1·¼	0.19	91.53	beta
	δ_4	0.07	3.15	–	–	–		0.10·¼	0.02	5.70	normal
	$\sigma_1\cdot(\varepsilon^g)$	–	–	–	–	–	–	1·¼	0.15	10.38	normal
	$\sigma_2\cdot(\varepsilon^e)$	–	–	–	–	–	–	1·¼	0.11	13.69	normal
Taylor rule	λ_1	0.90	est/calest/	–	0.91	calibr.	–	0.80	0.79	9.51	beta
	λ_2	1.35	cal	1.50	1.23	28.87	gamma	1.50	1.35	66.24	gamma
	λ_3	0.50	est/cal	0.50	0.44	6.05	normal	0.50	0.43	2.86	normal
	λ_4	–		0.30	0.17	2.51	normal	0.30	0.19	8.86	normal

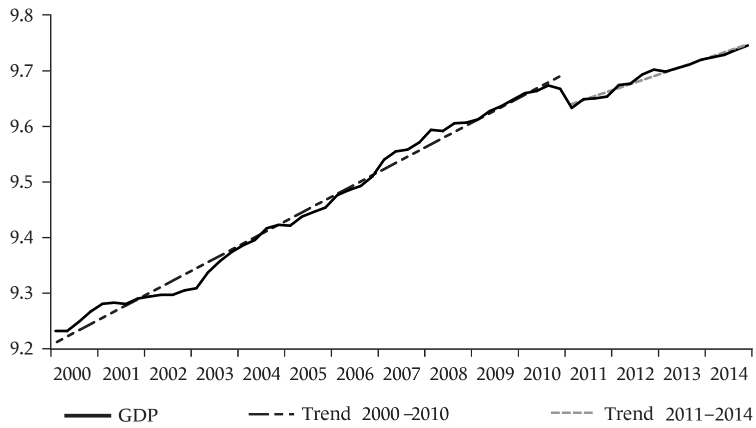
Table 6

Summary of results from Models A and B

	Core GPM	A	B
Increase of the nominal interest rate by 1 percentage point per 1 quarter, rule thereafter			
Output gap			
Strength	-1.23	-0.081	-0.072
Lag	4	4	4
Public expenditure			
Strength		-0.051	-0.084
Lag		7	2
Inflation			
Strength	-1.18	-0.1	-0.21
Lag	3	6	3
Real EUR/TND or RER (increase = appreciation)			
Strength	2.9	0.05	0.68
Lag	0	1	0
Appreciation of the real exchange rate by 1 percentage point per 1 quarter			
Output gap			
Strength		-0.25	-0.27
Lag		3	4
Public expenditure			
Strength		-0.16	-0.10
Lag		6	3
Inflation			
Strength	-0.055	-0.13	-0.11
Lag	1	3	3

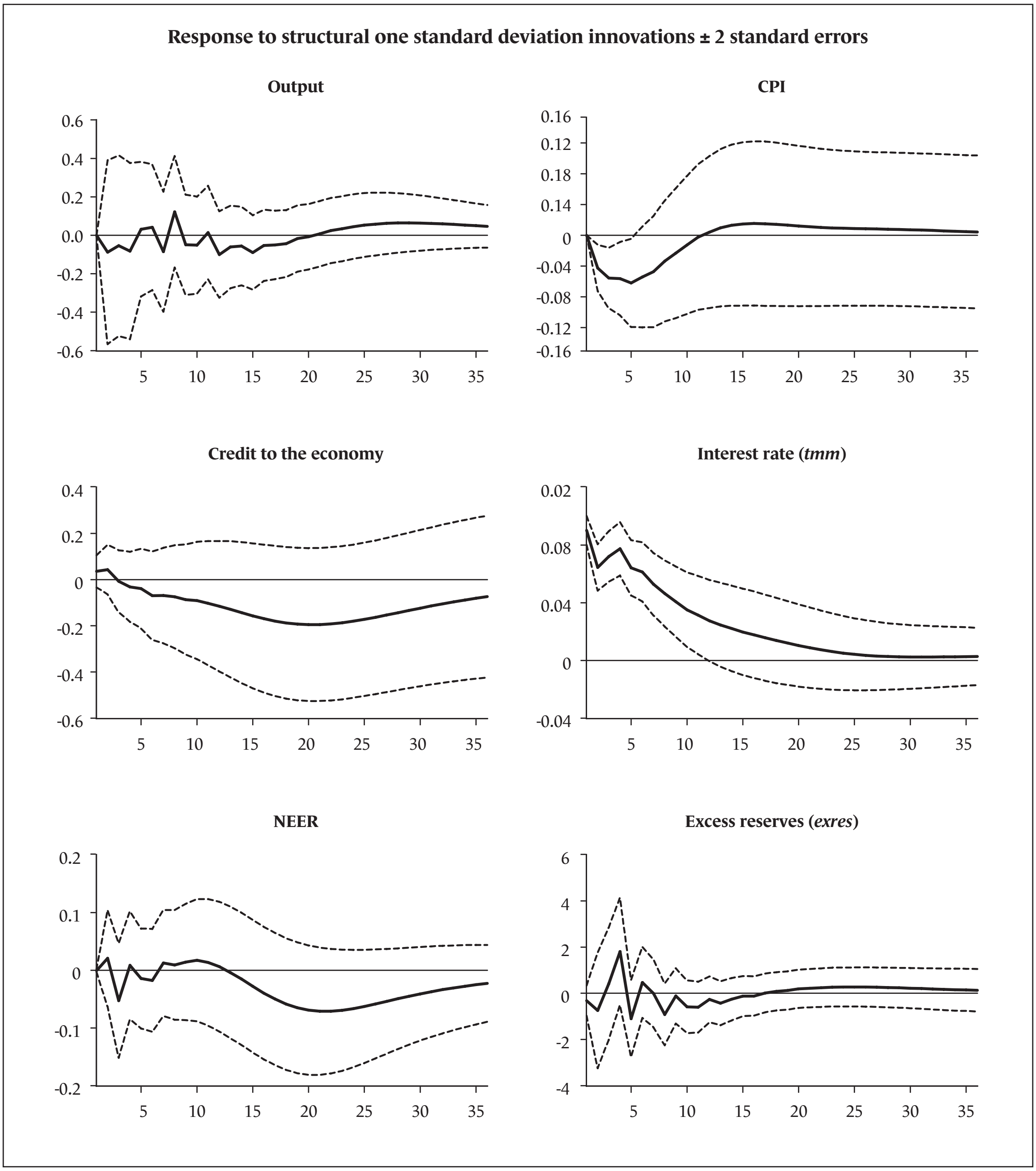
Notes:
Strength = strength of the maximum reaction.
Lag = lag of the maximum reaction.

Figure 1
Real GDP relative to pre- and post-revolution trends



Source: Institut National de la Statistique, Banque Centrale de Tunisie.

Figure 2
Impulse response functions. Model I.1. Panel A: interest rate shock



Note: test of over-identifying restrictions: Chi-square(6) = 4.17, p = 0.65.

Figure 2
Impulse response functions. Model I.1. Panel B: exchange rate shock

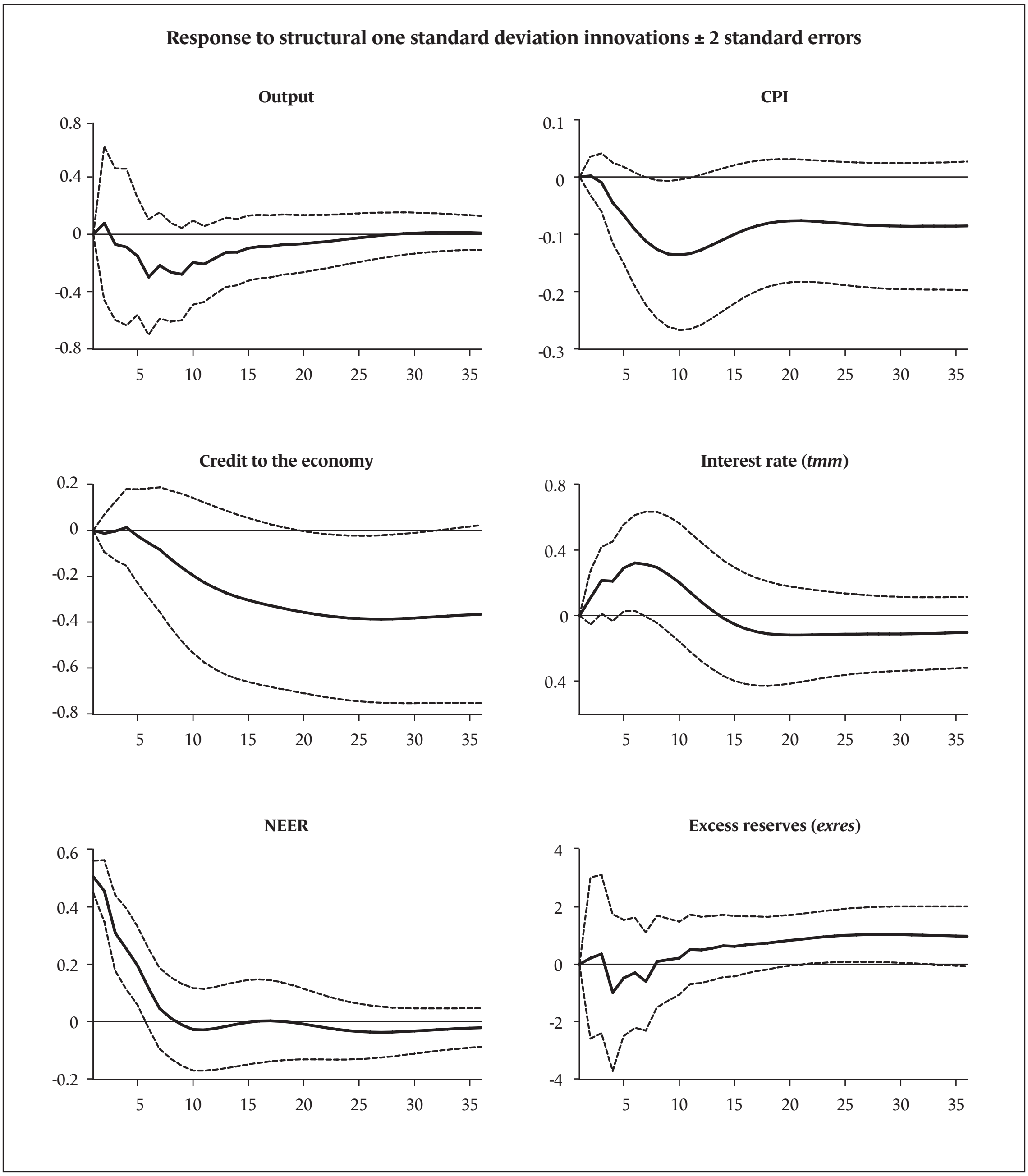


Figure 2
Impulse response functions. Model I.1. Panel C: excess reserves shock

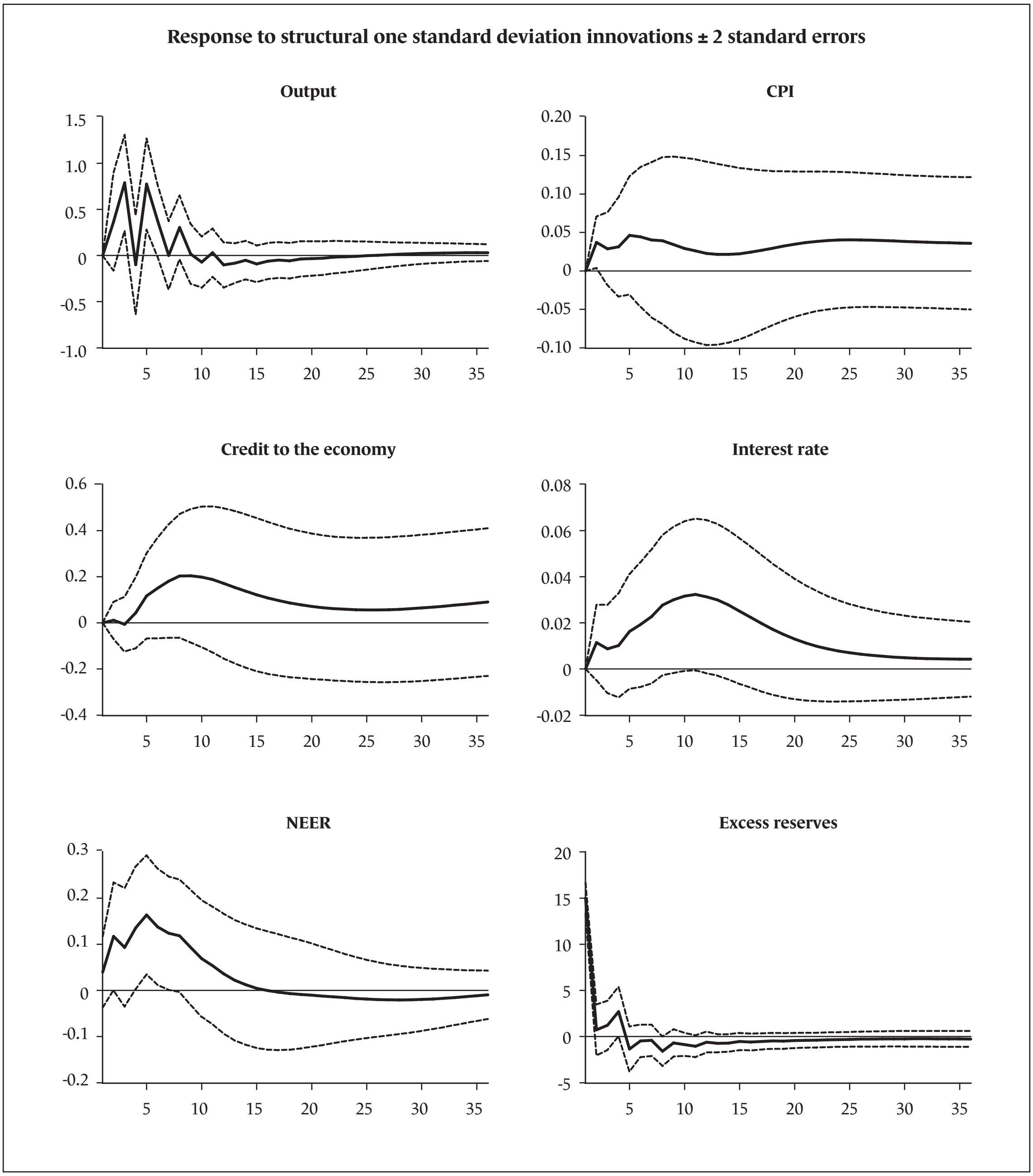
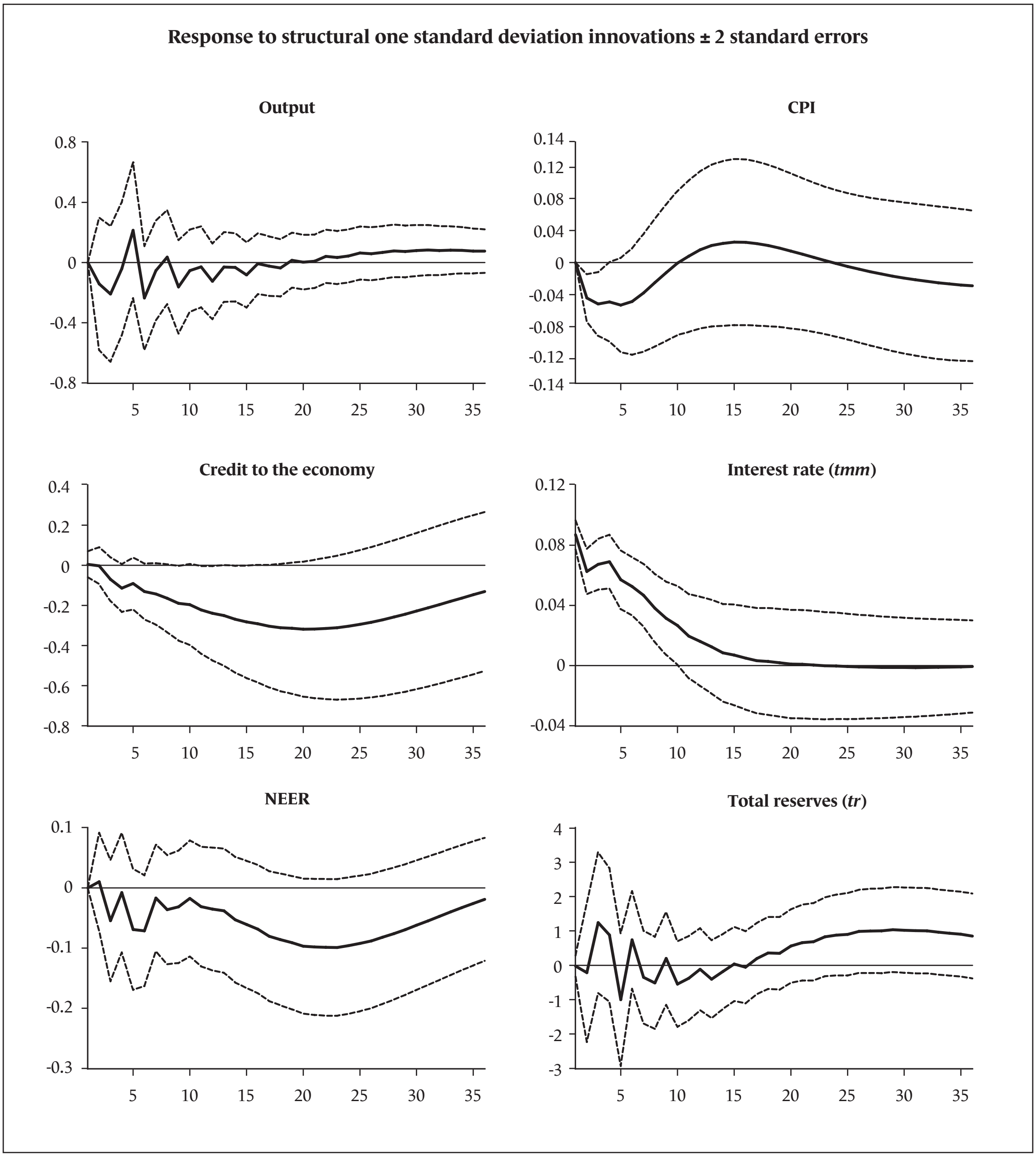


Figure 3
Impulse response functions. Model I.2. Panel A: interest rate shock



Note: test of over-identifying restrictions: Chi-square(6) = 4.83, p = 0.57.

Figure 3

Impulse response functions. Model I.2. Panel B: exchange rate shock

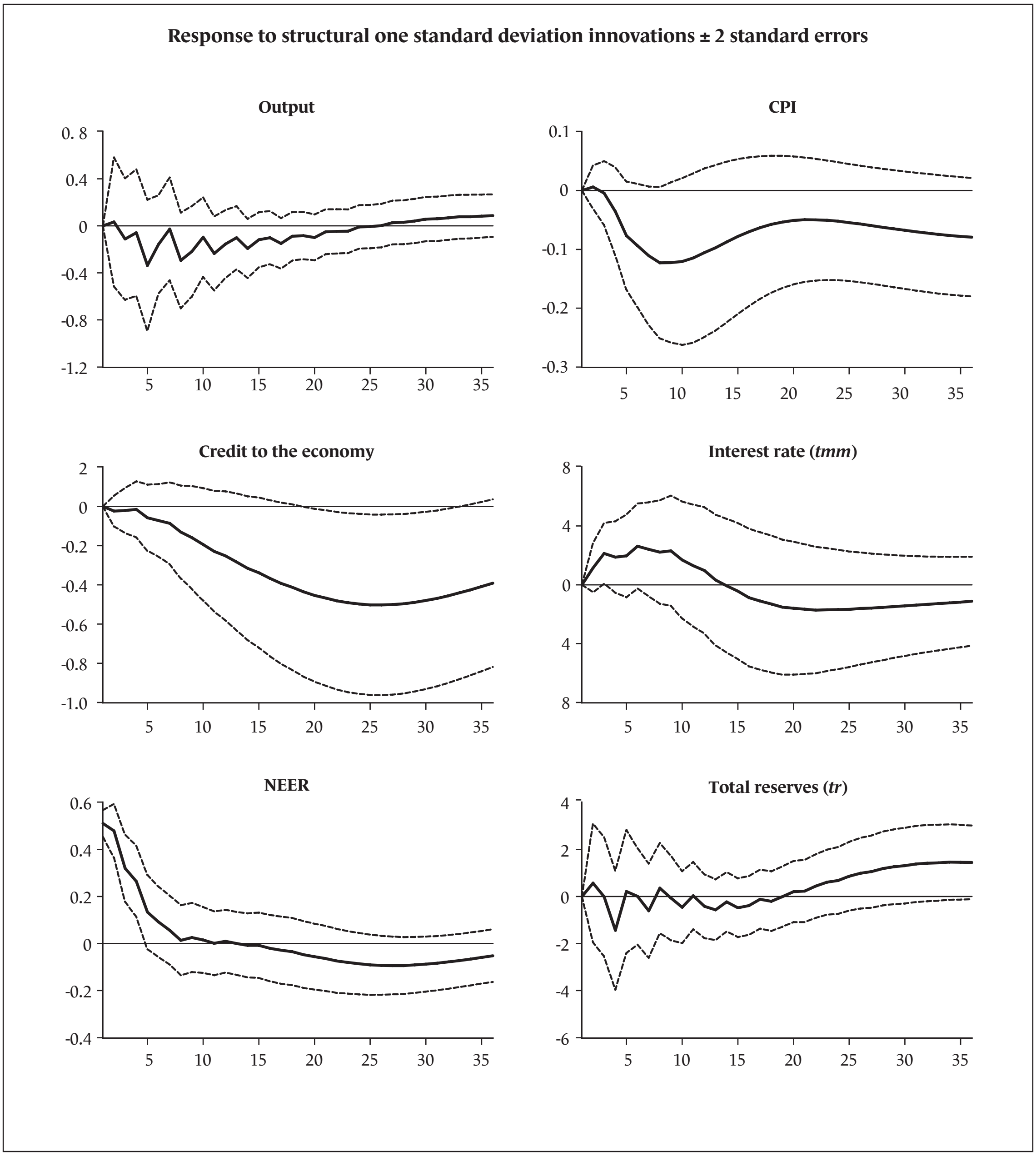


Figure 3
Impulse response functions. Model I.2. Panel C: total reserves shock

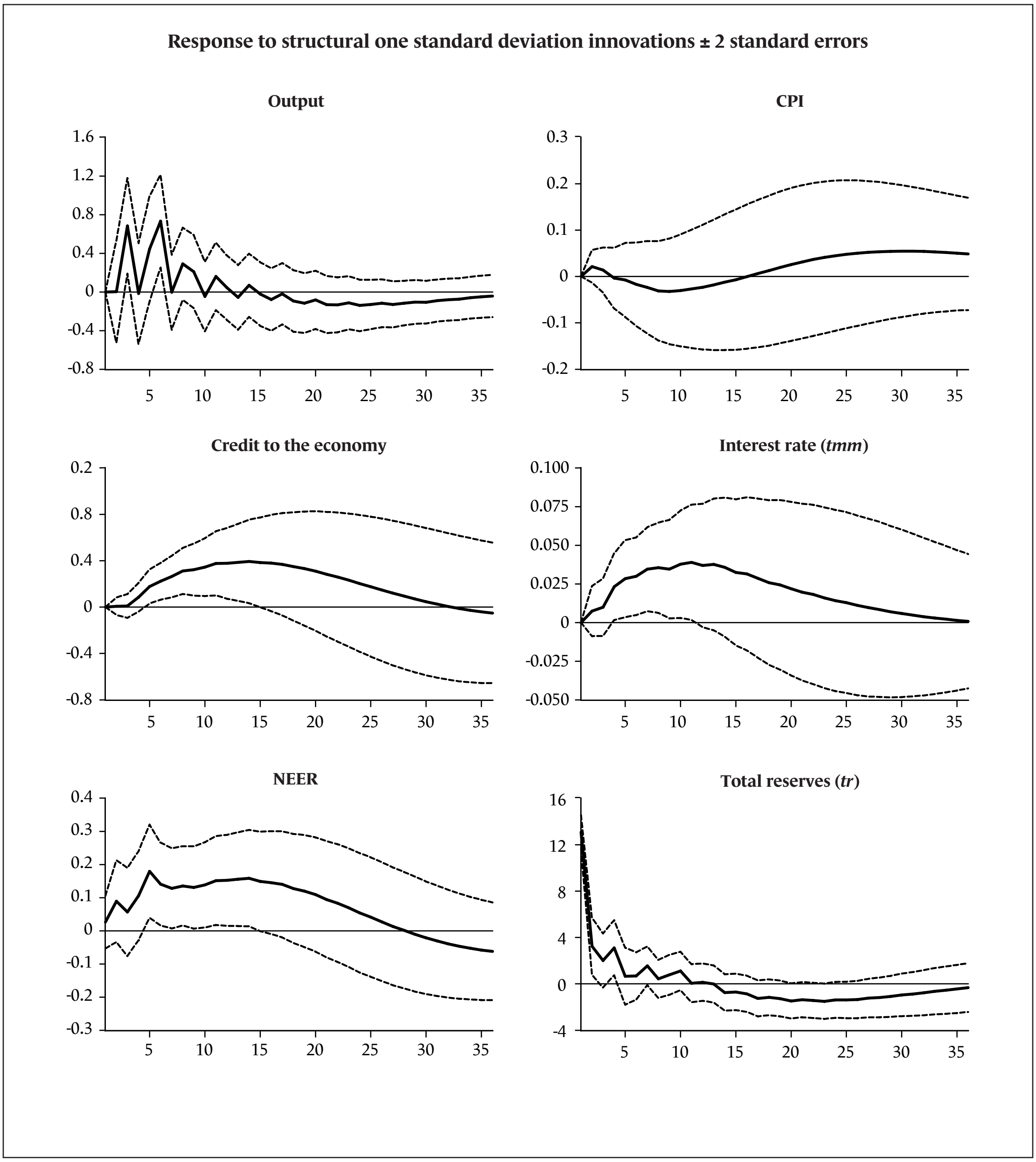
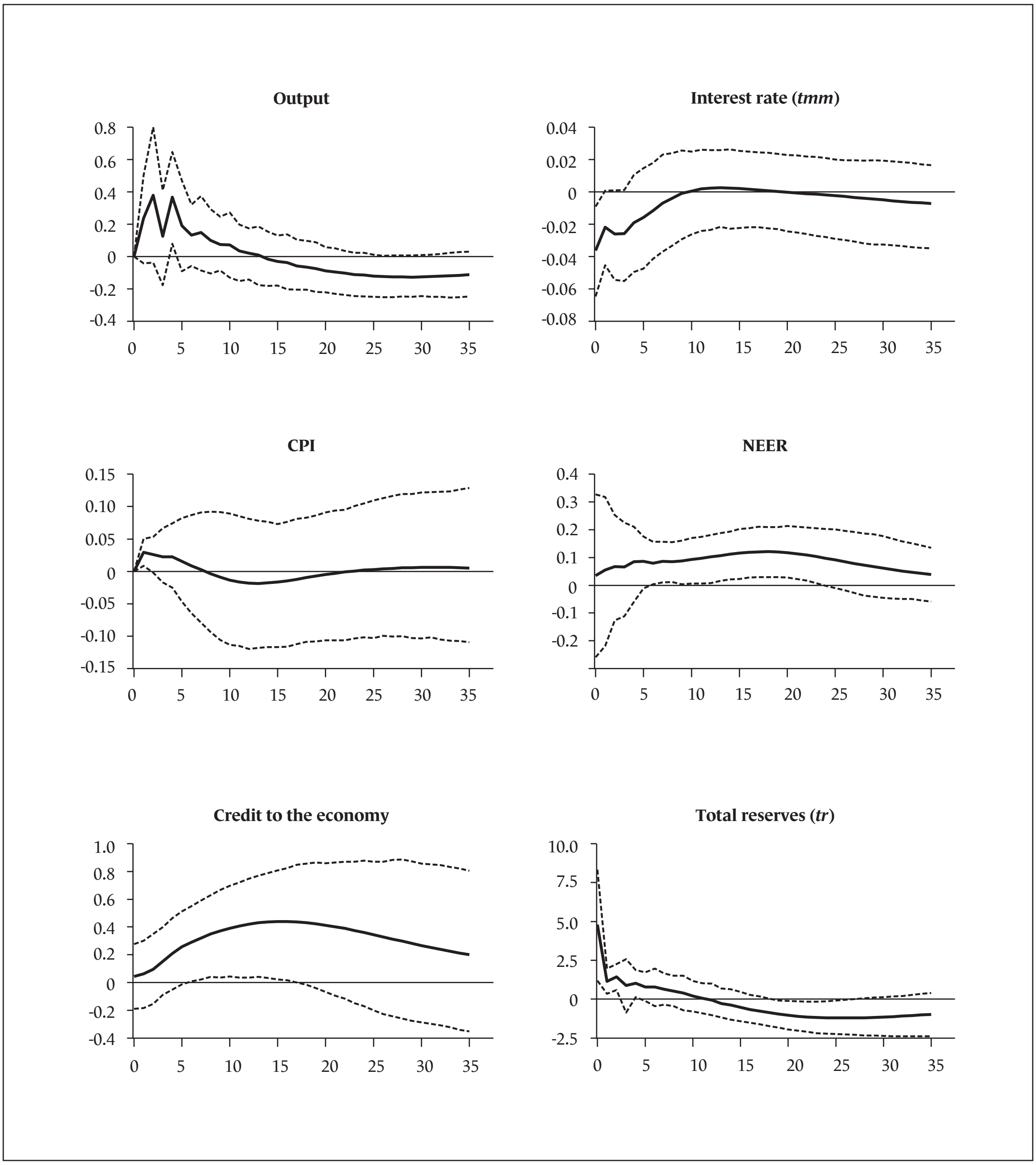
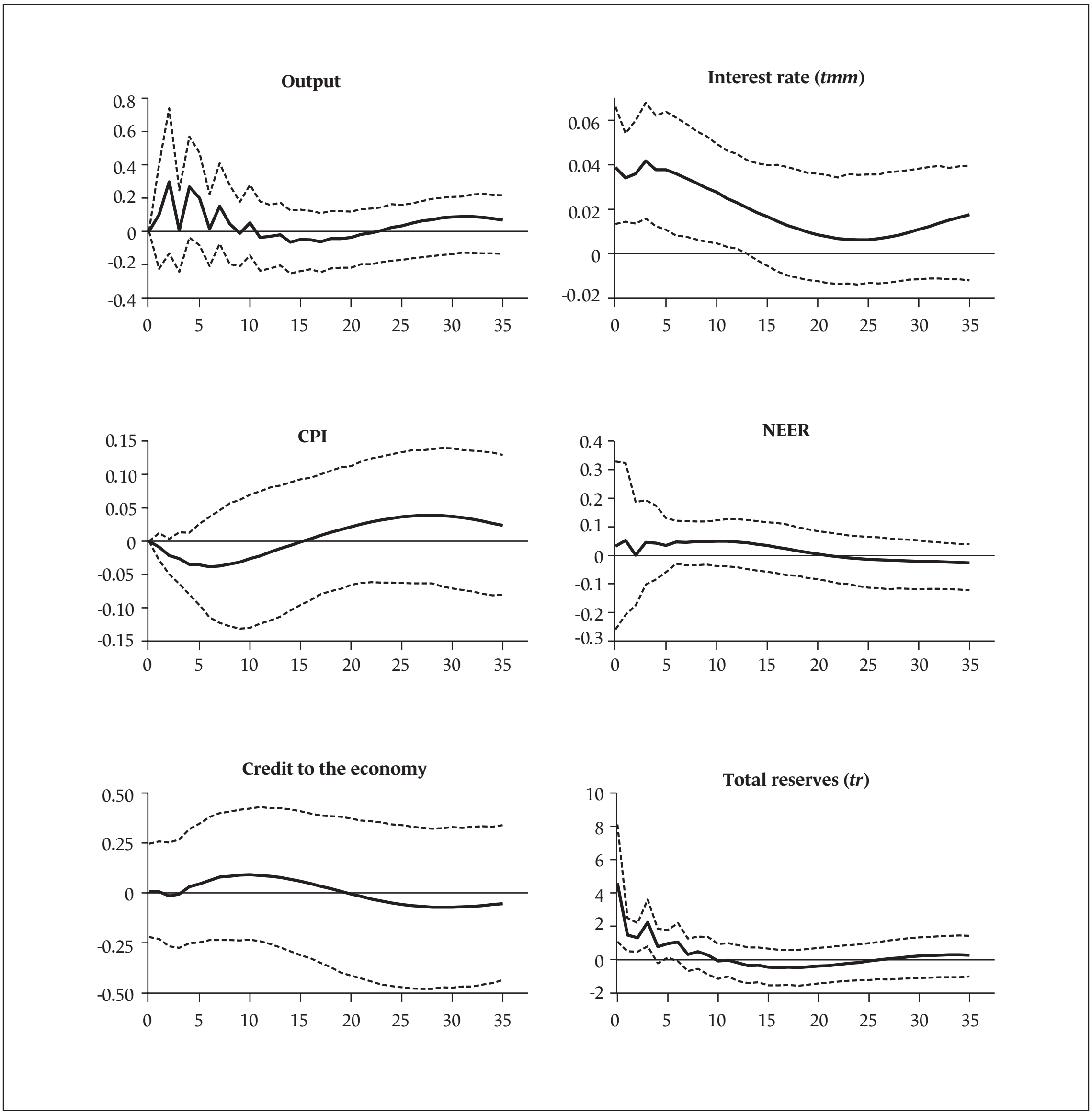


Figure 4
Impulse response functions. Model I.3. Panel A: total reserves supply shock



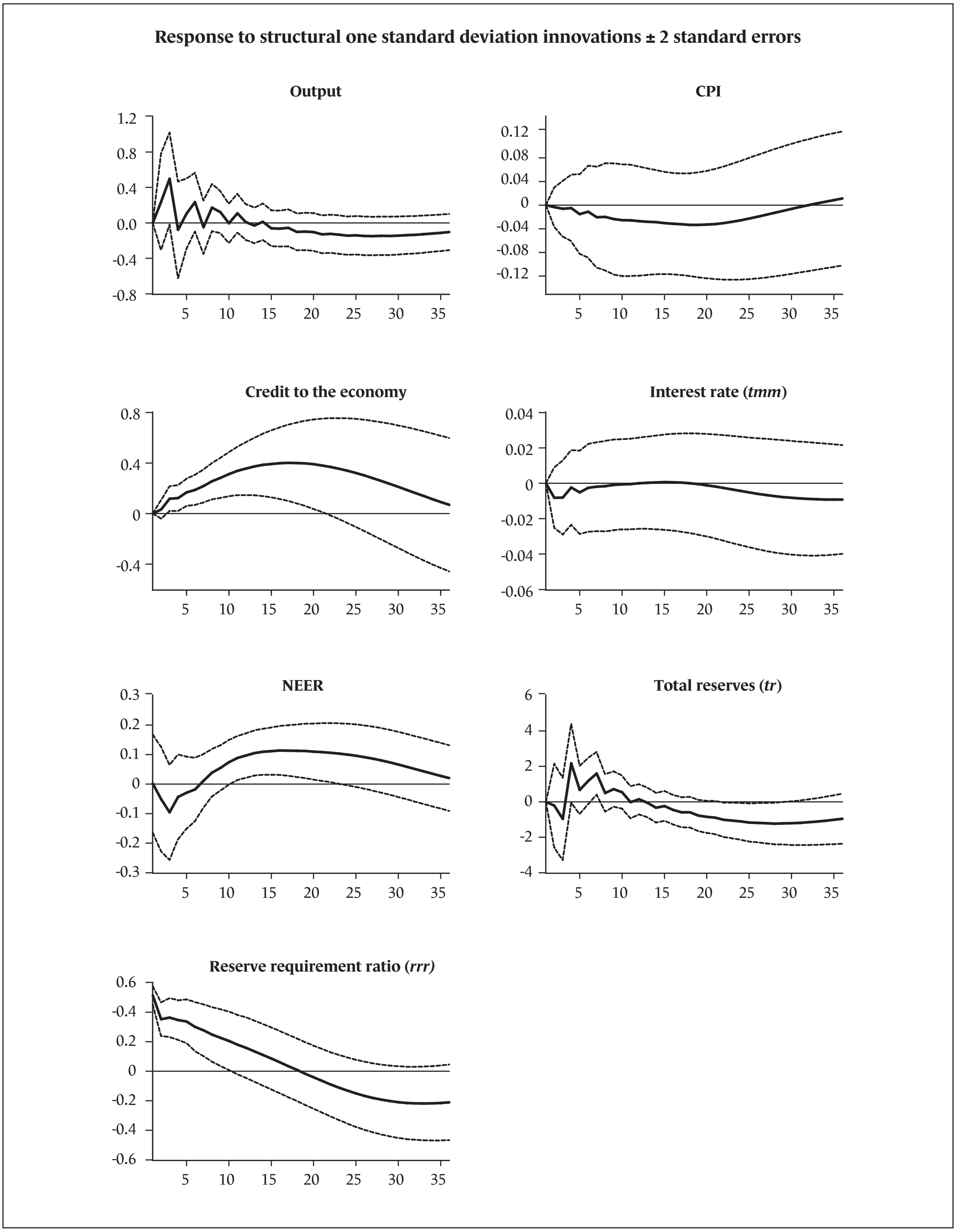
Note: SVAR with sign restrictions.

Figure 4
Impulse response functions. Model I.3. Panel B: total reserves demand shock



Note: SVAR with sign restrictions.

Figure 5
Impulse response functions. Model II.1. Panel A: reserve requirement ratio shock



Note: test of over-identifying restrictions: Chi-square(6) = 3.52, p = 0.74.

Figure 5

Impulse response functions. Model II.1. Panel B: exchange rate shock

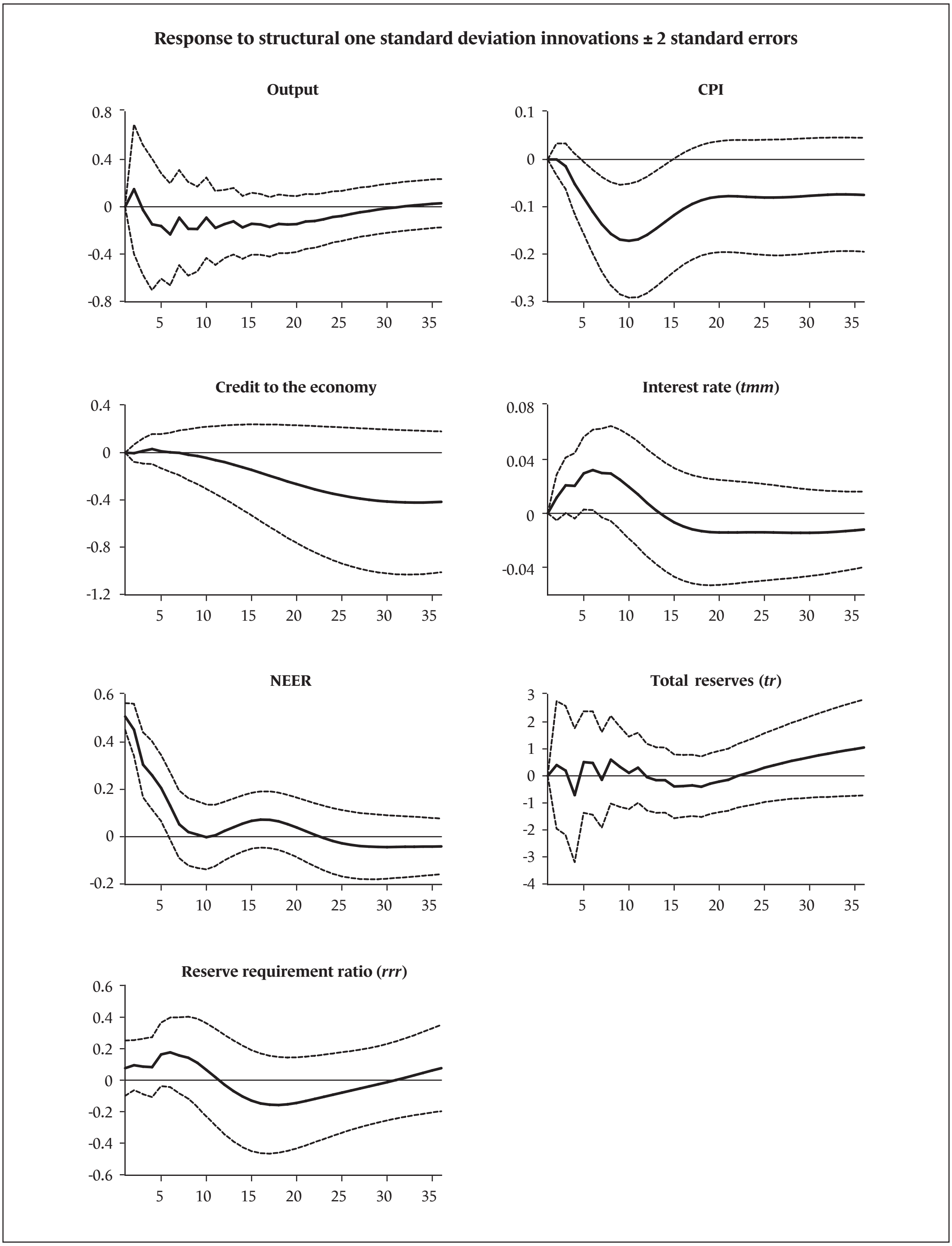


Figure 6
Model II.2. Panel A: sign restrictions

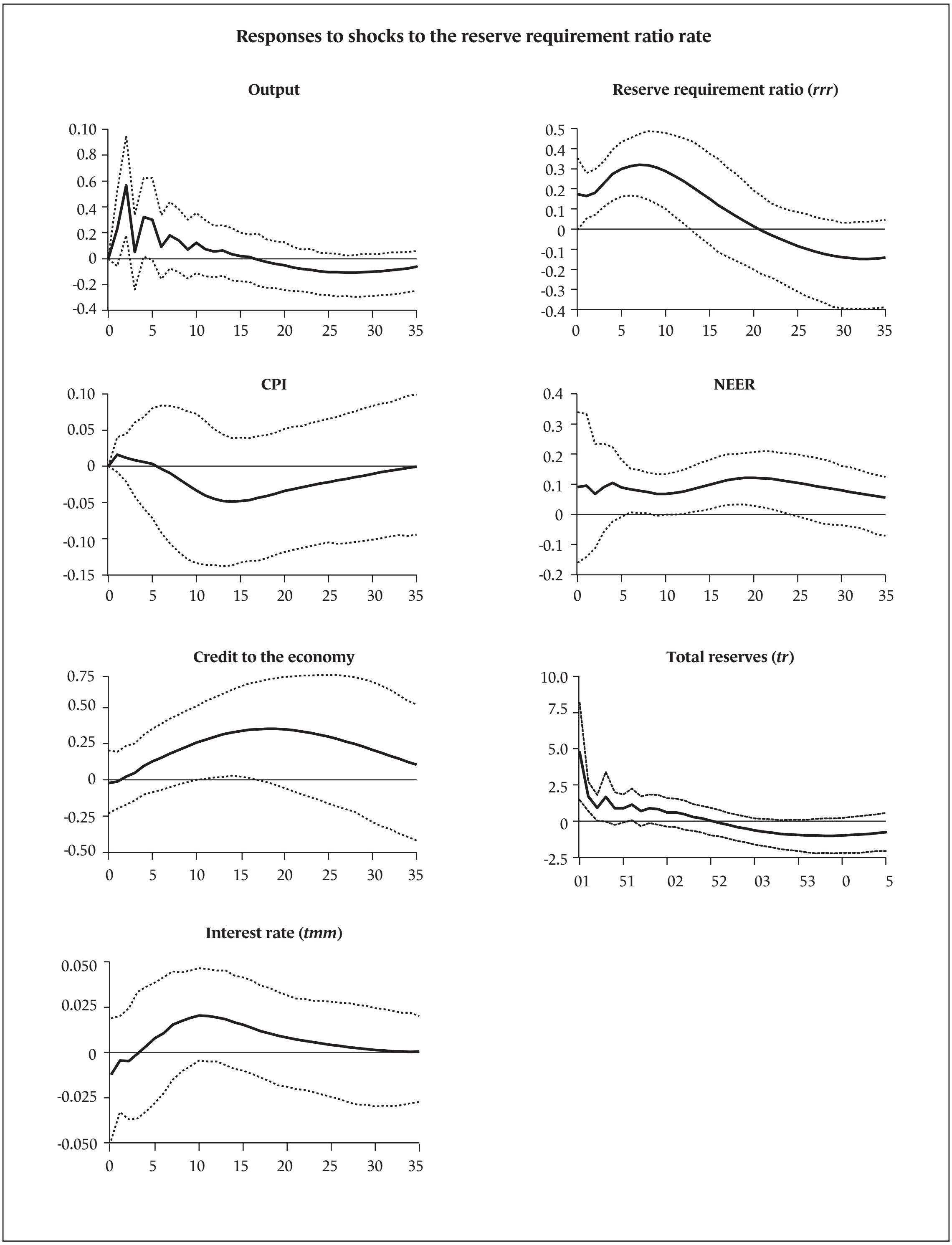


Figure 6
Model II.2. Panel B: sign restrictions

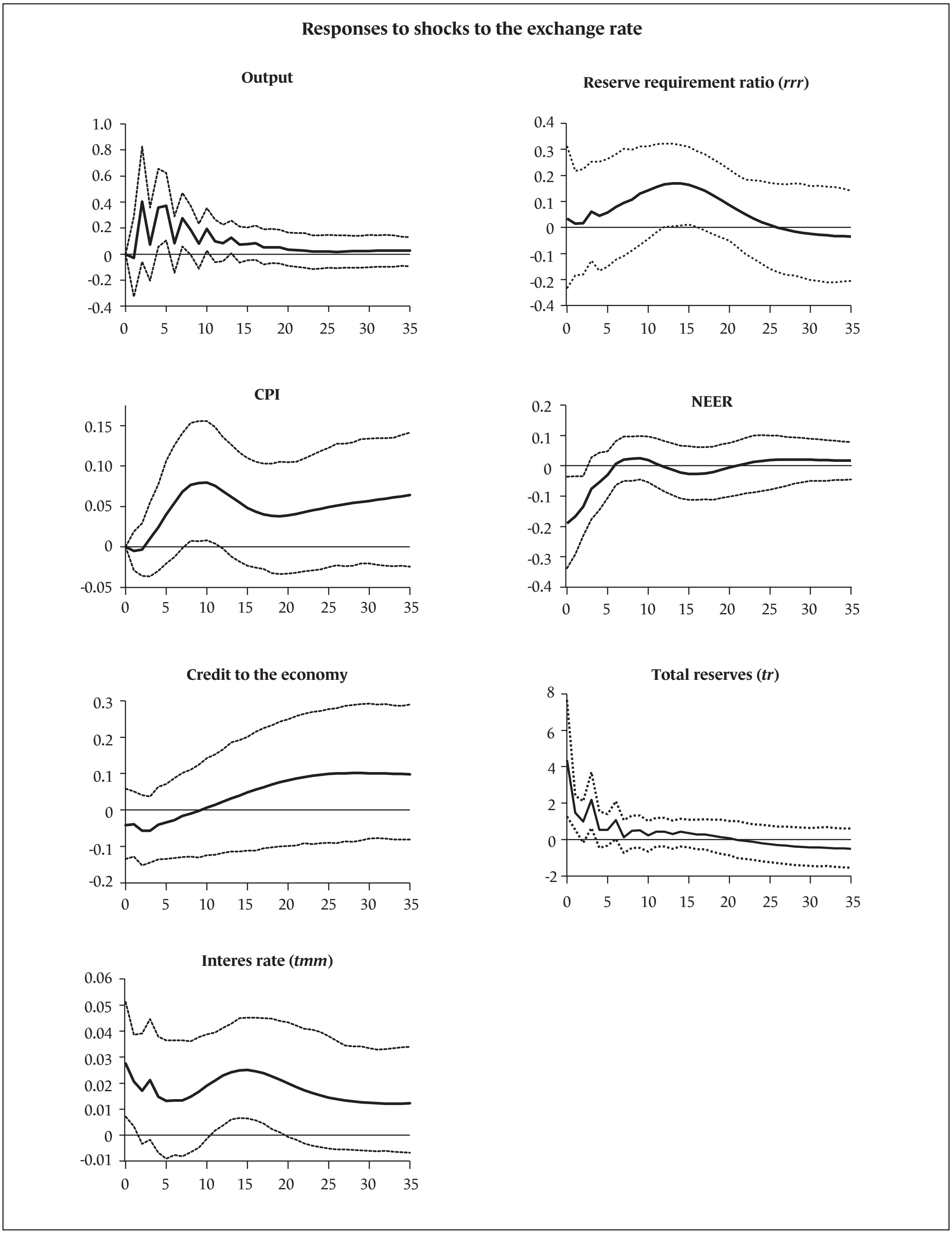
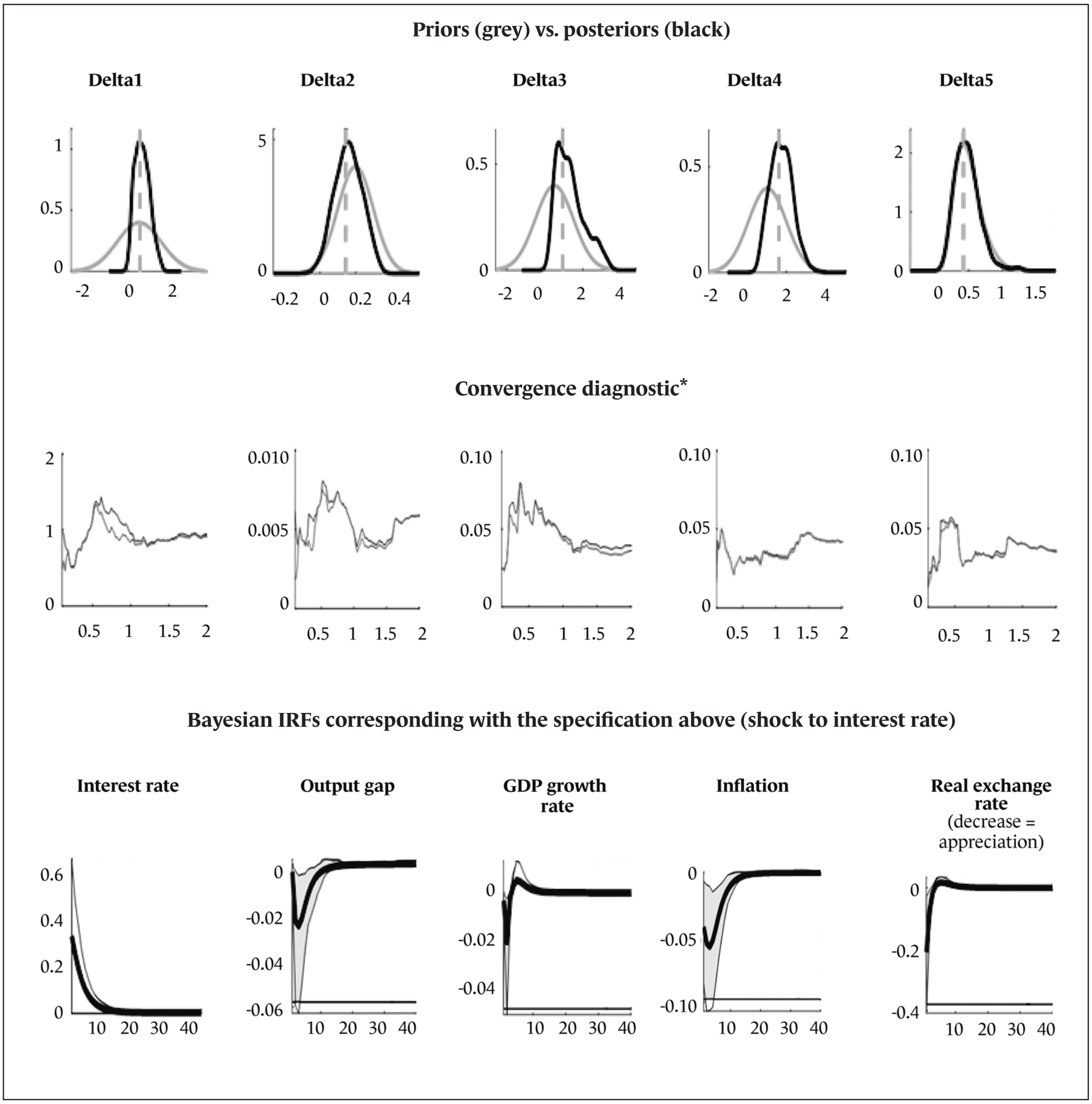


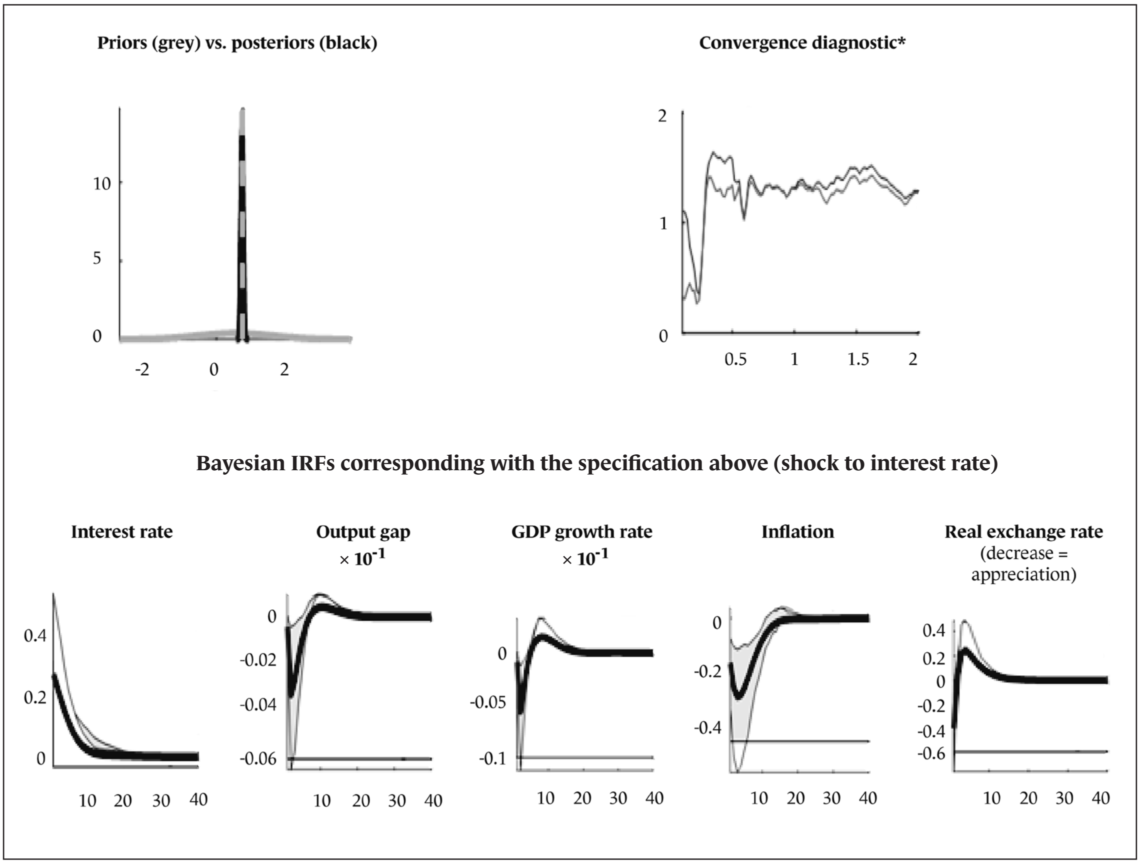
Figure 7

Model B. The exchange rate equation: specification, priors, convergence and the corresponding impulse response functions



* Statistics constructed around parameter variance; 20,000 iterations.

Figure 8
GPM. The exchange rate equation: specification, priors, convergence and the corresponding impulse response functions (Delta 1)



* Statistics constructed around parameter variance; 20,000 iterations.

Figure 9
Responses of output gap and inflation (y/y) to the interest rate increase by 1 percentage point per 1 quarter, rule thereafter

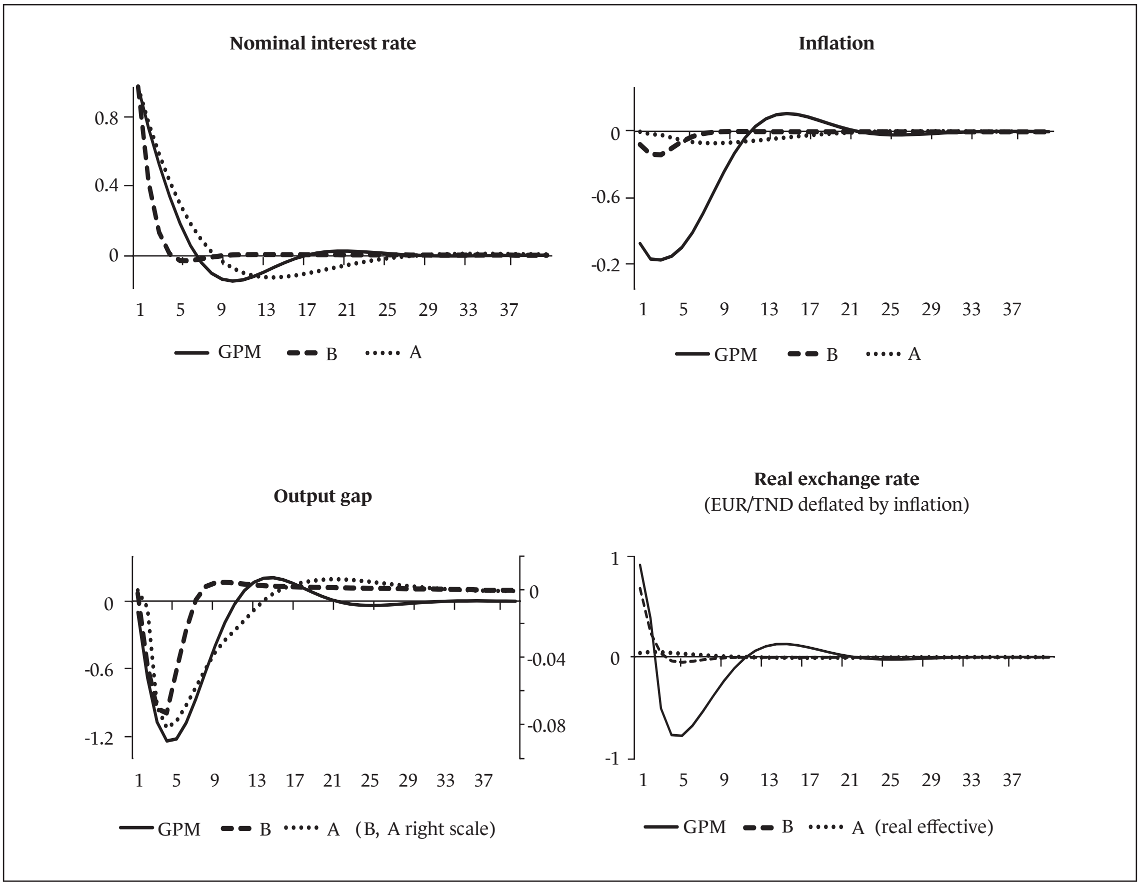


Figure 10

Responses of the output gap and inflation (y/y) to the real exchange rate appreciation by 1% per 1 quarter (REER – Model A, Tunisian dinar/euro – Model B)