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The monetary and fiscal policy interactions have gained a new research interest after the 2008 crisis due to the global increase of fiscal debt. This paper constructs a macroeconomic model of joint fiscal and monetary policy for an emerging open economy taking into account its structural uniqueness. In particular, the two instruments of monetary policy, interest rate and foreign exchange intervention; the two instruments of fiscal policy, government consumption and government investment; and a sudden stops shock through the collateral constraint of foreign borrowings are modeled here in a single DSGE framework. The parameters are calibrated for the case of Hungary using data over 1995Q1-2011Q3. The impulse response functions show that government consumption is unproductive and increases fiscal debt as opposed to government investment, foreign exchange intervention positively affects net exports but does not stimulate an economy per se causing inflation, and a negative shock to the upper bound of leverage ratio in the collateral constraint of foreign borrowings generates a sudden stops crisis for the emerging world. Monetary and fiscal policy intimately interact in the short and medium run such that there is an immediate response of monetary instruments to fiscal shocks, while fiscal instruments adjust to monetary shocks in the medium run.

JEL : E63, F41, G01
Keywords: Monetary Policy, Fiscal Policy, Emerging Open Economy, Sudden Stops, Collateral Constraint

Author

[1] Center for Economic Research and Graduate Education Economics Institute, Czech Republic, E-mail: aalgozhi@cerge-ei.cz

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Aliya Algozhina[*]
CERGE-EI[†]

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Abstract

The monetary and fiscal policy interactions have gained a new research interest after the 2008 crisis due to the global increase of fiscal debt. This paper constructs a macroeconomic model of joint fiscal and monetary policy for an emerging open economy taking into account its structural uniqueness. In particular, the two instruments of monetary policy, interest rate and foreign exchange intervention; the two instruments of fiscal policy, government consumption and government investment; and a sudden stops shock through the collateral constraint of foreign borrowings are modeled here in a single DSGE framework. The parameters are calibrated for the case of Hungary using data over 1995Q1-2011Q3. The impulse response functions show that government consumption is unproductive and increases fiscal debt as opposed to government investment, foreign exchange intervention positively affects net exports but does not stimulate an economy per se causing inflation, and a negative shock to the upper bound of leverage ratio in the collateral constraint of foreign borrowings generates a sudden stops crisis for the emerging world. Monetary and fiscal policy intimately interact in the short and medium run such that there is an immediate response of monetary instruments to fiscal shocks, while fiscal instruments adjust to monetary shocks in the medium run.

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E-mail: aalgozhi@cerge-ei.cz

[†]Center for Economic Research and Graduate Education–Economics Institute, a joint workplace of Charles University in Prague and the Academy of Sciences of the Czech Republic. Address: CERGE-EI, P.O. Box 882, Politických vězňů 7, Prague 1, 111 21, Czech Republic

1 Introduction

For over two decades remarkable progress has been made in macroeconomic modeling by synthesizing the New Keynesian theory and the real business cycle theory. As a result, in recent years macroeconomic linkages have been intensively modeled using a dynamic stochastic general equilibrium (DSGE) approach which highlights primarily the influential role of monetary policy (Christiano, Eichenbaum & Evans, 2005; Smets & Wouters, 2007). Central banks around the world develop their core DSGE models to frame their policy decisions, discuss clearly the sources of fluctuations, and perform counterfactual policy experiments. Although there are still challenges (Tovar, 2008), the DSGE models inject an increased discipline to judgement, thinking, and communication about monetary policy. Apart from the advanced economies, those models are estimated for the emerging markets as well (Castillo et al., 2006; Silveira, 2008; Andrle et al., 2009; Vilagi, 2008; Zeman & Senaj, 2009; Iordanov & Vassilev, 2008; Lee, 2009). However, fiscal policy in this framework is usually passive; thus, it can be either ignored or specified simply by a balanced government budget without any role for fiscal debt. In other words, Ricardian equivalence holds and monetary dominance is assumed, resulting in a weak fiscal side in the model.

Yet, the current post-crisis situation shows that active fiscal policy has been implemented globally causing high fiscal debt across countries. In addition, the developed world has reached its zero lower bound of interest rates, when expansionary fiscal policy can be quite effective in terms of stimulating economic activity (Christiano, Eichenbaum & Rebelo, 2011; Eggertsson, 2011; Woodford, 2011), and thus it may interact with the influential monetary policy which should be captured jointly in the model. Even earlier, Benigno and Woodford (2003) pointed out the problem of modeling these two policies in isolation which appeared to be inter-related more than expected from their analysis of optimal monetary and fiscal policy within a single framework.

The consequences of one policy decision to another occur because, on the one hand, the interest rate set by the monetary policy affects the burden of fiscal debt which may appropriately adjust in response to the interest rate change, while on the other hand, fiscal stimulus changes output which may, in turn, adjust a tradeoff between inflation and output facing the monetary policy. Moreover, according to the fiscal theory of price level (Leeper, 1991; Sims, 1994), high fiscal debt without a future increase of taxes can cause inflation, thus constraining monetary policy in achieving its own goal of price stability. Both policies, therefore, should take into account the consequences of their decisions on the targets of the other policy in order to be consistent and endogenously effective in a macroeconomic outcome.

Currently, there are two streams of literature on monetary and fiscal policy interactions in a DSGE framework. The first one deals with the optimal policy rules assuming that either tax or government spending is the only fiscal instrument modeled jointly with the Taylor-type monetary policy rule (Schmitt-Grohe & Uribe, 2007; Leith & Wren-Lewis, 2007; Chadha & Nolan, 2007). The second stream is focused on the fiscal multiplier defined as the ratio of a change in output to an exogenous change in the fiscal instrument (Woodford, 2011; Davig & Leeper, 2011; Cogan, Cwik, Taylor & Wieland, 2010; Christiano, Eichenbaum & Rebelo, 2011; Eggertsson, 2011), apart from the various econometric estimations which generally suffer from endogeneity, proper identification of fiscal shocks without any mix with automatic stabilizers, and ignorance of fiscal debt dynamics. Both of these streams of DSGE models, though, do not impose any heterogeneity of households assuming instead a representative agent who optimizes his future consumption path by the appropriate savings. This might result in a relatively low fiscal multiplier because once there is the fiscal expansion, active monetary policy tightens and a high interest rate encourages households to save rather than to consume; thus, consumption declines.

Realizing this problem in assessing fiscal stimulus, researchers have suggested incorporating two types of households: savers or traditional Ricardian households who are also known as the standard optimizers having savings in assets, and spenders or non-Ricardian households who do not have access to financial markets and simply consume their disposable income each period (Mankiw, 2000). The latter type is sometimes referred to as the rule-of-thumb or liquidity constrained households in the literature. Gali, Lopez-Salido, and Valles (2007) have extended, therefore, the standard New Keynesian model by incorporating these two types of households which allowed them to demonstrate that government spending has an effect on consumption consistent with the evidence due to the interaction between the behavior of the rule-of-thumb consumers and sticky prices. A new global integrated monetary and fiscal policy model constructed at the IMF (Kumhof et al., 2010) distinguishes these two types of households as well and estimates that multipliers of two-year stimulus range from 0.2 to 2.2 depending on the fiscal instrument, the extent of monetary accommodation, and the presence of a financial accelerator mechanism (Freedman et al., 2009).

However, the above models are applicable for the developed world and do not take into account three structural specifics relevant for an emerging open economy. First, the latter conducts its monetary policy using at least two instruments: an interest rate in accordance with the standard Taylor rule which assumes a tradeoff between inflation and the output gap, and foreign exchange intervention to manage the nominal exchange rate (Blanchard, Dell'Ariccia & Mauro, 2010). Second, fiscal policy can be active trying to stimulate the economy through an increase of government consumption and/or government investment[1] and not much through cutting taxes which are relatively inflexible to change. Third, emerging economies can have a heavily indebted private sector to the foreign world; thus, they are vulnerable to an external shock of sudden stops which is exactly the case they faced due to the global financial crisis 2008. Moreover, sudden stops shock seems to be related to collateral constraint (Mendoza, 2010; Mendoza, 2006; Chari, Kehoe & McGrattan, 2005; Kiyotaki & Moore, 1997) rather than to a financial accelerator mechanism à la Bernanke, Gertler, and Gilchrist (1999) associated essentially with the interest rate shock. This is because a sudden shrinkage of foreign funds supply can abruptly cause an economic downturn in the emerging open economies, which used to constantly have capital inflows earlier. Whereas a sudden increase of foreign interest rate might not necessarily cause a recession because agents may appropriately adjust

[1] I treat government consumption and government investment as two separate fiscal policy instruments because each of them can have a different effect on output and potentially on inflation. According to Aschauer (1989), there is a positive relationship between public investment and the growth rate of labor productivity, while government consumption is negatively related to the growth of output per hour in the G-7 countries.

their demand for foreign loans which are still available but would become expensive. Therefore, sudden stops shock by its name suggests modeling a quantitative shortage of foreign loans in the economy rather than a price effect of those loans.

In this respect, the aim of this paper is to build a DSGE model for the emerging open economy such that it captures these three structural specifics. The calibration of the model is based on Hungary as a first economy among all emerging markets hardly hit by the global financial crisis and already felt in mid-October 2008. The international organizations were called on for support using their emergency financing arrangements. In 2009, real GDP fell by 6.7%, the euro-forint exchange rate depreciated by 12%, unemployment increased to 9.8%, positive net exports were 10 times higher than in 2008 due to collapse in imports, and foreign exchange reserves of the central bank significantly dropped especially in 2009Q2. The main vulnerability of Hungary originated from its high public and private sectors' debt: fiscal debt amounted to 66% of GDP, while external debt reached 97% of GDP at the end of 2007 (IMF, 2008).

Based on a constructed model, my research questions focus on how multiple instruments of monetary and fiscal policy interact in an emerging open economy which exclusively borrows from abroad and whether sudden stops shock as a quantitative restriction in the collateral constraint can deliver output drop, depreciation, unemployment, capital reversals, and loss of central bank reserves consistent with the evidence as opposed to a foreign interest rate shock associated typically with the risk premium. These questions are addressed by analyzing impulse response functions to six exogenous shocks: two monetary policy shocks—interest rate and foreign exchange intervention, two fiscal policy shocks—government consumption and government investment, a sudden stops shock and a foreign interest rate shock to be compared with each other.

In section two, I will outline the model which has two types of households (savers and spenders), firms acting in a monopolistically competitive market, two monetary policy rules for each instrument, and respective fiscal policy rules. In section three, I will present the system of log-linear equations constituting the model which is calibrated for Hungary in section four. The impulse response functions are analyzed in section five followed by the main findings in the conclusion.

2 Model

Technically, the model has several frictions: an incomplete asset market, capital adjustment costs, collateral constraint, and a Calvo price setting. The crucial underlying assumption is that the foreign world is a saver, while the domestic economy is a borrower such that in equilibrium collateral constraint binds; thus, the foreign discount factor is higher than the steady state domestic discount factor meaning in turn that the interest rate of the emerging economy is always higher than foreign interest rate, which is consistent with the evidence. This explicit assumption suggests that an endogenous discount factor approach (Schmitt-Grohe & Uribe, 2003) might be appropriate to close my small open economy.

Since there are two types of households, only optimizers borrow from abroad and thus have the collateral constraint on physical capital. They also hold the domestic government bonds, own the firms, rent physical capital to the firms, and decide about investment. The firms monopolistically set prices on their final goods à la Calvo (1983) and their profits are transferred to the optimizers. The labor market is assumed to be competitive such that modeling unions or having high bargaining power over wages by households might be irrelevant in the emerging market setting.

The foreign world is modeled by its Phillips curve, AR (1) process for output, and the Taylor rule for interest rate. All foreign variables are denoted by an asterisk in this paper.

The domestic Taylor rule includes lagged interest rate, inflation, output gap, and the nominal exchange rate gap, but there is also a rule for foreign exchange intervention responding to the nominal exchange rate gap and its change (Sarno & Taylor, 2001). Government consumption and government investment respond to fiscal debt and to the output gap capturing a pro/countercyclical fiscal policy. Government investment can be productive accumulating government capital, which is an additional input in the Cobb-Douglass production function beyond labor and physical capital following Traum and Yang (2010).

2.1 Households

The economy is populated by a continuum of households on the interval [0,1], where the fraction μ is rule-of-thumb households. They do not have access to financial markets and consume all of their disposable income each period. In other words, they act myopically without any effect of a future policy on their economic decisions. The other $(1-\mu)$ fraction of households are forward-looking optimizers who hold government bonds, invest in physical capital, rent capital to the firms, borrow from abroad, and receive an additional income in terms of profits from the monopolistic firms. The labor market is competitive, wage is the same across all households, and both types of households work the same number of hours. The superscript S indicates a variable associated with savers (optimizers) and N with non-savers (rule-of-thumb households).

The optimizing household maximizes its utility given by (Schmitt-Grohe & Uribe, 2003):

$$E_0 \sum_{t=0}^{\infty} u_t \frac{[C_t^S - \phi^{-1} N_t^{\phi}]^{1-\sigma} - 1}{1-\sigma}, \tag{1}$$

where $\phi > 1$, $\sigma > 1$, and u_t is a discount factor which depends on the average per capita consumption and labor: $u_{t+1} = \beta(\widetilde{C}_t, \widetilde{N}_t) u_t$, $\beta(\widetilde{C}_t, \widetilde{N}_t) = [1 + \widetilde{C}_t - \phi^{-1} \widetilde{N}_t^{\phi}]^{-\chi}$, $\chi > 0$. This specification implies that the more household consumes, the more it is impatient.

The budget constraint of the optimizer in real terms is as follows:

$$C_t^S + I_t + b_t + R_{t-1}^* \frac{e_t}{e_{t-1}} \frac{b_{t-1}^*}{\pi_t} + T_t = W_t N_t + R_t^k K_{t-1} + R_{t-1} \frac{b_{t-1}}{\pi_t} + b_t^* + \Pi_t, \tag{2}$$

where $b_t = \frac{B_t}{P_t}$ is the real purchases of government bonds, e_t is a nominal exchange rate (the units of domestic currency per unit of foreign currency), $b_t^* = e_t \frac{B_t^*}{P_t}$ is the real foreign borrowings denominated in domestic currency, R_{t-1} and R_{t-1}^* are nominal gross domestic and foreign interest rates, respectively, T_t is the real lump-sum taxes, R_t^k is the real rental cost of physical capital, $\pi_t = \frac{P_t}{P_{t-1}}$ is inflation, and Π_t is the real profits transferred from the monopolistic firms.

The law of motion for physical capital has the quadratic capital adjustment costs consistent with the endogenous discount factor approach to close a small open economy (Schmitt-Grohe & Uribe, 2003):

$$K_t = (1-\delta)K_{t-1} + I_t - \frac{\kappa}{2}(K_t - K_{t-1})^2 \tag{3}$$

The collateral constraint relates gross foreign liabilities to a future value of physical capital:

$$R_t^* b_t^* \leq \Omega_t E_t\{\frac{Q_{t+1}\pi_{t+1}}{e_{t+1}/e_t}K_t\}, \tag{4}$$

where Q_t is a real shadow value of capital (Tobin's Q), and Ω_t is an upper bound of leverage ratio which follows AR(1) process and has a negative shock representing sudden stops.

$$\widehat{\Omega}_t = \rho_w \widehat{\Omega}_{t-1} - \epsilon_t^{\Omega} \tag{5}$$

The problem of optimizer is, therefore, to maximize (1) with respect to C_t^S, I_t, K_t, b_t, b_t^*, N_t subject to (2), (3), and (4). The first-order conditions of this problem are below, where λ_t, λ_t^k, and $\lambda_t \xi_t$ are Lagrange multipliers of the constraints (2), (3), (4), respectively.

$$[C_t^S]: \; U_{C_t^S} = \lambda_t = \frac{1}{[C_t^S - \frac{N_t^{\phi}}{\phi}]^{\sigma}} \tag{6}$$

$$[I_t]: \; \lambda_t^k = \lambda_t, \text{ thus } Q_t = \frac{\lambda_t^k}{\lambda_t} = 1 \tag{7}$$

$$\begin{aligned}[K_t] \quad : \quad & Q_t[1+\kappa(K_t - K_{t-1})] = E_t\{\beta(\widetilde{C}_t, \widetilde{N}_t)\frac{\lambda_{t+1}}{\lambda_t}[R_{t+1}^k + Q_{t+1}(1-\delta \\ & +\kappa(K_{t+1}-K_t)) + \xi_t \Omega_t \frac{Q_{t+1}\pi_{t+1}}{e_{t+1}/e_t}]\}\end{aligned} \tag{8}$$

$$[b_t]: \; \frac{1}{R_t} = \beta(\widetilde{C}_t, \widetilde{N}_t)E_t\{\frac{U_{C_{t+1}^S}}{U_{C_t^S}}\frac{P_t}{P_{t+1}}\} \tag{9}$$

$$[b_t^*]: \ \frac{1}{R_t^*} = \beta(\widetilde{C}_t, \widetilde{N}_t) E_t \{ \frac{U_{C_{t+1}^S}}{U_{C_t^S}} \frac{P_t}{P_{t+1}} \frac{e_{t+1}}{e_t} \} + \xi_t \tag{10}$$

$$[N_t]: \ W_t = N_t^{\phi - 1} \tag{11}$$

By dividing (10) into (9) we get the following uncovered interest rate parity (UIP) condition:

$$\frac{R_t}{R_t^*} = \frac{e_{t+1}}{e_t} + \frac{\xi_t U_{C_t^S}}{\beta(\widetilde{C}_t, \widetilde{N}_t) U_{C_{t+1}^S}} \pi_{t+1} \tag{12}$$

The rule-of-thumb households have the same preferences as optimizers. They choose only consumption and labor and their budget constraint in real terms is simply this:

$$C_t^N + T_t = W_t N_t \tag{13}$$

The first-order conditions with respect to N_t and C_t^N are identical to optimizer's solutions. Thus, the rule-of-thumb households face the same labor supply condition (11).

2.2 Firms

Each firm j is the monopolistic producer of goods following the Calvo price setting framework (Calvo, 1983). The problem of a firm is standard according to the New Keynesian model for the small open economy the details of which are provided in Gali (2008) and Walsh (2010). The only difference is that the Cobb-Douglass production function has three inputs: physical capital, labor, and government capital.

$$Y_t = A_t K_{t-1}^{\alpha} N_t^{1-\alpha} K_{G,t-1}^{\psi} \tag{14}$$

The inflation equation for the small open economy includes domestic inflation and terms of trade which can be alternatively represented by the real exchange rate:

$$\pi_t = \pi_t^h + \frac{1-\gamma}{\gamma} \bigtriangleup \ln RER_t, \tag{15}$$

where $(1-\gamma)$ is a degree of openness since CPI index is defined as $P_t = [\gamma P_{h,t}^{1-\eta} + (1-\gamma)P_{f,t}^{1-\eta}]^{\frac{1}{1-\eta}}$, where $\eta \in [0, \infty]$ is the elasticity of substitution between domestic and foreign goods in the following consumption bundle for each i type of household $C_t(i) = [\gamma^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}}(i) + (1-\gamma)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}}(i)]^{\frac{\eta}{\eta-1}}$. The aggregate consumption, in turn, is $C_t = \mu C_t^N + (1-\mu)C_t^S$.

The Phillips curve is, therefore:

$$\pi_t = \overline{\beta} E_t \pi_{t+1} + \lambda \widehat{mc}_t - \overline{\beta}\frac{1-\gamma}{\gamma} \bigtriangleup \ln RER_{t+1} + \frac{1-\gamma}{\gamma} \bigtriangleup \ln RER_t, \tag{16}$$

where $\bigtriangleup \ln RER_t = \bigtriangleup \ln e_t + \pi_t^* - \pi_t$, $\overline{\beta}$ is a steady state discount factor, $\widehat{mc}_t$ is the log deviation of real marginal cost from its steady state, and $\lambda = \frac{(1-\overline{\beta}\theta)(1-\theta)}{\theta}$, where θ is an index of price stickiness.

Real marginal cost is the same across firms and yields the following expression:

$$mc_t = \frac{W_t^{1-\alpha}(R_t^k)^\alpha}{A_t K_{G,t-1}^{\psi}(1-\alpha)^{1-\alpha}\alpha^\alpha} \tag{17}$$

2.3 Fiscal policy

The government collects lump-sum taxes and issues one-period bonds to finance its interest payments and expenditures which are assumed to go exclusively to home goods. The expenditures include government consumption G_t^C and government investment G_t^I. The government budget constraint can be written as follows:

$$b_t + T_t = G_t^I + G_t^C + R_{t-1}b_{t-1} \tag{18}$$

Government investment is productive so that the law of motion for government capital is given by:

$$K_{G,t} = (1-\delta^g)K_{G,t-1} + G_t^I \tag{19}$$

The fiscal instruments have the following rules responding to fiscal debt, and government spending responds to output gap as well in order to capture business cycles:

$$\widehat{T}_t = \varphi_b \widehat{b}_{t-1} + \varphi_I \widehat{G^I_t} + \varphi_C \widehat{G^C_t} \tag{20}$$

$$\widehat{G^I_t} = \rho_{GI} \widehat{G^I_{t-1}} + (1 - \rho_{GI})(\vartheta_{GI} \widehat{Y}_t - \gamma_{GI} \widehat{b}_{t-1}) + \epsilon_t^{GI} \tag{21}$$

$$\widehat{G^C_t} = \rho_{GC} \widehat{G^C_{t-1}} + (1 - \rho_{GC})(\vartheta_{GC} \widehat{Y}_t - \gamma_{GC} \widehat{b}_{t-1}) + \epsilon_t^{GC}, \tag{22}$$

where the hat denotes deviations of the variables from their steady states. Note, there is no shock to lump-sum taxes in (20) assuming that fiscal debt is not generated by the tax cuts in the first place; only government investment and consumption can suddenly increase.

2.4 Monetary policy

The nominal interest rate follows the Taylor rule responding to its lagged value, inflation, output gap, and the nominal exchange rate gap:

$$\widehat{R}_t = \rho \widehat{R}_{t-1} + (1 - \rho) \left[\phi_\pi \pi_t + \phi_y \widehat{Y}_t + \phi_e \widehat{e}_t \right] + \epsilon_t \tag{23}$$

Foreign exchange intervention defined as a purchase of foreign currency has its separate rule responding to the nominal exchange rate gap and its rate of depreciation[2] (Sarno & Taylor, 2001):

$$\widehat{Int}_t = \alpha_1 \widehat{e}_t + \alpha_2 \bigtriangleup \widehat{e}_t + \epsilon_t^{int}, \text{ where } \alpha_1 < 0, \; \alpha_2 < 0 \tag{24}$$

Reserves or net foreign assets of the central bank can be affected by its foreign exchange intervention:

$$NFA_t = NFA_{t-1} + Int_t \tag{25}$$

[2] Since the exchange rate is defined as a price of foreign currency in terms of domestic currency, the higher $\bigtriangleup \widehat{e}_t$ is, the more domestic currency depreciates.

2.5 Market clearing

Labor, capital, and goods markets clear according to the following conditions:

$$N_t = \int_0^1 N_t(j)dj, \qquad K_t = \int_0^1 K_t(j)dj$$

$$Y_t = (1-\mu)C_t^S + \mu C_t^N + I_t + G_t^C + G_t^I + NX_t \tag{26}$$

The balance of payments of the domestic economy requires that the sum of the current account and financial account should be equal to the change of central bank reserves which is, according to equation (25), the foreign exchange intervention:

$$NX_t = (1-\mu)(R_{t-1}^* \frac{e_t}{e_{t-1}} \frac{b_{t-1}^*}{\pi_t} - b_t^*) + Int_t \tag{27}$$

2.6 Foreign world

The foreign world is specified by the following three equations:

$$\widehat{Y}_t^* = \rho_{Y^*} \widehat{Y}_{t-1}^* + \epsilon_t^{Y^*} \tag{28}$$

$$\widehat{R}_t^* = \phi_\pi^* \pi_t^* + \phi_y^* \widehat{Y}_t^* + \epsilon_t^{i^*} \tag{29}$$

$$\pi_t^* = \beta^* E_t \pi_{t+1}^* + \lambda^* (\sigma + \frac{\phi^* + \alpha^*}{1-\alpha^*}) \widehat{Y}_t^* \tag{30}$$

The foreign Phillips curve (30) is in accordance with the standard, closed-economy, New Keynesian model (Gali, 2008).

3 System of equations

The model includes 18 endogenous variables constituting a system of 18 equations where the variables are represented in log-deviations from their steady states: inflation π_t, aggregate consumption of households $\widehat{C}_t$, hours worked $\widehat{N}_t$, the domestic interest rate $\widehat{R}_t$, net exports $\widehat{NX}_t$, foreign exchange intervention $\widehat{Int}_t$, the foreign interest rate $\widehat{R}_t^*$, foreign inflation π_t^*, foreign output $\widehat{Y}_t^*$, foreign borrowings $\widehat{b}_t^*$, private capital $\widehat{K}_t$, government capital $\widehat{K}_{G,t}$, the nominal exchange rate $\widehat{e}_t$, fiscal debt $\widehat{b}_t$, government consumption $\widehat{G_t^C}$, output $\widehat{Y}_t$, AR(1) process for productivity, and the upper bound of the leverage ratio $\widehat{\Omega}_t$ capturing sudden stops shock. The system of log-linear equations consists of the Taylor rule (23), foreign exchange intervention policy (24), the government consumption equation (22), the specification of sudden stops shock (5), three foreign world expressions (28), (29), and (30), and the following equations.

$$\begin{aligned}\pi_t &= \overline{\beta}\pi_{t+1} + \phi\gamma\lambda\widehat{N}_t - \gamma\lambda\widehat{Y}_t - (1-\gamma)\overline{\beta}\pi_{t+1}^* + (1-\gamma)\pi_t^* - \overline{\beta}(1-\gamma)\widehat{e}_{t+1} \\ &\quad +(1-\gamma)(1+\overline{\beta})\widehat{e}_t - (1-\gamma)\widehat{e}_{t-1}\end{aligned} \tag{31}$$

$$\begin{aligned}\widehat{NX}_t &= \frac{(1-\mu)\overline{R}^*\overline{b}^*}{\overline{NX}}\widehat{R}_{t-1}^* + \frac{(1-\mu)\overline{R}^*\overline{b}^*}{\overline{NX}} \vartriangle \widehat{e}_t - \frac{(1-\mu)\overline{b}^*}{\overline{NX}}\widehat{b}_t^* \\ &\quad + \frac{(1-\mu)\overline{R}^*\overline{b}^*}{\overline{NX}}\widehat{b}_{t-1}^* - \frac{(1-\mu)\overline{R}^*\overline{b}^*}{\overline{NX}}\pi_t + \frac{\overline{Int}}{\overline{NX}}\widehat{Int}_t\end{aligned} \tag{32}$$

$$\widehat{b}_t^* = \widehat{K}_t + \pi_{t+1} - \widehat{R}_t^* + \widehat{e}_t - \widehat{e}_{t+1} + \widehat{\Omega}_t \tag{33}$$

$$\widehat{a}_t = \rho_a\widehat{a}_{t-1} + \epsilon_t^a \tag{34}$$

$$\begin{aligned}\widehat{K}_t &= (1-\delta)\widehat{K}_{t-1} + \frac{\delta}{1-\widetilde{\gamma}}[\widehat{Y}_t - c_y\widehat{C}_t - g_y^C\widehat{G_t^C} - nx_y\widehat{NX}_t \\ &\quad + \frac{g_y^I(1-\delta^g)}{\delta^g}\widehat{K}_{G,t-1} - \frac{g_y^I}{\delta^g}\widehat{K}_{G,t}]\end{aligned} \tag{35}$$

where $(1-\widetilde{\gamma})$, g_y^I, g_y^C, c_y, nx_y are the shares of investment, government investment, government consumption, households' consumption, and net exports in aggregate output.

$$\begin{aligned}\widehat{K}_{G,t} &= (\rho_{GI}+1-\delta^g)\widehat{K}_{G,t-1}-\rho_{GI}(1-\delta^g)\widehat{K}_{G,t-2} \\ &\quad +(1-\rho_{GI})\delta^g(\vartheta_{GI}\widehat{Y}_t-\gamma_{GI}\widehat{b}_{t-1})+\delta^g\epsilon_t^{GI}\end{aligned} \tag{36}$$

$$\widehat{e}_{t+1}=\widehat{R}_t+\widehat{e}_t-\frac{\beta^*}{\overline{\beta}}\widehat{R}^*_t-\frac{\beta^*-\overline{\beta}}{\overline{\beta}}\widehat{\xi}_t, \tag{37}$$

where $\widehat{\xi}_t$ is an UIP shock.

$$\widehat{Y}_t=\alpha\widehat{K}_{t-1}+(1-\alpha)\widehat{N}_t+\psi\widehat{K}_{G,t-1}+\widehat{a}_t \tag{38}$$

$$\begin{aligned}(1-\overline{\Omega\xi})\chi\overline{N}^{\phi}\overline{\beta}^{\frac{1}{\chi}}\widehat{N}_t &= \widehat{R}_t-(1+\overline{\Omega\xi})\pi_{t+1}-(1-\overline{\beta}(1-\delta)-\overline{\Omega\xi})(\phi\widehat{N}_{t+1}-\widehat{K}_t) \\ &\quad -\overline{\Omega\xi}(\widehat{e}_t-\widehat{e}_{t+1})+(1-\overline{\Omega\xi})\chi\overline{C}\overline{\beta}^{\frac{1}{\chi}}\widehat{C}_t-\overline{\Omega}(\beta^*-\overline{\beta})(\widehat{\xi}_t+\widehat{\Omega}_t)\end{aligned} \tag{39}$$

$$\widehat{b}_t=\Psi_b\widehat{b}_{t-1}+\Psi_i\widehat{R}_{t-1}+\Psi_{kg}\left(\frac{\widehat{K}_{G,t}-(1-\delta^g)\widehat{K}_{G,t-1}}{\delta^g}\right)+\Psi_{gc}\widehat{G^C_t}, \tag{40}$$

where coefficients are as follows:

$$\Psi_b=\frac{\overline{bR}-\overline{T}\varphi_b}{\overline{bR}+\overline{G^I}+\overline{G^C}-\overline{T}}$$

$$\Psi_i=\frac{\overline{bR}}{\overline{bR}+\overline{G^I}+\overline{G^C}-\overline{T}}$$

$$\Psi_{kg}=\frac{\overline{G^I}-\overline{T}\varphi_I}{\overline{bR}+\overline{G^I}+\overline{G^C}-\overline{T}}$$

$$\Psi_{gc}=\frac{\overline{G^C}-\overline{T}\varphi_C}{\overline{bR}+\overline{G^I}+\overline{G^C}-\overline{T}}$$

The aggregate consumption equation is derived according to Gali, Lopez-Salido & Valles (2007):

$$\begin{aligned}\Theta_c \widehat{C}_t &= \widehat{C}_{t+1} + \Theta_n \widehat{N}_t - \Theta_{n1} \widehat{N}_{t+1} - \Theta_i (\widehat{R}_t - \pi_{t+1}) + \Theta_b \widehat{b}_t - \overline{C}^{-1} \mu \overline{T} \varphi_b \widehat{b}_{t-1} \quad (41)\\ &+ \Theta_y \widehat{Y}_{t+1} + \Theta_{kg} \widehat{K}_{G,t} - \Theta_{kg1} \widehat{K}_{G,t-1} + \Theta_{gc} \widehat{G_t^C},\end{aligned}$$

where coefficients are shown below.

$$\Theta_c = 1 - (1-\mu)\sigma^{-1}\chi\overline{\beta}^{1/\chi}(\overline{C} - \phi^{-1}\overline{N}^{\phi})$$

$$\Theta_n = \mu\overline{W}^{\frac{\phi}{\phi-1}}\phi\overline{C}^{-1} - (\sigma\overline{C})^{-1}(1-\mu)(\chi\overline{N}^{\phi}\overline{\beta}^{1/\chi}(\overline{C} - \phi^{-1}\overline{N}^{\phi}) - \sigma\overline{N}^{\phi})$$

$$\Theta_{n1} = \overline{C}^{-1}((1-\mu)\overline{N}^{\phi} + \mu\phi\overline{W}^{\frac{\phi}{\phi-1}})$$

$$\Theta_i = (\sigma\overline{C})^{-1}(1-\mu)(\overline{C} - \phi^{-1}\overline{N}^{\phi})$$

$$\Theta_b = \overline{C}^{-1}\mu\overline{T}(\varphi_b - \varphi_I\gamma_{GI}(1-\rho_{GI}) - \varphi_C\gamma_{GC}(1-\rho_{GC}))$$

$$\Theta_y = \overline{C}^{-1}\mu\overline{T}(\varphi_I\vartheta_{GI}(1-\rho_{GI}) + \varphi_C\vartheta_{GC}(1-\rho_{GC}))$$

$$\Theta_{kg} = (\overline{C}\delta^g)^{-1}\mu\overline{T}\varphi_I(\rho_{GI} - 1)$$

$$\Theta_{kg1} = (\overline{C}\delta^g)^{-1}\mu\overline{T}(1-\delta^g)\varphi_I(\rho_{GI} - 1)$$

$$\Theta_{gc} = \overline{C}^{-1}\mu\overline{T}\varphi_C(\rho_{GC} - 1)$$

The steady state values for the endogenous variables in terms of parameters are derived in Appendix A.

4 Calibration

All values for the parameters can be divided into three sets: standard values borrowed from other studies because of the non-availability of respective Hungarian data, fixed values borrowed from the estimated Hungarian DSGE model (Vilagi, 2008), and specifically calibrated parameters for this model. The first set includes $\delta = 0.025$, $\delta^g = 0.02$ (Traum & Yang, 2010), $\mu^p = 0.2$ (Gali, Lopez-Salido & Valles, 2007), $\sigma = 2$, $\chi = 0.11$ (Schmitt-Grohe & Uribe, 2003), and $\alpha_2 = -0.62$ (Gartner, 1987).

The second set consists of posterior estimates of Vilagi (2008) and his used fixed parameters: $\rho = 0.76$, $\phi_\pi = 1.37$, $\theta = 0.9$, $\phi_e = 0.025$, and $\mu = 0.25$.

The third largest set is the calibrated one using the averages of Hungarian data[3] over 1995Q1-2011Q3 for the steady state values of main variables derived in Appendix A. In particular, the ratios of consumption, government consumption, and net exports to GDP are as follows: $c_y = 0.66$, $g_y^C = 0.1$, and $nx_y = 0.0001$. The degree of openness is calculated as a ratio of imports to GDP, $1 - \gamma = 0.69$; thus, domestic bias is equal to 0.31, $\gamma = 0.31$. The steady state discount factor is set to 0.97 because the average T-bill rate is used as a proxy for the policy interest rate, which is 3% per quarter. This is because the domestic interest rate matters exclusively for government bonds in the model since investment is financed by foreign borrowings rather than the domestic financial market.

The foreign parameters are set at their standard values: $\beta^* = 0.99$, $\phi^* = 2$, $\phi_\pi^* = 1.5$, $\phi_y^* = 0.125$ (Gali, 2008), $\theta^* = 0.75$ (Gali, Lopez-Salido & Valles, 2007), $\alpha^* = 0.32$, and $\rho_{Y^*} = 0.9$. The upper bound of the leverage ratio $\overline{\Omega}$ appears to be 0.14 using the steady state expression of collateral constraint (47) in Appendix A. The income share of capital α is equal to 0.45, higher than its standard level because of the specific steady state rental cost of capital (43). Using data on wage and employment, the parameter ϕ is calibrated to 2 based on the labor supply condition (11). The income share of government capital ψ corresponds to 0.08 based on equation (44) in Appendix A. The parameter α_1 is set to -0.077 using the steady state equation for foreign exchange intervention (46), while the output gap elasticity of the policy rule is set to its standard value, $\phi_y = 0.125$. Fiscal parameters are calibrated using the respective steady state expressions for government consumption, government capital, fiscal debt, and lump-sum taxes in Appendix A: $\vartheta_{GI} = 1.03$, $\gamma_{GI} = 0.38$, $\vartheta_{GC} = 1.18$, $\gamma_{GC} = 0.4$, $\varphi_I = 0.255$, and $\varphi_C = 0.3$.

Some parameters are obtained by running regressions according to the model's equations based on the seasonally adjusted log of real data. For example, the au-

[3]The data include real GDP, CPI-deflated consumption, government consumption, fixed capital formation, exports, imports, employment, wage, T-bill rate, CPI, fiscal debt, and fiscal revenues from the IFS database of IMF, the euro-forint exchange rate and external debt in euro from the webpage of the Central Bank of Hungary.

toregressive coefficient in the government consumption equation (22) is equal to 0.4 using the data of government consumption, GDP, and fiscal debt. The standard deviation of residuals from this equation is used for the variance of the government consumption shock in the model, 0.04. Analogously, the standard deviation of the foreign exchange intervention shock is 2 based on the intervention regression (24). The parameter of the lump-sum taxes' response to fiscal debt is obtained by running the regression of fiscal revenues on fiscal debt and government consumption, $\varphi_b = 0.4$. The autoregressive coefficient for the productivity shock, its standard error, the standard errors for the interest rate shock and the UIP shock are set at their estimated average values between the crawling peg and inflation targeting regimes according to Vilagi (2008), respectively: 0.6, 2, 0.4, and 0.4.

5 Impulse response functions

The impulse response functions to 6 exogenous shocks are presented in Appendix B: two fiscal shocks—government consumption and government investment, two monetary shocks—interest rate and foreign exchange intervention, a sudden stops shock and a foreign interest rate shock to be compared with each other. As expected, fiscal shocks affect the output differently even though both of them depreciate the exchange rate, cause inflation, stimulate private consumption together with hours worked, and reduce private capital. In the Figure 1 of Appendix B the government investment shock boosts output and decreases fiscal debt as government investment accumulates government capital, which reduces the fiscal debt. The government consumption shock, in contrast, is unproductive, decreases output in the medium run and contributes to fiscal debt in Figure 2 of Appendix B. In both cases, we can observe that in response to an expansionary fiscal policy in terms of its either government consumption or government investment shock, monetary policy tightens in both of its instruments because interest rate is raised due to inflation and foreign exchange intervention declines due to depreciation. Despite tight monetary policy, still the productive government investment seems to be a desirable fiscal instrument for an emerging open economy, like Hungary, because it accumulates government capital which is associated typically with infrastructure and ultimately reduces the fiscal debt.

As for the monetary policy shocks, an increase of the interest rate does not have the usual contractionary effect. This is because investment in this model is financed by foreign borrowings; thus, it does not depend on the domestic interest rate per se. On the contrary, an increased interest rate positively affects hours worked which stimulate consumption and output, as hours worked are one of the production inputs. The foreign borrowings and net exports, however, decline because of appreciation caused by the increased interest rate.

The foreign exchange intervention shock causes depreciation, inflation and improves net exports in Figure 4 of Appendix B. However, it does not have an overall expansionary effect on the economy since capital is reduced because of increased net exports, hours worked decline because of depreciation, and consumption falls due to its positive relationship with hours worked in the model. This suggests that intervention as a second instrument of monetary policy is not a productive instrument to ultimately boost output per se.

Regarding interactions with fiscal policy instruments, we see that a tight monetary policy in terms of raising its interest rate causes a decline in government consumption and government capital in the medium run because they might appropriately adjust due to the increased burden of fiscal debt. The positive shock to intervention which decreases output causes again tight fiscal policy in terms of a decline in government consumption and government capital in the medium run because of the procyclical fiscal policy in Hungary (positive parameters ϑ_{GI} and ϑ_{GC}).

The sudden stops shock as a negative shock to the upper bound of the leverage ratio in the collateral constraint Ω_t delivers the outcomes quite consistent with the evidence 2009. In particular, output, consumption, hours worked, capital, and foreign borrowings drop in Figure 5 of Appendix B. Net exports, meanwhile, increase, which is in line with the capital reversals argument as one of the main "empirical regularities" characterizing sudden stops (Mendoza, 2010). We can even observe that the exchange rate depreciates and the central bank loses its foreign reserves as it is the case for Hungary especially in 2009Q2. However, inflation increases because of the assumed complete pass-through from depreciation to inflation in the model.

In contrast, a positive shock to the foreign interest rate, which is alternatively used to model sudden stops referring to the increase of risk premium, does not provide the drops in output, consumption, and employment in Figure 6 of Appendix B. Instead, it leads to even more significant inflation than in Figure 5 which does not seem to happen actually in the emerging economies hit by the global crisis. Therefore, the quantitative foreign credit shortage as an approach to model sudden stops appears to deliver more realistic dynamics rather than an increase of risk premium related to the price effect.

Turning to our posed question at the beginning of this paper, we can summarize that monetary and fiscal policy in an emerging open economy intimately interact in the short (immediate) and medium run. In the short run, monetary policy responds to fiscal shocks: tightens in both its instruments in response to government consumption and government investment shock. In the medium run, fiscal policy tends to adjust to monetary shocks: contracts in response to a tight monetary policy in terms of its interest rate increase, and if fiscal policy is procyclical, then it contracts as well in response to a foreign exchange intervention shock which appears to be unproductive causing inflation.

6 Conclusion

This paper provides a DSGE model designed for an emerging open economy to understand monetary and fiscal policy interactions with their two instruments for each policy: monetary instruments—interest rate and foreign exchange intervention, fiscal instruments—government consumption and government investment, and to address the sudden stops shock in describing properly the crisis situation of 2009 for the case of Hungary. It combines the New Keynesian model of the small open economy in an incomplete asset market with the collateral constraint related to foreign borrowings and with the two types of households: optimizing individuals and the rule-of-thumb households relaxing the assumption of Ricardian equivalence.

The novelty of this paper is threefold. First, it builds a DSGE framework for the emerging open economies, which structurally differ from the developed world extensively captured by the existing standard DSGE settings. Second, it endogenously models the monetary and fiscal policy with their two instruments for each, highlighting the productive effects of government investment as opposed to government consumption, and having the foreign exchange intervention in addition to the interest rate both of which follow the two separate monetary policy rules. Third, this paper has focused on sudden stops shock which causes an economic recession, capital reversals, depreciation, and loss of foreign reserves consistent with the evidence using the collateral constraint specification rather than a traditional financial accelerator mechanism. Moreover, it demonstrates that a simple negative shock to the upper bound of the leverage ratio in the collateral constraint is able to deliver quite realistic dynamics of a sudden stops crisis compared with the typical risk premium shock.

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7 Appendices

Appendix A: Steady state

The steady state values for the endogenous variables are shown in terms of the model's parameters in this appendix. The first-order condition with respect to b_t (9) gives that $\overline{R} = \frac{1}{\overline{\beta}}$. Similarly, $\overline{R}^* = \frac{1}{\beta^*}$. The UIP condition (12) suggests $\overline{\xi} = \beta^* - \overline{\beta}$ at steady state. In other words, positive $\overline{\xi}$ implies that collateral constraint binds at steady state (Faia & Iliopulos, 2010).

The government investment equation (21) evaluated at steady state can be represented as $\overline{G_I} = \frac{\overline{G_I}^{\rho_{GI}} \overline{Y}^{(1-\rho_{GI})\vartheta_{GI}}}{\overline{b}^{(1-\rho_{GI})\gamma_{GI}}}$ which allows expressing $\overline{G_I} = \frac{\overline{Y}^{\vartheta_{GI}}}{\overline{b}^{\gamma_{GI}}}$. Similarly, the steady state government consumption is as follows based on the equation (22) $\overline{G_C} = \frac{\overline{Y}^{\vartheta_{GC}}}{\overline{b}^{\gamma_{GC}}}$. The government capital accumulation equation (19) provides the steady state government capital $\overline{K_G} = \frac{\overline{G^I}}{\delta^g} = \frac{\overline{Y}^{\vartheta_{GI}}}{\delta^g \overline{b}^{\gamma_{GI}}}$ from which fiscal debt can be expressed in terms of output and government capital $\overline{b} = \left(\frac{\overline{Y}^{\vartheta_{GI}}}{\overline{K_G}\delta^g}\right)^{1/\gamma_{GI}}$. The steady state lump-sum taxes can be found by plugging the previous three equations for fiscal debt, government consumption, and investment into the tax equation (20) $\overline{T} = \frac{\overline{Y}^{\frac{\vartheta_{GI}\varphi_b - \vartheta_{GI}\varphi_C\gamma_{GC} + \vartheta_{GC}\varphi_C\gamma_{GI}}{\gamma_{GI}}}}{(\overline{K_G}\delta^g)^{\frac{\varphi_b - \gamma_{GC}\varphi_C - \gamma_{GI}\varphi_I}{\gamma_{GI}}}}$. Therefore, the government budget constraint (18) can be written in terms of output and government capital as follows:

$$\left(\frac{\overline{Y}^{\vartheta_{GI}}}{\overline{K_G}\delta^g}\right)^{1/\gamma_{GI}} + \frac{\overline{Y}^{\frac{\vartheta_{GI}\varphi_b - \vartheta_{GI}\varphi_C\gamma_{GC} + \vartheta_{GC}\varphi_C\gamma_{GI}}{\gamma_{GI}}}}{(\overline{K_G}\delta^g)^{\frac{\varphi_b - \gamma_{GC}\varphi_C - \gamma_{GI}\varphi_I}{\gamma_{GI}}}} = \overline{R}\left(\frac{\overline{Y}^{\vartheta_{GI}}}{\overline{K_G}\delta^g}\right)^{1/\gamma_{GI}} + \overline{K_G}\delta^g + \overline{Y}^{\vartheta_{GC} - \frac{\vartheta_{GI}\gamma_{GC}}{\gamma_{GI}}} (\overline{K_G}\delta^g)^{\frac{\gamma_{GC}}{\gamma_{GI}}} \tag{42}$$

The first-order condition with respect to capital (8) given that $\overline{Q} = 1$ yields the following steady state rental cost of capital:

$$\overline{R}^k = \frac{1}{\overline{\beta}} - (1 - \delta) - \frac{\overline{\xi\Omega}}{\overline{\beta}} \tag{43}$$

The problem of a firm is to equate the real marginal cost (17) with the inverse of price frictionless mark-up μ^p at steady state (Gali, 2008); thus, wage can be found as:

$$\overline{W} = (1-\alpha)\left(\frac{\overline{K_G}^{\psi}\alpha^{\alpha}}{(\overline{R}^k)^{\alpha}\mu^p}\right)^{\frac{1}{1-\alpha}}$$

The labor supply condition (11) gives $\overline{N} = \overline{W}^{\frac{1}{\phi-1}}$. Therefore, the production function (14) suggests that output can be expressed in terms of private capital and government capital:

$$\overline{Y} = \overline{K}^{\alpha}\overline{K_G}^{\frac{\psi\phi}{\phi-1}}\left(\frac{\alpha^{\alpha}(1-\alpha)^{1-a}}{(\overline{R}^k)^{\alpha}\mu^p}\right)^{\frac{1}{\phi-1}} \tag{44}$$

This means that government budget constraint (42) can be rewritten in terms of the both types of capital constituting, in turn, the first equation in a system. The second equation in that system comes from the market clearing condition shown gradually below.

The law of motion for physical capital (3) and the properties of function Ψ suggests $\overline{I} = \delta\overline{K}$.

Since we know that $\overline{R} = \frac{1}{\beta}$, $\beta(\widetilde{C}_t, \widetilde{N}_t) = [1 + \widetilde{C}_t - \phi^{-1}\widetilde{N}_t^{\phi}]^{-\chi}$ and assuming as in Gali, Lopez-Salido, and Valles (2007) that the steady state consumption is the same across household types; thus, in equilibrium individual and average per capita consumptions are identical (Schmitt-Grohe & Uribe, 2003), we can obtain:

$$\overline{C} = \overline{R}^{\frac{1}{\chi}} - 1 + \frac{\overline{N}^{\phi}}{\phi} = \overline{R}^{\frac{1}{\chi}} - 1 + \frac{(1-\alpha)^{\frac{\phi}{\phi-1}}}{\phi}\left(\frac{\overline{K_G}^{\psi}\alpha^{\alpha}}{(\overline{R}^k)^{\alpha}\mu^p}\right)^{\frac{\phi}{(\phi-1)(1-\alpha)}}$$

The steady state exchange rate can be found from the Taylor rule (23):

$$\bar{e} = \left[\frac{\overline{R}}{\overline{Y}^{\phi_y}}\right]^{1/\phi_e} \tag{45}$$

According to the intervention rule (24), the steady state foreign exchange intervention is as follows:

$$\overline{Int} = \overline{e}^{\alpha_1} \tag{46}$$

The collateral constraint (4) allows expressing the foreign borrowings in terms of private capital:

$$\overline{b^*} = \frac{\overline{\Omega K}}{\overline{R}^*} \tag{47}$$

The balance of payments equation (27) provides the steady state net exports:

$$\overline{NX} = (1-\mu)(\overline{\Omega K} - \frac{\overline{\Omega K}}{\overline{R}^*}) + \left[\frac{\overline{R}}{\overline{Y}^{\phi_y}}\right]^{\alpha_1/\phi_e}$$

Therefore, the market clearing condition (26) can be utilized as a second equation in the system to find the private and government capital:

$$\begin{aligned} \overline{Y} \;=\; & \delta\overline{K} + \overline{K_G}\delta^g + \overline{Y}^{\vartheta_{GC} - \frac{\vartheta_{GI}\gamma_{GC}}{\gamma_{GI}}}(\overline{K_G}\delta^g)^{\frac{\gamma_{GC}}{\gamma_{GI}}} + (\overline{R}^{\frac{1}{\chi}} - 1 \\ & + \frac{(1-\alpha)^{\frac{\phi}{\phi-1}}}{\phi}\left(\frac{\overline{K_G}^{\psi}\alpha^{\alpha}}{(\overline{R}^k)^{\alpha}\mu^p}\right)^{\frac{\phi}{(\phi-1)(1-\alpha)}}) + (1-\mu)(\overline{\Omega K} - \frac{\overline{\Omega K}}{\overline{R}^*}) + \left[\frac{\overline{R}}{\overline{Y}^{\phi_y}}\right]^{\frac{a_1}{\phi_e}}, \end{aligned} \tag{48}$$

where output is plugged from the equation (44).

Since private and government capital can be found in the system of two equations (42 and 48), we can extract all the other steady state variables from our earlier substitutions: output, investment, consumption, hours worked, fiscal debt, government investment, government consumption, lump-sum taxes, foreign borrowings, exchange rate, intervention, and net exports.

Appendix B: Impulse response functions

Figure 1: Impulse responses to a government investment shock

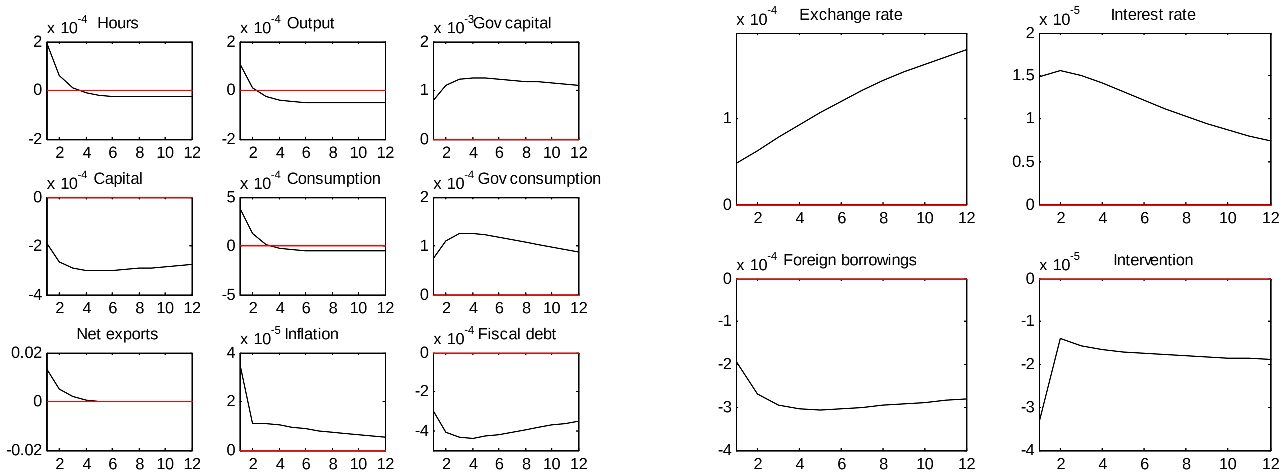

Figure 2: Impulse responses to a government consumption shock

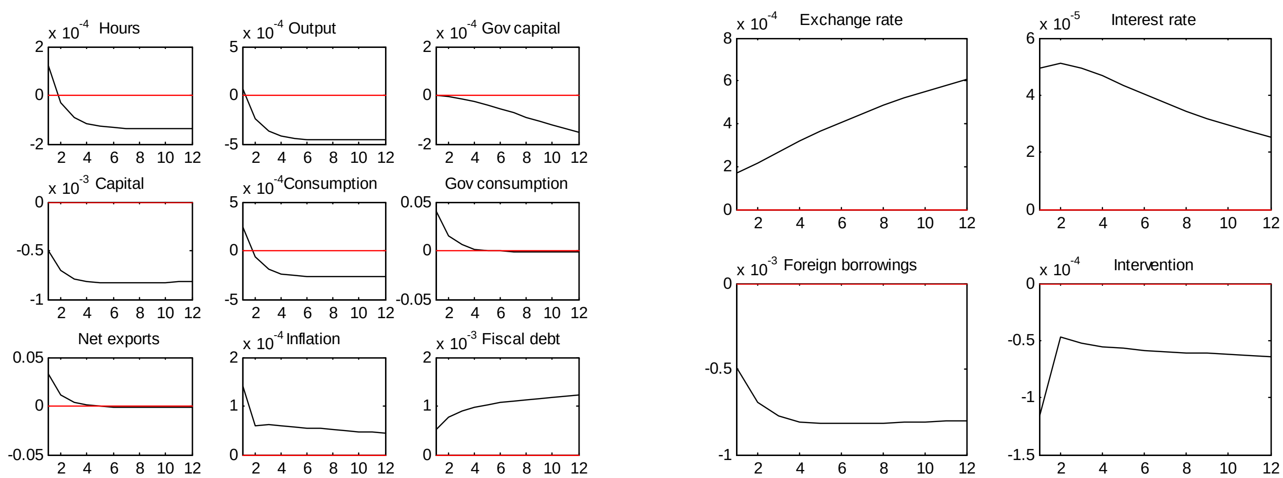

Figure 3: Impulse responses to a domestic interest rate shock

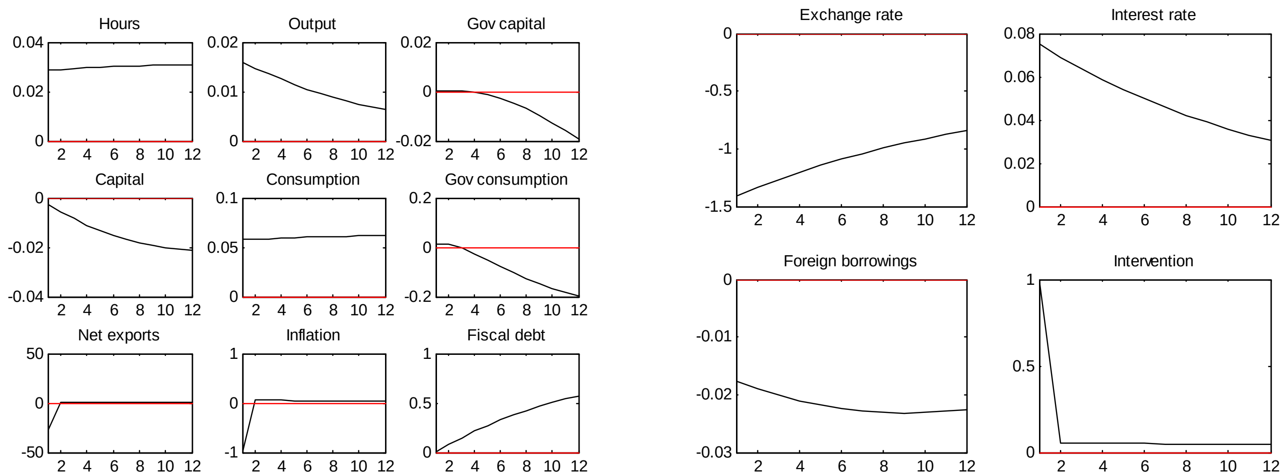

Figure 4: Impulse responses to a foreign exchange intervention shock

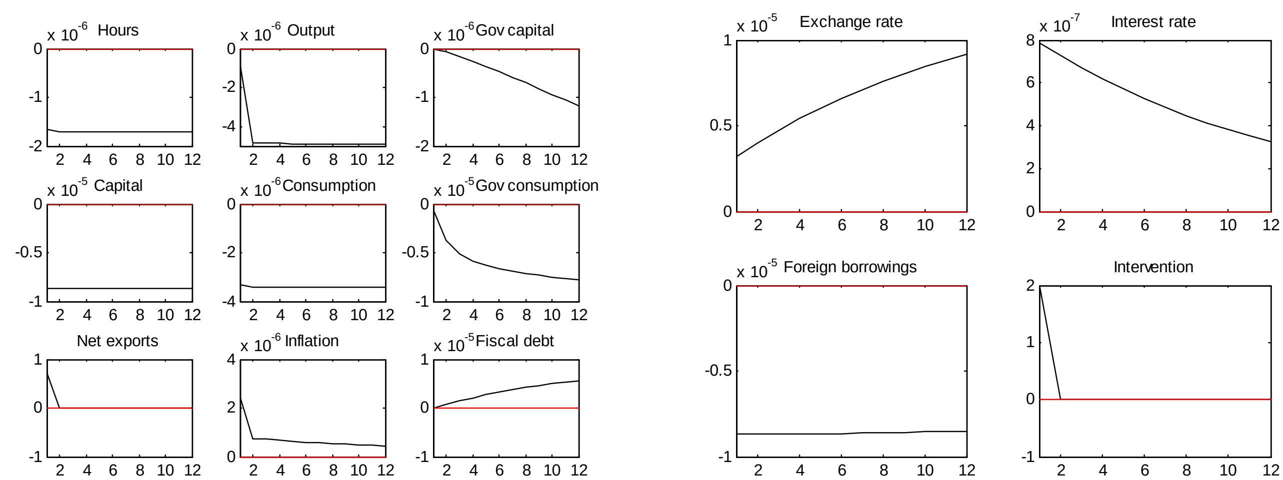

Figure 5: Impulse responses to a sudden stops shock

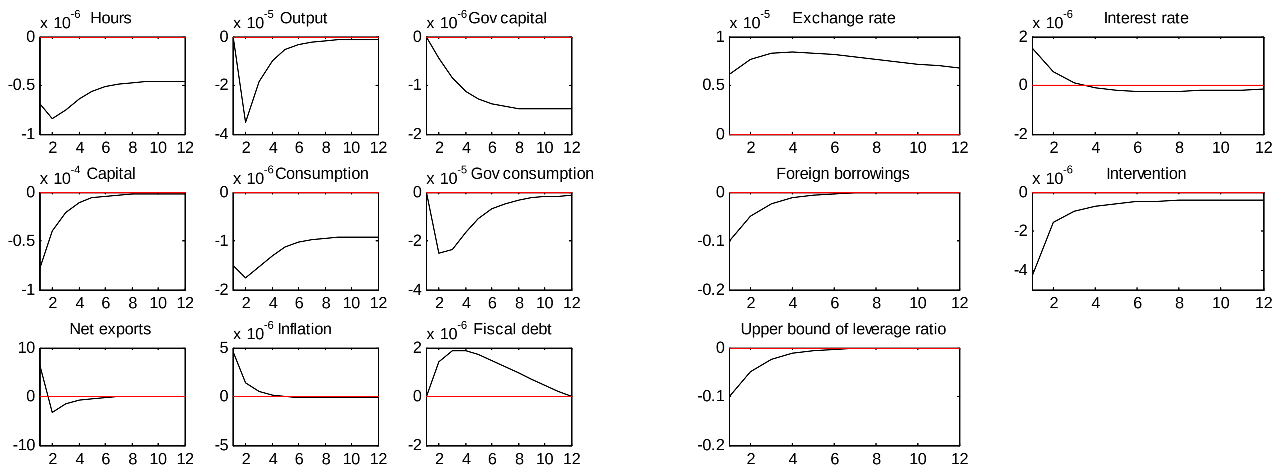

Figure 6: Impulse responses to a foreign interest rate shock

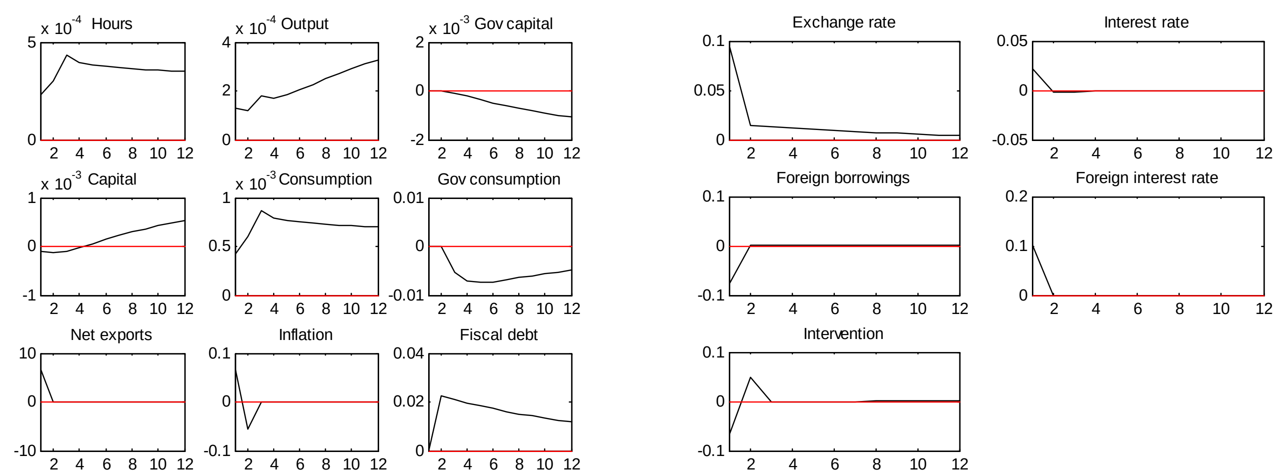

Figure 7: Impulse responses to a productivity shock