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# Contents

**SUMMARY.** A small open economy DSGE model with financial accelerator and monetary policy following currency board arrangement is presented. The specification builds on the work of *Gertler et al.* (2001, 2003) and extends it by implementing government that follows optimal simple rule and monetary authority obeying the rule of currency board arrangement. The model is calibrated to represent certain stylized facts about Bulgarian economy. Two temporary shocks are considered: an increase in international interest rate and a decrease in total factor productivity in the modeling economy. The roles of financial accelerator mechanism as well as fiscal policy rule are discussed.

# 1. Introduction

Standard DSGE models typically do not model financial linkages explicitly and consequently such models are not suitable for analyzing effects of changes in credit conditions on the real side of the economy. This simplification is due to the well-known *Modigliani – Miller* theorem, which states that with well-functioning markets and rational investors the value of the firm should not be affected by the share of debt in its financial structure (see *Modigliani* (1980), p. xiii).

In practice, however, during many economic crises financial markets played an important role in the amplification of the original shocks or have even been the source of original shock on their own. The financial accelerator mechanism is one of the approaches allowing positive relationship between the financial conditions and the real side of the economy and *vice versa* (*Bernanke et al.* (1998)). Another popular approach uses collateral constraints (*Kiyotaki and Moore* (1997)). Financial accelerator relaxes the assumption of symmetric information and includes costly state verification. The inclusion of a financial accelerator brings about the following results:

- the additional costs in case of bankruptcy induce a risk premium over the economy-wide interest rate;
- these costs (and the premium) are procyclical because the financial position and default rates of firms are also procyclical;
- the price of capital is also procyclical as investment itself is procyclical;
- combining the two effects above results in amplification and propagation of shocks in the economy;

The mechanism of financial accelerator is realized through two main channels. First, in case of an unexpected shock to the return of firm's project the loss is borne entirely by the entrepreneur, while the bank still continues to receive debt repayments. As a result, the shock on the financial position is more than proportionate to the original shock to the return of the projects. The effect is more pronounced when the firm is more leveraged. Second, the deteriorated financial position increases the probability of default which pushes up the external financing premium which in turn further damages the financial situation of the enterprizes.

The financial sector in Bulgaria is deepening fast and the access to credit has been improving in the recent years. This trend assigns more importance to financial conditions changes in the firms' decision making and provides a motivation to include the financial sector in the model. Furthermore, the international financial and economic crisis that started in 2008, apart from the trade channel, affected the Bulgarian economy through lower lending activity by the banking sector (mostly foreign owned). The implications arising from a currency board type monetary policy and active fiscal policy are also quite relevant for the case of Bulgaria.

The paper develops a small open economy DSGE model with financial accelerator a la *Gertler et al.* (2001, 2003). The model is extended to include the currency board arrangement (CBA) feature for Bulgaria. With the fiscal policy being the major policy instrument at hand, the question on how the government should react to different shocks to the economy in order to stabilize key economic variables becomes even more important. An optimal simple rule for conducting fiscal policy is obtained. The presence of financial accelerator and its significance for determining fiscal policy response is also discussed. The main mechanisms of reaction to different shocks are explained.

The second section describes the model structure while the third section explains the parametrization approach. The fourth section discusses the simulation results from shocks in the international interest rate and in productivity. The role of the financial accelerator and fiscal policy is discussed there. The fifth section concludes and outlines the directions for future work. Appendix 1 gives the equations that are included in the model code and Appendix 2 plots the impulse responses of the different shocks to the economy.

## 2. The Model

The model structure follows closely that of *Gertler et al.* (2001, 2003). The financial accelerator is an amplifying mechanism because the financial position of the firm affects the credit conditions and consequently determines investment decisions (demand for capital).

In contrast to *Gertler et al.* (2001, 2003) having no autonomous fiscal policy, in our model the government may accumulate fiscal reserves and use government spending conditional on meeting its budget constraint. The central bank is modeled in a way that captures the specificities of CBA in Bulgaria. In the current context it means that International Reserves should fully cover the currency in circulation and the fiscal reserve within the Central Bank, like in *Iordanov and Vassilev* (2008).

The model consists of five sectors: households, firms (entrepreneurs, capital producers and retailers), fiscal and monetary authority and external sector. Households supply labour, save and consume domestic and imported goods. The corporate sector includes entrepreneurs, capital producers and retailers. Entrepreneurs produce wholesale goods and borrow from financial intermediaries to finance capital accumulation necessary for production. The asymmetry of information creates bankruptcy costs borne by the financial intermediaries. That in turn induces variation in external financing premium and influences demand for capital. Capital producers supply capital incurring additional costs that are proportionate to the ratio of investment over capital. Retailers costlessly combine wholesale goods supplied by entrepreneurs. Retail market structure is monopolistic competition and prices are rigid. Monetary authority follows the principles of CBA. The government formulates the fiscal policy in order to minimize the deviation of output and domestic inflation from their steady-state values.

Each sector is described in more detail below. The steady-state values of the variables are written with a bar, e.g. $\overline{B}$, $\overline{P}^F_t$, etc.

## 2.1. Households

### 2.1.1. Consumption and Price Index

Households consume only tradable goods and combine domestic goods ($C^H$) with imported ones ($C^F$). $C^H$ and $C^F$ are incomplete substitutes. The consumption index ($C$) for any combination ($C^H$, $C^F$) takes the form of a CES function:

$$C_t = \left[\gamma^{\frac{1}{\rho}} {C_t^H}^{\frac{\rho-1}{\rho}} + (1-\gamma)^{\frac{1}{\rho}} {C_t^F}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}}$$

Households choose a combination ($C^H$, $C^F$) in order to minimize their costs given the value of total consumption ($C$) and prices of domestic ($P^H$) and foreign ($P^F$) goods.

$$\min_{C^F, C^H} \left\{P^F C^F + P^H C^H\right\} \tag{1}$$

s.t.

$$C = \left[\gamma^{\frac{1}{\rho}} {C^H}^{\frac{\rho-1}{\rho}} + (1-\gamma)^{\frac{1}{\rho}} {C^F}^{\frac{\rho-1}{\rho}}\right]^{\frac{\rho}{\rho-1}} \tag{2}$$

Solving the above problem, an expression linking the relative prices of domestic and foreign goods with their quantities as well as a consumer price index are obtained.

$$\frac{C_t^H}{C_t^F} = \frac{\gamma}{1-\gamma}\left(\frac{P_t^H}{P_t^F}\right)^{-\rho} \tag{3}$$

$$P_t = \left[\gamma {P_t^H}^{1-\rho} + (1-\gamma) {P_t^F}^{1-\rho}\right]^{\frac{1}{1-\rho}} \tag{4}$$

### *2.1.2. Household optimization problem*

Household behavior is modeled in a standard fashion common in most DSGE models. Households earn labour income ($W$) and real dividends from retailer's profits ($\Pi$). They also consume ($C$), pay lump-sum taxes in real terms ($T$), hold cash balances ($M$) and save within financial intermediaries in local ($B$) and in foreign ($B*$) currency. They receive interest ($i,i*$) on their local and foreign currency savings respectively.

The allocation mechanism between savings in domestic ($B$) and foreign ($B*$) currency deserves further clarification. In *Gertler et al.* (2001, 2003) savings in domestic currency are in fact corporate bond purchases. $B$ is the result of investment decisions of entrepreneurs and their net worth. Households are indifferent between saving in domestic and foreign currency as the return of these alternative investments is the same (due to the uncovered interest parity condition (UIP)). Consequently, $B*$ is a residual of saving decisions of households and bonds B issued by corporate entrepreneurs.

The saving setup described above differs substantially from the common practice in Bulgaria. However, slight modification of $B$ and $B*$ interpretation brings the model setup close to the Bulgarian case. Following Bernanke et al. (1998), households save exclusively in financial intermediaries (banks). Total savings are $B + SB*$ and under fixed exchange rate we calibrate $S_t = 1$ for $\forall t$. Now $B$ is the part of savings channeled to corporate sector by banks, while $B*$ is private saving (borrowing) that banks channel (borrow from) abroad.

Households maximize their discounted utility. The within-period utility depends on consumption ($C$), cash holdings in real terms ($\frac{M}{P}$) and leisure $(1 - L)$.

$$max_{C,L,M,B,B^*} \left\{ \mathbb{E}_t \sum_{i=0}^{\infty} \beta^i \left[ \log(C_{t+i} - bC_{t+i-1}) + \varphi \log \left( \frac{M_{t+i}}{P_{t+i}} \right) + \kappa \log(1 - L_{t+i}) \right] \right\} \tag{5}$$

s.t.

$$C_t = \frac{W_t}{P_t} L_t + \Pi_t - \frac{P_t^H}{P_t} T_t - \frac{M_t - M_{t-1}}{P_t} - \frac{B_{t+1} - (1 + i_{t-1})B_t}{P_t} - S_t \frac{B^*_{t+1} - (1 + i^*_{t-1})\Theta_t B^*_t}{P_t} \tag{6}$$

The within-period utility includes also lagged consumption in order to model habit formation and consumption inertia. This allows for smoother reaction of consumption in response to real interest rate changes. The interest rate on savings in foreign currency ($(1 + i^*_{t-i})\Theta_t$) depends on the net position of households ($B*$), i.e. $\Theta'(B*) < 0$ and $\Theta(\overline{B}) = 1$, where $\overline{B}*$ is the steady-state value of savings in foreign currency and $\Theta$ is the country risk premium. Consequently, if $B^*_t < \overline{B}*$, the interest rate on savings in foreign currency will exceed the risk-free international interest rate $(1 + i^*_{t-1})$. The functional form follows *Iordanov and Vassilev* (2008) ($\psi^R = 0.04\%$)

$$\Theta_t = \Theta({B_t}^*) = \psi^R \left( \exp\left( -\frac{B_t^* - \overline{B}^*}{P_t^H Y_t} \right) - 1 \right) + 1 \tag{7}$$

Including small risk premium linked to the external position of the economy is a necessary condition to ensure stationary external position of the economy. In the absence of such a condition, the exogenous shocks will cause net external assets (liabilities) to exhibit random walk property (*Schmitt-Grohe and Uribe* (2003)). This risk premium vanishes in the steady state and the elasticity to deviations of external position from steady-state is small, so this friction does not affect the short-term dynamics of the system.

#### *2.1.3. First Order Conditions Maximizing Discounted Household Utility*

The equations maximizing (5) s.t. (6) are:

- Labour supply

$$\lambda_t \frac{W_t}{P_t} = \kappa \frac{1}{1 - L_t} \tag{8}$$

- Consumption and saving

$$\lambda_t = \beta \mathbb{E}_t \left\{ \lambda_{t+1} (1 + i_t) \frac{P_t}{P_{t+1}} \right\} \tag{9}$$

$$\mathbb{E}_t \left\{ \lambda_{t+1} \frac{P_t}{P_{t+1}} \left[ (1 + i_t) - \Theta_t (1 + i_t^*) \frac{S_{t+1}}{S_t} \right] \right\} = 0 \tag{10}$$

$$\lambda_t = \frac{1}{C_t - bC_{t-1}} - \beta \frac{b}{C_{t+1} - bC_t} \tag{11}$$

- Cash balances

$$\lambda_t \left( \frac{M_t}{P_t} \right) \left( 1 - \frac{1}{1 + i_t} \right) = \varphi \tag{12}$$

Equations (8)–(12) together with the budget constraint (6) describe the solution of household optimization problem.

### *2.2. External Sector*

The external sector is exogenous. International nominal interest rate $(1 + i^*_t)$ is determined outside the model. For the purpose of stochastic simulations international nominal interest rate is modeled as AR(1) stationary process.

$$\log(1+i_t^*) - \log(1+\overline{i^*}) = \rho^R(\log(1+i_{t-1}^*) - \log(1+\overline{i^*})) + e_t^R, \quad (13)$$

where $\rho^R = 0.95$ и $e^R \sim N(0, \sigma_R^2)$.

The price of foreign goods in foreign currency ($P_t^{F*}$) translates to price in domestic currency ($P_t^F$) obeying the law of one price.

$P_t^F = S_t P_t^{F*}$

Analogously, the law of one price transforms the price of domestically produced goods to price of exports in foreign currency.

$P_t^H = S_t P_t^{H*}$

We set $P_t^{F*} = 1$ and $S_t = 1$ for $\forall t$. In steady state the terms of trade are calibrated at unity $\frac{\overline{P}^F}{\overline{P}^H} = 1$.

External demand for domestically produced goods depends on the world output ($Y_t^*$) and the price of exported goods ($P_t^{H*}$) relative to international price level ($P_t^*$).

$$C_t^{H*} = \left(\frac{P_t^{H*}}{P_t^*}\right)^{-\varepsilon} Y_t^* \quad (14)$$

The downward sloping demand schedule can be derived by analogy from the equation of domestic demand the retailers are facing (see 2.3.3). The assumption of small open economy allows the international price level and level of output to be independent on domestic prices and output.

## *2.3. Firms*

### *2.3.1. Capital Producers*

Capital producers operate under perfect competition. Capital production involves adjustment costs apart from purchases of domestic and foreign goods. Inclusion of adjustment costs is motivated by two reasons. First, they add inertia to the dynamics of capital formation. Second, they create variation in the price of capital induced by variation in investment. Similarly to the consumption index, the index of total investment combines goods produced domestically and imported from abroad.

$$I_t = \left[(\gamma_I)^{\frac{1}{\rho_I}} I_t^{H^{\frac{\rho_I-1}{\rho_I}}} + (1-\gamma_I)^{\frac{1}{\rho_I}} I_t^{F^{\frac{\rho_I-1}{\rho_I}}}\right]^{\frac{\rho_I}{\rho_I-1}} \quad (15)$$

By analogy to consumption (3) and consumer price index (4) a link between relative prices and quantities of domestic and imported goods is obtained.

$$\frac{I_t^H}{I_t^F} = \frac{\gamma_I}{1-\gamma_I}\left(\frac{P_t^H}{P_t^F}\right)^{-\rho_I} \tag{16}$$

$$P_{I,t} = \left[\gamma_I P_t^{H^{1-\rho_I}} + (1-\gamma_I) P_t^{F^{1-\rho_I}}\right]^{\frac{1}{1-\rho_I}} \tag{17}$$

Capital production technology is described by the following expression

$$\Phi\left(\frac{I_t}{K_t}\right) K_t = K_{t+1} - (1-\delta)K_t \tag{18}$$

$$\Phi'(\cdot) > 0, \Phi''(\cdot) < 0, \Phi(0) = 0$$

The nominal profit realized by capital producers is

$$Q_t \Phi\left(\frac{I_t}{K_t}\right) K_t - P_{I,t} I_t - P_t r_t^I K_t, \tag{19}$$

where Q is the price of capital.

Capital producers maximize their profit with respect to I, deciding one period in advance. The first order necessary condition with respect to I induces positive relation between investment and price of capital.

$$\mathbb{E}_{t-1}\left\{\frac{Q_t}{P_{I,t}} - \left[\frac{1}{\Phi'\left(\frac{I_t}{K_t}\right)}\right]\right\} = 0 \tag{20}$$

#### *2.3.2. Entrepreneurs, Financing and Production of Wholesale Goods*

The entrepreneurs produce wholesale goods under perfect competition, combining the factors of production – labour ($L$) and capital ($K$) – by Cobb – Douglas production function.

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}, \tag{21}$$

where

$$\log(A_t) - \log(\overline{A}) = \rho^A(\log(A_{t-1}) - \log(\overline{A})) + e_t^A, \tag{22}$$

$\rho^A = 0.95$ , $e^A \sim N(0, \sigma_A^2)$.

Entrepreneurs employ labour to equate the marginal productivity and the average wage ($W$)

$$(1-\alpha)\frac{Y_t}{L_t} = \frac{W_t}{P_t^{\omega}}, \tag{23}$$

where $P^{\omega}$ is the wholesale price.

The above equation is derived from maximizing the expression for entrepreneurial gross operating profit $A_t K_t^{\alpha} L_t^{1-\alpha} - \frac{W_t}{P_t^{\omega}} L_t$ with respect to $L$.

Entrepreneurs purchase capital using their own funds in real terms ($N$) and borrowing ($B$). The budget constraint for capital accumulation takes the form of

$$\frac{Q_t}{P_t} K_{t+1} = N_{t+1} + \frac{B_{t+1}}{P_t}. \tag{24}$$

At the end of each period the entrepreneur purchases the capital necessary for production in the next period. The price of capital is the current price. Entrepreneurs are risk neutral, meaning that the decisions are based on the expected values ignoring the uncertainty around them. The entrepreneurial income in real terms ($GY$) comes from three distinct sources:

- Production of wholesale goods ($\frac{P_t^{\omega}}{P_t} Y_t$)
- Current value of capital after depreciation δ

  ($\frac{Q_t}{P_t}(1-\delta)K_t$)

- Rent paid by capital producers for using the existing capital to produce new capital ($r_t^I K_t$).

The rent equals the marginal productivity of existing capital in the production of new capital: $r_t^I = \frac{Q_t}{P_t}\left(\Phi\left(\frac{I_t}{K_t}\right) - \Phi'\left(\frac{I_t}{K_t}\right)\frac{I_t}{K_t}\right)$. The RHS of this expression is obtained by first differencing (19) with respect to $K$.

$$GY_t = \frac{P_t^{\omega}}{P_t} Y_t + \frac{Q_t}{P_t}(1-\delta)K_t + r_t^I K_t \tag{25}$$

The expected return on capital $\{1 + r_{t+1}^{k}\}$ equals total revenues minus labour costs, divided by the capital in previous period prices.

$$\mathbb{E}_t\left\{1 + r_{t+1}^k\right\} = \mathbb{E}_t\left\{\frac{GY_{t+1} - \frac{W_{t+1}}{P_{t+1}} L_{t+1}}{\frac{Q_t}{P_t} K_{t+1}}\right\} \tag{26}$$

After substituting (23) and (25) in (26) we obtain

$$\mathbb{E}_t\left\{1 + r_{t+1}^k\right\} = \mathbb{E}_t\left\{\frac{\frac{P_{t+1}^{\omega}}{P_{t+1}}\alpha\frac{Y_{t+1}}{K_{t+1}} + (1-\delta)\frac{Q_{t+1}}{P_{t+1}} + r_{t+1}^I}{\frac{Q_t}{P_t}}\right\} \tag{27}$$

The purchase of capital is partially financed by external funds. The risk premium between the expected return and the economy-wide free interest rate depends on how heavily the firm is leveraged.

$$\mathbb{E}_t\left\{1+r_{t+1}^k\right\} = (1+\chi(\cdot))\,\mathbb{E}_t\left\{(1+i_t)\,\frac{P_t}{P_{t+1}}\right\} \tag{28}$$

$$\chi_t(\cdot) = \chi\left(\frac{Q_t K_{t+1}}{P_t N_{t+1}}\right)$$

$$\chi_t'(\cdot) > 0, \chi(0) = 0, \chi(\infty) = \infty$$

After the entrepreneur has put the factors into production, an idiosyncratic shock (ω) on the return is realized and wholesale goods are produced. In case the return has been sufficiently high the debt is repayed. Otherwise the entrepreneur declares bankruptcy. In order to repay the debt, the entrepreneur can sell the firm's capital. The remaining part is the net worth of the firm:

$$V_t = \left(1+r_t^k\right)\frac{Q_{t-1}}{P_{t-1}}K_t - \left[(1+\chi(\cdot))\left\{(1+i_{t-1})\,\frac{P_{t-1}}{P_t}\right\}\right]\frac{B_t}{P_{t-1}} \tag{29}$$

To avoid the possibility of entrepreneurs accumulating more net worth ($V$ and $N$) than the capital necessary for production and become net savers, a constant exogenous death rate ($\phi$) is introduced. This makes the planning horizon finite with expected value of $\frac{1}{1-\phi}$. The number of entrepreneurs is also constant as in every period the number of newly created firms matches that of firms exiting the market. Those who cease to operate make a small transfer ($D$) to the new firms. The rest of the net worth of exiting firms is consumed ($C^e$). The small transfer is necessary to ensure that newcomers possess at least a small amount of start-up capital, so that the interest rate they pay does not tend to infinity.

$$N_{t+1} = \phi V_t + (1-\phi)D_t \tag{30}$$

$$C_t^e = (1-\phi)\,(V_t - D_t)\,\frac{P_t}{P_t^H} \tag{31}$$

### *2.3.3. Retail Sector*

Retailers are presented as a continuum $\zeta \in [0,1]$. They purchase wholesale goods from entrepreneurs and resell them to households, capital producers and government. Retailers costlessly differentiate the goods and in doing so they gain certain market power. The main reason for including retail sector is to obtain inflation inertia through Calvo pricing. The aggregated volume ($Y$) and price of retail goods ($P^H$) take the following form

$$Y_t = \left[ \int_0^1 Y_t(\zeta)^{\frac{\vartheta-1}{\vartheta}} \, d\zeta \right]^{\frac{\vartheta}{\vartheta-1}}$$

$$P_t^H = \left[ \int_0^1 P_t^H(\zeta)^{1-\vartheta} \, d\zeta \right]^{\frac{1}{\vartheta-1}} \tag{32}$$

Consumers attempt to minimize their costs given the prices for each differentiated good.

$$\min_{Y_t(\zeta)} \int_0^1 P_t^H(\zeta) Y_t(\zeta) \, d\zeta$$

s.t.

$$Y_t = \left[ \int_0^1 Y_t(\zeta)^{\frac{\vartheta-1}{\vartheta}} \, d\zeta \right]^{\frac{\vartheta}{\vartheta-1}}$$

Solving the problem above downward sloping demand schedule facing each retailer is obtained.

$$Y_t(\zeta) = \left( \frac{P_t^H(\zeta)}{P_t^H} \right)^{-\vartheta} Y_t \tag{33}$$

In each period a fraction of randomly selected retailers $(1 - \theta)$ are given the opportunity to set up a new price $(P^{*H}(\zeta))$ and face demand $(Y^{*}(\zeta))$ for the current period and possibly for some periods ahead if they don't happen to update their prices again. By symmetry, all firms that are able to change their price choose the same level $(P^{*H})$ and face the same demand $(Y^{*})$. Then the overall price level is

$$P_t^H = \left[ \theta P_{t-1}^{H\,1-\vartheta} + (1-\theta) P_t^{*H\,1-\vartheta} \right]^{\frac{1}{1-\vartheta}}$$

or

$$P_t^{H\,1-\vartheta} = \left[ \theta P_{t-1}^{H\,1-\vartheta} + (1-\theta) P_t^{*H\,1-\vartheta} \right]$$

In order to obtain a Philips curve, the approach described in *Uhlig* (1995) is used. Around the steady state the above equation can be written as

$$P_t^H = \left( P_{t-1}^H \right)^{\theta} \left( P_t^{*H} \right)^{1-\theta} \tag{34}$$

Retailers that are able to change their prices set the price level optimally to maximize the discounted profits, weighted by the probability $(\theta)$ for the price to remain the same for the period.

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left[ \Lambda_{t,k} \frac{P_t^{*H} - P_{t+k}^{\omega}}{P_{t+k}} Y_{t+k}^* \right], \tag{35}$$

where $\Lambda_{t,k} = \beta^k \frac{\lambda_{t+k}}{\lambda_t}$ is the discount factor. The first order condition for maximizing the above expression with respect to $P^{*H}$ after substituting (33) into (35) is

$$\sum_{k=0}^{\infty} \theta^k \mathbb{E}_{t-1} \left\{ \Lambda_{t,k} \left( \frac{P_t^{*H}}{P_{t+k}^H} \right)^{-\vartheta} Y_{t+k}^* \left[ \frac{P_t^{*H}}{P_{t+k}} - \left( \frac{\vartheta}{\vartheta - 1} \right) \frac{P_{t+k}^{\omega}}{P_{t+k}} \right] \right\} = 0 \tag{36}$$

Log-linearizing around the steady state, the optimal price takes the form of

$$P_t^{*H} = \mu \prod_{i=0}^{\infty} \left( P_{t+i}^{\omega} \right)^{(1-\beta\theta)(\beta\theta)^i}, \text{ where } \mu = \frac{1}{1-1/\vartheta}.$$

Taking the ratio $\frac{P_t^H}{P_{t-1}^H} \left( \frac{P_{t+1}^H}{P_t^H} \right)^{-\beta}$ and substituting the previous equation and (34) into it, one obtains the Philips curve

$$\frac{P_t^H}{P_{t-1}^H} = \left( \mu \frac{P_t^{\omega}}{P_t^H} \right)^{\frac{(1-\theta)(1-\beta\theta)}{\theta}} \left( \frac{P_{t+1}^H}{P_t^H} \right)^{\beta} \tag{37}$$

The markup $\frac{P_t^{\omega}}{P_t^H}$ varies with the gap between the current demand and the steady-state levels. The mechanism is as follows. When retailers that are not able to change consumer prices face higher demand, they respond by increasing purchases of wholesale goods from entrepreneurs. That bids-up the producer prices and because retailers hold their prices fixed, the mark-up shrinks. The same logic applies when demand is lower than steady-state values.

### *2.4. Fiscal and Monetary Authorities*

The approach to modeling public policy is substantially different from the approach taken in *Gertler et al.* (2001, 2003).

The monetary authority follows the principles of CBA. As already mentioned at the beginning of Section 2, according to the CBA setup, International Reserves should fully cover the currency in circulation and the fiscal reserve within the central bank.

$$S_t F_t^* = M_t + \Upsilon_t, \tag{38}$$

where $F_t^*$ represents official foreign reserves within the central bank and $\Upsilon$ stands for government fiscal reserves.

The fiscal sector is extended. This extension seems natural, because in the absence of an active monetary policy, the fiscal policy becomes the main economic policy instrument. For reference, in the *Gertler et al.* (2001, 2003) model the government is not able to accumulate either reserves or debt. Expenditures are exogenous and revenues are adjusted to comply with the monetary policy rule. In the current model the government accumulates fiscal reserves ($\Upsilon$) and receives interest payments from the monetary authority depending on the international interest rate. Tax revenues are proportionate to output ($\overline{T}$ – fixed ratio of taxes to GDP).

$$P_t^H T_t = \overline{T} P_t^H Y_t \tag{39}$$

Government expenditure ($G^H$) follows a simple rule and is used for purchasing domestic goods only. Two types of simple rules are investigated in the model simulations below. First, the government aims at maintaining its reserves within the central bank constant by targeting balanced budget. This policy rule is rather passive and resembles the one in *Gertler et al.* (2001, 2003). In the second case, the government attempts to stabilize the economy by minimizing the gap between the actual and steady-state values of output and domestic inflation ($\pi^d$). Specifically, the (weighted) sum of the variances of output and domestic inflation is minimized. Currently equal weights are assigned to the volatility of output and inflation. The simple rule specifies that the deviation of government expenditures from steady-state responds linearly to the deviations from steady-state of lagged output, lagged domestic inflation and lagged price of capital. To ensure stability of fiscal reserve, government spending reacts to the lagged values of fiscal reserve to output ratio (small letters indicate deviations from steady-state). The optimization problem is as follows:

$$\min_{\rho_Y, \rho_P, \rho_Q, \rho_\Upsilon} \left[\sigma_Y + \sigma_\pi^d\right]$$

s.t.

$$g_t^H = \rho_Y y_{t-1} + \rho_P \pi_{t-1}^d + \rho_Q q_{t-1} + \rho_\Upsilon (\upsilon_{t-1} - y_{t-1} - p_{t-1}^H) \tag{40}$$

Coefficients $\rho_Y$, $\rho_P$, $\rho_Q$ and $\rho_\Upsilon$ are chosen optimally to minimize the sum of the variances of output and domestic inflation.

The budget constraint of the government states that the central bank's profits are transferred directly to the government.

$$\Upsilon_t = \left(1 + i_{t-1}^*\right) \Upsilon_{t-1} + i_{t-1}^* M_{t-1} + P_t^H T_t - P_t^H G_t^H. \tag{41}$$

### 2.5. Supply, Demand and Market Equilibrium

Real output is given by the following equation

$$Y_t = C_t^H + C_t^e + C_t^{H*} + I_t^H + G_t^H \tag{42}$$

In the program code the last equation substitutes the household budget constraint. The equilibrium is obtained when $Y$ from (42) equals $Y$ from (21) by changing the overall price index ($P_t^H$).

## 3. Model Parametrization

In the parametrization exercise we try to uncover the parameters that matter for the steady state by matching the values of financial and real observables for the last few years. For the other parameters we either assume the same values as in *Gertler et al.* (2001, 2003), or shift the parameter values to better reflect the specifics of Bulgarian economy.

Leverage ratio $\frac{QK}{N}$ is calibrated at 1.75 according to the *YB* (2007). In order to ensure that steady state exists the discount factor of households (β) must equal $(1 + \bar{i})^{-1}$. Calibrating β = 0.987, implies that the economy-wide interest rate is 5.4% (because in the steady state the price level is constant, real and nominal interest rates coincide). The reported deposit rate for households is 4.9% for 2008 according to BNB statistics. The steady state value is chosen relatively high in order to reflect country risk and more cautious international financial markets.

The return on capital is 10% (according to firms' balance sheet data for 2007 (*YB* (2007)). The calibrated value is comparatively high which helps to obtain lower ratio of capital to quarterly output (around 4:1). The bankruptcy costs are calibrated at higher levels following *Carlstrom and Fuerst* (1996) ($\mu = 0.2$ in the current model, opposed to $\mu = 0.12$ in *Gertler et al.* (2001, 2003)). As a residual, we obtain the interest rate on loans to firms at 6.7%. Under the current parametrization the NPL is set at 4.4% while 2008 values are 2.4%. The reported values differ from the calibrated ones. One reason would be that in the recent years the economic conditions were generally benign and the reported NPL level might be below the long-term values. Furthermore, the model setup allows for one-period loan contracts only while in the data long-term contacts are most common and a loan is classified as non-performing if the payment is delayed for 90 days. Higher spreads combined with low NPL levels and high return in the banking sector indicate that profits in the sector are above those implied by the perfect competition assumption. The current parametrization also suggests higher uncertainty in the individual return on capital $\log(\omega) \sim N(-(1/2)\sigma^2, \sigma^2)$, $\sigma = 0.35$.

The capital income share is calibrated at 30% – considerably lower than the reported figures but close to the commonly used values in other DSGE models. It is reasonable to assume that currently labour share in Bulgaria is lower than the marginal productivity of labour. This suggests using the commonly used value rather than the reported figure.

Depreciation rate is chosen at 3.5% and is higher than the reported figures (2.2%). This helps to reach higher ratio of investment to GDP of 14% (during the period 1998–2005 the value is 18%). Higher depreciation rate also reflects necessary upgrades in the obsolete productive capacity.

The share of imported investment goods is set at 40% following the data from Input Output Tables (2005).

The price of capital elasticity with respect to the level of investment is calibrated at lower levels than that in *Gertler et al.* (2001, 2003). The reason is that in countries with underdeveloped capital markets the value of the firm does not vary that much with the investment levels. The calibrated value better reflects the volatility and autocorrelation of investment and the correlation between investment and output found in the data for the previous years.

The retail margin over the wholesale price is set at 25%.

The share of imported consumption goods to GDP is set at $\frac{C^F}{Y} = 0.2$. For 2007 and 2008 the ratio is around 13%.

Government consumption is set at 30% of GDP as a compromise between the SNA data of around 20% (accrual basis) and fiscal reporting data of around 40% (cash basis). The level of international reserves to GDP is 64% according to international investment position data.

The ratio of foreign debt to GDP is $-\frac{\overline{B}^*}{\overline{Y}} = 1.$

## 4. Model Simulation

Two shocks to the model economy are considered – an increase in the international interest rate and a fall in total factor productivity. The shocks follow $AR(1)$ stationary process. The innovations are distributed normally $N(0,\sigma^2)$, $\sigma = 0.01$. The discussion of the simulation results concentrates on three issues:

- comment on the transitional dynamics of some variables and the linkages accounting for them;
- highlighting the role of financial accelerator in the model;
- comparison between the dynamics in response to shocks under different simple fiscal policy rules.

Following *Gertler et al.* (2001, 2003) and *Bernanke et al.* (1998), we isolate the role of financial accelerator by fixing the risk premium on its steady-state levels and the simulations are not affected by the financial position of the entrepreneurs. The distance between the two trajectories – with and without financial accelerator – gives a measure of financial accelerator effect for the Bulgarian economy.

### *4.1. Increase in International Interest Rate*

The AR(1) coefficient is 0.95. Higher interest rates eventually lead to lower GDP and the main contributing factor is lower investment. At the beginning inflation drops dramatically to equate supply and demand. After that, inflation gradually picks up and temporarily stays above the steady-state level. The mechanism leading to these dynamics is explained below (see Appendix 2, Figure 1).

In the first period international interest rate increases and leads to higher domestic nominal interest rate (due to the UIP). Price rigidity helps real interest rate to increase as well. Higher real interest rate stimulates household saving $B + B^*$ and lowers current in favor of future consumption (habit formation partially dampens the response). Imported goods drop more than domestic ones because their relative prices increase. Exports increase driven by relative price changes as well. Lower prices and higher interest rates cause a drop in return on capital and lower net worth of entrepreneurs. To prevent further increase in risk premium because of higher leverage, firms curb external financing and investment. This in turn brings down the price of capital which further diminishes firms' net worth and investment. This negative self-propelling mechanism gradually dies out as some firms exit the market, replaced by new entrants.

Labour income follows the downward path of nominal output but recovers more quickly due to the lower average wages. Lower labour income constrains consumption below steady-state throughout the simulated period.

Under fixed exchange rate inflation necessarily picks up above steady-state levels after initial sharp drop. This pattern is necessary to bring relative prices and exports/imports to their steady-state levels.

Under the simplest baseline fiscal policy rule, similar to *Gertler et al.* (2001, 2003), the government levies taxes proportional to output and aims at constant fiscal reserves by changing government consumption. This pattern implies targeting balanced budget in every period. Apart from tax revenues, interest rate income is generated by holding fiscal reserve within the central bank. In real terms this income increases because it is negotiated in nominal terms and prices fall below steady-state levels while international interest rates appreciate throughout the period.

Money demand shrinks as return on deposits increases and prices and demand decrease. $B$ and $B^*$ have opposite dynamics. As savings increase and demand for external financing by entrepreneurs decreases, banks channel the excess savings abroad.

The response is more pronounced and prolonged because of the financial accelerator mechanism. However, compared to the role of financial accelerator in *Gertler et al.* (2001, 2003), the difference is not so pronounced (see Appendix 2, Figure 1). The reason is the lower elasticity of price of capital to investment and the lower leverage ratio.

As an alternative to the simplest fiscal policy rule aiming at constant fiscal reserves, a simple optimal fiscal policy rule is found. It specifies that government consumption reacts to GDP, domestic inflation and lagged price of capital in order to minimize the deviation of output and inflation form their steady state values.

The coefficients of reaction in (40) are $\rho_Y = -0.44$, $\rho_P = -0.43$ and $\rho_Q = -1.32$ respectively. In the second period government consumption rises almost entirely compensating for the drop in investment (see Appendix 2, Figure 2). After that government consumption drops fast to its steady-state levels and even below in response to inflationary pressures and the mitigated drop in real output. To ensure that fiscal reserve returns to steady-state, government spending reacts to fiscal reserve changes. The coefficient is $\rho_\Upsilon = 0.29$ and the fiscal reserve returns to its steady state in approximately 20 periods (4 years).

### *4.2. Negative Total Factor Productivity Shock*

Again, the $AR(1)$ coefficient is 0.95. The mechanism that drives the dynamics of the model is described below (see Appendix 2, Figure 3).

Higher domestic prices worsen the competitive position of exports, suppressing exports below steady-state throughout the entire simulation period. Demand for production factors increases to compensate for lower productivity. However, higher prices reduce real wages below steady-state. Household consumption does not respond to the temporary increase in wages as consumption depends on the discounted value of all future real income. The transitional dynamics of household consumption has a U-shape as inflation initially brings real interest rate down, postponing savings for later periods. After inflation abates, consumption starts to increase on a chain basis, driven by the changes in real interest rate.

Investment dynamics is determined by the demand for capital and its return. In the first period the return on capital increases as the price of capital increases in response to intensified demand for production factors in period two. The financial position of entrepreneurs also improves because of the higher price of capital and lower real interest rate (higher inflation). The better financial position lowers the risk premium and further stimulates investment.

Allowing for optimal fiscal simple rule affects the performance of the economy only marginally (see Appendix 2, Figure 4). The relative ineffectiveness of fiscal policy in offsetting the negative productivity shock is a well-documented fact (see *Batini et al.* (2009)). It stems from the two conflicting tasks – drop in real output and higher relative domestic prices.

## 5. Conclusion and Directions for Future Work

The results presented above suggest that the current model structure and dynamics is rich enough to analyze the developments in the real economy and the financial sector. The chosen parametrization relevant for Bulgaria assigns moderate role to financial accelerator mechanism. The government is able to counteract a positive shock to international interest rate. The inclusion of price of capital in the optimal rule improves the results. On the other hand, fiscal policy hardly offsets a negative productivity shock.

During parametrization several problems were encountered – the capital to GDP ratio is too high, while investment is much lower than the reported figures. Conversely, the default rates are too high compared to the data. Calibrating positive external debt in the steady state suggests positive external balance which does not conform with the empirical evidence for Bulgaria in the recent years. This prompts to the fact that current values of trade deficits are away from the steady-state values. The directions for future work are derived from these problems:

- better parametrization to meet the data;
- adding additional shocks (to external financing premia, for example);
- structural changes in the model – adding stable growth path properties, adding labour market rigidities to disentangle the marginal labour productivity from average wage, including FDI flows to finance part of the current account;
- formulating alternative financial sector market structure to account for the higher concentration and higher profit margins.

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# Dynare Code

The equations included in the *Dynare* code are shown below.

- Demand

$$Y_t = C_t^H + C_t^e + C_t^{H*} + I_t^H + G_t^H \tag{42}$$

$$\lambda_t = \frac{1}{C_t - bC_{t-1}} - \beta \frac{b}{C_{t+1} - bC_t} \tag{11}$$

$$\lambda_t = \beta \mathbb{E}_t \left\{ \lambda_{t+1}(1+i_t) \frac{P_t}{P_{t+1}} \right\} \tag{9}$$

$$C = \left[ \gamma^{\frac{1}{\rho}} C^{H^{\frac{\rho-1}{\rho}}} + (1-\gamma)^{\frac{1}{\rho}} C^{F^{\frac{\rho-1}{\rho}}} \right]^{\frac{\rho}{\rho-1}} \tag{2}$$

$$\frac{C_t^H}{C_t^F} = \frac{\gamma}{1-\gamma} \left( \frac{P_t^H}{P_t^F} \right)^{-\rho} \tag{3}$$

$$P_t = \left[ \gamma P_t^{H^{1-\rho}} + (1-\gamma) P_t^{F^{1-\rho}} \right]^{\frac{1}{1-\rho}} \tag{4}$$

$$C_t^{H^*} = \left( \frac{P_t^{H^*}}{P_t^*} \right)^{-\varepsilon} Y_t^* \tag{14}$$

$$I_t = \left[ (\gamma_I)^{\frac{1}{\rho_I}} I_t^{H^{\frac{\rho_I-1}{\rho_I}}} + (1-\gamma_I)^{\frac{1}{\rho_I}} I_t^{F^{\frac{\rho_I-1}{\rho_I}}} \right]^{\frac{\rho_I}{\rho_I-1}} \tag{15}$$

$$\frac{I_t^H}{I_t^F} = \frac{\gamma_I}{1-\gamma_I} \left( \frac{P_t^H}{P_t^F} \right)^{-\rho_I} \tag{16}$$

$$P_{I,t} = \left[ \gamma_I P_t^{H^{1-\rho_I}} + (1-\gamma_I) P_t^{F^{1-\rho_I}} \right]^{\frac{1}{1-\rho_I}} \tag{17}$$

$$C_t^e = (1-\phi)\,(V_t - D_t)\, \frac{P_t}{P_t^H} \tag{31}$$

$$g_t^H = \rho_Y y_{t-1} + \rho_P \pi_{t-1}^d + \rho_Q q_{t-1} + \rho_\Upsilon (\upsilon_{t-1} - y_{t-1} - p_{t-1}^H) \qquad [40]$$

$$\lambda_t \left(\frac{M_t}{P_t}\right)\left(1 - \frac{1}{1+i_t}\right) = \varphi \qquad [12]$$

$$(1-\alpha)\frac{Y_t}{L_t} = \frac{W_t}{P_t^\omega} \qquad [23]$$

$$\mathbb{E}_t \left\{1 + r_{t+1}^k\right\} = \mathbb{E}_t \left\{ \frac{\frac{P_{t+1}^\omega}{P_{t+1}} \alpha \frac{Y_{t+1}}{K_{t+1}} + (1-\delta)\frac{Q_{t+1}}{P_{t+1}} + r_{t+1}^I}{\frac{Q_t}{P_t}} \right\} \qquad [27]$$

- Supply

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha} \qquad [21]$$

$$\lambda_t \frac{W_t}{P_t} = \kappa \frac{1}{1-L_t} \qquad [8]$$

$$\mathbb{E}_t \left\{1 + r_{t+1}^k\right\} = (1 + \chi(\cdot))\, \mathbb{E}_t \left\{(1+i_t)\frac{P_t}{P_{t+1}}\right\} \qquad [28]$$

- Pricing and interest rates

$$\mathbb{E}_{t-1} \left\{ \frac{Q_t}{P_{I,t}} - \left[\Phi'\left(\frac{I_t}{K_t}\right)^{-1}\right] \right\} = 0 \qquad [20]$$

$$\frac{P_t^H}{P_{t-1}^H} = \left(\mu \frac{P_t^\omega}{P_t^H}\right)^{\frac{(1-\theta)(1-\beta\theta)}{\theta}} \left(\frac{P_{t+1}^H}{P_t^H}\right)^\beta \qquad [37]$$

$$\mathbb{E}_t \left\{ \lambda_{t+1} \frac{P_t}{P_{t+1}} \left[(1+i_t) - \Theta_t (1+i_t^*)\frac{S_{t+1}}{S_t}\right]\right\} = 0 \qquad [10]$$

$$\Theta(\overline{B}^*) = \psi^R \left(\exp\left(\frac{-B^*}{P^H Y}\right) - 1\right) + 1 \qquad [7]$$

- Budget constraints and other identities

$$\Phi\left(\frac{I_t}{K_t}\right)K_t = K_{t+1} - (1-\delta)K_t \qquad [18]$$

$$\frac{Q_t}{P_t}K_{t+1} = N_{t+1} + \frac{B_{t+1}}{P_t} \qquad [24]$$

$$V_t = \left(1+r_t^k\right)\frac{Q_{t-1}}{P_{t-1}}K_t - \left[(1+\chi(\cdot))\left\{(1+i_{t-1})\frac{P_{t-1}}{P_t}\right\}\right]\frac{B_t}{P_{t-1}} \qquad [29]$$

$$N_{t+1} = \phi V_t + (1-\phi)D_t \qquad [30]$$

$$C_t^{H^*}P_t^H - C_t^F P_t^F - P_t^F I_t^F = S_t F_t^* - \left(1+i_{t-1}^*\right)S_t F_{t-1}^* + S_t\left(B_{t+1}^* - (1+i_{t-1}^*)\Theta_t B_t^*\right) \qquad (43)$$

$$\Upsilon_t = \left(1+i_{t-1}^*\right)\Upsilon_{t-1} + i_{t-1}^* M_{t-1} + P_t^H T_t - P_t^H G_t^H \qquad [41]$$

$$P_t^H T_t = \overline{T}P_t^H Y_t \qquad [39]$$

$$S_t F_t^* = M_t + \Upsilon_t \qquad [38]$$

- External finance premium

$$k_{t+1} = \frac{Q_t K_{t+1}}{P_t N_{t+1}} \qquad (44)$$

$$k = \chi^{-1}(\cdot) \qquad (45)$$

- Exogenous shocks

$$\log(1+i_t^*) - \log(1+\overline{i^*}) = \rho^R(\log(1+i_{t-1}^*) - \log(1+\overline{i^*})) + e_t^R \qquad [13]$$

$$\log(A_t) - \log(\overline{A}) = \rho^A(\log(A_{t-1}) - \log(\overline{A})) + e_t^A \qquad [22]$$

## Transitional Dynamics of Selected Variables

The figures below present the impulse responses of key economic variables following interest rate shock and productivity shock respectively. The magnitudes of the shocks equal one standard error, declared in the model code. All variables are presented as deviations from the steady-state. The titles *Qr*, *Wr* and *Rr* are the real counterparts of the price of capital, average wage and nominal country interest rate.

Figure 1

**MODEL WITH (-) AND WITHOUT (- -) FINANCIAL ACCELERATOR – SHOCK TO INTERNATIONAL INTEREST RATE**

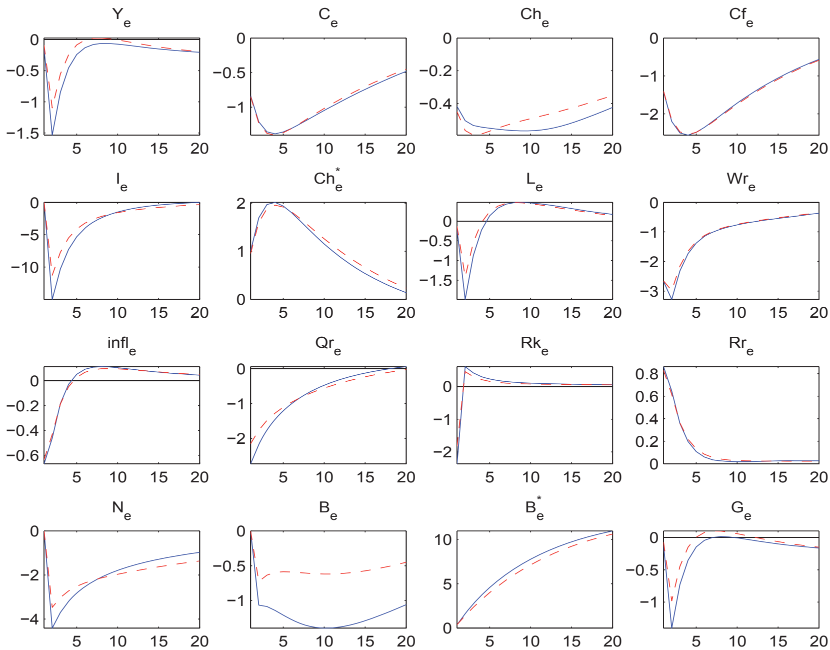


Figure 2

## MODEL WITH (- -) AND WITHOUT (-) OPTIMAL SIMPLE FISCAL POLICY RULE – SHOCK TO INTERNATIONAL INTEREST RATE

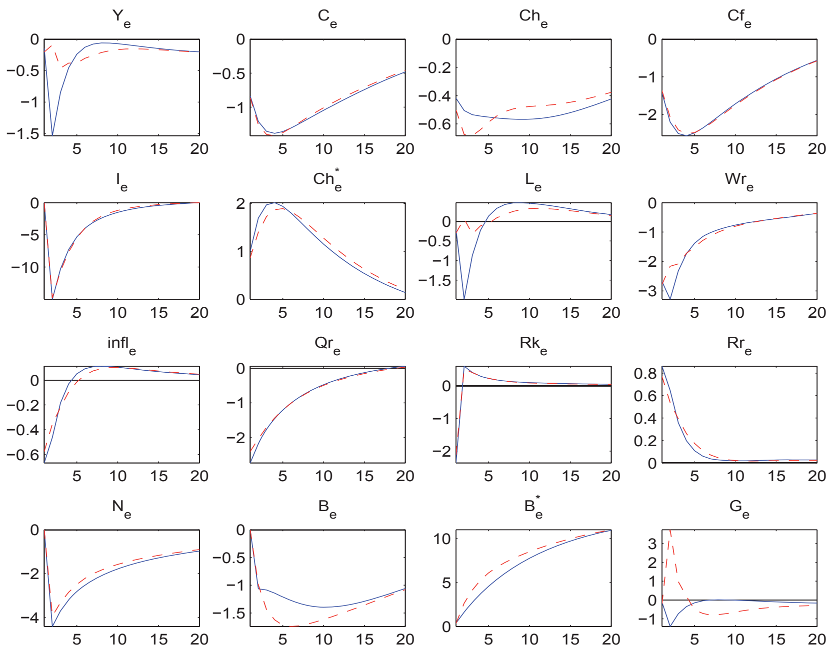


Figure 3

## MODEL WITH (-) AND WITHOUT (- -) FINANCIAL ACCELERATOR – SHOCK TO TFP

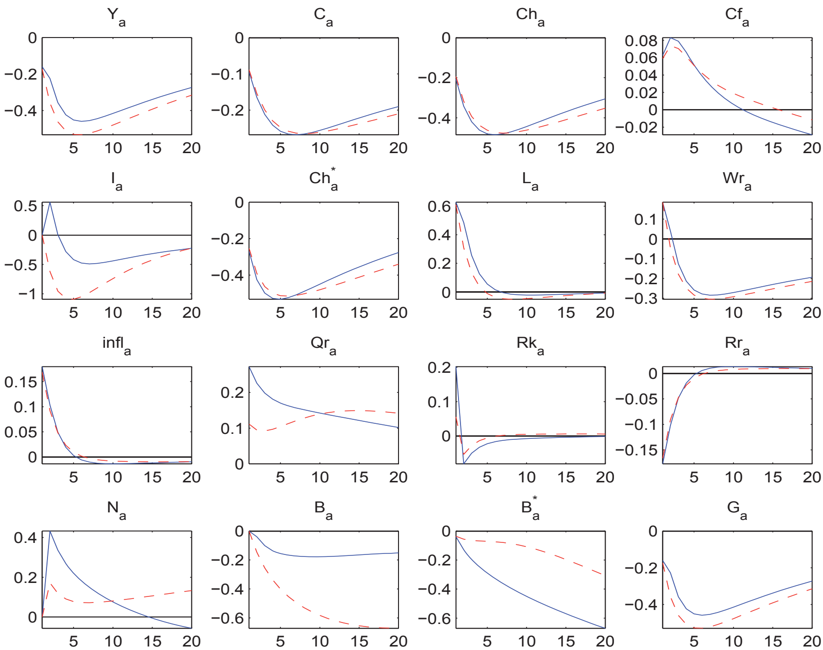
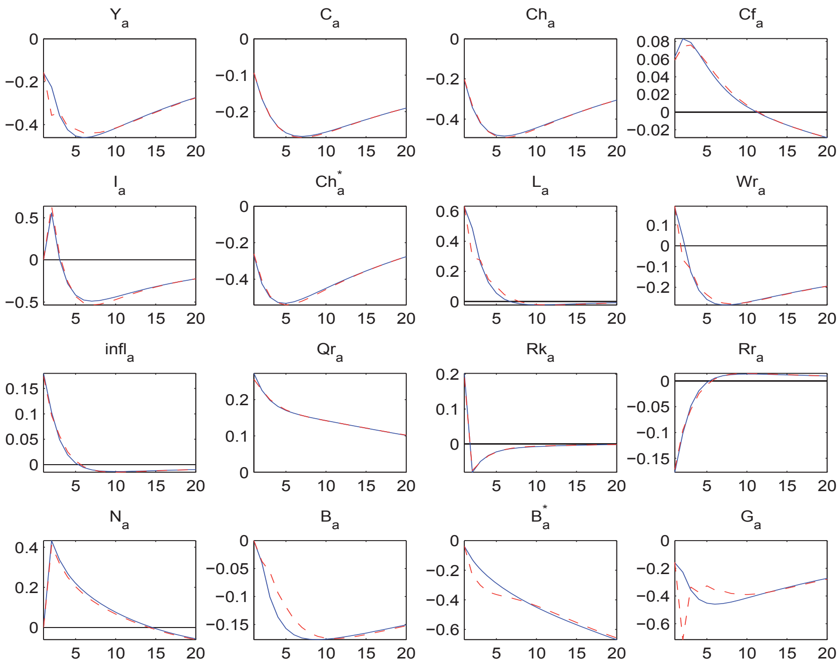


Figure 4

## MODEL WITH (- -) AND WITHOUT (-) OPTIMAL SIMPLE FISCAL POLICY RULE – SHOCK TO TFP



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