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Financial Variables in a Policy Rule: Does It Bring Macroeconomic Benefits?*

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Abstract

The main aim of this research is to find whether direct incorporation of the financial variables in the monetary policy rule can bring macroeconomic benefits in terms of lower volatility of inflation and output. This paper sheds light on the performance of the augmented Taylor rules with financial variables in a small open economy. For this purpose, a New Keynesian DSGE model with two types of financial frictions is constructed. This work provides three conclusions. First, incorporation of asset prices in the monetary policy rule can be beneficial for macroeconomic stabilisation in terms of lower implied volatilities of inflation and output in the response to certain domestic shocks. Second, the usefulness of the augmented monetary policy rule with asset prices deteriorates in case of the shocks originating abroad. The most favourable results as a response to foreign shocks delivers the rule accounting for movements in inflation and output, since this rule can accommodate foreign first-round effects. Third, when all shocks are set to be operative, the best performance delivers the rule accounting for movements in output.

1. Introduction

This research paper aims to compare the performance of the alternative monetary policy rules augmented with selected variables in a small open economy setting. Specifically, the monetary rules with output, the credit-to-GDP ratio, and asset prices are investigated. A version of a small open economy model based on Brzoza-Brzezina and Makarski (2011) with the banking sector modelled in line with Gambacorta and Signoretti (2014) is introduced to compare the performance of the rules in terms of implied volatilities of output and inflation.

The rule describing the setting of the policy interest rate has been described in the prominent research paper Taylor (1993). Since then, a considerable amount of research has been devoted to the augmented Taylor rules and their implications for economic policy. For example, Ho and McCauley (2003) or Mohanty and Klau (2004) document that the policy function extended by the exchange rate brings substantial benefits for emerging markets since this type of economies is significantly dependent on the movements in the exchange rates. Batini, Harrison, and Millard (2003) show that reacting to the movements in the exchange rates can be important; however, the weight assigned to the exchange rate should be substantially smaller than the weights placed on inflation and output. Moreover, a particular focus has been devoted to the mere form of the Taylor rule – Batini and Haldane (1998) elaborate on the original

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ideas of the Taylor rule and they construct and evaluate the simple forward-looking policy rules which include expected inflation – so-called inflation-forecast-based rules.

The recent financial crisis has shown that financial side of the economy plays a substantial role in macroeconomic fluctuations and that any turmoil in this sector causes significant problems in the real side of the economy as well. Therefore, various financial variables (such as asset prices or credit volume) have become the natural candidates for monitoring and the performance of the monetary policy rules augmented with financial variables become a subject of investigation. For example, Aydin and Volkan (2011) demonstrate that reacting to the movements in the financial variables is likely to bring macroeconomics benefits of lower volatility in inflation and output; however, any general rule-like behaviour does not seem to be optimal, and the performance of the augmented rules is shock-dependent. Cúrdia and Woodford (2010) investigate the role of spreads in the monetary policy rule. The main finding of this research paper is that the augmented rule improves the outcome with respect to the baseline scenario without spreads; however, there is no general optimal setting of the weights in the rule and its performance is shock-dependent. Simulations in Bauducco, Bulíř and Čihák (2011) suggest that, under certain conditions and parametrisation, monetary policy responding to financial instability can contribute to a faster return to the trend than a policy that follows the traditional Taylor rule. Gelain, Lansing, and Mendicino (2013) conclude that central bank's reaction to credit improves the performance of some variables, while the variances of inflation and output increase. Gambacorta and Signoretti (2014) show that adding the financial variables in the policy rule is likely to bring additional useful information for the setting of the policy interest rate and that it helps to better stabilise volatility of inflation and output compared to the standard monetary policy rules. On contrary, Svensson (2017) shows that leaning-against the wind policy is not optimal and can be even harmful for future economic development. Even though the evidence is vast, there is no clear answer to the question whether the central banks should react to the developments in the financial variables. Moreover, there is no research paper which would study this question in the small open economy setting.

The small open economy model employed in this paper is characterized by two types of financial frictions, and it is calibrated for the Czech Republic based on a data covering the period 2004-2016. The simulations of this model provide three main results. First, the monetary policy rule augmented with asset prices can help to stabilize macroeconomic developments in terms of lower implied volatilities of inflation and output. However, this result is shock-dependent and applies only to certain domestic shocks. Second, shocks originating abroad have a large impact on the small open economy; however, the use of the augmented rule with asset prices in this case proves to be not appropriate and it is outperformed by the rule accounting for movements in output. Third, when all shocks are set to be operative, the best performance delivers the rule accounting for movements in output. Even though the results seem to be promising, it is important to stress that they should be interpreted with certain caution. Moreover, the aim of this research are not precise quantitative prescriptions on the optimal weights, but rather qualitative ones.

The rest of the paper is organised as follows. Section 2 outlines the model. Section 3 discusses calibration and the properties of the calibrated model. Section 4 discusses the alternative monetary policy rules and the optimal weights. Section 5 compares the performance of the rules using the impulse response functions, and section 6 studies the robustness of the results. Section 7 concludes.

2. The Model

2.1 Households

The model outlined in this paper represents a small open economy. The employed framework is a variant of Brzoza-Brzezina and Makarski (2011) with the banking sector of Gambacorta and Signoretti (2014). The model operates with two types of financial frictions – a collateral constraint imposed on entrepreneurs introduced in line with Iacoviello (2005) and a constraint on the amount of bank leverage as in Gerali, Neri, Sessa, and Signoretti (2010). It also includes two sources of inefficiencies – nominal rigidities in the form of a Calvo (1983) pricing scheme with inflation indexation and the quadratic adjustment costs à la Rotemberg (1982).

The model operates with two types of agents: households and entrepreneurs. Households consume, supply labour and make deposits in commercial banks. Entrepreneurs consume, borrow funds from commercial banks and use them in a production process where labour supply and physical capital are combined to produce the wholesale goods. Entrepreneurs also face capital utilisation. Domestic and exporting retailers buy the wholesale goods, differentiate them at no cost and resell them in domestic and foreign goods markets. Importing retailers import goods produced in the foreign economy. Since retailers possess some degree of power in a price-setting scheme, the law of one price does not hold necessarily. Commercial banks collect deposits from households and provide loans to entrepreneurs at given interest rates. The central bank sets its main policy interest rate to influence conditions in the financial as well as the real side of the economy. The foreign sector is represented by three variables (inflation, interest rate and output) and it is modelled as simple independent AR processes.

Each household chooses consumption c_t^H, labour supply l_t, deposits d_t and foreign bonds b_t^* in order to maximise the expected utility (1) with respect to the budget constraint (2)

$$\mathrm{E}_0 \sum_{t=0}^{\infty} \beta_t^H \left(a_t^c \ \log(c_t^H(i) - \iota\, c_{t-1}^H) - \frac{l_t(i)^{1+\phi}}{1+\phi} \right), \tag{1}$$

$$\begin{aligned} c_t^H(i) + d_t(i) + e_t b_t^*(i) \leq w_t l_t + \frac{(1 + r_{t-1})d_{t-1}(i)}{\pi_t} \\ + \frac{(1 + r_{t-1}^*)(1 + f_{t-1})e_t b_{t-1}^*(i)}{\pi_t} + T_t(i) \end{aligned} \tag{2}$$

where β_H is the discount factor of households, ιc_{t-1}^H is the external habit stock with ι being a parameter characterizing the degree of habit persistence and ϕ is the inverse of the Frisch wage elasticity of labour supply. Preferences are subject to a disturbance affecting consumption a_t^c.[1] $\pi_t = P_t/P_{t-1}$ is the gross inflation rate with P_t being the price level, e_t is the nominal exchange rate, w_t is the real wage earned by households, r_t is the net nominal interest rate on deposits, $(1+r_t^*)(1+f_t)$ is a risk adjusted net nominal return paid on foreign bonds denominated in foreign currency, and T_t represents a lump-sum transfer that includes profits from the ownership of domestic retailers, importing retailers and capital goods producers.

Following Adolfson, Laseén, and Lindé (2008), the debt-elastic risk premium is defined as

$$(1+f_t) = \exp\left\{-\psi^*\left(\frac{e_t b_t^*}{P_t GDP_t}\right)\right\} = \exp\left\{-\psi^*\left(\frac{B_t^*}{GDP_t}\right)\right\} \tag{3}$$

with $B_t^* = e_t b_t^*/P_t$ being the real outstanding net foreign assets position of the domestic economy, GDP_t referring to gross domestic product, and ψ^* being the parameter characterising the elasticity of the risk premium. The first-order conditions for households are the labour supply equation, the Euler equation and the standard UIP condition

$$l_t^{\phi} = \frac{w_t a_t^c}{c_t^H - \iota c_{t-1}^H}, \tag{4}$$

$$(1+r_t) = \frac{1}{\beta_H}\frac{(c_{t+1}^H - \iota c_t^H)}{(c_t^H - \iota c_{t-1}^H)}\frac{a_t^c}{a_{t+1}^c}\pi_{t+1}, \tag{5}$$

$$\frac{(1+r_t)}{(1+r_t^*)} = \frac{q_{t+1}\pi_{t+1}}{q_t \pi_{t+1}^*}(1+f_t) \tag{6}$$

where $q_t = e_t P_t^*/P_t$ is the real exchange rate with P_t^* being the foreign price level.

2.2 Entrepreneurs

Entrepreneurs face a financing constraint in the production of wholesale goods. Each entrepreneur chooses consumption c_t^E, the level of capital K_t, labour l_t, the degree of capital utilisation $u_t$and the amount of loans b_t in order to maximise the expected utility (7) with respect to the constraints (8) and (9)

$$E_0 \sum_{t=0}^{\infty} \beta_t^E \log(c_t^E(i) - \iota\, c_{t-1}^E), \tag{7}$$

$$\begin{aligned} c_t^E(i) + w_t l_t(i) + \frac{(1+r_{t-1}^b)b_{t-1}(i)}{\pi_t} + p_t^K K_t(i) + \psi\big(u_t(i)\big)K_{t-1}(i) \\ \leq y_t^W(i) p_t^W + b_t(i) + p_t^K(1-\delta^K)K_{t-1}(i), \end{aligned} \tag{8}$$

[1] All shocks in the model (except for the monetary policy and bank capital shocks) follow an AR(1) process of the type $a_t = \rho_x a_{t-1} + \varepsilon_t^x$, where ρ_x is the autoregressive coefficient and ε_t^x is normally distributed with zero mean and standard deviation σ_x.

$$(1 + r_t^b)b_t(i) \leq mE_t\{p_{t+1}^K \pi_{t+1}(1 - \delta^K)K_t(i)\} \tag{9}$$

where β_E is the discount factor of entrepreneurs, δ^K represents the degree of depreciation of capital, p_t^K is the real price of capital, p_t^W is the real price of wholesale goods, and $\psi(u_t)K_{t-1}$ represents the real cost of setting a level u_t of capital utilisation. The cost of capital utilisation follows Schmitt-Grohé and Uribe (2007) and it is given by $\psi(u_t) = \xi_1 u_{t-1} + \xi_2/2(u_t - 1)^2$ where ξ_1 and ξ_2 are parameters. r_t^b is the net nominal interest rate on loans that are provided by commercial banks to entrepreneurs and m is the LTV ratio.

The production function is defined as

$$y_t^W(i) = a_t^E[K_{t-1}(i)u_t(i)]^\alpha l_t(i)^{1-\alpha} \tag{10}$$

where a_t^E is a productivity disturbance and α characterises a share of capital used in the production process. The first-order conditions for entrepreneurs are the investment-Euler equation, the return to capital, the labour demand condition and the consumption-Euler equation

$$\begin{aligned} \frac{p_t^K}{c_t^E - \iota c_{t-1}^E} = {} & v_t^E m p_{t+1}^K \pi_{t+1}(1 - \delta^K) \\ & + \frac{\beta_E}{c_{t+1}^E - \iota c_t^E}[R_{t+1}^K u_{t+1} + p_{t+1}^K(1 - \delta^K) - \psi(u_{t+1})], \end{aligned} \tag{11}$$

$$R_t^K = \xi_1 + \xi_2(u_t - 1), \tag{12}$$

$$w_t = (1 - \alpha)\frac{y_t^W p_t^W}{l_t}, \tag{13}$$

$$\frac{1}{c_t^E - \iota c_{t-1}^E} = v_t^E(1 + r_t^b) + \beta_E \frac{(1 + r_t^b)}{(c_{t+1}^E - \iota c_t^E)\pi_{t+1}} \tag{14}$$

where $R_t^K = a_t^E \alpha [K_{t-1}u_t]^{\alpha-1} l_t^{1-\alpha} p_t^W$ is the return to capital.

2.3 Capital Producers

Capital producers combine non-depreciated capital stock purchased from entrepreneurs with unsold final goods purchased from retailers as investment goods I_t to produce new capital stock. Capital is subject to depreciation represented by the depreciation rate δ^K. The aggregate capital stock evolves according to

$$K_t = \psi\left(\frac{I_t}{I_{t-1}}\right) + (1 - \delta^K)K_{t-1} \tag{15}$$

where $\psi(I_t/I_{t-1})$ represents the quadratic adjustment costs defined as $\psi(I_t/I_{t-1}) = I_t - \kappa^K/2(I_t/I_{t-1} - 1)^2 I_t$ with κ^K being the adjustment costs parameter. Given this, capital producers choose the optimal level of investment to maximise

$$E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left(p_t^K \left(1 - \frac{\kappa^K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) I_t - I_t \right). \tag{16}$$

The resulting first order condition determines the supply of capital

$$p_t^K \left[1 - \kappa^K \left(\frac{I_t}{I_{t-1}} - 1 \right) \frac{I_t}{I_{t-1}} - \frac{\kappa^K}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right] + \frac{\Lambda_{t+1}}{\Lambda_t} \left[p_{t+1}^K \kappa^K \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \right] = 1. \tag{17}$$

2.4 Final Goods Producers

Final goods producers aggregate differentiated products purchased from domestic retailers $y_{H,t}(i_H)$ and importing retailers $y_{F,t}(i_F)$ into a composite good. Producers utilise technology

$$y_t = \left[\eta^{\frac{\mu}{1+\mu}} y_{H,t}^{\frac{1}{1+\mu}} + (1-\eta)^{\frac{\mu}{1+\mu}} y_{F,t}^{\frac{1}{1+\mu}} \right]^{1+\mu} \tag{18}$$

where μ is the elasticity of substitution between domestic goods and imported goods, and η measures the degree of openness of the economy. The optimisation yields the following demand functions for differentiated goods

$$y_{H,t}(i_H) = \left(\frac{P_{H,t}(i_H)}{P_{H,t}} \right)^{-\frac{1+\mu_H}{\mu_H}} y_{H,t}, \quad y_{F,t}(i_F) = \left(\frac{P_{F,t}(i_F)}{P_{F,t}} \right)^{-\frac{1+\mu_F}{\mu_F}} y_{F,t} \tag{19}$$

where μ_H and μ_F measure the substitutability between goods. The demand functions for aggregate goods (home and imported) are given by

$$y_{H,t} = \eta \left(\frac{P_{H,t}}{P_t} \right)^{-\frac{1+\mu}{\mu}} y_t, \quad y_{F,t} = (1-\eta) \left(\frac{P_{F,t}}{P_t} \right)^{-\frac{1+\mu}{\mu}} y_t \tag{20}$$

and the aggregate consumer price index (CPI) is represented by the Dixit-Stiglitz function

$$P_t = \left[\eta P_{H,t}^{-\frac{1}{\mu}} + (1-\eta) P_{F,t}^{-\frac{1}{\mu}} \right]^{-\mu}. \tag{21}$$

For simplicity it is assumed that aggregate demand for exports takes the similar form as demand for imports in (20), only with different parameters

$$y_{H,t}^* = (1-\eta^*) \left(\frac{P_{H,t}^*}{P_t^*} \right)^{-\frac{1+\mu^*}{\mu^*}} y_t^*. \tag{22}$$

2.5 Retailers

There are three types of monopolistically competitive retailers: home goods retailers, importing retailers and exporting retailers. Retailers differentiate wholesale goods at no cost and resell them with a mark-up. All three types of retailers face the Calvo-pricing scheme with partial indexation to inflation.

Home goods retailers redistribute goods produced by entrepreneurs to final goods producers. They purchase wholesale goods from entrepreneurs at the wholesale price P_t^W and resell them at their retail price. The maximisation problem yields the first-order condition

$$E_0 \sum_{\tau=0}^{\infty} \theta_H^\tau \Lambda_{t,t+\tau} \left(-\frac{1}{\mu_H}\right) \left\{\left[x_{H,t+\tau}\tilde{p}_{H,t}(i_H) - (1+\mu_H)p_{t+\tau}^W\right] y_{H,t+\tau}(i_H)\right\} \tag{23}$$

where $x_{H,t+\tau} = X_{H,t+\tau} / \prod_{s=1}^{\tau} \pi_{t+s}$ is the real indexation factor, $p_{t+\tau}^W = P_{t+\tau}^W / P_{t+\tau}$ is the real price of wholesale goods, and $\tilde{p}_{H,t}(i_H) = \tilde{P}_{H,t}(i_H)/P_t$ is the real price set by optimising retailers.

Exporting retailers redistribute goods produced by entrepreneurs to foreign households. They purchase wholesale goods from entrepreneurs at the wholesale price P_t^W and resell them at their retail price. The maximisation problem yields the first-order condition

$$E_0 \sum_{\tau=0}^{\infty} (\theta_H^*)^\tau \Lambda_{t,t+\tau} \left(-\frac{1}{\mu_H^*}\right) \left\{\left[x_{t+\tau}^*\tilde{p}_{H,t}^*(i_H^*) - (1+\mu_H^*)\frac{p_{t+\tau}^W}{q_{t+\tau}}\right] y_{H,t+\tau}^*(i_H^*)\right\} \tag{24}$$

where $x_{t+\tau}^* = X_{t+\tau}^* / \prod_{s=1}^{\tau} \pi_{t+s}^*$ is the real indexation factor and $\tilde{p}_{H,t}^*(i_H^*) = \tilde{P}_{H,t}^*(i_H^*)/P_t$ is the real price set by optimising retailers.

Importing retailers are modelled in the same manner as home goods retailers. Importing retailers purchase the products from foreign entrepreneurs at price $e_t P_t^*$ (which can be rewritten as $q_t P_t$) expressed in domestic currency and they redistribute imported products at the retail price $P_{F,t}$. Since retailers possess some degree of power in setting their prices, law of one price does not hold necessarily (i.e. $P_{F,t} \neq e_t P_t^*$). Hence, this feature introduces the incomplete exchange rate pass-through into the model. The maximisation problem yields the first-order condition

$$E_0 \sum_{\tau=0}^{\infty} \theta_F^\tau \frac{\Lambda_{t,t+\tau}^*}{q_{t+\tau}} \left(-\frac{1}{\mu_F}\right) \left\{\left[x_{F,t+\tau}\tilde{p}_{F,t}(i_F) - (1+\mu_F)q_{t+\tau}\right] y_{F,t+\tau}(i_F)\right\} \tag{25}$$

where $x_{F,t+\tau} = X_{F,t+\tau} / \prod_{s=1}^{\tau} \pi_{t+s}$ is the real indexation factor and $\tilde{p}_{F,t}(i_F) = \tilde{P}_{F,t}(i_F)/P_t$ is the real price set by optimising retailers.

2.6 Commercial Banking Sector

The banking sector is modelled according to Gambacorta and Signoretti (2014), who introduce a simplified version of the banking sector derived by Gerali et al. (2010). Commercial banks possess certain market power in intermediation which enables them to change interest rates in response to various shocks. Banks must obey a balance-sheet condition stating that *loans* = *deposits* + *bank capital*. Banks also face an "optimal" exogenous target for the capital-to-asset ratio (i.e. the inverse of leverage). The banking sector is composed of a continuum of commercial banks indexed by $j \in (0,1)$. Each commercial bank consists of two units – wholesale and retail. The role of the wholesale unit is to collect deposits from households and to issue wholesale loans. The retail unit purchases wholesale loans, differentiates them and resells them to entrepreneurs.

2.6.1 Wholesale Unit

The wholesale unit of each bank operates under perfect competition. The wholesale unit obtains deposits d_t from households at the interest rate set by the central bank r_t and issues loans b_t at the net wholesale rate r_t^{wb}. The balance sheet of the wholesale branch consists of bank capital K_t^B and deposits d_t on the liability side, while on the asset side can be found loans b_t. Commercial banks face an optimal value of the capital-to-asset ratio ν^B with the quadratic adjustment costs parametrised by κ^B. Bank capital evolves according to

$$\pi_t K_t^B = (1-\delta^B)\frac{K_{t-1}^B}{a_t^B} + J_{t-1}^B \tag{26}$$

where δ^B is the depreciation rate representing the cost for managing the commercial banks' capital position, J_t^B represents overall profits as outlined by equation (30) and a_t^B is a disturbance term.

The wholesale unit chooses the optimal level of deposits d_t and loans b_t in order to maximise profits

$$r_t^{wb} b_t(j) - r_t d_t(j) - \frac{\kappa^B}{2}\left(\frac{K_t^B(j)}{b_t(j)} - \nu^B\right)^2 K_t^B(j) \tag{27}$$

with respect to the balance-sheet constraint $b_t = d_t + K_t^B$. The first order condition defines the wholesale interest rate on loans

$$r_t^{wb} = r_t - \kappa^B\left(\frac{K_t^B}{b_t} - \nu^B\right)\left(\frac{K_t^B}{b_t}\right)^2. \tag{28}$$

2.6.2 Retail Unit

The retail units operate in a monopolistically competitive market. Each retail unit purchases wholesale loans from the wholesale unit, differentiates them at no cost and resells them to entrepreneurs. It is assumed that the retail unit applies constant mark-up μ^B on the wholesale interest rate on loans r_t^{wb}. Therefore, the retail interest rate on loans r_t^b is defined as

$$\frac{r_t^b}{a_t^{rb}} = r_t - \kappa^B\left(\frac{K_t^B}{b_t} - \nu^B\right)\left(\frac{K_t^B}{b_t}\right)^2 + \mu^B \tag{29}$$

where $a_t^{r^b}$ is a disturbance on the interest rate on loans. Bank profits combine all partial net earnings. Aggregate bank profits (in real terms) are given by

$$J_t^B = r_t^b b_t - r_t d_t - \frac{\kappa^B}{2}\left(\frac{K_t^B}{b_t} - \nu^B\right)^2 K_t^B. \tag{30}$$

2.7 Central Bank

In the baseline scenario, monetary policy of the central bank is characterised by the strict inflation targeting regime in which the central bank adjusts the policy rate, r_t, in response to deviations of inflation π_t from its steady-state value. The monetary policy rule takes the form

$$(1 + r_t) = (1 + r)^{(1-\varrho_r)}(1 + r_{t-1})^{\varrho_r}\left(\frac{\pi_t}{\pi}\right)^{\varrho_\pi(1-\varrho_r)} a_t^r \tag{31}$$

where ϱ_r depicts monetary policy inertia, ϱ_π is a weight assigned to inflation and a_t^r is a disturbance to the policy interest rate.

2.8 Foreign Sector

The foreign sector is represented by three variables – output, inflation and interest rate – and it is modelled as independent AR(1) processes. Therefore, the foreign sector is represented by the following system of equations[2]

$$\begin{pmatrix}\hat{y}_t^*\\ \hat{\pi}_t^*\\ \hat{r}_t^*\end{pmatrix} = \begin{pmatrix}\rho_{y^*} & 0 & 0\\ 0 & \rho_{\pi^*} & 0\\ 0 & 0 & \rho_{r^*}\end{pmatrix}\begin{pmatrix}\hat{y}_{t-1}^*\\ \hat{\pi}_{t-1}^*\\ \hat{r}_{t-1}^*\end{pmatrix} + \begin{pmatrix}1 & 0 & 0\\ 0 & 1 & 0\\ 0 & 0 & 1\end{pmatrix}\begin{pmatrix}\varepsilon_t^{y^*}\\ \varepsilon_t^{\pi^*}\\ \varepsilon_t^{r^*}\end{pmatrix} \tag{32}$$

where $\varepsilon_t^{y^*}$, $\varepsilon_t^{\pi^*}$ and $\varepsilon_t^{r^*}$ are disturbances with zero mean and standard deviations σ^{y^*}, σ^{π^*} and σ^{r^*} respectively, and ρ_{y^*}, ρ_{π^*} and ρ_{r^*} are the autoregressive coefficients.

2.9 Market Clearing Conditions and GDP

The balance sheet identity of commercial banks requires loans to be equal to deposits and bank capital

$$b_t = d_t + K_t^B. \tag{33}$$

In goods market must hold

$$C_t + I_t + \psi(u_t)K_{t-1} = y_t \tag{34}$$

where aggregate consumption C_t is composed of consumption of households and consumption of entrepreneurs

$$C_t = c_t^H + c_t^E. \tag{35}$$

[2] Hatted variables represent percentage deviations from the steady state.

Aggregate production of wholesale goods must satisfy demand from home economy as well as demand from the foreign economy

$$y_t^W = \int_0^1 y_{H,t}(i)di + \int_0^1 y_{H,t}^*(i_H^*)di_H^*. \tag{36}$$

The balance of payments ensures that supply of new loans to the foreign economy equals interest rate payments on previous debt plus nominal net exports

$$\begin{aligned}\int_0^1 e_t P_{H,t}^*(i_H^*)y_{H,t}^*(i_H^*)di_H^* + e_t b_t^* \\ = \int_0^1 P_{F,t}(i_F)y_{F,t}(i_F)di_F + (1+r_{t-1}^*)(1+f_{t-1})e_t b_{t-1}^*.\end{aligned} \tag{37}$$

Lastly, gross domestic product (GDP_t) is defined as a sum of final goods and net exports

$$P_t GDP_t = P_t y_t + \int_0^1 e_t P_{H,t}^*(i_H^*)y_{H,t}^*(i_H^*)di_H^* - \int_0^1 P_{F,t}(i_F)y_{F,t}(i_F)di_F. \tag{38}$$

3. Calibration and Properties of the Model

3.1 Calibration for the Czech Republic

The parameters of the model are calibrated based on studies focusing on the Czech Republic or studies employing similar model mechanisms (when Czech studies are not available) and own computations using data from ARAD database. The data sample used for the computations covers the period 2004 to 2016 on a quarterly basis. Tables 6 and 7 summarize calibration. Some parameters are directly calibrated and certain steady states are computed as long-term averages characterising the period 2004-2016 (Table A1 in the *Appendix*), while the rest of the parameters and steady states is computed based on the steady-state relationships (Table A2 in the *Appendix*).

Based on the steady-state relation, the long-run average value of the quarterly net nominal policy interest rate $r = 0.00405$ ensures that the discount factor of households β_H is equal to 0.996. The discount factor of entrepreneurs, β_E, is set at 0.97 implying less patient behaviour compared to households, while the discount factor of foreign households $\beta_H^* = 0.996$. The share of capital employed in the production process (α) is set in line with Palas (2017) at 0.33, and the depreciation rate of capital (δ^K) is set at 0.015. Parameters of adjustment costs for capital utilization $\xi_1 = 0.0345$ and $\xi_2 = 0.0034$ imply that the ratio ξ_1/ξ_2 is equal to 10, which is in line with Gerali et al. (2010). The adjustment costs parameter for investment, κ^K, is set at 1.5. Based on Vašíček (2006), the habit consumption parameter ι equals 0.8 and inverse Frisch-labour supply elasticity ϕ is calibrated to 3. Adopting estimates of Svačina (2016) and Ryšánek, Tonner, and Vašíček (2011), Calvo and inflation indexation parameters are calibrated as follows: home goods price stickiness $\theta_H = 0.5$ and $\varsigma_H = 0.13$, imported goods price stickiness $\theta_F = 0.75$ and $\varsigma_F = 0.2$, exported goods price stickiness $\theta_H^* = 0.8$ and $\varsigma_H^* = 0.25$. Elasticities of substitution for domestic and foreign goods are set at $\mu = \mu^* = 1.96$ based on Ryšánek et al. (2011).

Following the same study, interest rate persistence $\varrho_r = 0.8$ and the weight put on inflation $\varrho_\pi = 1.8$. $\delta^B = 0.0399$ based on the steady-state relation. The optimal level of capital-to-asset ratio (ν^B) is set at 10.8 %, which is in line with the long-run average of the Czech banking sector. Following Gerali et al. (2010), the adjustment costs parameter related to the capital-to-asset position κ^B is equal to 10. The value of the LTV ratio of entrepreneurs $m = 0.51$ is computed as the long-run average of the value of loans and the value of shares and equity and other equity for corporations. The long-run average of the quarterly net nominal lending interest rate is computed to $r^b = 0.007923$, which implies the mark-up in the banking sector, μ^B, to be 0.0039 on a quarterly basis. The long-run average of the quarterly foreign net nominal interest rate $r^* = 0.003925$ implies elasticity of the risk premium, ψ^*, to be 0.0001. Autoregressive coefficients of the shocks along with their standard deviations are calibrated based on estimates of Ryšánek et al. (2011) and Svačina (2016): $\rho_c = 0.7$, $\rho_E = 0.9$, $\rho_{\pi^*} = 0.6$, $\rho_{r^*} = 0.75$, $\rho_{y^*} = 0.75$, $\sigma_c = 0.072$, $\sigma_E = 0.042$, $\sigma_{\pi^*} = 0.013$, $\sigma_{r^*} = 0.002$, and $\sigma_{y^*} = 0.015$. The standard deviations of the shocks on the interest rate on loans and bank capital are set arbitrarily at $\sigma_{r^b} = 0.003$ and $\sigma_B = 0.5$.

3.1 Model vs Data

The quantitative properties of the model are described using standard deviations and correlations with output, which measure the volatility of the variables and their co-movement with output (measured by GDP) respectively. The comparison between the statistical properties of the model and the data is summarized in Table 1.

Table 1 Business Cycle Properties of the Model

	Standard deviation		***Correlation with output***	
Variable	***Data***	***Model***	***Data***	***Model***
Output	2.03	3.19	1.00	1.00
Consumption	3.24	3.37	0.73	0.27
Inflation	0.77	0.83	0.21	-0.04
Investment	4.10	4.13	0.86	0.6
Policy interest rate	0.51	0.50	0.65	-0.64
Real exchange rate	2.86	3.10	0.26	0.73

Notes: The data covers the period 2004-2017 on a quarterly basis, the data sources are the same as for calibration. Standard deviations are in percent.

As second and third columns of Table 1 suggest, standard deviations generated by the model qualitatively match standard deviations found in the data. The data and the model suggest that the policy interest rate is the less volatile variable, while the most volatile proves to be investment. In quantitative terms, the model replicates volatility of the selected variables well except for output, where the simulated volatility reaches substantially higher value. In contrast to standard deviations, the model cannot generate reasonable correlations with output in certain cases, as is visible from the last two columns of Table 1.

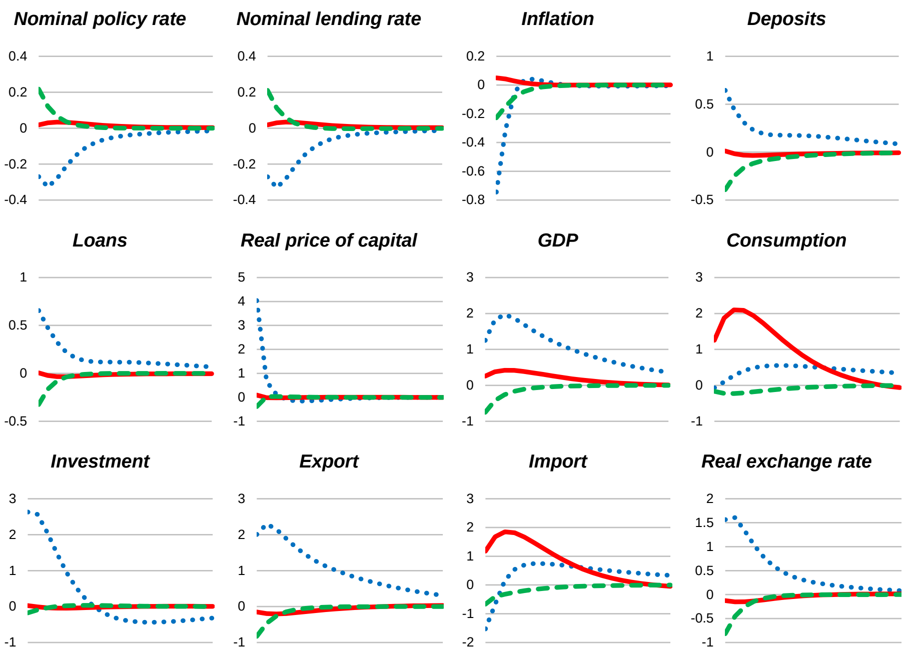
3.2 Impulse Response Functions

Figures 1, 2 and 3 show impulse responses to three categories of shocks. The first category depicted by Figure 1 is composed of three domestic non-financial shocks (productivity, consumption preference, monetary policy). Figure 2 illustrates the second category that includes two domestic financial shocks (bank capital, interest rate on loans). The last class is composed of three foreign shocks (inflation, interest rate, demand) and it is illustrated in Figure 3.

3.2.1 Domestic non-Financial Shocks

A positive technology shock implies an improvement in the production process which makes production more efficient causing output to increase. The innovation is followed by a decrease in the prices of the products. As a result, inflation decreases. The real exchange rate depreciates causing imports to fall and exports to rise. Given this dynamic, the central bank responds by cutting the policy interest rate. Regarding the financial side of the economy, the loan rate falls on impact because of the relaxed conditions in the economy. The lending is cheaper and the demand for credit increases which in turn forces the commercial banks to expand their balance sheets and increase leverage.

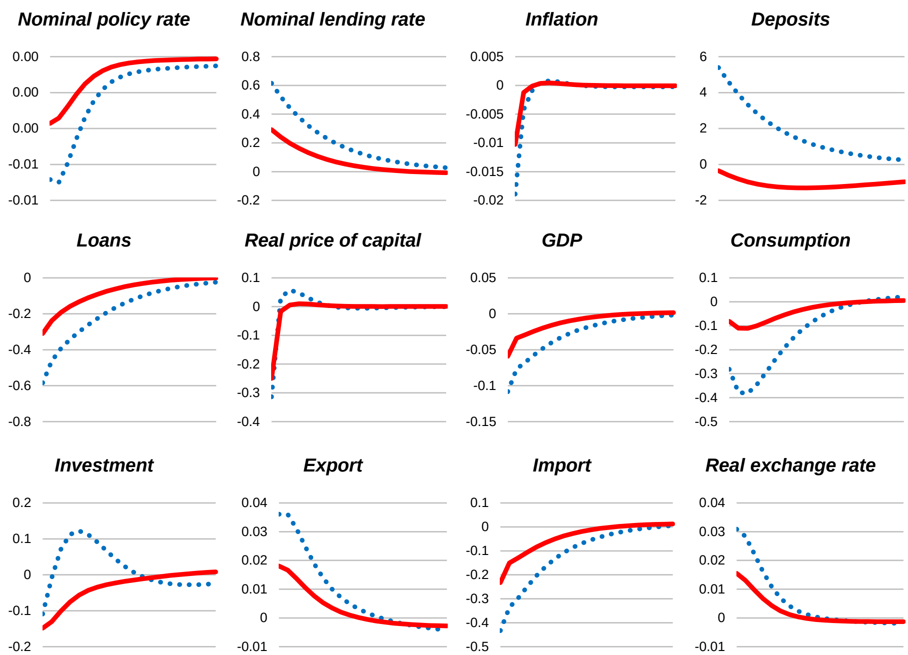
Figure 1 Impulse Response Functions for Domestic Non-Financial Shocks



Notes: Blue dotted line – a positive technology shock, red solid line – an increase in consumption preference, green dashed line – monetary policy tightening. The IRFs depict one standard deviation shocks. All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

A domestic demand side shock is represented by a positive one standard deviation consumption preference shock. The positive shock in consumption preferences causes households to consume more because they value present consumption more than the future one. The policy rate increases to offset inflationary pressures. The nominal interest rate follows the path of the policy interest rate, causing loans and investment to decrease. GDP increases mainly due to higher consumption. The real exchange rate appreciates on impact which causes exports to fall and imports to rise.

Figure 2 Impulse Response Functions for Domestic Financial Shocks



Notes: Blue dotted line – a bank capital loss, red solid line – an increase in lending interest rate. The IRFs depict one standard deviation shocks. All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

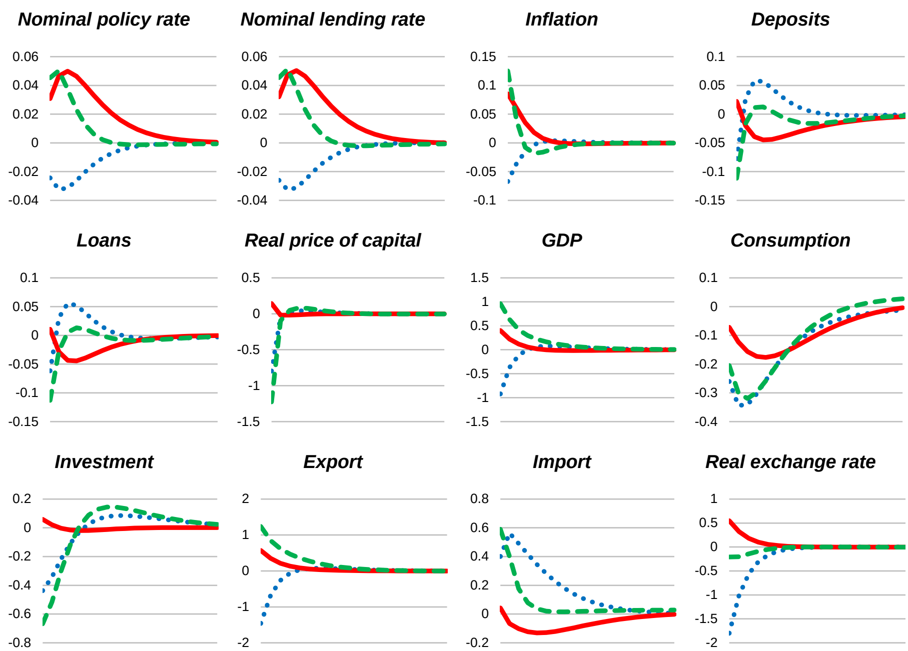
Following a one standard deviation contractionary monetary policy shock, aggregate demand declines. Output and inflation decrease on impact. The higher policy rate is reflected by an increase in the interest rate on loans. Lower demand for capital is mirrored by its lower price that together with lower inflation causes the value of the collateral to decrease, which leads to lower demand for loans. Investment declines. Deposits decrease more than loans to meet the balance sheet condition of the commercial banks. Appreciation of the real exchange rate leads to higher imports. On the other hand, exports fall with a stronger currency.

3.2.1 Domestic Financial Shocks

After a negative bank capital shock hits the financial sector, banks try to rebalance deposits and loans due to high leverage position. To do so, they increase the interest rate on loans, which in turn decreases the demand for loans. Given that the contraction in loans is lower than in bank capital, deposits increase to meet the balance sheet condition. Because of low loan supply, entrepreneurs do not possess enough resources for investment activities, and investment initially falls. Consumption falls as well. The central bank reacts to lower inflation caused by low economic activity by cutting the policy interest rate. Since the real exchange rate depreciates, exports grow and imports fall. Overall, low economic activity results in the decline in GDP.

A positive one standard deviation shock in the interest rate on loans tightens the collateral constraint, which results in a decline in the volume of loans and lower investment. Demand for capital decreases while consumption slightly decreases. A negative wage dynamic pushes inflation down causing the policy interest rate to decrease. Moderate depreciation of the real exchange rate is accompanied by a rather negligible increase in exports and a decrease in imports. The overall impact on GDP is negative.

Figure 3 Impulse Response Functions for Foreign Shocks



Notes: Blue dotted line – an increase in foreign inflation, red solid line – an increase in foreign interest rate, green dashed line – an increase in foreign demand. The IRFs depict one standard deviation shocks. All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

3.2.1 Foreign Shocks

A positive one standard deviation shock to foreign inflation is followed by appreciation of the real exchange rate, which is mirrored in higher imports and lower exports. The overall economic conditions create downward pressure on inflation. The central bank is forced to decrease the policy interest rate to support production and to increase inflation. The interest rate on loans follows the dynamics of the policy rate. The commercial banks expand their balance sheets in the following periods to satisfy higher demand for credit that is followed by higher investment activities in the subsequent quarters.

One standard deviation positive foreign interest rate shock causes the real exchange rate to depreciate on impact, which stimulates the demand for domestic exports while imports fall. Higher domestic production and the depreciated real exchange rate generate inflationary pressures that are counterattacked by the response of the central bank to increase the policy interest rate.

Higher foreign demand stimulates exports of the domestic economy substantially. As a result, production increases on impact to satisfy higher foreign demand. Because marginal costs of production are growing, inflation rises. The central bank accommodates higher inflation by an increase in its policy rate. Due to the policy action of the central bank, the real exchange rate appreciates, which causes imports to increase. The interest rate on loans increases as well causing the volume of loans to decrease.

4. Alternative Monetary Policy Rules

4.1 Optimisation of the Coefficients Under All Shocks

Compared to the baseline scenario in which the central bank sets its policy rate according to the developments of inflation (as described by equation (31)), in the alternative scenarios the central bank is assumed to implement several flexible CPI-targeting regimes. Considered secondary variables that are included individually in the Taylor-type rule are the following ones: output (GDP_t), asset prices (p_t^K) and the loans-to-GDP ratio ($O_t = b_t \backslash GDP_t$). Therefore, the Taylor-type rule describing all mentioned alternatives takes the general form

$$(1 + r_t) = (1 + r)^{(1-\varrho_r)} (1 + r_{t-1})^{\varrho_r} \left(\left(\frac{\pi_t}{\pi}\right)^{\varrho_\pi} \left(\frac{GDP_t}{GDP}\right)^{\varrho_{GDP}} \left(\frac{p_t^K}{p^K}\right)^{\varrho_{p^K}} \left(\frac{O_t}{O}\right)^{\varrho_O} \right)^{(1-\varrho_r)} a_t^r \quad (39)$$

where ϱ_{GDP}, ϱ_{p^K}, and ϱ_O are the weights assigned to the respective variables. The optimisation of the coefficients of the Taylor-type rules describing the strict and flexible CPI-targeting regimes is based on the minimisation of the loss function using the grid-search method.[3] The coefficient ϱ_π is allowed to take values from interval $[1.5,3]$ by increments of 0.1, while the coefficients ϱ_{GDP}, ϱ_{p^K}, and ϱ_O are restricted to interval $[0.05,1]$ by increments of 0.05. Following the concept of Taylor curves, the

[3] The aim of the optimisation is not a quantitative prescription on the optimal weights, but rather a qualitative one.

central bank is assumed to minimise a period loss function composed of two components: variances of inflation and output. Therefore, the loss function takes the form

$$L_1 = Var(\pi) + \zeta_1 Var(GDP) \tag{40}$$

where Var refers to variance and ζ_1 is the weight assigned to the variation in output. In the baseline scenario, the value of ζ_1 is assumed to be 0.2.

Table 2 Optimized Coefficients of the Taylor-Type Rules

Regime	ϱ_π	ϱ_{GDP}	ϱ_{p^K}	ϱ_O	Var π	Var GDP	L_1[4]
Strict CPI	2.50	–	–	–	0.005	0.112	0.027
Flexible CPI (output)	3.00	0.25	–	–	0.008	0.086	0.025
Flexible CPI (asset prices)	3.00	–	0.35	–	0.007	0.093	0.026
Flexible CPI (loans-to-GDP ratio	3.00	–	–	0.05	0.004	0.116	0.028

Notes: Variances are in percent.

The results of the optimisation routine, when all shocks in the model are set to be operative, are summarised in Table 2. The main driving force of stabilising volatilities of output and inflation is the response to the movements in inflation as is suggested by the maximum value of ϱ_π in three out of four investigated Taylor-type rules. In the case of the strict CPI rule, the optimisation delivers the value of ϱ_π equal to 2.5. This result suggests that if the central bank seeks to stabilise volatility of output as well, to aggressive response to movements in inflation can be suboptimal. The overall results show that the best performance delivers the rule augmented with output (mainly due to the stabilisation of the volatility of output, which is the lowest one among all alternatives), while the worst performance is achieved under the rule responding to the loans-to-GDP ratio. It seems that strong responses to the loans-to-GDP ratio are even harmful since higher values of the weight ϱ_O bring even worse results. The rule augmented with asset prices outperforms the strict CPI targeting rule and delivers the second lowest value of the loss function. The simulations also suggest that the response to the movements in asset prices should be rather modest.

In the next step, the weighting parameter on the variation in output, ζ_1, is allowed to take values within the range $(0,1]$ by increments of 0.1 in order to investigate the implications of the different weights assigned to output. For each value of ζ_1, the coefficients of all investigated rules are optimised and the combination of coefficients that delivers the minimum value of the loss function (40) is chosen as the best policy outcome. The results of this exercise are reported in Table 3.

As it is evident from Table 3, there is a better alternative for each weight ζ_1 that delivers an improvement in macroeconomic stabilisation compared to the strict CPI inflation targeting rule. Regardless the value of the weighting coefficient ζ_1, the best performance delivers the flexible CPI targeting rule augmented with output. The higher the importance of output stabilisation, the higher gains are achieved under this

[4] The value of the loss function is measured as the weighted sum of variances over 20 quarters of the simulation.

augmented rule. The gain achieves even 46 % for ζ_1 equal to 1. The worst results are attained under the rule augmented with the loans-to-GDP ratio which delivers slightly worse results than the strict CPI targeting rule.

Table 3 Sensitivity to the Changes in the Output Weight ζ_1

			Flexible CPI rules								
Strict CPI			*Output*			*Asset prices*			*Loans-to-GDP ratio*		
ζ_1	ϱ_π	L_1	ϱ_π	ϱ_{GDP}	*Gain*	ϱ_π	ϱ_{p^K}	*Gain*	ϱ_π	ϱ_O	*Gain*
0.1	3.0	0.02	3.0	0.05	0.4 %	3	0.05	0.1 %	3.0	0.05	0.1 %
0.2	2.5	0.03	3.0	0.25	6.3 %	3	0.35	4.7 %	2.8	0.05	-3.0 %
0.3	2.0	0.04	3.0	0.40	12.0 %	3	0.55	8.2 %	2.4	0.05	-4.7 %
0.4	1.7	0.05	3.0	0.55	17.5 %	3	0.65	10.5 %	2.3	0.05	-5.9 %
0.5	1.6	0.06	3.0	0.70	22.8 %	3	0.70	12.1 %	2.2	0.05	-7.0 %
0.6	1.5	0.07	3.0	0.80	27.8 %	3	0.75	13.3 %	2.1	0.05	-7.8 %
0.7	1.5	0.08	3.0	0.95	32.8 %	3	0.80	14.3 %	2.1	0.05	-8.4 %
0.8	1.5	0.09	3.0	1.00	37.7 %	3	0.80	15.1 %	2.0	0.05	-8.9 %
0.9	1.5	0.10	2.9	1.00	42.1 %	3	0.85	15.9 %	2.0	0.05	-9.2 %
1	1.5	0.11	2.8	1.00	46.1 %	3	0.85	16.6 %	2.0	0.05	-9.5 %

Notes: Gain is a percentage difference between the loss achieved under the baseline and augmented rule (a positive value means improvement).

4.2 A Variant of the Loss Function – Instrument Smoothing

To further investigate the robustness of the results, a variant of the loss function is introduced. Following Svensson (2000), equation (40) is expanded by the term reflecting nominal interest-rate smoothing that is of a certain importance for the policymakers who prefer stability in their instrument. Moreover, it has also implications for the financial stability reasons as mentioned by Rudebusch (2002). Thus, the expanded loss function L_2 is given by

$$L_2 = Var(\pi) + \zeta_1 Var(GDP) + \zeta_2 Var(\Delta r) \tag{40}$$

where ζ_2 is a non-negative weight that is allowed to take values within the interval $(0,1]$ by increments of 0.1. The same routine as in the case of the weight ζ_1 is applied to find the optimal coefficients of each rule for the respective value of ζ_2. It is important to stress that ζ_1 is fixed at its baseline value and only ζ_2 is allowed to vary. Table 4 shows the results.

Again, the baseline rule is outperformed by two alternatives (the rules accounting for output and asset prices) and the worst performance delivers the rule augmented with the loans-to-GDP ratio. Compared to the previous results, the gains are only modest – up to 8 %. The best performance is achieved under the rule augmented with asset prices regardless of the value of the weighting coefficient except for the case when ζ_2 equals 0.1. However, it is important to mention that these results hold for the fixed value of the weighting parameter on the variation in GDP ζ_1. If this parameter would be allowed to take higher values, the implied volatilities of inflation and GDP would dominate the loss function, and therefore, the instrument smoothing term would make only slight difference which would lead to the similar results as reported in Table 3. To conclude, regardless of the specification of the loss function, the baseline rule is outperformed by both rules accounting for output and asset prices.

Table 4 Sensitivity to the Changes in the Instrument Smoothing Weight ζ_2

	Strict CPI		Flexible CPI rules								
			Output			*Asset prices*			*Loans-to-GDP ratio*		
ζ_2	ϱ_π	L_2	ϱ_π	ϱ_{GDP}	Gain	ϱ_π	ϱ_{p^K}	Gain	ϱ_π	ϱ_O	Gain
0.1	2.5	0.03	3.0	0.25	5.7 %	3	0.35	5.0 %	2.8	0.05	3.0 %
0.2	2.4	0.03	3.0	0.20	5.2 %	3	0.4	5.2 %	2.7	0.05	-3.0 %
0.3	2.4	0.03	3.0	0.20	4.7 %	3	0.4	5.5 %	2.6	0.05	-3.0 %
0.4	2.3	0.03	2.9	0.20	4.3 %	3	0.4	5.8 %	2.6	0.05	-3.0 %
0.5	2.3	0.03	2.7	0.15	3.8 %	3	0.4	6.1 %	2.5	0.05	-3.0 %
0.6	2.2	0.03	2.7	0.15	3.5 %	3	0.4	6.3 %	2.5	0.05	-2.9 %
0.7	2.2	0.03	2.7	0.15	3.2 %	3	0.4	6.6 %	2.4	0.05	-2.9 %
0.8	2.2	0.03	2.6	0.15	2.9 %	3	0.4	6.8 %	2.4	0.05	-2.9 %
0.9	2.1	0.03	2.4	0.10	2.6 %	3	0.45	7.1 %	2.4	0.05	-2.9 %
1	2.1	0.03	2.4	0.10	2.4 %	3	0.45	7.3 %	2.3	0.05	-2.9 %

Notes: Gain is a percentage difference between the loss achieved under the baseline and augmented rule (a positive value means improvement).

4.2 The Performance of the Optimised Rules Under Single Shocks

The performance of each rule is re-assessed under single shocks to verify the conclusions stemming from the optimisation routine under the "all-shocks scenario". The experiment should also reveal why the rules that perform well deliver such plausible results. The coefficients in the rules are again those found under the optimisation routine using the loss function L_1. The results of the simulations are summarised in Table 5.

Table 5 Performance of the Optimized Rules Under Individual Shocks

		Augmented flexible CPI rules		
Shock to	*Strict CPI*	*Output*	*Asset prices*	*Loans-to-GDP ratio*
Bank capital	0.0000	0.0000	0.0000	<u>0.0000</u>
Consumption preference	0.0007	<u>0.0006</u>	0.0007	0.0007
Foreign inflation	0.0018	<u>0.0014</u>	0.0014	0.0018
Foreign interest rate	0.0004	<u>0.0002</u>	0.0003	0.0029
Foreign demand	0.0022	<u>0.0015</u>	0.0029	0.0023
Interest rate on loans	0.0000	0.0000	<u>0.0000</u>	0.0000
Technology	0.0204	0.0208	<u>0.0195</u>	0.0214

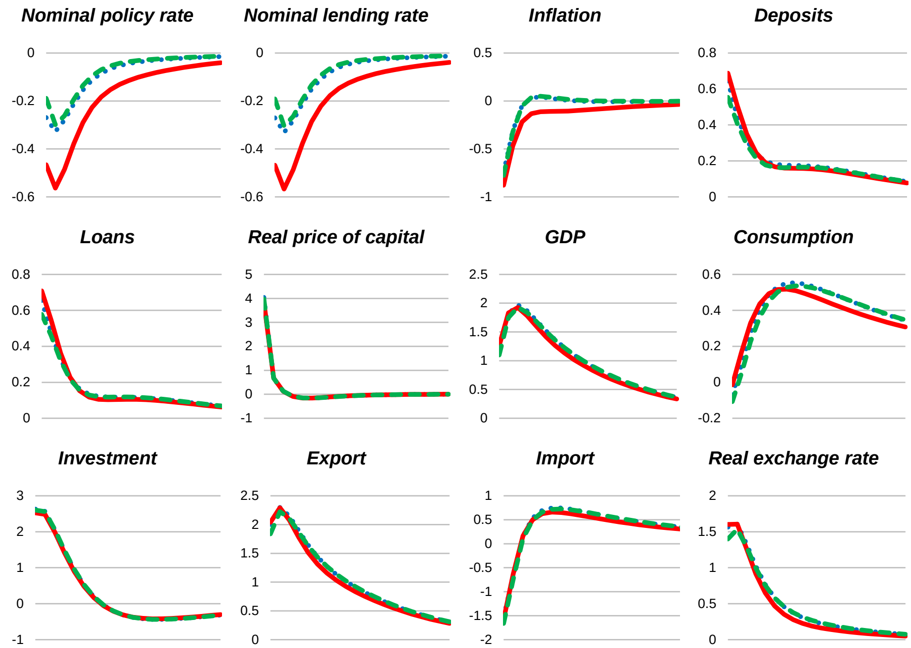
Notes: The reported values refer to the loss function L_1. The Taylor-type rules represent those with the coefficients optimised under the "all-shocks scenario"'.

Table 5 suggests that the flexible CPI targeting rule augmented with output is the best under most shocks. This rule dominates the others in case of all foreign shocks. This behaviour is caused by the fact that GDP is composed of net exports. Therefore, the rule can respond to the first-round effects of the foreign shocks, and thus can contribute to lower volatility of output. The rule accounting for movements in asset prices dominates in the case of domestic shocks – most notably in the case of the technology shock.[5] On the other hand, the rule does not perform well in the face of shocks originating abroad. Similar results are delivered by the strict CPI targeting rule and the rule with loans-to-GDP ratio. Overall, these results confirm the qualitative performance of the rules and help to disentangle the results stemming from the "all-shock scenario".

5. IRFs Under the Augmented Taylor-Type Rules

The following section offers a comparison of the baseline strict CPI targeting rule and the optimised flexible CPI targeting rules augmented with GDP and asset prices using the impulse response functions for three selected shocks.

Figure 4 Impulse Response Functions to a Positive Technology Shock



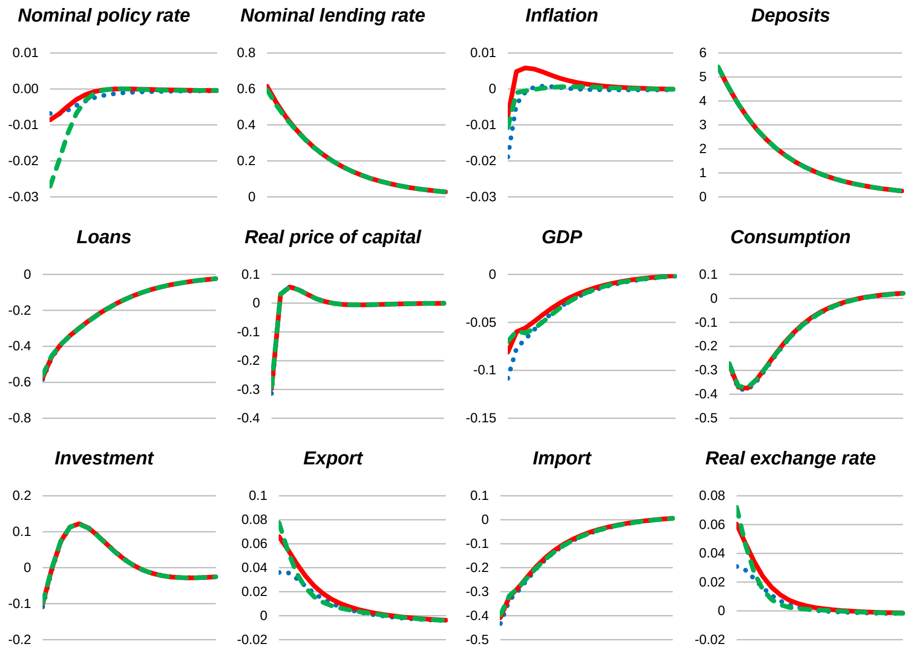
Notes: Blue dotted line – strict CPI rule, red solid line – flexible CPI rule (output), green dashed line – flexible CPI rule (asset prices). All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

In the case of the technology shock, both alternative rules suggest less aggressive reaction of the central bank. Under the rule augmented with asset prices, tighter monetary policy conditions (compared to the baseline scenario) imply less economic activity mirrored in a smaller increase in the volume of loans and slightly lower GDP. The interest rate setting is reflected in less depreciated real exchange rate.

[5] This finding is consistent with the results of Gambacorta and Signoretti (2014) who report the beneficial properties of the rule augmented with asset prices in stabilising inflation and output in the case of technology and mark-up shocks.

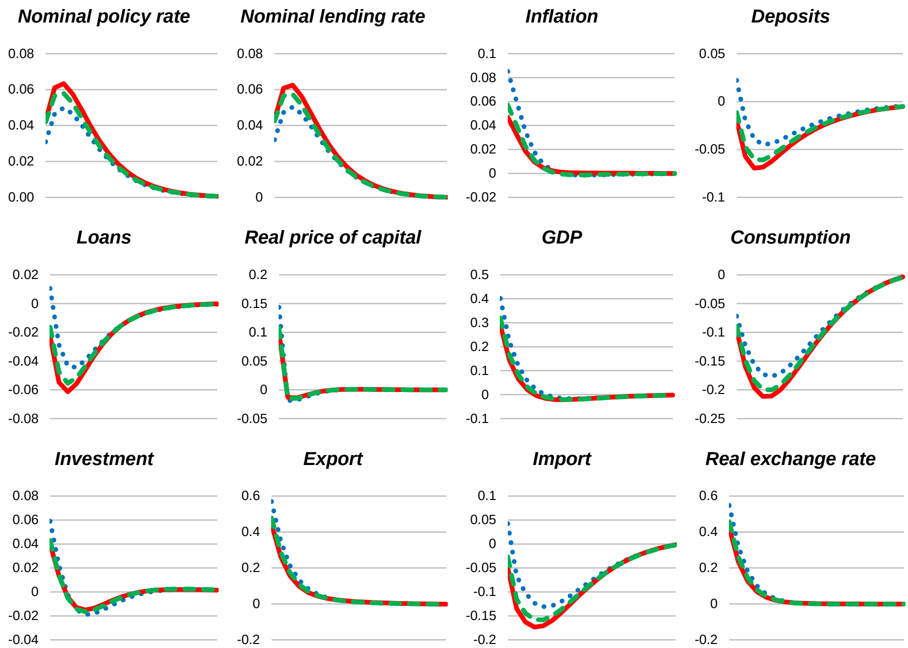
The impulse responses to the negative bank capital shock illustrate the inability of the central bank to improve the situation in the economy when the financial sector experiences a difficulty. The foreign shocks represent a positive shock in foreign interest rate. Both augmented rules bring higher monetary policy tightening. Through the real exchange rate depreciation and higher import prices, an increase in inflation is lower compared to the baseline scenario. Tight monetary conditions are also followed by the higher interest rate on loans that causes lower loan supply.

Figure 5 Impulse Response Functions to a Negative Bank Capital Shock



Notes: Blue dotted line – strict CPI rule, red solid line – flexible CPI rule (output), green dashed line – flexible CPI rule (asset prices). All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

Figure 6 Impulse Response Functions to a Positive Foreign Interest Rate Shock



Notes: Blue dotted line – strict CPI rule, red solid line – flexible CPI rule (output), green dashed line – flexible CPI rule (asset prices). All variables except for interest rates are expressed as percentage deviations from steady state. Interest rates are expressed in absolute deviations. The horizontal axis depicts reaction of the variables for 20 quarters after a shock occurs.

6. Sensitivity Analysis – Parameters of the Model

The following analysis shows to what extent is the model sensitive to the changes in calibration of several parameters. In particular, the simulations with optimised rules as in subsection 4.1 are repeated for different values of the selected parameters. Then the values of the loss function L_1 under the flexible CPI targeting rules are compared with the loss delivered by the strict CPI targeting rule. The parameters that are analysed can be categorised into two groups:

a) the parameters related to the financial side of the economy: the rate of bank capital adjustment costs κ^B, the LTV parameter m, and the target value of capital-to-asset ratio ν^B;

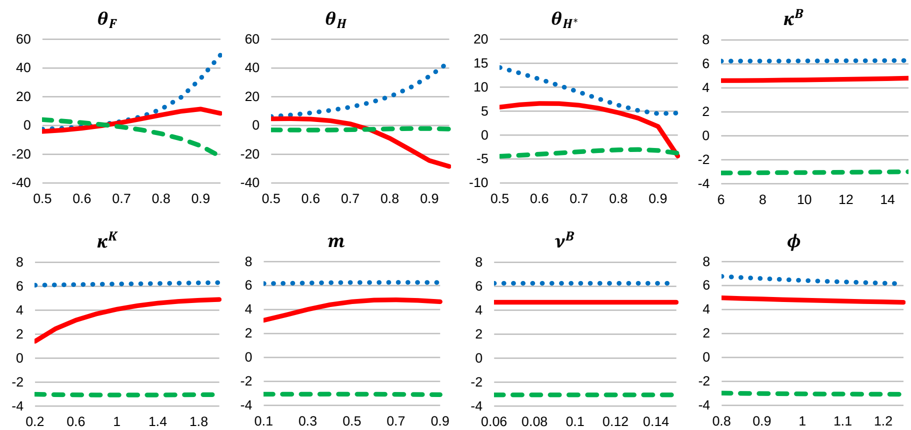
b) the parameters reflecting the stickiness in the economy: the Calvo parameters θ_F, θ_H and θ_{H^*}, the rate of investment adjustment costs κ^K, and the inverse of the Frisch elasticity of labour supply ϕ.

The results of the robustness analysis are displayed in Figure 7.

Regarding the banking sector parameters, the results are almost identical when changing the values of κ^B and ν^B. As Gambacorta and Signoretti (2014) discuss, these two parameters in a multiplicative form affect the slope of the loan supply. Based on the alternative values considered, the multiplication of the parameters is small in its magnitude such that the quantitative output of the model is not affected considerably. The performance of the rules under the last investigated parameter related to the financial side of the economy, m, is stable.

The results are quantitatively robust to changes in the degree of stickiness in the economy to some extent. In the case of the investment adjustment costs parameter κ^K and the inverse elasticity of labour supply ϕ, the analysis reveals no substantial differences for different values. The analysis shows that for the values of the price stickiness parameter θ_F below the threshold 0.7, the rules augmented with asset prices and output deliver less favourable results than the strict CPI targeting rule; however, the differences are negligible. The rule augmented with asset prices delivers the worst results also for the values of the price stickiness parameter θ_H exceeding 0.7. Despite this phenomenon, the conclusions drawn from the initial simulations seem to be robust.

Figure 7 Sensitivity Analysis to Different Values of the Selected Parameters



Notes: Blue dotted line – flexible CPI rule (output), red solid line – flexible CPI rule (asset prices), green dashed line – flexible CPI rule (loans-to-GDP ratio). The reported values represent the percentage gain (loss) of the flexible CPI inflation targeting rules compared to the strict CPI targeting rule. A positive value indicates gain; a negative value indicates loss.

7. Conclusion

Financial stability and its connection to monetary policy have become one of the most prominent topics discussed in the field of macroeconomics and monetary economics. In the light of the recent financial crisis, the natural question that has arisen is whether two conventional macroeconomic indicators – inflation and output – are sufficient ingredients of the monetary policy rules. Because of the strong relationship between the financial sector and the real side of the economy, the role of the financial variables within the monetary policy rules started to be investigated. Although the research is growing extensively in this field, the topic is rather new, and there is a lot to be examined. Moreover, most studies focus on the closed economies. This research contributes to the existing theoretical evidence by the analysis of the augmented monetary policy rules in the small open economy context. The purpose of this research is to test the augmented monetary policy rules in the DSGE model for the small open economy calibrated for the Czech Republic.

On one hand, the results show that reacting to the financial variables (namely asset prices) might be beneficial for the inflation and output stabilisation, and therefore for the monetary authority. However, this result is strongly shock-dependent and holds only for certain domestic shocks. On the other hand, the rule augmented with asset prices is outperformed by the flexible CPI targeting rule accounting for movements in output in the case of the shocks originating outside the domestic economy. When accounting for all shocks simultaneously, the best performance is reached under the flexible CPI targeting rule accounting for movements in output.

Even though the simulations show that reacting to asset prices might be beneficial in certain cases, it is important to stress that the results should be interpreted with certain caution. First, the model does not include any features related to the financial stress (such as an endogenous exit of non-financial firms or the crashes of the commercial banks) that are typical for a financial crisis. Therefore, the augmented rules are tested in normal times. Second, the model is linearised. This technique removes any non-linearity which might be characteristic of the crisis periods. Third, the results should be taken as qualitative rather than quantitative. The model is stylized; therefore, the results are likely not to resemble the reality precisely. Fourth, the model demonstrates that it could work according to “loanable funds theory”. In this setting, commercial banks do not create money endogenously, which does not need to hold in reality.

To summarise, the model indicates that the financial variables can be useful in certain cases in monetary policy decision making since the connection between the financial side and the real side of the economy is significant. On the other hand, the simulations show that when the shocks come from abroad, asset prices are not able to convey useful information about future developments. In this case, the rule augmented with output performs better since it can capture the external first-round effects. The simulations also show that monetary policy itself is not able to respond optimally when an unexpected shock hits the financial sector. This might suggest that rather different policy mix, such as unconventional monetary policy tools or fiscal measures should be implemented. However, none of these tools are available in the model, and therefore, cannot be tested.

APPENDIX

Table A1 Calibration A

Parameter	***Description***	***Value***
α	Share of capital used in the production process	0.330
β_E	Discount factor (entrepreneurs)	0.970
β_H^*	Discount factor (foreign households)	0.996
δ^K	Depreciation rate of capital	0.015
θ_F	Calvo parameter (importing retailers)	0.750
θ_H	Calvo parameter (domestic retailers)	0.500
θ_H^*	Calvo parameter (exporting retailers)	0.800
ι	Habit consumption parameter	0.800
κ^B	Adjustment costs parameter (banking sector)	10.000
κ^K	Adjustment costs parameter (capital producers)	1.500
m	LTV ratio of entrepreneurs	0.510
μ	Elasticity of substitution (home goods)	1.960
μ^*	Elasticity of substitution (foreign goods)	1.960
ν^B	Optimal level of capital-to-asset position	0.108
ξ_1	Adjustment costs parameter (capital utilization)	0.0345
ξ_2	Adjustment costs parameter (capital utilization)	0.0034
ρ_c	Autoregressive coefficient (consumption preference disturbance)	0.700
ρ_E	Autoregressive coefficient (technology disturbance)	0.900
ρ_{π^*}	Autoregressive coefficient (foreign inflation)	0.600
ρ_{r^b}	Autoregressive coefficient (interest rate on loans)	0.940
ρ_{r^*}	Autoregressive coefficient (foreign interest rate)	0.750
ρ_{y^*}	Autoregressive coefficient (foreign output)	0.750
ϱ_π	Taylor rule, weight on Inflation	1.800
ϱ_r	Taylor rule, interest rate persistence	0.800
σ_B	Standard deviation (bank capital disturbance)	0.500
σ_c	Standard deviation (consumption preference disturbance)	0.072
σ_E	Standard deviation (technology disturbance)	0.042
σ_{π^*}	Standard deviation (foreign Inflation)	0.013
σ_r	Standard deviation (policy interest rate)	0.003
σ_{r^b}	Standard deviation (loan rate disturbance)	0.003
σ_{r^*}	Standard deviation (foreign interest rate)	0.002
σ_{y^*}	Standard deviation (foreign output)	0.015
ς_F	Inflation indexation within Calvo pricing (importing retailers)	0.200
ς_H	Inflation indexation within Calvo pricing (domestic retailers)	0.130
ς_H^*	Inflation indexation within Calvo pricing (exporting retailers)	0.250
ϕ	Inverse Frisch-labour supply elasticity	3.000
b/GDP	Steady state (loans to GDP)	0.618
B^*/GDP	Steady state (foreign assets to GDP)	1.000
C/GDP	Steady state (consumption to GDP)	0.69
I/GDP	Steady state (investment to GDP)	0.268
$p_F y_F/GDP$	Steady state (imports to GDP)	0.637
q	Steady state (real exchange rate)	1.035
$qp_H^* y_H^*/GDP$	Steady state (exports to GDP)	0.672
r	Steady state (domestic quarterly net policy interest rate)	0.0041
r^b	State (quarterly net interest rate on loans)	0.0079
r^*	Steady state (foreign quarterly net interest rate)	0.0039

Notes: Direct calibration and steady-states computed based on data.

Table A2 Calibration B

Parameter	*Description*	*Value*
β_H	Discount factor (Domestic households)	0.9960
δ^B	Costs related to managing commercial bank's capital position)	0.0399
μ^B	Mark-up on loan rate	0.0039
ψ^*	Elasticity of the risk premium	0.0001
c^E/C	Steady state (consumption of entrepreneurs to aggregate consumption)	0.1193
c^H/C	Steady state (consumption of households to aggregate consumption)	0.8807
wl/GDP	Steady state (labour costs to GDP)	0.7229

Notes: Parameters and steady-states computed based on the steady-state relationships.

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