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Michał Brzoza-Brzezina

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Abstract

This paper compares the consequences of hitting the zero lower bound in small open and large closed economies. I costruct a two-economy New Kenynesian model and calibrate it so that one economy is small and open and the second large and closed. Then I conduct a number of experiments assuming that the zero lower bound binds for one or the other economy. At the ZLB bad shocks are amplified and good shocks dampened. I show that these modifications are much stronger in the large than in the small economy. As a result the large economy may suffer more at the ZLB.

JEL: E43, E52
Keywords: zero lower bound, small open economy, amplification of shocks

1   Introduction

Since the outbreak of the global financial crisis in 2007 several economies hit the zero lower bound on interest rates (ZLB). One particularly important effect of the ZLB is its role in changing the behavior of the economy. For instance, negative demand shocks (e.g. to time preference or investment) that occur in a ZLB period can lower output by much more than in normal times (Gust et al., 2012; Brzoza-Brzezina et al., 2015). Fiscal multipliers increase at the ZLB and money multipliers break down (Christiano et al., 2011; Albertini et al., 2014; van den End, 2014). Some shocks that increase output (e.g. a positive technology shock) can have much smaller, or even negative consequences for GDP at the ZLB (Neri and Notarpietro, 2014).[1]

This paper provides an explicit (and novel) comparison of the amplifying effects of the ZLB in large closed (LCE) and small open (SOE) economies and claims that the difference may be huge. The literature accentuates an important channel which potentially worsens the situation of SOEs at the ZLB. SOEs are prone to exchange rate appreciation that follows their inability to lower interest rates after a shock (Bäurle and Kaufmann, 2014; Bodenstein et al., 2009; Cook and Devereux, 2014). I show that there is a second channel that dominates the former. A different demand structure of the SOE (partly foreign demand oriented) makes it react less to shocks than the LCE. The interaction of this effect with the ZLB generates substantial differences in modification of shocks - amplification of bad shocks and dampening of good shocks at the ZLB is much stronger in an LCE than in a SOE.

Figure 1 can act as an informal motivation for the study. It presents the output gaps in large (US and EA) and small (CH, SE and UK) developed economies that hit the ZLB around 2009/2010. Clearly the gaps are much more negative in the LCEs. Of course, given the small number of countries and the multiple and diverse factors that affected them this evidence should be treated as anecdotal only.

The rest of the paper is structured as follows. Section 2 presents the model and its calibration, Section 3 shows the main results and Section 4 concludes.

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[1]Additionally a large literature shows that monetary authorities should adjust their strategies in presence of the zero lower bound, see eg. Adam and Billi (2006, 2007); Blanchard et al. (2010); Nakov (2008); Svensson (2003).

2 Model and calibration

I use a standard, new Keynesian two-economy model in the spirit of Smets and Wouters (2005) or Erceg et al. (2006) (though simpler). There are two symmetric economies, both populated by households, producers, retailers, final good aggregators and a central bank. Households derive utility from leisure and consumption (with habit formation assumed), can save in domestic and foreign bonds. Producers use labor provided by households to produce a homogeneous intermediate good. This is differentiated by retailers and then exported or sent to the domestic market. At this stage prices are sticky a la Calvo in local (consumer) currency. Final goods are aggregated from domestic and imported goods and used for consumption purposes. The central bank follows a Taylor rule that is standard but for the presence of the ZLB - interest rates cannot be negative. Below I present the problems of domestic agents, problems of foreign agents are analogous. Foreign variables are denoted with an asterix.

2.1 Households

Households work n_t, consume c_t and accumulate domestic B_t and foreign B_t^* bonds remunerated at the interbank rates R_t and R_t^* respectively. A representative household ι maximizes lifetime utility:

$$maxU_t = E_t \sum_{i=0}^{\infty} \beta^i e^{\varepsilon_{u,t+i}} \left[\frac{(c_{t+i}(\iota) - hc_{t+i-1})^{1-\sigma}}{1-\sigma} - A_n \frac{(n_{t+i}(\iota))^{1+\varphi}}{1+\varphi} \right] \quad (1)$$

subject to a sequence of budget constraints:

$$P_t c_t(\iota) + \frac{1}{R_t} B_{t+1}(\iota) + \frac{S_t}{\rho_t R_t^*} B_{t+1}^*(\iota) = W_t n_t(\iota) + B_t(\iota) + S_t B_t^*(\iota) + \Pi_t \quad (2)$$

where P_t, W_t, S_t and Π_t are, respectively the price of consumption goods, the nominal wage, the nominal exchange rate and dividends paid by imperfectly competitive intermediate goods producers. Moreover, β denotes the agents' discount rate and A_n is the weight of labor in utility. The inverse of the intertemporal elasticity of substitution in consumption is denoted by σ and φ is the inverse Frisch elasticity of labor supply. Consumption is subject to external habit persistence h. I assume that the intertemporal preference shock $\varepsilon_{u,t}$ follows an AR(1) process with persistence ρ_u and standard deviation of innovations σ_u. The international

risk premium ρ_t is assumed to depend on the ratio of foreign debt d_t to GDP y_t:

$$\rho_t = \gamma_\rho exp\left(\frac{d_t}{y_t}\right) \tag{3}$$

2.2 Producers

There are several types of firms: intermediate goods producers, home and foreign goods producers and final good producers.

2.2.1 Final good producers

Perfectly competitive final good producers purchase domestic and foreign goods y_H and y_F to produce a final good $\tilde{y}_t$. They maximize profits

$$P_t\tilde{y}_t - P_{H,t}y_{H,t} - P_{F,t}y_{F,t} \tag{4}$$

subject to the following technology

$$\tilde{y}_t = \left[\eta^{\frac{\mu-1}{\mu}}\left(y_{H,t}\right)^{\frac{1}{\mu}} + (1-\eta)^{\frac{\mu-1}{\mu}}\left(y_{F,t}\right)^{\frac{1}{\mu}}\right]^\mu \tag{5}$$

where η is the home bias in consumption and μ determines the elasticity of substitution between domestic and foreign goods.

2.2.2 Home and foreign goods producers

Homogeneous home and foreign goods are constructed from differentiated goods delivered by domestic and foreign intermediate goods producers respectively. In each country there are two types of aggregators. The domestic goods producer maximizes profits

$$P_{H,t}y_{H,t} - \int_0^1 P_{H,t}\left(j\right)y_{H,t}\left(j\right)dj \tag{6}$$

subject to production technology

$$y_{H,t} = \left(\int_0^1 y_{H,t}\left(j\right)^{\frac{1}{\mu_H}}dj\right)^{\mu_H} \tag{7}$$

The foreign goods producer maximizes profits

$$P_{F,t}y_{F,t} - \int_0^1 P_{F,t}\left(j\right)y_{F,t}\left(j\right)dj \tag{8}$$

subject to production technology

$$y_{F,t} = \left(\int_0^1 y_{F,t}(j)^{\frac{1}{\mu_F}} \, dj \right)^{\mu_F} \tag{9}$$

where $P_{H,t}$ and $P_{F,t}$ denote the prices of home and foreign goods while μ_H and μ_F determine the elasticities of substitution between their varieties.

2.2.3 Intermediate goods producers

Producers of intermediate goods $y_t(j)$ act under monopolistic competition. They produce specific (differentiated) goods and sell them to aggregators at home and abroad. They solve the same cost minimization problem, however, have different pricing problems for the domestic and foreign market. Local currency pricing is assumed, i.e. prices are sticky in the buyers currency. The first problem requires minimizing

$$c(y_t(j)) = \min_{n_t(j)} w_t n_t(j) \tag{10}$$

subject to technology

$$y_t(j) = z_t n_t(j) \tag{11}$$

where z_t denotes a productivity shock that follows an AR(1) process with persistence ρ_z and standard deviation of innovations σ_z. Intermediate goods producers set their prices according to the Calvo scheme. In each period, each producer j receives with probability $1 - \theta_H$ or $1 - \theta_H^*$ a signal to reoptimize her price on the domestic or foreign market respectively. She then maximizes:

$$\max_{\tilde{P}_{H,t}(j), \{y_{H,t}(j)\}_{s=0}^{\infty}} E_t \sum_s (\beta\theta_H)^s \Lambda_{t,t+s} \left(\frac{\tilde{P}_{H,t}(j)}{P_{t+s}} - mc_{t+s} \right) y_{H,t+s}(j) \tag{12}$$

when producing for the domestic market, or

$$\max_{\tilde{P}_{H,t}^*(j), \{y_{H,t}^*(j)\}_{s=0}^{\infty}} E_t \sum_s (\beta\theta_H^*)^s \Lambda_{t,t+s} \left(\frac{\tilde{P}_{H,t}^*(j) S_{t+s}}{P_{t+s}} - mc_{t+s} \right) y_{H,t+s}^*(j) \tag{13}$$

when producing for the export market. When setting prices they face downward sloping demand funtions that are solutions to maximizing (6) and its foreign analog respectively. In the equations above profits are avaluated according to

the households (i.e. the owners) marginal utility of consumption $\Lambda_{t,t+s} \equiv \frac{u'(c_{t+s})}{u'(c_t)}$, $\tilde{P}_{H,t}(j)$ and $\tilde{P}_{H,t}^*(j)$ the new price set on the domestic and foreign market by those firms that are allowed to change their price and mc_t the real marginal cost.

2.3 Closing and market clearing conditions

2.3.1 Monetary policy

The central bank follows a Taylor rule and is subject to the zero lower bound on interest rates (variables without time indices denote steady state levels)

$$\frac{R_t}{R} = max\left\{1, \left(\frac{R_{t-1}}{R}\right)^{\gamma_R}\left[\left(\frac{\pi_t}{\pi}\right)^{\gamma_\pi}\left(\frac{y_t}{y}\right)^{\gamma_y}\right]^{1-\gamma_R}\right\} \tag{14}$$

where GDP is defined as follows

$$y_t \equiv y_{H,t} + y_{H,t}^*\frac{1-\omega}{\omega} \tag{15}$$

2.3.2 Balance of Payments

The balance of payments satisfies

$$\omega p_{F,t}y_{F,t} - (1-\omega)q_t p_{H,t}^* y_{H,t}^* = \omega\left(d_t - \frac{q_t d_{t-1}\rho_{t-1}R_{t-1}^*}{q_{t-1}\pi_t^*}\right) \tag{16}$$

where $\omega \in (0;1)$ is the size of the home economy and q_t is the real exchange rate.

2.3.3 Market clearing

The labor market clears

$$\int_0^1 n_t(\iota)d\iota = \int_0^1 n_t(j)dj \tag{17}$$

and so does the market for final goods

$$\tilde{y}_t = c_t \tag{18}$$

2.4 Calibration

The calibration strategy is subordinated to the main goal of the paper, to document and explain the differences between small and large economies at the ZLB. Given this goal the calibration of structural parameters is fully symmetric, the

only difference being the size and home bias in trade of the two economies (so that one is large and closed and the other small and open). Consequently the calibration reflects rather a generic than a specific small and large economy. In particular Calvo probabilities and habits are set to .75, the intertemporal elasticity of substitution is 2, the smoothing parameter in the Taylor rule is .75, the response to inflation 2 and the response to output .125, roughly in line with much of the empirical DSGE literature (Smets and Wouters, 2005; Adolfson et al., 2007; Kolasa, 2009; Grabek et al., 2011). The elasticity of substitution between home and imported goods in the final aggregate is set to 2.5 (which implies $\mu = 1.66$). The small economy is assumed to produce 1% of world GDP and its openness (share of imports in final good) is calibrated at .28. The former number is chosen so that the LCE is not affected by external developments. The latter is consistent with data for Poland - a typical SOE - and not much different from many other SOEs. Calibrated parameters are presented in Table 1.The solution follows the piecewise-linear approach of Guerrieri and Iacoviello (2015).

3 Results

It has been recognized in the literature that being trapped at the ZLB can alter the behavior of the economy, in particular change its response to shocks. In what follows I compare the amplification of shocks that happen at the ZLB in a small and large economy. To allow for comparison I concentrate on shocks that occur both in small and large economies and the findings should be interpreted in this context.[2] To this end I choose a standard supply-side (technology) and a standard demand-side (time preference) shock (both modeled as AR(1) processes with autoreggression .75).

The experiment is done as follows. First I introduce a series of shocks that brings the economy to the ZLB (baseline scenario). This is done with a series of negative preference shocks that bring both economies into the ZLB for eight quarters. Of course, given the different reactions to shocks the shock series for the small and large economies differ, but the resulting baseline path for the interest rate is made approximately equal for the first 20 quarters.[3] Then I apply the proper shock whose propagation is to be analyzed. Both economies reach the ZLB in quarter 7 of the simulations and this is when the proper shock of interest (plus 1% for technology and minus 1% for preferences) is applied.

The results are shown in Figures 2-3. I present the reactions of output and the real exchange rate as the difference between the impulse response to the shocks of interest and the baseline scenario. The impulse response of the interest rate is left uncorrected to present better how the ZLB binds. Comparing the impulse responses for output with (solid line) and without (dashed line) the ZLB binding shows a crucial difference between the small and large economies. In the SOE the responses change only slightly, while in the closed economy their modification becomes substantial and can even - as in case of the technology shock - reverse the sign of output reaction. Noteworthy, this happens in spite of exchange rate appreciation that indeed occurs as described in the literature. Two questions stand out. First, why are the impulse responses in all cases corrected downwards at the ZLB? Second, why is the modification consistently stronger in the closed

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[2]This means that shocks that can occur only in one of the economies (e.g. international risk premium shocks) are beyond the scope of this study.

[3]To be precise, I first calculate the shocks to LCE such that the economy is trapped at the ZLB for 8 quarters. Then I turn these shocks off and calculate the series of preference shocks in the SOE such that the interest rate in the unconstrained (i.e. without the ZLB) model equals exactly the interest rate path in the unconstrained LCE for 20 quarters. The resulting interest rate paths in the constrained models are the same for 14 quarters (i.e. until the ZLB stops binding) and differ only marginally thereafter.

economy?

The answer to the first question is relatively simple. Both shocks lead (in normal times) to a fall in interest rates. If, because of the binding ZLB the interest rate cannot adjust, this generates a slowdown relative to the unconstrained model. The more novel and intriguing finding is the sharp difference in amplification between the open and closed economy. To explain the reasons it is useful to take a look at impulse responses in the unconstrained model. Figures 4 and 5 present the responses of output, inflation, interest rate and net exports to a +1% technology and -1% preference shock respectively. Output and inflation reactions to both shocks in the SOE are always above those in the LCE, and the reason is the role of net exports. Imports always decline, either reacting to cheaper domestic production (technology shock) or to lower domestic demand (preference shock). As a result, either the increase of output in the LCE is smaller (technology shock) or the decline of inflation and output deeper (preference shock). Consequently, the decline of the interest rate is always larger in the LCE. As a result, when the economy is at the ZLB, the inability to lower the interest rate has more serious consequences for the LCE. In particular the ZLB binds for longer magnifying the impact of the shock substantially. This effect is not compensated by the exchange rate appreciation in the SOE.

I conduct a number of robustness checks. First I change the parameters that may be crucial for the balance between the exchange rate effect and net exports effect. Two stand out: the elasticity of substitution between domestic and foreign goods and the import share $1 - \eta$. Both determine the construction of the final consumption good. I change the elasticity of substitution to 1.5 and to 6, but neither affects the results significantly. Regarding the import share, I experiment with values 0.5 and 0.1. Here the reactions are somewhat stronger, in particular in the latter case amplification increases somewhat in SOE (consistently with the economy becoming less open and hence, net exports playing a smaller role). But even in this case the difference between SOE and LCE remains striking. Finally, I experiment with a richer model - I allow for the presence of capital. This is owned by households and rented to intermediate good producers. This experiment allows to look at the amplification of an investment specific technology shock. The main findings are unaffected.

9

4 Conclusions

Since the outbreak of the financial crisis several economies have been trapped at the zero lower bound on interest rates. Anecdotal evidence shows that the consequences have been more serious for large closed than for small open economies. This paper checks in the context of a dynamic, structural model, how being trapped at the ZLB modifies the transmission of shocks in a small open and large closed economy. I show that amplification of bad shocks and dampening of good shocks is much weaker in the small than in the large economy.

There are two main channels whose net impact explains the result. First, the inability to lower interest rates generates an appreciation pressure in the small economy, hence, worsening its situation relative to the large economy. Second, the demand structure of the SOE, partly based on foreign demand, works in the opposite direction. Under our baseline calibration and robusness checks the second effect dominates, so that the reaction of the SOE to the analysed shocks is milder. This interacts with the zero lower bound in a powerfull way. Since the necessity to lower interest rates is smaller in the SOE, the inability to do so is less painfull. As a result the large economy may suffer more at the zero lower bound.

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Tables and figures

Figure 1: Output gaps in small and large economies trapped at the ZLB
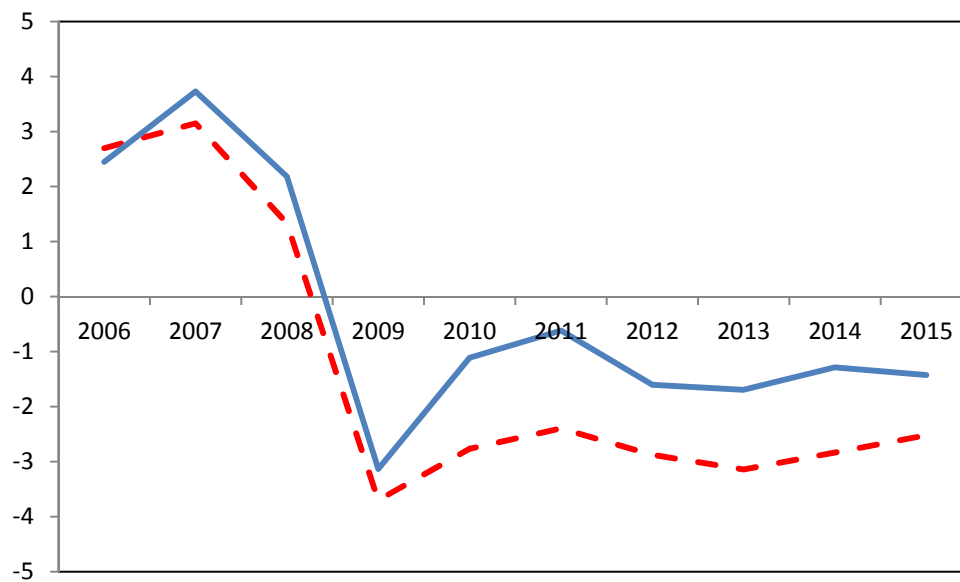
Note: Solid - CH+SE+UK, dashed - EA+US. Unweighted averages based on OECD data.

Table 1: Calibration

| Parameter	Value	Description
β, β^*	0.99	Discount factor
h, h^*	0.75	External habit
γ_ρ	0.0001	Risk premium elasticity
σ, σ^*	2	Inverse of intertemporal elasticity of substitution
φ, φ^*	2	Inverse of Frisch elasticity of labor supply
μ, μ^*	1.66	Parameter of final good aggregator
μ_H, μ_F, μ_H^*, μ_F^*	1.2	Parameters of home and foreign good aggregator
θ_H, θ_F, θ_H^*, θ_F^*	0.75	Calvo parameters
$1 - \eta$	0.28	Import share in the small economy
ω	0.01	Size of small economy
γ_R, γ_R^*	0.75	Autoreggresion in Taylor rule
γ_π, γ_π^*	2	Response to inflation in Taylor rule
γ_y, γ_y^*	0.125	Response to output in Taylor rule
ρ_u, ρ_u^*	0.75	Autoreggression of preference shock
ρ_z, ρ_z^*	0.75	Autoreggression of technology shock

Figure 2: Technology shock at the ZLB
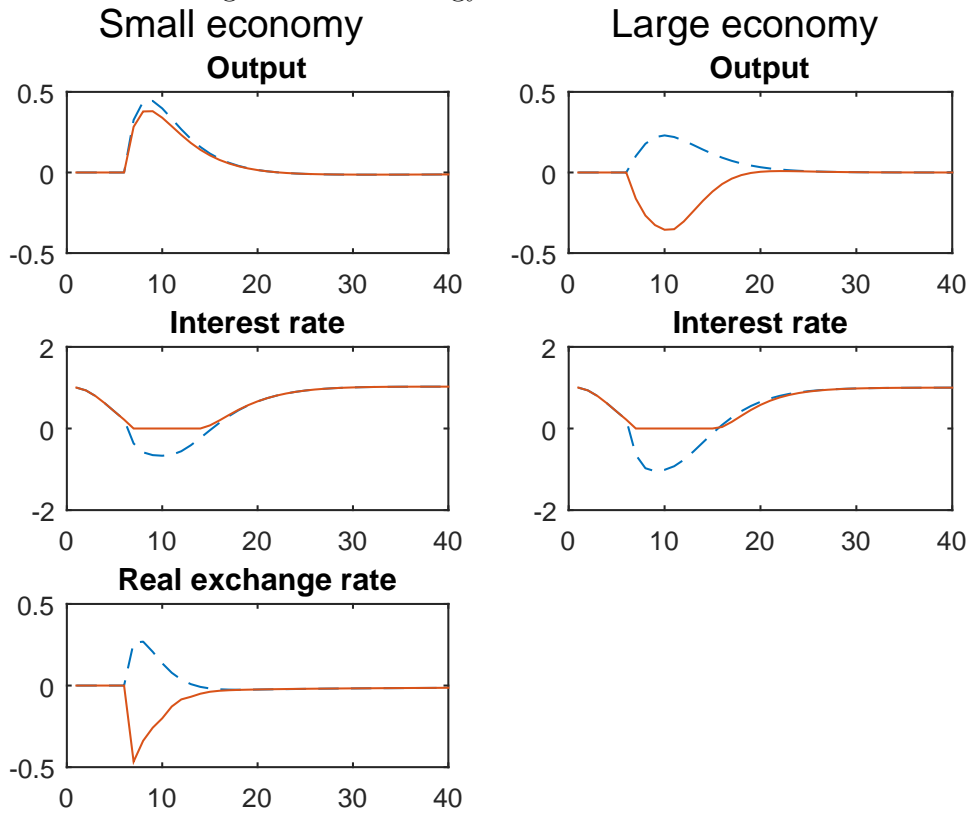
Note: Output and exchange rate (growth = depreciation) presented as percent deviations from baseline scenario. Solid - ZLB binding, dashed - ZLB not binding.

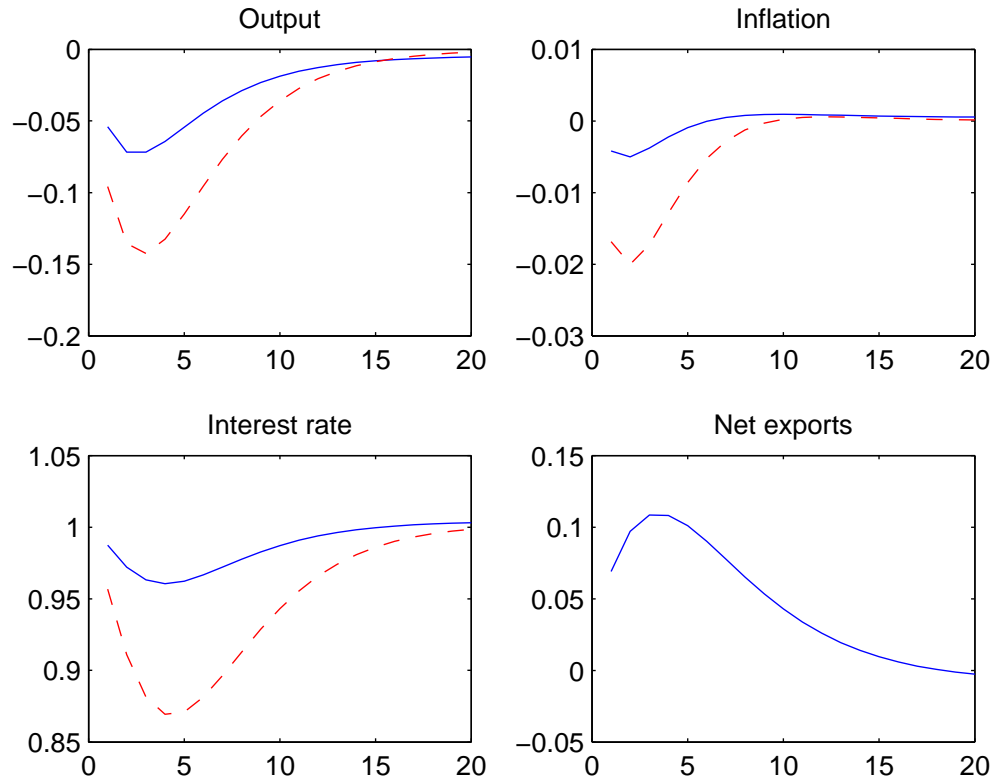Figure 3: Time preference shock at the ZLB
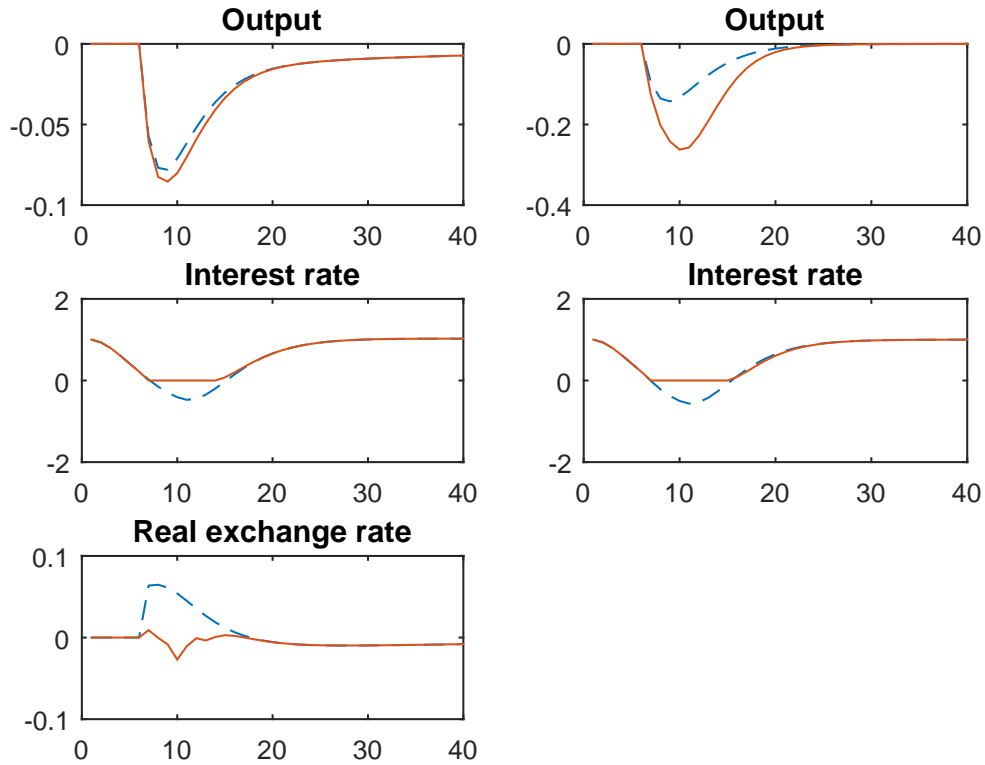
Note: Output and exchange rate (growth = depreciation) presented as percent deviations from baseline scenario. Solid - ZLB binding, dashed - ZLB not binding.

Figure 4: Technology shock - unconstrained model
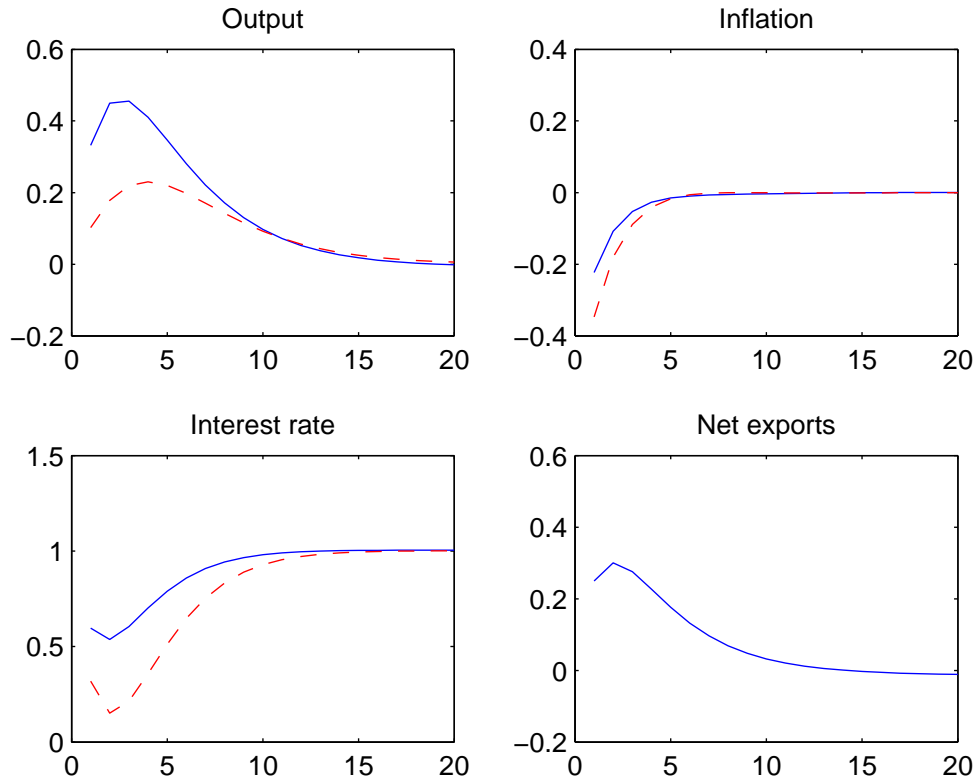
Output

Inflation

Interest rate

Net exports

Note: Output and inflation in percent deviations from steady state. Net exports in percent of GDP. Solid - SOE, dashed - LCE.

Figure 5: Time preference shock - unconstrained model

Note: Output and inflation in percent deviations from steady state. Net exports in percent of GDP. Solid - SOE, dashed - LCE.