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# banks and early deposit withdrawals in a new keynesian framework

by Alexander Totzek



# Banks and Early Deposit Withdrawals in a New Keynesian Framework\*

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## Abstract

When the current financial crisis has widened to a global economic crisis an urgent call for implementing financial markets and financial institutions in business cycle models emerged. By modelling commercial banks as a third type of economic agent, we are able to implement the feature of early deposit withdrawals in a New Keynesian model and to investigate the resulting implications for the real sector. The main results are that an extended withdrawal rate leads to persistent stagflationary effects which are dampened by reducing the refinancing costs of the banking sector and by increasing the loan rate stickiness.

*JEL classification:* E12, E44, E50, G01

*Keywords:* commercial banks, financial crises, deposit withdrawal

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# 1 Introduction

When the current financial crisis has widened to a global economic crisis an urgent call for implementing financial markets and financial institutions, especially commercial banks, in business cycle models emerged. One of these potential problems is the early deposit withdrawal as we can observe that the trust of the private sector in commercial banks declines as a consequence of today's financial crisis.

Figure 1 depicts large time deposits at commercial banks for the US economy.<sup>2</sup> The data is represented in logs and is de-trended by application of the Hodrick-Prescott filter. It shows that economic agents withdraw deposits after negative events hitting the financial markets. For instance, Figure 1 shows a massive decline in the amount of deposits after the 'Black Monday' (October 19, 1987), the 'Black Wednesday' (September 16, 1992), and the Asian crisis 1997/1998 as well as the Russian financial crisis in 1998 resulting in the failure of LTCM.

– Figure 1 about here –

Also in the subprime crisis households began to withdraw their money. This went as far as the British bank Northern Rock was even faced with a bank-run in September 2007, i.e. the extremist form of the money withdrawal.

There is, however, no attempt in this paper to depict all financial problems which have led to the subprime crisis. Instead, the aim is just to implement the feature of the early deposit withdrawal in a DSGE model. More precisely, we develop a New Keynesian model with explicit consideration of a banking sector allowing for early deposit withdrawals in order to analyze the resulting implications of the financial system for the whole economy.

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<sup>2</sup>The data is taken from the Economic Research Division of the Federal Reserve Bank of St. Louis.

Thereby, our paper is related to the recent literature as follows. As Henzel et al. (2009) and Hülsewig, Mayer, and Wollmershäuser (2009), we explicitly model a third type of economic agent – besides households and firms – namely the bank as a kind of profit maximizing firm that acts under monopolistic competition and is owned by private households. Banks are assumed to be provider of differentiated loans for firms using deposits from households. The underlying assumption is that firms require external credits to run production since they have to pre-finance their working capital as e.g. in Blinder (1987), Christiano and Eichenbaum (1992), Christiano et al. (1997, 2005), Barth and Ramey (2001), Passamani and Tamborini (2006), Hülsewig, Mayer, and Wollmershäuser (2009), and Rabanal (2007).

However, in contrast to Henzel et al. (2009) who have just implemented commercial banks for the purpose of generating an endogenous cost channel, we allow the household to withdraw deposits early within the period. One implication of this is that banks have to hold reserves to remain liquid over the period and potentially have to be refinanced.

There are several studies which investigate the impact of early deposit withdrawals on the financial system [e.g. Gilkeson et al. (1999), Ringbom et al. (2004) or Stanhouse and Stock (2004)]. Other studies apply such a framework for modelling problems in financial markets, as e.g. Carletti et al. (2007) who investigate the impact of bank mergers on liquidity needs or the famous study of Diamond and Dybvig (1983) which investigates optimal bank contracts for preventing bank-runs. But to our best knowledge, the feature of early deposit withdrawals has not yet been implemented in a New Keynesian framework.

The main results of our study are: (i) the extended withdrawal leads to temporary stagflation, (ii) even an impulse shock in the deposit withdrawal rate has

persistent real effects, (iii) the resulting destabilizing effects decrease in the degree of loan rate rigidity, (iv) the central bank can help stabilizing the system by decreasing the costs of refinancing, and (v) the shock in the withdrawal rate causes the marginal costs of both firms and banks to increase. Hence, our paper may also be regarded as a new approach for implementing a microfounded cost push shock in a New Keynesian framework.

The remainder is structured as follows. Section 2 presents the basic idea of the interaction between the types of economic agents and the effects resulting from deposit withdrawals. In section 3 the microfounded New Keynesian model for a closed economy with explicit consideration of the banking sector and the possibility for households to withdraw deposits early in a cash-in-advance framework is developed. The purpose of section 4 is to analyze the impulse responses to a shock in the withdrawal rate. The last section concludes.

## 2 Basic Idea

This section offers an economic intuition of how our model framework is constructed and what assignments are given to economic agents in the current approach.

Apart from consumption demand and labor supply decisions, the household can invest money in form of interest-bearing deposits with a duration of one period at a loan bank. Thereby, the household either withdraws its deposits early within the period or holds them until the end of the period and receives a next period return amounting to  $R_t^D D_t$  where  $R_t^D$  and  $D_t$  denote the gross nominal deposit rate and the deposits, respectively.

In the case of an early withdrawal, deposits are converted into liquid money

but the household will not receive any interest payments. Its payoff is then simply given by  $D_t$ . Hence, it is implicitly assumed that deposits contain an embedded withdrawal option. In contrast to the withdrawal per se which naturally leads to opportunity costs, the option is assumed to be costless [see e.g. Gilkeson et al. (2000) or Stanhouse and Ingram (2007)]. However, the household only withdraws its deposits with a probability of  $\delta_t$ .

Due to the temporal sequence of cash flows, firms have to pre-finance households' wages at the loan bank by credit. Hence, firms need external credits to run production. The bank's business is therefore assumed to be given by pre-financing the working capital of firms by using private deposits. Thereby, the amount of credit,  $L_t(i)$ , is limited by the amount of private deposits,  $D_t(i)$ , and the reserve holdings,  $\mathfrak{R}_t(i)$ , of the bank  $i$ . Reserves are held to ensure the bank against liquidity shortages as a consequence of withdrawals.

If the amount of actually withdrawn deposits, i.e. the demand for liquidity of the bank,  $\delta_t D_t(i)$ , exceeds the reserve holdings, the loan bank has to refinance the resulting liquidity gap using the lender of last resort with the refinancing rate,  $R_t^l$ . The lender of last resort replaces the interbank market for short-run capital. The main reason for this simplifying assumption is that in turbulent times/financial crises, interbank markets often fail [see e.g. Freixas et al. (2000) or Kahn and Santos (2005)]. For the sake of simplicity, we further assume that the lender of last resort possesses unlimited liquidity such that liquidity needs will not lead single banks into bankruptcy.

For illustrating the timing of these cash flows, Table 1 shows the balance sheet of the representative bank  $i$  under the assumption that the withdrawal rate  $\delta_t$  is constant, i.e.  $\delta_t = \delta$ .<sup>3</sup>

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<sup>3</sup>We will, of course, relax this assumption below.

– Table 1 about here –

At the beginning of the period,  $t = t_{start}$ , the households makes its deposits at bank  $i$ . The contributed amount of deposits, the bank transfers into loans provided to firms and into reserves. Thereby, the bank chooses the amount of reserves as  $\mathfrak{R}_t(i) = E[\delta_t|\Omega_t^B]D_t(i) = \delta D_t(i)$  to be ensured against the expected deposit withdrawal during the period.  $E_t$  and  $\Omega_t^B$  denote the rational expectations operator and the bank's information set in  $t$ , respectively.

Within the period, i.e.  $t = t_{in}$ , the constant fraction of households,  $\delta$ , now withdraws its deposits. Since the bank has accounted for this in its reserve holding decision, the balance sheet is even within that period.<sup>4</sup> There is thus no need for refinancing the bank in this case.

At the end of the period,  $t = t_{end}$  the fraction  $1 - \delta$  of households that has not withdrawn its deposits receives its interest payments,  $R_t^D D_t(i)$ . In addition, firms have to clear their debt, amounting to  $R_t^L L_t(i)$ .  $R_t^L$  denotes the gross loan rate. Since the bank is assumed to be a monopolistic competitor, the resulting profit should be positive.

However, in the following we do not assume the withdrawal rate to be constant anymore. Instead, we assume  $\delta_t$  to have a stochastic component, i.e.  $\delta_t = \delta + \nu_t$  where  $\delta$  and  $\nu_t$  represent the constant and the stochastic part of the early deposit withdrawal rate, respectively. By assumption,  $\nu_t$  is white noise.

As a consequence, the expected and the actual withdrawal rate do no longer coincide in general, since the stochastic component of the withdrawal rate is not included in the information set of the bank, i.e.  $\delta_t \neq E[\delta_t|\Omega_t^B]$  if  $\nu_t \neq 0$ . In this case, the bank cannot ensure its balance sheet to be even within the

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<sup>4</sup>Since the withdrawal rate is here assumed to be constant over time, the expectations of the bank given  $\Omega_t^B$  are correct, i.e.  $E_t[\delta_t|\Omega_t^B] = \delta_t = \delta$ .



period anymore. In fact, it can just ensure itself against the expected withdrawal,  $E[\delta_t|\Omega_t^B]D_t(i) = \delta D_t(i)$ . Thus, if a positive shock occurs, i.e.  $\nu_t > 0 \Leftrightarrow \delta_t > E_t[\delta_t|\Omega_t^B]$ , the bank does not hold enough reserves to remain liquid. The bank has to refinance the resulting liquidity gap on short notice using the lender of last resort.<sup>5</sup>

### 3 Microfoundation

In this section the microfounded New Keynesian model for a closed-economy with early deposit withdrawals in a cash-in-advance (CIA) framework is developed. Besides the central bank, we will distinguish between three types of economic agents, namely households, firms, and banks. Thereby and in contrast to Henzel et al. (2009) and Hülsewig, Mayer, and Wollershäuser (2009), firms and banks are assumed to be faced with quadratic adjustment costs. Moreover, the decision problem of a bank complicates when allowing for deposit withdrawals.

#### 3.1 Households

The household maximizes its expected life-time utility value given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{1}{1+\eta} N_t^{1+\eta} \right) \quad (1)$$

taking into account the budget constraint

$$P_t C_t + D_t + M_t = W_t N_t + M_{t-1} + \delta_{t-1} D_{t-1} + (1 - \delta_{t-1}) R_{t-1}^D D_{t-1} + \Pi_t + T_t \quad (2)$$

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<sup>5</sup>Correspondingly, if a contractionary shock occurs, i.e.  $\delta_t < E_t[\delta_t|\Omega_t^B]$ , the bank has a surplus of deposits during the period. For the sake of simplicity, we assume that the bank cannot invest this surplus in any kind of interest bearing asset within the current period.

where  $C_t$ ,  $N_t$ ,  $M_t$ ,  $D_t$ , and  $T_t$  represent the household's real consumption expenditure, the labor supply, money holdings, deposit holdings, and transfers in period  $t$ , respectively.  $P_t$  and  $W_t$  denote the aggregate price level and the nominal wage.  $\delta_t$  is the probability of withdrawing deposits early.  $R_t^D$  represents the gross deposit rate. The inverse of the intertemporal elasticity of substitution and the inverse of the Frisch elasticity of labor supply are represented by  $\sigma$  and  $\eta$ , respectively.  $\beta$  is a discount factor.  $\Pi_t$  denotes the profit income which results from the ownership of both firms and banks.

In addition, the household has to consider the CIA condition

$$P_t C_t \leq M_{t-1} + \delta_{t-1} D_{t-1} + W_t N_t \quad (3)$$

According to (3), goods are assumed to be traded at the beginning of each period, whereas deposit trades are done afterwards. Finally, the household obtains its profit income and transfers at the end of each period, while the labor income is paid at the beginning of the period. The timing of trades is illustrated in Figure 2.

– Figure 2 about here –

The Euler consumption equation and the optimal labor supply are now determined by maximizing (1) subjected to (2) and (3)

$$E_t C_{t+1}^{-\sigma} = \beta E_t \left\{ C_{t+2}^{-\sigma} \frac{R_t^D}{\pi_{t+2}} \right\} \quad (4)$$

$$N_t^\eta C_t^\sigma = \frac{W_t}{P_t} \quad (5)$$

where the inflation rate,  $\pi_t$ , is defined as  $P_t/P_{t-1}$ . Note that the time shift in the Euler consumption equation in comparison to the canonical New Keynesian

model results from the application of the CIA approach. The optimal labor supply equation is totally standard. For the sake of simplicity, we will omit the mathematical expectations operator,  $E_t$ , in the following.

## 3.2 Firms

In the following we turn to the production side. Thereby, we will distinguish final and intermediate good producers indexed by  $f$ .

### 3.2.1 Final Good Producers

The final good producer acts under perfect competition. For production he bundles a continuum of differentiated intermediate goods using the CES technology,  $Y_t \equiv \left( \int_0^1 Y_t(f)^{\frac{\xi-1}{\xi}} df \right)^{\frac{\xi}{\xi-1}}$ , where  $Y_t(f)$  and  $Y_t$  represent the differentiated intermediate good and the final good, respectively.  $\xi$  is the elasticity of substitution between intermediate goods.

By cost minimization, the goods demand is then given by

$$Y_t(f) = \left( \frac{P_t(f)}{P_t} \right)^{-\xi} Y_t \quad (6)$$

with the corresponding aggregate price index,  $P_t$ , following  $P_t = \left( \int_0^1 P_t(f)^{1-\xi} df \right)^{\frac{1}{1-\xi}}$ .

### 3.2.2 Intermediate Good Producers

The production function of the monopolistic intermediate good producer is assumed to be of Cobb-Douglas-type with decreasing returns on labor

$$Y_t(f) = N_t(f)^{1-\alpha} \quad (7)$$

Labor thus represents the only input factor.

As mentioned above, firms have to pre-finance wages due to the timing assumptions about cash flows. Thus, their cost minimization problem includes the producers' real wage which is defined as the consumers' real wage,  $W_t/P_t$ , times the gross loan rate,  $R_t^L$ . The real marginal costs of the domestic intermediate good producer are then given by

$$MC_t(f) = \frac{1}{1-\alpha} \frac{R_t^L W_t}{P_t} Y_t(f)^{\frac{\alpha}{1-\alpha}} \quad (8)$$

Moreover, we assume the intermediate good producer to be faced with quadratic adjustment costs in the spirit of Rotemberg (1982) amounting to  $\frac{\theta_F}{2} \left( \frac{P_t(f)}{P_{t-1}(f)} - 1 \right)^2 Y_t$  where  $\theta_F$  is interpreted as the menu costs of a firm resulting from relative price changes.

The profit of the representative intermediate good producer in real terms is then given by

$$E_t \sum_{t=0}^{\infty} \Delta_{0,t} \left[ \frac{P_t(f)}{P_t} Y_t(f) - MC_t(f) Y_t(f) - \frac{\theta_F}{2} \left( \frac{P_t(f)}{P_{t-1}(f)} - 1 \right)^2 Y_t \right] \quad (9)$$

with  $\Delta_{0,t} = \beta^t \frac{U_{C,t}}{U_{C,0}}$  denoting the real stochastic discount factor. Differentiating (9) over  $P_t(f)$  subjected to the goods demand (6) yields

$$\xi - 1 = \xi MC_t - \theta_F (\pi_t - 1) \pi_t + \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \theta_F (\pi_{t+1} - 1) \pi_{t+1} \frac{Y_{t+1}}{Y_t} \quad (10)$$

with  $\frac{\Delta_{0,t+1}}{\Delta_{0,t}} = \beta \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma}$ . By log-linearizing (10) around a zero inflation steady state ( $\bar{\pi} = 1$ ) and by inserting the log-linearized version of (8), we obtain the

Phillips curve given by<sup>6</sup>

$$\hat{\pi}_t = \beta \hat{\pi}_{t+1} + \omega_w \left( \widehat{R}_t^L + \widehat{W}_t - \widehat{P}_t \right) + \omega_y \widehat{Y}_t \quad (11)$$

with  $\omega_w = (\xi - 1)/\theta_F$  and  $\omega_y = (\xi - 1)\alpha/(\theta_F[1 - \alpha])$ . Equation (11) deviates from the canonical Phillips curve since producers' and consumers' real wages ( $\widehat{R}_t^L + \widehat{W}_t - \widehat{P}_t$  and  $\widehat{W}_t - \widehat{P}_t$ ) do not coincide in the present approach. Hence, like Hülsewig, Mayer, and Wollmershäuser (2009) or Henzel et al. (2009) and in contrast to Bernanke and Gertler (1995) among others we obtain an endogenous cost channel, i.e. the interest rate has a direct effect on the marginal costs of firms.<sup>7</sup>

### 3.3 Banks

Like Hülsewig, Mayer, and Wollmershäuser (2009) and Henzel et al. (2009) we assume the bank to be a kind of profit maximizing firm but in contrast to these studies, the banks have to hold reserves to be ensured against the expected withdrawals. Moreover, banks are potentially faced with refinancing costs when getting into a liquidity shortage.

Furthermore, we assume that banks provide differentiated loans for the intermediate good producers and act under monopolistic competition.<sup>8</sup> Like Carletti, Hartmann, and Spagnolo (2007) and Henzel et al. (2009) we argue that the differentiation of loans is caused by different specifications of commercial banks in types of lending or in geographical space. The corresponding empirical support is for example given by Cocco (2009) who find that even though the monopoly

<sup>6</sup>In the following, hats denote deviations from the respective steady state.

<sup>7</sup>As will be shown in the next section, the loan rate is an increasing function of the interest rate.

<sup>8</sup>In contrast, Goodfriend and McCallum (2007) and Tillmann (2009) assume for the sake of simplicity that banks act under perfect competition.

power of banks has declined in the last decades, it still cannot be neglected.

As mentioned in section 2, a bank's business consists of pre-financing working capital by credit and holding reserves using deposits. Banks are thereby assumed to be faced with three kinds of costs, namely acquisition costs, refinancing costs, and adjustment costs.

The acquisition costs are simply given by the payoff of the households when holding deposits,  $(1 - \delta_t)R_t^D D_t(i) + \delta_t D_t(i)$ . The refinancing costs, on the other hand, are given by the gross refinancing rate,  $R_t^I$ , times the amount that the bank has to refinance, i.e. the difference between the actually withdrawn deposits,  $\delta_t D_t(i)$ , and the amount of held reserves given the probability,  $\Phi(\delta_t)$ , that the latter difference is positive. More precisely,  $\Phi(\delta_t)$  is given by

$$\Phi(\delta_t) = \text{Prob}\{\delta_t D_t(i) - \mathfrak{R}_t(i) > 0\} = \text{Prob}\{\nu_t > 0\} \quad (12)$$

considering  $\delta_t = \delta + \nu_t$  and  $\mathfrak{R}_t(i) = E[\delta_t | \Omega_t^B] D_t(i) = \delta D_t(i)$ . Equation (12) shows that the probability of getting into a liquidity shortage can be simplified to the probability that the shock in the withdrawal rate is positive.<sup>9</sup>

The studies of Berger and Udell (1992), Parlous and Rajan (2001), Henzel et al. (2009), and Hülsewig, Mayer, and Wollmershäuser (2009) show that the loan rate is not totally flexible. We thus assume that banks are faced with quadratic adjustment costs given by  $\frac{\theta_B}{2} \left( \frac{R_t^I(i)}{R_{t-1}^I(i)} - 1 \right)^2 L_t$  where  $\theta_B$  is interpreted as the reputation costs of a bank resulting from relative changes in their loan rate.

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<sup>9</sup>Note that for all distributions of  $\nu_t$  with zero mean that are not skewed, equation (12) is just equal to 0.5.

The profit of the representative bank in nominal terms is then given by

$$E_t \sum_{t=0}^{\infty} \Psi_{0,t} \left[ R_t^L(i) L_t(i) - (1 - \delta_t) R_t^D D_t(i) - \delta_t D_t(i) - R_t^I [\delta_t D_t(i) - \mathfrak{R}_t(i)] \Phi(\delta_t) - \frac{\theta_B}{2} \left( \frac{R_t^L(i)}{R_{t-1}^L(i)} - 1 \right)^2 L_t \right] \quad (13)$$

where  $\Psi_{0,t} = \beta^t \frac{P_t U_{C,t}}{P_0 U_{C,0}}$  denotes the nominal stochastic discount factor. The optimal loan demand

$$L_t(i) = \left( \frac{R_t^L(i)}{R_t^L} \right)^{-\zeta} L_t \quad (14)$$

follows from the costs minimization of the firms with respect to the loan bundle,  $L_t$ , defined as  $\left( \int_0^1 L_t(i)^{\frac{\zeta-1}{\zeta}} di \right)^{\frac{\zeta}{\zeta-1}}$  where  $\zeta > 1$  represents the interest rate elasticity of the loan demand.

Moreover, the bank has to consider a balance sheet constraint given by

$$D_t(i) \geq L_t(i) + \mathfrak{R}_t(i) \quad (15)$$

which implies that the supplied amount of credit is restricted by the amount of deposits and the amount of reserves hold by the bank.

Maximizing (13) subjected to (14) and (15) yields the optimal loan rate

$$R_t^L(i) = \frac{\zeta}{\zeta - 1} \left[ (1 - \delta_t) R_t^D + \delta_t (1 + \Phi(\delta_t) R_t^I) \right] - \frac{\theta_B}{\zeta - 1} \left\{ \left( \frac{R_t^L(i)}{R_{t-1}^L(i)} - 1 \right) \frac{R_t^L(i)}{R_{t-1}^L(i)} - \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left( \frac{R_{t+1}^L(i)}{R_t^L(i)} - 1 \right) \frac{R_{t+1}^L(i)}{R_t^L(i)} \frac{L_{t+1}}{L_t} \right\} \quad (16)$$

where  $R_t^I = \Upsilon R_t^D$ .  $\Upsilon > 1$  represents the constant mark-up of the lender of last resort. As Stanhouse and Stock (2004) claim, the optimal loan rate (16)

is proportional to the withdrawal rate. Note that in absence of the loan rate rigidity, i.e.  $\theta_B = 0$ , the optimal loan rate simplifies to

$$R_t^L(i) = \frac{\zeta}{\zeta - 1} [(1 - \delta_t)R_t^D + \delta_t(1 + \Phi(\delta_t)R_t^I)] \quad (17)$$

The loan rate can then be represented as a constant mark-up over the weighted average of the banks' marginal costs in the cases with and without early withdrawals, i.e. with a probability of  $1 - \delta_t$  the loan rate is simply given by a constant mark-up over the deposit rate, whereas with the counter probability the bank must also consider refinancing costs.<sup>10</sup>

Correspondingly to the derivation of the Phillips curve, we assume that all banks are faced with the same maximization problem. Thus, the index  $i$  can be neglected when aggregating equation (16). Log-linearizing the loan rate reaction function yields

$$\widehat{R}_t^L = \beta\omega_l\widehat{R}_{t+1}^L + \omega_l\widehat{R}_{t-1}^L + \omega_d\widehat{R}_t^D + \omega_i\widehat{R}_t^I + \omega_\delta\nu_t \quad (18)$$

with

$$\begin{aligned} \omega_l &= \frac{\theta_B}{\zeta(1 + \bar{\delta}\Phi\Upsilon) + \theta_B(1 + \beta)}, & \omega_d &= \frac{(1 - \bar{\delta})\zeta}{\zeta(1 + \bar{\delta}\Phi\Upsilon) + \theta_B(1 + \beta)} \\ \omega_i &= \frac{\bar{\delta}\Phi\Upsilon\zeta}{\zeta(1 + \bar{\delta}\Phi\Upsilon) + \theta_B(1 + \beta)}, & \omega_\delta &= \frac{(\beta + \Phi\Upsilon - 1)\zeta}{\zeta(1 + \bar{\delta}\Phi\Upsilon) + \theta_B(1 + \beta)} \end{aligned} \quad (19)$$

<sup>10</sup>If we further assume that the households do not have the possibility to withdraw their deposits early ( $\delta_t = 0$ ), equation (17) simplifies to  $R_t^L(i) = \frac{\zeta}{\zeta-1}R_t^D$ , i.e. the optimal loan rate is then given by a constant mark-up over the deposit rate as in Dressler and Li (2009), Henzel et al. (2009), or Tillmann (2009).



### 3.4 Aggregate Resource Constraint

The aggregate resource constraint is obtained by substituting the real profits of banks and firms into the aggregated budget constraint of the households. The non-linear representation is given by

$$C_t = Y_t - \frac{\theta_F}{2} [\pi_t - 1]^2 Y_t - \frac{\theta_B}{2} \left[ \frac{R_t^L}{R_{t-1}^L} - 1 \right]^2 \frac{L_t}{P_t} \quad (20)$$

Note that we assume that the earnings of the lender of last resort resulting from refinancing banks are transferred back to the households.<sup>11</sup>

### 3.5 The Model

The model for a closed-economy framework with explicit consideration of a banking sector and the possibility of early deposit withdrawals derived above consists of equations (11), (18), and the log-linear versions of (4), (5), (7), and (20). Moreover, we set  $\widehat{R}_t = \widehat{R}_t^D$  which implies that money market credits and deposits are assumed to be perfect substitutes [see Freixas and Rochet (1997)] at least in log-linear form.<sup>12</sup> Finally, monetary policy is assumed to be of Taylor-type

$$\widehat{R}_t = (1 - \phi)(\lambda_\pi \widehat{\pi}_t + \lambda_y \widehat{Y}_t) + \phi \widehat{R}_{t-1} \quad (21)$$

## 4 Simulations

In this section, we present our baseline calibration and the impulse responses to a one-off shock in the stochastic component of the early deposit withdrawal rate

<sup>11</sup>Further note that on aggregate the CIA condition (3) and the balance sheet constraint of the banks (15) both hold with equality.

<sup>12</sup>See de Bondt (2005) for an approach where banks have also monopoly power in the deposit market.

of the households are discussed.<sup>13</sup>

In the baseline calibration, we set the discount factor,  $\beta$ , equal to 0.99 which implies a steady state value of the annual interest rate of about 4%. The inverse of the elasticity of intertemporal substitution,  $\sigma$ , and the inverse of the Frisch elasticity of labor supply,  $\eta$ , are both set equal to 2. Moreover, we set  $\alpha$  equal to 0.2 as widely applied in the literature. The price elasticity of demand for the intermediate good,  $\xi$ , and the loan elasticity,  $\zeta$ , are assumed to be equal to 6 and 3.5, implying a mark-up over the nominal costs of 20% and 40%, respectively [see Hülsewig, Mayer, and Wollmershäuser (2009)].

The adjustment costs of a bank,  $\theta_B$ , are chosen equal to 9.69 to obtain an equivalent slope of the loan rate reaction function as in the empirically estimated model of Henzel et al. (2009). Moreover, we set  $\theta_F$  equal to 14.72 to obtain a slope of the Phillips curve equal to that of the baseline New Keynesian model with Calvo pricing [see e.g. of Galí (2008)] with an average price duration of four quarters, i.e. a Calvo parameter equal to 0.75.<sup>14</sup>

We set the steady state value of the withdrawal rate,  $\bar{\delta}$ , equal to the minimum reserve requirement of the European Central Bank (2%) since this amount of reserves is designed to satisfy average withdrawal demands.<sup>15</sup> The standard deviation of the stochastic term in the withdrawal rate – the shock – is set equal to 1, implying an increase from 2% to 4%. The shock does not occur with any persistence. Finally, the central bank’s mark-up over the interest rate,  $\Upsilon$ , is assumed to be equal to 1.03. The coefficients of the Taylor rule (21)  $\phi$ ,  $\lambda_\pi$ , and  $\lambda_y$  are set equal to 0.9, 1.5, and 0.5, respectively.

<sup>13</sup>For all simulations we apply Dynare V.3 [see Juillard (2001)].

<sup>14</sup>The estimated model of Henzel et al. (2009) is a hybrid framework. We thus cannot use their calibration for the current purely forward-looking Phillips curve.

<sup>15</sup>Note that in our framework the average and the expected withdrawal coincide, if the time horizon tends to infinity.

– Figure 3 about here –

The impulse responses to a temporary one-off shock in the stochastic component of the withdrawal rate are illustrated in Figure 3 for the baseline calibration.<sup>16</sup> A first notable result is that in our framework even a one-off shock leads to persistent real effects. The endogenous persistence in comparison to the canonical New Keynesian model results from the application of the CIA condition and the hybrid representation of the loan rate reaction function.<sup>17</sup> Additionally, the smoothing term in the Taylor rule leads to some persistence as well. More precisely, by setting the smoothing parameter of the interest rate rule equal to zero, the system reaches the steady state only one period earlier. Hence, the smoothing term in the Taylor rule cannot be the crucial factor for endogenous persistence.

By calculating the system without considering the CIA condition (3), it turns out that the time paths still prove to be persistent – even in the case a smoothing term in the Taylor rule is nonexistent. In this case the only backward-looking term is in the loan rate reaction function. The time-shift in the Euler consumption equation vanishes. However, in this case the steady state is not reached significantly earlier. The major part of the persistence thus proves out to be caused by the loan rate reaction function rather than the time-shift in the Euler consumption function.

As mentioned in section 2, an expansionary shock in the deposit withdrawal rate causes the banks to underestimate the amount of households' withdrawals. The representative bank thus does not hold enough reserves and must therefore

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<sup>16</sup>Note that the withdrawal rate is depicted in percentage points, whereas the remaining variables in Figure 3, 4, and 6 are expressed in percentage deviations from their respective steady state values.

<sup>17</sup>Remark: The canonical New Keynesian model is purely forward-looking and thus has no intrinsic dynamic.

refinance the resulting liquidity gap at the lender of last resort. As a result, the banks' marginal costs for pre-financing the working capital of firms and hence also the loan rate increase. On the production side, this leads to higher marginal costs for the intermediate good producers, too. At this point, it is thus worthwhile to mention that the shock in the withdrawal rate leads to a rise in the marginal costs of both firms and banks. Hence, this paper may also be regarded as a new approach for implementing a microfounded cost push shock in a New Keynesian model.

The initial increase in marginal costs of firms leads, on the one hand, to an increase in inflation and, on the other hand, to a decrease in labor demand and thus to lower output according to the assumed production function. Taking the responses of output and inflation together, the shock leads, on impact, to stagflation. In addition, due to the decreasing labor demand the consumers' real wage declines while, on the other hand, this effect is dominated on the production side by an increasing loan rate. As a result, the shock drives a wedge between the two wages as the producers' real wage rises while the consumers' real wage declines.

Under the standard Taylor rule with or without smoothing the central bank will raise the nominal interest rate since the increase in inflation dominates the decrease in output.<sup>18</sup> An economic intuition behind this reaction of the central bank may be to raise the private opportunity costs of a withdrawal. However, this reaction amplifies the upward pressure on the loan rate since the increase in the interest rate leads to higher acquisition and refinancing costs for the banks. This directly follows from the banks' profit given by equation (13). According to (18), it is thus obvious that the loan rate is an increasing function in the interest

<sup>18</sup>Of course, this effect is additionally amplified by the relation  $\lambda_\pi > \lambda_y$ .

rate.

Figure 4 shows the impulse responses for different degrees of the loan rate stickiness, i.e. for different values of the banks' adjustment costs,  $\theta_B$ . Obviously, there exist two opposing effects. The higher the degree of loan rate stickiness is: (i) the more persistent the real effects of all variables and (ii) the lower the initial impact of the shock will be.

– Figure 4 about here –

Economically, these results are quite intuitive since, as mentioned above, the shock leads to increasing marginal costs of banks which have to be covered. Thus, the banks want to raise their loan rate. This directly follows from equation (16). However, if the loan rate becomes more sticky – as changes are more costly – the resulting adjustment path of the loan rate and thus the effects for the whole economy will become more persistent but of course dampened on impact. Naturally, a lower impact reaction stabilizes the system while the opposite holds true for the effect on persistence.

By having a look at the volatility of the model variables, it turns out that the overall effect resulting from an increasing loan rate stickiness stabilizes the system. For this reason, Figure 5 depicts the variances of inflation, the output gap, the nominal interest rate, and the loan rate. All these variances decline in the degree of the loan rate stickiness.<sup>19</sup> This result is in line with the empirical study of Ariss (2009) which shows that an increase in the degree of market power in the banking sector leads to more stable financial markets.<sup>20</sup>

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<sup>19</sup>Since there is only one input factor, labor, the corresponding variance of this variable will behave qualitatively equivalent to the variance of the output. Further note that the variances of the two real wages decline in  $\theta_B$ , too.

<sup>20</sup>Note that the Rotemberg parameter,  $\theta_B$ , also reflects the market power of banks. If  $\theta_B \rightarrow 0$ , banks act under complete competition; the loan rate is completely flexible.

– Figure 5 about here –

Taking a look at the coefficients in (19), it is obvious that the shock impact,  $\omega_\delta$ , is a decreasing function in the degree of loan rate stickiness. Additionally, this effect is amplified since the coefficients on the refinancing rate,  $\omega_i$ , and the deposit rate,  $\omega_d$ , decrease as well. As the overall effect is negative, the opposing effect on persistence resulting from the higher weight on past loan rate,  $\omega_l$ ,<sup>21</sup> thus cannot be the crucial factor, although it naturally dampens the stabilizing effect resulting from a lower impact reaction.<sup>22</sup>

We obtain a slightly different result when varying the mark-up of the central bank,  $\Upsilon$ , i.e. by altering the costs of refinancing. From Figure 6 we can directly observe that in this case the net effect is unambiguous. Decreasing the mark-up,  $\Upsilon$ , clearly enhances stability without any opposing effects.

– Figure 6 about here –

This result is very intuitive, too, since by reducing the refinancing costs the punishment of getting into a liquidity shortage and thus the marginal costs of banks are decreased. By taking a closer look at equation (16), it is obvious that a decline in the mark-up directly leads to decreasing marginal costs for the banks. According to (19) the shock impact is thus lowered. Moreover, because the persistence parameter,  $\omega_l$ , is a decreasing function in  $\Upsilon$ , the persistence effect helps stabilizing the system in this case.

In the long-run a central bank's policy concerning a decrease in this mark-up could naturally lead to moral hazard problems since the banks seem to be rewarded for their mismanagement as they underestimate the amount of early

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<sup>21</sup>Remark:  $d\omega_l/d\theta_B > 0$ .

<sup>22</sup>We obtain an equivalent result by decreasing the interest rate elasticity of the loan demand,  $\zeta$ , and by decreasing the elasticity of substitution between intermediate goods,  $\xi$ .

withdrawals. In the short-run, however, the reduction of the refinancing costs in turbulent times, of course, represents a supporting reaction of the central bank for stabilizing the system.

## 5 Conclusion

By explicitly modelling a third kind of economic agent – the bank as a kind of profit maximizing firm – we are able to investigate the financial problems arising from early deposit withdrawals within a New Keynesian framework.

We show that a one-off shock in the withdrawal rate leads to persistent and stagflationary real effects. Due to the expansionary shock in the withdrawal rate the marginal costs of both firms and banks increase. Hence, this paper may also be regarded as a new approach for implementing a microfounded cost push shock in a New Keynesian model.

Moreover, we show that the higher the reputation costs of a bank are, i.e. the more sticky the loan rate is, the more stable the system will be, as the impact effect dominates the effect on persistence. On the other hand, by decreasing the refinancing costs of banks, the impact effect co-moves with the effect on persistence. The overall effect then stabilizes the system without any opposing effects.

The purpose of further research could be the extension of the presented model to an open economy in order to depict exchange rate implications and international cash flows as well as to investigate international policy coordination. Maybe, it could also be helpful to implement the interbank sector.

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# Figures

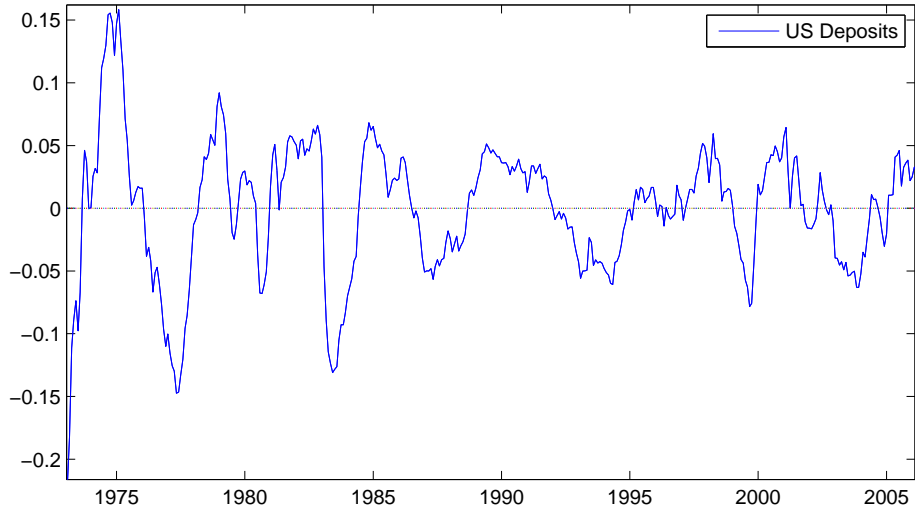


Figure 1: Large Time Deposits at Commercial Banks in the US economy [HP filtered data in logs]

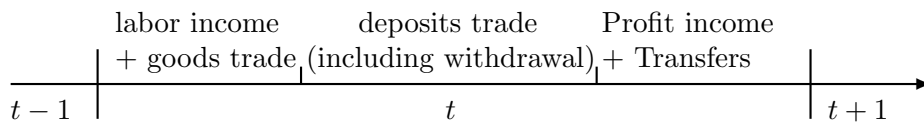


Figure 2: Trade timing

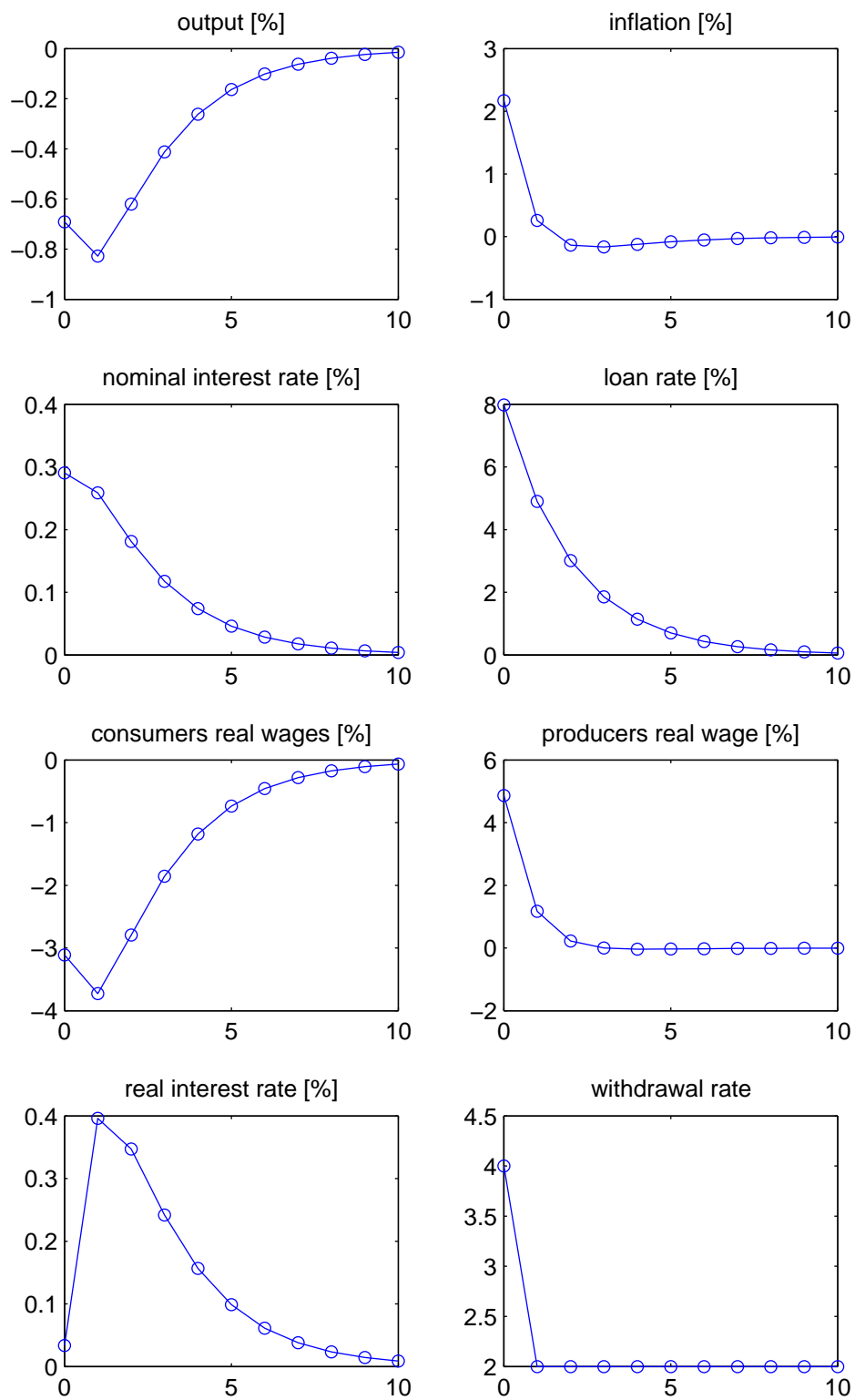


Figure 3: Time paths  
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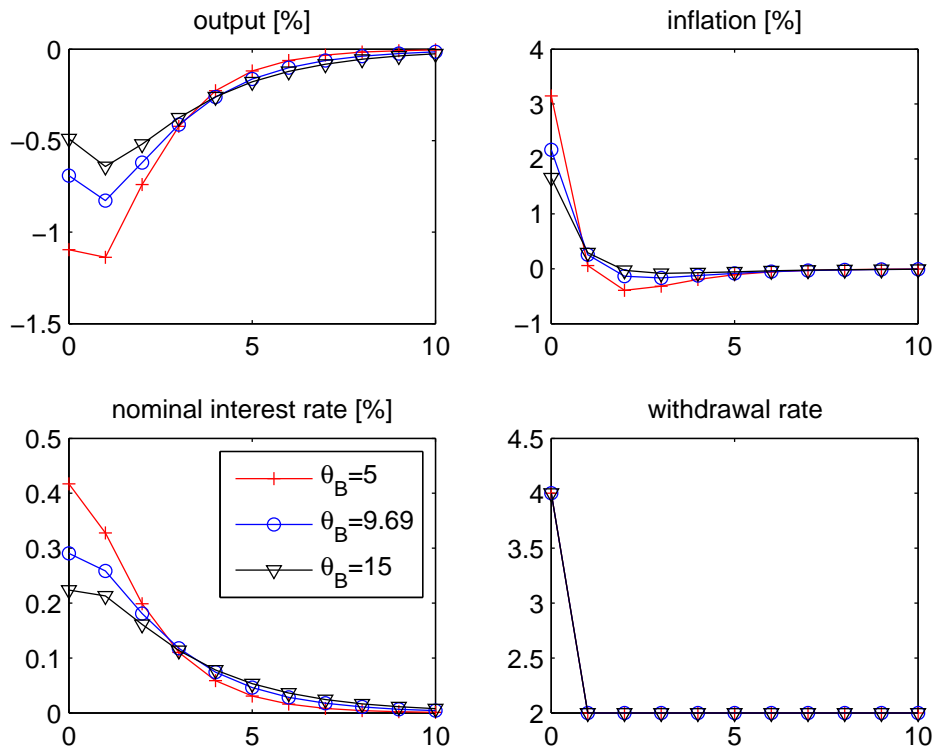


Figure 4: Time paths for different degrees of the loan rate stickiness

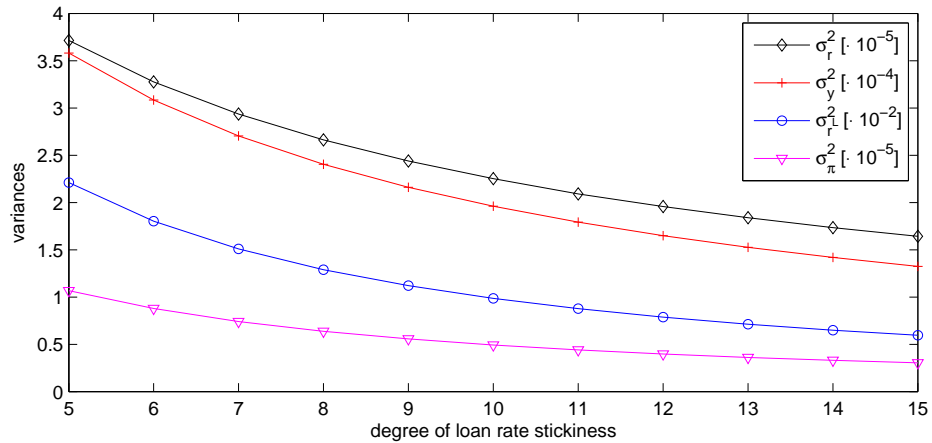


Figure 5: Variances of  $\hat{\pi}_t$ ,  $\hat{Y}_t$ ,  $\hat{R}_t$ , and  $\hat{R}_t^L$  under different degrees of loan rate stickiness

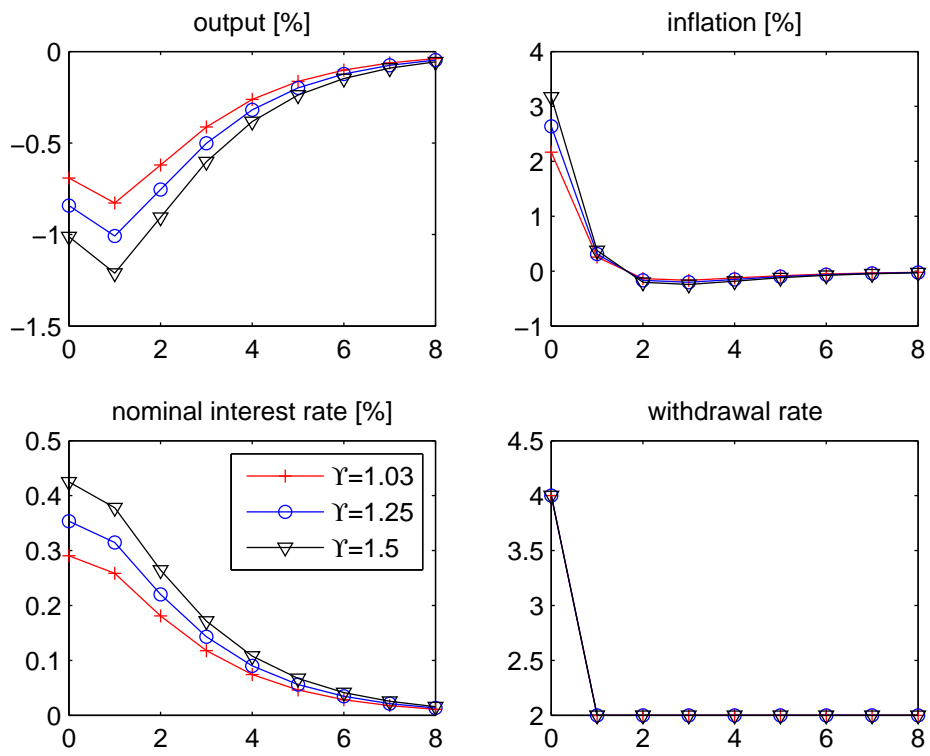


Figure 6: Time paths for varied mark-ups  $\gamma$

## Tables

$t = t_{start}$	$t = t_{in}$	$t = t_{end}$
$D_t(i)$	$-\delta D_t(i)$	$-(1 - \delta)R_t^D D_t(i)$
$-L_t(i)$	$\mathfrak{R}_t(i) = \delta D_t(i)$	$R_t^L L_t(i)$
$-\mathfrak{R}_t(i) = \delta D_t(i)$		
0	0	$> 0$

Table 1: The balance sheet of a bank  $i$  with  $\delta_t = \delta = const$