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 investigate the financial problems arising from early deposit withdrawals within a New Keynesian model. 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.

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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.

Past crises, as for example the Asian crisis, have shown that the loss of confidence in the financial sector typically causes private agents to withdraw their capital from financial institutions. 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.

The aim of this paper is therefore to analyze the financial problem of early deposit withdrawals within 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.

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 in e.g. Blinder (1987), Christiano and Eichenbaum (1992), Christiano et al. (1997), Christiano et al. (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. Finally, the main results are summarized in the conclusion.

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 of $R_t^D D_t$ 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 δ_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 and the reserve holdings of the bank i. Reserves, $\Re_t(i)$, 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^I. 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)]. We further assume that the lender of last resort possesses unlimited liquidity so that the liquidity needs will not lead single banks into bankruptcy.

Figure 1 depicts the resulting cash flows between the different types of agents.[2] The interactions between banks and the lender of last resort are put in parenthesis since they only occur if the amount of deposit withdrawals exceeds the banks' reserve holdings, i.e. only with a given probability. The rest of the figure is self-explanatory.

$<$ Figure 1 about here $>$

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 δ_t is constant, i.e. $\delta_t = \delta$.[3]

$<$ Table 1 about here $>$

At the beginning of the period, $t = t_{start}$, the households makes its deposits, $D_t(i)$, at bank i. The contributed amount of deposits, the bank transfers into loans, $L_t(i)$, provided to firms and into reserves, $\Re_t(i)$. Thereby, the bank chooses the amount of reserves as $\Re_t(i) = E_t[\delta_t|\Omega_t^B]D_t(i) = \delta D_t(i)$ to be ensured against the expected deposit withdrawal during the period. E_t and Ω_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, δ, now withdraws its deposits. Since the bank has accounted for this in its reserve

[2] For the sake of simplicity, dividend payments from banks and firms are neglected in Figure 1.
[3] We will, of course, relax this assumption below.

holding decision, the balance sheet is even within that period.[4] 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 δ_t to be constant anymore. Instead, we assume δ_t to have a stochastic component, i.e. $\delta_t = \delta + \nu_t$ where δ and ν_t represent the constant and the stochastic part of the early deposit withdrawal rate, respectively. By assumption, ν_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. $\delta_t \neq E_t[\delta_t|\Omega_t^B]$ if $\nu_t \neq 0$. In this case, the bank cannot ensure its balance sheet to be even within the period anymore. In fact, it can just ensure itself against the expected withdrawal, $E_t[\delta_t|\Omega_t^B]D_t(i) = \delta D_t(i)$. 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 resulting liquidity gap the bank has to refinance on short notice using the lender of last resort.[5]

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

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

[5]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.

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

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

taking into account the budget constraint

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

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. δ_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 σ and η, respectively. β is a discount factor. Π_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

$$P_t C_t \leq M_{t-1} + \delta_{t-1} D_{t-1} \tag{3}$$

The resulting timing of trades according to (3) is depicted in Figure 2.

< Figure 2 about here >

Thus, 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.

Maximizing (1) subjected to (2) and (3) yields the following first-order conditions

$$\frac{\partial \mathcal{L}}{\partial M_t} = \beta^t \lambda_t - \beta^{t+1} E_t \lambda_{t+1} - \beta^{t+1} E_t \mu_{t+1} = 0 \tag{4}$$

$$\frac{\partial \mathcal{L}}{\partial D_t} = \beta^t \lambda_t - \beta^{t+1} E_t \lambda_{t+1} (\delta_t + (1 - \delta_t) R_t^D) - \beta^{t+1} E_t \mu_{t+1} \delta_t = 0 \tag{5}$$

$$\frac{\partial \mathcal{L}}{\partial C_t} = \beta^t C_t^{-\sigma} + \beta^t \lambda_t P_t + \beta^t \mu_t P_t = 0 \tag{6}$$

$$\frac{\partial \mathcal{L}}{\partial N_t} = -\beta^t N_t^{\eta} - \beta^t W_t \lambda_t = 0 \tag{7}$$

where $\mathcal{L}$ represents the Lagrangian. λ_t and μ_t are the Langrange multipliers corresponding to equation (2) and (3), respectively. For the sake of simplicity, we will omit the mathematical expectations operator, E_t, in the following.

The Euler consumption equation and the optimal labor supply is then given by

$$R_t^D = \frac{C_{t+1}^{-\sigma}}{C_{t+2}^{-\sigma}} \frac{P_{t+2}}{P_{t+1}} \frac{1}{\beta} \tag{8}$$

$$N_t^{\eta} = \beta \frac{W_t}{P_{t+1}} C_{t+1}^{-\sigma} \tag{9}$$

Note that the time shift in comparison to the canonical New Keynesian model results from the application of the CIA approach.

3.2 Firms

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

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 following CES technology

$$Y_t = \left(\int_0^1 Y_t(f)^{\frac{\xi-1}{\xi}} df \right)^{\frac{\xi}{\xi-1}} \tag{10}$$

where $Y_t(f)$ and Y_t represent the differentiated intermediate good and the final good, respectively. ξ is the elasticity of substitution between intermediate goods.

By cost minimization, the goods demand is then given by

$$Y_t(f) = \left(\frac{P_t(f)}{P_t} \right)^{-\xi} Y_t \tag{11}$$

with the corresponding aggregate price index P_t following

$$P_t = \left(\int_0^1 P_t(f)^{1-\xi} df \right)^{\frac{1}{1-\xi}} \tag{12}$$

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

$$Y_t(f) = N_t(f)^{1-\alpha} \tag{13}$$

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

$$MC_t(f) = \frac{1}{1-\alpha}\frac{R_t^L W_t}{P_t} Y_t(f)^{\frac{\alpha}{1-\alpha}} \tag{14}$$

Moreover, we assume the intermediate good producer to be faced with quadratic adjustment costs given by $\frac{\theta_F}{2}\left(\frac{P_t(f)}{P_{t-1}(f)} - 1\right)^2 Y_t$ where θ_F is interpreted as the menu costs of a firm resulting from relative price changes.[6]

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

$$E_t \sum_{t=0}^{\infty} \Delta_{0,t} \left[\frac{P_t(f)}{P_t} Y_t(f) - MC_t(f) Y_t(f) - \frac{\theta_F}{2}\left(\frac{P_t(f)}{P_{t-1}(f)} - 1\right)^2 Y_t \right] \tag{15}$$

with $\Delta_{0,t} = \beta^t \frac{U_{C,t}}{U_{C,0}}$ denoting the stochastic discount factor.

Differentiating (15) over $P_t(f)$ subjected to the goods demand (11) yields[7]

$$\xi - 1 = \xi MC_t - \theta_F(\pi_t - 1)\pi_t + \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \theta_F(\pi_{t+1} - 1)\pi_{t+1}\frac{Y_{t+1}}{Y_t} \tag{16}$$

with $\frac{\Delta_{0,t+1}}{\Delta_{0,t}} = \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}$. By log-linearizing (16) around a zero inflation steady state ($\overline{\pi} = 1$) and by inserting the log-linearized version of (14) we obtain the Phillips curve given by[8]

$$\pi_t = \beta\pi_{t+1} + \omega_w(r_t^L + w_t - p_t) + \omega_y y_t \tag{17}$$

[6] In an earlier version of this paper we apply the original Rotemberg (1982) approach. However, the qualitative result remain unchanged.

[7] In nominal terms the result would be given by

$$P_t(f) = \frac{\xi}{\xi - 1} P_t MC_t - \frac{\theta_F P_t}{(\xi - 1)}\left\{(\pi_t - 1)\pi_t - \frac{\Delta_{0,t+1}}{\Delta_{0,t}}(\pi_{t+1} - 1)\pi_{t+1}\frac{Y_{t+1}}{Y_t}\right\}$$

As expected, the optimal price level of the representative intermediate good producer is simply given by a constant mark-up over the nominal marginal costs in absence of the nominal price rigidity ($\theta_F = 0$).

[8] In the following, lower case letters denote deviations from the respective steady state.

with

$$\omega_w = \frac{\xi}{\theta_F}, \qquad \omega_y = \frac{\xi\alpha}{\theta_F(1-\alpha)} \tag{18}$$

Equation (17) deviates from the canonical Phillips curve since producers' and consumers' real wages ($r_t^L + w_t - p_t$ and $w_t - p_t$) 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.

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.[9] 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 Coccorese (2009) who find that even though the monopoly 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, refi-

[9] In contrast, Goodfriend and McCallum (2007) and Tillmann (2009) assume for the sake of simplicity that banks act under perfect competition.

nancing 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, $\Re_t(i)$, given the probability, $\Phi(\delta_t)$, that the latter difference is positive. More precisely, $\Phi(\delta_t)$ is given by

$$\begin{aligned}\Phi(\delta_t) &= \text{Prob}\{\delta_t D_t(i) - \Re_t(i) > 0\} \\ &= \text{Prob}\{(\delta+\nu_t)D_t(i) - \delta D_t(i) > 0\} \\ &= \text{Prob}\{\nu_t > 0\} \qquad (19)\end{aligned}$$

with $\delta_t = \delta + \nu_t$ and $\Re_t(i) = E_t[\delta_t|\Omega_t^B]D_t(i) = \delta D_t(i)$. Equation (19) 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.[10]

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

The profit of the representative bank is then given by

$$\begin{aligned}E_t \sum_{t=0}^{\infty} \Delta_{0,t} \Big[& R_t^L(i)L_t(i) - (1-\delta_t)R_t^D D_t(i) - \delta_t D_t(i) \\ & - R_t^I\left[\delta_t D_t(i) - \Re_t(i)\right]\Phi(\delta_t) - \frac{\theta_B}{2}\left(\frac{R_t^L(i)}{R_{t-1}^L(i)} - 1\right)^2 L_t \Big] \qquad (20)\end{aligned}$$

[10] Note that for all distributions of ν_t that are not skewed, equation (19) is just equal to 0.5.

where the optimal loan demand

$$L_t(i) = \left(\frac{R_t^L(i)}{R_t^L} \right)^{-\zeta} L_t \tag{21}$$

follows from the costs minimization of the firms with respect to the loan bundle L_t given by

$$L_t = \left(\int_0^1 L_t(i)^{\frac{\zeta-1}{\zeta}} di \right)^{\frac{\zeta}{\zeta-1}} \tag{22}$$

where $\zeta > 1$ represents the interest rate elasticity of the loan demand.

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

$$D_t(i) \geq L_t(i) + \Re_t(i) \tag{23}$$

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 (20) subjected to (21) and (23) yields the optimal loan rate

$$\begin{aligned} R_t^L(i) = {} & \frac{\zeta}{\zeta-1} \left[(1-\delta_t) R_t^D + \delta_t (1 + \Phi(\delta_t) R_t^I) \right] \\ & - \frac{\theta_B}{\zeta-1} \left\{ \left(\frac{R_t^L(i)}{R_{t-1}^L(i)} - 1 \right) \frac{R_t^L(i)}{R_{t-1}^L(i)} - \frac{\Delta_{0,t+1}}{\Delta_{0,t}} \left(\frac{R_{t+1}^L(i)}{R_t^L(i)} - 1 \right) \frac{R_{t+1}^L(i)}{R_t^L(i)} \frac{L_{t+1}}{L_t} \right\} \end{aligned} \tag{24}$$

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 (24) is proportional to the withdrawal rate.

Note that in absence of the loan rate rigidity, i.e. $\theta_B = 0$, the optimal loan rate is simply given by

$$R_t^L(i) = \frac{\zeta}{\zeta-1} \left[(1-\delta_t) R_t^D + \delta_t (1 + \Phi(\delta_t) R_t^I) \right] \tag{25}$$

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 the refinancing costs.[11]

Log-linearizing equation (24) yields[12]

$$r_t^L = \beta\omega_l r_{t+1}^L + \omega_l r_{t-1}^L + \omega_d r_t^D + \omega_i r_t^I + \omega_\delta \nu_t \tag{26}$$

with

$$\begin{aligned} \omega_l &= \frac{\theta_B}{\zeta(1+\bar{\delta}\Phi\Upsilon)+\theta_B(1+\beta)}, \qquad & \omega_d &= \frac{(1-\bar{\delta})\zeta}{\zeta(1+\bar{\delta}\Phi\Upsilon)+\theta_B(1+\beta)} \\ \omega_i &= \frac{\bar{\delta}\Phi\Upsilon\zeta}{\zeta(1+\bar{\delta}\Phi\Upsilon)+\theta_B(1+\beta)}, \qquad & \omega_\delta &= \frac{(\beta+\Phi\Upsilon-1)\zeta}{\zeta(1+\bar{\delta}\Phi\Upsilon)+\theta_B(1+\beta)} \end{aligned} \tag{27}$$

3.4 Aggregate Resource Constraint

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

$$C_t = Y_t - \frac{\theta_F}{2}\left(\pi_t - 1\right)^2 Y_t - \frac{\theta_B}{2}\left[\frac{R_t^L}{R_{t-1}^L} - 1\right]^2 L_t \tag{28}$$

Note that we assume that the earnings of the lender of last resort resulting from refinancing banks are transferred back to the households.[13]

[11] If we further assume that the households do not have the possibility to withdraw their deposits early ($\delta_t = 0$), equation (25) 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).

[12] 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 by aggregating (24).

[13] Further note that on aggregate the CIA condition (3) and the balance sheet constraint of the banks (23) both hold with equality.

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 (17), (26), and the log-linear versions of (8), (9), (13), and (28). Moreover, we set $r_t = r_t^D$ 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. Finally, monetary policy is assumed to be of Taylor-type. The whole model in the log-linear form is then given by[14]

$$c_t = c_{t+1} - \frac{1}{\sigma}\left(r_{t-1}^D - \pi_{t+1}\right) \tag{29}$$

$$c_t = y_t \tag{30}$$

$$y_t = (1-\alpha)n_t \tag{31}$$

$$w_t - p_{t+1} = \sigma c_{t+1} + \eta n_t \tag{32}$$

$$r_t^L = \beta\omega_l r_{t+1}^L + \omega_l r_{t-1}^L + \omega_d r_t^D + \omega_i r_t^I + \omega_\delta \nu_t \tag{33}$$

$$\pi_t = \beta\pi_{t+1} + \omega_w(r_t^L + w_t - p_t) + \omega_y y_t \tag{34}$$

$$r_t = r_t^D = r_t^I \tag{35}$$

$$r_t = (1-\phi)(\lambda_\pi \pi_t + \lambda_y y_t) + \phi r_{t-1} \tag{36}$$

In the baseline calibration, we set β 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, σ, and the Frisch elasticity of labor supply, η, are both set equal to 2. Moreover, we set α equal to 0.2 as widely applied in the literature. The price elasticity of demand for the intermediate good ξ and the loan elasticity ζ 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)].

We set the steady state value of the withdrawal rate, $\overline{\delta}$, equal to the mini-

[14] Note that (32) must be represented as $w_t - p_t - \pi_{t+1} = \sigma c_{t+1} + \eta n_t$ for the simulations.

mum reserve requirement of the European Central Bank (2%) since this amount of reserves is designed to satisfy average withdrawal demands.[15] 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.

The adjustment costs of a bank, θ_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 θ_F equal to 14.72 to obtain a slope of the Phillips curve equal to that of the baseline New Keynesian model[16] 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.

Finally, the central bank's mark-up over the interest rate Υ is assumed to be equal to 1.03. The coefficients of the Taylor rule (36) ϕ, λ_π, and λ_y are set equal to 0.9, 1.5, and 0.5, respectively.

4 Simulations

In this section, the impulse responses to a one-off shock in the stochastic component of the early deposit withdrawal rate of the households are discussed.[17] They are illustrated in Figure 3 for the baseline calibration.[18]

< Figure 3 about here >

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

[15] Note that in our framework the average and the expected withdrawal coincide, if the time horizon tends to infinity.

[16] 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.

[17] For all simulations we apply Dynare V.3 [see Juillard (2001)].

[18] 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.

and the hybrid representation of the loan rate reaction function. 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 (29) – (36) 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.[19] However, in this case all variables reach their respective steady state variables after two periods. Thus, the hybrid representation of the loan rate can therefore also not be the crucial factor. Hence, the major part of the observed persistence must be caused by the time shift in the Euler consumption equation and in the labor supply due to the CIA approach.

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 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 worth mentioning 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 then 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

[19]In this case the only backward-looking term is in the loan rate reaction function.

the responses of output and inflation together, the current 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 a higher loan rate. As a result, the shock drives a wedge between the two wages as the producers' real wage increases while the consumers' real wage declines.

Under a 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.[20] 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 effect on the loan rate since the refinancing costs are given by a mark-up over the nominal interest rate.

Needless to say that in the current framework all real variables return to their initial values during the adjustment process. The hump-shaped adjustment path in output results from the time lag in the Euler consumption equation and in the labor supply as well as the hybrid representation of the loan rate adjustments. Also the undershooting in inflation is a result of the adjustment path of the consumption.

Figure 4 shows the impulse responses for different degrees of the loan rate stickiness, i.e. for different values of the banks' adjustment costs, θ_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. Thus, the banks want

[20] Of course, this effect is additionally amplified by the relation $\lambda_\pi > \lambda_y$.

to raise their loan rate. This directly follows from (24). However, if the loan rate becomes more sticky – as relative loan rate changes are more costly – the resulting effects for the whole economy will become more persistent but of course smaller on impact.

By having a look at the volatility of the model variables, it turns out that the overall effect 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.[21]

< Figure 5 about here >

Taking a look at equation (27), it is obvious that the shock impact ω_δ is a decreasing function in the degree of loan rate stickiness, too. The opposing effect on persistence thus cannot be the crucial factor for the overall effect, although it naturally dampens the impact effect on stabilizing the system.[22]

We obtain a slightly different result when varying the mark-up of the central bank, Υ, i.e. by altering the costs of refinancing. From Figure 6 we can directly observe that there does not exist an opposing persistence effect by varying Υ since the degree of loan rate stickiness is not altered. In this case the overall effect thus coincides with the impact effect and stabilizes the economy without any opposing effects when this mark-up is decreasing.

< 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 (24), it is obvious that a decline in the mark-up Υ directly leads to decreasing marginal costs for the banks and

[21] 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 θ_B, too.

[22] We obtain an equivalent result by decreasing the interest rate elasticity of the loan demand ζ and by decreasing the elasticity of substitution between intermediate goods ξ.

according to (27) thus to a lower shock impact. Hence, the shock impact decline as refinancing costs decrease.

In the long-run this could naturally lead to moral hazard problems since the banks seem to be rewarded for their mismanagement by underestimating the amount of early 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 persistence effect is non-existent. The impact effect thus coincides with the overall effect and stabilizes the system since 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.

References

Barth, M. J., Ramey, V., 2001. The Cost Channel of Monetary Transmission. NBER Macroeconomics Annual 2001; 16; 199-240.

Berger, A., Udell, G., 1992. Some Evidence on the Empirical Significance of Credit Rationing. Journal of Political Economy 1992; 100; 1047-1077.

Bernanke, B. S., Gertler, M., 1995. Inside the Black-Box: The Credit Channel of Monetary Policy Transmission. Journal of Economic Perspectives 1995; 9; 27-48.

Blinder, A., 1987. Credit Rationing and Effective Supply Failures. Economic Journal 1987; 87; 327-354.

Carletti, E., Hartmann, P., Spagnolo, G., 2007. Bank Mergers, Competition, and Liquidity. Journal of Money, Credit and Banking 2007; 39; 1067-1105.

Christiano, L. J., Eichenbaum, M., 1992. Liquidity Effects and the Monetary Transmission Mechanism. American Economic Review 1992; 80; 703-725.

Christiano, L. J., Eichenbaum, M., Evans, C. L., 1997. Sticky Price and Limited Participation Models of Money: A Comparison. European Economic Review 1997; 41; 1201-1249.

Christiano, L. J., Eichenbaum, M., Evans, C. L., 2005. Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. Journal of Political Economy 2005; 113; 1-45.

Coccorese, P., 2009. Market Power in Local Banking Monopolies. Journal of Banking & Finance 2009; 33; 1187-1360.

Diamond, D. W., Dybvig, P. H., 1983. Bank Runs, Deposit Insurance, and Liquidity. Journal of Political Economy 1983; 91; 401-419.

Dressler, S. C., Li, V. E., 2009. Inside Money, Credit, and Investment. Journal of Economic Dynamics and Control 2009; 33; 970-984.

Freixas, X., Parigi, B. M., Rochet, J.-C., 2000. Systemic Risk, Interbank Relations and Liquidity Provision by the Central Bank. Journal of Money, Credit and Banking 2000; 32; 611-638.

Freixas, X., Rochet, J.-C., 1997. Microeconomics of Banking, MIT Press Cambridge, Massachusetts; 1997.

Galí, J., 2008. Monetary Policy, Inflation, and the Business Cycle. Princeton and Oxford, New Jersey and Oxfordshire; 2008.

Gilkeson, J. H., List, J. A., Ruff, C. K., 1999. Evidence of Early Withdrawal in Time Deposit Portfolios. Journal of Financial Services Research 1999; 15; 103-122.

Gilkeson, J. H., Porter, G. E., Smith, S. D., 2000. The Impact of the Early Withdrawal Option on Time Deposit Pricing. Quarterly Review of Economics and Finance 2000; 40; 107-120.

Goodfriend, M., McCallum, B. T., 2007. Banking and Interest Rates in Monetary Policy Analysis: A Quantitative Exploration. Journal of Monetary Economics 2007; 54; 1480-1507.

Henzel, S., Hülsewig, O., Mayer E., Wollmershäuser, T., 2009. The Price Puzzle Revisited: Can the Cost Channel Explain a Rise in Inflation after a Monetary Policy Shock? Journal of Macroeconomics 2009; 31; 268-289.

Hülsewig, O., Mayer, E., Wollmershäuser, T., 2009. Bank Behavior, Incomplete Interest Rate Pass-Through, and the Cost Channel of Monetary Policy Transmission. Economic Modelling; forthcoming.

Juillard, M., 2001. DYNARE: A program for the simulation of rational expectation models. Society for Computational Economics: Computing in

Economics and Finance 2001; 213.

Kahn, C. M., Santos, J. A. C., 2005. Allocating Bank Regulatory Powers: Lender of Last Resort, Deposit Insurance and Supervision. European Economic Review 2005; 49; 2107-2136.

Parlous, C., Rajan, U., 2001. Competition in Loan Contracts. American Economic Review 2001; 91; 1311-1328.

Passamani, G., Tamborini, R., 2006. Monetary Policy with Firms' Bank Dependence and Default Risk. In: Arestis P., Zezza G. (Eds), Advances in Monetary Theory and Macroeconomics, London, England; 2007; 7-27.

Rabanal, P., 2007. Does Inflation Increase after a Monetary Policy Tightening? Answers Based on an Estimated DSGE Model. Journal of Economic Dynamics and Control 2007; 31; 906-937.

Ringbom, S., Shy, O., Stenbacka, R., 2004. Optimal Liquidity Management and Bail-Out Policy in the Banking Industry. Journal of Banking & Finance 2004; 24; 1319-1335.

Rotemberg, R., 1982. Monopolistic Price Adjustment and Aggregate Output. Review of Economic Studies 1982; 49; 517-531.

Stanhouse, B., Ingram, M., 2007. A Computational Approach to the Optimal Structure of Bank Input Prices. Journal of Banking & Finance 2007; 31; 439-453.

Stanhouse, B., Stock, D., 2004. The Impact of Loan Prepayment Risk and Deposit Withdrawal Risk on the Optimal Intermediation Margin. Journal of Banking & Finance 2004; 28; 1825-1843.

Tillmann, P., 2009. Optimal Monetary Policy with an Uncertain Cost Channel. Journal of Money, Credit and Banking 2009; 41; 885-906.

Tables and Figures

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

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

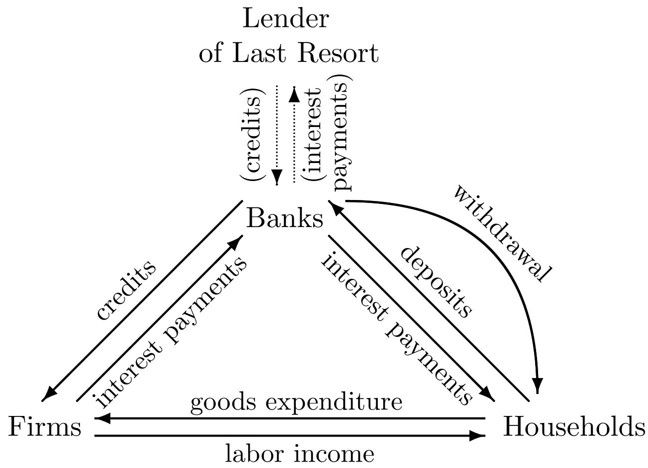

Figure 1: Cash flows

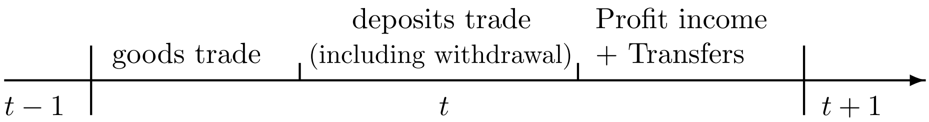

Figure 2: Trade timing

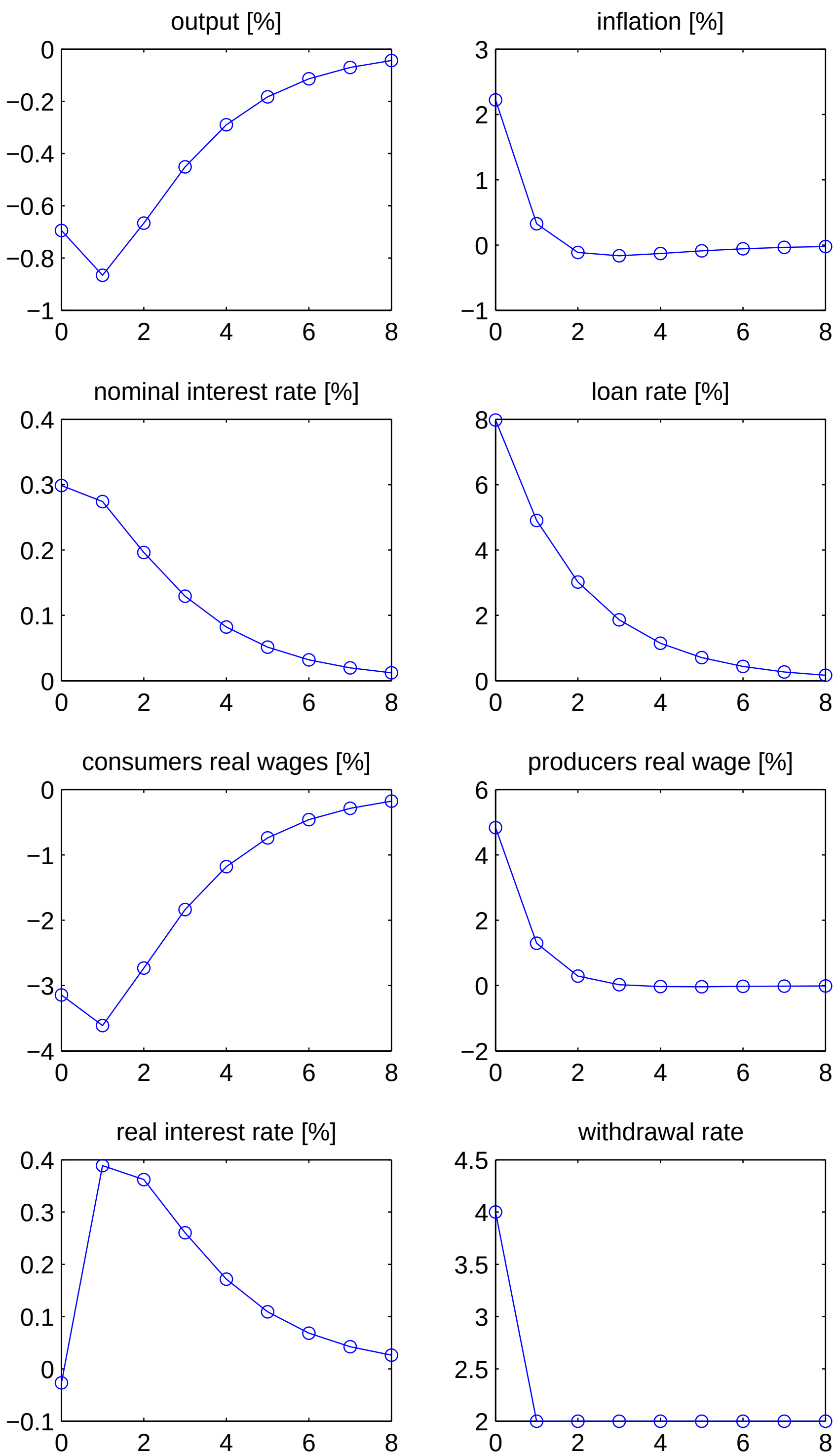

Figure 3: Time paths

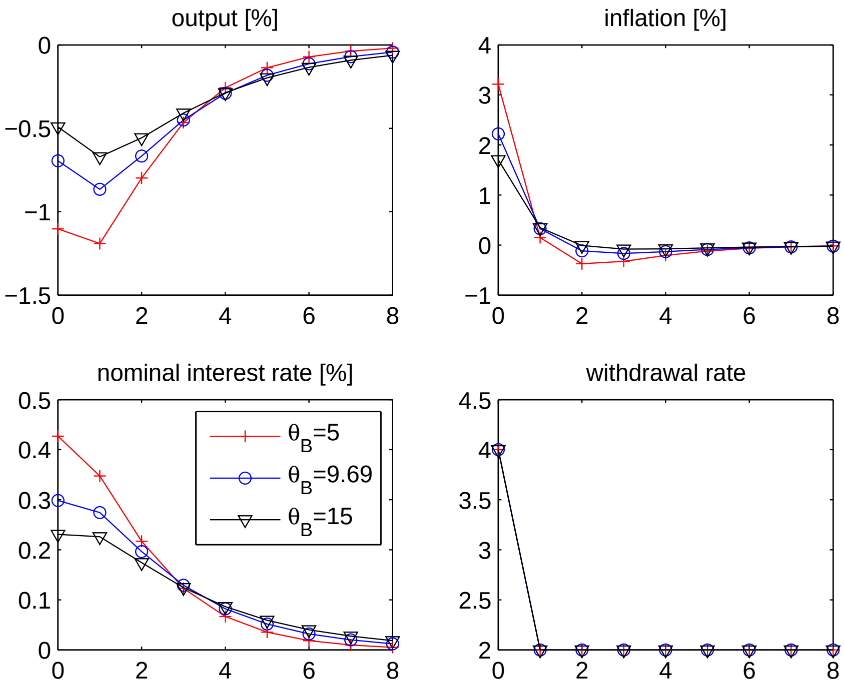

Figure 4: Time paths for different degrees of the loan rate stickiness

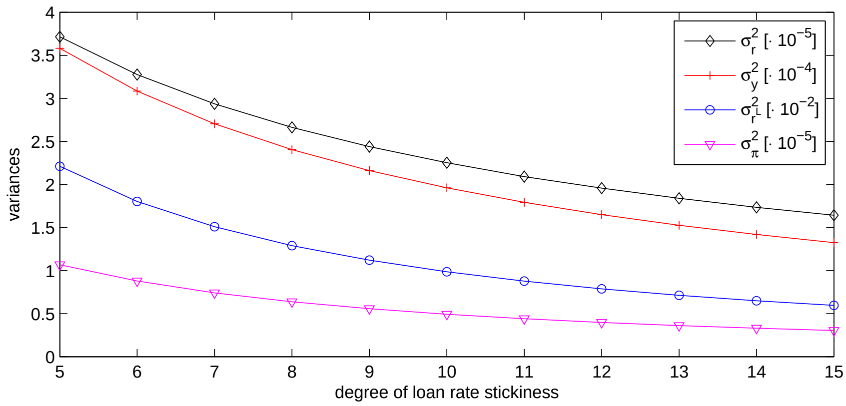

Figure 5: Variances of π_t, y_t, r_t, and r_t^L under different degrees of loan rate stickiness

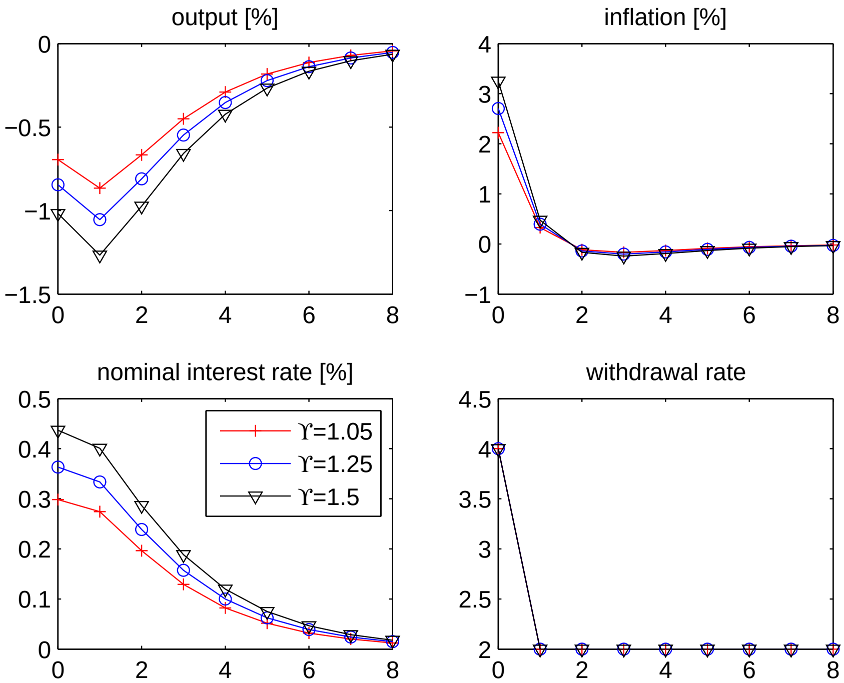

Figure 6: Time paths for varied mark-ups Υ