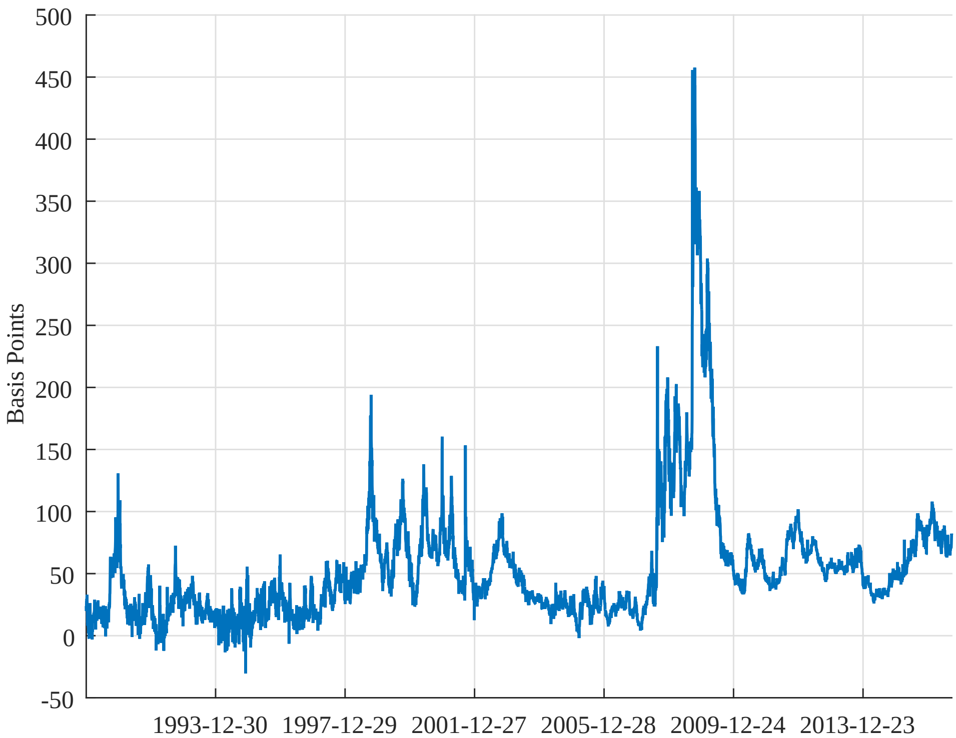
Additional material

D Descriptive statistics on interest rate spreads

Figure 4 shows the time series of the liquidity premium LP in equation (1). Figure 5 provides time series plots of all spreads along with a linear projection on the common factor and a constant. Summary statistics on all spreads and the liquidity premium derived from the factor model are given in Table 4.

Figure 4: Time Series of the Liquidity Premium LP

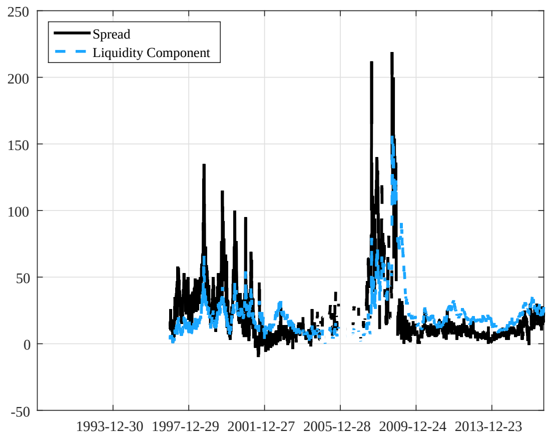


Notes: Plot of a time series of the liquidity premium in equation (1) in basis points using daily data from 1990-01-2 to 2016-09-16, constructed from a panel of 8 liquidity spreads using principal component analysis.

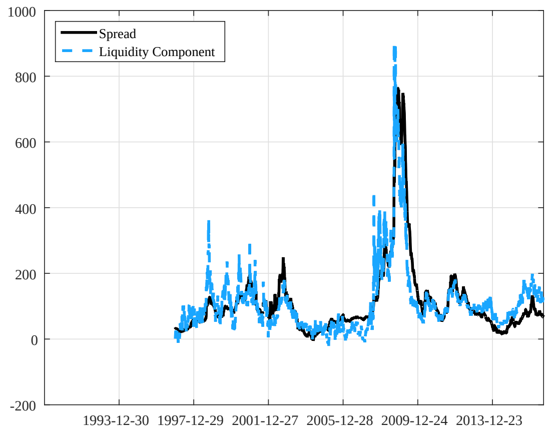
Figure 6 compares the rate on Fed treasury repurchase agreements to the federal funds rate, which is most often considered as the monetary policy instrument. The two rates behave very similarly and the average spread between the two is less than one basis points. By contrast, the liquidity spreads considered in our empirical analysis are, on average, 16 to more than 200 basis points large, see Table 2.

Figure 5: Time Series of Liquidity Premia and Common Factor

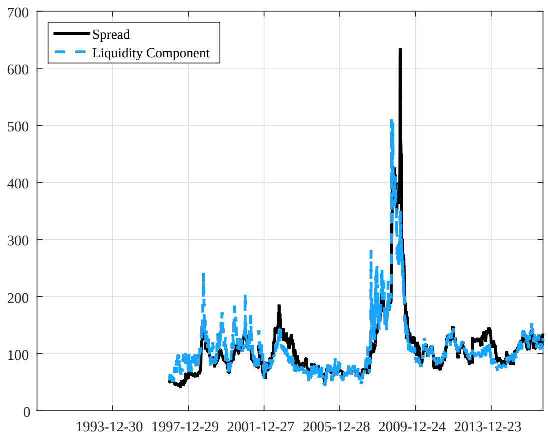
(a) Commercial Paper 3M



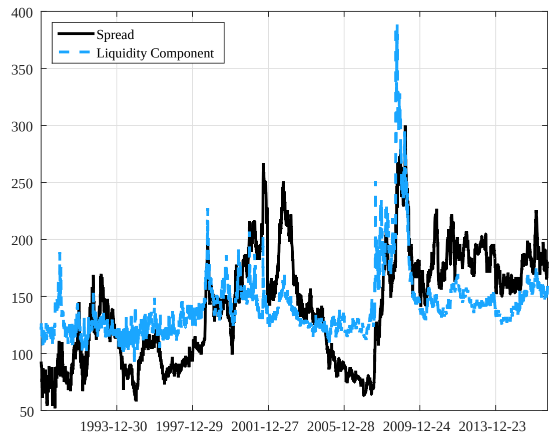
(b) Corporate Bonds 3Y



(c) Corporate Bonds 5Y

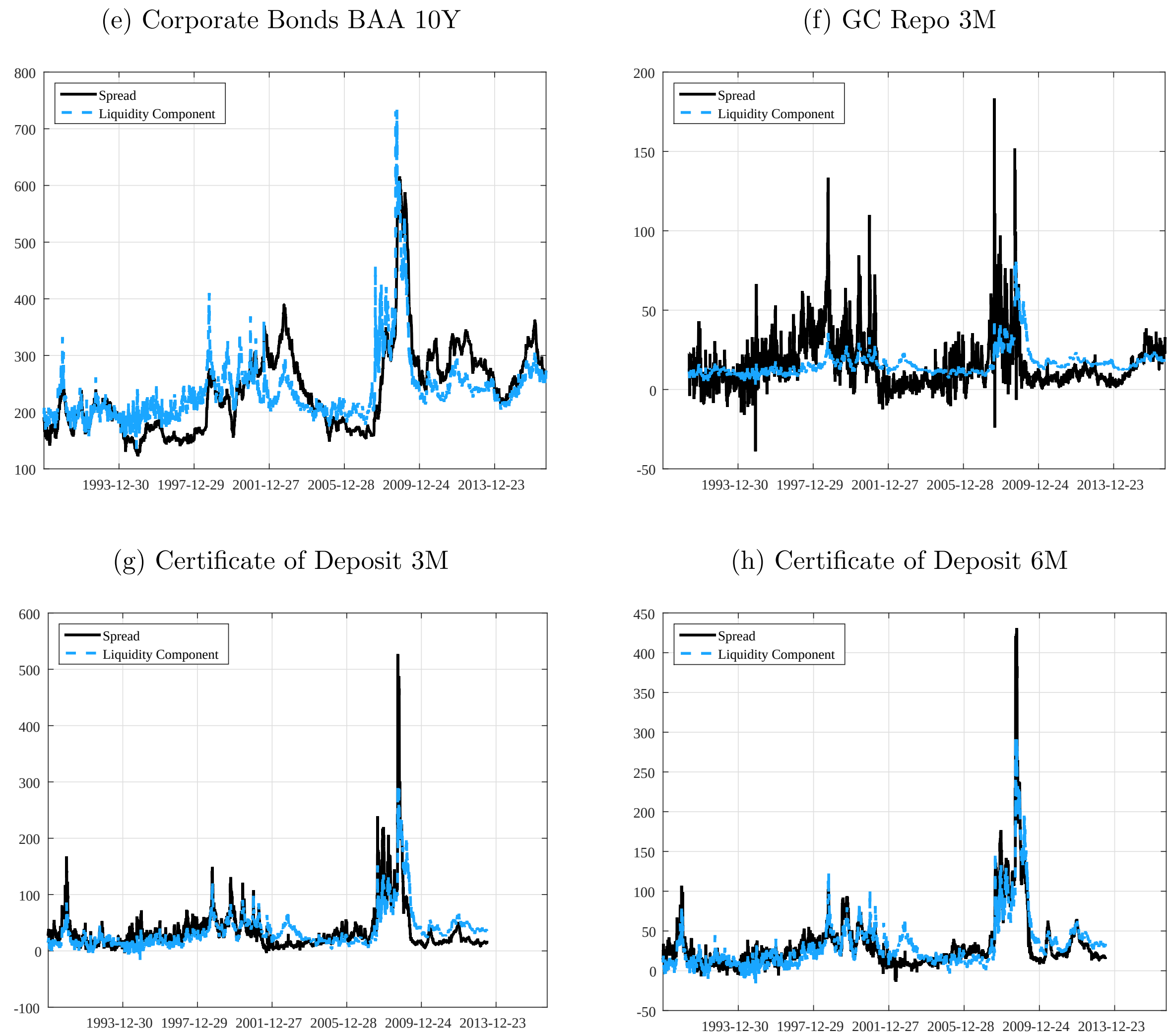


(d) Corporate Bonds AAA 10Y



Notes: Figure shows daily time series of liquidity spreads (black lines) along with their linear projections on the common factor and a constant (blue lines).

Figure 5 continued



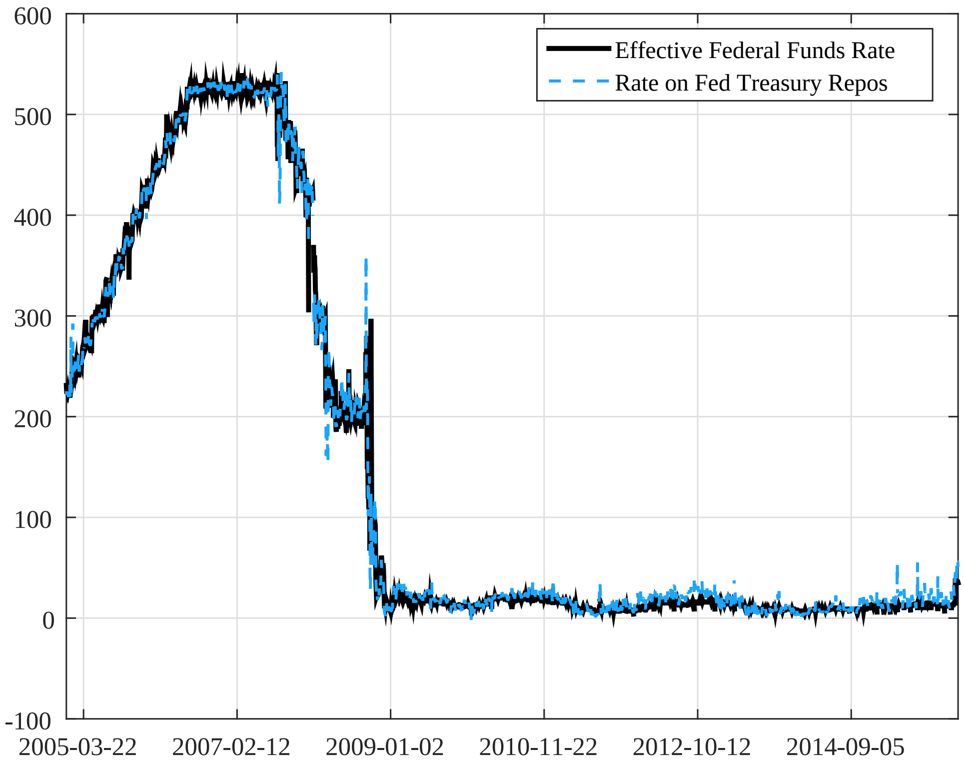
Notes: Figure shows daily time series of liquidity spreads (black lines) along with their linear projections on the common factor and a constant (blue lines).

Table 4: Summary Statistics of Liquidity Premia

Spread	Time Range	Mean	Std. Dev.
Commercial Paper 3M	1997-01-02 to 2016-09-16	21.82	24.79
Corporate Bonds 3Y	1997-01-02 to 2016-09-16	110.99	120.10
Corporate Bonds 5Y	1997-01-02 to 2016-09-16	108.89	60.61
Corporate Bonds AAA 10Y	1990-01-02 to 2016-09-16	141.55	47.74
Corporate Bonds BAA 10Y	1990-01-02 to 2016-09-16	238.00	77.47
Certificate of Deposit 3M	1990-01-02 to 2013-06-28	35.69	40.97
Certificate of Deposit 6M	1990-01-02 to 2013-06-28	31.83	37.49
GC Repo 3M	1991-05-21 to 2016-09-16	16.04	16.24
Liquidity Premium (Factor)	1990-01-02 to 2016-09-16	53.47	49.45

Notes: Mean and Standard Deviation (Std. Dev.) given in basis points.

Figure 6: Federal funds rate and treasury repo rate



Notes: Figure shows daily time series of the effective federal funds rate (black line) and the interest rate on Fed treasury repos (blue dashed line).

E Estimation of the Target and the Path Factor

In this appendix, we describe the data sources of the federal funds and Eurodollar futures that we use. We explain how futures are used to extract the surprise component of monetary policy at FOMC meeting dates and how we derive the target and the path factor as in Gürkaynak et al. (2005).

Data Sources All futures data are taken from Quandl (`https://www.quandl.com`). For the federal funds rate, we use the '30 Day Federal Funds Futures, Continuous Contract' series for the front month and the next 3 months thereafter. The mnemonics read [CHRIS/CME_FF'X'], where 'X'$=\{1,2,3,4\}$ is the number of months until delivery of the contract. The raw data for the continuous contract calculation is from the Chicago Mercantile Exchange, where the futures are traded. We extract the daily settlement price (series 'settle'), which is given as 100 minus the average daily federal funds overnight rate for the delivery month, between 1990-01-02 to 2016-09-16.

For Eurodollars, we use the 'Eurodollar Futures, Continuous Contract' series with the mnemonic [CHRIS/CME_ED'X'], where 'X'$=\{6,9,12\}$ gives the number of months until delivery of the contract. The raw data for the continuous contract calculation is from the Chicago Mercantile Exchange, where the futures are traded. We extract the daily settlement price (series 'settle'), which is given as 100 minus the 3-month London interbank offered rate for spot settlement on the 3rd Wednesday of the contract month, between 1990-01-02 to 2016-09-16.

Construction of the Monetary Surprise Components We now explain how the monetary policy surprise components based on federal funds and Eurodollar futures are constructed. We compile the surprise changes of the various futures in a matrix X of size $[T \times v]$, where T denotes the number of FOMC dates and v the number of different futures. Our sample covers $T = 237$ FOMC dates in total and we use $v = 5$ futures with maturities of 1, 3, 6, 9, and 12 months. Each row of X measures the expectation changes about monetary policy between the end-of-day value at the FOMC meeting date and the end-of-day value at the day before for the v futures. Following Gürkaynak et al. (2007), we use Eurodollar futures contracts with $v = 6, 9, 12$ months. Due to the spot settlement of these contracts, this difference directly gives a measure for the change in expectations about interest rates in 6, 9, and 12 months, respectively. The first two columns entail the surprise changes of expectations using mainly the 1- and the 3-month federal funds futures, whose calculation is more involved, since these contracts settle on the average federal funds rate in the delivery month. The following exposition is based on Gürkaynak et al. (2005) and Gürkaynak (2005).

Given the specification of the federal funds future contracts, the current month future settlement rate at the day before the FOMC meeting in t, $ff^1_{t-\Delta 1}$, can be written as

$$ff^1_{t-\Delta 1} = \frac{d_1}{m_1} r_{t-\Delta 1} + \frac{m_1 - d_1}{m_1} E_{t-\Delta 1}(r_t) + \varpi^1_{t-\Delta 1}, \tag{49}$$

where $r_{t-\Delta 1}$ is the average federal funds rate that has prevailed in this month until the day before the meeting (i.e., day $t - \Delta 1$), $E_{t-\Delta 1}(r_t)$ is the expectation at $t - \Delta 1$ about the federal funds rate for the rest of the month, d_1 the day of the FOMC meeting t in the current month with length m_1, and $\varpi^1_{t-\Delta 1}$ any potentially present term or risk premia. Analogously, the settlement rate at the day of the meeting itself reads

$$ff^1_t = \frac{d_1}{m_1} r_{t-\Delta 1} + \frac{m_1 - d_1}{m_1} r_t + \varpi^1_t. \tag{50}$$

Defining the surprise change in the target of the federal funds rate after the current meeting as $mp^1_t \equiv r_t - E_{t-\Delta 1}(r_t)$, allows its calculation according to

$$mp^1_t = \left(ff^1_t - ff^1_{t-\Delta 1}\right) \frac{m_1}{m_1 - d_1}, \tag{51}$$

which assumes that term and risk premia ϖ^1 do not change significantly between t and $t - \Delta 1$, which Gürkaynak et al. (2005) argue to be in line with empirical evidence. The change in the futures rates is scaled with the factor $m_1/(m_1 - d_1)$, since the surprise change of the federal funds rate only applies to the remaining $m_1 - d_1$ days of the month. For meeting dates very close to the end of the month, the scaling factor becomes relatively big, which can be problematic when there is too much noise in the data. We therefore follow Gürkaynak (2005) and use the unscaled change in the futures that are due in the next month, $mp^1_t = \left(ff^2_t - ff^2_{t-\Delta 1}\right)$, when the meeting is within the last 7 days of the month. Another special case are FOMC meetings at the first day of the month. In this case, the monetary surprise has to be calculated as $mp^1_t = \left(ff^1_t - ff^2_{t-\Delta 1}\right)$.

In a next step, we determine the change of expectations about the federal funds rate that will prevail after the second FOMC meeting $(t + 1)$ from the perspective of $t - \Delta 1$, r_{t+1}. These values form the entries in the second column of X. Since there are 8 regularly scheduled FOMC meetings per year, the next meeting $(t + 1)$ will be in $j = \{1, 2\}$ months.[23] At date $t - \Delta 1$, the futures rate that covers the second meeting

[23] In case of additional unscheduled meetings, the next meeting can also be in the same month. 23 of the 237 FOMC meetings in our sample are unscheduled intermeeting moves. Most of these observations occurred in the early 1990s and some happened after surprising financial turmoil, e.g. 2001 and 2007/8. Following Gürkaynak (2005), we assume that on every FOMC meeting, future intermeeting moves are assumed to occur with zero probability.

from now is then given by

$$ff_{t-\Delta 1}^{1+j} = \frac{d_{1+j}}{m_{1+j}} E_{t-\Delta 1}\left(r_t\right) + \frac{m_{1+j} - d_{1+j}}{m_{1+j}} E_{t-\Delta 1}\left(r_{t+1}\right) + \varpi_{t-\Delta 1}^{1+j}, \tag{52}$$

where ff^{1+j} refers to the futures contract that expires in $1+j$ months, while d_{1+j} and m_{1+j} refer to the day and the length of the month of the second FOMC meeting from now, respectively. Analogously to the procedure above, we calculate the change in the expected target of the federal funds rate after the next meeting as

$$mp_t^{1+j} \equiv E_t\left(r_{t+1}\right) - E_{t-\Delta 1}\left(r_{t+1}\right) = \left[\left(ff_t^{1+j} - ff_{t-\Delta 1}^{1+j}\right) - \frac{d_{1+j}}{m_{1+j}} mp_t^1\right] \frac{m_{1+j}}{m_{1+j} - d_{1+j}}. \tag{53}$$

We apply the same corrections as above in case the meeting $t+1$ is on the first day or within the last week of the month.

Factor Estimation and Transformation We normalize each column of X to have a zero mean and a unit variance before extracting the first two principal components.[24] As there is a very small number of missing values for the 12-month Eurodollar future, we apply the method of Stock and Watson (2002). This gives us a matrix F with the two factors F_1 and F_2, which we again normalize to have a unit variance. Without further transformation, the factors F are a statistical decomposition that explains a maximal fraction of the variance of X, but they lack an economic interpretation. In order to give F a meaningful interpretation, we rotate it according to

$$\widetilde{F} = FU, \tag{54}$$

where U is a $[2 \times 2]$ matrix, to obtain two new factors $\widetilde{F}_1$ and $\widetilde{F}_2$. Next, we determine the elements of the transformation matrix U. The matrix U is given by the four elements

$$U = \begin{bmatrix} a_1 \, b_1 \\ a_2 \, b_2 \end{bmatrix},$$

whose identification requires four restrictions that we adopt from Gürkaynak et al. (2005).

We normalize the columns of U to unit length, which leads to the conditions

$$a_1^2 + a_2^2 = 1 \text{ and } b_1^2 + b_2^2 = 1. \tag{55}$$

This assumption implies that the variance of $\widetilde{F}_1$ and $\widetilde{F}_2$ is unity. The next restriction

[24] Using the same selection of futures, Gürkaynak et al. (2005) show that X is appropriately described by two factors.

demands that $\widetilde{F}_1$ and $\widetilde{F}_2$ are orthogonal to each other, i.e., $E\left(\widetilde{F}_1, \widetilde{F}_2\right) = 0$ which implies that the scalar product of the columns of U equals zero,

$$\langle U \rangle = a_1 b_1 + a_2 b_2 = 0. \tag{56}$$

The final restriction is that the second factor $\widetilde{F}_2$ does not affect the current monetary policy surprise, mp_t^1, that forms the first column of X. This is implemented as follows. Starting from $F = \widetilde{F}U^{-1}$, we write F_1 and F_2 as functions of $\widetilde{F}_1$ and $\widetilde{F}_2$, which yields $F_1 = 1/\det(U) \cdot \left(b_2 \widetilde{F}_1 - a_2 \widetilde{F}_2\right)$ and $F_2 = 1/\det(U) \cdot \left(a_1 \widetilde{F}_2 - b_1 \widetilde{F}_1\right)$. The current monetary surprise can be written as $mp_t^1 = \lambda_1 F_1 + \lambda_2 F_2$, where λ_1 and λ_2 are elements of the estimated loading matrix Λ. Then, mp_t^1 can be rearranged to $mp_t^1 = 1/\det(U) \cdot \left[(\lambda_1 b_2 - \lambda_2 b_1)\widetilde{F}_1 + (\lambda_2 a_1 - \lambda_1 a_2)\widetilde{F}_2\right]$. Setting the coefficient of $\widetilde{F}_2$ to zero, then implements the restriction as

$$\lambda_2 a_1 - \lambda_1 a_2 = 0. \tag{57}$$

Using (55)-(57), we can solve for the elements of U to obtain the series for the target and the path factor, $\widetilde{F}_1$ and $\widetilde{F}_2$.

F Model version with a banking sector

To demonstrate that the type of endogenous liquidity premium that is responsible for our main results does neither rely on the absence of inside money nor on the specific asset structure, we introduce perfectly competitive banks which supply deposits to households and loans to firms. Deposits can be used for transaction purposes by households, while banks hold reserves as a constant fraction of deposits. They acquire these reserves from the central bank in open market operations in exchange for eligible assets, i.e., treasury bills. Firms demand loans to finance wage outlays before goods are sold and they transfer dividends to their shareholders, i.e., households. The remaining elements of the model, in particular, the production technology, price setting decisions of retailers, and the entire public sector, are unchanged. The timing of events also corresponds to our benchmark model (see Section 3): At the beginning of each period, aggregate shocks materialize. Then, banks can acquire reserves from the central bank via open market operations. Subsequently, the labor market opens, goods are produced, and the goods market opens. At the end of each period, the asset market opens.

Households There is a continuum of infinitely lived households with identical wealth endowments and preferences given by (3), where we disregard the index i for convenience. Households can store their wealth in shares of firms $z_t \in [0,1]$ valued at the price V_t with the initial stock of shares $z_{-1} > 0$. The budget constraint of the household reads

$$\left(D_t/R_t^D\right) + V_t z_t + P_t c_t + P_t \widetilde{c}_t + P_t \tau_t \leq D_{t-1} + \left(V_t + P_t \varrho_t\right) z_{t-1} + P_t w_t n_t + P_t \varphi_t, \quad (58)$$

where ϱ_t denotes dividends from intermediate goods producing firms, φ_t profits from banks and retailers. Demand deposits D_t are offered by commercial banks at the price $1/R_t^D$. To purchase cash goods, households could in principle hold money, which is dominated by the rate of return of other assets. Instead, we consider the demand deposits to serve the same purpose. Households typically hold more deposits than necessary for consumption expenditures such that the goods market constraint, which resembles a cash in advance constraint, can be summarized as

$$P_t c_t \leq \omega D_{t-1}, \quad (59)$$

where $D_{t-1} \geq 0$ denotes holdings of bank deposits at the beginning of period t and $\omega \in [0,1]$ denotes an exogenously determined fraction of deposits withdrawn by the representative household. Given that households can withdraw deposits at any point in time, they have no incentive to hold non-interest-bearing money. Maximizing the objective (3) subject to the budget constraint (58), the goods market constraint (59), and $z_t \geq 0$ for given initial values leads to the first-order conditions for working time, consumption, $-u_{n,t} = w_t \lambda_t$, $u_{c,t} = \lambda_t + \psi_t$, and for shares, and deposits

$$\beta E_t \left[\lambda_{t+1} R^q_{t+1} \pi^{-1}_{t+1} \right] = \lambda_t, \tag{60}$$

$$\beta E_t \left[\left(\lambda_{t+1} + \omega \psi_{t+1} \right) \pi^{-1}_{t+1} \right] = \lambda_t / R^D_t, \tag{61}$$

where $R^q_t = \left(V_t + P_t \varrho_t \right) / V_{t-1}$ denotes the nominal rate of return on equity, and λ_t and ψ_t denote the multipliers on the budget constraint (58) and the goods market constraint (59). Finally, the complementary slackness conditions $0 \leq \omega d_{t-1} \pi_t^{-1} - c_t$, $\psi_t \geq 0$, $\psi_t \left(\omega d_{t-1} \pi_t^{-1} - c_t \right) = 0$, where $d_t = D_t / P_t$, as well as (58) with equality and associated transversality conditions hold.

Banking sector There is a continuum of perfectly competitive banks $i \in [0, 1]$. A bank i receives demand deposits $D_{i,t}$ from households and holds reserves $M_{i,t-1}$ to meet liquidity demands from withdrawals of deposits

$$\omega D_{i,t-1} \leq I_{i,t} + M_{i,t-1}. \tag{62}$$

By imposing the constraint (62), we implicitly assume that a reserve requirement is either identical to the expected withdrawals or slack. Banks supply one-period risk-free loans $L_{i,t}$ to firms at a period t price $1/R^L_t$ and a payoff $L_{i,t}$ in period $t+1$. Thus, R^L_t denotes the rate at which firms can borrow. Banks can further invest in short-term government bonds that are issued at the price $1/R_t$, which are eligible for open market operations, see (6). Bank i's profits $P_t \varphi^B_{i,t}$ are given by

$$\begin{aligned} P_t \varphi^B_{i,t} = & \left(D_{i,t} / R^D_t \right) - D_{i,t-1} - M_{i,t} + M_{i,t-1} - I_{i,t} \left(R^m_t - 1 \right) \\ & - \left(B_{i,t} / R_t \right) + B_{i,t-1} - \left(L_{i,t} / R^L_t \right) + L_{i,t-1}. \end{aligned} \tag{63}$$

Banks maximize the sum of discounted profits, $E_t \sum_{k=0}^{\infty} p_{t,t+k} \varphi^B_{i,t+k}$, where $p_{t,t+k}$ denotes the stochastic discount factor $p_{t,t+k} = \beta^k \lambda_{t+k} / \lambda_t$, subject to the money supply constraint (6), the liquidity constraint (62), the budget constraint (63), and the borrowing constraints $\lim_{s \to \infty} E_t [p_{t,t+k} D_{i,t+s} / P_{t+s}] \geq 0$, $B_{i,t} \geq 0$, and $M_{i,t} \geq 0$. The first-order conditions with respect to deposits, T-bills, corporate and interbank loans, money holdings, and reserves can be written as

$$\frac{1}{R_t^D} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \omega \varkappa_{i,t+1}}{\pi_{t+1}}, \tag{64}$$

$$\frac{1}{R_t} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \xi_{i,t+1}}{\pi_{t+1}}, \tag{65}$$

$$\frac{1}{R_t^L} = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \pi_{t+1}^{-1}, \tag{66}$$

$$1 = \beta E_t \frac{\lambda_{t+1}}{\lambda_t} \frac{1 + \varkappa_{i,t+1}}{\pi_{t+1}}, \tag{67}$$

$$\varkappa_{i,t} + 1 = R_t^m \left(\xi_{i,t} + 1 \right), \tag{68}$$

where $\xi_{i,t}$ and $\varkappa_{i,t}$ denote the multipliers on the money supply constraint (6) and the liquidity constraint (62), respectively. Further, the following complementary slackness conditions hold: *i)* $0 \leq b_{i,t-1}\pi_t^{-1} - R_t^m i_{i,t}$, $\xi_{i,t} \geq 0$, $\xi_{i,t}\left(b_{i,t-1}\pi_t^{-1} - R_t^m i_{i,t}\right) = 0$, and *ii.)* $0 \leq i_{i,t} + m_{i,t-1}\pi_t^{-1} - \omega d_{i,t-1}\pi_t^{-1}$, $\varkappa_{i,t} \geq 0$, $\varkappa_{i,t}\left(i_{i,t} + m_{i,t-1}\pi_t^{-1} - \omega d_{i,t-1}\pi_t^{-1}\right) = 0$, where $d_{i,t} = d_{i,t}/P_t$, $m_{i,t} = M_{i,t}/P_t$, $b_{i,t} = B_{i,t}/P_t$, and $i_{i,t} = I_{i,t}/P_t$, and the associated transversality conditions.

Production sector The intermediate goods producing firms are identical, perfectly competitive, owned by the households, and produce an intermediate good y_t^m with labor n_t according to $y_t = n_t^\alpha$. They sell the intermediate good to retailers at the price P_t^m. We neglect retained earnings and assume that firms rely on bank loans to finance wage outlays before goods are sold. The firms' loan demand satisfies

$$L_t/R_t^L \geq P_t w_t n_t. \tag{69}$$

Firms are committed to fully repay their liabilities, such that bank loans are default-risk free. The problem of a representative firm can then be summarized as $\max E_t \sum_{k=0}^{\infty} p_{t,t+k}\varrho_{t+k}$, where ϱ_t denotes real dividends $\varrho_t = (P_t^m/P_t)n_t^\alpha - w_t n_t - l_{t-1}\pi_t^{-1} + l_t/R_t^L$, subject to (69). The first-order conditions for loan and labor demand are

$$1 + \gamma_t = R_t^L E_t[p_{t,t+1}\pi_{t+1}^{-1}], \tag{70}$$

$$P_t^m/P_t \alpha n_t^{\alpha-1} = (1 + \gamma_t)\, w_t, \tag{71}$$

where γ_t denotes the multiplier on the constraint (69). Monopolistically competitive retailers and perfectly competitive bundlers behave as described in Section 3.1.

Equilibrium The public sector is described in Section 3.2. Given that banks behave in an identical way, we can omit all indices. Combining the banks' loan supply condition (66) with the firm's loan demand condition (70), shows that $\gamma_t = 0$. Hence,

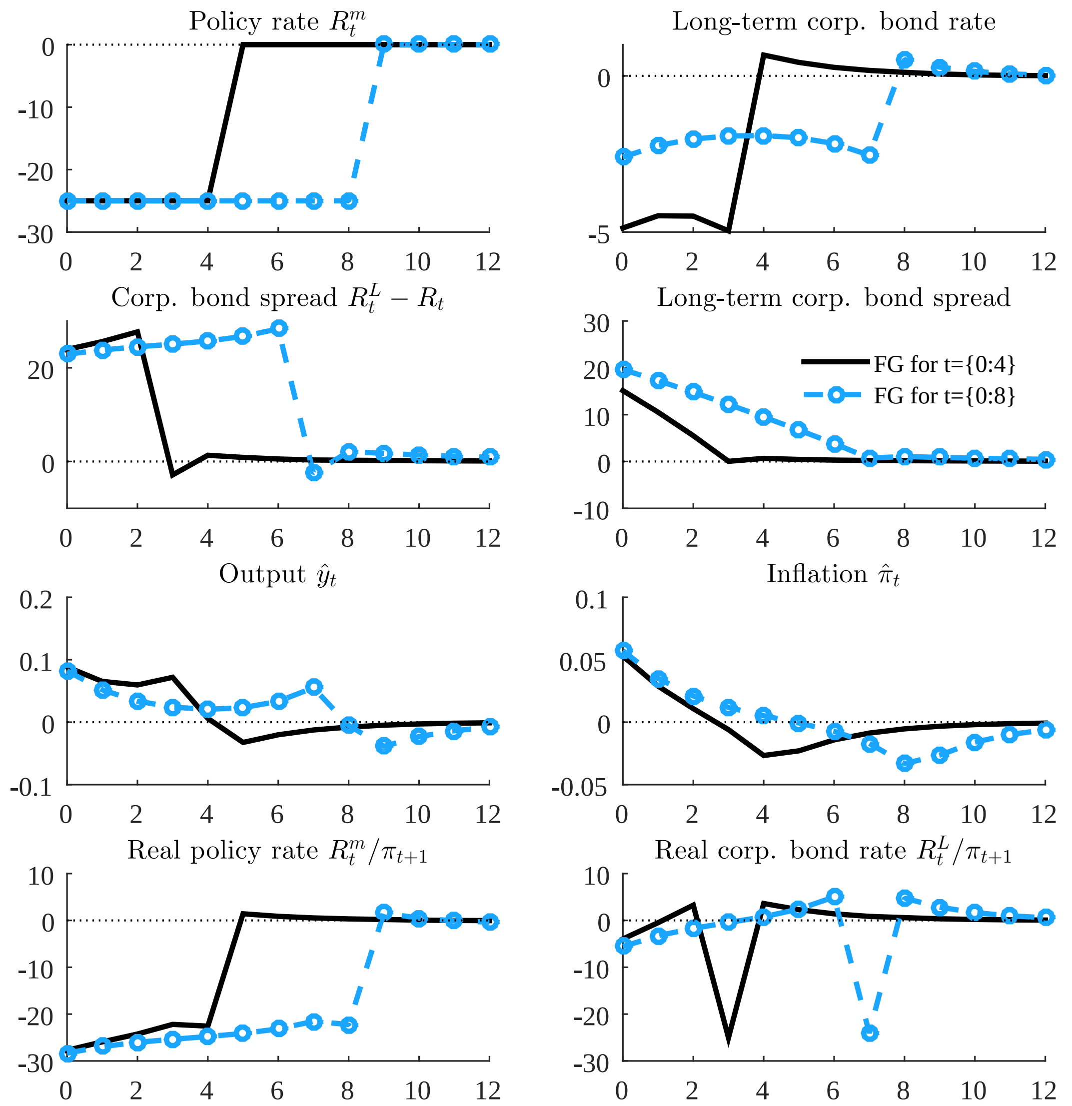
(69) is slack, such that the firm's labor demand (71) will be undistorted and reads $P_t^m/P_t = w_t/\left(\alpha n_t^{\alpha-1}\right)$ such that Modigliani-Miller theorem applies. Substituting out the deposit rate with (64) in (61), gives $E_t[\frac{\lambda_{t+1}+\omega\psi_{t+1}}{\lambda_t}\pi_{t+1}^{-1}] = E_t[\frac{\lambda_{t+1}}{\lambda_t}(1+\varkappa_{t+1}\omega)\pi_{t+1}^{-1}]$, which is satisfied if $\varkappa_t = \psi_t/\lambda_t$. Hence, the equilibrium versions of the conditions (67) and (68) imply $(\psi_t+\lambda_t)/\lambda_t = R_t^m(\xi_t+1)$ and $\beta\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$, which can – by using the unchanged condition (7) – be combined to $\xi_t = \left(R_t^{IS}/R_t^m\right) - 1$. Exactly as (13), the latter equation implies that the money supply constraint (6) is binding, if the central bank sets the policy rate R_t^m below R_t^{IS}.

Combining (65) with (67) and (68), $R_t \cdot E_t\varsigma_{1,t+1} = E_t[R_{t+1}^m \cdot \varsigma_{1,t+1}]$, where $\varsigma_{1,t+1} = \lambda_{t+1}\left(1+\xi_{t+1}\right)/\pi_{t+1}$, shows that the treasury rate equals the expected policy rate up to first order (see 17). Further, combining (66), with $\beta E_t\pi_{t+1}^{-1}\left(\lambda_{t+1}+\psi_{t+1}\right) = \lambda_t$ (see 66) shows that the loan rate R_t^L relates to the expected marginal rate of intertemporal substitution $(1/R_t^L)\cdot E_t\varsigma_{2,t+1} = E_t[\left(1/R_{t+1}^{IS}\right)\cdot\varsigma_{2,t+1}]$, where $\varsigma_{2,t+1} = \left(\lambda_{t+1}+\psi_{t+1}\right)/\pi_{t+1}$. Likewise, (61) implies that the expected rates of return on equity is related to the expected marginal rate of intertemporal substitution: $E_t\varsigma_{2,t+1} = E_t\left[\left(R_{t+1}^q/R_{t+1}^{IS}\right)\cdot\varsigma_{2,t+1}\right]$. Hence, the loan rate equals to the expected marginal rate of intertemporal substitution up to first order (see 18) and $E_tR_{t+1}^q = E_tR_{t+1}^{IS}+$ h.o.t. Substituting out $\varkappa_t$ in the equilibrium version of (67) with $\varkappa_t = \psi_t/\lambda_t$ and combining with the unchanged condition (7), leads to $\psi_t = u_{c,t}\left(1-1/R_t^{IS}\right)$, which equals (12). Finally, combining (59) with (62) leads to a consolidated liquidity constraint $P_tc_t \leq I_t + M_{t-1}$, which exactly accords to (5). Hence, a rational expectations equilibrium of the economy with banks can be summarized by the equilibrium characterization given in Definition 1.

G Additional Figures

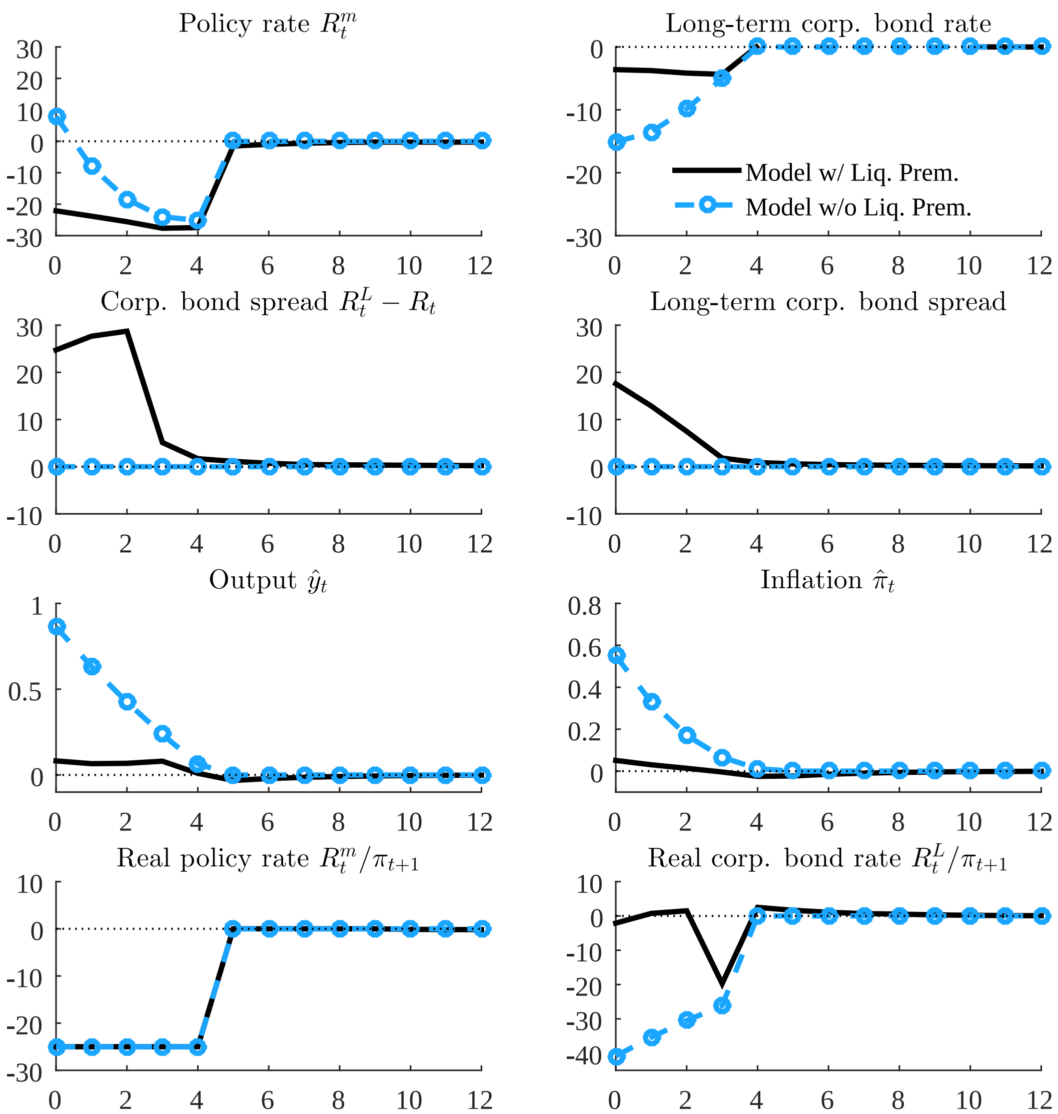
Figure 7 repeats our one-year forward-guidance experiment for a higher value of the intertemporal elasticity of substitution, i.e., $\sigma = 2$. This parameter value leads to very similar results compared to those for the baseline value of $\sigma = 1.5$ shown in Figure 1.

Figure 7: Effects of forward guidance with $\sigma = 2$.



Notes: Impulse responses to forward guidance about policy rate R_t^m announced at the beginning of period 0 in model with endogenous liquidity premium. Y-axis: Deviations from steady state in percent ($\hat{y}_t$, $\hat{\pi}_t$) or in basis points (else). X-axis: quarters. Black solid (blue circled) line: Announced policy rate reduction of 25 basis points in quarters 0 to 4 (0 to 8). Long-term corporate bonds rate constructed as $\prod_s^q (\widehat{R}_{t+s}^L)^{1/q}$, where q equals the length of the forward guidance period. Long-term treasury rate and long-term spread are constructed accordingly.

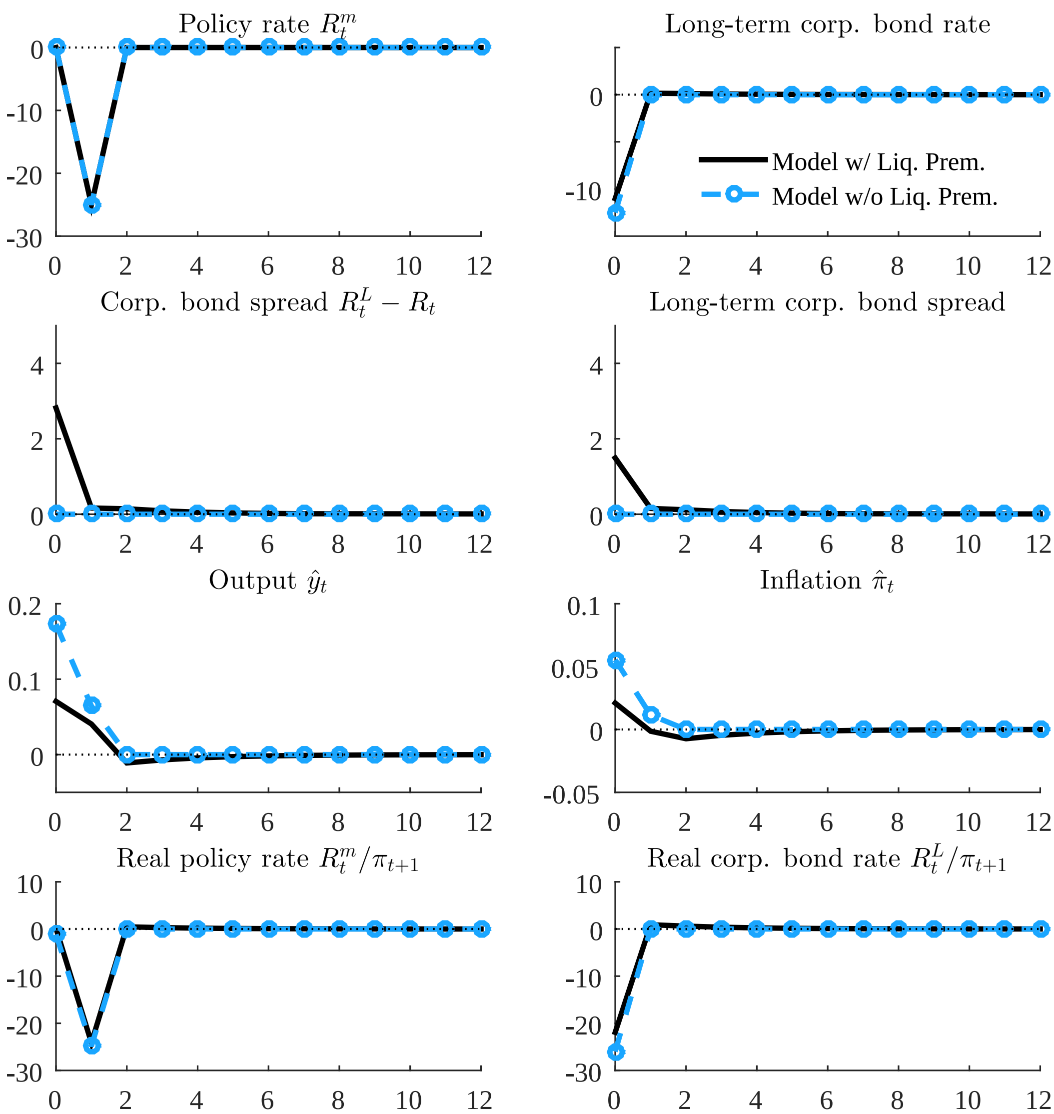
Figure 8: Comparison with a model version without liquidity premium – Real Policy Rate



Notes: Impulse responses to *real* policy rate (R_t^m/π_{t+1}) reduction of 25 basis points in quarters 0 to 4, announced at the beginning of quarter 0. Y-axis: Deviations from steady state in percent ($\hat{y}_t$, $\hat{\pi}_t$) or in basis points (else). X-axis: quarters. Black line: Baseline model with endogenous liquidity premium. Blue circled line: Model version without liquidity premium. Long-term corporate bonds rate constructed as $\prod_s^q(\widehat{R}_{t+s}^L)^{1/q}$, where q equals the length of the forward guidance period. Long-term treasury rate and long-term spread are constructed accordingly.

Figure 8 repeats the comparison of Figure 3, but now the central bank provides forward guidance about the real instead of the nominal policy rate. Overall, whether guidance is in terms of the real instead of the nominal rate does not make much of a difference for the model with the endogenous liquidity premium. The difference is larger for the model version without the liquidity premium, as the exacerbating effect via higher

Figure 9: Isolated effects of an announced future reduction in the monetary policy rate

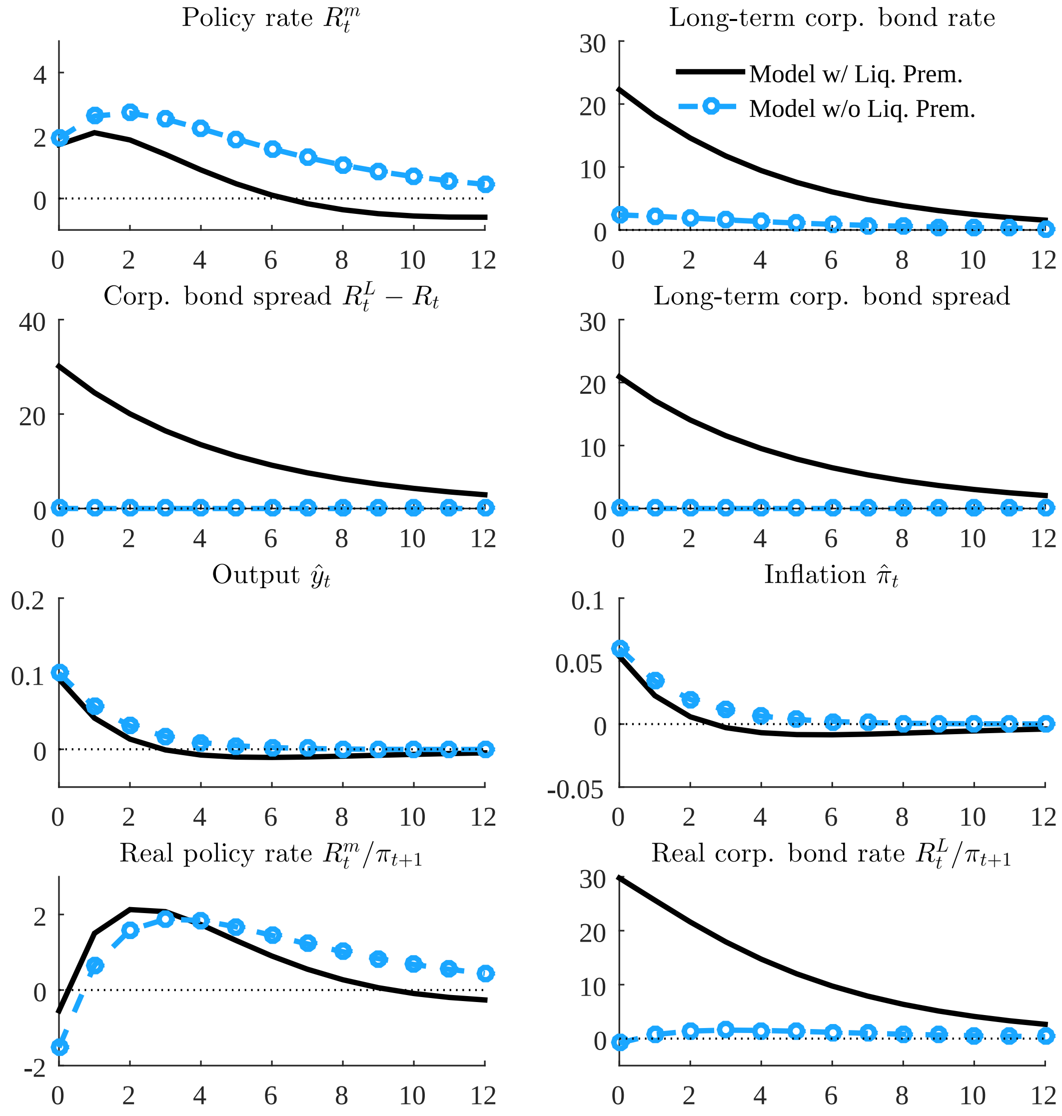


Notes: Impulse responses to policy rate (R_t^m/π_{t+1}) reduction of 25 basis points in quarters 1, announced at the beginning of quarter 0. Y-axis: Deviations from steady state in percent ($\hat{y}_t$, $\hat{\pi}_t$) or in basis points (else). X-axis: quarters. Black line: Baseline model with endogenous liquidity premium. Blue circled line: Model version without liquidity premium. Long-term corporate bonds rate constructed as $\prod_s^q(\widehat{R}_{t+s}^L)^{1/q}$, where q equals the length of the forward guidance period. Long-term treasury rate and long-term spread are constructed accordingly.

inflation that lowers real rates is now absent. The responses of real activity and inflation are nevertheless still much stronger than in the model with the liquidity premium.

Figure 9 shows the effects of an isolated reduction in the policy rate for period $t = 1$ which is announced in period $t = 0$. In our model with the liquidity premium, the announcement raises liquidity premia, inflation, and output. The latter effect differs from those in the simplified model version considered in Proposition 1 due to the inclusion

Figure 10: Effects of a time preference shock



Notes: Responses to a time preference shock realizing at the beginning of period 0. Y-axis: Deviations from steady state in percent ($\hat{y}_t$, $\hat{\pi}_t$) or in basis points (else). X-axis: quarters. Black line: Baseline model with endogenous liquidity premium. Blue circled line: Model version without liquidity premium. Long-term corporate bonds rate constructed as $\prod_s^4 (\widehat{R}_{t+s}^L)^{1/4}$, long-term treasury rate and long-term spread constructed accordingly.

of credit goods, which reduces the overall importance of the cash-in-advance constraint (5). Still, introducing endogenous liquidity premia, weakens the output (and inflation) effect of announced future changes in the monetary policy rate considerably compared to a basic New Keynesian model.

Figure 10 shows the effects of a time-preference shock. For this experiment, we incorporate a stochastic component ξ to the lifetime utility function which now reads $E_0 \sum_{t=0}^{\infty} \beta^t \xi_t u(c_{i,t}, \widetilde{c}_{i,t}, n_t)$, where $\ln \xi_t = \rho_\xi \ln \xi_{t-1} + \varepsilon_t^\xi$, instead of (3). We use $\rho_\xi = 0.8$ and normalize the size of the shock $\varepsilon_t^{\xi} < 0$ considered in Figure 10 to generate an impact output response of 0.1%. This experiment shows that, in our model with the liquidity premium, such a non-monetary demand shock induces a positive relation between the monetary policy rate and liquidity premia, consistent with evidence documented by Nagel (2016).