Unemployment Risk, Liquidity Traps, and Monetary Policy

Online Appendix (Not for Publication)

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A Bounded Rationality

In order to mitigate the forward guidance puzzle (see e.g., Del Negro et al., 2015), we assume that workers are cognitively myopic as in Gabaix (2020). By reacting myopically to distant events, such as future interest rate changes, forward guidance becomes significantly less powerful than in the canonical rational-expectations New Keynesian model.

Under boundedly rational expectations, the agent perceives that the state-vector X_t evolves according to:

$$X_{t+1} = G\left(X_t, \epsilon_{t+1}\right)^{\zeta} X^{1-\zeta}, \tag{A.1}$$

with equilibrium transition function G and mean-0 innovation ϵ_{t+1}. The parameter $\zeta \in [0, 1]$ is a cognitive discounting parameter, such that $\zeta = 1$ implies fully rational expectations. Taking the logarithm of the above:

$$\log X_{t+1} = \zeta \log G\left(X_t, \epsilon_{t+1}\right) + (1 - \zeta) \log X. \tag{A.2}$$

The linearised model implies:

$$\log\left(\frac{X_{t+1}}{X}\right) = \zeta\left(\Gamma \log\left(\frac{X_t}{X}\right) + \epsilon_{t+1}\right). \tag{A.3}$$

Hence, the expectation of the boundedly rational agent is given by:

$$E_t^{BR} \log\left(\frac{X_{t+k}}{X}\right) = \zeta^k \Gamma^k \left(\frac{X_{t+k}}{X}\right) = \Gamma^k E_t \left(\frac{X_{t+k}}{X}\right). \tag{A.4}$$

In practice, this type of expectation affects two equilibrium conditions in our model. First, the worker's Euler equation becomes:

$$1 = \beta E_t \frac{\left(\left(1 - s_{t+1}\right) {w_{t+1}}^{-1} + s_{t+1} {\delta_{t+1}}^{-1}\right)^{\zeta}}{\left(\left(1 - s\right) w^{-1} + s\delta^{-1}\right)^{\zeta - 1} {w_t}^{-1}} \frac{\left(1 + i_t\right) z_t}{1 + \pi_{t+1}}. \tag{A.5}$$

Second, the value of being employed is given by:

$$S_t^W = \log w_t - \log \delta_t + \beta E_t \frac{\left(\left(1 - s_{t+1} - f_{t+1}\right) S_{t+1}^W\right)^{\zeta}}{\left(\left(1 - s - f\right) S^W\right)^{\zeta - 1}}. \tag{A.6}$$

A.1 Log-Linear Expressions

In this section, we show that log-linearising our modified Euler equation delivers the same expression as replacing the expectation operator after log-linearising the actual Euler equation, as done in Gabaix (2020).

First, consider the actual Euler equation with myopic expectations:

$$1 = \beta E_t^{BR} \frac{(1 - s_{t+1}) {w_{t+1}}^{-1} + s_{t+1} {\delta_{t+1}}^{-1}}{{w_t}^{-1}} \frac{(1 + i_t) z_t}{1 + \pi_{t+1}}. \tag{A.7}$$

Log-linearising around the non-stochastic steady-state delivers:

$$\begin{aligned} 0 = -E_t^{BR} \left(\frac{(1-s) w^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{w}_{t+1} + \frac{s\delta^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{\delta}_{t+1} + \frac{s \left(w^{-1} + \delta^{-1}\right)}{(1-s) w^{-1} + s\delta^{-1}} \hat{s}_{t+1} \right) \\ + \hat{w}_t + i_t + \hat{z}_t - E_t \pi_{t+1}, \end{aligned} \tag{A.8}$$

where $\hat{x}_t \equiv \log x_t - \log x$, with x being the steady-state value of a generic variable x_t. Using the fact that $E_t^{BR} \hat{x}_{t+1} = \zeta E_t \hat{x}_{t+1}$, we have:

$$\begin{aligned} 0 = -\zeta E_t \left(\frac{(1-s) w^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{w}_{t+1} + \frac{s\delta^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{\delta}_{t+1} + \frac{s \left(w^{-1} + \delta^{-1}\right)}{(1-s) w^{-1} + s\delta^{-1}} \hat{s}_{t+1} \right) \\ + \hat{w}_t + i_t + \hat{z}_t - E_t \pi_{t+1}. \end{aligned} \tag{A.9}$$

Second, consider our modified Euler equation:

$$1 = \beta E_t \frac{\left((1 - s_{t+1}) {w_{t+1}}^{-1} + s_{t+1} {\delta_{t+1}}^{-1}\right)^{\zeta}}{\left((1-s) w^{-1} + s\delta^{-1}\right)^{\zeta - 1} {w_t}^{-1}} \frac{(1 + i_t) z_t}{1 + \pi_{t+1}}. \tag{A.10}$$

Log-linearising around the non-stochastic steady-state gives us the following expression:

$$\begin{aligned} 0 = -\zeta E_t \left(\frac{(1-s) w^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{w}_{t+1} + \frac{s\delta^{-1}}{(1-s) w^{-1} + s\delta^{-1}} \hat{\delta}_{t+1} + \frac{s \left(w^{-1} + \delta^{-1}\right)}{(1-s) w^{-1} + s\delta^{-1}} \hat{s}_{t+1} \right) \\ + \hat{w}_t + i_t + \hat{z}_t - E_t \pi_{t+1}, \end{aligned} \tag{A.11}$$

which is the same as Equation (A.9). Finally, it bears noting that households' myopia does not affect π_{t+1}. This is because households react to changes in the real rate $r_t \equiv \frac{1+i_t}{1+E_t \pi_{t+1}} - 1$ and $E_t^{BR} r_t = r_t$.

B Equilibrium Conditions

B.1 Workers

- Home production

$$\delta_t = \frac{\delta}{w} w_t, \tag{B.1}$$

- Euler equation

$$E_t M^e_{t,t+1} \frac{(1+i_t)\, z_t}{1+\pi_{t+1}} = 1, \tag{B.2}$$

- IMRS of employed workers

$$E_{t-1} M^e_{t-1,t} = \beta \frac{\left((1-s_t)\, {w_t}^{-1} + s_t {\delta_t}^{-1}\right)^{\zeta}}{\left((1-s)\, w^{-1} + s\delta^{-1}\right)^{\zeta-1} {w_{t-1}}^{-1}}, \tag{B.3}$$

B.2 Firm Owners

- Total consumption of firm owners

$$c^F_t = y_t - w_t n_t - \kappa v_t - \frac{\psi}{2} {\pi_t}^2 y_t + \varpi, \tag{B.4}$$

- IMRS of firm owners

$$M^F_{t-1,t} = \beta \left(\frac{c^F_t}{c^F_{t-1}}\right)^{-1}, \tag{B.5}$$

B.3 Labour Market Flows

- Job-finding rate

$${f_t}^{\frac{\gamma}{1-\gamma}} = \left(1-\tau^I\right)(q_t - w_t + T)\, \frac{\mu^{\frac{1}{1-\gamma}}}{\kappa} + (1-\rho)\, E_t M^F_{t,t+1} {f_{t+1}}^{\frac{\gamma}{1-\gamma}}, \tag{B.6}$$

- Period-to-period job-loss rate

$$s_t = \rho\,(1-f_t)\,, \tag{B.7}$$

- Employment rate

$$n_t = (1-s_t)\, n_{t-1} + (1-n_{t-1})\, f_t, \tag{B.8}$$

- Vacancies

$$v_t = \left(\frac{n_t - (1-\rho)\, n_{t-1}}{\left(1-(1-\rho)\, n_{t-1}\right)^{\gamma}}\right)^{\frac{1}{1-\gamma}}, \tag{B.9}$$

B.4 Wholesale Firms

- New Keynesian Phillips curve

$$\psi\left(1+\pi_t\right)\pi_t = \psi E_t M_{t,t+1}^F\left(1+\pi_{t+1}\right)\pi_{t+1}\frac{y_{t+1}}{y_t} + 1 - \theta + \theta\left(1-\tau^W\right)q_t, \tag{B.10}$$

B.5 Nash Bargaining

- Value of being employed $(V^e - V^u)$

$$S_t^W = \log w_t - \log \delta_t + \beta E_t \frac{\left(\left(1-s_{t+1}-f_{t+1}\right)S_{t+1}^W\right)^{\zeta}}{\left(\left(1-s-f\right)S^W\right)^{\zeta-1}}, \tag{B.11}$$

- Job value (from the free-entry condition)

$$J_t^F = \kappa\frac{f_t^{\frac{\gamma}{1-\gamma}}}{\mu^{\frac{1}{1-\gamma}}}, \tag{B.12}$$

- Nash-bargaining wage

$$\left(1-\alpha\right)J_t^F = \alpha\left(1-\tau^I\right)S_t^W w_t^N, \tag{B.13}$$

- Wage rigidity

$$w_t = w^{\phi} {w_t^N}^{1-\phi}, \tag{B.14}$$

B.6 Market Clearing

- Production function

$$y_t = n_t, \tag{B.15}$$

B.7 Policy rate

- Zero Lower Bound

$$i_t \geq 0. \tag{B.16}$$

C Ramsey Optimal Policy Problem

Following Schmitt-Grohé and Uribe (2005), we assume that, in every period, the Ramsey planner honours commitments made in the very distant past, i.e., $t=-\infty$, in choosing the optimal policy. This means that the constraints that the planner faces at date $t \geq 0$ are the same as those at date $t<0$, implying that the predetermined Lagrange multipliers at date $t=0$ are not necessarily assumed to be zero. The law of iterated expectations is used to eliminate the conditional expectation that appeared in each constraint. This form of policy is referred to as an optimal policy from the timeless perspective (Woodford, 2003).

Let $\lambda_{1,t}$, $\lambda_{2,t}$, $\lambda_{3,t}$, $\lambda_{4,t}$, $\lambda_{5,t}$, $\lambda_{6,t}$, $\lambda_{7,t}$, $\lambda_{8,t}$, $\lambda_{9,t}$, $\lambda_{10,t}$, $\lambda_{11,t}$, $\lambda_{12,t}$, $\lambda_{13,t}$, $\lambda_{14,t}$, $\lambda_{15,t}$, and $\lambda_{16,t}$ be Lagrange multipliers on the constraints (B.1) to (B.16). Given $\{n_t, w_t, \delta_t, c_t^F, M_{t-1,t}^e, i_t, \pi_t, s_t, y_t, v_t, M_{t-1,t}^F, q_t, f_t, S_t^W, J_t^F, w_t^N\}_{-\infty}^{-1}$, $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}, \lambda_{6,t}, \lambda_{7,t}, \lambda_{8,t}, \lambda_{9,t}, \lambda_{10,t}, \lambda_{11,t}, \lambda_{12,t}, \lambda_{13,t}, \lambda_{14,t}, \lambda_{15,t}, \lambda_{16,t}\}_{-\infty}^{-1}$, and a stochastic process $\{z_t\}_0^{\infty}$, a Ramsey equilibrium consists of a set of control variables $\{n_t, w_t, \delta_t, c_t^F, M_{t-1,t}^e, i_t, \pi_t, s_t, y_t, v_t, M_{t-1,t}^F, q_t, f_t, S_t^W, J_t^F, w_t^N\}_0^{\infty}$ and a set of co-state variables $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}, \lambda_{5,t}, \lambda_{6,t}, \lambda_{7,t}, \lambda_{8,t}, \lambda_{9,t}, \lambda_{10,t}, \lambda_{11,t}, \lambda_{12,t}, \lambda_{13,t}, \lambda_{14,t}, \lambda_{15,t}, \lambda_{16,t}\}_0^{\infty}$ that solve:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \left(n_t \log w_t + (1-n_t) \log \delta_t + \Lambda \log c_t^F \right), \tag{C.1}$$

subject to (B.1) to (B.16). Predetermined Lagrangian multipliers are set equal to their steady state. The augmented Lagrangian for the optimal policy problem then reads as follows:

$$\begin{aligned}
L = \max E_0 \sum_{t=0}^{\infty} \beta^t \Bigg(& n_t \log w_t + (1-n_t)\log \delta_t + \Lambda \log c_t^F + \lambda_{1,t}\left(\delta_t - \frac{\delta}{w} w_t\right) \\
& + \lambda_{2,t}\left(1 - M_{t,t+1}^e \frac{(1+i_t) z_t}{1+\pi_{t+1}}\right) + \lambda_{3,t}\left(M_{t-1,t}^e {w_{t-1}}^{-1} - \beta \frac{\left((1-s_t) {w_t}^{-1} + s_t {\delta_t}^{-1}\right)^{\zeta}}{\left((1-s) w^{-1} + s\delta^{-1}\right)^{\zeta-1}}\right) \\
& + \lambda_{4,t}\left(y_t - w_t n_t - \kappa v_t - \frac{\psi}{2} {\pi_t}^2 y_t + \varpi - c_t^F\right) + \lambda_{5,t}\left(\beta {c_t^F}^{-1} - M_{t-1,t}^F {c_{t-1}^F}^{-1}\right) \\
& + \lambda_{6,t}\left(\left(1-\tau^I\right)(q_t - w_t + T)\frac{\mu^{\frac{1}{1-\gamma}}}{\kappa} + (1-\rho) M_{t,t+1}^F {f_{t+1}}^{\frac{\gamma}{1-\gamma}} - {f_t}^{\frac{\gamma}{1-\gamma}}\right) \\
& + \lambda_{7,t}\left(s_t - \rho(1-f_t)\right) + \lambda_{8,t}\left((1-s_t) n_{t-1} + (1-n_{t-1}) f_t - n_t\right) \\
& + \lambda_{9,t}\left(v_t (1-(1-\rho) n_{t-1})^{\frac{\gamma}{1-\gamma}} - (n_t - (1-\rho) n_{t-1})^{\frac{1}{1-\gamma}}\right) \\
& + \lambda_{10,t}\left(\psi(1+\pi_t)\pi_t y_t - \psi M_{t,t+1}^F (1+\pi_{t+1})\pi_{t+1} y_{t+1} - (1-\theta) y_t - \theta\left(1-\tau^W\right) q_t y_t\right) \\
& + \lambda_{11,t}\left(\log w_t - \log \delta_t + \beta \frac{\left((1-s_{t+1}-f_{t+1}) S_{t+1}^W\right)^{\zeta}}{\left((1-s-f) S^W\right)^{\zeta-1}} - S_t^W\right) + \lambda_{12,t}\left(J_t^F - \kappa \frac{{f_t}^{\frac{\gamma}{1-\gamma}}}{\mu^{\frac{1}{1-\gamma}}}\right) \\
& + \lambda_{13,t}\left(\alpha\left(1-\tau^I\right) S_t^W w_t^N - (1-\alpha) J_t^F\right) + \lambda_{14,t}\left(w_t - w^{\phi} {w_t^N}^{1-\phi}\right) + \lambda_{15,t}(n_t - y_t) + \lambda_{16,t} i_t \Bigg).
\end{aligned} \tag{C.2}$$

The first-order conditions are as follows:

$$[n_t]: \quad \log w_t - \log \delta_t - \lambda_{4,t} w_t - \lambda_{8,t} - \lambda_{9,t} \frac{1}{1-\gamma} \left(n_t - (1-\rho) n_{t-1}\right)^{\frac{1}{1-\gamma}-1} + \lambda_{15,t}$$
$$+\beta E_t \lambda_{8,t+1} \left(1 - s_{t+1} - f_{t+1}\right) \quad (C.3)$$
$$-\beta E_t \lambda_{9,t+1} \left(v_{t+1} \frac{\gamma}{1-\gamma} \left(1 - (1-\rho) n_t\right)^{\frac{\gamma}{1-\gamma}-1} (1-\rho) - \frac{1}{1-\gamma} \left(n_{t+1} - (1-\rho) n_t\right)^{\frac{1}{1-\gamma}-1} (1-\rho) \right) = 0,$$

$$[w_t]: \quad \frac{n_t}{w_t} - \lambda_{1,t} \frac{\delta}{w} + \lambda_{3,t} \beta \frac{\zeta \left((1-s_t) {w_t}^{-1} + s_t {\delta_t}^{-1} \right)^{\zeta-1} (1-s_t) {w_t}^{-2}}{\left((1-s) w^{-1} + s\delta^{-1} \right)^{\zeta-1}} - \lambda_{4,t} n_t - \lambda_{6,t} \left(1-\tau^I\right) \frac{\mu^{\frac{1}{1-\gamma}}}{\kappa} \quad (C.4)$$
$$+\lambda_{11,t} {w_t}^{-1} + \lambda_{14,t} - \beta \lambda_{3,t+1} M^e_{t,t+1} {w_t}^{-2} = 0,$$

$$[\delta_t]: \quad \frac{1-n_t}{\delta_t} + \lambda_{1,t} + \lambda_{3,t} \beta \frac{\zeta \left((1-s_t) {w_t}^{-1} + s_t {\delta_t}^{-1} \right)^{\zeta-1} s_t {\delta_t}^{-2}}{\left((1-s) w^{-1} + s\delta^{-1} \right)^{\zeta-1}} - \lambda_{11,t} {\delta_t}^{-1} = 0, \quad (C.5)$$

$$\left[c^F_t\right]: \quad \frac{\Lambda}{c^F_t} - \lambda_{4,t} - \lambda_{5,t} \beta {c^F_t}^{-2} + \beta E_t \lambda_{5,t+1} M^F_{t,t+1} {c^F_t}^{-2} = 0, \quad (C.6)$$

$$\left[M^e_{t-1,t}\right]: \quad \lambda_{3,t} {w_{t-1}}^{-1} - \frac{1}{\beta} \lambda_{2,t-1} \frac{(1+i_{t-1}) z_{t-1}}{1+\pi_t} = 0, \quad (C.7)$$

$$[i_t]: \quad \lambda_{2,t} M^e_{t,t+1} \frac{z_t}{1+\pi_{t+1}} + \lambda_{16,t} = 0, \quad (C.8)$$

$$[\pi_t]: \quad -\lambda_{4,t} \psi \pi_t y_t + \lambda_{10,t} \psi (1+2\pi_t) y_t + \frac{1}{\beta} \lambda_{2,t-1} M^e_{t-1,t} \frac{(1+i_{t-1}) z_{t-1}}{(1+\pi_t)^2} - \frac{1}{\beta} \lambda_{10,t-1} \psi M^F_{t-1,t} (1+2\pi) y_t = 0, \quad (C.9)$$

$$[s_t]: \quad \lambda_{3,t} \beta \frac{\zeta \left((1-s_t) {w_t}^{-1} + s_t {\delta_t}^{-1} \right)^{\zeta-1} \left({w_t}^{-1} - {\delta_t}^{-1} \right)}{\left((1-s) w^{-1} + s\delta^{-1} \right)^{\zeta-1}} + \lambda_{7,t} - \lambda_{8,t} n_{t-1} \quad (C.10)$$
$$-\frac{1}{\beta} \lambda_{11,t-1} \beta \frac{\zeta (1-s_t-f_t)^{\zeta-1} {S^W_t}^{\zeta}}{\left((1-s-f) S^W \right)^{\zeta-1}} = 0,$$

$$[y_t]: \quad \lambda_{4,t} \left(1 - \frac{\psi}{2} {\pi_t}^2 \right) + \lambda_{10,t} \left(\psi (1+\pi_t) \pi_t - 1 + \theta - \theta \left(1-\tau^W\right) q_t \right) - \lambda_{15,t} \quad (C.11)$$
$$-\frac{1}{\beta} \lambda_{9,t-1} \psi M^F_{t-1,t} (1+\pi_t) \pi_t = 0,$$

$$[v_t]: \quad -\lambda_{4,t} \kappa + \lambda_{9,t} \left(1 - (1-\rho) n_{t-1}\right)^{\frac{\gamma}{1-\gamma}} = 0, \quad (C.12)$$

$$\left[M^F_{t-1,t}\right]: \quad -\lambda_{5,t} {c^F_{t-1}}^{-1} + \frac{1}{\beta} \lambda_{6,t-1} (1-\rho) {f_t}^{\frac{\gamma}{1-\gamma}} - \frac{1}{\beta} \lambda_{10,t-1} \psi (1+\pi_t) \pi_t y_t = 0, \quad (C.13)$$

$$[q_t]: \quad \lambda_{6,t} \left(1-\tau^I\right) \frac{\mu^{\frac{1}{1-\gamma}}}{\kappa} - \lambda_{10,t} \theta \left(1-\tau^W\right) y_t = 0, \quad (C.14)$$

$$[f_t]: \quad -\lambda_{6,t} \frac{\gamma}{1-\gamma} {f_t}^{\frac{\gamma}{1-\gamma}-1} + \lambda_{7,t} \rho + \lambda_{8,t} (1-n_{t-1}) - \lambda_{12,t} \kappa \frac{\gamma}{1-\gamma} \frac{{f_t}^{\frac{\gamma}{1-\gamma}-1}}{\mu^{\frac{1}{1-\gamma}}} \quad (C.15)$$
$$+\frac{1}{\beta} \lambda_{6,t-1} (1-\rho) M^F_{t-1,t} \frac{\gamma}{1-\gamma} {f_t}^{\frac{\gamma}{1-\gamma}-1} - \frac{1}{\beta} \lambda_{11,t-1} \beta \frac{\zeta (1-s_t-f_t)^{\zeta-1} {S^W_t}^{\zeta}}{\left((1-s-f) S^W \right)^{\zeta-1}} = 0,$$

$$\left[S_t^W\right]: \quad -\lambda_{11,t} + \lambda_{13,t}\alpha\left(1-\tau^I\right)w_t^N + \frac{1}{\beta}\lambda_{11,t-1}\beta\frac{\zeta\left(1-s_t-f_t\right)^{\zeta} S_t^{W\,\zeta-1}}{\left(\left(1-s-f\right)S^W\right)^{\zeta-1}} = 0, \tag{C.16}$$

$$\left[J_t^F\right]: \quad \lambda_{12,t} - \lambda_{13,t}\left(1-\alpha\right) = 0, \tag{C.17}$$

$$\left[w_t^N\right]: \quad \lambda_{13,t}\alpha\left(1-\tau^I\right)S_t^W - \lambda_{14,t}\left(1-\phi\right)w^{\phi}w_t^{N\,-\phi} = 0, \tag{C.18}$$

$$\left[\lambda_{1,t}\right]: \quad \delta_t - \frac{\delta}{w}w_t = 0, \tag{C.19}$$

$$\left[\lambda_{2,t}\right]: \quad 1 - E_t M_{t,t+1}^e\frac{\left(1+i_t\right)z_t}{1+\pi_{t+1}} = 0, \tag{C.20}$$

$$\left[\lambda_{3,t}\right]: \quad M_{t-1,t}^e {w_{t-1}}^{-1} - \beta\frac{\left(\left(1-s_t\right){w_t}^{-1} + s_t{\delta_t}^{-1}\right)^{\zeta}}{\left(\left(1-s\right)w^{-1} + s\delta^{-1}\right)^{\zeta-1}{w_{t-1}}^{-1}} = 0, \tag{C.21}$$

$$\left[\lambda_{4,t}\right]: \quad y_t - w_t n_t - \kappa v_t - \frac{\psi}{2}{\pi_t}^2 y_t + \varpi - c_t^F = 0, \tag{C.22}$$

$$\left[\lambda_{5,t}\right]: \quad \beta {c_t^F}^{-1} - M_{t-1,t}^F {c_{t-1}^F}^{-1} = 0, \tag{C.23}$$

$$\left[\lambda_{6,t}\right]: \quad \left(1-\tau^I\right)\left(q_t - w_t + T\right)\frac{\mu^{\frac{1}{1-\gamma}}}{\kappa} + \left(1-\rho\right)E_t M_{t,t+1}^F {f_{t+1}}^{\frac{\gamma}{1-\gamma}} - {f_t}^{\frac{\gamma}{1-\gamma}} = 0, \tag{C.24}$$

$$\left[\lambda_{7,t}\right]: \quad s_t - \rho\left(1-f_t\right) = 0, \tag{C.25}$$

$$\left[\lambda_{8,t}\right]: \quad \left(1-s_t\right)n_{t-1} + \left(1-n_{t-1}\right)f_t - n_t = 0, \tag{C.26}$$

$$\left[\lambda_{9,t}\right]: \quad v_t\left(1-\left(1-\rho\right)n_{t-1}\right)^{\frac{\gamma}{1-\gamma}} - \left(n_t - \left(1-\rho\right)n_{t-1}\right)^{\frac{1}{1-\gamma}} = 0, \tag{C.27}$$

$$\left[\lambda_{10,t}\right]: \quad \psi\left(1+\pi_t\right)\pi_t y_t - \psi E_t M_{t,t+1}^F\left(1+\pi_{t+1}\right)\pi_{t+1}y_{t+1} - \left(1-\theta\right)y_t - \theta\left(1-\tau^W\right)q_t y_t = 0, \tag{C.28}$$

$$\left[\lambda_{11,t}\right]: \quad \log w_t - \log\delta_t + \beta E_t\frac{\left(\left(1-s_{t+1}-f_{t+1}\right)S_{t+1}^W\right)^{\zeta}}{\left(\left(1-s-f\right)S^W\right)^{\zeta-1}} - S_t^W = 0, \tag{C.29}$$

$$\left[\lambda_{12,t}\right]: \quad J_t^F - \kappa\frac{{f_t}^{\frac{\gamma}{1-\gamma}}}{\mu^{\frac{1}{1-\gamma}}} = 0, \tag{C.30}$$

$$\left[\lambda_{13,t}\right]: \quad \alpha\left(1-\tau^I\right)S_t^W w_t^N - \left(1-\alpha\right)J_t^F = 0, \tag{C.31}$$

$$\left[\lambda_{14,t}\right]: \quad w_t - w^{\phi}\left(w_t^N\right)^{1-\phi} = 0, \tag{C.32}$$

$$\left[\lambda_{15,t}\right]: \quad n_t - y_t = 0, \tag{C.33}$$

$$\left[\lambda_{16,t}\right]: \quad i_t \geq 0. \tag{C.34}$$

D Further Details about the Analytical Two-Period Model

In this section of the appendix, we provide more details about the derivations of the two-period model used in Section 2.2 of the main text.

D.1 Strict Inflation Targeting: Full Derivation

Under the strict inflation-targeting policy the central bank sets the nominal policy rate to keep inflation at its steady-state value whenever the policy rate is above the zero lower bound:

$$\hat{\pi}_t = 0 \quad \text{s.t.} \quad \hat{i}_t \geq -\frac{i}{1+i}. \tag{D.1}$$

Therefore, we have the following two-period solution:

$$\hat{y}_0 = \eta \hat{y}_1 + \frac{i}{1+i} + \hat{\pi}_1 - \hat{z}, \tag{D.2}$$

$$\hat{\pi}_0 = \beta \hat{\pi}_1 + \varphi \hat{y}_0, \tag{D.3}$$

$$\hat{y}_1 = -\hat{i}_1, \tag{D.4}$$

$$\hat{\pi}_1 = \varphi \hat{y}_1. \tag{D.5}$$

Given the last two equations, we have $\hat{i}_1 = 0$. The system of equations above can be written in matrix form as:

$$\begin{bmatrix} 1 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & -\beta \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -\varphi & 1 \end{bmatrix} \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \end{bmatrix} \implies \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & -\beta \\ 0 & 0 & 1 & 0 \\ 0 & 0 & -\varphi & 1 \end{bmatrix}^{-1} \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

It follows that:

$$\hat{y}_0 = -\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.6}$$

$$\hat{\pi}_0 = -\varphi \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.7}$$

$$\hat{i}_1 = \hat{y}_1 = \hat{\pi}_1 = 0. \tag{D.8}$$

Period-0 output and inflation $\hat{y}_0$ and $\hat{\pi}_0$ are independent of the coefficient η (and, hence, independent of δ and ζ) because, under strict inflation targeting, $\hat{y}_1$ and $\hat{\pi}_1$ are always zero.

D.2 Optimal Monetary Policy: Full Derivation

Under the optimal monetary policy, the central bank minimises the following loss function:

$$\frac{1}{2}E_0\sum_{t=0}^{\infty}\beta^t\left({\pi_t}^2+\vartheta {y_t}^2\right), \tag{D.9}$$

subject to Equations (6) and (7) in the main text. We then have the following conditions:

$$\hat{y}_0=\eta\hat{y}_1+\frac{i}{1+i}+\hat{\pi}_1-\hat{z}, \tag{D.10}$$

$$\hat{\pi}_0=\beta\hat{\pi}_1+\varphi\hat{y}_0, \tag{D.11}$$

$$\hat{\pi}_0+\lambda_0^{PC}=0, \tag{D.12}$$

$$\vartheta\hat{y}_0+\lambda_0^{IS}-\varphi\lambda_0^{PC}=0, \tag{D.13}$$

$$\hat{y}_1=-\hat{i}_1, \tag{D.14}$$

$$\hat{\pi}_1=\varphi\hat{y}_1, \tag{D.15}$$

$$\hat{\pi}_1+\lambda_1^{PC}-\frac{1}{\beta}\lambda_0^{IS}-\lambda_0^{PC}=0, \tag{D.16}$$

$$\vartheta\hat{y}_1+\lambda_1^{IS}-\varphi\lambda_0^{PC}-\frac{\eta}{\beta}\lambda_0^{IS}=0. \tag{D.17}$$

Since $\hat{i}_1>-\frac{i}{1+i}$, we have that $\lambda_1^{IS}=0$. Combining Equations (D.12), (D.13), (D.14) and (D.17) gives us the expression for $\hat{i}_1$ as a function of past macroeconomic conditions:

$$\hat{i}_1=\frac{\eta}{\beta}\hat{y}_0+\frac{\varphi}{\vartheta}\left(\frac{\eta+\beta}{\beta}\right)\hat{\pi}_0 \tag{D.18}$$

The system of equations above can be rewritten in matrix form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 & 0 & 0 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ \vartheta & 0 & 1 & -\varphi & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & -\varphi & 1 & 0 & 0 \\ 0 & 0 & -\frac{1}{\beta} & -1 & 0 & 1 & 1 & 0 \\ 0 & 0 & -\frac{\eta}{\beta} & 0 & \vartheta & 0 & -\varphi & 0 \end{bmatrix} \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \lambda_0^{IS} \\ \lambda_0^{PC} \\ \hat{y}_1 \\ \hat{\pi}_1 \\ \lambda_1^{PC} \\ \hat{i}_1 \end{bmatrix} = \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \Longrightarrow$$

$$\begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \lambda_0^{IS} \\ \lambda_0^{PC} \\ \hat{y}_1 \\ \hat{\pi}_1 \\ \lambda_1^{PC} \\ \hat{i}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 & 0 & 0 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 0 & 0 & 0 \\ \vartheta & 0 & 1 & -\varphi & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & -\varphi & 1 & 0 & 0 \\ 0 & 0 & -\frac{1}{\beta} & -1 & 0 & 1 & 1 & 0 \\ 0 & 0 & -\frac{\eta}{\beta} & 0 & \vartheta & 0 & -\varphi & 0 \end{bmatrix}^{-1} \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

Therefore, we have that:

$$\hat{y}_0 = -\frac{\beta\left(\varphi^2\left(1+\beta+\eta+\varphi\right)+\vartheta\right)}{\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.19}$$

$$\hat{\pi}_0 = -\frac{\beta\varphi\left(\varphi^2+\left(1-\eta-\varphi\right)\vartheta\right)}{\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.20}$$

$$\hat{i}_1 = -\frac{\left(\alpha+\varphi^2\right)\eta+\varphi^3+\beta\varphi^2+\alpha\varphi}{\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.21}$$

$$\hat{y}_1 = \frac{\left(\alpha+\varphi^2\right)\eta+\varphi^3+\beta\varphi^2+\alpha\varphi}{\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.22}$$

$$\hat{\pi}_1 = \frac{\left(\varphi^3+\alpha\varphi\right)\eta+\varphi^4+\beta\varphi^3+\alpha\varphi^2}{\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta}\left(\hat{z}-\frac{i}{1+i}\right). \tag{D.23}$$

To understand how η affects period-0 output and inflation, we take the following derivatives:

$$\frac{d\hat{y}_0}{d\eta} = \frac{\beta\left(\beta^2\varphi^4 + \beta\varphi^2\left(1+2\eta+2\varphi\right)\left(\varphi^2+\vartheta\right) + \left(\eta+\varphi\right)\left(\varphi^2+\vartheta\right)\left(\varphi^2\left(2+\eta+\varphi\right)+2\vartheta\right)\right)}{\left(\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) > 0, \tag{D.24}$$

$$\frac{d\hat{\pi}_0}{d\eta} = \frac{\beta\varphi\left(\beta^2\varphi^2\vartheta + \beta\left(\varphi^2+\vartheta\right)\left(2\varphi^2+\vartheta\right) + \left(\eta+\varphi\right)\left(\varphi^2+\vartheta\right)\left(2\varphi^2+\left(2-\eta-\varphi\right)\vartheta\right)\right)}{\left(\varphi^2\left(\beta^2+\left(\eta+\varphi\right)^2+\beta\left(1+2\eta+2\varphi\right)\right)+\left(\beta+\left(\eta+\varphi\right)^2\right)\vartheta\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) > 0. \tag{D.25}$$

Hence, an increase in η (either due to a decrease in δ or an increase in ζ) mitigates the fall in output and inflation following a negative demand shock.

D.3 Strict Price Level Targeting: Full Derivation

Consider the following model:

$$\hat{y}_t = \eta E_t\hat{y}_{t+1} - \hat{i}_t + E_t\hat{\pi}_{t+1} - \hat{z}_t, \tag{D.26}$$

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \varphi\hat{y}_t, \tag{D.27}$$

$$\hat{p}_t = 0 \quad \text{s.t.} \quad \hat{i}_t > -\frac{i}{1+i}, \tag{D.28}$$

$$\hat{\pi}_t = \hat{p}_t - \hat{p}_{t-1}. \tag{D.29}$$

When the ZLB is not binding, the central bank sets the policy rate to stabilise the price level $\hat{p}_t$.

Assume $\hat{z}_0 = z$, $\hat{i}_0 = -\frac{i}{1+i}$, $\hat{z}_1 = 0$, and $\hat{y}_2 = \hat{\pi}_2 = 0$. The two-period model can be written as follows:

$$\hat{y}_0 = \eta\hat{y}_1 + \frac{i}{1+i} + \hat{\pi}_1 - \hat{z}, \tag{D.30}$$

$$\hat{\pi}_0 = \beta\hat{\pi}_1 + \varphi\hat{y}_0, \tag{D.31}$$

$$\hat{\pi}_0 = \hat{p}_0, \tag{D.32}$$

$$\hat{i}_1 = -\hat{y}_1, \tag{D.33}$$

$$\hat{y}_1 = \frac{1}{\varphi}\hat{\pi}_1, \tag{D.34}$$

$$\hat{\pi}_1 = -\hat{p}_0 \Longrightarrow \hat{\pi}_1 = -\hat{\pi}_0. \tag{D.35}$$

In matrix form:

$$\begin{bmatrix} 1 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & -\beta \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & -\frac{1}{\varphi} \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \implies \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & -\beta \\ 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 1 & -\frac{1}{\varphi} \\ 0 & 1 & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

Hence, the solution is as follows:

$$\hat{y}_0 = -\frac{1+\beta}{1+\beta+\eta+\varphi}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.36}$$

$$\hat{\pi}_0 = -\frac{\varphi}{1+\beta+\eta+\varphi}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.37}$$

$$\hat{i}_1 = -\frac{1}{1+\beta+\eta+\varphi}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.38}$$

$$\hat{y}_1 = \frac{1}{1+\beta+\eta+\varphi}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.39}$$

$$\hat{\pi}_1 = \frac{\varphi}{1+\beta+\eta+\varphi}\left(\hat{z} - \frac{i}{1+i}\right). \tag{D.40}$$

How does the discounting term affect the impact response of output and inflation?

$$\frac{\partial \hat{y}_0}{\partial \eta} = \frac{1+\beta}{(1+\beta+\eta+\varphi)^2}\left(\hat{z} - \frac{i}{1+i}\right) > 0, \tag{D.41}$$

$$\frac{\partial \hat{\pi}_0}{\partial \eta} = \frac{\varphi}{(1+\beta+\eta+\varphi)^2}\left(\hat{z} - \frac{i}{1+i}\right) > 0. \tag{D.42}$$

Making individuals more rational (i.e., a larger ζ) or increasing the consumption loss upon unemployment (i.e., a smaller δ) increases η and makes the falls in inflation and output after a risk premium shock less severe.

D.4 Inertial Policy Rule: Full Derivation

Consider the following model:

$$\hat{y}_t = \eta E_t \hat{y}_{t+1} - \hat{i}_t + E_t \hat{\pi}_{t+1} - \hat{z}_t, \tag{D.43}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \varphi \hat{y}_t, \tag{D.44}$$

$$\hat{i}_t = \max\left(\hat{i}^\star_t, -\frac{i}{1+i}\right), \tag{D.45}$$

$$\hat{i}^\star_t = \rho_i \hat{i}^\star_{t-1} + (1-\rho_i)\,\phi_\pi \hat{\pi}_t. \tag{D.46}$$

The actual policy rate $\hat{i}_t$ is constrained by the ZLB. The shadow rate $\hat{i}^\star_t$ represents the monetary policy stance and is set according to a simple Taylor-type rule with an autoregressive term.

Assume $\hat{z}_0 = z$, $\hat{i}_0 = -\frac{i}{1+i}$, $\hat{z}_1 = 0$, and $\hat{y}_2 = \hat{\pi}_2 = 0$. The two-period model can be written as follows:

$$\hat{y}_0 = \eta \hat{y}_1 + \frac{i}{1+i} + \hat{\pi}_1 - \hat{z}, \tag{D.47}$$

$$\hat{\pi}_0 = \beta \hat{\pi}_1 + \varphi \hat{y}_0, \tag{D.48}$$

$$\hat{i}^\star_0 = (1-\rho_i)\,\phi_\pi \hat{\pi}_0, \tag{D.49}$$

$$\hat{y}_1 = -\hat{i}_1, \tag{D.50}$$

$$\hat{\pi}_1 = \varphi \hat{y}_1, \tag{D.51}$$

$$\hat{i}_1 = \rho_i \hat{i}^\star_0 + (1-\rho_i)\,\phi_\pi \hat{\pi}_1. \tag{D.52}$$

Intuition: The larger the drop in $\hat{i}^\star_0$, the bigger the fall in $\hat{i}_1$ and hence, bigger boost in $\hat{y}_1$ and $\hat{\pi}_1$, which have a positive impact on $\hat{y}_0$ and $\hat{\pi}_0$. The smaller δ, the larger is η, which implies a bigger impact of $\hat{y}_1$ on $\hat{y}_0$ and indirectly on $\hat{\pi}_0$.

In matrix form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta \\ 0 & -(1-\rho_i)\phi_\pi & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & -\varphi & 1 \\ 0 & 0 & -\rho_i & 1 & 0 & -(1-\rho_i)\phi_\pi \end{bmatrix} \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{i}_0^* \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \Longrightarrow$$

$$\begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{i}_0^* \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta \\ 0 & -(1-\rho_i)\phi_\pi & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & -\varphi & 1 \\ 0 & 0 & -\rho_i & 1 & 0 & -(1-\rho_i)\phi_\pi \end{bmatrix}^{-1} \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

Hence, the solution is as follows:

$$\hat{y}_0 = -\left(1 - \frac{\phi_\pi \varphi \rho_i (\eta + \varphi)(\rho_i - 1)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.53}$$

$$\hat{\pi}_0 = -\varphi\left(1 - \frac{\phi_\pi \varphi \rho_i (\beta + \eta + \varphi)(\rho_i - 1)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.54}$$

$$\hat{i}_0^\star = \varphi\phi_\pi(\rho_i - 1)\left(1 - \frac{\varphi \rho_i (\beta + \eta + \varphi)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.55}$$

$$\hat{i}_1 = -\left(\frac{\phi_\pi \varphi \rho_i (\rho_i - 1)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.56}$$

$$\hat{y}_1 = \left(\frac{\phi_\pi \varphi \rho_i (\rho_i - 1)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.57}$$

$$\hat{\pi}_1 = \left(\frac{\phi_\pi \varphi^2 \rho_i (\rho_i - 1)}{\phi_\pi \varphi (\rho_i - 1)(\rho_i(\eta + \beta + \varphi) + 1) - 1}\right)\left(\hat{z} - \frac{i}{1+i}\right). \tag{D.58}$$

To simplify expressions, consider the case that $\phi_\pi \to \infty$:

$$\hat{y}_0 = -\frac{1 + \rho_i\beta}{\rho_i(\eta + \beta + \varphi) + 1}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.59}$$

$$\hat{\pi}_0 = -\frac{\varphi}{\rho_i(\eta + \beta + \varphi) + 1}\left(\hat{z} - \frac{i}{1+i}\right), \tag{D.60}$$

$$\hat{i}_1 = -\frac{\rho_i}{\rho_i\left(\eta+\beta+\varphi\right)+1}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.61}$$

$$\hat{y}_1 = \frac{\rho_i}{\rho_i\left(\eta+\beta+\varphi\right)+1}\left(\hat{z}-\frac{i}{1+i}\right), \tag{D.62}$$

$$\hat{\pi}_1 = \frac{\varphi\rho_i}{\rho_i\left(\eta+\beta+\varphi\right)+1}\left(\hat{z}-\frac{i}{1+i}\right). \tag{D.63}$$

If $\rho_i = 1$ the solution is equal to that under strict price level targeting.

How does the discounting term affect the impact response of output and inflation?

$$\frac{\partial \hat{y}_0}{\partial \eta} = \frac{\rho_i\left(1+\rho_i\beta\right)}{\left(\rho_i\left(\eta+\beta+\varphi\right)+1\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) \geq 0, \tag{D.64}$$

$$\frac{\partial \hat{\pi}_0}{\partial \eta} = \frac{\rho_i\varphi}{\left(\rho_i\left(\eta+\beta+\varphi\right)+1\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) \geq 0. \tag{D.65}$$

If $\rho_i > 0$ (when $\rho_i = 0$, we end up in the strict inflation targeting case) making individuals more rational (i.e., a larger ζ) or increasing the consumption loss upon unemployment (i.e., a smaller δ) increases η and makes the falls in inflation and output after a risk premium shock less severe.

D.5 Average Inflation Targeting: Full Derivation

Consider the following model:

$$\hat{y}_t = \eta E_t\hat{y}_{t+1} - \hat{i}_t + E_t\hat{\pi}_{t+1} - \hat{z}_t, \tag{D.66}$$

$$\hat{\pi}_t = \beta E_t\hat{\pi}_{t+1} + \varphi\hat{y}_t, \tag{D.67}$$

$$\hat{\pi}_t^{avg} = \omega\hat{\pi}_t + (1-\omega)\,\hat{\pi}_{t-1}^{avg}, \tag{D.68}$$

$$\hat{\pi}_t^{avg} = 0 \quad \text{s.t.} \quad \hat{i}_t > -\frac{i}{1+i}. \tag{D.69}$$

When the ZLB constraint is not binding, the central bank sets the policy rate to stabilise a geometric average of inflation $\hat{\pi}^{avg}$. The averaging parameter $\omega \in [0,1]$.

Assume $\hat{z}_0 = z$, $\hat{i}_0 = -\frac{i}{1+i}$, $\hat{z}_1 = 0$, and $\hat{y}_2 = \hat{\pi}_2 = 0$. The two-period model can be written as follows:

$$\hat{y}_0 = \eta\hat{y}_1 + \frac{i}{1+i} + \hat{\pi}_1 - \hat{z}, \tag{D.70}$$

$$\hat{\pi}_0 = \beta\hat{\pi}_1 + \varphi\hat{y}_0, \tag{D.71}$$

$$\hat{\pi}_0^{avg} = \omega \hat{\pi}_0, \tag{D.72}$$

$$\hat{i}_1 = \left(\frac{1-\omega}{\varphi}\right) \hat{\pi}_0, \tag{D.73}$$

$$\hat{\pi}_1 = \varphi \hat{y}_1, \tag{D.74}$$

$$\hat{\pi}_1 = -\left(\frac{1-\omega}{\omega}\right) \hat{\pi}_0^{avg}, \tag{D.75}$$

$$\hat{\pi}_1^{avg} = 0. \tag{D.76}$$

The two-period model can be cast in matrix form:

$$\begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta \\ 0 & -\omega & 1 & 0 & 0 & 0 \\ 0 & \left(\frac{1-\omega}{\varphi}\right) & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\varphi & 1 \\ 0 & 0 & \left(\frac{1-\omega}{\omega}\right) & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{\pi}_0^{avg} \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} \Longrightarrow$$

$$\begin{bmatrix} \hat{y}_0 \\ \hat{\pi}_0 \\ \hat{\pi}_0^{avg} \\ \hat{i}_1 \\ \hat{y}_1 \\ \hat{\pi}_1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 & -\eta & -1 \\ -\varphi & 1 & 0 & 0 & 0 & -\beta \\ 0 & -\omega & 1 & 0 & 0 & 0 \\ 0 & \left(\frac{1-\omega}{\varphi}\right) & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & -\varphi & 1 \\ 0 & 0 & \left(\frac{1-\omega}{\omega}\right) & 0 & 0 & 1 \end{bmatrix}^{-1} \begin{bmatrix} \frac{i}{1+i} - \hat{z} \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}.$$

Hence, the solution is as follows:

$$\hat{y}_0 = -\frac{1+\beta(1-\omega)}{1+(\beta+\eta+\varphi)(1-\omega)} \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.77}$$

$$\hat{\pi}_0 = -\frac{\varphi}{1+(\beta+\eta+\varphi)(1-\omega)} \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.78}$$

$$\hat{\pi}_0^{avg} = -\frac{\omega\varphi}{1+(\beta+\eta+\varphi)(1-\omega)} \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.79}$$

$$\hat{i}_1 = -\frac{1-\omega}{1+(\beta+\eta+\varphi)(1-\omega)} \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.80}$$

$$\hat{y}_1 = \frac{1-\omega}{1+(\beta+\eta+\varphi)(1-\omega)} \left(\hat{z} - \frac{i}{1+i}\right), \tag{D.81}$$

$$\hat{\pi}_1 = \frac{\varphi\left(1-\omega\right)}{1+\left(\beta+\eta+\varphi\right)\left(1-\omega\right)}\left(\hat{z}-\frac{i}{1+i}\right). \tag{D.82}$$

If $\omega = 0$, the responses are exactly the same as under strict price level targeting.

How does the discounting term affect the impact response of output and inflation?

$$\frac{\partial \hat{y}_0}{\partial \eta} = \frac{\left(1-\omega\right)+\beta\left(1-\omega\right)^2}{\left(1+\left(\beta+\eta+\varphi\right)\left(1-\omega\right)\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) > 0, \tag{D.83}$$

$$\frac{\partial \hat{\pi}_0}{\partial \eta} = \frac{\varphi\left(1-\omega\right)}{\left(1+\left(\beta+\eta+\varphi\right)\left(1-\omega\right)\right)^2}\left(\hat{z}-\frac{i}{1+i}\right) > 0. \tag{D.84}$$

If $\omega < 1$ (when $\omega = 1$, we end up in the strict inflation targeting case) making individuals more rational (i.e., a larger ζ) or increasing the consumption loss upon unemployment (i.e., a smaller δ) increases η and makes the falls in inflation and output after a risk premium shock less severe.

E Numerical Exercise: Three-Period Model

To complement the analytical exercise (Sections 2 and D) and main numerical analysis, based on the infinite-horizon model (Section 4.2), we also consider a simple three-period version of the model to highlight the key mechanism behind our results. In an infinite-horizon setting with a strict inflation-targeting policy, the response of inflation becomes rapidly very large as we decrease the degree of unemployment insurance. This issue is less extreme in the three-period version of the model.

For this exercise, we assume agents have perfect foresight and consider the impact of a 3 per cent increase in the period-0 risk premium ($z_0 = 1.03$). In the following periods, the risk premium returns to its steady-state value ($z_1 = z_2 = 1.0$). The rise in the risk premium leads the nominal interest rate to hit the ZLB on impact, i.e., $i_0 = 0$. We then compare how the responses depend on the degree of unemployment insurance under strict inflation targeting and the optimal monetary policy. We consider four different possible levels of the ratio δ_t/w_t, such that a smaller value implies lower unemployment insurance.

Figure E.1 displays the responses of the model variables to the rise in the risk premium when the central bank follows a strict inflation-targeting rule. The increase in the risk premium causes employed workers to reduce their consumption via their Euler equation. Given that prices are sticky, firms reduce their production y_0 and labour demand n_0 to adjust to the falling demand, whereas inflation π_0 declines more sluggishly. The fall in the firm's profits causes a decline in the firm owners' consumption c_0^F. Furthermore, the fall in demand causes a tightening in labour market conditions, reducing vacancies v_0, the job-finding rate f_0, and wages, and increasing the job-loss rate s_0. Since the nominal rate is at zero, the central bank cannot reduce it to respond to the fall in inflation. Hence, the real rate rises and the fall in demand is larger than away from the ZLB.

When there is perfect risk-sharing between working households ($\delta_t/w_t = 1$), a rise in the job-loss rate does not affect their saving behaviour. In the imperfect-insurance case ($\delta_t/w_t < 1$), instead, a tightening in labour-market conditions increases the stochastic discount factor of employed workers, who increase their savings for precautionary reasons. Precautionary savings further amplify the initial decline in inflation. Since the ZLB constraint does not bind anymore in period 1, the monetary policy authority can adjust the interest rate to bring inflation back to zero ($\pi_1 = 0$). As a result, the real interest rate in period 0 is the same both under PI or II ($r_0 \approx i_0 - \pi_1 = 0$). Similarly, the fall in output and real wages, and the rise in the job-loss rate, are unaffected by the degree of unemployment insurance.

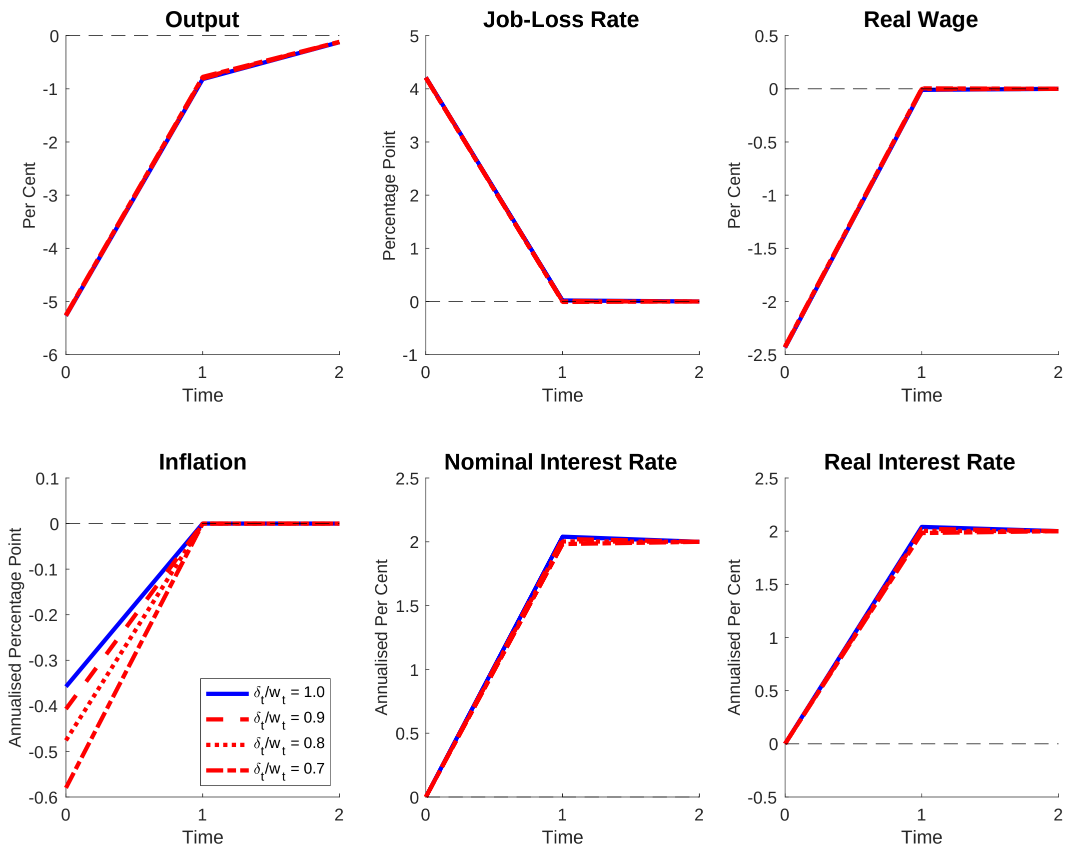

Figure E.1: Strict Inflation Targeting in a Three-Period Model

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind in period 0 under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

Under the optimal monetary policy, as displayed in Figure E.2, the central bank can commit to a specific path for the nominal interest rate. In particular, the central bank keeps the rate at zero for one additional period. The lower interest rate (compared to the strict inflation-targeting policy) has a positive effect on y_1 and π_1. The increase in inflation expectations reduces the period-0 real interest rate r_0, which attenuates the decline in real activity y_0 and inflation π_0 (standard forward guidance channel). In the presence of II, future improvements in labour market conditions further strengthen this mechanism. In other words, $i_1 = 0$ has a positive effect on the period-1 job-finding rate f_1 and a negative one on the job-loss rate s_1. The latter decreases the stochastic discount factor of employed workers, hence mitigating their period-0 precautionary savings and fall in consumption $c_{e,0}$. As a result of the optimal policy, we see that the smaller the degree of unemployment-risk sharing, i.e., the smaller δ_t/w_t, the more muted the responses of output, the job-loss rate, and the real wage to a negative demand shock.

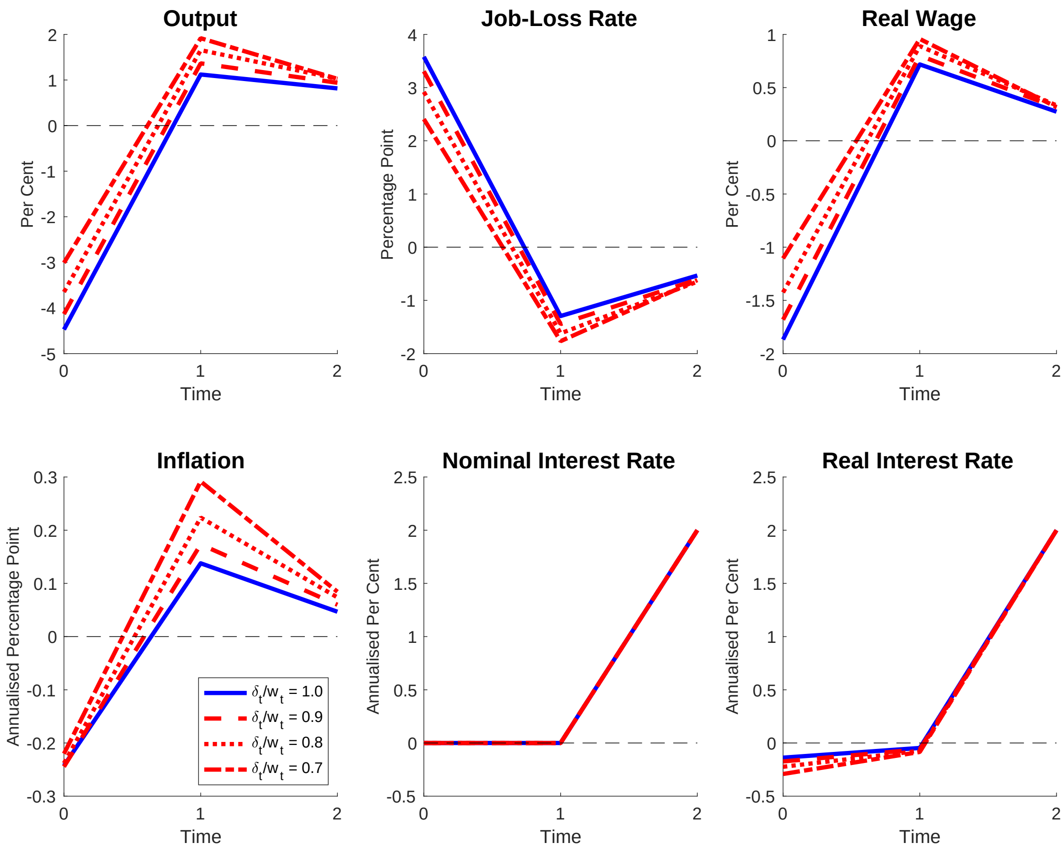

Figure E.2: Optimal Monetary Policy in a Three-Period Model

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind in period 0 under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

F The Power of Forward Guidance: Keeping the Shock Fixed

In this section of the appendix, we study how our results are affected by varying the workers' cognitive discounting parameter (ζ), similarly as in Section 4.3. Unlike the main text, in this case, we keep the shock size fixed as we vary ζ.

We compare three alternative values of ζ, namely $\zeta = 1$ (rational expectations), $\zeta = 0.75$ (the benchmark value of myopia), and $\zeta = 0.5$ (below the range of empirically plausible values). As in the main text, we consider both a strict inflation-targeting rule and the optimal monetary policy.

F.1 No Zero Lower Bound

First, we consider the case in which the central bank does not face a zero lower bound constraint[1]. To this end, we solve the model using a standard first-order perturbation method. The shock is calibrated as shown in Table 1 in the main text. Absent a ZLB constraint, the central bank can fully offset the negative demand shock by following a strict inflation-targeting policy (divine coincidence). This result is independent of the degree of cognitive discounting and/or market incompleteness. Results under the strict inflation-targeting rule and the optimal monetary policy are identical and displayed in Figure F.1.

F.2 Zero Lower Bound and Fixed Baseline Shock

Next, we consider the case where the central bank is constrained by an occasionally binding ZLB constraint and the economy is hit by a negative shock, calibrated as in Table 1 in the main text.

Figure F.2 displays the results under strict inflation targeting. Similarly as in the main text, when workers become more myopic (i.e. smaller ζ), the responses of output and inflation become more muted, and the gap between the cases with complete and incomplete markets narrows. This is because, with a lower ζ, workers internalise less not only the future path of interest rates but also the expected worsening in labour market conditions. Hence, the precautionary savings motive under incomplete markets becomes weaker.

Figure F.3 displays the results under the optimal policy. Results for output and inflation are similar to those in the main text (Figure 4). Irrespective of the degree of bounder rationality ζ, incomplete markets do not significantly exacerbate the recession when monetary policy is conducted optimally.

[1] Challe (2020) studies the optimal policy away from the ZLB in response to different shocks, such as supply and cost-push shocks.

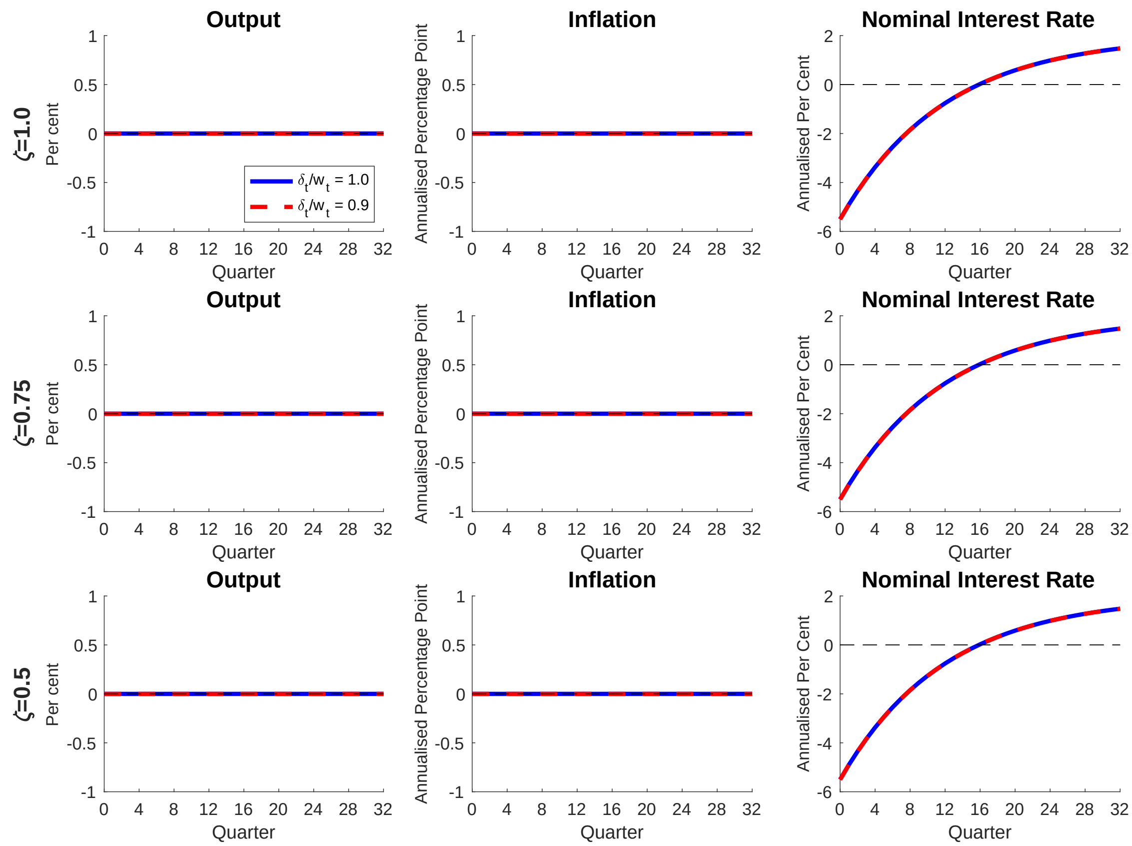

Figure F.1: Cognitive Discounting Away from the Zero Lower Bound

Note: The figure displays the responses to an adverse risk-premium shock. Each line represents a different degree of unemployment risk sharing.

F.3 Zero Lower Bound and Smaller Shock

In this section, we set the shock size to be 50% smaller than in the baseline calibration. Figures F.4 and F.5 display the results under strict inflation targeting and the optimal monetary policy. The results are consistent with the responses following the larger baseline shock and the results in the main text. As above, under strict inflation targeting, a smaller ζ reduces the gap between the cases with complete and incomplete markets. Under the optimal policy, incomplete markets do not significantly aggravate the recession irrespective of the degree of bounded rationality.

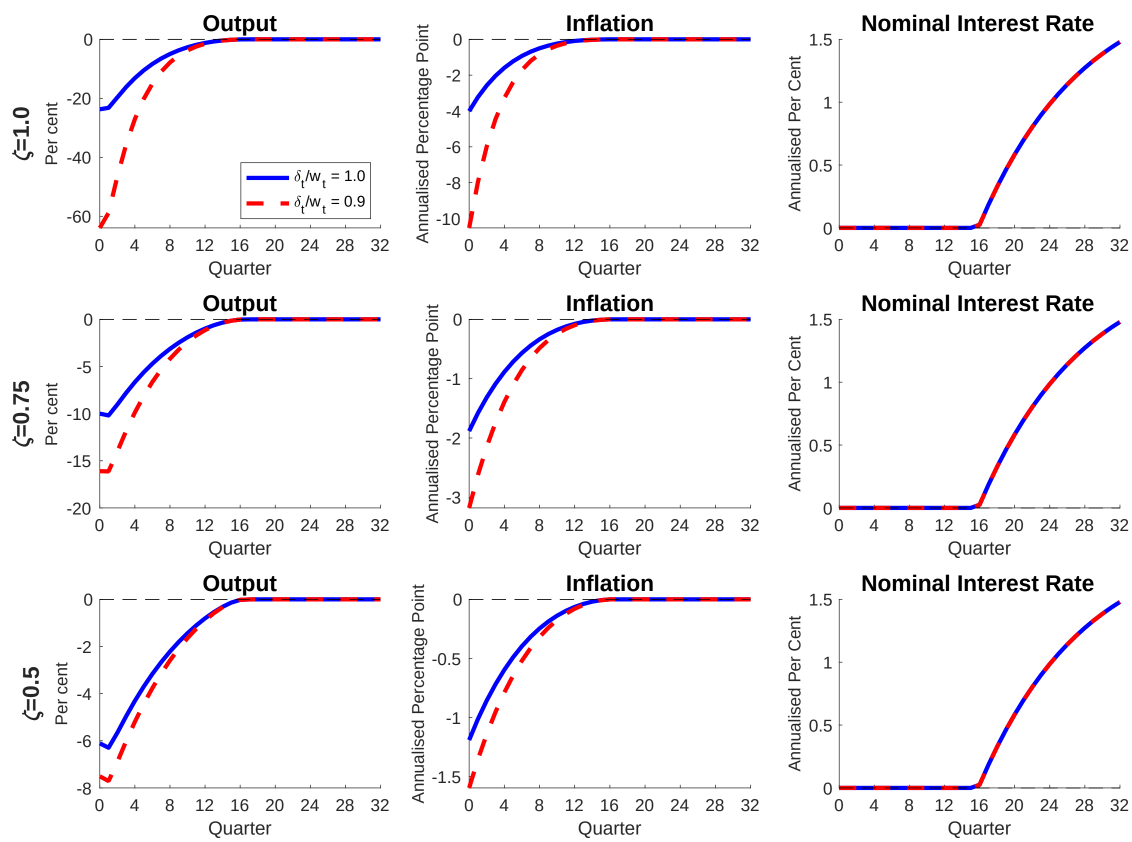

Figure F.2: Strict Inflation Targeting and Cognitive Discounting: ZLB & Fixed Shock

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind for 16 quarters under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

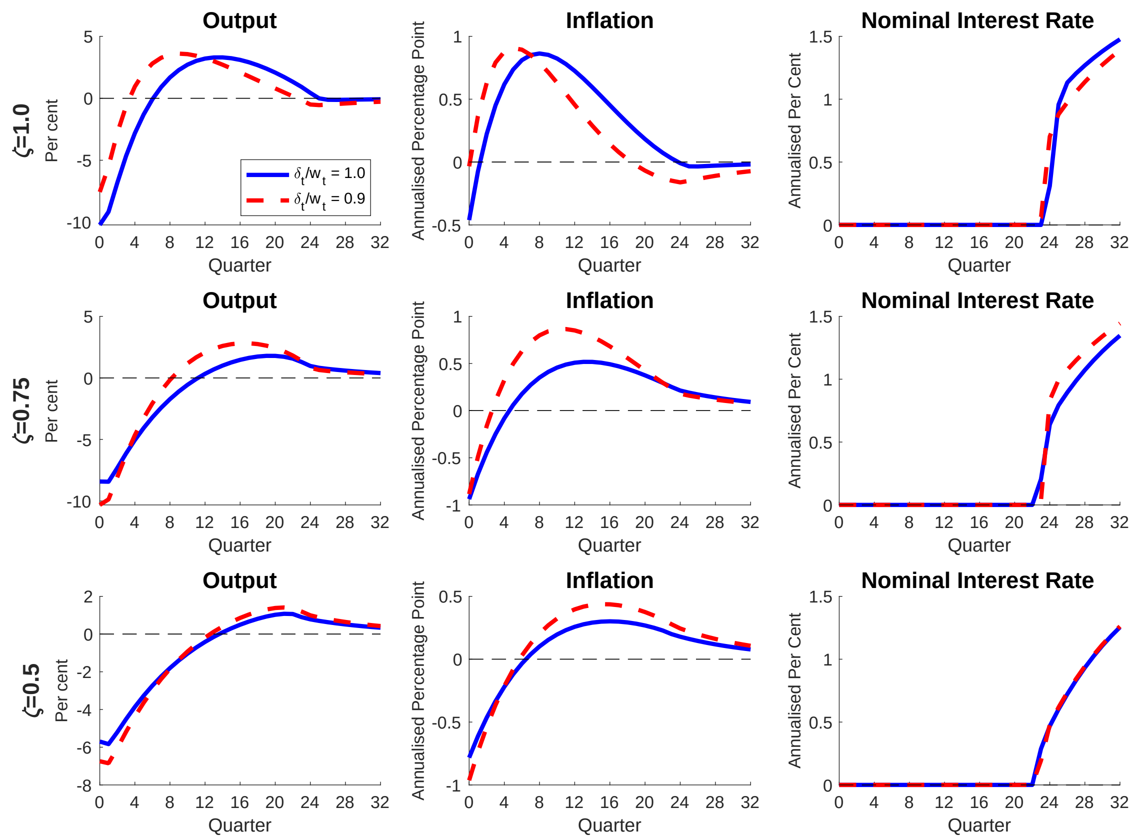

Figure F.3: Optimal Monetary Policy and Cognitive Discounting: ZLB & Fixed Shock

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind for 16 quarters under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

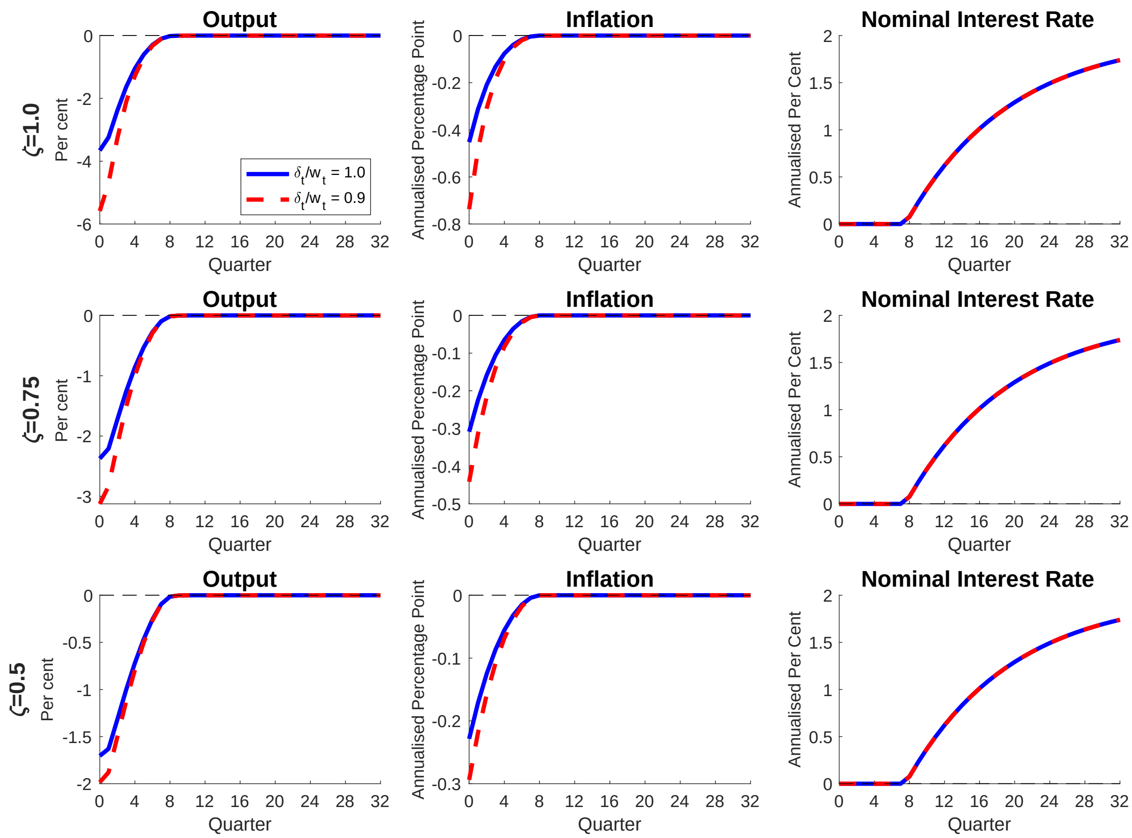

Figure F.4: Strict Inflation Targeting and Cognitive Discounting: ZLB & Small Shock (Fixed)

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind for 16 quarters under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

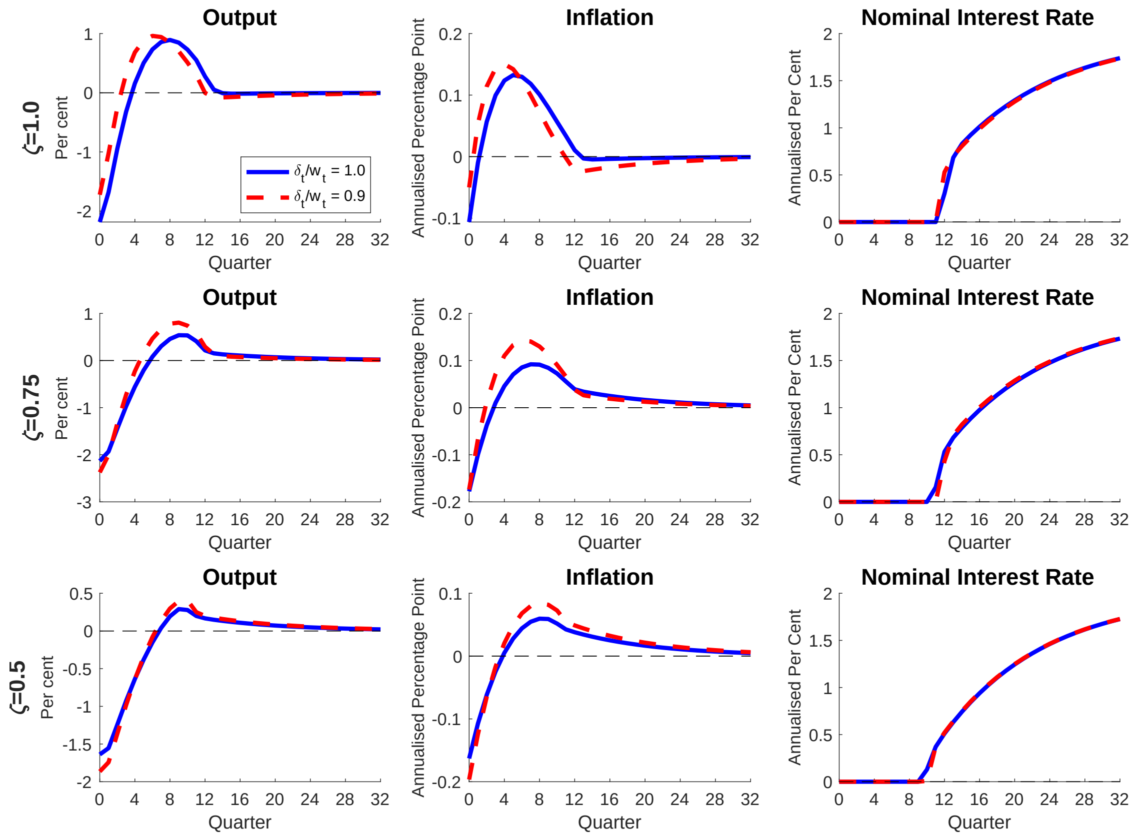

Figure F.5: Optimal Monetary Policy and Cognitive Discounting: ZLB & Small Shock (Fixed)

Note: The figure displays the responses to an adverse risk-premium shock that leads the ZLB constraint to bind for 16 quarters under strict inflation targeting. Each line represents a different degree of unemployment risk sharing.

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