A Analytical Details

A.1 Households

Cost Minimization Households decide the composition of the consumption basket to minimize expenditures

$$\min_{\{C_{it}^k\}_i} \int_0^1 P_{it} C_{it}^k di$$
$$s.t. \left(\int_0^1 \left(C_{it}^k - \theta C_{it-1} \right)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}} \geq \overline{X}_t^k$$

The demand for individual goods i is

$$C_{it}^k = \left(\frac{P_{it}}{P_t} \right)^{-\eta} X_t^k + \theta C_{it-1},$$

where P_t is the overall price level, expressed as an aggregate of the good i prices, $P_t = \left(\int_0^1 P_{it}^{1-\eta} di \right)^{\frac{1}{1-\eta}}$.

Utility Maximization The solution to the utility maximization problem is obtained by solving the Lagrangian function,

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left[u\left(X_t^k, N_t^k \right) - \lambda_t^k \left(P_t X_t^k + P_t \vartheta_t + Q_{t,t+1} D_{t+1}^k - W_t N_t^k (1-\tau) - D_t^k - \Phi_t - T_t \right) \right].$$

In the budget constraint, we have re-expressed the total spending on the consumption basket, $\int_0^1 P_{it}C_{it}^k di$, in terms of quantities that affect the household's utility,

$$\int_0^1 P_{it}C_{it}^k di = P_t X_t^k + P_t \vartheta_t,$$

where under deep habits ϑ_t is given as $\vartheta_t \equiv \theta \int_0^1 \left(\frac{P_{it}}{P_t}\right) C_{it-1} di$, while under superficial habits it takes the simpler form, $\vartheta_t \equiv \theta C_{t-1}$. Households take ϑ_t as given when maximizing utility.

The first order conditions are then,

$$\left(X_t^k\right): \qquad u_X(t) = \lambda_t^k P_t$$

$$\left(N_t^k\right): \qquad -u_N(t) = u_X(t)\, \frac{W_t}{P_t}(1-\tau)$$

$$\left(D_t^k\right): \qquad 1 = \beta E_t\left[\frac{u_X(t+1)}{u_X(t)}\frac{P_t}{P_{t+1}}\right] R_t$$

where $R_t = \frac{1}{E_t[Q_{t,t+1}]}$ is the one-period gross return on nominal riskless bonds.

With utility given by $u(X,N) = \frac{X^{1-\sigma}}{1-\sigma} - \frac{N^{1+\upsilon}}{1+\upsilon}$, the first derivatives are

$$u_X(\cdot) = X^{-\sigma} \qquad and \qquad u_N(\cdot) = -N^{\upsilon}.$$

A.2 Firms

The cost minimization involves the choice of labor input N_{it} subject to the available production technology

$$\min_{N_{it}} W_t N_{it}$$
$$s.t.\ A_t N_{it} = Y_{it}$$

The minimization problem implies a labor demand, $N_{it} = \frac{Y_{it}}{A_t}$, and a nominal marginal cost which is the same across all brand producing firms, $MC_t = (1 - \varkappa) \frac{W_t}{A_t}$. Profits are defined as:

$$\begin{aligned} \Phi_{it} &\equiv P_{it} Y_{it} - W_t N_{it} - \frac{\varphi}{2} \left(\frac{P_{it}}{\pi P_{it-1}} - 1 \right)^2 P_t Y_t \\ &= (P_{it} - MC_t) Y_{it} - \frac{\varphi}{2} \left(\frac{P_{it}}{\pi P_{it-1}} - 1 \right)^2 P_t Y_t \end{aligned}$$

where the last term represents the nominal costs of adjusting prices, as in Rotemberg (1982), and π is the steady state inflation.

Each firm then chooses processes for P_{it} and Y_{it} to maximize the present discounted value of profits, under the restriction that all demand be satisfied at the chosen price ($C_{it} = Y_{it}$):

$$\begin{aligned} \max_{\{P_{it},\ Y_{it}\}} E_t \sum_{s=0}^{\infty} Q_{t,t+s} \Phi_{it+s} &= E_t \sum_{s=0}^{\infty} Q_{t,t+s} \left[(P_{it+s} - MC_{t+s}) Y_{it+s} - \frac{\varphi}{2} \left(\frac{P_{it+s}}{\pi P_{it+s-1}} - 1 \right)^2 P_{t+s} Y_{t+s} \right] \\ s.t. Y_{it+s} &= \left(\frac{P_{it+s}}{P_{t+s}} \right)^{-\eta} X_{t+s} + \theta Y_{it+s-1} \\ Q_{t,t+s} &= \beta^s \left(\frac{X_{t+s}}{X_t} \right)^{-\sigma} \frac{P_t}{P_{t+s}} \end{aligned}$$

The first order conditions are:

$$v_{it} = (P_{it} - MC_t) + \theta E_t \left[Q_{t,t+1} v_{it+1} \right]$$

and

$$Y_{it} = v_{it} \left[\eta \left(\frac{P_{it}}{P_t} \right)^{-\eta-1} \frac{X_t}{P_t} \right] + \left[\varphi \left(\frac{P_{it}}{\pi P_{it-1}} - 1 \right) \frac{P_t Y_t}{\pi P_{it-1}} - \varphi E_t Q_{t,t+1} \left(\frac{P_{it+1}}{\pi P_{it}} - 1 \right) \frac{P_{it+1}}{\pi \left(P_{it} \right)^2} P_{t+1} Y_{t+1} \right]$$

where v_{it} is the Lagrange multiplier on the dynamic demand constraint and represents the shadow price of producing good i.

B Equilibrium Conditions

B.1 Aggregation and Symmetry

Aggregate output: In this setup, all firms and all households are symmetric. This implies that aggregate output is given by

$$Y_t = A_t N_t$$

Aggregate resource constraint: Aggregate profits are

$$\Phi_t = P_t Y_t - W_t N_t - \frac{\varphi}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 P_t Y_t$$

and the household budget constraint becomes in equilibrium (note: $P_t X_t + P_t \vartheta_t$ reduces to $P_t C_t$)

$$P_t C_t = W_t N_t (1-\tau) + \Phi_t + T_t$$

Combine the household budget constraint with the government budget constraint ($\tau W_t N_t = T_t$) and the definition of profits to obtain the aggregate resource constraint

$$C_t + \frac{\varphi}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 Y_t = Y_t$$

B.2 System of Non-linear Equations

$$X_t = C_t - \theta C_{t-1} \tag{32}$$

$$N_t^{\upsilon} X_t^{\sigma} = \frac{W_t}{P_t} \equiv w_t (1-\tau) \tag{33}$$

$$X_t^{-\sigma} = \beta E_t \left[X_{t+1}^{-\sigma} \; R_t \pi_{t+1}^{-1} \right] \tag{34}$$

$$Y_t = \eta \omega_t X_t + \varphi \left(\frac{\pi_t}{\pi} - 1\right) \frac{\pi_t}{\pi} Y_t - \varphi \beta E_t \left[\left(\frac{X_{t+1}}{X_t}\right)^{-\sigma} \left(\frac{\pi_{t+1}}{\pi} - 1\right) \frac{\pi_{t+1}}{\pi} Y_{t+1} \right] \tag{35}$$

$$\omega_t = \left(1 - \frac{1}{\mu_t}\right) + \theta \beta E_t \left[\left(\frac{X_{t+1}}{X_t}\right)^{-\sigma} \omega_{t+1} \right] \tag{36}$$

$$Y_t = A_t N_t \tag{37}$$

$$Y_t = C_t + \frac{\varphi}{2}\left(\frac{\pi_t}{\pi} - 1\right)^2 Y_t \tag{38}$$

$$mc_t = \frac{w_t}{A_t} \tag{39}$$

$$\mu_t = \frac{1}{mc_t} \tag{40}$$

$$\ln A_t = \rho \ln A_{t-1} + \epsilon_t \tag{41}$$

B.3 The Deterministic Steady State

The non-stochastic long-run equilibrium is characterized by constant real variables and nominal variables growing at a constant rate. The equilibrium conditions (32) - (41) reduce to:

$$X = (1-\theta)\, C \tag{42}$$

$$N^{\upsilon} X^{\sigma} = w(1-\tau) \tag{43}$$

$$1 = \beta\left(R\pi^{-1}\right) = \beta r \tag{44}$$

$$Y = \eta\omega X \tag{45}$$

$$\mu = \left[1-(1-\theta\beta)\,\omega\right]^{-1} \tag{46}$$

$$Y = AN \tag{47}$$

$$Y = C \tag{48}$$

$$mc = \frac{w}{A} \tag{49}$$

$$\mu = \frac{1}{mc}$$

$$A = 1$$

Table 1 contains the imposed calibration restrictions. We assume values for the real interest rate, the Frisch labor supply elasticity, steady state inflation, and the parameters σ, η, φ, and θ. The discount factor β matches the assumed real rate of interest, $\beta = r^{-1}$, while the nominal interest rate is $R = r\pi$. Given the specification of the utility function, υ is the inverse of the Frisch labor supply elasticity, $\epsilon_{Nw} = \frac{1}{\upsilon}$.

With no price adjustment costs in the deterministic steady state, $C = Y$. Then, using equations (42) and (45), the steady state value of the shadow price ω is

$$\omega = \left[\eta\,(1-\theta)\right]^{-1},$$

while the markup μ is given by equation (46) and the marginal cost is its inverse, $mc = \mu^{-1}$.

To determine the steady state value of labor, we substitute for X in terms of Y in (43) and then, using the aggregate production function, we obtain the following expression,

$$N^{\sigma+\upsilon}\left[(1-\theta)\,A\right]^{\sigma} = w(1-\tau), \tag{50}$$

which can be solved for N. Note that this expression depends on the real wage w, which can be obtained from equation (49). However, in order to assess the level of taxation needed to make the long-run equilibrium efficient, we substitute for real wages using the steady-state condition for marginal costs, $mc = w/A = 1/\mu$

$$N^{\sigma+\upsilon}\left[(1-\theta)A\right]^{\sigma} = \frac{A}{\mu}(1-\tau), \tag{51}$$

In order for this condition to match the social planner's allocation (65) it must be the case that $\tau = 1 - \mu(1-\theta\beta)$. See Appendix E for the social planner's problem. Finally, equations (47) and (42) can be solved for aggregate output Y (or consumption C) and habit-adjusted consumption X.

B.4 System of Log-linear Equations

Log-linearizing the equilibrium conditions (32) - (41) around the efficient deterministic steady state gives the following set of equations:

$$\widehat{X}_t = (1-\theta)^{-1}\left(\widehat{C}_t - \theta\widehat{C}_{t-1}\right)$$

$$\sigma\widehat{X}_t + \upsilon\widehat{N}_t = \widehat{w}_t$$

$$\widehat{X}_t = E_t\widehat{X}_{t+1} - \frac{1}{\sigma}\left(\widehat{R}_t - E_t\widehat{\pi}_{t+1}\right)$$

$$\widehat{Y}_t = \widehat{\omega}_t + \widehat{X}_t + \varphi\left(\widehat{\pi}_t - \beta E_t\widehat{\pi}_{t+1}\right) \tag{52}$$

$$\widehat{\omega}_t = \frac{1}{\mu\omega}\widehat{\mu}_t + \theta\beta E_t\widehat{\omega}_{t+1} + \theta\beta\sigma\left(\widehat{X}_t - E_t\widehat{X}_{t+1}\right) \tag{53}$$

$$\widehat{Y}_t = \widehat{A}_t + \widehat{N}_t$$

$$\widehat{Y}_t = \widehat{C}_t$$

$$\widehat{mc}_t = \widehat{w}_t - \widehat{A}_t$$

$$\widehat{\mu}_t = -\widehat{mc}_t$$

$$\widehat{A}_t = \rho\widehat{A}_{t-1} + \varepsilon_t$$

The New Keynesian Phillips Curve is given by the pricing equation (52)

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} + \frac{1}{\varphi}\left(\widehat{Y}_t - \widehat{\omega}_t - \widehat{X}_t\right)$$

where the evolution of the shadow value $\widehat{\omega}_t$ is given by equation (53).

C The Case of Superficial External Habits

C.1 Households

Habits are "superficial" when they are formed at the level of the aggregate consumption good. Households derive utility from the habit-adjusted composite good X_t^k,

$$X_t^k = C_t^k - \theta C_{t-1},$$

where household k's consumption, C_t^k, is an aggregate of a continuum of final goods, indexed by $i \in [0,1]$,

$$C_t^k = \left(\int_0^1 \left(C_{it}^k \right)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}},$$

with $\eta > 1$ the elasticity of substitution between them and $C_{t-1} \equiv \int_0^1 C_{t-1}^k dk$ the cross-sectional average of consumption.

Cost Minimization Households decide the composition of the consumption basket to minimize expenditures

$$\min_{\{C_{it}^k\}_i} \int_0^1 P_{it} C_{it}^k di$$

$$s.t. \left(\int_0^1 \left(C_{it}^k \right)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}} \geq \overline{C}_t^k.$$

The demand for individual goods i is

$$C_{it}^k = \left(\frac{P_{it}}{P_t} \right)^{-\eta} C_t^k,$$

where $P_t \equiv \left(\int_0^1 P_{it}^{1-\eta} di \right)^{\frac{1}{1-\eta}}$ is the consumer price index. The overall demand for good i is obtained by aggregating across all households

$$C_{it} = \int_0^1 C_{it}^k dk = \left(\frac{P_{it}}{P_t} \right)^{-\eta} C_t. \tag{54}$$

Unlike in the case of deep habits, this demand is *not* dynamic.

C.2 Firms

The firms' cost minimization problem is unchanged, while the profit maximization is still dynamic (due to the nature of price inertia) but subject to the static demand (54). The price is set optimally to satisfy the following relationship:

$$\left[1-\eta\left(1-\frac{1}{\mu_t}\right)\right]Y_t=\varphi\left(\frac{\pi_t}{\pi}-1\right)\frac{\pi_t}{\pi}Y_t-\varphi\beta E_t\left[\left(\frac{X_{t+1}}{X_t}\right)^{-\sigma}\left(\frac{\pi_{t+1}}{\pi}-1\right)\frac{\pi_{t+1}}{\pi}Y_{t+1}\right]. \tag{55}$$

C.3 Equilibrium

In this setup, we obtain the familiar looking New Keynesian Phillips Curve,

$$\widehat{\pi}_t=\beta E_t\widehat{\pi}_{t+1}+\frac{\eta-1}{\varphi}\widehat{mc}_t \tag{56}$$

to which we add the IS curve,

$$\widehat{X}_t=E_t\widehat{X}_{t+1}-\frac{1}{\sigma}\widehat{R}_t+\frac{1}{\sigma}E_t\widehat{\pi}_{t+1}, \tag{57}$$

and two equations defining the habit-adjusted consumption and the real marginal cost,

$$\widehat{X}_t=\frac{1}{1-\theta}\left(\widehat{Y}_t-\theta\widehat{Y}_{t-1}\right) \tag{58}$$

$$\widehat{mc}_t=\sigma\widehat{X}_t+\upsilon\widehat{Y}_t-(1+\upsilon)\,\widehat{A}_t. \tag{59}$$

D The Case of Internal Habits

D.1 Households

Habits are internal and superficial when they are formed at the level of the aggregate consumption bundle but households endogenize the effects of their current consumption choices on future utility. Each household k derives utility from a habit-adjusted composite good X_t^k,

$$X_t^k = C_t^k - \theta C_{t-1}^k$$

where C_t^k is the time-t aggregate of a continuum of goods, indexed by $i \in [0,1]$,

$$C_t^k = \left(\int_0^1 \left(C_{it}^k \right)^{\frac{\eta-1}{\eta}} di \right)^{\frac{\eta}{\eta-1}}$$

with $\eta > 0$ the elasticity of substitution between them, and C_{t-1}^k is the previous period consumption of household k. Since households are symmetric and, in this case, we also do not need to distinguish between individual and aggregate variables, in what follows we drop the k superscript.

Cost Minimization The households' cost minimization problem yields a typical static demand for each good i,

$$C_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\eta} C_t$$

where $P_t \equiv \left(\int_0^1 P_{it}^{1-\eta} di \right)^{\frac{1}{1-\eta}}$.

Utility maximization The Lagrangian function is

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left[\left(\frac{(C_t - \theta C_{t-1})^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\upsilon}}{1+\upsilon} \right) - \lambda_t \left(P_t C_t + E_t Q_{t,t+1} D_{t+1} - W_t N_t (1-\tau) - D_t - \Phi_t - T_t \right) \right]$$

where $R_t = \frac{1}{E_t[Q_{t,t+1}]}$ is the one-period gross return on nominal riskless bonds. Anticipating that current consumption decisions affect the stock of habits entering into the future, the consumption Euler equation is given by,

$$X_t^{-\sigma} - \theta \beta E_t X_{t+1}^{-\sigma} = \beta E_t \left[\left(X_{t+1}^{-\sigma} - \theta \beta E_{t+1} X_{t+2}^{-\sigma} \right) \frac{R_t}{\pi_{t+1}} \right]$$

and the labor supply condition by,

$$\frac{(N_t)^{\upsilon}}{\left(X_t^{-\sigma} - \theta \beta E_t X_{t+1}^{-\sigma} \right)} = w_t (1-\tau)$$

In log-linear form, the first order condition for labor and the Euler equation become

$$\upsilon \widehat{N}_t = \widehat{w}_t - \frac{\sigma}{1-\theta\beta}\left(\widehat{X}_t - \theta\beta E_t \widehat{X}_{t+1}\right) \tag{60}$$

and

$$\widehat{X}_t - \theta\beta E_t \widehat{X}_{t+1} = E_t\left(\widehat{X}_{t+1} - \theta\beta E_{t+1}\widehat{X}_{t+2}\right) - \frac{1-\theta\beta}{\sigma}\left(\widehat{R}_t - E_t \widehat{\pi}_{t+1}\right) \tag{61}$$

D.2 Firms

The firms' behavior is unchanged, except that the stochastic discount factor in their profit maximization problem is given by,

$$Q_{t,t+s} = \beta^s\left(\frac{\lambda_{t+s}}{\lambda_t}\right) = \beta^s\left(\frac{X_{t+s}^{-\sigma} - \theta\beta E_{t+s}X_{t+s+1}^{-\sigma}}{X_t^{-\sigma} - \theta\beta E_t X_{t+1}^{-\sigma}}\right)\frac{P_t}{P_{t+s}}$$

and the firms' FOC for price is then

$$\left[1-\eta\left(1-mc_t\right)\right]Y_t = \varphi\left(\frac{\pi_t}{\pi}-1\right)\frac{\pi_t}{\pi}Y_t - \varphi\beta E_t\left[\left(\frac{X_{t+1}^{-\sigma} - \theta\beta E_{t+1}X_{t+2}^{-\sigma}}{X_t^{-\sigma} - \theta\beta E_t X_{t+1}^{-\sigma}}\right)\left(\frac{\pi_{t+1}}{\pi}-1\right)\frac{\pi_{t+1}}{\pi}Y_{t+1}\right]$$

In a deterministic steady state, this relationship still reduces to $1 = \eta\left(1-mc\right)$, and the log-linearized equation, which is essentially the NKPC, is the same as under external superficial habits.

The marginal cost relationship is slightly modified due to the different marginal rate of substitution between consumption and labor:

$$\begin{aligned}
\widehat{mc}_t &= \widehat{w}_t - \widehat{A}_t \\
&= \left[\frac{\sigma}{1-\theta\beta}\left(\widehat{X}_t - \theta\beta E_t\widehat{X}_{t+1}\right) + \upsilon\widehat{N}_t\right] - \widehat{A}_t \\
&= \frac{\sigma}{1-\theta\beta}\left(\widehat{X}_t - \theta\beta E_t\widehat{X}_{t+1}\right) + \upsilon\widehat{Y}_t - \left(1+\upsilon\right)\widehat{A}_t \qquad (62)
\end{aligned}$$

Hence, the system of relevant equations includes the IS curve (61), the NKPC (56), the marginal cost relationship (62), and the usual definition of the habit-adjusted consumption (58).

In gap form

In the case of internal habits, it is easy to write these relationships in 'gap' form. Let $\widehat{Y}_t^g \equiv \widehat{Y}_t - \widehat{Y}_t^*$ and $\widehat{X}_t^g \equiv \widehat{X}_t - \widehat{X}_t^*$ denote the relevant 'gap' variables. Using the equations describing the social planner's allocation below, the marginal cost equation can be written as

$$\begin{aligned}
\widehat{mc}_t &= \frac{\sigma}{1-\theta\beta}\left(\widehat{X}_t - \theta\beta E_t \widehat{X}_{t+1}\right) + \upsilon \widehat{Y}_t - (1+\upsilon)\widehat{A}_t \\
&= \frac{\sigma}{1-\theta\beta}\left(\widehat{X}_t - \theta\beta E_t \widehat{X}_{t+1}\right) + \upsilon \widehat{Y}_t - \frac{\sigma}{1-\theta\beta}\left(\widehat{X}^*_t - \theta\beta E_t \widehat{X}^*_{t+1}\right) - \upsilon \widehat{Y}^*_t \\
&= \frac{\sigma}{1-\theta\beta}\left[\left(\widehat{X}_t - \widehat{X}^*_t\right) - \theta\beta E_t\left(\widehat{X}_{t+1} - \widehat{X}^*_{t+1}\right)\right] + \upsilon\left(\widehat{Y}_t - \widehat{Y}^*_t\right) \\
&= \frac{\sigma}{1-\theta\beta}\left(\widehat{X}^g_t - \theta\beta E_t \widehat{X}^g_{t+1}\right) + \upsilon \widehat{Y}^g_t
\end{aligned}$$

and the NKPC is then,

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} + \frac{\eta-1}{\varphi}\left[\frac{\sigma}{1-\theta\beta}\left(\widehat{X}^g_t - \theta\beta E_t \widehat{X}^g_{t+1}\right) + \upsilon \widehat{Y}^g_t\right] \tag{63}$$

The IS curve can also be written using gap variables and additional terms involving only the social planner's allocation. From the social planner's problem, $\widehat{X}^*_t - \theta\beta E_t \widehat{X}^*_{t+1} = \frac{1-\theta\beta}{\sigma}\left[(1+\upsilon)\widehat{A}_t - \upsilon \widehat{Y}^*_t\right]$, which then allows us to write the IS curve as (add and subtract the time t and $(t+1)$ expressions from the LHS and RHS of the IS equation):

$$\widehat{X}^g_t - \theta\beta E_t \widehat{X}^g_{t+1} = \left\{ \begin{array}{c} E_t\left(\widehat{X}^g_{t+1} - \theta\beta E_{t+1}\widehat{X}^g_{t+2}\right) - \frac{1-\theta\beta}{\sigma}\left(\widehat{R}_t - E_t\widehat{\pi}_{t+1}\right) \\ \\ + \frac{1-\theta\beta}{\sigma}\left[(1+\upsilon)(\rho-1)\widehat{A}_t - \upsilon\left(E_t\widehat{Y}^*_{t+1} - \widehat{Y}^*_t\right)\right] \end{array} \right\}$$

D.3 Optimal Policy: internal habits

In the case of internal (superficial) habits, we can show analytically that in response to technology shocks the Ramsey planner can set the nominal interest rate so as to match the social planner's allocation, without creating inflation. Using the link between gap variables, $\widehat{X}^g_t = \frac{1}{1-\theta}\left(\widehat{Y}^g_t - \theta\widehat{Y}^g_{t-1}\right)$, we first express all relevant equations in terms of inflation and output gap. The welfare function Γ_0 is

$$\Gamma_0 = -\frac{1}{2}\Omega E_0 \sum_{t=0}^{\infty}\beta^t\left\{\delta\left(\widehat{Y}^g_t - \theta\widehat{Y}^g_{t-1}\right)^2 + \upsilon\left(\widehat{Y}^g_t\right)^2 + \varphi\widehat{\pi}^2_t\right\} + tip + O[2]$$

and the New Keynesian Phillips curve (63) is

$$\widehat{\pi}_t = \beta E_t\widehat{\pi}_{t+1} - \frac{\eta-1}{\varphi}\delta\left[\theta\beta E_t\widehat{Y}^g_{t+1} - \zeta\widehat{Y}^g_t + \theta\widehat{Y}^g_{t-1}\right] \tag{64}$$

where Ω, δ, and ζ are defined as: $\Omega \equiv \overline{N}^{1+\upsilon}$, $\delta \equiv \frac{\sigma}{(1-\theta\beta)(1-\theta)}$, and $\zeta \equiv \left(1+\theta^2\beta+\frac{\upsilon}{\delta}\right)$.

With the IS curve not binding, the Lagrangian is

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} -\frac{1}{2}\Omega \left[\delta \left(\widehat{Y}_t^g - \theta \widehat{Y}_{t-1}^g \right)^2 + \upsilon \widehat{Y}_t^g + \varphi \widehat{\pi}_t^2 \right] \\ -\gamma_t \left[\widehat{\pi}_t - \beta \widehat{\pi}_{t+1} + \frac{\eta-1}{\varphi} \delta \left(\theta \beta E_t \widehat{Y}_{t+1}^g - \zeta \widehat{Y}_t^g + \theta \widehat{Y}_{t-1}^g \right) \right] \end{array} \right\}$$

and the first order conditions for the output gap and inflation are:

$$\left(\widehat{Y}_t^g \right) \quad : \quad \zeta \left(\widehat{Y}_t^g - \frac{\eta-1}{\varphi\Omega} \gamma_t \right) = \theta \beta E_t \left(\widehat{Y}_{t+1}^g - \frac{\eta-1}{\varphi\Omega} \gamma_{t+1} \right) + \theta \left(\widehat{Y}_{t-1}^g - \frac{\eta-1}{\varphi\Omega} \gamma_{t-1} \right)$$

$$\left(\widehat{\pi}_t \right) \quad : \quad \widehat{\pi}_t = -\frac{1}{\varphi\Omega} \left(\gamma_t - \gamma_{t-1} \right)$$

with the additional restriction that, under full commitment, the central bank ignores past commitments in the first period and sets all pre-existing conditions to zero, $\widehat{Y}_{-1}^g = \gamma_{-1} = 0$. By varying interest rates to eliminate the output gap, the value of the Lagrange multiplier associated with the NKPC is zero, $\gamma_t = 0$, and the policy maker can achieve the flexible-price allocation which is desirable since there are no frictions other than nominal inertia in this economy featuring internal habits.

E The Social Planner's Problem

The subsidy level that ensures an efficient long-run equilibrium is obtained by comparing the steady state solution of the social planner's problem with the steady state obtained in the decentralized equilibrium. The social planner ignores the nominal inertia and all other inefficiencies and chooses real allocations that maximize the representative consumer's utility subject to the aggregate resource constraint, the aggregate production function, and the law of motion for habit-adjusted consumption:

$$\begin{aligned} & \max_{\{X_t^*, C_t^*, N_t^*\}} E_0 \sum_{t=0}^{\infty} \beta^t u\left(X_t^*, N_t^*\right) \\ s.t.\ Y_t^* &= C_t^* \\ Y_t^* &= A_t N_t^* \\ X_t^* &= C_t^* - \theta C_{t-1}^* \end{aligned}$$

The optimal choice implies the following relationship between the marginal rate of substitution between labor and habit-adjusted consumption and the intertemporal marginal rate of substitution in habit-adjusted consumption

$$\frac{\chi\left(N_t^*\right)^{\upsilon}}{\left(X_t^*\right)^{-\sigma}} = A_t \left[1 - \theta\beta E_t \left(\frac{X_{t+1}^*}{X_t^*}\right)^{-\sigma}\right].$$

The steady state equivalent of this expression can be written as,

$$\chi\left(N^*\right)^{\upsilon+\sigma}\left[\left(1-\theta\right)A\right]^{\sigma} = A\left(1-\theta\beta\right). \tag{65}$$

The dynamics of this model are driven by technology shocks to the system of equilibrium conditions composed of the Euler equation, the resource constraint, and the evolution of habit-adjusted consumption. In log-linear form, these are:

$$\widehat{X}_t^* = \theta\beta E_t \widehat{X}_{t+1}^* + \frac{1-\theta\beta}{\sigma}\left(-\upsilon \widehat{N}_t^* + \widehat{A}_t\right)$$

$$\widehat{Y}_t^* = \widehat{A}_t + \widehat{N}_t^*$$

$$\widehat{X}_t^* = \frac{1}{1-\theta}\left(\widehat{Y}_t^* - \theta\widehat{Y}_{t-1}^*\right),$$

which combined yield the following dynamic equation

$$\zeta\widehat{Y}_t^* = \theta\beta E_t \widehat{Y}_{t+1}^* + \theta\widehat{Y}_{t-1}^* + \left(\frac{1+\upsilon}{\delta}\right)\widehat{A}_t$$

where $\zeta \equiv \left(1 + \theta^2\beta + \frac{\upsilon}{\delta}\right)$ and $\delta \equiv \frac{\sigma}{(1-\theta\beta)(1-\theta)}$. In the absence of deep habits, $\theta = 0$, the model reduces to the basic New Keynesian model where $\widehat{Y}_t^* = \left(\frac{1+\upsilon}{\sigma+\upsilon}\right)\widehat{A}_t$.

F Derivation of Welfare

Individual utility in period t is

$$\frac{X_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{1+\upsilon}}{1+\upsilon}$$

where $X_t = C_t - \theta C_{t-1}$ is the habit-adjusted aggregate consumption. Before considering the elements of the utility function, we need to note the following general result relating to second order approximations

$$\frac{Y_t - Y}{Y_t} = \widehat{Y}_t + \frac{1}{2}\widehat{Y}_t^2 + O[2]$$

where $\widehat{Y}_t = \ln\left(\frac{Y_t}{Y}\right)$ and $O[2]$ represents terms that are of order higher than 2 in the bound on the amplitude of the relevant shocks. This will be used in various places in the derivation of welfare. Now consider the second order approximation to the first term,

$$\frac{X_t^{1-\sigma}}{1-\sigma} = \overline{X}^{1-\sigma}\left(\frac{X_t - \overline{X}}{\overline{X}}\right) - \frac{\sigma}{2}\overline{X}^{1-\sigma}\left(\frac{X_t - \overline{X}}{\overline{X}}\right)^2 + tip + O[2]$$

where *tip* represents 'terms independent of policy'. Using the results above this can be rewritten in terms of hatted variables

$$\frac{X_t^{1-\sigma}}{1-\sigma} = \overline{X}^{1-\sigma}\left\{\widehat{X}_t + \frac{1}{2}(1-\sigma)\widehat{X}_t^2\right\} + tip + O[2].$$

In pure consumption terms, the value of X_t can be approximated to second order by:

$$\widehat{X}_t = \frac{1}{1-\theta}\left(\widehat{C}_t + \frac{1}{2}\widehat{C}_t^2\right) - \frac{\theta}{1-\theta}\left(\widehat{C}_{t-1} + \frac{1}{2}\widehat{C}_{t-1}^2\right) - \frac{1}{2}\widehat{X}_t^2 + O[2]$$

To a first order,

$$\widehat{X}_t = \frac{1}{1-\theta}\widehat{C}_t - \frac{\theta}{1-\theta}\widehat{C}_{t-1} + O[1]$$

which implies

$$\widehat{X}_t^2 = \frac{1}{(1-\theta)^2}\left(\widehat{C}_t - \theta\widehat{C}_{t-1}\right)^2 + O[2]$$

Therefore,

$$\frac{X_t^{1-\sigma}}{1-\sigma} = \overline{X}^{1-\sigma}\left\{\frac{1}{1-\theta}\left(\widehat{C}_t + \frac{1}{2}\widehat{C}_t^2\right) - \frac{\theta}{1-\theta}\left(\widehat{C}_{t-1} + \frac{1}{2}\widehat{C}_{t-1}^2\right) + \frac{1}{2}(-\sigma)\widehat{X}_t^2\right\} + tip + O[2]$$

Summing over the future,

$$\sum_{t=0}^{\infty}\beta^t\frac{X_t^{1-\sigma}}{1-\sigma} = \overline{X}^{1-\sigma}\sum_{t=0}^{\infty}\beta^t\left\{\frac{1-\theta\beta}{1-\theta}\left(\widehat{C}_t + \frac{1}{2}\widehat{C}_t^2\right) - \frac{1}{2}\sigma\widehat{X}_t^2\right\} + tip + O[2].$$

The term in labour supply can be written as

$$\frac{N_t^{1+\upsilon}}{1+\upsilon} = \overline{N}^{1+\upsilon}\left\{\widehat{N}_t + \frac{1}{2}\left(1+\upsilon\right)\widehat{N}_t^2\right\} + tip + O[2]$$

Now we need to relate the labor input to output which, in this case without price dispersion, is simply,

$$N_t = \frac{Y_t}{A_t}$$

and can be approximated to first order,

$$\widehat{N}_t = \widehat{Y}_t - \widehat{A}_t$$

which implies

$$\widehat{N}_t^2 = \left(\widehat{Y}_t - \widehat{A}_t\right)^2$$

so we can then write

$$\frac{N_t^{1+\upsilon}}{1+\upsilon} = \overline{N}^{1+\upsilon}\left\{\widehat{Y}_t + \frac{1}{2}\left(1+\upsilon\right)\widehat{Y}_t^2 - \left(1+\upsilon\right)\widehat{Y}_t\widehat{A}_t\right\} + tip + O[2]$$

Welfare is then given by

$$\begin{aligned}\Gamma_0 \quad = \quad & \overline{X}^{1-\sigma}E_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{1-\theta\beta}{1-\theta}\left(\widehat{C}_t + \frac{1}{2}\widehat{C}_t^2\right) - \frac{1}{2}\sigma\hat{X}_t^2\right\} \\ & -\overline{N}^{1+\upsilon}E_0\sum_{t=0}^{\infty}\beta^t\left\{\widehat{Y}_t + \frac{1}{2}\left(1+\upsilon\right)\widehat{Y}_t^2 - \left(1+\upsilon\right)\widehat{Y}_t\widehat{A}_t\right\} \\ & + tip + O[2]\end{aligned}$$

From the social planner's problem we know, $\overline{X}^{-\sigma}(1-\theta\beta) = \overline{N}^{\upsilon}$ such that $\overline{X}^{1-\sigma}(1-\theta\beta) = (1-\theta)\overline{N}^{1+\upsilon}$. If we use the appropriate subsidy to render the steady-state efficient and also use the second order approximation to the national accounting identity,

$$\widehat{C}_t + \frac{1}{2}\widehat{C}_t^2 = \widehat{Y}_t + \frac{1}{2}\widehat{Y}_t^2 - \frac{\varphi}{2}\widehat{\pi}_t^2 + O[2],$$

we can eliminate the level terms and write the sum of discounted utilities as:

$$\Gamma_0 = -\frac{1}{2}\overline{N}^{1+\upsilon}E_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{\sigma\left(1-\theta\right)}{1-\theta\beta}\widehat{X}_t^2 + \upsilon\left(\widehat{Y}_t - \frac{1+\upsilon}{\upsilon}\widehat{A}_t\right)^2 + \varphi\widehat{\pi}_t^2\right\} + tip + O[2] \quad (66)$$

The welfare function can be also expressed in the usual "gap" form. To do so, we employ the social planner's solution in log-linear form to re-write the output term in the welfare function as,

$$\upsilon\left(\widehat{Y}_t-\frac{1+\upsilon}{\upsilon}\widehat{A}_t\right)^2=\upsilon\left(\widehat{Y}_t-\widehat{Y}_t^*\right)^2+2\frac{\sigma}{1-\theta\beta}\widehat{Y}_t\left(\widehat{X}_t^*-\theta\beta E_t\widehat{X}_{t+1}^*\right)+tip$$

Summing across time periods, we have

$$E_0\sum_{t=0}^{\infty}\beta^t\upsilon\left(\widehat{Y}_t-\frac{1+\upsilon}{\upsilon}\widehat{A}_t\right)^2=E_0\sum_{t=0}^{\infty}\beta^t\left[\upsilon\left(\widehat{Y}_t-\widehat{Y}_t^*\right)^2-2\frac{\sigma}{1-\theta\beta}\widehat{Y}_t\left(\widehat{X}_t^*-\theta\beta E_t\widehat{X}_{t+1}^*\right)\right]+tip+O\left[2\right]$$

Then note that we can write

$$\widehat{X}_t^2=\left(\widehat{X}_t-\widehat{X}_t^*\right)^2+2\widehat{X}_t\widehat{X}_t^*-\left(\widehat{X}_t^*\right)^2$$

and, keeping only the terms relevant for policy, the welfare function becomes,

$$\Gamma_0=-\frac{1}{2}\overline{N}^{1+\upsilon}E_0\sum_{t=0}^{\infty}\beta^t\left\{\begin{array}{c}\frac{\sigma(1-\theta)}{1-\theta\beta}\left(\widehat{X}_t-\widehat{X}_t^*\right)^2+2\frac{\sigma(1-\theta)}{1-\theta\beta}\widehat{X}_t\widehat{X}_t^*+\upsilon\left(\widehat{Y}_t-\widehat{Y}_t^*\right)^2\\ \\ -2\frac{\sigma}{1-\theta\beta}\widehat{Y}_t\left(\widehat{X}_t^*-\theta\beta E_t\widehat{X}_{t+1}^*\right)+\varphi\widehat{\pi}_t^2\end{array}\right\}+tip+O[2]$$

Finally, we can show that

$$E_0\sum_{t=0}^{\infty}\beta^t\frac{\sigma}{1-\theta\beta}\widehat{Y}_t\left(\widehat{X}_t^*-\theta\beta E_t\widehat{X}_{t+1}^*\right)=\left[E_0\sum_{t=0}^{\infty}\beta^t\frac{\sigma\left(1-\theta\right)}{1-\theta\beta}\widehat{X}_t\widehat{X}_t^*\right]+tip$$

which allows to write the welfare function in gap form as follows

$$\Gamma_0=-\frac{1}{2}\overline{N}^{1+\upsilon}E_0\sum_{t=0}^{\infty}\beta^t\left\{\frac{\sigma\left(1-\theta\right)}{1-\theta\beta}\left(\widehat{X}_t-\widehat{X}_t^*\right)^2+\upsilon\left(\widehat{Y}_t-\widehat{Y}_t^*\right)^2+\varphi\widehat{\pi}_t^2\right\}+tip+O[2]$$

F.1 Welfare Measure

We measure welfare as the unconditional expectation of lifetime utility, approximated as

$$\begin{aligned}W&=E\sum_{t=0}^{\infty}\beta^t u\left(X_t,N_t\right)\\&=\frac{1}{1-\beta}\left\{\overline{u}+\frac{1}{2}\left[\left(\Lambda_C+\Lambda_{C_{-1}}\right)var\left(\widehat{Y}_t\right)+2\Lambda_{CC_{-1}}\ cov\left(\widehat{Y}_t,\widehat{Y}_{t-1}\right)+\Lambda_N var\left(\widehat{N}_t\right)+\Lambda_\pi var\left(\widehat{\pi}_t\right)\right]\right\}\end{aligned}$$

with $\overline{u}$ the steady-state level of the momentary utility and the Λ coefficients defined as

$$\left\{\begin{array}{l}\Lambda_C \equiv \frac{1}{1-\theta}\left(1-\frac{\sigma}{1-\theta}\right)\overline{X}^{1-\sigma} \\ \\ \Lambda_{C_{-1}} \equiv -\frac{\theta}{1-\theta}\left(1+\frac{\sigma\theta}{1-\theta}\right)\overline{X}^{1-\sigma} \\ \\ \Lambda_{CC_{-1}} \equiv \frac{\sigma\theta}{(1-\theta)^2}\overline{X}^{1-\sigma}\end{array}\right. \qquad and \qquad \left\{\begin{array}{c}\Lambda_N \equiv -\left(1+\upsilon\right)\overline{N}^{1+\upsilon} \\ \\ \Lambda_\pi \equiv -\varphi\overline{X}^{1-\sigma}\end{array}\right.$$

The welfare terms associated with the Ramsey policy that are involved in computing the welfare costs of alternative policies, as in expression (28) in the text, are given by,

$$\begin{aligned} W_X^R &= E\sum_{t=0}^{\infty}\beta^t\frac{\left(X_t^R\right)^{1-\sigma}}{1-\sigma} \\ &= \frac{1}{1-\beta}\left\{\frac{\left(\overline{X}\right)^{1-\sigma}}{1-\sigma}+\frac{1}{2}\left[\left(\Lambda_C+\Lambda_{C_{-1}}\right)var\left(\widehat{Y}_t^R\right)+2\Lambda_{CC_{-1}}\ cov\left(\widehat{Y}_t^R,\widehat{Y}_{t-1}^R\right)+\Lambda_\pi var\left(\widehat{\pi}_t^R\right)\right]\right\}\end{aligned}$$

and

$$W_N^R = -E\sum_{t=0}^{\infty}\beta^t\frac{\left(N_t^R\right)^{1+\upsilon}}{1+\upsilon} = \frac{1}{1-\beta}\left\{-\frac{\left(\overline{N}\right)^{1+\upsilon}}{1+\upsilon}+\frac{1}{2}\Lambda_N var\left(\widehat{N}_t^R\right)\right\}$$

G Optimal Policy: Commitment

Upon substitution of the habit-adjusted consumption term, the central bank's objective function becomes

$$\frac{1}{2}\Omega E_0 \sum_{t=0}^{\infty} \beta^t \left[(\delta + \upsilon) \widehat{Y}_t^2 - 2\theta\delta \widehat{Y}_t \widehat{Y}_{t-1} + \theta^2 \delta \widehat{Y}_{t-1}^2 - 2(1+\upsilon) \widehat{Y}_t \widehat{A}_t + \varphi \widehat{\pi}_t^2 \right]$$

where $\Omega \equiv \overline{N}^{1+\upsilon}$ and $\delta \equiv \frac{\sigma}{(1-\theta\beta)(1-\theta)}$ and we re-write the constraints as,

$$\left(\frac{1+\theta}{1-\theta}\right) \widehat{Y}_t = \frac{1}{1-\theta} E_t \widehat{Y}_{t+1} + \frac{1}{\sigma} E_t \widehat{\pi}_{t+1} + \frac{\theta}{1-\theta} \widehat{Y}_{t-1} - \frac{1}{\sigma} \widehat{R}_t$$

$$\widehat{\pi}_t = \beta E_t \widehat{\pi}_{t+1} - \kappa_2 \widehat{Y}_t + \kappa_2 \widehat{Y}_{t-1} - \kappa_1 \widehat{\omega}_t$$

$$\mu\omega\widehat{\omega}_t = \mu\omega\theta\beta E_t \widehat{\omega}_{t+1} - \gamma_1 \beta E_t \widehat{Y}_{t+1} + \gamma_2 \widehat{Y}_t + \gamma_3 \widehat{Y}_{t-1} + (1+\upsilon) \widehat{A}_t$$

where

$$\begin{cases} \kappa_1 \equiv \frac{1}{\varphi} \\ \\ \kappa_2 \equiv \kappa_1 \frac{\theta}{1-\theta} \end{cases} \qquad \textit{and} \qquad \begin{cases} \gamma_1 \equiv \mu\omega \frac{\sigma\theta}{1-\theta} \\ \\ \gamma_2 \equiv \gamma_1 \beta (1+\theta) - \left(\frac{\sigma}{1-\theta} + \upsilon\right) \\ \\ \gamma_3 \equiv \frac{\sigma\theta}{1-\theta} (1 - \mu\omega\theta\beta) \end{cases}$$

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} \frac{1}{2}\Omega \left[-(\delta+\upsilon) \widehat{Y}_t^2 + 2\theta\delta \widehat{Y}_t \widehat{Y}_{t-1} - \theta^2 \delta \widehat{Y}_{t-1}^2 + 2(1+\upsilon) \widehat{Y}_t \widehat{A}_t - \varphi \widehat{\pi}_t^2 \right] \\ -\chi_t \left[\left(\frac{1+\theta}{1-\theta}\right) \widehat{Y}_t - \frac{1}{1-\theta} \widehat{Y}_{t+1} - \frac{1}{\sigma} \widehat{\pi}_{t+1} - \frac{\theta}{1-\theta} \widehat{Y}_{t-1} + \frac{1}{\sigma} \widehat{R}_t \right] \\ -\psi_t \left[\widehat{\pi}_t - \beta \widehat{\pi}_{t+1} + \kappa_2 \widehat{Y}_t - \kappa_2 \widehat{Y}_{t-1} + \kappa_1 \widehat{\omega}_t \right] \\ -\varsigma_t \left[\mu\omega\widehat{\omega}_t - \mu\omega\theta\beta E_t \widehat{\omega}_{t+1} + \gamma_1 \beta E_t \widehat{Y}_{t+1} - \gamma_2 \widehat{Y}_t - \gamma_3 \widehat{Y}_{t-1} - (1+\upsilon) \widehat{A}_t \right] \end{array} \right\}$$

The government chooses paths for $\widehat{R}_t$, $\widehat{Y}_t$, $\widehat{\pi}_t$, and $\widehat{\omega}_t$. The first order condition with respect to the nominal interest rate gives:

$$-\sigma^{-1} E_0 \beta^t \chi_t = 0, \qquad \forall t \geq 0 \tag{67}$$

which implies that the IS curve is not binding and it can therefore be excluded from the optimization problem. Once the optimal rules for the other variables have been obtained, we use the IS curve to determine the path of the nominal interest rate. So, the central bank now chooses $\left\{\widehat{Y}_t, \widehat{\pi}_t, \widehat{\omega}_t\right\}$. The Lagrangian takes the form:

$$L = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \begin{array}{c} \frac{1}{2}\Omega \left[-(\delta+\upsilon) \widehat{Y}_t^2 + 2\theta\delta \widehat{Y}_t \widehat{Y}_{t-1} - \theta^2 \delta \widehat{Y}_{t-1}^2 + 2(1+\upsilon) \widehat{Y}_t \widehat{A}_t - \varphi \widehat{\pi}_t^2 \right] \\ -\psi_t \left[\widehat{\pi}_t - \beta \widehat{\pi}_{t+1} + \kappa_2 \widehat{Y}_t - \kappa_2 \widehat{Y}_{t-1} + \kappa_1 \widehat{\omega}_t \right] \\ -\varsigma_t \left[\mu\omega\widehat{\omega}_t - \mu\omega\theta\beta E_t \widehat{\omega}_{t+1} + \gamma_1 \beta E_t \widehat{Y}_{t+1} - \gamma_2 \widehat{Y}_t - \gamma_3 \widehat{Y}_{t-1} - (1+\upsilon) \widehat{A}_t \right] \end{array} \right\}.$$

The first order condition for the shadow value $\widehat{\omega}_t$ gives the relationship between the two Lagrange multipliers,

$$\kappa_1 \psi_t = -\mu\omega \left(\varsigma_t - \theta \varsigma_{t-1} \right)$$

while for inflation we have the rather usual expression

$$\widehat{\pi}_t = -\frac{1}{\varphi\Omega} \left(\psi_t - \psi_{t-1} \right).$$

The first order condition for output gives

$$-\Omega\delta\zeta\widehat{Y}_t + \Omega\delta\theta\widehat{Y}_{t-1} + \Omega\left(1+\upsilon\right)\widehat{A}_t - \kappa_2\psi_t + \gamma_2\varsigma_t - \gamma_1\varsigma_{t-1} + \beta E_t\left[\Omega\delta\theta\widehat{Y}_{t+1} + \kappa_2\psi_{t+1} + \gamma_3\varsigma_{t+1}\right] = 0$$

where, as defined before, $\zeta \equiv \left(1 + \theta^2\beta + \frac{\upsilon}{\delta}\right)$.

Under full commitment, the central bank ignores past commitments in the first period by setting all pre-existing conditions to zero, $\widehat{Y}_{-1} = 0$ and $\psi_{-1} = \varsigma_{-1} = 0$. To find the solution, solve the system of equations composed of the first order conditions, the three constraints, and the technology process.

G.1 Optimal Policy: Discretion

In order to solve the time-consistent policy problem we employ the iterative algorithm of Soderlind (1999), which follows Currie and Levine (1993) in solving the Bellman equation. The per-period objective function can be written in matrix form as $Z_t' Q Z_t$, where $Z_{t+1} = \begin{bmatrix} \widehat{A}_{t+1} & \widehat{Y}_t & E_t\widehat{Y}_{t+1} & E_t\widehat{\omega}_{t+1} & E_t\widehat{\pi}_{t+1} \end{bmatrix}'$ and

$$Q = \frac{1}{2}\Omega \begin{bmatrix} 0 & 0 & -\left(1+\upsilon\right) & 0 & 0 \\ 0 & \theta^2\delta & -\theta\delta & 0 & 0 \\ -\left(1+\upsilon\right) & -\theta\delta & \left(\delta+\upsilon\right) & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \varphi \end{bmatrix}$$

and the structural description of the economy is given by,

$$Z_{t+1} = AZ_t + Bu_t + \xi_{t+1},$$

where $u_t = \left[\widehat{R}_t\right]$, $\xi_{t+1} = \begin{bmatrix} \varepsilon_{t+1}^A & 0 & 0 & 0 & 0 \end{bmatrix}'$, $A \equiv A_0^{-1}A_1$, $B \equiv A_0^{-1}B_0$,

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & \gamma_1\beta & 0 & 0 \\ 0 & 0 & \frac{1}{1-\theta} & 0 & \sigma^{-1} \\ 0 & 0 & 0 & 0 & \beta \end{bmatrix}, \qquad A_1 = \begin{bmatrix} \rho & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 1+\upsilon & \gamma_3 & \gamma_2 & -\mu\omega & 0 \\ 0 & -\frac{\theta}{1-\theta} & \frac{1+\theta}{1-\theta} & 0 & 0 \\ 0 & -\kappa_2 & \kappa_2 & \kappa_1 & 1 \end{bmatrix}$$

and

$$B_0 = \left[\begin{array}{ccccc} 0 & 0 & 0 & \sigma^{-1} & 0 \end{array} \right]'.$$

This completes the description of the required inputs for Soderlind (1999)'s Matlab code which computes optimal discretionary policy.

References

Currie, D., and P. Levine (1993): *Rules, Reputation and Macroeconomic Policy Coordination*. Cambridge University Press, Cambridge.

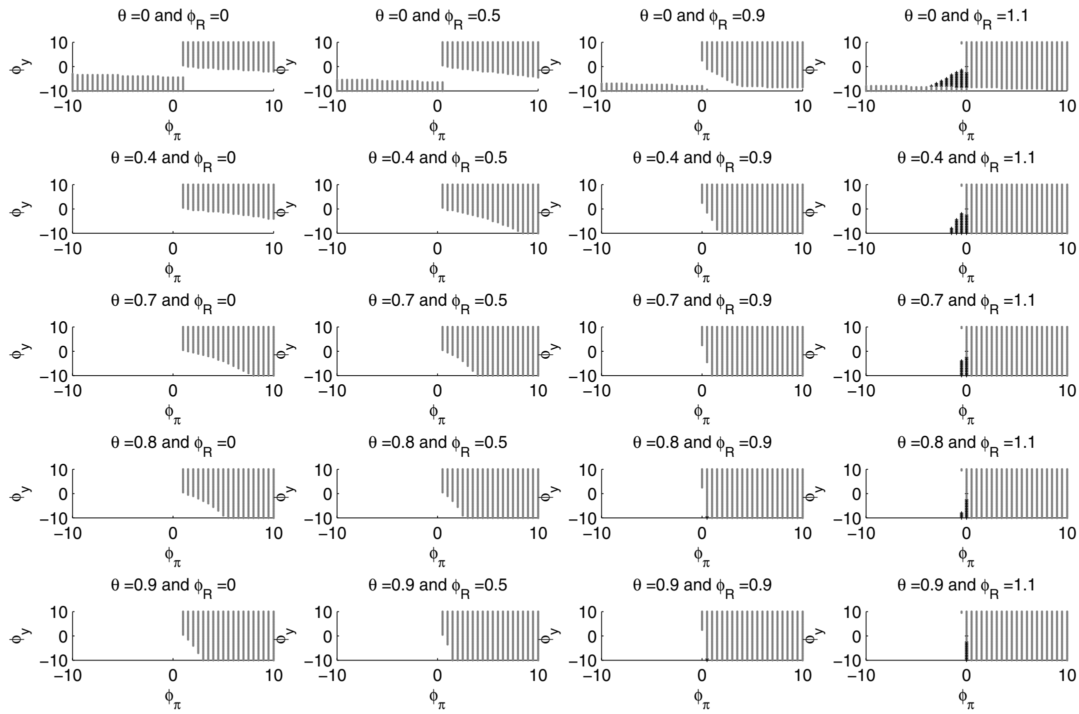

Figure 11: Determinacy properties of the model with *internal habits*, when monetary policy follows the rule $\widehat{R}_t = \phi_\pi \widehat{\pi}_t + \phi_y \widehat{Y}_t + \phi_R \widehat{R}_{t-1}$: determinacy (light grey dots), indeterminacy (blanks), and instability (dark grey stars).

H Additional Figures

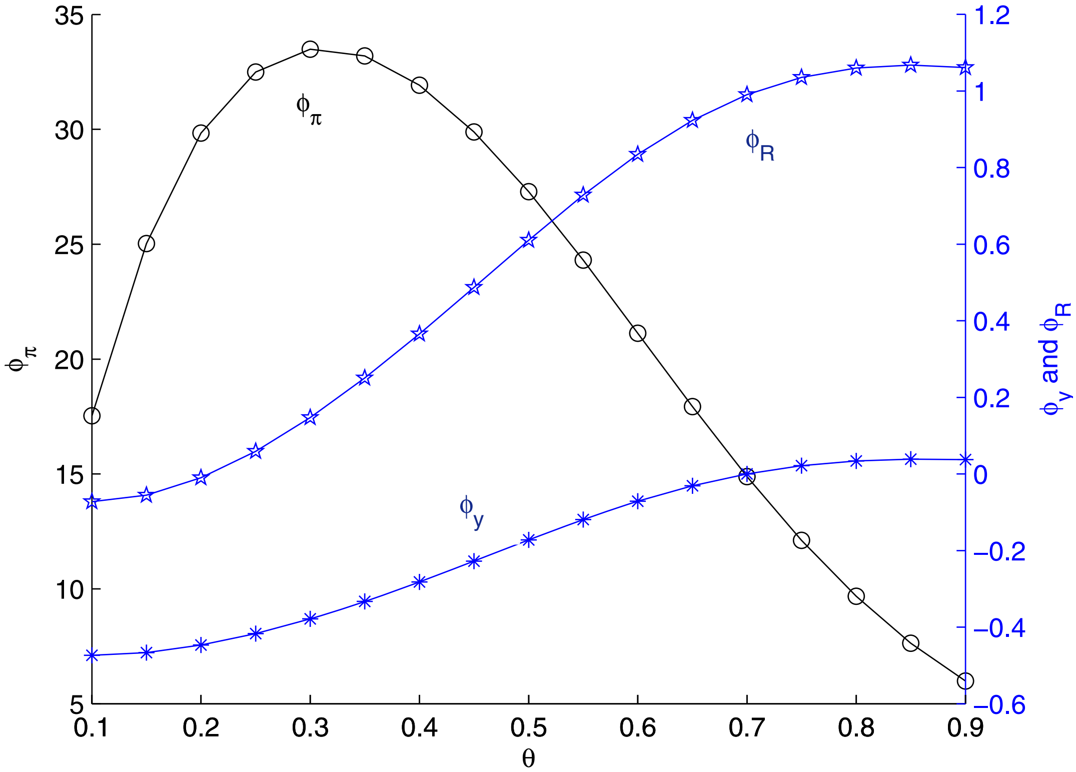

Figure 12: Optimal policy rule parameters for varying degrees of *superficial habits, the unconstrained case.*

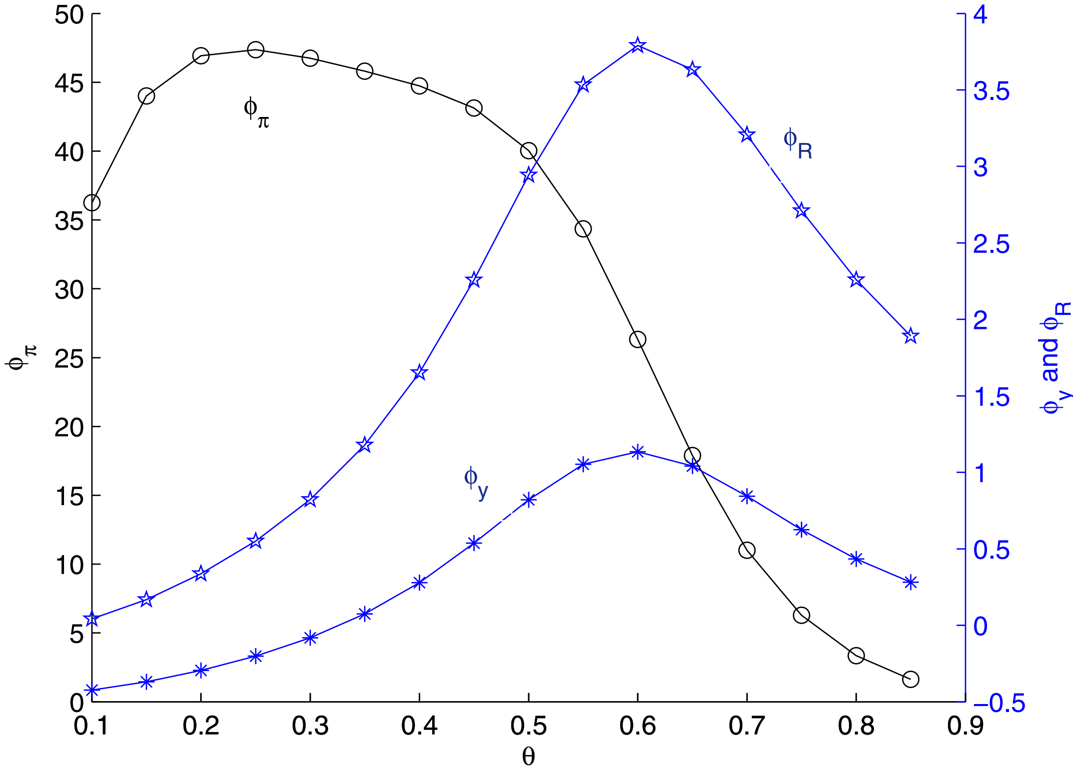

Figure 13: Optimal policy rule parameters for varying degrees of *deep habits, the unconstrained case.*

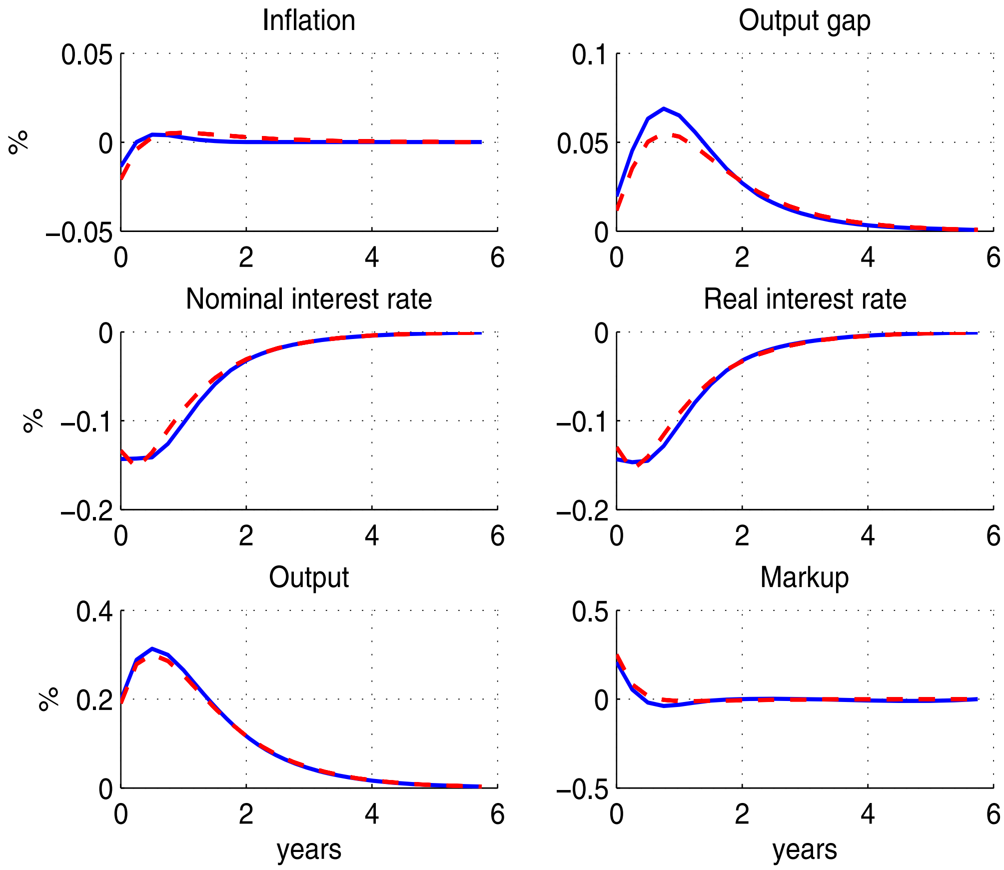

Figure 14: Impulse responses to a 1% positive technology shock in the model with *deep habits* with $\theta = 0.6$, under the optimal Taylor rule (dash lines) and optimal commitment policy (solid lines).