SUPPLEMENTAL APPENDICES TO THE MANUSCRIPT "LAND PRICES AND UNEMPLOYMENT"

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Abstract. We provide supplemental appendices for the main text of the manuscript "Land Prices and Unemployment." The appendices contain a detailed description of the equivalence between multiple-worker firm and single-work firm problems, equilibrium conditions, steady state equations, and log-linearized equations for the benchmark model and various other model specifications, data used in the paper, prior distributions, measurement equations for estimation, additional estimated results, and relevant estimation issues. This description is detailed enough for the reader to replicate all the results we obtain for the paper.

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A. The BVAR model and impulse responses to a land-price shock

The BVAR model is estimated with the following 7 variables: consumption, investment, job vacancies, unemployment, total hours, real wages, and land prices, with the same ordering of variables for Cholesky identification. The land price is ordered the last so that all other shocks can have a contemporaneous effect on the land price. The estimation results are robust to other orderings. For example, in an earlier draft of the paper, we ordered the land price first and obtained similar results, although that ordering is not a priori appealing. Furthermore, to be conceptually consistent with the DSGE model, all variables in the BVAR model are expressed in log levels. The BVAR model is estimated with 3 lags.

The priors that we use follow closely Sims and Zha (1998) with the prior hyperparameter values set at $\lambda_1 = \lambda_2 = \lambda_3 = 1$, $\lambda_4 = 1.2$, and $\mu_5 = \mu_6 = 3$ according to their notation. The hyperparameters μ_5 and μ_6 allow for the presence of cointegration. Since the land price comoves strongly with other variables, this component of cointegration prior is essential for capturing the data dynamics. By the marginal data density (marginal likelihood) criterion, the data favors the lag length being three over longer lag lengths such as four or five.

Figure 1 shows the estimated impulse responses to a negative one-standard-deviation shock to land prices with 90% error bands (the shaded bands) from the BVAR, along with the impulse responses to a housing demand shock estimated from the DSGE model (asterisk lines). As one can see, the impulse responses from the DSGE model are remarkably in line with the BVAR results.

B. An equivalent setup with the large representative firm

In this section, we show that the benchmark model in the main text is equivalent to an alternative setup with one large representative firm as in the real business cycles (RBC) literature.[1] In this alternative setup, the decision problems for households and capitalists are identical to those in the benchmark model presented in the text. The environment for firms is different. Instead of the one-firm one-worker setup in the benchmark model, we assume that there is one large representative firm. The firm employs N_t workers in each period, combined with capital and land to produce output. The firm bargains with the marginal worker who is seeking for a job to determine the wage rate and average hours. Once the wage rate and hours are determined, they apply to all active workers. We continue to assume that capitalists own the firm.

[1]See Pissarides (2000) for a related discussion.

We begin with the representative household's problem. Denote by $V_{ht}\left(N_{t-1}\right)$ the value function of the household. It satisfies the Bellman equation

$$V_{ht}\left(N_{t-1}\right)=\max_{C_{ht},L_{ht},B_{ht}}\frac{\left(L_{ht}^{\varphi_{Lt}}\left(C_{ht}-\eta_h C_{ht-1}\right)/Z_t^p\right)^{1-\gamma}}{1-\gamma}-\chi g\left(h_t\right)N_t+\beta_h E_t V_{ht+1}\left(N_t\right),$$

subject to the budget constraint

$$C_{ht}+\frac{B_{ht}}{R_t}+Q_{lt}\left(L_{ht}-L_{h,t-1}\right)=B_{ht-1}+W_t h_t N_t+bZ_t^p\left(1-N_t\right)-T_t,\quad \forall t\geq 0. \tag{B.1}$$

We define the household surplus in consumption units as

$$S_t^H\equiv\frac{1}{\Lambda_{ht}}\frac{\partial V_{ht}\left(N_{t-1}\right)}{\partial N_t}. \tag{B.2}$$

This is the marginal value to the household when a new member is employed. Note that we consider a marginal change in N_t because a newly hired worker immediately starts working as in Blanchard and Galí (2010).

By the envelope condition,

$$\begin{aligned}\frac{\partial V_{ht}\left(N_{t-1}\right)}{\partial N_t} &= \Lambda_{ht}\left(W_t h_t-bZ_t^p\right)-\chi_t g\left(h_t\right)+\beta_h E_t\frac{\partial V_{ht+1}\left(N_t\right)}{\partial N_t} \qquad \text{(B.3)}\\ &= \Lambda_{ht}\left(W_t h_t-bZ_t^p\right)-\chi_t g\left(h_t\right)+\beta_h E_t\frac{\partial V_{ht+1}\left(N_t\right)}{\partial N_{t+1}}\frac{\partial N_t}{\partial N_{t+1}},\end{aligned}$$

where marginal utility of consumption Λ_{ht} is equal to the Lagrange multiplier associated with the budget constraint (B.1).

Note that

$$\begin{aligned}N_t &= (1-\rho)N_{t-1}+m_t\\ &= (1-\rho)N_{t-1}+q_t^u u_t\\ &= (1-\rho)N_{t-1}+q_t^u\left[1-(1-\rho)N_{t-1}\right].\end{aligned}$$

Since the household takes the job finding rate q_t^u as given when an additional worker is hired, one can compute that

$$\frac{\partial N_t}{\partial N_{t-1}}=(1-\rho)-q_t^u\left(1-\rho\right)=\left(1-q_t^u\right)\left(1-\rho_t\right). \tag{B.4}$$

Substituting (B.2) and (B.4) into (B.3), we obtain

$$S_t^H=W_t h_t-bZ_t^p-\frac{1}{\Lambda_{ht}}\chi_t g\left(h_t\right)+E_t\frac{\beta_h\Lambda_{ht+1}}{\Lambda_{ht}}\left(1-q_{t+1}^u\right)\left(1-\rho\right)S_{t+1}^H.$$

This equation shows that S_t^H corresponds to $J_t^W-J_t^U$ in the main text of the manuscript.

Now, consider the representative firm's problem. The firm chooses capital and labor inputs and posts vacancies to maximize the present value of dividends. The flow dividend is given by

$$D_t = Y_t - R_{kt}k_tN_t - R_{lt}l_{ct}N_t - W_th_tN_t - v_t\kappa Z_t^p,$$

where

$$Y_t = Z_t^{1-\alpha+\phi\alpha}\left(l_{ct}^{\phi}k_t^{1-\phi}\right)^{\alpha} h_t^{1-\alpha}N_t = y_tN_t.$$

The firm's value, denoted as $P_t\left(N_{t-1}\right)$, satisfies the Bellman equation

$$P_t\left(N_{t-1}\right) = \max_{k_t,l_{ct},v_t} \; D_t + E_t\frac{\beta_c\Lambda_{ct+1}}{\Lambda_{ct}}P_{t+1}\left(N_t\right), \tag{B.5}$$

subject to

$$N_t = (1-\rho)\,N_{t-1} + q_t^v v_t. \tag{B.6}$$

Since the firm takes q_t^v as given when choosing vacancies v_t, equation (B.6) implies that

$$\frac{\partial N_t}{\partial N_{t-1}} = 1-\rho. \tag{B.7}$$

The first-order conditions for k_t, $l_{c,t}$, and v_t are given by

$$R_{kt} = \frac{\partial y_t}{\partial k_t},\;\; R_{lt} = \frac{\partial y_t}{\partial l_{ct}},\;\; \kappa Z_t^p = \frac{\partial P_t\left(N_t\right)}{\partial N_t}q_t^v. \tag{B.8}$$

By the envelope condition

$$\begin{aligned}\frac{\partial P_t\left(N_{t-1}\right)}{\partial N_{t-1}} &= \frac{\partial N_t}{\partial N_{t-1}}\left(\frac{\partial Y_t}{\partial N_t} - W_th_t\right) + E_t\frac{\beta_c\Lambda_{ct+1}}{\Lambda_{ct}}\frac{\partial P_{t+1}\left(N_t\right)}{\partial N_t}\frac{\partial N_t}{\partial N_{t-1}}\\ &= \left[y_t - R_{kt}k_t - R_{lt}l_{ct} - W_th_t + E_t\frac{\beta_c\Lambda_{ct+1}}{\Lambda_{ct}}\frac{\partial P_{t+1}\left(N_t\right)}{\partial N_t}\right](1-\rho),\end{aligned}$$

where we have used equation (B.7).

Define the firm surplus as

$$S_t^F \equiv \frac{\partial P_t\left(N_{t-1}\right)}{\partial N_t} = \frac{\partial P_t\left(N_{t-1}\right)}{\partial N_{t-1}}\frac{\partial N_{t-1}}{\partial N_t} = \frac{\partial P_t\left(N_{t-1}\right)}{\partial N_{t-1}}\frac{1}{1-\rho},$$

where we have used equation (B.7) again. Combining the above two equations, we obtain

$$S_t^F = y_t - R_{kt}k_t - R_{lt}l_{ct} - W_th_t + E_t\frac{\beta_c\Lambda_{ct+1}}{\Lambda_{ct}}(1-\rho)\,S_{t+1}^F.$$

Note that S_t^F corresponds to J_t^F in the main text. Thus, the last equation in (B.8) corresponds to the free-entry condition

$$J_t^F = \frac{\kappa Z_t^p}{q_t^v}.$$

Wages and hours are determined by Nash bargaining between the marginal worker and the representative firm. As in the standard DMP framework, when an additional worker is hired, surplus is computed as the marginal value to the household as well as to the firm. The Nash bargaining problem is given by

$$\max_{W_t,\,h_t} \ \left(S_t^H\right)^{\frac{\vartheta_t}{1+\vartheta_t}} \left(S_t^F\right)^{\frac{1}{1+\vartheta_t}},$$

which is the same as the problem in the main text

$$\max_{W_t, h_t} \ \left(J_t^W - J_t^U\right)^{\frac{\vartheta_t}{1+\vartheta_t}} \left(J_t^F\right)^{\frac{1}{1+\vartheta_t}}.$$

It is straightforward to show that this alternative setup of labor-market frictions produces equilibrium dynamics identical to those in the benchmark model presented in the main text.

C. The benchmark DSGE model

C.1. **Stationary equilibrium conditions.** We first present the system of stationary equilibrium conditions for the benchmark DSGE model. To induce stationarity, we transform variables so that

$$\begin{aligned}
\tilde{C}_{ht} &= \frac{C_{ht}}{Z_t^p}, \quad \tilde{C}_{ct} = \frac{C_{ct}}{Z_t^p}, \quad \tilde{I}_t = \frac{I_t}{Z_t^p}, \quad \tilde{K}_t = \frac{K_t}{Z_t^p}, \quad \tilde{Y}_t = \frac{Y_t}{Z_t^p}, \quad \tilde{B}_t = \frac{B_t}{Z_t^p}, \quad \tilde{T}_t = \frac{T_t}{Z_t^p}, \\
\tilde{Q}_{lt} &= \frac{Q_{lt}}{Z_t^p}, \quad \tilde{R}_{lt} = \frac{R_{lt}}{Z_t^p}, \quad \tilde{W}_t = \frac{W_t}{Z_t^p}, \quad \tilde{W}_t^{NB} = \frac{W_t^{NB}}{Z_t^p}, \quad \tilde{S}_t = \frac{S_t}{Z_t^p}, \quad \tilde{\Lambda}_{ct} = \Lambda_{ct} Z_t^p, \\
\tilde{\Lambda}_{ht} &= \Lambda_{ht} Z_t^p, \quad \tilde{\mu}_t = \mu_t Z_t^p, \quad \tilde{J}_t^F = \frac{J_t^F}{Z_t^p}, \quad \tilde{J}_t^w = \frac{J_t^w}{Z_t^p}, \quad \tilde{J}_t^u = \frac{J_t^u}{Z_t^p}.
\end{aligned}$$

The stationary equilibrium is summarized by a system of 34 equations for 34 variables $\tilde{\mu}_t$, Q_{kt}, $\tilde{Q}_{lt}$, $\tilde{B}_t$, γ_{It}, $\tilde{I}_t$, e_t, $\tilde{\Lambda}_{ct}$, $\tilde{C}_{ht}$, R_t, L_{ht}, $\tilde{\Lambda}_{ht}$, m_t, q_t^u, q_t^v, N_t, u_t, $\tilde{Y}_t$, R_{kt}, $\tilde{R}_{lt}$, $\tilde{K}_t$, $\tilde{C}_t$, L_{ct}, v_t, $\tilde{W}_t^{NB}$, $\tilde{S}_t$, $\tilde{W}_t$, $\tilde{C}_{ct}$, U_t, $\tilde{J}_t^F$, $\tilde{J}_t^W$, $\tilde{J}_t^U$, θ_t, and h_t. We write the equations in the same order as in the dynare code.

(1) Capitalist's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}}. \tag{C.1}$$

(2) Capitalist's capital Euler equation:

$$Q_{kt} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} \left[R_{k,t+1} e_{t+1} - \Phi\left(e_{t+1}\right) + (1-\delta) Q_{k,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_2 \xi_t E_t Q_{k,t+1} \tag{C.2}$$

(3) Capitalist's land Euler equation:

$$\tilde{Q}_{lt} = E_t \beta_c \frac{\tilde{\Lambda}_{ct+1}}{\tilde{\Lambda}_{ct}} \left[\tilde{Q}_{l,t+1} + \tilde{R}_{l,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_1 \xi_t E_t \tilde{Q}_{l,t+1} \lambda_{z,t+1}. \tag{C.3}$$

(4) Borrowing constraint:

$$\tilde{B}_t = \xi_t \mathrm{E}_t \left(\omega_1 \tilde{Q}_{l,t+1} \lambda_{z,t+1} L_{ct} + \omega_2 Q_{k,t+1} \tilde{K}_t\right). \tag{C.4}$$

(5) Investment growth rate:

$$\frac{I_t}{I_{t-1}} \equiv \gamma_{It} = \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \lambda_{zt}. \tag{C.5}$$

(6) Capitalist's investment Euler equation:

$$\begin{aligned} 1 &= Q_{kt}\varphi_{It}\left[1 - \frac{\Omega}{2}\left(\gamma_{It} - \bar{\gamma}_I\right)^2 - \Omega\left(\gamma_{It} - \bar{\gamma}_I\right)\gamma_{It}\right] \\ &+ \mathrm{E}_t\beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} Q_{kt+1}\varphi_{I,t+1}\Omega\left(\gamma_{I,t+1} - \bar{\gamma}_I\right)\gamma_{I,t+1}^2. \end{aligned} \tag{C.6}$$

(7) Capacity utilization decision:

$$R_{kt} = \gamma_2\left(e_t - 1\right) + \gamma_1. \tag{C.7}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_{ct} = \frac{1}{\tilde{C}_{ct} - \eta_c\tilde{C}_{c,t-1}/\lambda_{zt}} - E_t\frac{\beta_c\eta_c}{\tilde{C}_{c,t+1}\lambda_{z,t+1} - \eta_c\tilde{C}_{ct}}. \tag{C.8}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_{ht} + \frac{\tilde{B}_t}{R_t} + \tilde{Q}_{lt}\left(L_{ht} - L_{h,t-1}\right) = \frac{\tilde{B}_{t-1}}{\lambda_{zt}} + \tilde{W}_t h_t N_t. \tag{C.9}$$

(10) Household's bond Euler equation:

$$\frac{1}{R_t} = E_t\beta_h\frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}\lambda_{z,t+1}}. \tag{C.10}$$

(11) Household's land Euler equation:

$$\tilde{Q}_{lt} = MRS_{lt} + E_t\beta_h\frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\tilde{Q}_{l,t+1}, \tag{C.11}$$

where the marginal rate of substituition between housing and consumption is given by

$$MRS_{lt} = \frac{\widetilde{MUL_t}}{\tilde{\Lambda}_{ht}}.$$

(12) Household's marginal utility of consumption

$$\begin{aligned} \tilde{\Lambda}_{ht} &= L_{ht}^{\varphi_{Lt}(1-\gamma)}\left(\tilde{C}_{ht} - \frac{\eta_h\tilde{C}_{h,t-1}}{\lambda_{zt}}\right)^{-\gamma} \\ &- \beta_h\eta_h E_t\left[L_{h,t+1}^{(1-\gamma)\varphi_{L,t+1}}\left(\tilde{C}_{h,t+1} - \frac{\eta_h\tilde{C}_{h,t}}{\lambda_{z,t+1}}\right)^{-\gamma}\frac{1}{\lambda_{z,t+1}}\right]. \end{aligned} \tag{C.12}$$

(13) Household's marginal utility of housing

$$\widetilde{MUL}_t = \varphi_{Lt} L_{ht}^{\varphi_{Lt}(1-\gamma)-1} \left(\tilde{C}_{ht} - \eta_h \frac{\tilde{C}_{ht-1}}{\lambda_{zt}} \right)^{1-\gamma}. \tag{C.13}$$

(14) Matching function

$$m_t = \varphi_{mt} u_t^a v_t^{1-a}. \tag{C.14}$$

(15) Job finding rate

$$q_t^u = \frac{m_t}{u_t}. \tag{C.15}$$

(16) Vacancy filling rate

$$q_t^v = \frac{m_t}{v_t}. \tag{C.16}$$

(17) Employment dynamics:

$$N_t = (1-\rho) N_{t-1} + m_t. \tag{C.17}$$

(18) Number of searching workers:

$$u_t = 1 - (1-\rho) N_{t-1}. \tag{C.18}$$

(19) Aggregate production function:

$$\tilde{Y}_t = \left[(Z_t^m L_{c,t-1})^{\phi} \left(\frac{e_t \tilde{K}_{t-1}}{\lambda_{zt}} \right)^{1-\phi} \right]^{\alpha} (Z_t^m h_t N_t)^{1-\alpha}. \tag{C.19}$$

(20) Capital rental rate:

$$R_{kt} = \alpha(1-\phi) \frac{\tilde{Y}_t \lambda_{zt}}{e_t \tilde{K}_{t-1}}. \tag{C.20}$$

(21) Land rental rate:

$$\tilde{R}_{lt} = \alpha\phi \frac{\tilde{Y}_t}{L_{c,t-1}}. \tag{C.21}$$

(22) Capital law of motion:

$$\tilde{K}_t = (1-\delta) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \varphi_{It} \left[1 - \frac{\Omega}{2} (\gamma_{It} - \bar{\gamma}_I)^2 \right] \tilde{I}_t. \tag{C.22}$$

(23) Aggregate Resource constraint:

$$\tilde{C}_t + \tilde{I}_t + \tilde{G}_t + \Phi(e_t) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \kappa v_t = \tilde{Y}_t. \tag{C.23}$$

(24) Land market clears (normalize aggregate supply of land to $\bar{L} = 1$):

$$L_{ct} + L_{ht} = 1. \tag{C.24}$$

(25) Optimal vacancy posting:

$$\frac{\kappa}{q_t^v} = (1-\alpha)\frac{\tilde{Y}_t}{N_t} - \tilde{W}_t h_t + E_t \frac{\beta_c \tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}} (1-\rho) \frac{\kappa}{q_{t+1}^v}. \tag{C.25}$$

(26) Nash bargaining wage:

$$\tilde{W}_t^{NB} h_t = \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + b + \vartheta_t \frac{\kappa}{q_t^v} - E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[(1-\rho) \left(1 - q_{t+1}^u\right) \vartheta_{t+1} \frac{\kappa}{q_{t+1}^v} \right], \tag{C.26}$$

where

$$g\left(h_t\right) = \frac{h_t^{1+\nu}}{1+\nu}, \;\; \nu \geq 0.$$

(27) Wage rigidity:

$$\tilde{W}_t = \psi \tilde{W}_{t-1} + (1-\psi) \tilde{W}_t^{NB}. \tag{C.27}$$

(28) Aggregate consumption

$$\tilde{C}_t = \tilde{C}_{ht} + \tilde{C}_{ct}. \tag{C.28}$$

(29) Unemployment rate:

$$U_t = 1 - N_t. \tag{C.29}$$

(30) The value of the firm:

$$\tilde{J}_t^F = \frac{\kappa}{q_t^v}. \tag{C.30}$$

(31) The value of employment:

$$\tilde{J}_t^W = \tilde{W}_t h_t - \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[\left(1 - \rho\left(1 - q_{t+1}^u\right)\right) \left(\tilde{J}_{t+1}^W - \tilde{J}_{t+1}^U \right) + \tilde{J}_{t+1}^U \right]. \tag{C.31}$$

(32) The value of unemployment:

$$\tilde{J}_t^U = b + E_t \frac{\beta_h \tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}} \left[q_{t+1}^u \tilde{J}_{t+1}^W + (1 - q_{t+1}^u) \tilde{J}_{t+1}^U \right]. \tag{C.32}$$

(33) Market tightness:

$$\theta_t = \frac{v_t}{u_t}. \tag{C.33}$$

(34) MRS for hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}} = (1-\alpha)\frac{Y_t}{N_t h_t}. \tag{C.34}$$

C.2. **Steady state.**

(1) Shadow value of collateral:

$$\frac{\tilde{\mu}}{\tilde{\Lambda}_c} = \frac{\beta_h - \beta_c}{\bar{\lambda}_z}. \tag{C.35}$$

(2) Capital Euler equation

$$1 = \frac{\beta_c}{\bar{\lambda}_z}(R_k + 1 - \delta) + \bar{\xi}\omega_2 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}. \tag{C.36}$$

(3) Capitalist's land Euler equation:

$$\left(1 - \beta_c - \bar{\xi}\omega_1 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}\bar{\lambda}_z\right)\tilde{Q}_l = \beta_c \tilde{R}_l. \tag{C.37}$$

(4) Borrowing constraint:

$$\tilde{B} = \bar{\xi}\left(\omega_1 \tilde{Q}_l \bar{\lambda}_z L_c + \omega_2 \tilde{K}\right). \tag{C.38}$$

(5) Investment growth rate:

$$\bar{\gamma}_I = \bar{\lambda}_z. \tag{C.39}$$

(6) Investment Euler equation (Tobin's marginal q):

$$Q_k = \frac{1}{\bar{\varphi}_I} = 1. \tag{C.40}$$

(7) Capacity utilization

$$\gamma_1 = R_k. \tag{C.41}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_c = \frac{1}{\tilde{C}_c}\frac{\bar{\lambda}_z - \beta_c\eta_c}{\bar{\lambda}_z - \eta_c}. \tag{C.42}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_h = \frac{1 - \beta_h}{\bar{\lambda}_z}\tilde{B} + \tilde{W}hN. \tag{C.43}$$

(10) Household's bond Euler equation:

$$R = \frac{\bar{\lambda}_z}{\beta_h}. \tag{C.44}$$

(11) Household's land Euler equation:

$$(1 - \beta_h)\tilde{Q}_l = MRS_l. \tag{C.45}$$

(12) Household's marginal utility of consumption

$$\tilde{\Lambda}_h = \left[1 - \frac{\beta_h\eta_h}{\bar{\lambda}_z}\right] L_h^{\bar{\varphi}_L(1-\gamma)}\tilde{C}_h^{-\gamma}\left(1 - \frac{\eta_h}{\bar{\lambda}_z}\right)^{-\gamma}. \tag{C.46}$$

(13) Household's marginal rate of substitution between housing and non-housing consumption

$$MRS_l = \frac{\bar{\varphi}_L \tilde{C}_h}{L_h} \frac{\bar{\lambda}_z - \eta_h}{\bar{\lambda}_z - \beta_h \eta_h}. \tag{C.47}$$

(14) Matching function

$$m = \bar{\varphi}_m u^a v^{1-a}. \tag{C.48}$$

(15) Job finding rate

$$q^u = \frac{m}{u}. \tag{C.49}$$

(16) Vacancy filling rate

$$q^v = \frac{m}{v}. \tag{C.50}$$

(17) Employment dynamics:

$$\bar{\rho} N = m. \tag{C.51}$$

(18) Number of searching workers:

$$u = 1 - (1 - \bar{\rho}) N. \tag{C.52}$$

(19) Aggregate production function:

$$\tilde{Y} = \left[(Z^m L_c)^{\phi} \left(\frac{\tilde{K}}{\bar{\lambda}_z} \right)^{1-\phi} \right]^{\alpha} (\bar{Z}^m N h)^{1-\alpha}. \tag{C.53}$$

(20) Capital rental rate:

$$R_k = \alpha (1 - \phi) \frac{\tilde{Y} \bar{\lambda}_z}{\tilde{K}}. \tag{C.54}$$

(21) Land rental rate:

$$\tilde{R}_l = \alpha \phi \frac{\tilde{Y}}{L_c}. \tag{C.55}$$

(22) Capital law of motion:

$$\frac{\tilde{I}}{\tilde{K}} = 1 - \frac{1 - \delta}{\bar{\lambda}_z}. \tag{C.56}$$

(23) Aggregate Resource constraint:

$$\tilde{C} + \tilde{I} + \tilde{G} + \kappa v = \tilde{Y}. \tag{C.57}$$

(24) Land market clear

$$L_c + L_h = 1. \tag{C.58}$$

(25) Optimal vacancy posting:

$$[1 - (1 - \bar{\rho}) \beta_c] \frac{\kappa}{q^v} = (1 - \alpha) \frac{\tilde{Y}}{N} - \tilde{W} h. \tag{C.59}$$

(26) Nash bargaining wage:

$$\tilde{W}^{NB}h = \frac{\chi g(h)}{\tilde{\Lambda}_h} + b + \bar{\vartheta}\frac{\kappa}{q^v}\left[1 - \beta_h(1-\bar{\rho})(1-q^u)\right]. \tag{C.60}$$

(27) Wage rigidity:

$$\tilde{W} = \tilde{W}^{NB}. \tag{C.61}$$

(28) Aggregate consumption

$$\tilde{C} = \tilde{C}_h + \tilde{C}_c. \tag{C.62}$$

(29) Unemployment rate:

$$U = 1 - N. \tag{C.63}$$

(30) The value of the firm:

$$\tilde{J}^F = \frac{\kappa}{q^v}. \tag{C.64}$$

(31) The value of employment:

$$[1 - \beta_h[1 - \bar{\rho}(1-q^u)]\tilde{J}^W = \tilde{W}h - \frac{\bar{\chi}g(h)}{\tilde{\Lambda}_h} + \beta_h\bar{\rho}(1-q^u)\tilde{J}^U. \tag{C.65}$$

(32) The value of unemployment:

$$[1 - \beta_h(1-q^u)]\tilde{J}^U = b + \beta_h q^u \tilde{J}^W. \tag{C.66}$$

(33) Market tightness:

$$\theta = \frac{v}{u}. \tag{C.67}$$

(34) MRS for hours:

$$\frac{\bar{\chi}g'(h)}{\Lambda_h} = (1-\alpha)\frac{Y}{Nh}. \tag{C.68}$$

C.3. **Log-linearized system.** We use $\hat{X}_t$ to denote percentage deviation from the deterministic steady state $\tilde{X}$ for any detrended variable $\tilde{X}_t$. The log-linearized system for the detrended system is given below.

(1) Capitalist's bond Euler equation:

$$\begin{aligned} d\tilde{\Lambda}_{ct} &= \frac{\beta_c R}{\bar{\lambda}_z}E_t d\Lambda_{ct+1} + \frac{\beta_c\tilde{\Lambda}_c}{\bar{\lambda}_z}dR_t - \frac{\beta_c R\tilde{\Lambda}_c}{\bar{\lambda}_z^2}E_t d\lambda_{z,t+1} \\ &\quad + Rd\tilde{\mu}_t + \tilde{\mu}dR_t, \end{aligned}$$

$$\hat{\Lambda}_{ct} = \frac{\beta_c R}{\bar{\lambda}_z}\left(E_t\hat{\Lambda}_{ct+1} + \hat{R}_t - E_t\hat{\lambda}_{z,t+1}\right) + \frac{R\tilde{\mu}}{\tilde{\Lambda}_c}\left(\hat{\mu}_t + \hat{R}_t\right).$$

(2) Capitalist's capital Euler equation:

$$
\begin{aligned}
& \tilde{\Lambda}_c dQ_{kt} + Q_k d\tilde{\Lambda}_{ct} \\
= \; & \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z} E_t \left[dR_{kt+1} + R_k de_{t+1} - \gamma_1 de_{t+1} + (1-\delta) \, dQ_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} E_t d\tilde{\Lambda}_{ct+1} \left[R_k + (1-\delta) \, Q_k \right] \\
& - \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z^2} E_t d\lambda_{z,t+1} \left[R_k + (1-\delta) \, Q_k \right] \\
& + \omega_2 \xi Q_k d\tilde{\mu}_t + \omega_2 d\xi_t Q_k \tilde{\mu} + \omega_2 \xi \tilde{\mu} E_t dQ_{k,t+1},
\end{aligned}
$$

$$
\begin{aligned}
& Q_k \hat{Q}_{kt} + Q_k \hat{\Lambda}_{ct} \\
= \; & \frac{\beta_c}{\bar{\lambda}_z} E_t \left[R_k \left(\hat{R}_{kt+1} + \hat{e}_{t+1} \right) - \gamma_1 \hat{e}_{t+1} + (1-\delta) \, Q_k \hat{Q}_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} \left[R_k + (1-\delta) \, Q_k \right] E_t \left(\hat{\Lambda}_{ct+1} - \hat{\lambda}_{z,t+1} \right) \\
& + \omega_2 \bar{\xi} Q_k \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{k,t+1} \right).
\end{aligned}
$$

(3) Capital's housing Euler equation:

$$
\begin{aligned}
& \tilde{Q}_l d\tilde{\Lambda}_{ct} + \tilde{\Lambda}_c d\tilde{Q}_{lt} \\
= \; & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) E_t d\tilde{\Lambda}_{ct+1} + \beta_c \tilde{\Lambda}_c E_t \left(d\tilde{Q}_{l,t+1} + d\tilde{R}_{l,t+1} \right) \\
& + \omega_1 \left(\bar{\lambda}_z \bar{\xi} \tilde{Q}_l d\tilde{\mu}_t + \bar{\lambda}_z \tilde{\mu} \tilde{Q}_l d\xi_t + \bar{\lambda}_z \bar{\xi} \tilde{\mu} E_t d\tilde{Q}_{l,t+1} + \bar{\xi} \tilde{Q}_l \tilde{\mu} E_t d\lambda_{z,t+1} \right)
\end{aligned}
$$

$$
\begin{aligned}
& \tilde{Q}_l \tilde{\Lambda}_c \left(\hat{\Lambda}_{ct} + \hat{Q}_{lt} \right) \\
= \; & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) \tilde{\Lambda}_c E_t \hat{\Lambda}_{c,t+1} + \beta_c \tilde{\Lambda}_c E_t \left(\tilde{Q}_l \hat{Q}_{l,t+1} + \tilde{R}_l \hat{R}_{l,t+1} \right) \\
& + \omega_1 \bar{\lambda}_z \bar{\xi} \tilde{Q}_l \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right).
\end{aligned}
$$

(4) Capitalist's binding borrowing constraint:

$$
\begin{aligned}
d\tilde{B}_t \; = \; & \left(\omega_1 \tilde{Q}_l \lambda_z L_c + \omega_2 Q_k \tilde{K} \right) d\xi_t \\
& + \xi \omega_1 E_t \left(\lambda_z L_c d\tilde{Q}_{l,t+1} + \tilde{Q}_l \lambda_z dL_{ct} + \tilde{Q}_l d\lambda_{z,t+1} L_c \right) \\
& + \xi \omega_2 \left(\tilde{K} E_t dQ_{k,t+1} + Q_k d\tilde{K}_t \right)
\end{aligned}
$$

$$\hat{B}_t = \hat{\xi}_t + \frac{\omega_1 \bar{\xi} \tilde{Q}_l \lambda_z L_c}{\tilde{B}} \left(\hat{L}_{ct} + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right) + \frac{\omega_2 \bar{\xi} Q_k \tilde{K}}{\tilde{B}} \left(\hat{K}_t + E_t \hat{Q}_{k,t+1} \right).$$

(5) Investment growth rate:

$$\hat{\gamma}_{It} + \hat{I}_{t-1} = \hat{I}_t + \hat{\lambda}_{zt}.$$

(6) Capitalist's investment Euler equation:

$$0 = dQ_{kt} + d\varphi_{It} - \Omega \bar{\gamma}_I d\gamma_{It} + E_t \frac{\beta_c}{\bar{\lambda}_z} \Omega \bar{\gamma}_I^2 d\gamma_{It+1},$$

$$\hat{Q}_{kt} + \hat{\varphi}_{It} = \Omega \bar{\gamma}_I^2 \left(\hat{\gamma}_{It} - \frac{\beta_c}{\bar{\lambda}_z} \bar{\gamma}_I \hat{\gamma}_{I,t+1} \right).$$

(7) Capitalist's capacity utilization decision:

$$R_k \hat{R}_{kt} = \gamma_2 \hat{e}_t.$$

(8) Capitalist's marginal utility:

$$d\tilde{\Lambda}_{ct} = \frac{-d\tilde{C}_{ct} + \eta_c d\tilde{C}_{ct-1}/\bar{\lambda}_z - \eta_c \tilde{C}_c d\lambda_{z,t}/\bar{\lambda}_z^2}{\left(\tilde{C}_c \left(1 - \eta_c/\bar{\lambda}_z \right) \right)^2} - \beta_c \eta_c E_t \frac{-\bar{\lambda}_z d\tilde{C}_{ct+1} - \tilde{C}_c d\lambda_{z,t+1} + \eta_c d\tilde{C}_{ct}}{\left(\tilde{C}_c \left(\bar{\lambda}_z - \eta_c \right) \right)^2},$$

$$\tilde{\Lambda}_c \hat{\Lambda}_{ct} = \frac{-\hat{C}_{ct} + \eta_c/\bar{\lambda}_z \left(\hat{C}_{c,t-1} - \hat{\lambda}_{zt} \right)}{\tilde{C}_c \left(1 - \eta_c/\bar{\lambda}_z \right)^2} - \beta_c \eta_c E_t \frac{-\bar{\lambda}_z \left(\hat{C}_{c,t+1} + \hat{\lambda}_{z,t+1} \right) + \eta_c \hat{C}_{ct}}{\tilde{C}_c \left(\bar{\lambda}_z - \eta_c \right)^2}.$$

(9) Household's flow of funds constraint:

$$d\tilde{C}_{ht} + \frac{d\tilde{B}_t}{R} - \frac{\tilde{B} dR_t}{R^2} + \tilde{Q}_l \left(dL_{ht} - dL_{h,t-1} \right) = \frac{d\tilde{B}_{t-1}}{\bar{\lambda}_z} - \frac{\tilde{B}}{\bar{\lambda}_z^2} d\lambda_{zt} + Nhd\tilde{W}_t + h\tilde{W} dN_t + N\tilde{W} dh_t.$$

$$\begin{aligned} & C_h\hat{C}_{ht} + \frac{\tilde{B}}{R}\left(\hat{B}_t - \hat{R}_t\right) + \tilde{Q}_l L_h \left(\hat{L}_{ht} - \hat{L}_{ht-1}\right) \\ = \; & \frac{\tilde{B}}{\bar{\lambda}_z}\left(\hat{B}_{t-1} - \hat{\lambda}_{zt}\right) + \tilde{W}Nh\left(\hat{W}_t + \hat{N}_t + \hat{h}_t\right). \end{aligned}$$

(10) Household's bond Euler equation:

$$\hat{\Lambda}_{ht} = E_t\left(\hat{\Lambda}_{ht+1} - \hat{\lambda}_{z,t+1}\right) + \hat{R}_t.$$

(11) Household's housing Euler equation:

$$\begin{aligned} & \tilde{Q}_l d\tilde{\Lambda}_{ht} + \tilde{\Lambda}_h d\tilde{Q}_{lt} \\ = \; & MRS_l d\tilde{\Lambda}_{ht} + \tilde{\Lambda}_h dMRS_{lt} + \beta_h\tilde{Q}_l E_t d\tilde{\Lambda}_{ht+1} + \beta_h\tilde{\Lambda}_h E_t d\tilde{Q}_{l,t+1}, \end{aligned}$$

$$\begin{aligned} & \tilde{Q}_l\tilde{\Lambda}_h\left(\hat{\Lambda}_{ht} + \hat{Q}_{lt}\right) \\ = \; & MRS_l\tilde{\Lambda}_h\left(\hat{\Lambda}_{ht} + \widehat{MRS}_{ht}\right) + \beta_h\tilde{\Lambda}_h\tilde{Q}_l E_t\left(\hat{\Lambda}_{ht+1} + \hat{Q}_{l,t+1}\right), \end{aligned}$$

where

$$\widehat{MRS}_{ht} = \widehat{MUL}_t - \hat{\Lambda}_{ht}.$$

(12) Household's marginal utility of consumption:

$$\begin{aligned} d\tilde{\Lambda}_{ht} = \; & -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z}d\tilde{C}_{ht-1} + \frac{\eta_h\tilde{C}_h}{\lambda_z^2}d\lambda_{zt}\right) \quad \text{(C.69)} \\ & + \left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}\left(\ln L_h d\varphi_{Lt} + \varphi_L\frac{dL_{ht}}{L_h}\right) \\ & + \beta_h\eta_h\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} E_t\left(d\tilde{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z}d\tilde{C}_{ht} + \frac{\eta_h\tilde{C}_h}{\lambda_z^2}d\lambda_{zt+1}\right)\frac{1}{\bar{\lambda}_z} \\ & - \beta_h\eta_h\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}E_t\left(\ln L_h d\varphi_{Lt+1} + \varphi_L\frac{dL_{ht+1}}{L_h}\right)\frac{1}{\bar{\lambda}_z} \\ & + \beta_h\eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\lambda_z}\right)^{-\gamma}\frac{d\lambda_{z,t+1}}{\lambda_z^2}\right], \end{aligned}$$

$$\begin{aligned} \tilde{\Lambda}_{ht}\hat{\Lambda}_{ht} = \; & -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(\tilde{C}_h\hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht-1} + \frac{\eta_h\tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt}\right) \quad \text{(C.70)} \\ & + \left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}\left(\bar{\varphi}_L\hat{\varphi}_{Lt}\ln L_h + \bar{\varphi}_L\hat{L}_{ht}\right) \quad \text{(C.71)} \end{aligned}$$

$$+\beta_h\eta_h\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}E_t\left(\tilde{C}_h\hat{C}_{ht+1}-\frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht}+\frac{\eta_h\tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt+1}\right)\frac{1}{\bar{\lambda}_z} \tag{C.72}$$

$$-\beta_h\eta_h\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}E_t\left(\bar{\varphi}_L\hat{\varphi}_{Lt+1}\ln L_h+\bar{\varphi}_L\hat{L}_{ht+1}\right)\frac{1}{\bar{\lambda}_z} \tag{C.73}$$

$$+\beta_h\eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\frac{\hat{\lambda}_{z,t+1}}{\bar{\lambda}_z}\right]. \tag{C.74}$$

(13) Household's marginal utility of housing

$$\begin{aligned}
d\widetilde{MUL}_t &= \bar{\varphi}_L\,(1-\gamma)\,L_h^{\varphi_L(1-\gamma)-1}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\left(d\tilde{C}_{ht}-\frac{\eta_h}{\bar{\lambda}_z}d\tilde{C}_{ht-1}+\frac{\eta_h\tilde{C}_h}{\lambda_z^2}d\lambda_{zt}\right)\\
&\quad+\bar{\varphi}_L\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma}L_h^{\varphi_L(1-\gamma)-1}\left((1-\gamma)\,d\varphi_{Lt}\ln L_h+\left(\bar{\varphi}_L\,(1-\gamma)-1\right)\frac{dL_{ht}}{L_h}\right)\\
&\quad+L_h^{\varphi_L(1-\gamma)-1}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma}d\varphi_{L,t}.
\end{aligned}$$

$$\begin{aligned}
\widetilde{MUL}\;\widehat{MUL}_t &= \bar{\varphi}_L\,(1-\gamma)\,L_h^{\varphi_L(1-\gamma)-1}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\left(\tilde{C}_h\hat{C}_{ht}-\frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_{ht-1}\hat{C}_{ht-1}+\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}d\hat{\lambda}_{zt}\right)\\
&\quad+\bar{\varphi}_L\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma}L_h^{\varphi_L(1-\gamma)-1}\left((1-\gamma)\,\bar{\varphi}_L\ln L_h\hat{\varphi}_{Lt}+\left(\bar{\varphi}_L\,(1-\gamma)-1\right)\hat{L}_{ht}\right)\\
&\quad+\bar{\varphi}_L\,L_h^{\varphi_L(1-\gamma)-1}\left(\tilde{C}_h-\frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma}\hat{\varphi}_{L,t}.
\end{aligned}$$

(14) Matching function:

$$\hat{m}_t=\hat{\varphi}_{mt}+a\hat{u}_t+(1-a)\,\hat{v}_t.$$

(15) Job finding rate:

$$\hat{q}_t^u=\hat{m}_t-\hat{u}_t.$$

(16) Job filling rate:

$$\hat{q}_t^v=\hat{m}_t-\hat{v}_t.$$

(17) Employment dynamics:

$$dN_t=(1-\bar{\rho})\,dN_{t-1}+dm_t,$$

$$\hat{N}_t=(1-\bar{\rho})\,\hat{N}_{t-1}+\bar{\rho}\hat{m}_t.$$

(18) Number of searching workers:

$$du_t = -\left(1-\bar{\rho}\right)dN_{t-1},$$

$$u\hat{u}_t = -\left(1-\bar{\rho}\right)N\hat{N}_{t-1}.$$

(19) Aggregate production function:

$$\hat{Y}_t = \alpha\left[\left(1-\phi\right)\left(\hat{K}_{t-1}+\hat{e}_t-\hat{\lambda}_{zt}\right)+\phi\left(\hat{Z}_t^m+\hat{L}_{c,t-1}\right)\right]+\left(1-\alpha\right)\left(\hat{N}_t+\hat{h}_t+\hat{Z}_t^m\right).$$

(20) Capital rental rate:

$$\hat{R}_{kt} = \hat{Y}_t+\hat{\lambda}_{zt}-\hat{K}_{t-1}-\hat{e}_t.$$

(21) Land rental rate:

$$\hat{R}_{lt} = \hat{Y}_t-\hat{L}_{c,t-1}.$$

(22) Capital law of motion:

$$d\tilde{K}_t = \left(1-\delta\right)d\tilde{K}_{t-1}/\bar{\lambda}_z-\left(1-\delta\right)\tilde{K}/\bar{\lambda}_z^2 d\lambda_{zt}+dI_t+\tilde{I}d\varphi_{It},$$

$$\hat{K}_t = \frac{1-\delta}{\bar{\lambda}_z}\left(\hat{K}_{t-1}-\hat{\lambda}_{zt}\right)+\frac{\tilde{I}}{\tilde{K}}\left(\hat{I}_t+\hat{\varphi}_{It}\right).$$

(23) Aggregate resource constraint:

$$d\tilde{Y}_t = d\tilde{I}_t+d\tilde{C}_{ct}+d\tilde{C}_{ht}+\frac{\tilde{K}\gamma_1}{\bar{\lambda}_z}de_t+\kappa dv_t+d\tilde{G}_t,$$

$$\hat{Y}_t = \frac{\tilde{I}}{\tilde{Y}}\hat{I}_t+\frac{\tilde{C}_c}{\tilde{Y}}\hat{C}_{ct}+\frac{\tilde{C}_h}{\tilde{Y}}\hat{C}_{ht}+\frac{\tilde{K}\gamma_1}{\bar{\lambda}_z\tilde{Y}}\hat{e}_t+\frac{\kappa v}{\tilde{Y}}\hat{v}_t+\frac{\tilde{G}}{\tilde{Y}}\hat{G}_t.$$

(24) Housing market clearing condition:

$$L_c\hat{L}_{ct}+L_h\hat{L}_{ht}=0.$$

(25) Optimal vacancy posting condition:

$$-\frac{\kappa}{\left(q^v\right)^2}dq_t^v = \left(1-\alpha\right)\frac{d\tilde{Y}_t}{N}-\left(1-\alpha\right)\frac{\tilde{Y}}{N^2}dN_t-hd\tilde{W}_t-\tilde{W}dh_t$$

$$+E_t\frac{\beta_c d\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}}\left(1-\rho\right)\frac{\kappa}{q^v}-E_t\frac{\beta_c d\tilde{\Lambda}_{c,t}}{\tilde{\Lambda}}\left(1-\rho\right)\frac{\kappa}{q^v}-E_t\beta_c\left(1-\rho\right)\frac{\kappa}{\left(q^v\right)^2}dq_{t+1}^v$$

$$-\frac{\kappa}{q^v}\hat{q}_t^v = \left(1-\alpha\right)\frac{\tilde{Y}}{N}\left(\hat{Y}_t-\hat{N}_t\right)-\tilde{W}h\left(\hat{W}_t+\hat{h}_t\right)$$

$$+\beta_c\left(1-\bar{\rho}\right)\frac{\kappa}{q^v}E_t\left(\hat{\Lambda}_{c,t+1}-\hat{\Lambda}_{c,t}\right)-\beta_c\frac{\kappa}{q^v}E_t\left(1-\bar{\rho}\right)\hat{q}_{t+1}^v.$$

(26) Nash bargained wage:

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB}+\hat{h}_t\right)=\frac{\chi h^{\nu}dh_t}{\tilde{\Lambda}_h}-\frac{h^{1+\nu}\chi d\tilde{\Lambda}_{ht}}{(1+\nu)\left(\tilde{\Lambda}_h\right)^2}+d\vartheta_t\frac{\kappa}{q^v}-\bar{\vartheta}\frac{\kappa dq_t^v}{(q^v)^2}$$

$$-\beta_h(1-\rho)(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1}-\hat{\Lambda}_{h,t}\right]+\beta_h(1-\rho)\bar{\vartheta}\frac{\kappa}{q^v}E_t dq_{t+1}^u$$
$$+\beta_h(1-\rho)(1-q^u)\bar{\vartheta}E_t\frac{\kappa dq_{t+1}^v}{(q^v)^2}-\beta_h(1-\rho)(1-q^u)d\vartheta_{t+1}\frac{\kappa}{q^v}$$

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB}+\hat{h}_t\right)=\frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h(1+\nu)}\left((1+\nu)\hat{h}_t-\hat{\Lambda}_{ht}\right)+\frac{\bar{\vartheta}\kappa}{q^v}\left(\hat{\vartheta}_t-\hat{q}_t^v\right)$$

$$-\beta_h(1-\bar{\rho})(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1}-\hat{\Lambda}_{h,t}\right]+\beta_h\bar{\vartheta}\frac{\kappa}{q^v}(1-\rho)q^uE_t\hat{q}_{t+1}^u$$
$$-\beta_h(1-\rho)(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left(\hat{\vartheta}_{t+1}-\hat{q}_{t+1}^v\right)$$

(27) Wage rigidity:

$$\hat{W}_t=\psi\hat{W}_{t-1}+(1-\psi)\hat{W}_t^{NB}.$$

(28) Aggregate consumption:

$$\tilde{C}\hat{C}_t=\tilde{C}_c\hat{C}_{ct}+\tilde{C}_h\hat{C}_{ht}.$$

(29) Unemployment rate

$$U\hat{U}_t=-N\hat{N}_t.$$

(30) The value of the firm.

$$\hat{J}_t^F=-\hat{q}_t^v.$$

(31) The value of employment:

$$\tilde{J}_t^W=\tilde{W}_th_t-\frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}}+E_t\frac{\beta_h\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\left[\left(1-\rho\left(1-q_{t+1}^u\right)\right)\left(\tilde{J}_{t+1}^W-\tilde{J}_{t+1}^U\right)+\tilde{J}_{t+1}^U\right]. \tag{C.75}$$

$$\tilde{J}^W\hat{J}_t^W=\tilde{W}h\left(\hat{W}_t+\hat{h}_t\right)-\frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h(1+\nu)}\left((1+\nu)\hat{h}_t-\hat{\Lambda}_{ht}\right)$$
$$+\beta_h\left[(1-\bar{\rho}(1-q^u))\tilde{J}^W+\bar{\rho}(1-q^u)\tilde{J}^U\right]E_t\left(\hat{\Lambda}_{ht+1}-\hat{\Lambda}_{ht}\right)$$
$$+\beta_hE_t\left[(1-\bar{\rho}(1-q^u))\tilde{J}^W\hat{J}_{t+1}^W+\bar{\rho}(1-q^u)\tilde{J}^U\hat{J}_{t+1}^U\right]+\beta_h\bar{\rho}q^u\left(\tilde{J}^W-\tilde{J}^U\right)E_t\hat{q}_{t+1}^u.$$

(32) The value of unemployment:

$$\tilde{J}_t^U = b + E_t \frac{\beta_h \tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}} \left[q_{t+1}^u \tilde{J}_{t+1}^W + (1 - q_{t+1}^u) \tilde{J}_{t+1}^U \right]. \tag{C.76}$$

$$\tilde{J}^U \hat{J}_t^U = \beta_h \left[q^u \left(\tilde{J}^W - \tilde{J}^U \right) + \tilde{J}^U \right] E_t \left(\hat{\Lambda}_{ht+1} - \hat{\Lambda}_{ht} \right)$$
$$+ \beta_h q^u \left(\tilde{J}^W - \tilde{J}^U \right) E_t \hat{q}_{t+1}^u + \beta_h E_t \left[q^u \tilde{J}^W \hat{J}_{t+1}^W + (1 - q^u) \tilde{J}^U \hat{J}_{t+1}^U \right]$$

(33) Market tightness:

$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t.$$

(34) Hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}} = (1 - \alpha) \frac{Y_t}{N_t h_t}. \tag{C.77}$$

$$\nu \hat{h}_t - \hat{\Lambda}_{ht} = \hat{Y}_t - \hat{N}_t - \hat{h}_t$$

D. Data, shocks, and measurement

D.1. **Data description.** All data are constructed by Patrick Higgins at the Federal Reserve Bank of Atlanta. Some of the data are taken directly from the Haver Analytics Database (Haver for short), from Bureau of Economic Analysis (BEA), or from Bureau of Labor Statistics (BLS). This section describes, in detail, how each time series is constructed.

The model estimation is based on six U.S. aggregate time series: the real price of land (Q_{lt}^{Data}), real per capita consumption (C_t^{Data}), real per capita investment (I_t^{Data}), vacancies (v_t^{Data}), the unemployment rate (U_t^{Data}), and per capita total hours (H_t^{Data}). All these series are constructed to be consistent with the corresponding series in Greenwood, Hercowitz, and Krusell (1997), Cummins and Violante (2002), and Davis and Heathcote (2007).

The time series of real wages are used by the BVAR for data description, but not used by the model for the purpose of testing how the model fares in predicting movements of real wages *out of sample*. Since the earliest date for the land-price data to be available is the first quarter of 1975, the sample period used for this paper range from the first quarter of 1975 to the third quarter of 2015.

These series are defined as follows:

- $Q_{lt}^{\text{Data}} = \frac{\text{LiqLandPricesSAFHFACoreLogicSplice87}}{\text{DGDP\_USNA}}$;
- $C_t^{\text{Data}} = \frac{\text{NomConsNHSplusND/DGDP\_USNA}}{\text{POPSMOOTH\_USECON}}$;
- $I_t^{\text{Data}} = \frac{\text{(CDX\_USNA + FNEX\_USNA + FNPX\_USNA)/DGDP\_USNA}}{\text{POPSMOOTH\_USECON}}$;
- $v_t^{\text{Data}} = \frac{\text{JOLTSHiggins}}{\text{JOLTSHiggins+LANAGRA\_USECON}}$;
- $U_t^{\text{Data}} = \text{UnempRate}$;
- $H_t^{\text{Data}} = \frac{\text{TotalHours}}{\text{POPSMOOTH\_USECON}}$;

- $w_t^{\text{Data}} = \frac{\text{LXNFC\_USECON}}{\text{DGDP\_USNA}}$.

The original data, the constructed data, and their sources are described below.

LiqLandPricesSAFHFACoreLogicSplice87: Liquidity-adjusted price index for residential land. The series is constructed as follows. We seasonally adjust the FHFA home price index (USHPI@USECON) for 1975Q1-1991Q1, spliced together with Haver's seasonally adjusted CoreLogic home price index (USLPHPIS@USECON) for the third month of the first quarter of 1987 to present. We then use this home price index to construct the land price series with the Davis and Heathcote (2007) method.[2] The adjustment methods of Quart and Quigley (1989, 1991) are used to take account of time-on-market uncertainty. The CoreLogic home price index series provided by Core Logic Databases is similar to the Case-Shiller home price index but covers far more counties than the Case-Shiller series.

The CoreLogic land price, as well as the Cash-Shiller land price, shows much larger fluctuations than the FHFA land price. The large difference comes mainly from home price indices. The FHFA home price series includes only conforming/conventional mortgages insured by Fannie Mae and Freddie Mac and excludes subprime or expensive homes with mortgages above the conforming loan limit ($417,000 in 2008 for example). The FHFA series is an equally weighted home price index so that expensive homes receive the same weight as inexpensive homes. The CoreLogic and Case-Shiller series are both value-weighted so that a home's weight in the index is (roughly) proportional to its price. Before 1987, the geographic coverage of the CoreLogic series is sparse relative to the the FHFA series and thus the FHFA series is probably more representative of the home price. But in the 1990s and 2000s, subprime or un-conforming mortgages were so popular that an exclusion of the prices of such homes would bias against the actual volatility of home/land prices. The volatility of our CoreLogic land price series is similar to the land price series constructed in other studies (Sirmans and Slade, 2012; Nichols, Oliner, and Mulhall, 2013). Our results obtain when we use the FHFA land price, which is constructed in the same way except that the CoreLogic home price index after 1987 is now replaced by the FHFA home price index.

Source for USHPI@USECON and USLPHPIS@USECON: BEA and Haver.

[2]For details of this methods, see `http://www.marginalq.com/morris/landdata_files/2006-11-Davis-Heathcote-Land.appendix.pdf`.

DGDP_USNA: Implicit gross domestic product deflator (2009=100). The results in the paper obtain when we use other overall price indices, such as consumer price index and personal consumption expenditure index.

NomConsNHSplusND: Nominal personal consumption expenditures: non-housing services and nondurable goods consumption (seasonally adjusted, millon of dollars). Source: BEA and Haver.

POPSMOOTH_USECON: Smoothed civilian noninstitutional population with ages 16 years and over (thousands). This series is smoothed by eliminating breaks in population from 10-year censuses and post 2000 American Community Surveys using the "error of closure" method. This fairly simple method is used by the Census Bureau to get a smooth monthly population series to reduce the unusual influence of drastic demographic changes.[3] Source: BLS and Haver.

CDX_USNA: Nominal durable goods (seasonally adjusted, million of dollars). Source: BEA and Haver.

FNEX_USNA: Nominal equipment investment (seasonally adjusted, million of dollars). Source: BEA and Haver.

FNPX_USNA: Nominal investment in intellectual property products, including software (seasonally adjusted, million of dollars). Source: BEA and Haver.

JOLTSHiggins: Job opennings. From January 1975 to December 2000, we use the composite Help-Wanted-Index built by Barnichon (2010),[4] expressed in number of vacancies and rescaled to match its value in December 2000 to LJJTLA@USECON (LJJTLA@USECON is a series of total seasonally adjusted job openings expressed in thousands from the BLS-JOLTS survey that started in December 2000). From January 2001 to present, our series is the same as LJJTLA@USECON. We then take the quarterly average of the monthly series. Source for LJJTLA@USECON: BLS and Haver.

LANAGRA_USECON: Total nonfarm payroll employees (seasonally adjusted, thousands). Source: BLS and Haver.

UnempRate: Unemployment rate. Source: BLS and Haver.

TotalHours: Total hours in the nonfarm business sector. Source: BLS and Haver.

LXNFC_USECON: Nominal compensation per hour for the nonfarm business sector (seasonally adjusted, 2009=100). Source: BLS and Haver.

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[3]The detailed explanation can be found in `http://www.census.gov/popest/archives/methodology/intercensal\_nat\_meth.html`.

[4]The series can be downloaded from Regis Barnichon's website at `http://sites.google.com/site/regisbarnichon/cv/HWI_index.txt?attredirects=0`.

D.2. **Shocks.** We include six shocks in the benchmark model: a housing demand shock (φ_{Lt}), a credit shock (ξ_t), two technology shocks (the permanent shock λ_{zt} and the stationary shock Z_t^m), and two labor market shocks (the matching efficiency shock φ_{mt} and the bargaining shock ϑ_t). Housing demand shocks are shown to be an important driving force of house-price (land-price) fluctuations in DSGE models without labor search frictions (Iacoviello and Neri, 2010; Liu, Wang, and Zha, 2013). Credit shocks are important for macroeconomic fluctuations in a DSGE model with financial frictions (Jermann and Quadrini, 2012). Technology shocks are typically considered as important sources of business cycles in an RBC model.

The matching function describes a reduced-form aggregate relation between the number of hires on one hand and the number of searching workers and job vacancies on the other. There is no presumption that this reduced-form relation holds exactly in the data. In fact, frequent deviations to this relation have been observed. For examples, in our sample, there have been important shifts in the Beveridge curve relation (a relation between the unemployment rate and the job vacancy rate derived from the matching function). Shifts in the Beveridge curve can be captured by variations in the matching efficiency (i.e., the residuals in the matching function).

Recent studies find that incorporating matching efficiency shocks is important for fitting a DSGE model to the labor market data (Lubik, 2009; Justiniano and Michelacci, 2011; Sala, Söderström, and Trigari, 2012). Other studies find that introducing shocks to the relative bargaining power in a DSGE model with search frictions helps fit the data for labor market variables (Gertler, Sala, and Trigari, 2008; Christoffel, Kuester, and Linzert, 2009; Christiano, Trabandt, and Walentin, 2011). We are aware of the legitimate criticism that such shocks do not offer a deeper understanding of the labor market, and thus we allow these two shocks to be correlated. The results for the impulse responses of a housing demand shock, however, do not depend on these correlations. We use these shocks to be consistent with the existing literature as well as for the purpose of fitting the model to the data without insisting on interpretation of these shocks' effect on the labor market. Moreover, controlling for the effects of these and other shocks is necessary for identifying and estimating the effect of a housing demand shock on the dynamic link between the land price and the unemployment rate.

D.3. **Measurement.** In this section we derive the six measurement equations used for estimation. For the three nonstationary variables Q_{lt}, C_t, and I_t, we have

$$\tilde{Q}_{lt} = \frac{Q_{lt}}{Z_t^p},$$

$$\log(Q_{lt}) = \log(\tilde{Q}_{lt}) + \log(Z_t^p),$$
$$\Delta \log(Q_{lt}) = \Delta \log(\tilde{Q}_{lt}) + \Delta \log(Z_t^p),$$
$$\Delta \log(Q_{lt}) = \Delta \hat{Q}_{lt} + \log \lambda_z + \hat{\lambda}_{z,t},$$
$$\Delta \log(C_t^{\text{Data}}) = \Delta \log(Q_{lt}) = \log \lambda_z + \hat{\lambda}_{z,t} + \Delta \hat{Q}_{lt},$$

$$\tilde{C}_t = \frac{C_t}{Z_t^p},$$
$$\log(C_t) = \log(\tilde{C}_t) + \log(Z_t^p),$$
$$\Delta \log(C_t) = \Delta \log(\tilde{C}_t) + \Delta \log(Z_t^p),$$
$$\Delta \log(C_t) = \Delta \hat{C}_t + \log \lambda_z + \hat{\lambda}_{z,t},$$
$$\Delta \log(C_t^{\text{Data}}) = \Delta \log(C_t) = \log \lambda_z + \hat{\lambda}_{z,t} + \Delta \hat{C}_t,$$

and

$$\tilde{I}_t = \frac{I_t}{Z_t^p},$$
$$\log(I_t) = \log(\tilde{I}_t) + \log(Z_t^p),$$
$$\Delta \log(I_t) = \Delta \log(\tilde{I}_t) + \Delta \log(Z_t^p),$$
$$\Delta \log(I_t) = \Delta \hat{I}_t + \log \lambda_z + \hat{\lambda}_{z,t},$$
$$\Delta \log(C_t^{\text{Data}}) = \Delta \log(I_t) = \log \lambda_z + \hat{\lambda}_{z,t} + \Delta \hat{I}_t,$$

where the superscript "hat" means the log difference from the mean and "Data" indicates that the corresponding time series is observed (i.e., data). The other three observed time series are stationary variables and the corresponding measurement equations are straightforward as

$$\hat{U}_t^{\text{Data}} = \hat{U}_t,$$
$$\hat{H}_t^{\text{Data}} = \hat{H}_t,$$
$$\hat{v}_t^{Data} = \hat{v}_t,$$

where $H_t = h_t N_t$ in the model.

E. Prior distributions for structural parameters

We categorize the structural parameters in three groups. The first group of parameters are calibrated because they are difficult to identify by the model. These parameters are a, the elasticity parameter in the matching function; b, the flow benefit of unemployment; ϑ, the Nash bargaining weight; α, the income share of capital input; γ, the relative risk aversion;

ξ, the average loan-to-value ratio; ρ, the job separation rate; ω_1, the fraction of land value that can be used as collateral; and Z^m, the mean of the stationary technology shock.

We set the match elasticity parameter to $a = 0.5$ as suggested by Hall and Milgrom (2008) and Gertler and Trigari (2009), which is in the range estimated by Petrongolo and Pissarides (2001). Following Christiano, Eichenbaum, and Trabandt (2013), we set the replacement ratio to $\frac{b}{W} = 0.75$, where W is the steady-state real wage.[5] We set the value of ϑ such that the worker's bargaining weight is $\frac{\vartheta}{1+\vartheta} = 0.3$ as estimated by Christiano, Trabandt, and Walentin (2011). We set $\alpha = 0.33$, consistent with the average labor income share of about two-thirds. We set the risk aversion parameter to $\gamma = 2$, in line with in the macroeconomics and finance literature (Kocherlakota, 1996; Lucas Jr., 2003). Following Liu, Wang, and Zha (2013), we set the mean value of the loan-to-value ratio to $\xi = 0.75$. We set the job separation rate to $\rho = 0.12$ as suggested by Blanchard and Galí (2010), which is broadly consistent with the average monthly job separation rate of 0.034 reported in the Job Openings and Labor Turnover Survey (JOLTS). We normalize the values of ω_1 and Z^m to unity.

The second group of structural parameters are estimated. They are η_h and η_c, the habit persistence parameters for households and capitalists; ν, the curvature parameter of the disutility function of labor hours; γ_2, the curvature parameter of the capacity utilization cost function; Ω, the investment adjustment cost parameter; λ_z, the mean growth rate of technology; ω_2, the fraction of capital value in the collateral constraint; λ_z, the mean growth rate; and all the parameters for shock processes. The complete prior specifications are reported in Tables 1 and 2.[6]

We first discuss Table 1. The prior for the technology growth rate λ_z is such that the 90-percent probability interval for the annualized growth rate lies between 0.4% and 6%. Thus, this prior is very diffuse.

We assume that the priors for η_h and η_c follow the beta distribution with the hyperparameters taking the values of 1 and 2. This particular specification allows the possibility of no persistence at all for the habit parameters. Clearly, the 90% probability interval covers most of the calibrated values of habit persistence parameters in the literature (Boldrin, Christiano, and Fisher, 2001).

The priors for the remaining parameters to be estimated follow gamma distributions, all of which allow the possibility of zero value. The 90% probability interval for Ω and γ_2 ranges from 0.17 to 10, covering most of the values considered in the DSGE literature (Christiano,

[5]Our estimated results are insensitive to the value of the replacement ratio. For example, the results hold if we lower the ratio to $\frac{b}{W} = 0.4$ as suggested by Ravenna and Walsh (2008) and Hall (2005).

[6]For comparison, Tables 3 and 4 reproduce some of the prior information for comparison with the estimated posterior distributions.

Eichenbaum, and Evans, 2005; Smets and Wouters, 2007; Liu, Waggoner, and Zha, 2011). The hyperparameter values for the prior distributions of ν and ω_2 are selected so that the 90% probability intervals for these parameters cover a wide range of values.

We now discuss Table 2. The selected hyperparameters for the prior distributions of all the persistence parameters allow the possibility of zero persistence and at the same time give a wide range of values as shown by the 90% probability intervals. The priors for the standard deviations follow the inverse gamma distribution with the 90% probability interval given by $[0.0001, 2]$. The priors for all these shock process parameters are very agnostic and in fact much looser than those used in the DSGE literature.

The third group of structural parameters are determined by the deterministic steady state, conditional on calibrated and estimated values of the first two groups of parameters. These parameters include δ, the capital depreciation rate; β_h and β_c, the subjective discount factors for households and capitalists; ϕ, the land income share; γ_1, the slope parameter in the capacity utilization function; φ_L, the steady state level of the housing demand shock; χ, the scale parameter for the disutility of working; and κ, the vacancy cost parameter.

The values of these parameters are obtained so that the model's steady-state equilibrium matches the following first-moment conditions in the data: (1) the investment-output ratio is 0.275; (2) the average loan interest rate is 4% per year; (3) the ratio of the capitalist's land value to workers' land value is 1.0; (4) the average ratio of capital stock to annual output is 1.25;[7] (5) the average ratio of job vacancy costs to output is 0.005 (Christiano, Eichenbaum, and Trabandt, 2013); (6) the steady-state unemployment rate is 0.055; (7) the average quarterly job filling rate is about 0.7 (den Haan, Ramey, and Watson, 2000).

Given the calibrated parameter values, the prior distributions of the first two groups of parameters, and the steady state equilibrium, we simulate the prior distributions for the third group of parameters. The 90% probability intervals for these parameters are reported in the bottom panel of Table 1.

F. Estimation issues

We use our own algorithm to estimate the structural model. One natural question is why we do not avail ourselves of the canned Dynare package. There are two distinct problems making the current Dynare tool ineffective. First, as one can see from Supplemental Appendice C.2, G.3, H.2, and I.1 that the steady state is too complicated for Dynare to solve it efficiently because it involves solving a large system of nonlinear equations for each iteration or Monte Carlo Markov Chain (MCMC) random draw of model paramaters. Second, the

[7]The capital stock in our model is the value of equipment, intellectual property products, and durable goods.

posterior distribution is full of thin winding ridges as well as local peaks, finding its mode has proven to be a difficult task. More often than not, Dynare either terminates prematurely in finding the peak or stops because of the failure of solving the steady state. At the premature solution, one would conclude with a misleading result that land-price dynamics have very small effects on unemployment or the link between land price and unemployment is weak. Such a result is in flat contradiction of the data.

Our own optimization routine, based on Sims, Waggoner, and Zha (2008) and Waggoner, Wu, and Zha (Forthcoming) and coded in C/C++, has proven to be efficient in finding the *global* posterior mode. The routine relies on a combination of MCMC simulations and continual Broyden–Fletcher–Goldfarb–Shanno (BFGS) updates of the inverse of the Hessian matrix. When the inverse Hessian matrix is close to be numerically ill-conditioned, our program resets it to a diagonal matrix. We first randomly select 100 different starting points from the prior. For each starting values of the model parameters, we alternate using a constrained optimization algorithm and an unconstrained BFGS optimization routine to find a local peak. We then use the local peak to generate a sequence of 100 MCMC posterior draws. We use the draw at the end of this long sequence as a new initial point for the optimization routine to search for another local peaks. We repeat this process 200 times. We collect all these local peaks and select the estimated parameter values that correspond to the highest posterior peak.

The MDD estimation requires an equally amount of computation. To ensure its absolute accuracy, we use three state-of-art techniques that are based on completely different methodologies: the Sims, Waggoner, and Zha (2008) method, the Mueller method described in Liu, Waggoner, and Zha (2011), and the bridge-sampling method developed by Meng and Wong (1996). For each MDD estimate, we simulate two millions of posterior draws and one million of proposal draws. On a 8-core modern desktop, finding each posterior mode takes about 40 hours; estimation of each MDD takes about 50 hours. The computing time will be significantly reduced if one has a large cluster of processors or have access to cloud computing. We are in the process of collaborating with the Dynare team to incorporate our estimation software into the Dynare package and to find ways to speed up the computation.

G. An alternative model with households renting land

In the benchmark model, households own land but cannot rent housing services. However, firms rent land from the capitalist. To examine the extent to which our results depend on this asymmetric treatment of land rental markets, we now consider a version of the model, in which households and firms both rent land from the capitalist.

G.1. **Model description.** The representative household still consumes both goods and housing services and saves in the risk-free bond market. Instead of owning land, we assume that the household rents land services from the capitalist, who is the only owner of land in the economy. As in the benchmark model, there is a continuum of workers within the representative household. A fraction of workers is employed and the other fraction (unemployed workers) searches for jobs in the frictional labor market.

The representative household's utility function is the same as in the text. The budget constraints are changed into

$$C_{ht} + \frac{B_{ht}}{R_t} + R_{lt} L_{ht} = B_{ht-1} + W_t h_t N_t + b Z_t^p (1 - N_t) - T_t, \quad \forall t \geq 0. \tag{G.1}$$

The budget constraint here reflects the assumption that the household only cares about the utility value of land services, so there is no incentive for the household to own land.

The representative capitalist has the same utility function as in the text, with the flow-of-funds constraints changed into

$$C_{ct} + Q_{lt} (L_t - L_{t-1}) + I_t + \Phi(e_t) K_{t-1} + B_{c,t-1} = \frac{B_{ct}}{R_t} + R_{kt} e_t K_{t-1} + R_{lt} L_{t-1} + \Pi_t. \tag{G.2}$$

The capitalist is the only owner of land in this economy and she derives rental income this ownership. The capitalist rents out land to both the household and firms. Denote by L_{ct} the quantity of land rented to firms. Aggregate production function is given by

$$Y_t = \left[(Z_t L_{ct})^{\phi} (e_t K_{t-1})^{1-\phi} \right]^{\alpha} (Z_t h_t N_t)^{1-\alpha}. \tag{G.3}$$

Land market clearing implies that

$$L_{ht} + L_{ct} = L_{t-1} = \bar{L}, \tag{G.4}$$

where L_{ht} and L_{ct} denote the quantity of land rented by households and firms respectively, and the last equality reflects our assumption that aggregate quantity of land is fixed in equilibrium.

G.2. **Stationary equilibrium conditions.** We now summarize the equilibrium conditions in this alternative model with households renting land from capitalists. To obtain stationarity we transform the variables as follows:

$$\begin{aligned}
\tilde{C}_{ht} &= \frac{C_{ht}}{Z_t^p}, \quad \tilde{C}_{ct} = \frac{C_{ct}}{Z_t^p}, \quad \tilde{I}_t = \frac{I_t}{Z_t^p}, \quad \tilde{K}_t = \frac{K_t}{Z_t^p}, \quad \tilde{Y}_t = \frac{Y_t}{Z_t^p}, \quad \tilde{B}_t = \frac{B_t}{Z_t^p}, \quad \tilde{T}_t = \frac{T_t}{Z_t^p}, \\
\tilde{Q}_{lt} &= \frac{Q_{lt}}{Z_t^p}, \quad \tilde{R}_{lt} = \frac{R_{lt}}{Z_t^p}, \quad \tilde{W}_t = \frac{W_t}{Z_t^p}, \quad \tilde{W}_t^{NB} = \frac{W_t^{NB}}{Z_t^p}, \quad \tilde{S}_t = \frac{S_t}{Z_t^p}, \quad \tilde{\Lambda}_{ct} = \Lambda_{ct} Z_t^p, \\
\tilde{\Lambda}_{ht} &= \Lambda_{ht} Z_t^p, \quad \tilde{\mu}_t = \mu_t Z_t^p, \quad \tilde{J}_t^F = \frac{J_t^F}{Z_t^p}, \quad \tilde{J}_t^w = \frac{J_t^w}{Z_t^p}, \quad \tilde{J}_t^u = \frac{J_t^u}{Z_t^p}.
\end{aligned}$$

The stationary equilibrium is summarized by a system of 32 equations for 32 variables. The 32 variables are $\tilde{\mu}_t$, Q_{kt}, $\tilde{Q}_{lt}$, $\tilde{B}_t$, γ_{It}, $\tilde{I}_t$, e_t, $\tilde{\Lambda}_{ct}$, $\tilde{C}_{ht}$, R_t, L_{ht}, $\tilde{\Lambda}_{ht}$, m_t, q_t^u, q_t^v, N_t, u_t, $\tilde{Y}_t$, R_{kt}, $\tilde{R}_{lt}$, $\tilde{K}_t$, $\tilde{C}_t$, L_{ct}, v_t, $\widetilde{MUL}_t$, $\tilde{W}_t$, $\tilde{C}_{ct}$, U_t, $\tilde{J}_t^F$, $\tilde{J}_t^W$, $\tilde{J}_t^U$, and h_t. The 32 equations, displayed below, are in the same order as in our computer code.

(1) Capitalist's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}}. \tag{G.5}$$

(2) Capitalist's capital Euler equation:

$$Q_{kt} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} \left[R_{k,t+1} e_{t+1} - \Phi\left(e_{t+1}\right) + (1-\delta) Q_{k,t+1} \right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_2 \xi_t E_t Q_{k,t+1} \tag{G.6}$$

(3) Capitalist's land Euler equation:

$$\tilde{Q}_{lt} = E_t \beta_c \frac{\tilde{\Lambda}_{ct+1}}{\tilde{\Lambda}_{ct}} \left[\tilde{Q}_{l,t+1} + \tilde{R}_{l,t+1} \right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_1 \xi_t E_t \tilde{Q}_{l,t+1} \lambda_{z,t+1}. \tag{G.7}$$

(4) Borrowing constraint:

$$\tilde{B}_t = \xi_t \mathrm{E}_t \left(\omega_1 \tilde{Q}_{l,t+1} \lambda_{z,t+1} L_t + \omega_2 Q_{k,t+1} \tilde{K}_t \right). \tag{G.8}$$

(5) Investment growth rate:

$$\frac{I_t}{I_{t-1}} \equiv \gamma_{It} = \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \lambda_{zt}. \tag{G.9}$$

(6) Capitalist's investment Euler equation:

$$\begin{aligned} 1 \;&=\; Q_{kt} \varphi_{It} \left[1 - \frac{\Omega}{2} \left(\gamma_{It} - \gamma_I \right)^2 - \Omega \left(\gamma_{It} - \gamma_I \right) \gamma_{It} \right] \\ &+\; \mathrm{E}_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} Q_{kt+1} \varphi_{I,t+1} \Omega \left(\gamma_{I,t+1} - \gamma_I \right) \gamma_{I,t+1}^2. \end{aligned} \tag{G.10}$$

(7) Capacity utilization decision:

$$R_{kt} = \gamma_2 \left(e_t - 1 \right) + \gamma_1. \tag{G.11}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_{ct} = \frac{1}{\tilde{C}_{ct} - \eta_c \tilde{C}_{c,t-1} / \lambda_{zt}} - E_t \frac{\beta_c \eta_c}{\tilde{C}_{c,t+1} \lambda_{z,t+1} - \eta_c \tilde{C}_{ct}}. \tag{G.12}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_{ht} + \frac{\tilde{B}_t}{R_t} + \tilde{R}_{lt} L_{ht} = \frac{\tilde{B}_{t-1}}{\lambda_{zt}} + \tilde{W}_t h_t N_t, \tag{G.13}$$

(10) Household's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_h \frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht} \lambda_{z,t+1}}. \tag{G.14}$$

(11) Household's land rental decision:

$$\tilde{R}_{lt} = \frac{\widetilde{MUL}_t}{\tilde{\Lambda}_{ht}}. \tag{G.15}$$

(12) Household's marginal utility of consumption

$$\begin{aligned} \tilde{\Lambda}_{ht} &= L_{ht}^{\varphi_{Lt}(1-\gamma)} \left(\tilde{C}_{ht} - \frac{\eta_h \tilde{C}_{h,t-1}}{\lambda_{zt}} \right)^{-\gamma} \\ &- \beta_h \eta_h E_t \left[L_{h,t+1}^{(1-\gamma)\varphi_{L,t+1}} \left(\tilde{C}_{h,t+1} - \frac{\eta_h \tilde{C}_{h,t}}{\lambda_{z,t+1}} \right)^{-\gamma} \frac{1}{\lambda_{z,t+1}} \right]. \end{aligned} \tag{G.16}$$

(13) Household's marginal utility of housing

$$\widetilde{MUL}_t = \varphi_{Lt} L_{ht}^{\varphi_{Lt}(1-\gamma)-1} \left(\tilde{C}_{ht} - \eta_h \frac{\tilde{C}_{ht-1}}{\lambda_{zt}} \right)^{1-\gamma}. \tag{G.17}$$

(14) Matching function

$$m_t = \varphi_{mt} u_t^a v_t^{1-a}. \tag{G.18}$$

(15) Job finding rate

$$q_t^u = \frac{m_t}{u_t}. \tag{G.19}$$

(16) Vacancy filling rate

$$q_t^v = \frac{m_t}{v_t}. \tag{G.20}$$

(17) Employment dynamics:

$$N_t = (1-\rho) N_{t-1} + m_t. \tag{G.21}$$

(18) Number of searching workers:

$$u_t = 1 - (1-\rho) N_{t-1}. \tag{G.22}$$

(19) Aggregate production function:

$$\tilde{Y}_t = \left[(Z_t^m L_{ct})^{\phi} \left(\frac{e_t \tilde{K}_{t-1}}{\lambda_{zt}} \right)^{1-\phi} \right]^{\alpha} (Z_t^m h_t N_t)^{1-\alpha}. \tag{G.23}$$

(20) Capital rental rate:

$$R_{kt} = \alpha(1-\phi) \frac{\tilde{Y}_t \lambda_{zt}}{e_t \tilde{K}_{t-1}}. \tag{G.24}$$

(21) Land rental rate:

$$\tilde{R}_{lt} = \alpha\phi\frac{\tilde{Y}_t}{L_{ct}}. \tag{G.25}$$

(22) Capital law of motion:

$$\tilde{K}_t = (1-\delta)\frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \varphi_{It}\left[1 - \frac{\Omega}{2}\left(\gamma_{It} - \gamma_I\right)^2\right]\tilde{I}_t. \tag{G.26}$$

(23) Aggregate Resource constraint:

$$\tilde{C}_t + \tilde{I}_t + \tilde{G}_t + \Phi\left(e_t\right)\frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \kappa v_t = \tilde{Y}_t. \tag{G.27}$$

(24) Land market clears (normalize aggregate supply of land to $L = 1$):

$$L_{ct} + L_{ht} = L_{t-1} = 1. \tag{G.28}$$

(25) Optimal vacancy posting:

$$\frac{\kappa}{q_t^v} = (1-\alpha)\frac{\tilde{Y}_t}{N_t} - \tilde{W}_t h_t + E_t\frac{\beta_c\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}}(1-\rho)\frac{\kappa}{q_{t+1}^v}. \tag{G.29}$$

(26) Nash bargaining wage:

$$\tilde{W}_t h_t = \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + b + \vartheta_t\frac{\kappa}{q_t^v} - E_t\frac{\beta_h\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\left[(1-\rho)\left(1-q_{t+1}^u\right)\vartheta_{t+1}\frac{\kappa}{q_{t+1}^v}\right], \tag{G.30}$$

where

$$g\left(h_t\right) = \frac{h_t^{1+\nu}}{1+\nu}, \;\; \nu \geq 0.$$

(27) Aggregate consumption

$$\tilde{C}_t = \tilde{C}_{ht} + \tilde{C}_{ct}. \tag{G.31}$$

(28) Unemployment rate:

$$U_t = 1 - N_t. \tag{G.32}$$

(29) The value of the firm:

$$\tilde{J}_t^F = \frac{\kappa}{q_t^v}. \tag{G.33}$$

(30) The value of employment:

$$\tilde{J}_t^W = \tilde{W}_t h_t - \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + E_t\frac{\beta_h\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\left[\left(1-\rho\left(1-q_{t+1}^u\right)\right)\left(\tilde{J}_{t+1}^W - \tilde{J}_{t+1}^U\right) + \tilde{J}_{t+1}^U\right]. \tag{G.34}$$

(31) The value of unemployment:

$$\tilde{J}_t^U = b + E_t\frac{\beta_h\tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}}\left[q_{t+1}^u\tilde{J}_{t+1}^W + (1-q_{t+1}^u)\tilde{J}_{t+1}^U\right]. \tag{G.35}$$

(32) Bargaining solution for hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}} = (1-\alpha)\frac{Y_t}{N_t h_t}. \tag{G.36}$$

G.3. **Steady state.**

(1) Shadow value of collateral:

$$\frac{\tilde{\mu}}{\tilde{\Lambda}_c} = \frac{\beta_h - \beta_c}{\bar{\lambda}_z}. \tag{G.37}$$

(2) Capital Euler equation

$$1 = \frac{\beta_c}{\bar{\lambda}_z}(R_k + 1 - \delta) + \bar{\xi}\omega_2 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}. \tag{G.38}$$

(3) Capitalist's land Euler equation:

$$\left(1 - \beta_c - \bar{\xi}\omega_1 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}\bar{\lambda}_z\right)\tilde{Q}_l = \beta_c \tilde{R}_l. \tag{G.39}$$

(4) Borrowing constraint:

$$\tilde{B} = \bar{\xi}\left(\omega_1 \tilde{Q}_l \bar{\lambda}_z L + \omega_2 \tilde{K}\right). \tag{G.40}$$

(5) Investment growth rate:

$$\bar{\gamma}_I = \bar{\lambda}_z. \tag{G.41}$$

(6) Investment Euler equation (Tobin's marginal q):

$$Q_k = \frac{1}{\bar{\varphi}_I} = 1. \tag{G.42}$$

(7) Capacity utilization

$$\gamma_1 = R_k. \tag{G.43}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_c = \frac{1}{\tilde{C}_c}\frac{\bar{\lambda}_z - \beta_c \eta_c}{\bar{\lambda}_z - \eta_c}. \tag{G.44}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_h + \tilde{R}_l L_h = \frac{1 - \beta_h}{\bar{\lambda}_z}\tilde{B} + \tilde{W} h N. \tag{G.45}$$

(10) Household's bond Euler equation:

$$R = \frac{\bar{\lambda}_z}{\beta_h}. \tag{G.46}$$

(11) Household's land rental decision:

$$\tilde{R}_l = \frac{M\tilde{U}L}{\tilde{\Lambda}_h}. \tag{G.47}$$

(12) Household's marginal utility of consumption

$$\tilde{\Lambda}_h = \left[1 - \frac{\beta_h \eta_h}{\bar{\lambda}_z}\right] L_h^{\bar{\varphi}_L(1-\gamma)} \tilde{C}_h^{-\gamma}\left(1 - \frac{\eta_h}{\bar{\lambda}_z}\right)^{-\gamma}. \tag{G.48}$$

(13) Household's marginal rate of substitution between housing and non-housing consumption

$$MRS_l = \frac{\bar{\varphi}_L \tilde{C}_h}{L_h} \frac{\bar{\lambda}_z - \eta_h}{\bar{\lambda}_z - \beta_h \eta_h}. \tag{G.49}$$

(14) Matching function

$$m = \bar{\varphi}_m u^a v^{1-a}. \tag{G.50}$$

(15) Job finding rate

$$q^u = \frac{m}{u}. \tag{G.51}$$

(16) Vacancy filling rate

$$q^v = \frac{m}{v}. \tag{G.52}$$

(17) Employment dynamics:

$$\bar{\rho} N = m. \tag{G.53}$$

(18) Number of searching workers:

$$u = 1 - (1 - \bar{\rho}) N. \tag{G.54}$$

(19) Aggregate production function:

$$\tilde{Y} = \left[(Z^m L_c)^{\phi} \left(\frac{\tilde{K}}{\bar{\lambda}_z} \right)^{1-\phi} \right]^{\alpha} (\bar{Z}^m N h)^{1-\alpha}. \tag{G.55}$$

(20) Capital rental rate:

$$R_k = \alpha(1-\phi) \frac{\tilde{Y} \bar{\lambda}_z}{\tilde{K}}. \tag{G.56}$$

(21) Land rental rate:

$$\tilde{R}_l = \alpha \phi \frac{\tilde{Y}}{L_c}. \tag{G.57}$$

(22) Capital law of motion:

$$\frac{\tilde{I}}{\tilde{K}} = 1 - \frac{1-\delta}{\bar{\lambda}_z}. \tag{G.58}$$

(23) Aggregate Resource constraint:

$$\tilde{C} + \tilde{I} + \tilde{G} + \kappa v = \tilde{Y}. \tag{G.59}$$

(24) Land market clearing condition:

$$L_c + L_h = 1. \tag{G.60}$$

(25) Optimal vacancy posting:

$$\left[1 - (1-\bar{\rho}) \beta_c \right] \frac{\kappa}{q^v} = (1-\alpha) \frac{\tilde{Y}}{N} - \tilde{W} h. \tag{G.61}$$

(26) Nash bargaining wage:

$$\tilde{W}^{NB}h = \frac{\chi g(h)}{\tilde{\Lambda}_h} + b + \bar{\vartheta}\frac{\kappa}{q^v}\left[1 - \beta_h(1-\bar{\rho})(1-q^u)\right]. \tag{G.62}$$

(27) Wage rigidity:

$$\tilde{W} = \tilde{W}^{NB}. \tag{G.63}$$

(28) Aggregate consumption

$$\tilde{C} = \tilde{C}_h + \tilde{C}_c. \tag{G.64}$$

(29) Unemployment rate:

$$U = 1 - N. \tag{G.65}$$

(30) The value of the firm:

$$\tilde{J}^F = \frac{\kappa}{q^v}. \tag{G.66}$$

(31) The value of employment:

$$[1 - \beta_h[1 - \bar{\rho}(1-q^u)]\tilde{J}^W = \tilde{W}h - \frac{\bar{\chi}g(h)}{\tilde{\Lambda}_h} + \beta_h\bar{\rho}(1-q^u)\tilde{J}^U. \tag{G.67}$$

(32) The value of unemployment:

$$[1 - \beta_h(1-q^u)]\tilde{J}^U = b + \beta_h q^u \tilde{J}^W. \tag{G.68}$$

(33) Market tightness:

$$\theta = \frac{v}{u}. \tag{G.69}$$

(34) MRS for hours:

$$\frac{\bar{\chi}g'(h)}{\Lambda_h} = (1-\alpha)\frac{Y}{Nh}. \tag{G.70}$$

G.4. **Log-linearized system.** We use $\hat{X}_t$ to denote percentage deviation of a stationary variable $\tilde{X}_t$ from the deterministic steady state $\tilde{X}$. The log-linearized system for the detrended system is given below.

(1) Capitalist's bond Euler equation:

$$\begin{aligned} d\tilde{\Lambda}_{ct} &= \frac{\beta_c R}{\bar{\lambda}_z}E_t d\Lambda_{ct+1} + \frac{\beta_c\tilde{\Lambda}_c}{\bar{\lambda}_z}dR_t - \frac{\beta_c R\tilde{\Lambda}_c}{\bar{\lambda}_z^2}E_t d\lambda_{z,t+1} \\ &\quad + Rd\tilde{\mu}_t + \tilde{\mu}dR_t, \end{aligned}$$

$$\hat{\Lambda}_{ct} = \frac{\beta_c R}{\bar{\lambda}_z}\left(E_t\hat{\Lambda}_{ct+1} + \hat{R}_t - E_t\hat{\lambda}_{z,t+1}\right) + \frac{R\tilde{\mu}}{\tilde{\Lambda}_c}\left(\hat{\mu}_t + \hat{R}_t\right).$$

(2) Capitalist's capital Euler equation:

$$\begin{aligned}
& \tilde{\Lambda}_c dQ_{kt} + Q_k d\tilde{\Lambda}_{ct} \\
= \; & \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z} E_t \left[dR_{kt+1} + R_k de_{t+1} - \gamma_1 de_{t+1} + (1-\delta) dQ_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} E_t d\tilde{\Lambda}_{ct+1} \left[R_k + (1-\delta) Q_k \right] \\
& - \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z^2} E_t d\lambda_{z,t+1} \left[R_k + (1-\delta) Q_k \right] \\
& + \omega_2 \xi Q_k d\tilde{\mu}_t + \omega_2 d\xi_t Q_k \tilde{\mu} + \omega_2 \xi \tilde{\mu} E_t dQ_{k,t+1},
\end{aligned}$$

$$\begin{aligned}
& Q_k \hat{Q}_{kt} + Q_k \hat{\Lambda}_{ct} \\
= \; & \frac{\beta_c}{\bar{\lambda}_z} E_t \left[R_k \left(\hat{R}_{kt+1} + \hat{e}_{t+1} \right) - \gamma_1 \hat{e}_{t+1} + (1-\delta) Q_k \hat{Q}_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} \left[R_k + (1-\delta) Q_k \right] E_t \left(\hat{\Lambda}_{ct+1} - \hat{\lambda}_{z,t+1} \right) \\
& + \omega_2 \bar{\xi} Q_k \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{k,t+1} \right).
\end{aligned}$$

(3) Capital's housing Euler equation:

$$\begin{aligned}
& \tilde{Q}_l d\tilde{\Lambda}_{ct} + \tilde{\Lambda}_c d\tilde{Q}_{lt} \\
= \; & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) E_t d\tilde{\Lambda}_{ct+1} + \beta_c \tilde{\Lambda}_c E_t \left(d\tilde{Q}_{l,t+1} + d\tilde{R}_{l,t+1} \right) \\
& + \omega_1 \left(\bar{\lambda}_z \bar{\xi} \tilde{Q}_l d\tilde{\mu}_t + \bar{\lambda}_z \tilde{\mu} \tilde{Q}_l d\xi_t + \bar{\lambda}_z \bar{\xi} \tilde{\mu} E_t d\tilde{Q}_{l,t+1} + \bar{\xi} \tilde{Q}_l \tilde{\mu} E_t d\lambda_{z,t+1} \right)
\end{aligned}$$

$$\begin{aligned}
& \tilde{Q}_l \tilde{\Lambda}_c \left(\hat{\Lambda}_{ct} + \hat{Q}_{lt} \right) \\
= \; & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) \tilde{\Lambda}_c E_t \hat{\Lambda}_{c,t+1} + \beta_c \tilde{\Lambda}_c E_t \left(\tilde{Q}_l \hat{Q}_{l,t+1} + \tilde{R}_l \hat{R}_{l,t+1} \right) \\
& + \omega_1 \bar{\lambda}_z \bar{\xi} \tilde{Q}_l \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right).
\end{aligned}$$

(4) Capitalist's binding borrowing constraint:

$$\begin{aligned}
d\tilde{B}_t \; = \; & \left(\omega_1 \tilde{Q}_l \lambda_z L + \omega_2 Q_k \tilde{K} \right) d\xi_t \\
& + \xi \omega_1 E_t \left(\lambda_z L d\tilde{Q}_{l,t+1} + \tilde{Q}_l \lambda_z dL_t + \tilde{Q}_l d\lambda_{z,t+1} L \right) \\
& + \xi \omega_2 \left(\tilde{K} E_t dQ_{k,t+1} + Q_k d\tilde{K}_t \right)
\end{aligned}$$

$$
\begin{aligned}
\hat{B}_t &= \hat{\xi}_t + \frac{\omega_1 \bar{\xi} \tilde{Q}_l \lambda_z}{\tilde{B}} \left(E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right) \\
&\quad + \frac{\omega_2 \bar{\xi} Q_k \tilde{K}}{\tilde{B}} \left(\hat{K}_t + E_t \hat{Q}_{k,t+1} \right).
\end{aligned}
$$

where we have imposed the equilibrium conditions that total land supply is fixed at $L_t = 1$.

(5) Investment growth rate:

$$
\hat{\gamma}_{It} + \hat{I}_{t-1} = \hat{I}_t + \hat{\lambda}_{zt}.
$$

(6) Capitalist's investment Euler equation:

$$
0 = dQ_{kt} + d\varphi_{It} - \Omega \bar{\gamma}_I d\gamma_{It} + E_t \frac{\beta_c}{\bar{\lambda}_z} \Omega \bar{\gamma}_I^2 d\gamma_{It+1},
$$

$$
\hat{Q}_{kt} + \hat{\varphi}_{It} = \Omega \bar{\gamma}_I^2 \left(\hat{\gamma}_{It} - \frac{\beta_c}{\bar{\lambda}_z} \bar{\gamma}_I \hat{\gamma}_{I,t+1} \right).
$$

(7) Capitalist's capacity utilization decision:

$$
R_k \hat{R}_{kt} = \gamma_2 \hat{e}_t.
$$

(8) Capitalist's marginal utility:

$$
\begin{aligned}
d\tilde{\Lambda}_{ct} &= \frac{-d\tilde{C}_{ct} + \eta_c d\tilde{C}_{ct-1}/\bar{\lambda}_z - \eta_c \tilde{C}_c d\lambda_{z,t}/\bar{\lambda}_z^2}{\left(\tilde{C}_c \left(1 - \eta_c/\bar{\lambda}_z \right) \right)^2} \\
&\quad - \beta_c \eta_c E_t \frac{-\bar{\lambda}_z d\tilde{C}_{ct+1} - \tilde{C}_c d\lambda_{z,t+1} + \eta_c d\tilde{C}_{ct}}{\left(\tilde{C}_c \left(\bar{\lambda}_z - \eta_c \right) \right)^2},
\end{aligned}
$$

$$
\begin{aligned}
\tilde{\Lambda}_c \hat{\Lambda}_{ct} &= \frac{-\hat{C}_{ct} + \eta_c/\bar{\lambda}_z \left(\hat{C}_{c,t-1} - \hat{\lambda}_{zt} \right)}{\tilde{C}_c \left(1 - \eta_c/\bar{\lambda}_z \right)^2} \\
&\quad - \beta_c \eta_c E_t \frac{-\bar{\lambda}_z \left(\hat{C}_{c,t+1} + \hat{\lambda}_{z,t+1} \right) + \eta_c \hat{C}_{ct}}{\tilde{C}_c \left(\bar{\lambda}_z - \eta_c \right)^2}.
\end{aligned}
$$

(9) Household's flow of funds constraint:

$$
\begin{aligned}
& d\tilde{C}_{ht} + \frac{d\tilde{B}_t}{R} - \frac{\tilde{B} dR_t}{R^2} + \tilde{R}_l dL_{ht} + L_h d\tilde{R}_{lt} \\
= \; & \frac{d\tilde{B}_{t-1}}{\bar{\lambda}_z} - \frac{\tilde{B}}{\bar{\lambda}_z^2} d\lambda_{zt} + Nhd\tilde{W}_t + h\tilde{W} dN_t + N\tilde{W} dh_t,
\end{aligned}
$$

$$\begin{aligned}&\tilde{C}_h\hat{C}_{ht} + \frac{\tilde{B}}{R}\left(\hat{B}_t - \hat{R}_t\right) + \tilde{R}_l L_h\left(\hat{R}_{lt} + \hat{L}_{ht}\right)\\ = \;& \frac{\tilde{B}}{\bar{\lambda}_z}\left(\hat{B}_{t-1} - \hat{\lambda}_{zt}\right) + \tilde{W}Nh\left(\hat{W}_t + \hat{N}_t + \hat{h}_t\right).\end{aligned}$$

(10) Household's bond Euler equation:

$$\hat{\Lambda}_{ht} = E_t\left(\hat{\Lambda}_{ht+1} - \hat{\lambda}_{z,t+1}\right) + \hat{R}_t.$$

(11) Household's land rental decision:

$$\hat{R}_{lt} = \widehat{MUL}_t - \hat{\Lambda}_{ht}.$$

(12) Household's marginal utility of consumption:

$$\begin{aligned} d\tilde{\Lambda}_{ht} = \;& -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z}d\tilde{C}_{ht-1} + \frac{\eta_h\tilde{C}_h}{\lambda_z^2}d\lambda_{zt}\right) \quad (G.71)\\ &+\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}\left(\ln L_h d\varphi_{Lt} + \varphi_L\frac{dL_{ht}}{L_h}\right)\\ &+\beta_h\eta_h\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}E_t\left(d\tilde{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z}d\tilde{C}_{ht} + \frac{\eta_h\tilde{C}_h}{\lambda_z^2}d\lambda_{zt+1}\right)\frac{1}{\bar{\lambda}_z}\\ &-\beta_h\eta_h\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}E_t\left(\ln L_h d\varphi_{Lt+1} + \varphi_L\frac{dL_{ht+1}}{L_h}\right)\frac{1}{\bar{\lambda}_z}\\ &+\beta_h\eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\lambda_z}\right)^{-\gamma}\frac{d\lambda_{z,t+1}}{\lambda_z^2}\right],\end{aligned}$$

$$\begin{aligned}\tilde{\Lambda}_{ht}\hat{\Lambda}_{ht} = \;& -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(\tilde{C}_h\hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht-1} + \frac{\eta_h\tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt}\right) \quad (G.72)\\ &+\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}\left(\bar{\varphi}_L\hat{\varphi}_{Lt}\ln L_h + \bar{\varphi}_L\hat{L}_{ht}\right) \quad (G.73)\end{aligned}$$

$$\begin{aligned}&+\beta_h\eta_h\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}E_t\left(\tilde{C}_h\hat{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht} + \frac{\eta_h\tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt+1}\right)\frac{1}{\bar{\lambda}_z} \quad (G.74)\\ &-\beta_h\eta_h\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma)\,L_h^{\varphi_L(1-\gamma)}E_t\left(\bar{\varphi}_L\hat{\varphi}_{Lt+1}\ln L_h + \bar{\varphi}_L\hat{L}_{ht+1}\right)\frac{1}{\bar{\lambda}_z} \quad (G.75)\\ &+\beta_h\eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h - \frac{\eta_h\tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\frac{\hat{\lambda}_{z,t+1}}{\bar{\lambda}_z}\right]. \quad (G.76)\end{aligned}$$

(13) Household's marginal utility of housing

$$\begin{aligned} d\widetilde{MUL}_t &= \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt}\right) \\ &+ \bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1} \left((1-\gamma)\, d\varphi_{Lt} \ln L_h + (\bar{\varphi}_L (1-\gamma) - 1) \frac{dL_{ht}}{L_h}\right) \\ &+ L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} d\varphi_{L,t}. \end{aligned}$$

$$\begin{aligned} \widetilde{MUL}\ \widehat{MUL}_t &= \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \left(\tilde{C}_h \hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} \tilde{C}_{ht-1} \hat{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z} d\hat{\lambda}_{zt}\right) \\ &+ \bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1} \left((1-\gamma)\, \bar{\varphi}_L \ln L_h \hat{\varphi}_{Lt} + (\bar{\varphi}_L (1-\gamma) - 1) \hat{L}_{ht}\right) \\ &+ \bar{\varphi}_L L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} \hat{\varphi}_{L,t}. \end{aligned}$$

(14) Matching function:

$$\hat{m}_t = \hat{\varphi}_{mt} + a\hat{u}_t + (1-a)\,\hat{v}_t.$$

(15) Job finding rate:

$$\hat{q}_t^u = \hat{m}_t - \hat{u}_t.$$

(16) Job filling rate:

$$\hat{q}_t^v = \hat{m}_t - \hat{v}_t.$$

(17) Employment dynamics:

$$dN_t = (1-\bar{\rho})\, dN_{t-1} + dm_t,$$

$$\hat{N}_t = (1-\bar{\rho})\, \hat{N}_{t-1} + \bar{\rho}\hat{m}_t.$$

(18) Number of searching workers:

$$du_t = -(1-\bar{\rho})\, dN_{t-1},$$

$$u\hat{u}_t = -(1-\bar{\rho})\, N\hat{N}_{t-1}.$$

(19) Aggregate production function:

$$\hat{Y}_t = \alpha \left[(1-\phi)\left(\hat{K}_{t-1} + \hat{e}_t - \hat{\lambda}_{zt}\right) + \phi\left(\hat{Z}_t^m + \hat{L}_{ct}\right)\right] + (1-\alpha)\left(\hat{N}_t + \hat{h}_t + \hat{Z}_t^m\right).$$

(20) Capital rental rate:

$$\hat{R}_{kt} = \hat{Y}_t + \hat{\lambda}_{zt} - \hat{K}_{t-1} - \hat{e}_t.$$

(21) Land rental rate:

$$\hat{R}_{lt} = \hat{Y}_t - \hat{L}_{ct}.$$

(22) Capital law of motion:

$$d\tilde{K}_t = (1-\delta)\, d\tilde{K}_{t-1}/\bar{\lambda}_z - (1-\delta)\, \tilde{K}/\bar{\lambda}_z^2 d\lambda_{zt} + dI_t + \tilde{I} d\varphi_{It},$$

$$\hat{K}_t = \frac{1-\delta}{\bar{\lambda}_z}\left(\hat{K}_{t-1} - \hat{\lambda}_{zt}\right) + \frac{\tilde{I}}{\tilde{K}}\left(\hat{I}_t + \hat{\varphi}_{It}\right).$$

(23) Aggregate resource constraint:

$$d\tilde{Y}_t = d\tilde{I}_t + d\tilde{C}_{ct} + d\tilde{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z} de_t + \kappa dv_t + d\tilde{G}_t,$$

$$\hat{Y}_t = \frac{\tilde{I}}{\tilde{Y}}\hat{I}_t + \frac{\tilde{C}_c}{\tilde{Y}}\hat{C}_{ct} + \frac{\tilde{C}_h}{\tilde{Y}}\hat{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z\tilde{Y}}\hat{e}_t + \frac{\kappa v}{\tilde{Y}}\hat{v}_t + \frac{\tilde{G}}{\tilde{Y}}\hat{G}_t.$$

(24) Housing market clearing condition:

$$L_c\hat{L}_{ct} + L_h\hat{L}_{ht} = 0.$$

(25) Optimal vacancy posting condition:

$$-\frac{\kappa}{(q^v)^2}dq_t^v = (1-\alpha)\frac{d\tilde{Y}_t}{N} - (1-\alpha)\frac{\tilde{Y}}{N^2}dN_t - hd\tilde{W}_t - \tilde{W}dh_t$$

$$+E_t\frac{\beta_c d\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v} - E_t\frac{\beta_c d\tilde{\Lambda}_{c,t}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v} - E_t\beta_c(1-\rho)\frac{\kappa}{(q^v)^2}dq_{t+1}^v$$

$$-\frac{\kappa}{q^v}\hat{q}_t^v = (1-\alpha)\frac{\tilde{Y}}{N}\left(\hat{Y}_t - \hat{N}_t\right) - \tilde{W}h\left(\hat{W}_t + \hat{h}_t\right)$$

$$+\beta_c(1-\bar{\rho})\frac{\kappa}{q^v}E_t\left(\hat{\Lambda}_{c,t+1} - \hat{\Lambda}_{c,t}\right) - \beta_c\frac{\kappa}{q^v}E_t(1-\bar{\rho})\,\hat{q}_{t+1}^v.$$

(26) Nash bargained wage:

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB} + \hat{h}_t\right) = \frac{\chi h^\nu dh_t}{\tilde{\Lambda}_h} - \frac{h^{1+\nu}\chi d\tilde{\Lambda}_{ht}}{(1+\nu)\left(\tilde{\Lambda}_h\right)^2} + d\vartheta_t\frac{\kappa}{q^v} - \bar{\vartheta}\frac{\kappa dq_t^v}{(q^v)^2}$$

$$-\beta_h(1-\rho)(1-q^u)\,\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1} - \hat{\Lambda}_{h,t}\right] + \beta_h(1-\rho)\,\bar{\vartheta}\frac{\kappa}{q^v}E_t dq_{t+1}^u$$

$$+\beta_h(1-\rho)(1-q^u)\,\bar{\vartheta}E_t\frac{\kappa dq_{t+1}^v}{(q^v)^2} - \beta_h(1-\rho)(1-q^u)\,d\vartheta_{t+1}\frac{\kappa}{q^v}$$

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB} + \hat{h}_t\right) = \frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h(1+\nu)}\left((1+\nu)\,\hat{h}_t - \hat{\Lambda}_{ht}\right) + \frac{\bar{\vartheta}\kappa}{q^v}\left(\hat{\vartheta}_t - \hat{q}_t^v\right)$$

$$-\beta_h \left(1-\bar{\rho}\right)\left(1-q^u\right)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1}-\hat{\Lambda}_{h,t}\right]+\beta_h\bar{\vartheta}\frac{\kappa}{q^v}\left(1-\rho\right)q^u E_t\hat{q}^u_{t+1}$$
$$-\beta_h\left(1-\rho\right)\left(1-q^u\right)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left(\hat{\vartheta}_{t+1}-\hat{q}^v_{t+1}\right)$$

(27) Wage rigidity:

$$\hat{W}_t=\psi\hat{W}_{t-1}+\left(1-\psi\right)\hat{W}^{NB}_t.$$

(28) Aggregate consumption:

$$\tilde{C}\hat{C}_t=\tilde{C}_c\hat{C}_{ct}+\tilde{C}_h\hat{C}_{ht}.$$

(29) Unemployment rate

$$U\hat{U}_t=-N\hat{N}_t.$$

(30) The value of the firm.

$$\hat{J}^F_t=-\hat{q}^v_t.$$

(31) The value of employment:

$$\tilde{J}^W_t=\tilde{W}_t h_t-\frac{\chi g\left(h_t\right)}{\tilde{\Lambda}_{ht}}+E_t\frac{\beta_h\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\left[\left(1-\rho\left(1-q^u_{t+1}\right)\right)\left(\tilde{J}^W_{t+1}-\tilde{J}^U_{t+1}\right)+\tilde{J}^U_{t+1}\right]. \tag{G.77}$$

$$\tilde{J}^W\hat{J}^W_t=\tilde{W}h\left(\hat{W}_t+\hat{h}_t\right)-\frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h\left(1+\nu\right)}\left(\left(1+\nu\right)\hat{h}_t-\hat{\Lambda}_{ht}\right)$$
$$+\beta_h\left[\left(1-\bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W+\bar{\rho}\left(1-q^u\right)\tilde{J}^U\right]E_t\left(\hat{\Lambda}_{ht+1}-\hat{\Lambda}_{ht}\right)$$
$$+\beta_h E_t\left[\left(1-\bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W\hat{J}^W_{t+1}+\bar{\rho}\left(1-q^u\right)\tilde{J}^U\hat{J}^U_{t+1}\right]+\beta_h\bar{\rho}q^u\left(\tilde{J}^W-\tilde{J}^U\right)E_t\hat{q}^u_{t+1}.$$

(32) The value of unemployment:

$$\tilde{J}^U_t=b+E_t\frac{\beta_h\tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}}\left[q^u_{t+1}\tilde{J}^W_{t+1}+(1-q^u_{t+1})\tilde{J}^U_{t+1}\right]. \tag{G.78}$$

$$\tilde{J}^U\hat{J}^U_t=\beta_h\left[q^u\left(\tilde{J}^W-\tilde{J}^U\right)+\tilde{J}^U\right]E_t\left(\hat{\Lambda}_{ht+1}-\hat{\Lambda}_{ht}\right)$$
$$+\beta_h q^u\left(\tilde{J}^W-\tilde{J}^U\right)E_t\hat{q}^u_{t+1}+\beta_h E_t\left[q^u\tilde{J}^W\hat{J}^W_{t+1}+\left(1-q^u\right)\tilde{J}^U\hat{J}^U_{t+1}\right]$$

(33) Market tightness:

$$\hat{\theta}_t=\hat{v}_t-\hat{u}_t.$$

(34) Hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}}=(1-\alpha)\frac{Y_t}{N_t h_t}. \tag{G.79}$$

$$\nu\hat{h}_t-\hat{\Lambda}_{ht}=\hat{Y}_t-\hat{N}_t-\hat{h}_t$$

H. The model without housing demand shocks but with shocks to disutility of working

The labor channel in our benchmark model is an important mechanism that amplifies the effects of housing demand shocks on labor market variables. To highlight the importance of the this channel, we consider a variation of the benchmark model without the housing preference shocks. We still would like to fit the model to the same 6 time series data, so we need to have at least 6 shocks to avoid stochastic singularity in the estimation.

In this section, we replace the housing demand shock by a shock to households' disutility of working. In particular, we allow the term ξ in the households' utility function (Eq (3) in the text) to be time varying. We assume that the disutility shock follows the stationary stochastic process

$$\ln \chi_t = (1-\rho_\chi)\bar{\chi} + \rho_\chi \ln \chi_{t-1} + \varepsilon_{\chi t},$$

where ρ_χ is the persistent parameter and $\varepsilon_{\chi t}$ is an i.i.d white noise process with mean zero and variance σ_χ^2.

H.1. **Stationary equilibrium conditions.** To induce stationarity, we transform variables so that

$$\begin{aligned}
\tilde{C}_{ht} &= \frac{C_{ht}}{Z_t^p}, \quad \tilde{C}_{ct} = \frac{C_{ct}}{Z_t^p}, \quad \tilde{I}_t = \frac{I_t}{Z_t^p}, \quad \tilde{K}_t = \frac{K_t}{Z_t^p}, \quad \tilde{Y}_t = \frac{Y_t}{Z_t^p}, \quad \tilde{B}_t = \frac{B_t}{Z_t^p}, \quad \tilde{T}_t = \frac{T_t}{Z_t^p}, \\
\tilde{Q}_{lt} &= \frac{Q_{lt}}{Z_t^p}, \quad \tilde{R}_{lt} = \frac{R_{lt}}{Z_t^p}, \quad \tilde{W}_t = \frac{W_t}{Z_t^p}, \quad \tilde{W}_t^{NB} = \frac{W_t^{NB}}{Z_t^p}, \quad \tilde{S}_t = \frac{S_t}{Z_t^p}, \quad \tilde{\Lambda}_{ct} = \Lambda_{ct} Z_t^p, \\
\tilde{\Lambda}_{ht} &= \Lambda_{ht} Z_t^p, \quad \tilde{\mu}_t = \mu_t Z_t^p, \quad \tilde{J}_t^F = \frac{J_t^F}{Z_t^p}, \quad \tilde{J}_t^w = \frac{J_t^w}{Z_t^p}, \quad \tilde{J}_t^u = \frac{J_t^u}{Z_t^p}.
\end{aligned}$$

The stationary equilibrium is summarized by a system of 34 equations for 34 variables $\tilde{\mu}_t$, Q_{kt}, $\tilde{Q}_{lt}$, $\tilde{B}_t$, γ_{It}, $\tilde{I}_t$, e_t, $\tilde{\Lambda}_{ct}$, $\tilde{C}_{ht}$, R_t, L_{ht}, $\tilde{\Lambda}_{ht}$, m_t, q_t^u, q_t^v, N_t, u_t, $\tilde{Y}_t$, R_{kt}, $\tilde{R}_{lt}$, $\tilde{K}_t$, $\tilde{C}_t$, L_{ct}, v_t, $\tilde{W}_t^{NB}$, $\tilde{S}_t$, $\tilde{W}_t$, $\tilde{C}_{ct}$, U_t, $\tilde{J}_t^F$, $\tilde{J}_t^W$, $\tilde{J}_t^U$, θ_t, and h_t. We write the equations in the same order as in the dynare code.

(1) Capitalist's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}}. \tag{H.1}$$

(2) Capitalist's capital Euler equation:

$$Q_{kt} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} \left[R_{k,t+1}e_{t+1} - \Phi\left(e_{t+1}\right) + (1-\delta)\, Q_{k,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_2 \xi_t E_t Q_{k,t+1} \tag{H.2}$$

(3) Capitalist's land Euler equation:

$$\tilde{Q}_{lt} = E_t \beta_c \frac{\tilde{\Lambda}_{ct+1}}{\tilde{\Lambda}_{ct}} \left[\tilde{Q}_{l,t+1} + \tilde{R}_{l,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_1 \xi_t E_t \tilde{Q}_{l,t+1} \lambda_{z,t+1}. \tag{H.3}$$

(4) Borrowing constraint:

$$\tilde{B}_t = \xi_t \mathrm{E}_t \left(\omega_1 \tilde{Q}_{l,t+1} \lambda_{z,t+1} L_{ct} + \omega_2 Q_{k,t+1} \tilde{K}_t \right). \tag{H.4}$$

(5) Investment growth rate:

$$\frac{I_t}{I_{t-1}} \equiv \gamma_{It} = \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \lambda_{zt}. \tag{H.5}$$

(6) Capitalist's investment Euler equation:

$$\begin{aligned} 1 &= Q_{kt} \varphi_{It} \left[1 - \frac{\Omega}{2} \left(\gamma_{It} - \bar{\gamma}_I \right)^2 - \Omega \left(\gamma_{It} - \bar{\gamma}_I \right) \gamma_{It} \right] \\ &+ \mathrm{E}_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct} \lambda_{z,t+1}} Q_{kt+1} \varphi_{I,t+1} \Omega \left(\gamma_{I,t+1} - \bar{\gamma}_I \right) \gamma_{I,t+1}^2. \end{aligned} \tag{H.6}$$

(7) Capacity utilization decision:

$$R_{kt} = \gamma_2 \left(e_t - 1 \right) + \gamma_1. \tag{H.7}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_{ct} = \frac{1}{\tilde{C}_{ct} - \eta_c \tilde{C}_{c,t-1} / \lambda_{zt}} - E_t \frac{\beta_c \eta_c}{\tilde{C}_{c,t+1} \lambda_{z,t+1} - \eta_c \tilde{C}_{ct}}. \tag{H.8}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_{ht} + \frac{\tilde{B}_t}{R_t} + \tilde{Q}_{lt} \left(L_{ht} - L_{h,t-1} \right) = \frac{\tilde{B}_{t-1}}{\lambda_{zt}} + \tilde{W}_t h_t N_t. \tag{H.9}$$

(10) Household's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_h \frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht} \lambda_{z,t+1}}. \tag{H.10}$$

(11) Household's land Euler equation:

$$\tilde{Q}_{lt} = MRS_{lt} + E_t \beta_h \frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \tilde{Q}_{l,t+1}, \tag{H.11}$$

where the marginal rate of substituition between housing and consumption is given by

$$MRS_{lt} = \frac{\widetilde{MUL_t}}{\tilde{\Lambda}_{ht}}.$$

(12) Household's marginal utility of consumption

$$\begin{aligned} \tilde{\Lambda}_{ht} &= L_{ht}^{\varphi_L (1-\gamma)} \left(\tilde{C}_{ht} - \frac{\eta_h \tilde{C}_{h,t-1}}{\lambda_{zt}} \right)^{-\gamma} \\ &- \beta_h \eta_h E_t \left[L_{h,t+1}^{(1-\gamma)\varphi_L} \left(\tilde{C}_{h,t+1} - \frac{\eta_h \tilde{C}_{h,t}}{\lambda_{z,t+1}} \right)^{-\gamma} \frac{1}{\lambda_{z,t+1}} \right]. \end{aligned} \tag{H.12}$$

(13) Household's marginal utility of housing

$$\widetilde{MUL}_t = \varphi_L L_{ht}^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_{ht} - \eta_h \frac{\tilde{C}_{ht-1}}{\lambda_{zt}} \right)^{1-\gamma}. \quad \text{(H.13)}$$

(14) Matching function

$$m_t = \varphi_{mt} u_t^a v_t^{1-a}. \quad \text{(H.14)}$$

(15) Job finding rate

$$q_t^u = \frac{m_t}{u_t}. \quad \text{(H.15)}$$

(16) Vacancy filling rate

$$q_t^v = \frac{m_t}{v_t}. \quad \text{(H.16)}$$

(17) Employment dynamics:

$$N_t = (1-\rho) N_{t-1} + m_t. \quad \text{(H.17)}$$

(18) Number of searching workers:

$$u_t = 1 - (1-\rho) N_{t-1}. \quad \text{(H.18)}$$

(19) Aggregate production function:

$$\tilde{Y}_t = \left[(Z_t^m L_{c,t-1})^{\phi} \left(\frac{e_t \tilde{K}_{t-1}}{\lambda_{zt}} \right)^{1-\phi} \right]^{\alpha} (Z_t^m h_t N_t)^{1-\alpha}. \quad \text{(H.19)}$$

(20) Capital rental rate:

$$R_{kt} = \alpha(1-\phi) \frac{\tilde{Y}_t \lambda_{zt}}{e_t \tilde{K}_{t-1}}. \quad \text{(H.20)}$$

(21) Land rental rate:

$$\tilde{R}_{lt} = \alpha\phi \frac{\tilde{Y}_t}{L_{c,t-1}}. \quad \text{(H.21)}$$

(22) Capital law of motion:

$$\tilde{K}_t = (1-\delta) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \varphi_{It} \left[1 - \frac{\Omega}{2} (\gamma_{It} - \bar{\gamma}_I)^2 \right] \tilde{I}_t. \quad \text{(H.22)}$$

(23) Aggregate Resource constraint:

$$\tilde{C}_t + \tilde{I}_t + \tilde{G}_t + \Phi(e_t) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \kappa v_t = \tilde{Y}_t. \quad \text{(H.23)}$$

(24) Land market clears (normalize aggregate supply of land to $\bar{L} = 1$):

$$L_{ct} + L_{ht} = 1. \quad \text{(H.24)}$$

(25) Optimal vacancy posting:

$$\frac{\kappa}{q_t^v} = (1-\alpha)\frac{\tilde{Y}_t}{N_t} - \tilde{W}_t h_t + E_t \frac{\beta_c \tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}} (1-\rho) \frac{\kappa}{q_{t+1}^v}. \tag{H.25}$$

(26) Nash bargaining wage:

$$\tilde{W}_t^{NB} h_t = \frac{\chi_t g(h_t)}{\tilde{\Lambda}_{ht}} + b + \vartheta_t \frac{\kappa}{q_t^v} - E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[(1-\rho) \left(1 - q_{t+1}^u\right) \vartheta_{t+1} \frac{\kappa}{q_{t+1}^v} \right], \tag{H.26}$$

where

$$g(h_t) = \frac{h_t^{1+\nu}}{1+\nu}, \;\; \nu \geq 0.$$

(27) Wage rigidity:

$$\tilde{W}_t = \psi \tilde{W}_{t-1} + (1-\psi) \tilde{W}_t^{NB}. \tag{H.27}$$

(28) Aggregate consumption

$$\tilde{C}_t = \tilde{C}_{ht} + \tilde{C}_{ct}. \tag{H.28}$$

(29) Unemployment rate:

$$U_t = 1 - N_t. \tag{H.29}$$

(30) The value of the firm:

$$\tilde{J}_t^F = \frac{\kappa}{q_t^v}. \tag{H.30}$$

(31) The value of employment:

$$\tilde{J}_t^W = \tilde{W}_t h_t - \frac{\chi_t g(h_t)}{\tilde{\Lambda}_{ht}} + E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[\left(1 - \rho \left(1 - q_{t+1}^u\right)\right) \left(\tilde{J}_{t+1}^W - \tilde{J}_{t+1}^U \right) + \tilde{J}_{t+1}^U \right]. \tag{H.31}$$

(32) The value of unemployment:

$$\tilde{J}_t^U = b + E_t \frac{\beta_h \tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}} \left[q_{t+1}^u \tilde{J}_{t+1}^W + (1 - q_{t+1}^u) \tilde{J}_{t+1}^U \right]. \tag{H.32}$$

(33) Market tightness:

$$\theta_t = \frac{v_t}{u_t}. \tag{H.33}$$

(34) MRS for hours:

$$\frac{\chi_t g'(h_t)}{\Lambda_{ht}} = (1-\alpha) \frac{Y_t}{N_t h_t}. \tag{H.34}$$

H.2. **Steady state.**

(1) Shadow value of collateral:

$$\frac{\tilde{\mu}}{\tilde{\Lambda}_c} = \frac{\beta_h - \beta_c}{\bar{\lambda}_z}. \tag{H.35}$$

(2) Capital Euler equation

$$1 = \frac{\beta_c}{\bar{\lambda}_z}(R_k + 1 - \delta) + \bar{\xi}\omega_2 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}. \tag{H.36}$$

(3) Capitalist's land Euler equation:

$$\left(1 - \beta_c - \bar{\xi}\omega_1 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}\bar{\lambda}_z\right)\tilde{Q}_l = \beta_c \tilde{R}_l. \tag{H.37}$$

(4) Borrowing constraint:

$$\tilde{B} = \bar{\xi}\left(\omega_1 \tilde{Q}_l \bar{\lambda}_z L_c + \omega_2 \tilde{K}\right). \tag{H.38}$$

(5) Investment growth rate:

$$\bar{\gamma}_I = \bar{\lambda}_z. \tag{H.39}$$

(6) Investment Euler equation (Tobin's marginal q):

$$Q_k = \frac{1}{\bar{\varphi}_I} = 1. \tag{H.40}$$

(7) Capacity utilization

$$\gamma_1 = R_k. \tag{H.41}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_c = \frac{1}{\tilde{C}_c}\frac{\bar{\lambda}_z - \beta_c \eta_c}{\bar{\lambda}_z - \eta_c}. \tag{H.42}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_h = \frac{1 - \beta_h}{\bar{\lambda}_z}\tilde{B} + \tilde{W} h N. \tag{H.43}$$

(10) Household's bond Euler equation:

$$R = \frac{\bar{\lambda}_z}{\beta_h}. \tag{H.44}$$

(11) Household's land Euler equation:

$$(1 - \beta_h)\tilde{Q}_l = MRS_l. \tag{H.45}$$

(12) Household's marginal utility of consumption

$$\tilde{\Lambda}_h = \left[1 - \frac{\beta_h \eta_h}{\bar{\lambda}_z}\right] L_h^{\bar{\varphi}_L(1-\gamma)} \tilde{C}_h^{-\gamma}\left(1 - \frac{\eta_h}{\bar{\lambda}_z}\right)^{-\gamma}. \tag{H.46}$$

(13) Household's marginal rate of substitution between housing and non-housing consumption

$$MRS_l = \frac{\bar{\varphi}_L \tilde{C}_h}{L_h} \frac{\bar{\lambda}_z - \eta_h}{\bar{\lambda}_z - \beta_h \eta_h}. \tag{H.47}$$

(14) Matching function

$$m = \bar{\varphi}_m u^a v^{1-a}. \tag{H.48}$$

(15) Job finding rate

$$q^u = \frac{m}{u}. \tag{H.49}$$

(16) Vacancy filling rate

$$q^v = \frac{m}{v}. \tag{H.50}$$

(17) Employment dynamics:

$$\bar{\rho} N = m. \tag{H.51}$$

(18) Number of searching workers:

$$u = 1 - (1 - \bar{\rho}) N. \tag{H.52}$$

(19) Aggregate production function:

$$\tilde{Y} = \left[(Z^m L_c)^{\phi} \left(\frac{\tilde{K}}{\bar{\lambda}_z} \right)^{1-\phi} \right]^{\alpha} (\bar{Z}^m N h)^{1-\alpha}. \tag{H.53}$$

(20) Capital rental rate:

$$R_k = \alpha(1-\phi) \frac{\tilde{Y} \bar{\lambda}_z}{\tilde{K}}. \tag{H.54}$$

(21) Land rental rate:

$$\tilde{R}_l = \alpha \phi \frac{\tilde{Y}}{L_c}. \tag{H.55}$$

(22) Capital law of motion:

$$\frac{\tilde{I}}{\tilde{K}} = 1 - \frac{1-\delta}{\bar{\lambda}_z}. \tag{H.56}$$

(23) Aggregate Resource constraint:

$$\tilde{C} + \tilde{I} + \tilde{G} + \kappa v = \tilde{Y}. \tag{H.57}$$

(24) Land market clear

$$L_c + L_h = 1. \tag{H.58}$$

(25) Optimal vacancy posting:

$$\left[1 - (1 - \bar{\rho}) \beta_c \right] \frac{\kappa}{q^v} = (1 - \alpha) \frac{\tilde{Y}}{N} - \tilde{W} h. \tag{H.59}$$

(26) Nash bargaining wage:

$$\tilde{W}^{NB}h = \frac{\chi g(h)}{\tilde{\Lambda}_h} + b + \bar{\vartheta}\frac{\kappa}{q^v}\left[1 - \beta_h(1-\bar{\rho})(1-q^u)\right]. \tag{H.60}$$

(27) Wage rigidity:

$$\tilde{W} = \tilde{W}^{NB}. \tag{H.61}$$

(28) Aggregate consumption

$$\tilde{C} = \tilde{C}_h + \tilde{C}_c. \tag{H.62}$$

(29) Unemployment rate:

$$U = 1 - N. \tag{H.63}$$

(30) The value of the firm:

$$\tilde{J}^F = \frac{\kappa}{q^v}. \tag{H.64}$$

(31) The value of employment:

$$[1 - \beta_h[1 - \bar{\rho}(1-q^u)]\tilde{J}^W = \tilde{W}h - \frac{\bar{\chi}g(h)}{\tilde{\Lambda}_h} + \beta_h\bar{\rho}(1-q^u)\tilde{J}^U. \tag{H.65}$$

(32) The value of unemployment:

$$[1 - \beta_h(1-q^u)]\tilde{J}^U = b + \beta_h q^u \tilde{J}^W. \tag{H.66}$$

(33) Market tightness:

$$\theta = \frac{v}{u}. \tag{H.67}$$

(34) MRS for hours:

$$\frac{\bar{\chi}g'(h)}{\Lambda_h} = (1-\alpha)\frac{Y}{Nh}. \tag{H.68}$$

H.3. **Log-linearized system.** We use $\hat{X}_t$ to denote percentage deviation from the deterministic steady state $\tilde{X}$ for any detrended variable $\tilde{X}_t$. The log-linearized system for the detrended system is given below.

(1) Capitalist's bond Euler equation:

$$\begin{aligned} d\tilde{\Lambda}_{ct} &= \frac{\beta_c R}{\bar{\lambda}_z}E_t d\Lambda_{ct+1} + \frac{\beta_c\tilde{\Lambda}_c}{\bar{\lambda}_z}dR_t - \frac{\beta_c R\tilde{\Lambda}_c}{\bar{\lambda}_z^2}E_t d\lambda_{z,t+1} \\ &\quad + Rd\tilde{\mu}_t + \tilde{\mu}dR_t, \end{aligned}$$

$$\hat{\Lambda}_{ct} = \frac{\beta_c R}{\bar{\lambda}_z}\left(E_t\hat{\Lambda}_{ct+1} + \hat{R}_t - E_t\hat{\lambda}_{z,t+1}\right) + \frac{R\tilde{\mu}}{\tilde{\Lambda}_c}\left(\hat{\mu}_t + \hat{R}_t\right).$$

(2) Capitalist's capital Euler equation:

$$
\begin{aligned}
& \tilde{\Lambda}_c dQ_{kt} + Q_k d\tilde{\Lambda}_{ct} \\
= \;& \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z} E_t \left[dR_{kt+1} + R_k de_{t+1} - \gamma_1 de_{t+1} + (1-\delta) dQ_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} E_t d\tilde{\Lambda}_{ct+1} \left[R_k + (1-\delta) Q_k \right] \\
& - \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z^2} E_t d\lambda_{z,t+1} \left[R_k + (1-\delta) Q_k \right] \\
& + \omega_2 \xi Q_k d\tilde{\mu}_t + \omega_2 d\xi_t Q_k \tilde{\mu} + \omega_2 \xi \tilde{\mu} E_t dQ_{k,t+1},
\end{aligned}
$$

$$
\begin{aligned}
& Q_k \hat{Q}_{kt} + Q_k \hat{\Lambda}_{ct} \\
= \;& \frac{\beta_c}{\bar{\lambda}_z} E_t \left[R_k \left(\hat{R}_{kt+1} + \hat{e}_{t+1} \right) - \gamma_1 \hat{e}_{t+1} + (1-\delta) Q_k \hat{Q}_{kt+1} \right] \\
& + \frac{\beta_c}{\bar{\lambda}_z} \left[R_k + (1-\delta) Q_k \right] E_t \left(\hat{\Lambda}_{ct+1} - \hat{\lambda}_{z,t+1} \right) \\
& + \omega_2 \bar{\xi} Q_k \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{k,t+1} \right).
\end{aligned}
$$

(3) Capital's housing Euler equation:

$$
\begin{aligned}
& \tilde{Q}_l d\tilde{\Lambda}_{ct} + \tilde{\Lambda}_c d\tilde{Q}_{lt} \\
= \;& \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) E_t d\tilde{\Lambda}_{ct+1} + \beta_c \tilde{\Lambda}_c E_t \left(d\tilde{Q}_{l,t+1} + d\tilde{R}_{l,t+1} \right) \\
& + \omega_1 \left(\bar{\lambda}_z \bar{\xi} \tilde{Q}_l d\tilde{\mu}_t + \bar{\lambda}_z \tilde{\mu} \tilde{Q}_l d\xi_t + \bar{\lambda}_z \bar{\xi} \tilde{\mu} E_t d\tilde{Q}_{l,t+1} + \bar{\xi} \tilde{Q}_l \tilde{\mu} E_t d\lambda_{z,t+1} \right)
\end{aligned}
$$

$$
\begin{aligned}
& \tilde{Q}_l \tilde{\Lambda}_c \left(\hat{\Lambda}_{ct} + \hat{Q}_{lt} \right) \\
= \;& \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) \tilde{\Lambda}_c E_t \hat{\Lambda}_{c,t+1} + \beta_c \tilde{\Lambda}_c E_t \left(\tilde{Q}_l \hat{Q}_{l,t+1} + \tilde{R}_l \hat{R}_{l,t+1} \right) \\
& + \omega_1 \bar{\lambda}_z \bar{\xi} \tilde{Q}_l \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right).
\end{aligned}
$$

(4) Capitalist's binding borrowing constraint:

$$
\begin{aligned}
d\tilde{B}_t = \;& \left(\omega_1 \tilde{Q}_l \lambda_z L_c + \omega_2 Q_k \tilde{K} \right) d\xi_t \\
& + \xi \omega_1 E_t \left(\lambda_z L_c d\tilde{Q}_{l,t+1} + \tilde{Q}_l \lambda_z dL_{ct} + \tilde{Q}_l d\lambda_{z,t+1} L_c \right) \\
& + \xi \omega_2 \left(\tilde{K} E_t dQ_{k,t+1} + Q_k d\tilde{K}_t \right)
\end{aligned}
$$

$$\hat{B}_t = \hat{\xi}_t + \frac{\omega_1\bar{\xi}\tilde{Q}_l\lambda_z L_c}{\tilde{B}}\left(\hat{L}_{ct} + E_t\hat{Q}_{l,t+1} + E_t\hat{\lambda}_{z,t+1}\right) + \frac{\omega_2\bar{\xi}Q_k\tilde{K}}{\tilde{B}}\left(\hat{K}_t + E_t\hat{Q}_{k,t+1}\right).$$

(5) Investment growth rate:

$$\hat{\gamma}_{It} + \hat{I}_{t-1} = \hat{I}_t + \hat{\lambda}_{zt}.$$

(6) Capitalist's investment Euler equation:

$$0 = dQ_{kt} + d\varphi_{It} - \Omega\bar{\gamma}_I d\gamma_{It} + E_t\frac{\beta_c}{\bar{\lambda}_z}\Omega\bar{\gamma}_I^2 d\gamma_{It+1},$$

$$\hat{Q}_{kt} + \hat{\varphi}_{It} = \Omega\bar{\gamma}_I^2\left(\hat{\gamma}_{It} - \frac{\beta_c}{\bar{\lambda}_z}\bar{\gamma}_I\hat{\gamma}_{I,t+1}\right).$$

(7) Capitalist's capacity utilization decision:

$$R_k\hat{R}_{kt} = \gamma_2\hat{e}_t.$$

(8) Capitalist's marginal utility:

$$d\tilde{\Lambda}_{ct} = \frac{-d\tilde{C}_{ct} + \eta_c d\tilde{C}_{ct-1}/\bar{\lambda}_z - \eta_c\tilde{C}_c d\lambda_{z,t}/\bar{\lambda}_z^2}{\left(\tilde{C}_c\left(1-\eta_c/\bar{\lambda}_z\right)\right)^2} - \beta_c\eta_c E_t\frac{-\bar{\lambda}_z d\tilde{C}_{ct+1} - \tilde{C}_c d\lambda_{z,t+1} + \eta_c d\tilde{C}_{ct}}{\left(\tilde{C}_c\left(\bar{\lambda}_z - \eta_c\right)\right)^2},$$

$$\tilde{\Lambda}_c\hat{\Lambda}_{ct} = \frac{-\hat{C}_{ct} + \eta_c/\bar{\lambda}_z\left(\hat{C}_{c,t-1} - \hat{\lambda}_{zt}\right)}{\tilde{C}_c\left(1-\eta_c/\bar{\lambda}_z\right)^2} - \beta_c\eta_c E_t\frac{-\bar{\lambda}_z\left(\hat{C}_{c,t+1} + \hat{\lambda}_{z,t+1}\right) + \eta_c\hat{C}_{ct}}{\tilde{C}_c\left(\bar{\lambda}_z - \eta_c\right)^2}.$$

(9) Household's flow of funds constraint:

$$d\tilde{C}_{ht} + \frac{d\tilde{B}_t}{R} - \frac{\tilde{B}dR_t}{R^2} + \tilde{Q}_l\left(dL_{ht} - dL_{h,t-1}\right) = \frac{d\tilde{B}_{t-1}}{\bar{\lambda}_z} - \frac{\tilde{B}}{\bar{\lambda}_z^2}d\lambda_{zt} + Nhd\tilde{W}_t + h\tilde{W}dN_t + N\tilde{W}dh_t.$$

$$\begin{aligned} & C_h \hat{C}_{ht} + \frac{\tilde{B}}{R}\left(\hat{B}_t - \hat{R}_t\right) + \tilde{Q}_l L_h \left(\hat{L}_{ht} - \hat{L}_{ht-1}\right) \\ = \; & \frac{\tilde{B}}{\bar{\lambda}_z}\left(\hat{B}_{t-1} - \hat{\lambda}_{zt}\right) + \tilde{W} N h \left(\hat{W}_t + \hat{N}_t + \hat{h}_t\right). \end{aligned}$$

(10) Household's bond Euler equation:

$$\hat{\Lambda}_{ht} = E_t\left(\hat{\Lambda}_{ht+1} - \hat{\lambda}_{z,t+1}\right) + \hat{R}_t.$$

(11) Household's housing Euler equation:

$$\begin{aligned} & \tilde{Q}_l d\tilde{\Lambda}_{ht} + \tilde{\Lambda}_h d\tilde{Q}_{lt} \\ = \; & MRS_l d\tilde{\Lambda}_{ht} + \tilde{\Lambda}_h dMRS_{lt} + \beta_h \tilde{Q}_l E_t d\tilde{\Lambda}_{ht+1} + \beta_h \tilde{\Lambda}_h E_t d\tilde{Q}_{l,t+1}, \end{aligned}$$

$$\begin{aligned} & \tilde{Q}_l \tilde{\Lambda}_h \left(\hat{\Lambda}_{ht} + \hat{Q}_{lt}\right) \\ = \; & MRS_l \tilde{\Lambda}_h \left(\hat{\Lambda}_{ht} + \widehat{MRS}_{ht}\right) + \beta_h \tilde{\Lambda}_h \tilde{Q}_l E_t \left(\hat{\Lambda}_{ht+1} + \hat{Q}_{l,t+1}\right), \end{aligned}$$

where

$$\widehat{MRS}_{ht} = \widehat{MUL}_t - \hat{\Lambda}_{ht}.$$

(12) Household's marginal utility of consumption:

$$\begin{aligned} d\tilde{\Lambda}_{ht} = \; & -\gamma L_h^{\varphi_L(1-\gamma)} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} \left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt}\right) \quad \text{(H.69)} \\ & + \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} (1-\gamma) L_h^{\varphi_L(1-\gamma)} \left(\varphi_L \frac{dL_{ht}}{L_h}\right) \\ & + \beta_h \eta_h \gamma L_h^{\varphi_L(1-\gamma)} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} E_t \left(d\tilde{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt+1}\right) \frac{1}{\bar{\lambda}_z} \\ & - \beta_h \eta_h \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} (1-\gamma) L_h^{\varphi_L(1-\gamma)} E_t \left(\varphi_L \frac{dL_{ht+1}}{L_h}\right) \frac{1}{\bar{\lambda}_z} \\ & + \beta_h \eta_h E_t \left[L_h^{(1-\gamma)\varphi_l} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\lambda_z}\right)^{-\gamma} \frac{d\lambda_{z,t+1}}{\lambda_z^2}\right], \end{aligned}$$

$$\begin{aligned} \tilde{\Lambda}_{ht} \hat{\Lambda}_{ht} = \; & -\gamma L_h^{\varphi_L(1-\gamma)} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} \left(\tilde{C}_h \hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} \tilde{C}_h \hat{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z} \hat{\lambda}_{zt}\right) \quad \text{(H.70)} \\ & + \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} (1-\gamma) L_h^{\varphi_L(1-\gamma)} \left(\bar{\varphi}_L \hat{L}_{ht}\right) \quad \text{(H.71)} \end{aligned}$$

$$+\beta_h \eta_h \gamma L_h^{\varphi_L(1-\gamma)} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} E_t \left(\tilde{C}_h \hat{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z} \tilde{C}_h \hat{C}_{ht} + \frac{\eta_h \tilde{C}_h}{\lambda_z} \hat{\lambda}_{zt+1}\right) \frac{1}{\bar{\lambda}_z} \tag{H.72}$$

$$-\beta_h \eta_h \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} (1-\gamma) L_h^{\varphi_L(1-\gamma)} E_t \left(\bar{\varphi}_L \hat{L}_{ht+1}\right) \frac{1}{\bar{\lambda}_z} \tag{H.73}$$

$$+\beta_h \eta_h E_t \left[L_h^{(1-\gamma)\varphi_l} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \frac{\hat{\lambda}_{z,t+1}}{\bar{\lambda}_z} \right]. \tag{H.74}$$

(13) Household's marginal utility of housing

$$\begin{aligned} d\widetilde{MUL}_t &= \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt}\right) \\ &\quad + \bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1} \left(\left(\bar{\varphi}_L (1-\gamma) - 1\right) \frac{dL_{ht}}{L_h}\right). \end{aligned}$$

$$\begin{aligned} \widetilde{MUL}\ \widehat{MUL}_t &= \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \left(\tilde{C}_h \hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} \tilde{C}_{ht-1} \hat{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z} d\hat{\lambda}_{zt}\right) \\ &\quad + \bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1} \left(\left(\bar{\varphi}_L (1-\gamma) - 1\right) \hat{L}_{ht}\right). \end{aligned}$$

(14) Matching function:

$$\hat{m}_t = \hat{\varphi}_{mt} + a\hat{u}_t + (1-a)\,\hat{v}_t.$$

(15) Job finding rate:

$$\hat{q}_t^u = \hat{m}_t - \hat{u}_t.$$

(16) Job filling rate:

$$\hat{q}_t^v = \hat{m}_t - \hat{v}_t.$$

(17) Employment dynamics:

$$dN_t = (1-\bar{\rho})\, dN_{t-1} + dm_t,$$

$$\hat{N}_t = (1-\bar{\rho})\, \hat{N}_{t-1} + \bar{\rho}\hat{m}_t.$$

(18) Number of searching workers:

$$du_t = -(1-\bar{\rho})\, dN_{t-1},$$

$$u\hat{u}_t = -(1-\bar{\rho})\, N\hat{N}_{t-1}.$$

(19) Aggregate production function:

$$\hat{Y}_t = \alpha \left[(1-\phi) \left(\hat{K}_{t-1} + \hat{e}_t - \hat{\lambda}_{zt}\right) + \phi \left(\hat{Z}_t^m + \hat{L}_{c,t-1}\right) \right] + (1-\alpha) \left(\hat{N}_t + \hat{h}_t + \hat{Z}_t^m\right).$$

(20) Capital rental rate:

$$\hat{R}_{kt} = \hat{Y}_t + \hat{\lambda}_{zt} - \hat{K}_{t-1} - \hat{e}_t.$$

(21) Land rental rate:

$$\hat{R}_{lt} = \hat{Y}_t - \hat{L}_{c,t-1}.$$

(22) Capital law of motion:

$$d\tilde{K}_t = (1-\delta)\, d\tilde{K}_{t-1}/\bar{\lambda}_z - (1-\delta)\, \tilde{K}/\bar{\lambda}_z^2 d\lambda_{zt} + dI_t + \tilde{I} d\varphi_{It},$$

$$\hat{K}_t = \frac{1-\delta}{\bar{\lambda}_z}\left(\hat{K}_{t-1} - \hat{\lambda}_{zt}\right) + \frac{\tilde{I}}{\tilde{K}}\left(\hat{I}_t + \hat{\varphi}_{It}\right).$$

(23) Aggregate resource constraint:

$$d\tilde{Y}_t = d\tilde{I}_t + d\tilde{C}_{ct} + d\tilde{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z} de_t + \kappa dv_t + d\tilde{G}_t,$$

$$\hat{Y}_t = \frac{\tilde{I}}{\tilde{Y}}\hat{I}_t + \frac{\tilde{C}_c}{\tilde{Y}}\hat{C}_{ct} + \frac{\tilde{C}_h}{\tilde{Y}}\hat{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z \tilde{Y}}\hat{e}_t + \frac{\kappa v}{\tilde{Y}}\hat{v}_t + \frac{\tilde{G}}{\tilde{Y}}\hat{G}_t.$$

(24) Housing market clearing condition:

$$L_c \hat{L}_{ct} + L_h \hat{L}_{ht} = 0.$$

(25) Optimal vacancy posting condition:

$$-\frac{\kappa}{(q^v)^2} dq_t^v = (1-\alpha)\frac{d\tilde{Y}_t}{N} - (1-\alpha)\frac{\tilde{Y}}{N^2} dN_t - hd\tilde{W}_t - \tilde{W} dh_t$$

$$+E_t \frac{\beta_c d\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v} - E_t \frac{\beta_c d\tilde{\Lambda}_{c,t}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v} - E_t \beta_c (1-\rho)\frac{\kappa}{(q^v)^2} dq_{t+1}^v$$

$$-\frac{\kappa}{q^v}\hat{q}_t^v = (1-\alpha)\frac{\tilde{Y}}{N}\left(\hat{Y}_t - \hat{N}_t\right) - \tilde{W}h\left(\hat{W}_t + \hat{h}_t\right)$$
$$+\beta_c (1-\bar{\rho})\frac{\kappa}{q^v} E_t\left(\hat{\Lambda}_{c,t+1} - \hat{\Lambda}_{c,t}\right) - \beta_c \frac{\kappa}{q^v} E_t (1-\bar{\rho})\, \hat{q}_{t+1}^v.$$

(26) Nash bargained wage:

$$\tilde{W}^{NB} h\left(\hat{W}_t^{NB} + \hat{h}_t\right) = \frac{h^{1+\nu} d\chi_t}{(1+\nu)\tilde{\Lambda}_h} + \frac{\chi h^\nu dh_t}{\tilde{\Lambda}_h} - \frac{h^{1+\nu}\chi d\tilde{\Lambda}_{ht}}{(1+\nu)\left(\tilde{\Lambda}_h\right)^2} + d\vartheta_t \frac{\kappa}{q^v} - \bar{\vartheta}\frac{\kappa dq_t^v}{(q^v)^2}$$

$$-\beta_h (1-\rho)(1-q^u)\,\bar{\vartheta}\frac{\kappa}{q^v} E_t\left[\hat{\Lambda}_{h,t+1} - \hat{\Lambda}_{h,t}\right] + \beta_h (1-\rho)\,\bar{\vartheta}\frac{\kappa}{q^v} E_t dq_{t+1}^u$$
$$+\beta_h (1-\rho)(1-q^u)\,\bar{\vartheta} E_t \frac{\kappa dq_{t+1}^v}{(q^v)^2}$$
$$-\beta_h (1-\rho)(1-q^u)\, d\vartheta_{t+1}\frac{\kappa}{q^v}$$

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB}+\hat{h}_t\right)=\frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h\left(1+\nu\right)}\left(\hat{\chi}_t+\left(1+\nu\right)\hat{h}_t-\hat{\Lambda}_{ht}\right)+\frac{\bar{\vartheta}\kappa}{q^v}\left(\hat{\vartheta}_t-\hat{q}_t^v\right)$$
$$-\beta_h\left(1-\bar{\rho}\right)\left(1-q^u\right)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1}-\hat{\Lambda}_{h,t}\right]+\beta_h\bar{\vartheta}\frac{\kappa}{q^v}\left(1-\rho\right)q^uE_t\hat{q}_{t+1}^u$$
$$-\beta_h\left(1-\rho\right)\left(1-q^u\right)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left(\hat{\vartheta}_{t+1}-\hat{q}_{t+1}^v\right)$$

(27) Wage rigidity:

$$\hat{W}_t=\psi\hat{W}_{t-1}+\left(1-\psi\right)\hat{W}_t^{NB}.$$

(28) Aggregate consumption:

$$\tilde{C}\hat{C}_t=\tilde{C}_c\hat{C}_{ct}+\tilde{C}_h\hat{C}_{ht}.$$

(29) Unemployment rate

$$U\hat{U}_t=-N\hat{N}_t.$$

(30) The value of the firm.

$$\hat{J}_t^F=-\hat{q}_t^v.$$

(31) The value of employment:

$$\tilde{J}_t^W=\tilde{W}_th_t-\frac{\chi_tg\left(h_t\right)}{\tilde{\Lambda}_{ht}}+E_t\frac{\beta_h\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}}\left[\left(1-\rho\left(1-q_{t+1}^u\right)\right)\left(\tilde{J}_{t+1}^W-\tilde{J}_{t+1}^U\right)+\tilde{J}_{t+1}^U\right]. \tag{H.75}$$

$$\tilde{J}^W\hat{J}_t^W=\tilde{W}h\left(\hat{W}_t+\hat{h}_t\right)-\frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h\left(1+\nu\right)}\left(\hat{\chi}_t+\left(1+\nu\right)\hat{h}_t-\hat{\Lambda}_{ht}\right)$$
$$+\beta_h\left[\left(1-\bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W+\bar{\rho}\left(1-q^u\right)\tilde{J}^U\right]E_t\left(\hat{\Lambda}_{ht+1}-\hat{\Lambda}_{ht}\right)$$
$$+\beta_hE_t\left[\left(1-\bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W\hat{J}_{t+1}^W+\bar{\rho}\left(1-q^u\right)\tilde{J}^U\hat{J}_{t+1}^U\right]+\beta_h\bar{\rho}q^u\left(\tilde{J}^W-\tilde{J}^U\right)E_t\hat{q}_{t+1}^u.$$

(32) The value of unemployment:

$$\tilde{J}_t^U=b+E_t\frac{\beta_h\tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}}\left[q_{t+1}^u\tilde{J}_{t+1}^W+(1-q_{t+1}^u)\tilde{J}_{t+1}^U\right]. \tag{H.76}$$

$$\tilde{J}^U\hat{J}_t^U=\beta_h\left[q^u\left(\tilde{J}^W-\tilde{J}^U\right)+\tilde{J}^U\right]E_t\left(\hat{\Lambda}_{ht+1}-\hat{\Lambda}_{ht}\right)$$
$$+\beta_hq^u\left(\tilde{J}^W-\tilde{J}^U\right)E_t\hat{q}_{t+1}^u+\beta_hE_t\left[q^u\tilde{J}^W\hat{J}_{t+1}^W+\left(1-q^u\right)\tilde{J}^U\hat{J}_{t+1}^U\right]$$

(33) Market tightness:

$$\hat{\theta}_t=\hat{v}_t-\hat{u}_t.$$

(34) Hours:

$$\frac{\chi_tg'(h_t)}{\Lambda_{ht}}=(1-\alpha)\frac{Y_t}{N_th_t}. \tag{H.77}$$
$$\hat{\chi}_t+\nu\hat{h}_t-\hat{\Lambda}_{ht}=\hat{Y}_t-\hat{N}_t-\hat{h}_t$$

I. The model without housing demand shocks but with shocks to the job separation rate

In this section, we replace the housing demand shock by a shock to the job separation rate. We assume that the job separation shock follows the stationary stochastic process

$$\ln \rho_t = (1-\rho_\rho)\bar{\rho} + \rho_\rho \ln \rho_{t-1} + \varepsilon_{\rho t},$$

where ρ_ρ is the persistent parameter and $\varepsilon_{\rho t}$ is an i.i.d white noise process with mean zero and variance σ_ρ^2.

The stationary equilibrium is summarized by a system of 34 equations for 34 variables $\tilde{\mu}_t$, Q_{kt}, $\tilde{Q}_{lt}$, $\tilde{B}_t$, γ_{It}, $\tilde{I}_t$, e_t, $\tilde{\Lambda}_{ct}$, $\tilde{C}_{ht}$, R_t, L_{ht}, $\tilde{\Lambda}_{ht}$, m_t, q_t^u, q_t^v, N_t, u_t, $\tilde{Y}_t$, R_{kt}, $\tilde{R}_{lt}$, $\tilde{K}_t$, $\tilde{C}_t$, L_{ct}, v_t, $\tilde{W}_t^{NB}$, $\tilde{S}_t$, $\tilde{W}_t$, $\tilde{C}_{ct}$, U_t, $\tilde{J}_t^F$, $\tilde{J}_t^W$, $\tilde{J}_t^U$, θ_t, and h_t. We write the equations in the same order as in the dynare code.

(1) Capitalist's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}}. \tag{I.1}$$

(2) Capitalist's capital Euler equation:

$$Q_{kt} = E_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} \left[R_{k,t+1} e_{t+1} - \Phi\left(e_{t+1}\right) + (1-\delta)\, Q_{k,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_2 \xi_t E_t Q_{k,t+1} \tag{I.2}$$

(3) Capitalist's land Euler equation:

$$\tilde{Q}_{lt} = E_t \beta_c \frac{\tilde{\Lambda}_{ct+1}}{\tilde{\Lambda}_{ct}} \left[\tilde{Q}_{l,t+1} + \tilde{R}_{l,t+1}\right] + \frac{\tilde{\mu}_t}{\tilde{\Lambda}_{ct}} \omega_1 \xi_t E_t \tilde{Q}_{l,t+1} \lambda_{z,t+1}. \tag{I.3}$$

(4) Borrowing constraint:

$$\tilde{B}_t = \xi_t \mathrm{E}_t \left(\omega_1 \tilde{Q}_{l,t+1} \lambda_{z,t+1} L_{ct} + \omega_2 Q_{k,t+1} \tilde{K}_t\right). \tag{I.4}$$

(5) Investment growth rate:

$$\frac{I_t}{I_{t-1}} \equiv \gamma_{It} = \frac{\tilde{I}_t}{\tilde{I}_{t-1}} \lambda_{zt}. \tag{I.5}$$

(6) Capitalist's investment Euler equation:

$$\begin{aligned} 1 &= Q_{kt}\varphi_{It}\left[1 - \frac{\Omega}{2}\left(\gamma_{It} - \bar{\gamma}_I\right)^2 - \Omega\left(\gamma_{It} - \bar{\gamma}_I\right)\gamma_{It}\right] \\ &+ \mathrm{E}_t \beta_c \frac{\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}\lambda_{z,t+1}} Q_{kt+1}\varphi_{I,t+1}\Omega\left(\gamma_{I,t+1} - \bar{\gamma}_I\right)\gamma_{I,t+1}^2. \end{aligned} \tag{I.6}$$

(7) Capacity utilization decision:

$$R_{kt} = \gamma_2\left(e_t - 1\right) + \gamma_1. \tag{I.7}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_{ct} = \frac{1}{\tilde{C}_{ct} - \eta_c \tilde{C}_{c,t-1}/\lambda_{zt}} - E_t \frac{\beta_c \eta_c}{\tilde{C}_{c,t+1}\lambda_{z,t+1} - \eta_c \tilde{C}_{ct}}. \tag{I.8}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_{ht} + \frac{\tilde{B}_t}{R_t} + \tilde{Q}_{lt}\left(L_{ht} - L_{h,t-1}\right) = \frac{\tilde{B}_{t-1}}{\lambda_{zt}} + \tilde{W}_t h_t N_t. \tag{I.9}$$

(10) Household's bond Euler equation:

$$\frac{1}{R_t} = E_t \beta_h \frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}\lambda_{z,t+1}}. \tag{I.10}$$

(11) Household's land Euler equation:

$$\tilde{Q}_{lt} = MRS_{lt} + E_t \beta_h \frac{\tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \tilde{Q}_{l,t+1}, \tag{I.11}$$

where the marginal rate of substituition between housing and consumption is given by

$$MRS_{lt} = \frac{\widetilde{MUL}_t}{\tilde{\Lambda}_{ht}}.$$

(12) Household's marginal utility of consumption

$$\begin{aligned} \tilde{\Lambda}_{ht} &= L_{ht}^{\varphi_L(1-\gamma)} \left(\tilde{C}_{ht} - \frac{\eta_h \tilde{C}_{h,t-1}}{\lambda_{zt}}\right)^{-\gamma} \\ &- \beta_h \eta_h E_t \left[L_{h,t+1}^{(1-\gamma)\varphi_L} \left(\tilde{C}_{h,t+1} - \frac{\eta_h \tilde{C}_{h,t}}{\lambda_{z,t+1}}\right)^{-\gamma} \frac{1}{\lambda_{z,t+1}} \right]. \end{aligned} \tag{I.12}$$

(13) Household's marginal utility of housing

$$\widetilde{MUL}_t = \varphi_L L_{ht}^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_{ht} - \eta_h \frac{\tilde{C}_{ht-1}}{\lambda_{zt}}\right)^{1-\gamma}. \tag{I.13}$$

(14) Matching function

$$m_t = \varphi_{mt} u_t^a v_t^{1-a}. \tag{I.14}$$

(15) Job finding rate

$$q_t^u = \frac{m_t}{u_t}. \tag{I.15}$$

(16) Vacancy filling rate

$$q_t^v = \frac{m_t}{v_t}. \tag{I.16}$$

(17) Employment dynamics:

$$N_t = \left(1 - \rho_t\right) N_{t-1} + m_t. \tag{I.17}$$

(18) Number of searching workers:

$$u_t = 1 - (1 - \rho_t) N_{t-1}. \tag{I.18}$$

(19) Aggregate production function:

$$\tilde{Y}_t = \left[(Z_t^m L_{c,t-1})^{\phi} \left(\frac{e_t \tilde{K}_{t-1}}{\lambda_{zt}} \right)^{1-\phi} \right]^{\alpha} (Z_t^m h_t N_t)^{1-\alpha}. \tag{I.19}$$

(20) Capital rental rate:

$$R_{kt} = \alpha (1 - \phi) \frac{\tilde{Y}_t \lambda_{zt}}{e_t \tilde{K}_{t-1}}. \tag{I.20}$$

(21) Land rental rate:

$$\tilde{R}_{lt} = \alpha \phi \frac{\tilde{Y}_t}{L_{c,t-1}}. \tag{I.21}$$

(22) Capital law of motion:

$$\tilde{K}_t = (1 - \delta) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \varphi_{It} \left[1 - \frac{\Omega}{2} (\gamma_{It} - \bar{\gamma}_I)^2 \right] \tilde{I}_t. \tag{I.22}$$

(23) Aggregate Resource constraint:

$$\tilde{C}_t + \tilde{I}_t + \tilde{G}_t + \Phi(e_t) \frac{\tilde{K}_{t-1}}{\lambda_{zt}} + \kappa v_t = \tilde{Y}_t. \tag{I.23}$$

(24) Land market clears (normalize aggregate supply of land to $\bar{L} = 1$):

$$L_{ct} + L_{ht} = 1. \tag{I.24}$$

(25) Optimal vacancy posting:

$$\frac{\kappa}{q_t^v} = (1 - \alpha) \frac{\tilde{Y}_t}{N_t} - \tilde{W}_t h_t + E_t \frac{\beta_c \tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}_{ct}} (1 - \rho_{t+1}) \frac{\kappa}{q_{t+1}^v}. \tag{I.25}$$

(26) Nash bargaining wage:

$$\tilde{W}_t^{NB} h_t = \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + b + \vartheta_t \frac{\kappa}{q_t^v} - E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[(1 - \rho_{t+1}) \left(1 - q_{t+1}^u\right) \vartheta_{t+1} \frac{\kappa}{q_{t+1}^v} \right], \tag{I.26}$$

where

$$g(h_t) = \frac{h_t^{1+\nu}}{1+\nu}, \;\; \nu \geq 0.$$

(27) Wage rigidity:

$$\tilde{W}_t = \psi \tilde{W}_{t-1} + (1 - \psi) \tilde{W}_t^{NB}. \tag{I.27}$$

(28) Aggregate consumption

$$\tilde{C}_t = \tilde{C}_{ht} + \tilde{C}_{ct}. \tag{I.28}$$

(29) Unemployment rate:

$$U_t = 1 - N_t. \tag{I.29}$$

(30) The value of the firm:

$$\tilde{J}_t^F = \frac{\kappa}{q_t^v}. \tag{I.30}$$

(31) The value of employment:

$$\tilde{J}_t^W = \tilde{W}_t h_t - \frac{\chi g(h_t)}{\tilde{\Lambda}_{ht}} + E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[\left(1 - \rho_{t+1}\left(1 - q_{t+1}^u\right)\right) \left(\tilde{J}_{t+1}^W - \tilde{J}_{t+1}^U \right) + \tilde{J}_{t+1}^U \right]. \tag{I.31}$$

(32) The value of unemployment:

$$\tilde{J}_t^U = b + E_t \frac{\beta_h \tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}} \left[q_{t+1}^u \tilde{J}_{t+1}^W + (1 - q_{t+1}^u) \tilde{J}_{t+1}^U \right]. \tag{I.32}$$

(33) Market tightness:

$$\theta_t = \frac{v_t}{u_t}. \tag{I.33}$$

(34) MRS for hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}} = (1 - \alpha) \frac{Y_t}{N_t h_t}. \tag{I.34}$$

I.1. **Steady state.**

(1) Shadow value of collateral:

$$\frac{\tilde{\mu}}{\tilde{\Lambda}_c} = \frac{\beta_h - \beta_c}{\bar{\lambda}_z}. \tag{I.35}$$

(2) Capital Euler equation

$$1 = \frac{\beta_c}{\bar{\lambda}_z}(R_k + 1 - \delta) + \bar{\xi}\omega_2 \frac{\tilde{\mu}}{\tilde{\Lambda}_c}. \tag{I.36}$$

(3) Capitalist's land Euler equation:

$$\left(1 - \beta_c - \bar{\xi}\omega_1 \frac{\tilde{\mu}}{\tilde{\Lambda}_c} \bar{\lambda}_z\right) \tilde{Q}_l = \beta_c \tilde{R}_l. \tag{I.37}$$

(4) Borrowing constraint:

$$\tilde{B} = \bar{\xi} \left(\omega_1 \tilde{Q}_l \bar{\lambda}_z L_c + \omega_2 \tilde{K} \right). \tag{I.38}$$

(5) Investment growth rate:

$$\bar{\gamma}_I = \bar{\lambda}_z. \tag{I.39}$$

(6) Investment Euler equation (Tobin's marginal q):

$$Q_k = \frac{1}{\bar{\varphi}_I} = 1. \tag{I.40}$$

(7) Capacity utilization

$$\gamma_1 = R_k. \tag{I.41}$$

(8) Capitalist's marginal utility

$$\tilde{\Lambda}_c = \frac{1}{\tilde{C}_c} \frac{\bar{\lambda}_z - \beta_c \eta_c}{\bar{\lambda}_z - \eta_c}. \tag{I.42}$$

(9) Household's flow-of-funds constraint:

$$\tilde{C}_h = \frac{1 - \beta_h}{\bar{\lambda}_z} \tilde{B} + \tilde{W} h N. \tag{I.43}$$

(10) Household's bond Euler equation:

$$R = \frac{\bar{\lambda}_z}{\beta_h}. \tag{I.44}$$

(11) Household's land Euler equation:

$$(1 - \beta_h) \tilde{Q}_l = MRS_l. \tag{I.45}$$

(12) Household's marginal utility of consumption

$$\tilde{\Lambda}_h = \left[1 - \frac{\beta_h \eta_h}{\bar{\lambda}_z} \right] L_h^{\bar{\varphi}_L (1-\gamma)} \tilde{C}_h^{-\gamma} \left(1 - \frac{\eta_h}{\bar{\lambda}_z} \right)^{-\gamma}. \tag{I.46}$$

(13) Household's marginal rate of substitution between housing and non-housing consumption

$$MRS_l = \frac{\bar{\varphi}_L \tilde{C}_h}{L_h} \frac{\bar{\lambda}_z - \eta_h}{\bar{\lambda}_z - \beta_h \eta_h}. \tag{I.47}$$

(14) Matching function

$$m = \bar{\varphi}_m u^a v^{1-a}. \tag{I.48}$$

(15) Job finding rate

$$q^u = \frac{m}{u}. \tag{I.49}$$

(16) Vacancy filling rate

$$q^v = \frac{m}{v}. \tag{I.50}$$

(17) Employment dynamics:

$$\bar{\rho} N = m. \tag{I.51}$$

(18) Number of searching workers:

$$u = 1 - (1 - \bar{\rho}) N. \tag{I.52}$$

(19) Aggregate production function:

$$\tilde{Y} = \left[(Z^m L_c)^{\phi} \left(\frac{\tilde{K}}{\bar{\lambda}_z} \right)^{1-\phi} \right]^{\alpha} (\bar{Z}^m N h)^{1-\alpha}. \tag{I.53}$$

(20) Capital rental rate:

$$R_k = \alpha(1-\phi)\frac{\tilde{Y}\bar{\lambda}_z}{\tilde{K}}. \tag{I.54}$$

(21) Land rental rate:

$$\tilde{R}_l = \alpha\phi\frac{\tilde{Y}}{L_c}. \tag{I.55}$$

(22) Capital law of motion:

$$\frac{\tilde{I}}{\tilde{K}} = 1 - \frac{1-\delta}{\bar{\lambda}_z}. \tag{I.56}$$

(23) Aggregate Resource constraint:

$$\tilde{C} + \tilde{I} + \tilde{G} + \kappa v = \tilde{Y}. \tag{I.57}$$

(24) Land market clear

$$L_c + L_h = 1. \tag{I.58}$$

(25) Optimal vacancy posting:

$$[1-(1-\bar{\rho})\beta_c]\,\frac{\kappa}{q^v} = (1-\alpha)\frac{\tilde{Y}}{N} - \tilde{W}h. \tag{I.59}$$

(26) Nash bargaining wage:

$$\tilde{W}^{NB}h = \frac{\chi g(h)}{\tilde{\Lambda}_h} + b + \bar{\vartheta}\frac{\kappa}{q^v}\left[1-\beta_h(1-\bar{\rho})(1-q^u)\right]. \tag{I.60}$$

(27) Wage rigidity:

$$\tilde{W} = \tilde{W}^{NB}. \tag{I.61}$$

(28) Aggregate consumption

$$\tilde{C} = \tilde{C}_h + \tilde{C}_c. \tag{I.62}$$

(29) Unemployment rate:

$$U = 1 - N. \tag{I.63}$$

(30) The value of the firm:

$$\tilde{J}^F = \frac{\kappa}{q^v}. \tag{I.64}$$

(31) The value of employment:

$$[1-\beta_h[1-\bar{\rho}(1-q^u)]\tilde{J}^W = \tilde{W}h - \frac{\bar{\chi}g(h)}{\tilde{\Lambda}_h} + \beta_h\bar{\rho}(1-q^u)\tilde{J}^U. \tag{I.65}$$

(32) The value of unemployment:

$$[1-\beta_h(1-q^u)]\tilde{J}^U = b + \beta_h q^u\tilde{J}^W. \tag{I.66}$$

(33) Market tightness:

$$\theta = \frac{v}{u}. \tag{I.67}$$

(34) MRS for hours:

$$\frac{\bar{\chi}g'(h)}{\Lambda_h} = (1-\alpha)\frac{Y}{Nh}. \tag{I.68}$$

I.2. **Log-linearized system.** We use $\hat{X}_t$ to denote percentage deviation from the deterministic steady state $\tilde{X}$ for any detrended variable $\tilde{X}_t$. The log-linearized system for the detrended system is given below.

(1) Capitalist's bond Euler equation:

$$\begin{aligned} d\tilde{\Lambda}_{ct} &= \frac{\beta_c R}{\bar{\lambda}_z} E_t d\Lambda_{ct+1} + \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z} dR_t - \frac{\beta_c R \tilde{\Lambda}_c}{\bar{\lambda}_z^2} E_t d\lambda_{z,t+1} \\ & \quad + R d\tilde{\mu}_t + \tilde{\mu} dR_t, \end{aligned}$$

$$\hat{\Lambda}_{ct} = \frac{\beta_c R}{\bar{\lambda}_z}\left(E_t \hat{\Lambda}_{ct+1} + \hat{R}_t - E_t \hat{\lambda}_{z,t+1}\right) + \frac{R\tilde{\mu}}{\tilde{\Lambda}_c}\left(\hat{\mu}_t + \hat{R}_t\right).$$

(2) Capitalist's capital Euler equation:

$$\begin{aligned} & \tilde{\Lambda}_c dQ_{kt} + Q_k d\tilde{\Lambda}_{ct} \\ = & \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z} E_t \left[dR_{kt+1} + R_k de_{t+1} - \gamma_1 de_{t+1} + (1-\delta) dQ_{kt+1} \right] \\ & + \frac{\beta_c}{\bar{\lambda}_z} E_t d\tilde{\Lambda}_{ct+1} \left[R_k + (1-\delta) Q_k \right] \\ & - \frac{\beta_c \tilde{\Lambda}_c}{\bar{\lambda}_z^2} E_t d\lambda_{z,t+1} \left[R_k + (1-\delta) Q_k \right] \\ & + \omega_2 \xi Q_k d\tilde{\mu}_t + \omega_2 d\xi_t Q_k \tilde{\mu} + \omega_2 \xi \tilde{\mu} E_t dQ_{k,t+1}, \end{aligned}$$

$$\begin{aligned} & Q_k \hat{Q}_{kt} + Q_k \hat{\Lambda}_{ct} \\ = & \frac{\beta_c}{\bar{\lambda}_z} E_t \left[R_k \left(\hat{R}_{kt+1} + \hat{e}_{t+1} \right) - \gamma_1 \hat{e}_{t+1} + (1-\delta) Q_k \hat{Q}_{kt+1} \right] \\ & + \frac{\beta_c}{\bar{\lambda}_z} \left[R_k + (1-\delta) Q_k \right] E_t \left(\hat{\Lambda}_{ct+1} - \hat{\lambda}_{z,t+1} \right) \\ & + \omega_2 \bar{\xi} Q_k \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{k,t+1} \right). \end{aligned}$$

(3) Capital's housing Euler equation:

$$\begin{aligned} & \tilde{Q}_l d\tilde{\Lambda}_{ct} + \tilde{\Lambda}_c d\tilde{Q}_{lt} \\ = & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) E_t d\tilde{\Lambda}_{ct+1} + \beta_c \tilde{\Lambda}_c E_t \left(d\tilde{Q}_{l,t+1} + d\tilde{R}_{l,t+1} \right) \\ & + \omega_1 \left(\bar{\lambda}_z \bar{\xi} \tilde{Q}_l d\tilde{\mu}_t + \bar{\lambda}_z \tilde{\mu} \tilde{Q}_l d\xi_t + \bar{\lambda}_z \bar{\xi} \tilde{\mu} E_t d\tilde{Q}_{l,t+1} + \bar{\xi} \tilde{Q}_l \tilde{\mu} E_t d\lambda_{z,t+1} \right) \end{aligned}$$

$$\begin{aligned}
& \tilde{Q}_l \tilde{\Lambda}_c \left(\hat{\Lambda}_{ct} + \hat{Q}_{lt} \right) \\
= \; & \beta_c \left(\tilde{Q}_l + \tilde{R}_l \right) \tilde{\Lambda}_c E_t \hat{\Lambda}_{c,t+1} + \beta_c \tilde{\Lambda}_c E_t \left(\tilde{Q}_l \hat{Q}_{l,t+1} + \tilde{R}_l \hat{R}_{l,t+1} \right) \\
& + \omega_1 \bar{\lambda}_z \bar{\xi} \tilde{Q}_l \tilde{\mu} \left(\hat{\mu}_t + \hat{\xi}_t + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right).
\end{aligned}$$

(4) Capitalist's binding borrowing constraint:

$$\begin{aligned}
d\tilde{B}_t \;=\; & \left(\omega_1 \tilde{Q}_l \lambda_z L_c + \omega_2 Q_k \tilde{K} \right) d\xi_t \\
& + \xi \omega_1 E_t \left(\lambda_z L_c d\tilde{Q}_{l,t+1} + \tilde{Q}_l \lambda_z dL_{ct} + \tilde{Q}_l d\lambda_{z,t+1} L_c \right) \\
& + \xi \omega_2 \left(\tilde{K} E_t dQ_{k,t+1} + Q_k d\tilde{K}_t \right)
\end{aligned}$$

$$\begin{aligned}
\hat{B}_t \;=\; & \hat{\xi}_t + \frac{\omega_1 \bar{\xi} \tilde{Q}_l \lambda_z L_c}{\tilde{B}} \left(\hat{L}_{ct} + E_t \hat{Q}_{l,t+1} + E_t \hat{\lambda}_{z,t+1} \right) \\
& + \frac{\omega_2 \bar{\xi} Q_k \tilde{K}}{\tilde{B}} \left(\hat{K}_t + E_t \hat{Q}_{k,t+1} \right).
\end{aligned}$$

(5) Investment growth rate:

$$\hat{\gamma}_{It} + \hat{I}_{t-1} = \hat{I}_t + \hat{\lambda}_{zt}.$$

(6) Capitalist's investment Euler equation:

$$0 = dQ_{kt} + d\varphi_{It} - \Omega \bar{\gamma}_I d\gamma_{It} + E_t \frac{\beta_c}{\bar{\lambda}_z} \Omega \bar{\gamma}_I^2 d\gamma_{It+1},$$

$$\hat{Q}_{kt} + \hat{\varphi}_{It} = \Omega \bar{\gamma}_I^2 \left(\hat{\gamma}_{It} - \frac{\beta_c}{\bar{\lambda}_z} \bar{\gamma}_I \hat{\gamma}_{I,t+1} \right).$$

(7) Capitalist's capacity utilization decision:

$$R_k \hat{R}_{kt} = \gamma_2 \hat{e}_t.$$

(8) Capitalist's marginal utility:

$$\begin{aligned}
d\tilde{\Lambda}_{ct} \;=\; & \frac{-d\tilde{C}_{ct} + \eta_c d\tilde{C}_{ct-1}/\bar{\lambda}_z - \eta_c \tilde{C}_c d\lambda_{z,t}/\bar{\lambda}_z^2}{\left(\tilde{C}_c \left(1 - \eta_c/\bar{\lambda}_z \right) \right)^2} \\
& - \beta_c \eta_c E_t \frac{-\bar{\lambda}_z d\tilde{C}_{ct+1} - \tilde{C}_c d\lambda_{z,t+1} + \eta_c d\tilde{C}_{ct}}{\left(\tilde{C}_c \left(\bar{\lambda}_z - \eta_c \right) \right)^2},
\end{aligned}$$

$$\begin{aligned}\tilde{\Lambda}_c\hat{\Lambda}_{ct} &= \frac{-\hat{C}_{ct}+\eta_c/\bar{\lambda}_z\left(\hat{C}_{c,t-1}-\hat{\lambda}_{zt}\right)}{\tilde{C}_c\left(1-\eta_c/\bar{\lambda}_z\right)^2} \\ &\quad -\beta_c\eta_c E_t\frac{-\bar{\lambda}_z\left(\hat{C}_{c,t+1}+\hat{\lambda}_{z,t+1}\right)+\eta_c\hat{C}_{ct}}{\tilde{C}_c\left(\bar{\lambda}_z-\eta_c\right)^2}.\end{aligned}$$

(9) Household's flow of funds constraint:

$$\begin{aligned}& d\tilde{C}_{ht}+\frac{d\tilde{B}_t}{R}-\frac{\tilde{B}dR_t}{R^2}+\tilde{Q}_l\left(dL_{ht}-dL_{h,t-1}\right) \\ = \; & \frac{d\tilde{B}_{t-1}}{\bar{\lambda}_z}-\frac{\tilde{B}}{\bar{\lambda}_z^2}d\lambda_{zt}+Nhd\tilde{W}_t+h\tilde{W}dN_t+N\tilde{W}dh_t.\end{aligned}$$

$$\begin{aligned}& C_h\hat{C}_{ht}+\frac{\tilde{B}}{R}\left(\hat{B}_t-\hat{R}_t\right)+\tilde{Q}_lL_h\left(\hat{L}_{ht}-\hat{L}_{ht-1}\right) \\ = \; & \frac{\tilde{B}}{\bar{\lambda}_z}\left(\hat{B}_{t-1}-\hat{\lambda}_{zt}\right)+\tilde{W}Nh\left(\hat{W}_t+\hat{N}_t+\hat{h}_t\right).\end{aligned}$$

(10) Household's bond Euler equation:

$$\hat{\Lambda}_{ht}=E_t\left(\hat{\Lambda}_{ht+1}-\hat{\lambda}_{z,t+1}\right)+\hat{R}_t.$$

(11) Household's housing Euler equation:

$$\begin{aligned}& \tilde{Q}_ld\tilde{\Lambda}_{ht}+\tilde{\Lambda}_hd\tilde{Q}_{lt} \\ = \; & MRS_ld\tilde{\Lambda}_{ht}+\tilde{\Lambda}_hdMRS_{lt}+\beta_h\tilde{Q}_lE_td\tilde{\Lambda}_{ht+1}+\beta_h\tilde{\Lambda}_hE_td\tilde{Q}_{l,t+1},\end{aligned}$$

$$\begin{aligned}& \tilde{Q}_l\tilde{\Lambda}_h\left(\hat{\Lambda}_{ht}+\hat{Q}_{lt}\right) \\ = \; & MRS_l\tilde{\Lambda}_h\left(\hat{\Lambda}_{ht}+\widehat{MRS}_{ht}\right)+\beta_h\tilde{\Lambda}_h\tilde{Q}_lE_t\left(\hat{\Lambda}_{ht+1}+\hat{Q}_{l,t+1}\right),\end{aligned}$$

where

$$\widehat{MRS}_{ht}=\widehat{MUL}_t-\hat{\Lambda}_{ht}.$$

(12) Household's marginal utility of consumption:

$$
\begin{aligned}
d\tilde{\Lambda}_{ht} \quad = \quad & -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt}\right) \qquad \text{(I.69)} \\
& + \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma) L_h^{\varphi_L(1-\gamma)}\left(\varphi_L \frac{dL_{ht}}{L_h}\right) \\
& + \beta_h \eta_h \gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} E_t\left(d\tilde{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt+1}\right)\frac{1}{\bar{\lambda}_z} \\
& - \beta_h \eta_h \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma) L_h^{\varphi_L(1-\gamma)} E_t\left(\varphi_L \frac{dL_{ht+1}}{L_h}\right)\frac{1}{\bar{\lambda}_z} \\
& + \beta_h \eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\lambda_z}\right)^{-\gamma}\frac{d\lambda_{z,t+1}}{\lambda_z^2}\right],
\end{aligned}
$$

$$
\begin{aligned}
\tilde{\Lambda}_{ht}\hat{\Lambda}_{ht} \quad = \quad & -\gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1}\left(\tilde{C}_h\hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt}\right) \qquad \text{(I.70)} \\
& + \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma) L_h^{\varphi_L(1-\gamma)}\left(\bar{\varphi}_L \hat{L}_{ht}\right) \qquad \text{(I.71)}
\end{aligned}
$$

$$
\begin{aligned}
& + \beta_h \eta_h \gamma L_h^{\varphi_L(1-\gamma)}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma-1} E_t\left(\tilde{C}_h\hat{C}_{ht+1} - \frac{\eta_h}{\bar{\lambda}_z}\tilde{C}_h\hat{C}_{ht} + \frac{\eta_h \tilde{C}_h}{\lambda_z}\hat{\lambda}_{zt+1}\right)\frac{1}{\bar{\lambda}_z} \qquad \text{(I.72)} \\
& - \beta_h \eta_h \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}(1-\gamma) L_h^{\varphi_L(1-\gamma)} E_t\left(\bar{\varphi}_L \hat{L}_{ht+1}\right)\frac{1}{\bar{\lambda}_z} \qquad \text{(I.73)} \\
& + \beta_h \eta_h E_t\left[L_h^{(1-\gamma)\varphi_l}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\frac{\hat{\lambda}_{z,t+1}}{\bar{\lambda}_z}\right]. \qquad \text{(I.74)}
\end{aligned}
$$

(13) Household's marginal utility of housing

$$
\begin{aligned}
d\widetilde{MUL}_t \quad = \quad & \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1}\left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma}\left(d\tilde{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} d\tilde{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\lambda_z^2} d\lambda_{zt}\right) \\
& + \bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1}\left(\left(\bar{\varphi}_L (1-\gamma) - 1\right)\frac{dL_{ht}}{L_h}\right).
\end{aligned}
$$

$$\widetilde{MUL}\ \widehat{MUL}_t = \bar{\varphi}_L (1-\gamma) L_h^{\varphi_L(1-\gamma)-1} \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{-\gamma} \left(\tilde{C}_h \hat{C}_{ht} - \frac{\eta_h}{\bar{\lambda}_z} \tilde{C}_{ht-1} \hat{C}_{ht-1} + \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z} d\hat{\lambda}_{zt}\right)$$
$$+\bar{\varphi}_L \left(\tilde{C}_h - \frac{\eta_h \tilde{C}_h}{\bar{\lambda}_z}\right)^{1-\gamma} L_h^{\varphi_L(1-\gamma)-1} \left(\left(\bar{\varphi}_L (1-\gamma) - 1\right) \hat{L}_{ht}\right).$$

(14) Matching function:

$$\hat{m}_t = \hat{\varphi}_{mt} + a\hat{u}_t + (1-a)\hat{v}_t.$$

(15) Job finding rate:

$$\hat{q}_t^u = \hat{m}_t - \hat{u}_t.$$

(16) Job filling rate:

$$\hat{q}_t^v = \hat{m}_t - \hat{v}_t.$$

(17) Employment dynamics:

$$dN_t = (1-\bar{\rho})\, dN_{t-1} - N d\rho_t + dm_t,$$
$$\hat{N}_t = (1-\bar{\rho})\, \hat{N}_{t-1} + \bar{\rho}\left(\hat{m}_t - \hat{\rho}_t\right).$$

(18) Number of searching workers:

$$du_t = -(1-\bar{\rho})\, dN_{t-1} + N d\rho_t,$$
$$u\hat{u}_t = -(1-\bar{\rho})\, N\hat{N}_{t-1} + N\bar{\rho}\hat{\rho}_t.$$

(19) Aggregate production function:

$$\hat{Y}_t = \alpha\left[(1-\phi)\left(\hat{K}_{t-1} + \hat{e}_t - \hat{\lambda}_{zt}\right) + \phi\left(\hat{Z}_t^m + \hat{L}_{c,t-1}\right)\right] + (1-\alpha)\left(\hat{N}_t + \hat{h}_t + \hat{Z}_t^m\right).$$

(20) Capital rental rate:

$$\hat{R}_{kt} = \hat{Y}_t + \hat{\lambda}_{zt} - \hat{K}_{t-1} - \hat{e}_t.$$

(21) Land rental rate:

$$\hat{R}_{lt} = \hat{Y}_t - \hat{L}_{c,t-1}.$$

(22) Capital law of motion:

$$d\tilde{K}_t = (1-\delta)\, d\tilde{K}_{t-1}/\bar{\lambda}_z - (1-\delta)\, \tilde{K}/\bar{\lambda}_z^2 d\lambda_{zt} + dI_t + \tilde{I} d\varphi_{It},$$
$$\hat{K}_t = \frac{1-\delta}{\bar{\lambda}_z}\left(\hat{K}_{t-1} - \hat{\lambda}_{zt}\right) + \frac{\tilde{I}}{\tilde{K}}\left(\hat{I}_t + \hat{\varphi}_{It}\right).$$

(23) Aggregate resource constraint:

$$d\tilde{Y}_t = d\tilde{I}_t + d\tilde{C}_{ct} + d\tilde{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z} de_t + \kappa dv_t + d\tilde{G}_t,$$
$$\hat{Y}_t = \frac{\tilde{I}}{\tilde{Y}}\hat{I}_t + \frac{\tilde{C}_c}{\tilde{Y}}\hat{C}_{ct} + \frac{\tilde{C}_h}{\tilde{Y}}\hat{C}_{ht} + \frac{\tilde{K}\gamma_1}{\bar{\lambda}_z \tilde{Y}}\hat{e}_t + \frac{\kappa v}{\tilde{Y}}\hat{v}_t + \frac{\tilde{G}}{\tilde{Y}}\hat{G}_t.$$

(24) Housing market clearing condition:

$$L_c \hat{L}_{ct} + L_h \hat{L}_{ht} = 0.$$

(25) Optimal vacancy posting condition:

$$-\frac{\kappa}{(q^v)^2} dq_t^v = (1-\alpha)\frac{d\tilde{Y}_t}{N} - (1-\alpha)\frac{\tilde{Y}}{N^2} dN_t - h d\tilde{W}_t - \tilde{W} dh_t$$

$$+E_t \frac{\beta_c d\tilde{\Lambda}_{c,t+1}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v} - E_t \frac{\beta_c d\tilde{\Lambda}_{c,t}}{\tilde{\Lambda}}(1-\rho)\frac{\kappa}{q^v}$$
$$-E_t \beta_c d\rho_{t+1}\frac{\kappa}{q^v} - E_t \beta_c (1-\rho)\frac{\kappa}{(q^v)^2} dq_{t+1}^v$$

$$-\frac{\kappa}{q^v}\hat{q}_t^v = (1-\alpha)\frac{\tilde{Y}}{N}\left(\hat{Y}_t - \hat{N}_t\right) - \tilde{W}h\left(\hat{W}_t + \hat{h}_t\right)$$
$$+\beta_c(1-\bar{\rho})\frac{\kappa}{q^v}E_t\left(\hat{\Lambda}_{c,t+1} - \hat{\Lambda}_{c,t}\right) - \beta_c \frac{\kappa}{q^v}E_t\left[\bar{\rho}\hat{\rho}_{t+1} + (1-\bar{\rho})\hat{q}_{t+1}^v\right]$$

(26) Nash bargained wage:

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB} + \hat{h}_t\right) = \frac{\chi h^\nu dh_t}{\tilde{\Lambda}_h} - \frac{h^{1+\nu}\chi d\tilde{\Lambda}_{ht}}{(1+\nu)\left(\tilde{\Lambda}_h\right)^2} + d\vartheta_t \frac{\kappa}{q^v} - \bar{\vartheta}\frac{\kappa dq_t^v}{(q^v)^2}$$

$$-\beta_h(1-\rho)(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1} - \hat{\Lambda}_{h,t}\right]$$
$$+\beta_h(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t d\rho_{t+1} + \beta_h(1-\rho)\bar{\vartheta}\frac{\kappa}{q^v}E_t dq_{t+1}^u$$
$$+\beta_h(1-\rho)(1-q^u)\bar{\vartheta}E_t\frac{\kappa dq_{t+1}^v}{(q^v)^2}$$
$$-\beta_h(1-\rho)(1-q^u)d\vartheta_{t+1}\frac{\kappa}{q^v}$$

$$\tilde{W}^{NB}h\left(\hat{W}_t^{NB} + \hat{h}_t\right) = \frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h(1+\nu)}\left((1+\nu)\hat{h}_t - \hat{\Lambda}_{ht}\right) + \frac{\bar{\vartheta}\kappa}{q^v}\left(\hat{\vartheta}_t - \hat{q}_t^v\right)$$

$$-\beta_h(1-\bar{\rho})(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left[\hat{\Lambda}_{h,t+1} - \hat{\Lambda}_{h,t}\right]$$
$$+\beta_h\bar{\vartheta}\frac{\kappa}{q^v}(1-q^u)\rho E_t\hat{\rho}_{t+1} + \beta_h\bar{\vartheta}\frac{\kappa}{q^v}(1-\rho)q^u E_t\hat{q}_{t+1}^u$$
$$-\beta_h(1-\rho)(1-q^u)\bar{\vartheta}\frac{\kappa}{q^v}E_t\left(\hat{\vartheta}_{t+1} - \hat{q}_{t+1}^v\right)$$

(27) Wage rigidity:

$$\hat{W}_t = \psi\hat{W}_{t-1} + (1-\psi)\hat{W}_t^{NB}.$$

(28) Aggregate consumption:

$$\tilde{C}\hat{C}_t = \tilde{C}_c\hat{C}_{ct} + \tilde{C}_h\hat{C}_{ht}.$$

(29) Unemployment rate

$$U\hat{U}_t = -N\hat{N}_t.$$

(30) The value of the firm.

$$\hat{J}^F_t = -\hat{q}^v_t.$$

(31) The value of employment:

$$\tilde{J}^W_t = \tilde{W}_t h_t - \frac{\chi g\left(h_t\right)}{\tilde{\Lambda}_{ht}} + E_t \frac{\beta_h \tilde{\Lambda}_{h,t+1}}{\tilde{\Lambda}_{ht}} \left[\left(1 - \rho_{t+1}\left(1 - q^u_{t+1}\right)\right)\left(\tilde{J}^W_{t+1} - \tilde{J}^U_{t+1}\right) + \tilde{J}^U_{t+1}\right]. \quad \text{(I.75)}$$

$$\begin{aligned}
\tilde{J}^W \hat{J}^W_t = {} & \tilde{W}h\left(\hat{W}_t + \hat{h}_t\right) - \frac{\chi h^{1+\nu}}{\tilde{\Lambda}_h\left(1+\nu\right)}\left(\left(1+\nu\right)\hat{h}_t - \hat{\Lambda}_{ht}\right) \\
& + \beta_h\left[\left(1 - \bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W + \bar{\rho}\left(1-q^u\right)\tilde{J}^U\right] E_t\left(\hat{\Lambda}_{ht+1} - \hat{\Lambda}_{ht}\right) \\
& + \beta_h E_t\left[\left(1 - \bar{\rho}\left(1-q^u\right)\right)\tilde{J}^W \hat{J}^W_{t+1} + \bar{\rho}\left(1-q^u\right)\tilde{J}^U \hat{J}^U_{t+1}\right] \\
& - \beta_h\left(1-q^u\right)\left(\tilde{J}^W - \tilde{J}^U\right)\bar{\rho}E_t\hat{\rho}_{t+1} + \beta_h\bar{\rho}q^u\left(\tilde{J}^W - \tilde{J}^U\right)E_t\hat{q}^u_{t+1}.
\end{aligned}$$

(32) The value of unemployment:

$$\tilde{J}^U_t = b + E_t \frac{\beta_h \tilde{\Lambda}_{ht+1}}{\tilde{\Lambda}_{ht}}\left[q^u_{t+1}\tilde{J}^W_{t+1} + (1 - q^u_{t+1})\tilde{J}^U_{t+1}\right]. \quad \text{(I.76)}$$

$$\begin{aligned}
\tilde{J}^U \hat{J}^U_t = {} & \beta_h\left[q^u\left(\tilde{J}^W - \tilde{J}^U\right) + \tilde{J}^U\right] E_t\left(\hat{\Lambda}_{ht+1} - \hat{\Lambda}_{ht}\right) \\
& + \beta_h q^u\left(\tilde{J}^W - \tilde{J}^U\right)E_t\hat{q}^u_{t+1} + \beta_h E_t\left[q^u \tilde{J}^W \hat{J}^W_{t+1} + \left(1-q^u\right)\tilde{J}^U \hat{J}^U_{t+1}\right]
\end{aligned}$$

(33) Market tightness:

$$\hat{\theta}_t = \hat{v}_t - \hat{u}_t.$$

(34) Hours:

$$\frac{\chi g'(h_t)}{\Lambda_{ht}} = (1-\alpha)\frac{Y_t}{N_t h_t}. \quad \text{(I.77)}$$

$$\nu\hat{h}_t - \hat{\Lambda}_{ht} = \hat{Y}_t - \hat{N}_t - \hat{h}_t$$

Table 1. Prior distributions of structural parameters

Description	Parameter	Distribution	a	b	Low	High
Habit (capitalist)	η_c	Beta(a,b)	1.00	2.00	0.025	0.776
Habit (worker)	η_h	Beta(a,b)	1.00	2.00	0.025	0.776
Investment adjustment costs	Ω	Gamma(a,b)	1.00	0.30	0.171	10.00
Capacity utilization (curvature)	γ_2	Gamma(a,b)	1.00	0.30	0.171	10.00
Inverse Frisch elasticity (hours)	ν_h	Gamma(a,b)	1.00	0.60	0.086	5.000
Weight of capital value	ω_2	Gamma(a,b)	1.00	1.00	0.048	2.821
Output growth	$100(\lambda_z - 1)$	Gamma(a,b)	1.86	3.01	0.100	1.500
Depreciation rate	δ	Simulated			0.043	0.051
Worker's discount	β_h	Simulated			0.991	0.999
Capitalist's discount	β_c	Simulated			0.968	0.997
Land share	ϕ	Simulated			0.032	0.085
Capacity utilization (slope)	γ_1	Simulated			0.060	0.064
Housing demand	φ_L	Simulated			0.003	0.031
Disutility of labor hours	χ	Simulated			0.014	0.527

Note: "Low" and "high" denotes the bounds of the 90% probability interval for each parameter.

Table 2. Prior distributions of shock parameters

Description	Parameter	Distribution	a	b	Low	High
Persist: Housing demand	ρ_L	Gamma(a,b)	1.0	2.0	0.025	0.776
Persist: Wage bargaining	ρ_ϑ	Gamma(a,b)	1.0	2.0	0.025	0.776
Persist: Matching efficiency	ρ_m	Gamma(a,b)	1.0	2.0	0.025	0.776
Persist: Permanent technology	ρ_{zp}	Gamma(a,b)	1.0	2.0	0.025	0.776
Persist: Stationary technology	ρ_{zm}	Gamma(a,b)	1.0	2.0	0.025	0.776
Persist: Credit constraint	ρ_ξ	Gamma(a,b)	1.0	2.0	0.025	0.776
Std Dev: Housing demand	σ_L	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000
Std Dev: Wage bargaining	σ_ϑ	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000
Std Dev: Matching efficiency	σ_m	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000
Std Dev: Permanent technology	σ_{zp}	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000
Std Dev: Stationary technology	σ_{zm}	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000
Std Dev: Credit constraint	σ_ξ	Inv-Gam(a,b)	0.326	1.45e04	1.00e-04	2.000

Note: "Low" and "high" denotes the bounds of the 90% probability interval for each parameter.

TABLE 3. Prior and posterior distributions of structural parameters

	Prior			Posterior		
Parameter	Distribution	low	high	Mode	Low	High
η_c	Beta	0.025	0.776	0.996	0.988	0.997
η_h	Beta	0.025	0.776	0.166	0.048	0.329
Ω	Gamma	0.171	10.00	0.114	0.084	0.170
γ_2	Gamma	0.171	10.00	0.729	0.410	1.611
ν	Gamma	0.086	5.000	0.001	0.000	0.006
ω_2	Gamma	0.048	2.821	0.099	0.089	0.127
$100(\lambda_z - 1)$	Gamma	0.100	1.500	0.478	0.435	0.538
δ	Simulated	0.043	0.051	0.050	0.049	0.050
β_h	Simulated	0.991	0.999	0.995	0.994	0.995
β_c	Simulated	0.968	0.997	0.991	0.991	0.992
ϕ	Simulated	0.032	0.085	0.046	0.043	0.048
γ_1	Simulated	0.060	0.064	0.063	0.063	0.063
φ_L	Simulated	0.003	0.031	0.019	0.017	0.021
χ	Simulated	0.014	0.527	0.301	0.263	0.374

Note: "Low" and "high" denotes the bounds of the 90% probability interval for each parameter.

Table 4. Prior and posterior distributions of shock parameters

	Prior			Posterior		
Parameter	Distribution	low	high	Mode	Low	High
ρ_L	Beta	0.025	0.776	0.998	0.995	0.999
ρ_ϑ	Beta	0.025	0.776	0.966	0.947	0.986
ρ_m	Beta	0.025	0.776	0.983	0.962	0.992
ρ_{zp}	Beta	0.025	0.776	0.217	0.107	0.330
ρ_{zm}	Beta	0.025	0.776	0.952	0.929	0.960
ρ_ξ	Beta	0.025	0.776	0.966	0.957	0.985
σ_L	Inv-Gamma	1.00e-04	2.000	0.077	0.070	0.122
σ_ϑ	Inv-Gamma	1.00e-04	2.000	0.039	0.037	0.045
σ_m	Inv-Gamma	1.00e-04	2.000	0.019	0.018	0.021
σ_{zp}	Inv-Gamma	1.00e-04	2.000	0.008	0.007	0.010
σ_{zm}	Inv-Gamma	1.00e-04	2.000	0.014	0.013	0.016
σ_ξ	Inv-Gamma	1.00e-04	2.000	0.038	0.032	0.049

Note: "Low" and "high" denotes the bounds of the 90% probability interval for each parameter.

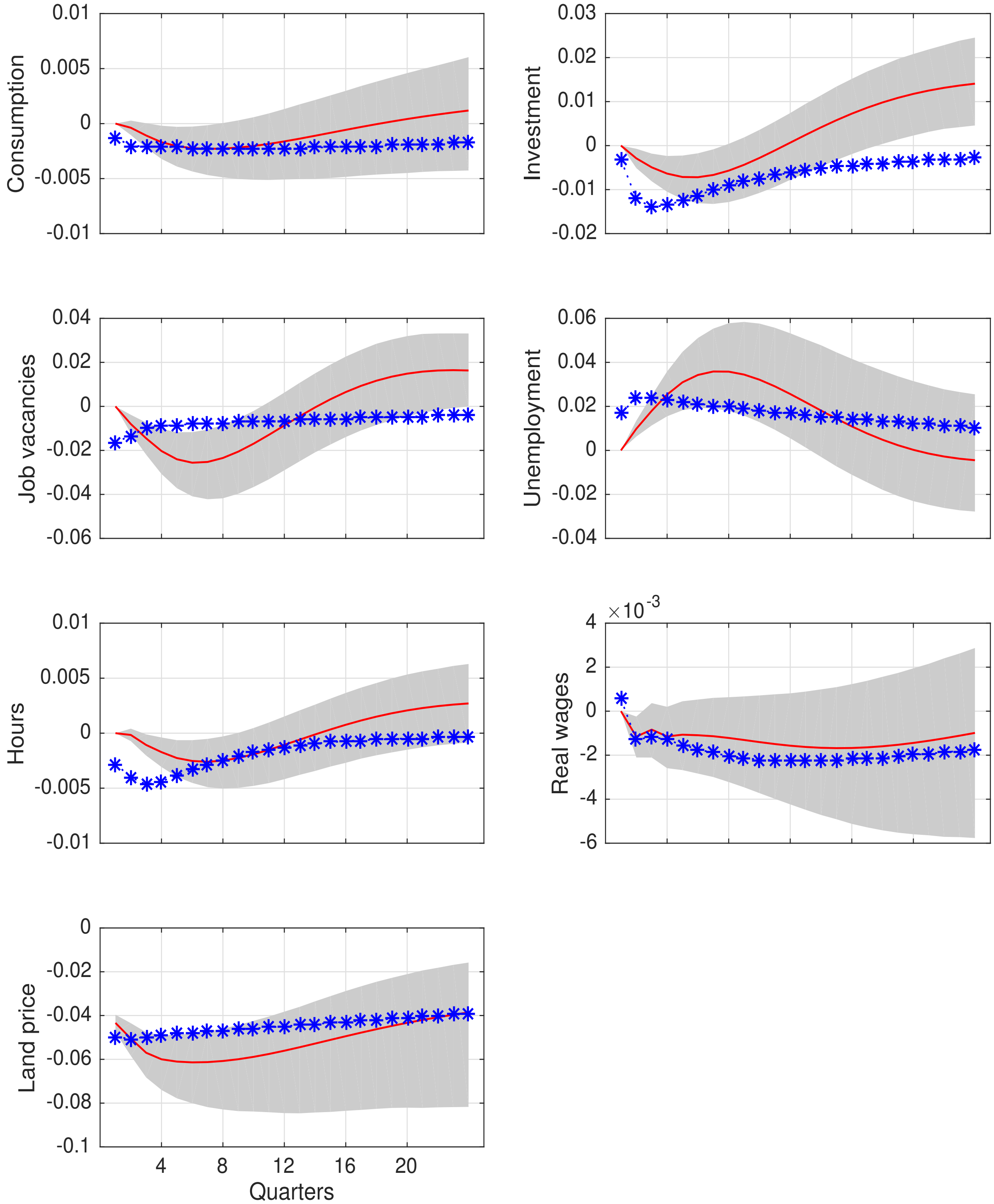

FIGURE 1. The estimated impulse responses to a negative one-standard-deviation shock to the land price. Shaded areas represent the corresponding 90% probability bands. Asterisk lines represent the estimated dynamic responses for the DSGE model.

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