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Model name: `rbc_hf`

1 CONSUMER

1.1 Optimisation problem

$$\max_{K^{\mathrm{s}}_t, C_t, L^{\mathrm{s}}_t, I_t, H_t} U_t = \beta \mathrm{E}_t \left[U_{t+1} \right] + (1 - \eta)^{-1} \left((1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu} \right)^{1-\eta} \tag{1.1}$$

s.t. :

$$C_t + I_t = \pi_t + K^{\mathrm{s}}_{t-1} r_t + L^{\mathrm{s}}_t W_t \quad \left(\lambda^{\mathrm{CONSUMER}^1}_t \right) \tag{1.2}$$

$$K^{\mathrm{s}}_t = I_t + K^{\mathrm{s}}_{t-1} (1 - \delta) \quad \left(\lambda^{\mathrm{CONSUMER}^2}_t \right) \tag{1.3}$$

$$H_t = C_{t-1} \quad \left(\lambda^{\mathrm{CONSUMER}^3}_t \right) \tag{1.4}$$

1.2 First order conditions

$$-\lambda^{\mathrm{CONSUMER}^2}_t + \beta \left((1 - \delta) \mathrm{E}_t \left[\lambda^{\mathrm{CONSUMER}^2}_{t+1} \right] + \mathrm{E}_t \left[\lambda^{\mathrm{CONSUMER}^1}_{t+1} r_{t+1} \right] \right) = 0 \quad (K^{\mathrm{s}}_t) \tag{1.5}$$

$$-\lambda^{\mathrm{CONSUMER}^1}_t + \beta \mathrm{E}_t \left[\lambda^{\mathrm{CONSUMER}^3}_{t+1} \right] + \mu (1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{-1+\mu} \left((1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu} \right)^{-\eta} = 0 \quad (C_t) \tag{1.6}$$

$$\lambda^{\mathrm{CONSUMER}^1}_t W_t + (-1 + \mu) (1 - L^{\mathrm{s}}_t)^{-\mu} (C_t - \mathit{pers} H_t)^{\mu} \left((1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu} \right)^{-\eta} = 0 \quad (L^{\mathrm{s}}_t) \tag{1.7}$$

$$-\lambda^{\mathrm{CONSUMER}^1}_t + \lambda^{\mathrm{CONSUMER}^2}_t = 0 \quad (I_t) \tag{1.8}$$

$$-\lambda^{\mathrm{CONSUMER}^3}_t - \mu \mathit{pers} (1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{-1+\mu} \left((1 - L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu} \right)^{-\eta} = 0 \quad (H_t) \tag{1.9}$$

2 FIRM

2.1 Optimisation problem

$$\max_{K^{\mathrm{d}}_t, L^{\mathrm{d}}_t, Y_t} \pi_t = Y_t - L^{\mathrm{d}}_t W_t - r_t K^{\mathrm{d}}_t \tag{2.1}$$

s.t. :

$$Y_t = Z_t {K^{\mathrm{d}}_t}^{\alpha} {L^{\mathrm{d}}_t}^{1-\alpha} \quad \left(\lambda^{\mathrm{FIRM}^1}_t \right) \tag{2.2}$$

2.2 First order conditions

$$-r_t + \alpha \lambda_t^{\mathrm{FIRM}^1} Z_t {K_t^{\mathrm{d}}}^{-1+\alpha} {L_t^{\mathrm{d}}}^{1-\alpha} = 0 \quad \left(K_t^{\mathrm{d}}\right) \tag{2.3}$$

$$-W_t + \lambda_t^{\mathrm{FIRM}^1} Z_t \left(1 - \alpha\right) {K_t^{\mathrm{d}}}^{\alpha} {L_t^{\mathrm{d}}}^{-\alpha} = 0 \quad \left(L_t^{\mathrm{d}}\right) \tag{2.4}$$

$$1 - \lambda_t^{\mathrm{FIRM}^1} = 0 \quad \left(Y_t\right) \tag{2.5}$$

2.3 First order conditions after reduction

$$-r_t + \alpha Z_t {K_t^{\mathrm{d}}}^{-1+\alpha} {L_t^{\mathrm{d}}}^{1-\alpha} = 0 \quad \left(K_t^{\mathrm{d}}\right) \tag{2.6}$$

$$-W_t + Z_t \left(1 - \alpha\right) {K_t^{\mathrm{d}}}^{\alpha} {L_t^{\mathrm{d}}}^{-\alpha} = 0 \quad \left(L_t^{\mathrm{d}}\right) \tag{2.7}$$

3 EQUILIBRIUM

3.1 Identities

$$K_t^{\mathrm{d}} = K_{t-1}^{\mathrm{s}} \tag{3.1}$$

$$L_t^{\mathrm{d}} = L_t^{\mathrm{s}} \tag{3.2}$$

4 EXOG

4.1 Identities

$$Z_t = e^{\epsilon_t^{\mathrm{Z}} + \phi \log Z_{t-1}} \tag{4.1}$$

5 Equilibrium relationships (after reduction)

$$C_{t-1} - H_t = 0 \tag{5.1}$$

$$-\lambda_t^{\mathrm{CONSUMER}^2} + \beta \left(\left(1 - \delta\right) \mathrm{E}_t \left[\lambda_{t+1}^{\mathrm{CONSUMER}^2}\right] + \mathrm{E}_t \left[\lambda_{t+1}^{\mathrm{CONSUMER}^2} r_{t+1}\right]\right) = 0 \tag{5.2}$$

$$-r_t + \alpha Z_t {K_{t-1}^{\mathrm{s}}}^{-1+\alpha} {L_t^{\mathrm{s}}}^{1-\alpha} = 0 \tag{5.3}$$

$$-W_t + Z_t \left(1 - \alpha\right) {K_{t-1}^{\mathrm{s}}}^{\alpha} {L_t^{\mathrm{s}}}^{-\alpha} = 0 \tag{5.4}$$

$$-Y_t + Z_t {K^{\mathrm{s}}_{t-1}}^{\alpha} {L^{\mathrm{s}}_t}^{1-\alpha} = 0 \tag{5.5}$$

$$-Z_t + e^{\epsilon^Z_t + \phi \log Z_{t-1}} = 0 \tag{5.6}$$

$$\lambda^{\mathrm{CONSUMER}^2}_t W_t + (-1+\mu)\,(1-L^{\mathrm{s}}_t)^{-\mu} (C_t - \mathit{pers} H_t)^{\mu} \left((1-L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu}\right)^{-\eta} = 0 \tag{5.7}$$

$$-\lambda^{\mathrm{CONSUMER}^2}_t - \beta \mu \mathit{pers} \mathrm{E}_t \left[\left(1-L^{\mathrm{s}}_{t+1}\right)^{1-\mu} (C_{t+1} - \mathit{pers} H_{t+1})^{-1+\mu} \left(\left(1-L^{\mathrm{s}}_{t+1}\right)^{1-\mu} (C_{t+1} - \mathit{pers} H_{t+1})^{\mu}\right)^{-\eta}\right] + \mu (1-L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{-1+\mu} \left((1-L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu}\right)^{-\eta} = 0 \tag{5.8}$$

$$-C_t - I_t + Y_t = 0 \tag{5.9}$$

$$I_t - K^{\mathrm{s}}_t + K^{\mathrm{s}}_{t-1}\,(1-\delta) = 0 \tag{5.10}$$

$$U_t - \beta \mathrm{E}_t\left[U_{t+1}\right] - (1-\eta)^{-1} \left((1-L^{\mathrm{s}}_t)^{1-\mu} (C_t - \mathit{pers} H_t)^{\mu}\right)^{1-\eta} = 0 \tag{5.11}$$

6 Steady state relationships (after reduction)

$$-\lambda^{\mathrm{CONSUMER}^2}_{\mathrm{ss}} + \beta \left(\lambda^{\mathrm{CONSUMER}^2}_{\mathrm{ss}} r_{\mathrm{ss}} + \lambda^{\mathrm{CONSUMER}^2}_{\mathrm{ss}}\,(1-\delta)\right) = 0 \tag{6.1}$$

$$-r_{\mathrm{ss}} + \alpha Z_{\mathrm{ss}} {K^{\mathrm{s}}_{\mathrm{ss}}}^{-1+\alpha} {L^{\mathrm{s}}_{\mathrm{ss}}}^{1-\alpha} = 0 \tag{6.2}$$

$$C_{\mathrm{ss}} - H_{\mathrm{ss}} = 0 \tag{6.3}$$

$$-W_{\mathrm{ss}} + Z_{\mathrm{ss}}\,(1-\alpha)\, {K^{\mathrm{s}}_{\mathrm{ss}}}^{\alpha} {L^{\mathrm{s}}_{\mathrm{ss}}}^{-\alpha} = 0 \tag{6.4}$$

$$-Y_{\mathrm{ss}} + Z_{\mathrm{ss}} {K^{\mathrm{s}}_{\mathrm{ss}}}^{\alpha} {L^{\mathrm{s}}_{\mathrm{ss}}}^{1-\alpha} = 0 \tag{6.5}$$

$$-Z_{\mathrm{ss}} + e^{\phi \log Z_{\mathrm{ss}}} = 0 \tag{6.6}$$

$$\lambda^{\mathrm{CONSUMER}^2}_{\mathrm{ss}} W_{\mathrm{ss}} + (-1+\mu)\,(1-L^{\mathrm{s}}_{\mathrm{ss}})^{-\mu} (C_{\mathrm{ss}} - \mathit{pers} H_{\mathrm{ss}})^{\mu} \left((1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu} (C_{\mathrm{ss}} - \mathit{pers} H_{\mathrm{ss}})^{\mu}\right)^{-\eta} = 0 \tag{6.7}$$

$$-\lambda_{\mathrm{ss}}^{\mathrm{CONSUMER}^2}+\mu(1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu}(C_{\mathrm{ss}}-\mathit{pers}H_{\mathrm{ss}})^{-1+\mu}\left((1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu}(C_{\mathrm{ss}}-\mathit{pers}H_{\mathrm{ss}})^{\mu}\right)^{-\eta}-\beta\mu\mathit{pers}(1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu}(C_{\mathrm{ss}}-\mathit{pers}H_{\mathrm{ss}})^{-1+\mu}\left((1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu}(C_{\mathrm{ss}}-\mathit{pers}H_{\mathrm{ss}})^{\mu}\right)^{-\eta}=0 \tag{6.8}$$

$$-C_{\mathrm{ss}}-I_{\mathrm{ss}}+Y_{\mathrm{ss}}=0 \tag{6.9}$$

$$I_{\mathrm{ss}}-K^{\mathrm{s}}_{\mathrm{ss}}+K^{\mathrm{s}}_{\mathrm{ss}}\,(1-\delta)=0 \tag{6.10}$$

$$U_{\mathrm{ss}}-\beta U_{\mathrm{ss}}-(1-\eta)^{-1}\left((1-L^{\mathrm{s}}_{\mathrm{ss}})^{1-\mu}(C_{\mathrm{ss}}-\mathit{pers}H_{\mathrm{ss}})^{\mu}\right)^{1-\eta}=0 \tag{6.11}$$

7 Calibrating equations

$$-0.36Y_{\mathrm{ss}}+r_{\mathrm{ss}}K^{\mathrm{s}}_{\mathrm{ss}}=0 \tag{7.1}$$

8 Parameter settings

$$\beta=0.99 \tag{8.1}$$

$$\delta=0.025 \tag{8.2}$$

$$\eta=2 \tag{8.3}$$

$$\mu=0.3 \tag{8.4}$$

$$\mathit{pers}=0.57 \tag{8.5}$$

$$\phi=0.95 \tag{8.6}$$

9 Steady-state values

	Steady-state value
$\lambda^{\mathrm{CONSUMER}^2}$	0.7116
r	0.0351
C	0.7494
H	0.7494
I	0.2584
K^{s}	10.3356
L^{s}	0.2721
U	-175.4236
W	2.3706
Y	1.0078
Z	1

10 The solution of the 1st order perturbation

Matrix P

$$\begin{array}{cc} & \begin{array}{ccc} C_{t-1} & K^{\mathrm{s}}_{t-1} & Z_{t-1} \end{array} \\ \begin{array}{c} C_t \\ K^{\mathrm{s}}_t \\ Z_t \end{array} & \begin{pmatrix} 0.5544 & 0.0151 & 0.1764 \\ -0.5092 & 0.9817 & 1.1759 \\ 0 & 0 & 0.95 \end{pmatrix} \end{array}$$

Matrix Q

$$\begin{array}{cc} & \epsilon^{\mathrm{Z}} \\ \begin{array}{c} C \\ K^{\mathrm{s}} \\ Z \end{array} & \begin{pmatrix} 0.1857 \\ 1.2377 \\ 1 \end{pmatrix} \end{array}$$

Matrix R

$$\begin{array}{cc} & \begin{array}{ccc} C_{t-1} & K^{\mathrm{s}}_{t-1} & Z_{t-1} \end{array} \\ \begin{array}{l} \lambda^{\mathrm{CONSUMER}^2}_t \\ r_t \\ H_t \\ I_t \\ L^{\mathrm{s}}_t \\ U_t \\ W_t \\ Y_t \end{array} & \begin{pmatrix} 0.0599 & -0.0494 & -0.3592 \\ 0.0016 & -0.0026 & 0.0471 \\ 1 & 0 & 0 \\ -0.5092 & 0.0067 & 1.1759 \\ 0.0191 & -0.0056 & 0.1666 \\ -0.9309 & 0.7188 & 11.4498 \\ -0.0598 & 0.1002 & 1.7296 \\ 0.0452 & 0.0218 & 1.3522 \end{pmatrix} \end{array}$$

Matrix S

$$\begin{array}{cc} & \epsilon^{\mathrm{Z}} \\ \begin{array}{l} \lambda^{\mathrm{CONSUMER}^2} \\ r \\ H \\ I \\ L^{\mathrm{s}} \\ U \\ W \\ Y \end{array} & \begin{pmatrix} -0.3781 \\ 0.0496 \\ 0 \\ 1.2377 \\ 0.1753 \\ 12.0524 \\ 1.8206 \\ 1.4234 \end{pmatrix} \end{array}$$

11 Model statistics

11.1 Basic statistics

	Steady-state value	Std. dev.	Variance	Loglin
r	0.0351	0.0046	0	N
C	0.7494	0.0333	0.0011	N
H	0.7494	0.0333	0.0011	N
I	0.2584	0.1077	0.0116	N
K^{s}	10.3356	0.3633	0.132	N
L^{s}	0.2721	0.0164	0.0003	N
U	-175.4236	1.1325	1.2825	N
W	2.3706	0.1719	0.0295	N
Y	1.0078	0.1325	0.0175	N
Z	1	0.0922	0.0085	N

11.2 Correlation matrix

	r	C	H	I	K^{s}	L^{s}	U	W	Y	Z
r	1	0.623	0.263	0.993	0.14	0.994	0.918	0.92	0.965	0.98
C		1	0.911	0.674	0.826	0.701	0.867	0.865	0.799	0.758
H			1	0.315	0.899	0.358	0.584	0.582	0.485	0.429
I				1	0.232	0.997	0.95	0.951	0.983	0.992
K^{s}					1	0.243	0.521	0.516	0.396	0.332
L^{s}						1	0.954	0.956	0.987	0.996
U							1	1	0.99	0.978
W								1	0.991	0.979
Y									1	0.998
Z										1

11.3 Cross correlations with the reference variable (Y)

	$\sigma[\cdot]$ rel. to $\sigma[Y]$	Y_{t-5}	Y_{t-4}	Y_{t-3}	Y_{t-2}	Y_{t-1}	Y_t	Y_{t+1}	Y_{t+2}	Y_{t+3}	Y_{t+4}	Y_{t+5}
r_t	0.035	0.126	0.245	0.388	0.556	0.749	0.965	0.613	0.331	0.109	-0.059	-0.182
C_t	0.251	-0.244	-0.131	0.025	0.228	0.485	0.799	0.867	0.804	0.677	0.527	0.375
H_t	0.251	-0.32	-0.244	-0.131	0.025	0.228	0.485	0.799	0.867	0.804	0.677	0.527
I_t	0.813	0.069	0.193	0.345	0.527	0.74	0.983	0.622	0.349	0.143	-0.011	-0.122
K^{s}_t	2.742	-0.459	-0.39	-0.278	-0.115	0.107	0.396	0.57	0.66	0.685	0.665	0.612
L^{s}_t	0.124	0.076	0.2	0.352	0.534	0.746	0.987	0.668	0.402	0.185	0.016	-0.113
U_t	8.55	-0.077	0.053	0.222	0.432	0.688	0.99	0.754	0.545	0.366	0.214	0.089
W_t	1.298	-0.073	0.057	0.226	0.436	0.69	0.991	0.755	0.546	0.365	0.211	0.085
Y_t	1	-0.005	0.124	0.286	0.486	0.724	1	0.724	0.486	0.286	0.124	-0.005
Z_t	0.696	0.028	0.155	0.314	0.507	0.735	0.998	0.698	0.446	0.24	0.076	-0.051

11.4 Autocorrelations

	Lag 1	Lag 2	Lag 3	Lag 4	Lag 5
r	0.707	0.462	0.261	0.101	0
C	0.911	0.738	0.537	0.337	0.156
H	0.911	0.738	0.537	0.337	0.156
I	0.667	0.413	0.217	0.069	-0.043
K^{s}	0.955	0.851	0.71	0.55	0.384
L^{s}	0.716	0.473	0.271	0.108	-0.02
U	0.737	0.509	0.316	0.155	0.025
W	0.74	0.512	0.317	0.155	0.024
Y	0.724	0.486	0.286	0.124	-0.005
Z	0.713	0.471	0.271	0.11	-0.016

12 Impulse response functions

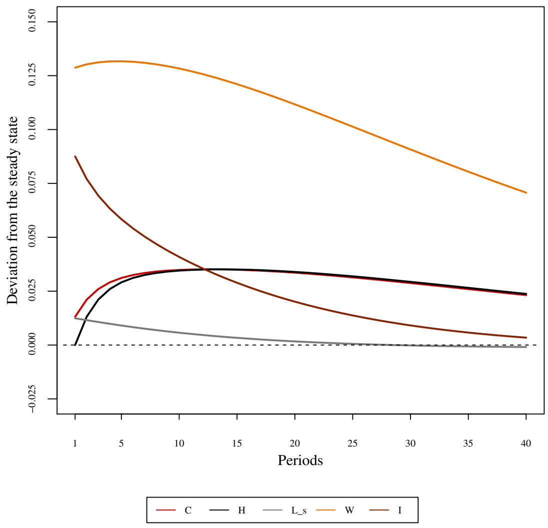

Figure 1: Impulse responses $(C, H, L^{\mathrm{s}}, W, I)$ to ϵ^{Z} shock

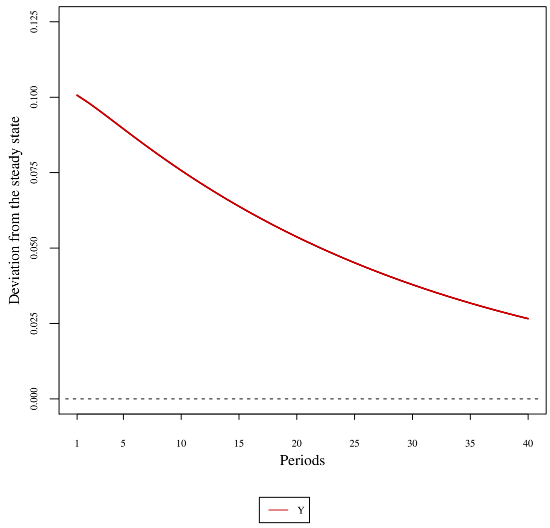

Figure 2: Impulse response (Y) to ϵ^{Z} shock