Unconventional Monetary Policy According to HANK

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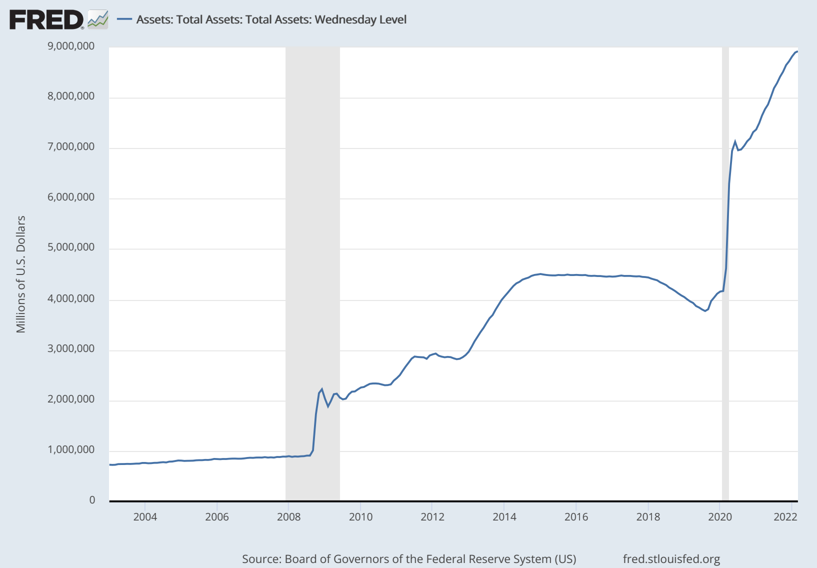
Fed Asset Purchases



Research Question

How does quantitative easing (QE) transmit to the aggregate economy when there are heterogeneous households with uninsurable income risk?

- Is QE more or less effective?
- Is much lost by using a representative agent framework?
- What are the distributional consequences of QE shocks?
- Do micro- and macro-level wealth distributions matter or not?

Literature

Marrying two literatures:

1. DSGE models to study QE (RANK)
   - Gertler and Karadi (2011, 2013); Carlstrom, Fuerst, and Paustian (2017); Sims and Wu (2020, 2021); Sims, Wu, and Zhang (forthcoming)
2. DSGE models to study monetary policy with heterogeneous agents (HANK)
   - McKay, Nakamura, and Steinsson (2016); Kaplan, Moll, and Violante (2018); Auclert (2019); Acharya and Dogra (2020); Alves, Kaplan, Moll, and Violanta (2020); Ravn and Sterk (2020)

Approach

DSGE model with constrained financial intermediaries (Sims and Wu 2020) and heterogenous households

- Intermediaries borrow short and lend long, subject to a leverage constraint
- Production firms float long-term debt to finance investment
- QE shocks ease these constraints, stimulate investment
- Households similar to Krusell and Smith (1998) with endogenous labor supply, subject to borrowing constraint and uninsurable income risk

Solve model using perturbation methods

Findings

Aggregate effects of a QE shock are **very** similar in a HANK version of the model compared to a RANK version

- QE **slightly** more stimulative; driven by poorest households
- Micro wealth distribution (Gini coefficient, Lorenz curve) **not important** for aggregate transmission
- Macro parameters (unemployment rate, unemployment benefit) have **small implications** for aggregate transmission, in direction one might expect

Conclusion: RANK model good approximation to HANK model for understanding QE

Plan

1. Model
2. Solution method
3. HANK vs. RANK
4. Micro wealth distribution
5. Macro wealth distribution
6. Conclusion

Model

Overview

1. Households: uninsurable, idiosyncratic employment risk, borrowing constraint, save via short-term deposits
2. Production firms: float long-term bonds to finance investment
3. Financial intermediaries: stand between households and production firms
4. Price and wage stickiness
5. Central bank
6. Fiscal authority

Households

$$\max_{c_{j,t},l_{j,t},d_{j,t}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\log c_{j,t} - \chi \frac{l_{j,t}^{1+\eta}}{1+\eta} \right)$$

s.t.

$$\begin{aligned} d_{j,t} &= \frac{R^d_{t-1}}{\Pi_t} d_{j,t-1} + mrs_t \big[(1-\tau) l_{j,t} \varepsilon_{j,t} + \mu (1-\varepsilon_{j,t}) \big] \\ &\quad - c_{j,t} - \mathcal{T}_{j,t} + div_{j,t} - X_j \\ d_{j,t} &\geq \underline{d} \\ l_{j,t} &\leq \bar{l} \end{aligned}$$

Income Risk

$$\varepsilon_{jt} \in \{0, 1\}$$

$$\begin{bmatrix} p(\varepsilon_{j,t+1} = 0 | \varepsilon_{jt} = 0) & p(\varepsilon_{j,t+1} = 1 | \varepsilon_{jt} = 0) \\ p(\varepsilon_{j,t+1} = 0 | \varepsilon_{jt} = 1) & p(\varepsilon_{j,t+1} = 1 | \varepsilon_{jt} = 1) \end{bmatrix} = \begin{bmatrix} p & 1 - p \\ \frac{U}{1-U}(1 - p) & 1 - \frac{U}{1-U}(1 - p) \end{bmatrix}$$

$$U = p(\varepsilon_{jt} = 0)$$

$$L_t = \int_0^1 l_{j,t} dj$$

Optimality

$$c_{j,t}^{-1} \geq \beta R_t^d \mathbb{E}_t \frac{c_{j,t+1}^{-1}}{\Pi_{t+1}}$$

$$l_{j,t}^{\eta} \leq \frac{(1-\tau) mrs_t}{\chi c_{j,t}}$$

Wholesale Producer

Production:

$$Y_{m,t} = Z_t (u_t K_t)^{\alpha} L_{d,t}^{1-\alpha}$$

Accumulation:

$$K_{t+1} = \widehat{I_t} + (1 - \delta(u_t))K_t$$

Long-term bonds: coupons decay at rate $\kappa \in [0, 1]$, trade at Q_t

Investment constraint:

$$\psi P_t^k \widehat{I_t} \leq Q_t (F_{m,t} - \kappa F_{m,t-1})$$

Financial Intermediaries

Probability of exit: $1-\sigma$

New intermediaries get X in startup net worth

Balance sheet:

$$Q_t F_t + Q_{B,t} B_t + RE_t = D_t + N_t$$

Law of motion

$$\begin{aligned} N_t &= \left(R_t^F - R_{t-1}^d\right) Q_{t-1} F_{t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} B_{t-1} \\ &\quad + \left(R_{t-1}^{re} - R_{t-1}^d\right) RE_{t-1} + R_{t-1}^d N_{t-1} \end{aligned}$$

$$R_t^F = \frac{1+\kappa Q_t}{Q_{t-1}}, \qquad R_t^B = \frac{1+\kappa Q_{B,t}}{Q_{B,t-1}}$$

Costly Enforcement Constraint

As in Gertler and Karadi (2011, 2013) and Sims and Wu (2021):

$$V_t \geq \theta \left(Q_t f_t + \Delta Q_{B,t} b_t \right)$$

Optimality:

$$\begin{aligned}
\mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} \left(R_{t+1}^F - R_t^d \right) &= \frac{\lambda_t}{1+\lambda_t} \theta \\
\mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} \left(R_{t+1}^B - R_t^d \right) &= \frac{\lambda_t}{1+\lambda_t} \theta \Delta \\
\mathbb{E}_t \Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1} \left(R_t^{re} - R_t^d \right) &= 0
\end{aligned}$$

Where:

$$\begin{aligned}
\Omega_t &= 1 - \sigma + \sigma \theta \phi_t \\
\phi_t &= \frac{1+\lambda_t}{\theta} \mathbb{E}_t [\Lambda_{t,t+1} \Omega_{t+1} \Pi_{t+1}^{-1}] R_t^d .
\end{aligned}$$

Endogenous Leverage Constraint

Value of firm:

$$V_t = \theta \phi_t n_t.$$

When the constraint binds

$$\phi_t = \frac{Q_t f_t + \Delta Q_{B,t} b_t}{n_t}$$

So:

$$\theta \phi_t \geq 1 + \lambda_t$$

Fiscal and Monetary Policy

Fiscal budget:

$$P_t G_t + P_{t-1} \bar{b}_G + MRS_t \mu U = \\ P_t \mathcal{T}_t + P_t T_{cb,t} + Q_{B,t} P_t \bar{b}_G (1 - \kappa \Pi_t^{-1}) + \tau MRS_t L_t$$

Taylor rule:

$$\ln R_t^{re} = (1-\rho_r) \ln R^{re} + \rho_r \ln R_{t-1}^{re} + \\ (1-\rho_r) \left[\phi_\pi \left(\ln \Pi_t - \ln \Pi\right) + \phi_y \left(\ln Y_t - \ln Y_{t-1}\right)\right] + \sigma_r \epsilon_{r,t}$$

Balance sheet

$$Q_t F_{cb,t} + Q_{B,t} B_{cb,t} = RE_t$$

Solution Method

Perturbation

Solving heterogeneous agent models is hard

Similar to Winberry (2018), develop a way to solve the model via perturbation methods in Dynare

- Quick
- People understand it
- Easy to have lots of state variables and many sources of aggregate uncertainty
- Different than Winberry (2018), use non-parametric approximation for cross-sectional wealth distribution

Equilibrium

Equilibrium conditions

- Individual decisions: $c_t\left(d_{t-1},\varepsilon_t\right), l_t\left(d_{t-1},\varepsilon_t\right), d_t\left(d_{t-1},\varepsilon_t\right)$
- Cross-sectional distribution: $p(d_{t-1},\varepsilon_t)$
- Aggregation

$$\begin{aligned} d_{t-1} &= \sum_{\varepsilon_t}\int d_{t-1}p\left(d_{t-1},\varepsilon_t\right)dd_{t-1} \\ L_t &= \sum_{\varepsilon_t}\int l_t\left(d_{t-1},\varepsilon_t\right)p\left(d_{t-1},\varepsilon_t\right)dd_{t-1} \end{aligned}$$

- Aggregate variables

Individual Decisions

- Approximate conditional expectation on $\{d_m\}_{m=1}^{M}$ grid

  Chebyshev polynomials

$$\beta R_t^d \, \mathbb{E}_t \left[\frac{c_{t+1}^{-1}}{\Pi_{t+1}} \right] \equiv T(\varepsilon_t, d_{t-1} = d_m) \approx \exp \left\{ \sum_{n=0}^{M-1} \theta_{n,t}(\varepsilon_t) T_n(d_{t-1} = d_m) \right\}$$

- Solve policy function with a system of equations

$$\begin{aligned}
d_t &= \max \left\{ \frac{R_{t-1}^d}{\Pi_t} d_{t-1} + mrs_t[(1-\tau) l_t \varepsilon_t + \mu(1-\varepsilon_t)] - T(d_{t-1}, \varepsilon_t)^{-1} - \mathcal{T}_t + div_t - X, \underline{d} \right\} \\
l_t &= \min \left\{ \left[\frac{(1-\tau) mrs_t}{\chi c_t} \right]^{\frac{1}{\eta}}, \bar{l} \right\} \\
c_t &= \frac{R_{t-1}^d}{\Pi_t} d_{t-1} + mrs_t[(1-\tau) l_t \varepsilon_t + \mu(1-\varepsilon_t)] - d_t - \mathcal{T}_t + div_t - X
\end{aligned}$$

  $\Rightarrow (M+1) \times 2 \times 3$ equations for $d_t\,(d_m, \varepsilon_t)\,, l_t\,(d_m, \varepsilon_t)\,, c_t\,(d_m, \varepsilon_t)$

- c_{t+1} can be expressed as a function of $T(d_t, \varepsilon_{t+1})$

$$\beta R_t^d \, \mathbb{E}_t \left[\frac{1}{\Pi_{t+1}} c_{t+1} \left(\exp \left\{ \sum_{n=0}^{M-1} \theta_{n,t+1}(\varepsilon_{t+1}) T_n(d_t) \right\} \right)^{-1} \right] \approx \exp \left\{ \sum_{n=0}^{M-1} \theta_{n,t}(\varepsilon_t) T_n(d_{t-1} = d_m) \right\}$$

  $\Rightarrow M \times 2$ equations for $M \times 2$ variables $\theta_{n,t}(\varepsilon_t)$

Cross-Sectional Distribution: Young (2010)

Transition dynamics for $p(d_t, \varepsilon_{t+1})$

$$p(d_t, \varepsilon_{t+1}) = \sum_{\varepsilon_t} \sum_{d_m} p(d_t | d_{t-1} = d_m, \varepsilon_t) p(\varepsilon_{t+1} | \varepsilon_t) p(d_{t-1} = d_m, \varepsilon_t)$$

Young (2010): approximate $p(d_t | d_{t-1} = d_m, \varepsilon_t)$ with the d_m grid:

- find the two neighboring grids $d_{m'}, d_{m'+1}$ that are closest to d_t
- Assign weights to the two grids based on distance

$$\begin{aligned} p(d_t = d_{m'} | d_{t-1} = d_m, \varepsilon_t) &= 1 - \frac{d_t - d_{m'}}{d_{m'+1} - d_{m'}} \\ p(d_t = d_{m'+1} | d_{t-1} = d_m, \varepsilon_t) &= \frac{d_t - d_{m'}}{d_{m'+1} - d_{m'}} \end{aligned}$$

$(M+1) \times 2$ equations for $(M+1) \times 2$ probabilities

Stationary Equilibrium

We solve a fixed point problem over D and L

1. Given D and L, solve for aggregate variables
2. Solve for Chebyshev coefficients: a fixed point problem
3. Solve for stationary distribution $p(d, \varepsilon)$: a fixed point problem
4. With the policy function from step 2 and distribution from step 3, update $\tilde{D}$ and $\tilde{L}$

Repeat until convergence

Calibration of non-HANK Parameters

We follow Sims and Wu (2020)

- Financial intermediary parameters (e.g. leverage, bond coupon decay, steady-state bond holdings and issuance)
- Standard medium-scale NK parameters (e.g. price and wage stickiness, investment adjustment cost, utilization costs)

Calibration of HANK Parameters

Parameters	Value	Target	Description
L^U	0.05		Fraction unemployed
p	0.5	2 quarter duration	Unemployment duration
χ		$L^{RANK} = 0.95$	Labor disutility scaling parameter
μ	0.4		Unemployment benefit
τ	0.3		Labor income tax rate
$\underline{d}$	0		Borrowing constraint
$\bar{l}$	1.5		Time endowment

Other parameters as in Sims and Wu (2021) Details

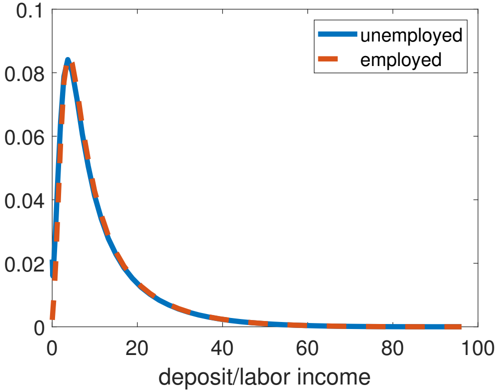
Lump Sum Distribution

We assume throughout that all households receive the same fiscal transfer

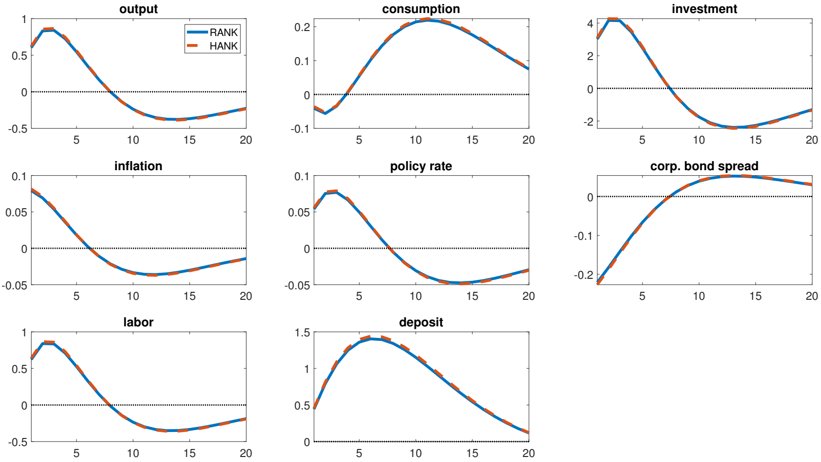
As a baseline, assume that all households receive the same dividends each period

Main Results

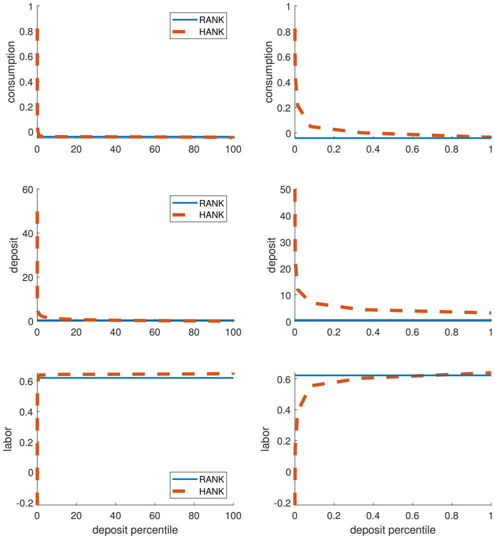
Stationary Wealth Distribution



Impulse Responses: QE Shock



First-Period Individual Responses



Take-Aways

HANK responses **nearly identical** to RANK responses

Aggregate consumption falls less, driven by the behavior of the poorest households

Suggests RANK is a good approximation to HANK

Micro Distribution of Wealth

Inequality

What do micro-level measures of inequality (e.g. Gini coefficient, Lorenz curve) look like in our model?

Do they matter for aggregate transmission of QE shocks?

How does distribution of lump sum transfers (dividends) matter for both inequality metrics and aggregate transmission?

Dividend Distribution

$$\frac{div_{j,t}}{div_t} = \left(a_t + b_t d_{j,t-1}^{\vartheta}\right).$$

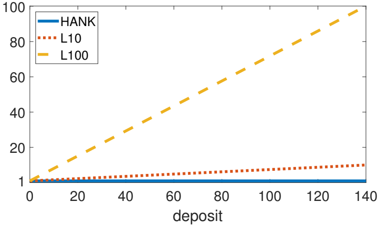
a_t and b_t chosen so that:

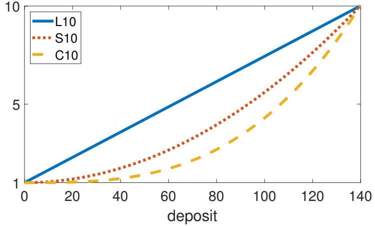
$$\int_0^1 \left(a_t + b_t d_{j,t-1}^{\vartheta}\right) dj = 1,$$

$$\frac{a_t + b_t \bar{d}^{\vartheta}}{a_t + b_t \underline{d}^{\vartheta}} = n.$$

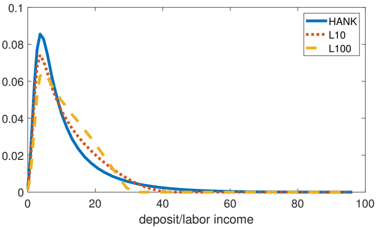
Vary n as well as ϑ; influences how dividends are distributed across the wealth distribution

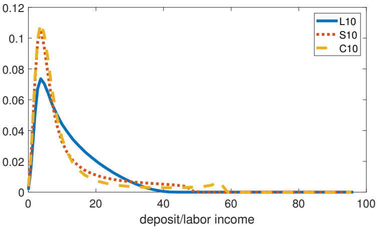
Relative Weights



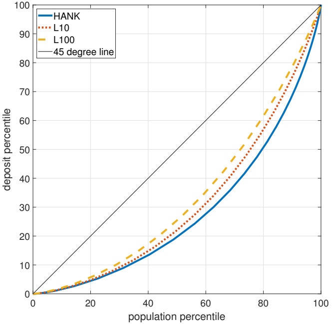


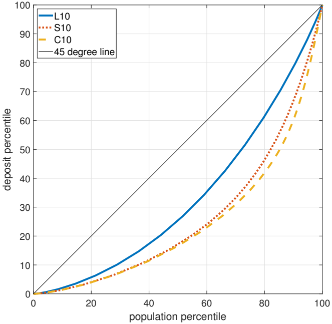
Stationary Distribution





Lorenz Curves

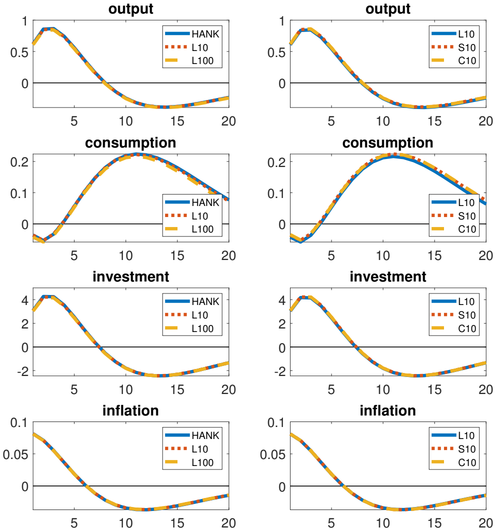




Gini Coefficients

	HANK	L10	L100	S10	C10
Gini coeff.	0.44	0.39	0.34	0.48	0.51

Impulse Responses



Take-Aways

Seems to be **little relationship** between micro-level wealth distribution and macro aggregates

Consumption responses slightly different with more curvature in dividend distribution rule, but hardly noticeable for macro aggregates

Macro Distribution of Wealth

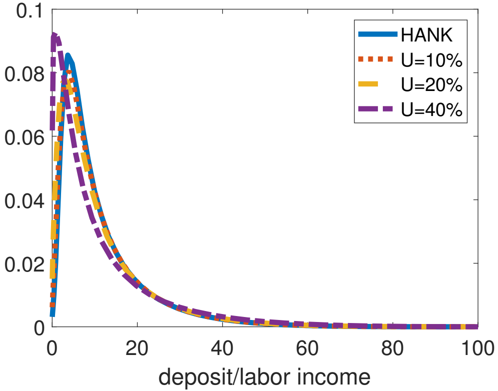
Experiments

Not many people located near borrowing constraint in our baseline model

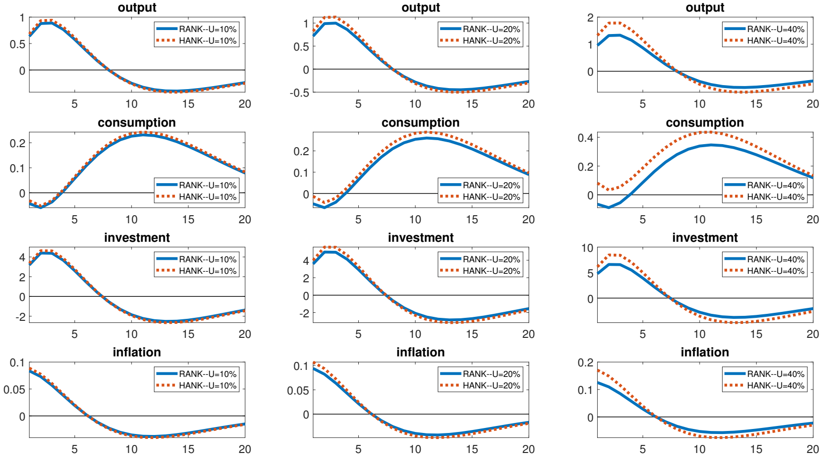
Consider varying three macro parameters related to employment, with affect stationary distributions

1. Unemployment rate, U
2. Unemployment benefit, μ
3. Unemployment duration, p

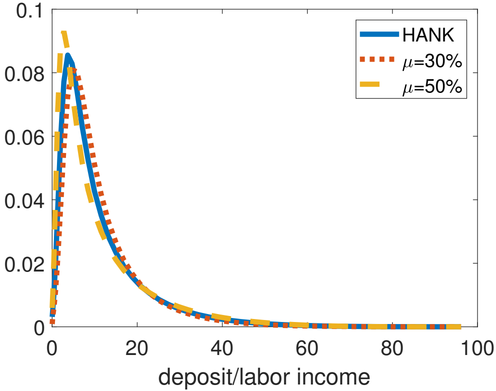
Stationary Distribution: HANK vs. Higher U



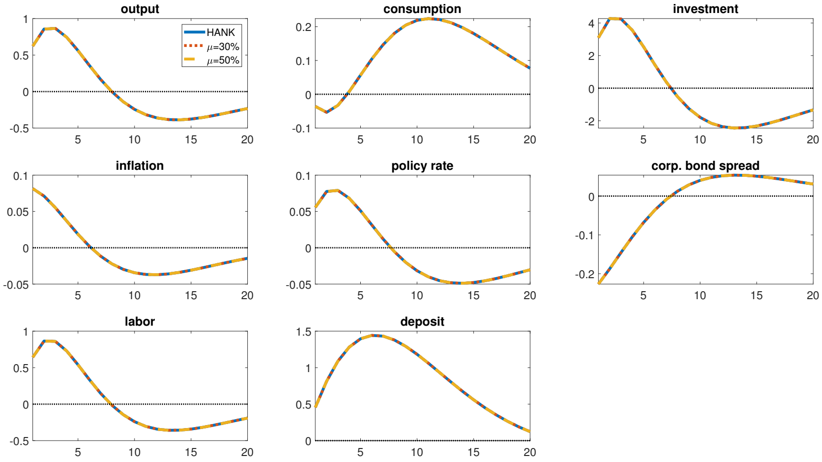
Impulse Responses: HANK vs. RANK with Higher U



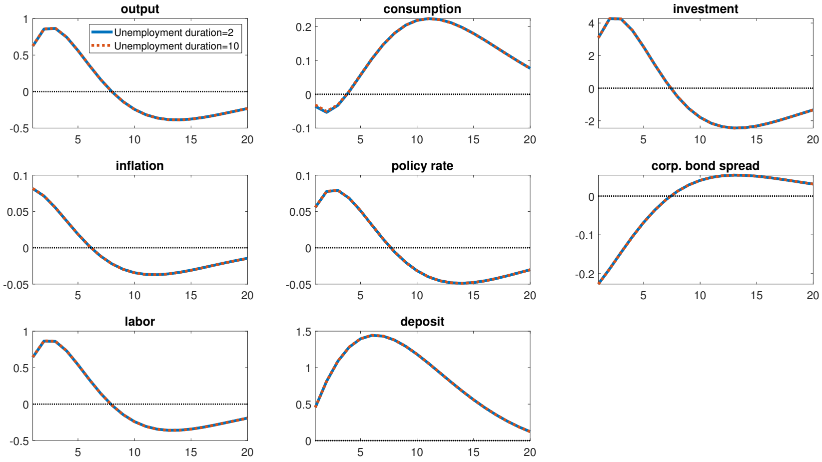
Stationary Distribution: HANK with Different μ



Impulse Responses: HANK with Different μ



Impulse Responses: HANK with Different p



Take-Aways

Only **small** differences in aggregate effects of QE shock for different:

1. Unemployment rate
2. Unemployment benefit
3. Unemployment duration

Conclusion

We combine financial intermediaries, long-term bonds, and scope for central bank bond purchases (QE) to matter with heterogeneous households with uninsurable income risk

Does household heterogeneity matter for aggregate QE transmission?

- **No**
- Micro-level wealth heterogeneity does not matter
- Macro-level parameters (unemployment, unemployment benefit, unemployment duration) might matter a little more, but not much for macro aggregates

Conclusion: at least with our modeling of the frictions allowing QE to matter, **RANK is a good approximation to HANK**

Chebyshev Polynomials

$$T(\varepsilon_t, d_{t-1}) \approx \exp\left\{\sum_{n=0}^{N_T} \theta_{n,t}(\varepsilon_t)\, T_n(\xi(d_{t-1}))\right\}$$

- Chebyshev polynomials are defined as following:

$$T_n(x) = \cos(n \arccos x)$$

  can also be defined recursively
- The algorithm aims to fit a set of nodes $\{d_m\}_{m=1}^{M_T}$
  - $\xi(d) = 2\frac{d-\underline{d}}{\bar{d}-\underline{d}} - 1$ transforms the interval $a \in (\underline{d}, \bar{d})$ to $(-1, 1)$
  - The Chebyshev nodes defined on $(-1, 1)$ are

$$x_m = -\cos\left(\frac{2m-1}{2M}\pi\right)$$

  - $d_m = \xi^{-1}(x_m)$:

$$d_m = (x_m + 1)\left(\frac{\bar{d} - \underline{d}}{2}\right) + \underline{d}.$$

Back

Additional Parameters

Parameters	Value	Target	Description
SW parameters			
κ	$1-40^{-1}$	bond duration $=40$	Coupon decay parameter
ψ	0.81		Fraction of investment from debt
σ	0.95		Intermediary survival probability
θ		$400(R^F - R^d) = 3$	Recoverability parameter
X		Leverage $=4$	Transfer to new intermediaries
Δ	1/3		Government bond recoverability
b_{cb}		$\frac{b_{cb}Q_B}{4Y} = 0.06$	Steady state central bank Treasury holdings
f_{cb}	0		Steady state central private bond holdings
ρ_b	0.8		AR central bank Treasury
ρ_f	0.8		AR central bank private bonds
$\bar{b}_G$		$\frac{B_G Q_B}{4Y} = 0.41$	Steady state government debt
G		$\frac{G}{Y} = 0.2$	Steady state government spending
Standard parameters			
β	0.995		Discount factor
η	1		Inverse Frisch elasticity
α	0.33		Production function exponent on capital
δ_0	0.025		Steady state depreciation
δ_1		$u=1$	Utilization linear term
δ_2	0.01		Utilization squared term
κ_I	2		Investment adjustment cost
Π	1		Steady state (gross) inflation
ϵ_p/ϵ_w	11		Elasticity of substitution goods/labor
ϕ_p/ϕ_w	0.75		Price/wage rigidity
ρ_r	0.8		Taylor rule smoothing
ϕ_π	1.5		Taylor rule inflation
ϕ_y	0.25		Taylor rule output growth

Back