A Behavioral Heterogeneous Agent New Keynesian Model

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3. Advanced economies remained stable at zero lower bound. Debortoli et al. (2020), Cochrane (2018)

4. Income of households with higher marginal propensities to consume tends to be more exposed to aggregate income fluctuations $\Rightarrow$ important for MP transmission. Auclert (2019), Patterson (2019)

This paper

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$\Rightarrow$ resolves tension in existing models between facts 1 & 4 and facts 2 & 3 (Werning (2015), Bilbiie (2021))

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Framework featuring NK core + household heterogeneity and bounded rationality (cognitive discounting)

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  1. Limited-heterogeneity setup
     - analytical results: clear understanding of interaction of household heterogeneity and bounded rationality
  2. Full-blown heterogeneity setup
     - all results carry over
     - role of heterogeneity in cognitive discounting and policy implications

Fighting Supply-Driven Inflation

Revisit supply-driven inflationary pressures (negative TFP shock)

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Behavioral HANK highlights stronger trade-off: price stability vs. fiscal sustainability and inequality

Outline

1. **Tractable Model**
2. Analytical Results
3. Full-Blown Heterogeneity Model
4. Monetary and Fiscal Policy Implications

Model

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- Two types of households: *U*nconstrained and *H*and-to-mouth households with fixed shares of $1 - \lambda$ and λ
  - differ in income (components), access to financial markets $\Rightarrow$ MPCs and income exposure
  - idiosyncratic risk of type switching $\Rightarrow$ precautionary savings motive
  - full insurance within type; zero liquidity

▸ Details

Households

Standard CRRA utility

$$\mathcal{U}(C_t^i, N_t^i) \equiv \begin{cases} \frac{(C_t^i)^{1-\gamma}}{1-\gamma} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi}, & \text{if } \gamma \neq 1, \\ \log\left(C_t^i\right) - \frac{(N_t^i)^{1+\varphi}}{1+\varphi}, & \text{if } \gamma = 1. \end{cases}$$

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Unconstrained households:

- remain unconstrained with prob. s, become hand-to-mouth with prob. $1 - s$

$$C_t^U + B_{t+1}^U + \nu_t \iota_{t+1} = W_t N_t^U + \iota_t \left(\nu_t + \tilde{D}_t\right) + s\frac{1 + i_{t-1}}{1 + \pi_t} B_t^U$$

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<u>*H*and-to-mouth households:</u>

- remain hand-to-mouth with prob. h, become unconstrained with prob. $1-h$

$$C_t^H + \cancel{B_{t+1}^H} + \cancel{\nu_t \iota_{t+1}^H} = W_t N_t^H + \cancel{\iota_t^H \left(\nu_t + \tilde{D}_t\right)} + (1-s)\frac{1-\lambda}{\lambda}\frac{1+i_{t-1}}{1+\pi_t}B_t^U + T_t^H$$

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$\Rightarrow$ high-MPC households

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Government:

- Fiscal policy taxes profits and redistributes to hand-to-mouth households:

$$T_t^H = \frac{\tau^D}{\lambda} D_t$$

$\Rightarrow$ allows us to regulate income exposure

- Monetary policy

$$\hat{i}_t = \phi_\pi \pi_t + \varepsilon_t^{MP}$$

▸ Details

Equilibrium: Key Equations

- H consumption:

$$\widehat{c}_t^H = \chi \widehat{y}_t, \text{ where } \chi \equiv 1 + \varphi\left(1 - \frac{\tau^D}{\lambda}\right)$$

  - $\widehat{y}_t$: aggregate income
  - χ : exposure of high MPC households to aggregate income (Bilbiie (2020))
  - Fact 4: $\chi > 1$ (Auclert (2019), Patterson (2019))

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- U households' Euler equation:

$$\widehat{c}_t^U = s\mathbb{E}_t^{BR}\left[\widehat{c}_{t+1}^U\right] + \underbrace{(1-s)}_{\text{type-switch prob.}} \mathbb{E}_t^{BR}\left[\widehat{c}_{t+1}^H\right] - \frac{1}{\gamma}\left(\widehat{i}_t - \mathbb{E}_t \pi_{t+1}\right)$$

Bounded Rationality

We allow for cognitive discounting (following Gabaix (2020)):

$$\mathbb{E}_t^{BR}\left[X_{t+1}\right] = \mathbb{E}_t^{BR}\left[X_t^d + \tilde{X}_{t+1}\right] = X_t^d + \bar{m}\mathbb{E}_t\left[\tilde{X}_{t+1}\right]$$

- $\mathbb{E}_t\left[\cdot\right]$: rational expectations operator; X_t^d: expectation anchor (steady state); $\tilde{X}_{t+1}$: deviation from X_t^d.
- $\bar{m} \in [0, 1]$: degree of rationality
- Rational expectations as a special case: $\bar{m} = 1$ ▸ Microfoundation
- Data: $\bar{m} \in [0.6, 0, 85] \Rightarrow \bar{m} = 0.85$ as upper bound

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Monetary Policy in Behavioral HANK ▸ Calibration

Aggregate IS equation

$$\widehat{y}_t = \psi_{\mathbf{f}} \mathbb{E}_t \widehat{y}_{t+1} - \psi_{\mathbf{c}} \frac{1}{\gamma} \left(\widehat{i}_t - \mathbb{E}_t \pi_{t+1} \right)$$

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⇒ GE amplification of conventional monetary policy shock (Fact 1 ✓)

▸ GE/PE decomposition

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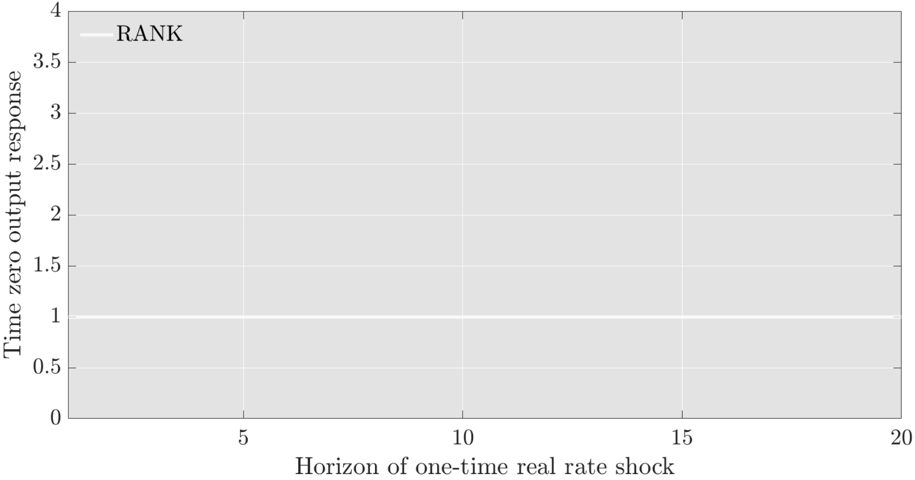
$\Rightarrow$ NOT possible with rational expectations, given $\chi > 1$! Werning (2015), Bilbiie (2021)

Monetary Policy in behavioral HANK

Experiment: real rate shock at different horizons ⇒ effect on time zero output?



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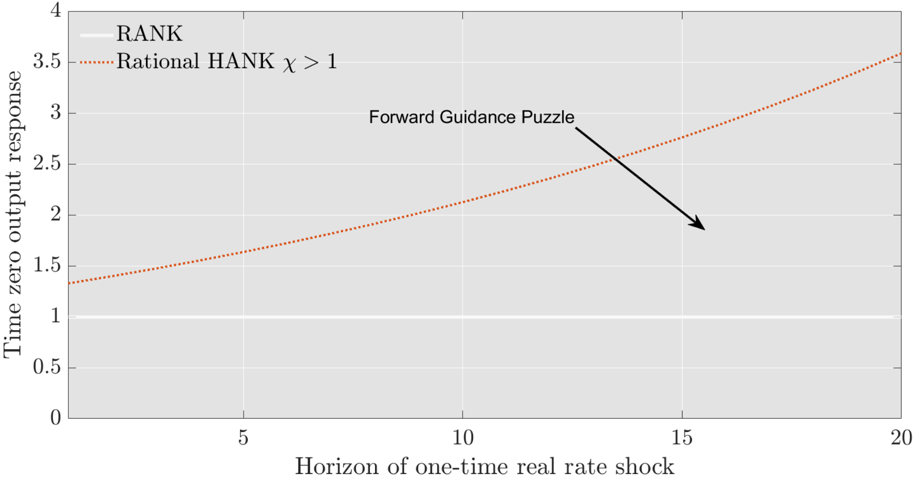

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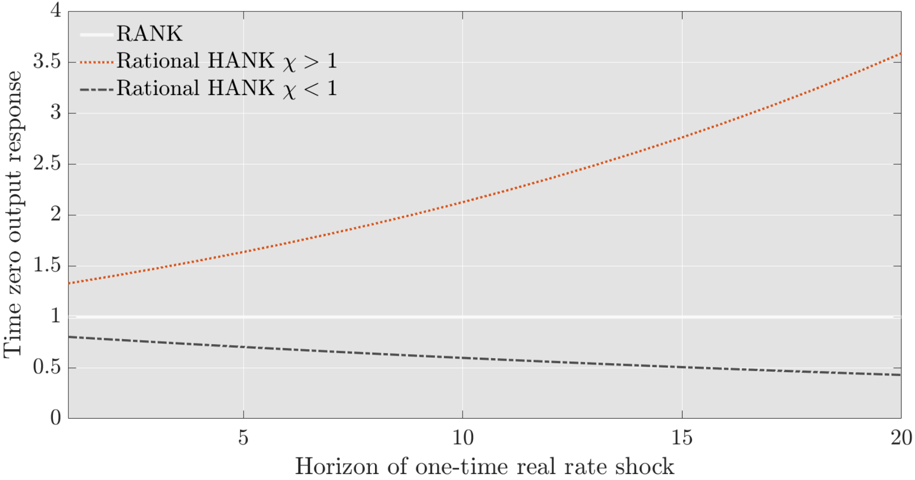

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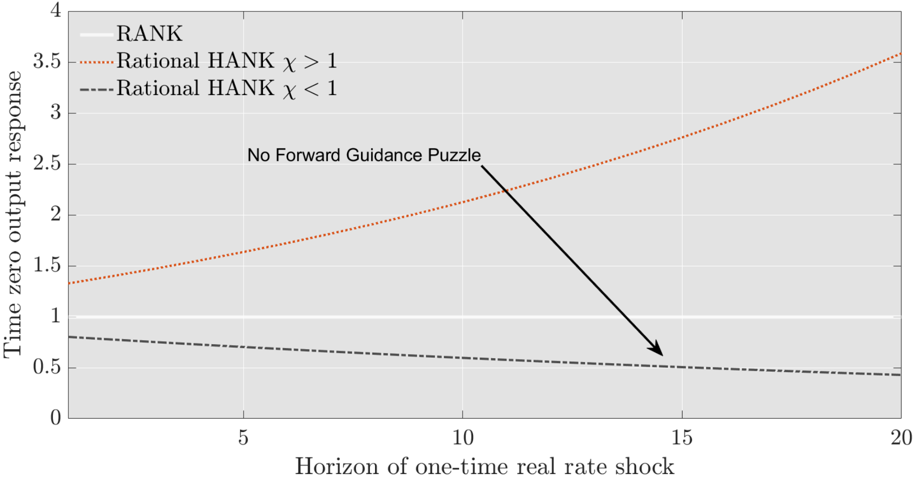

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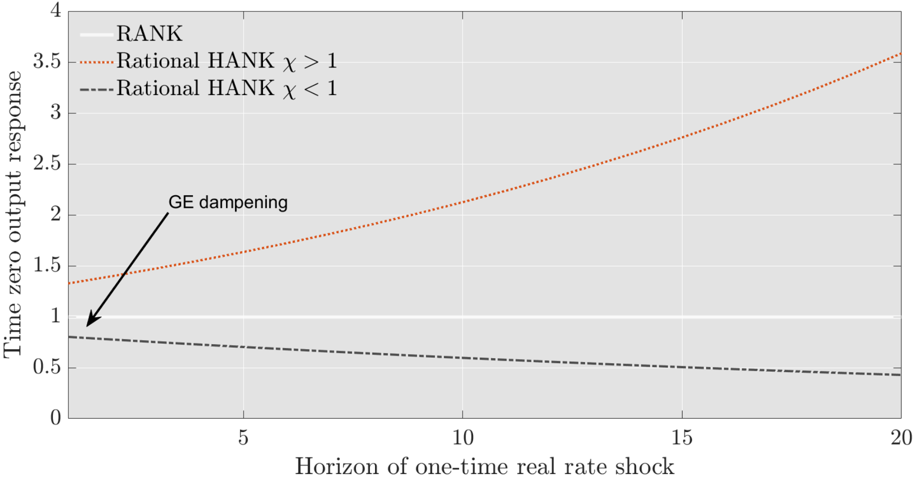

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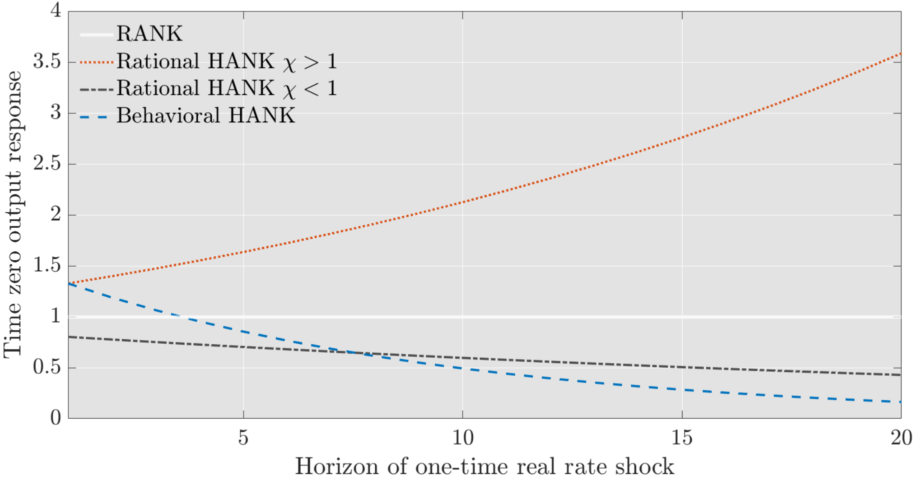

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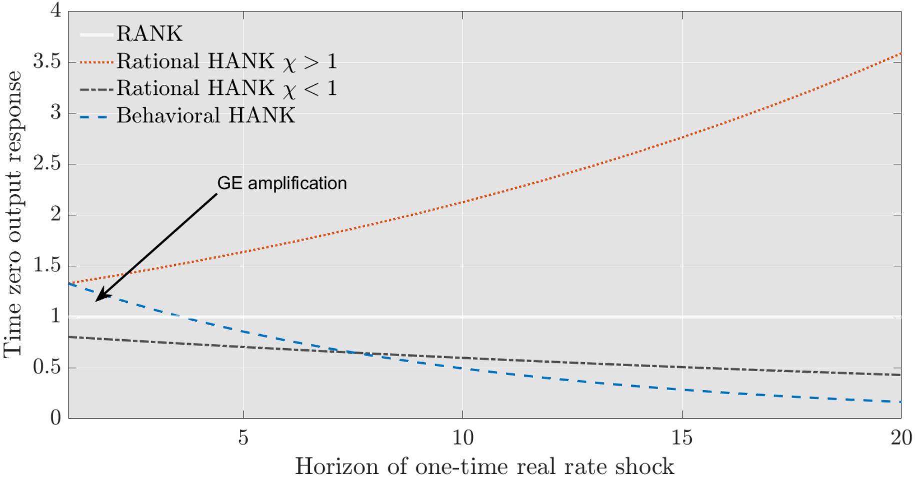

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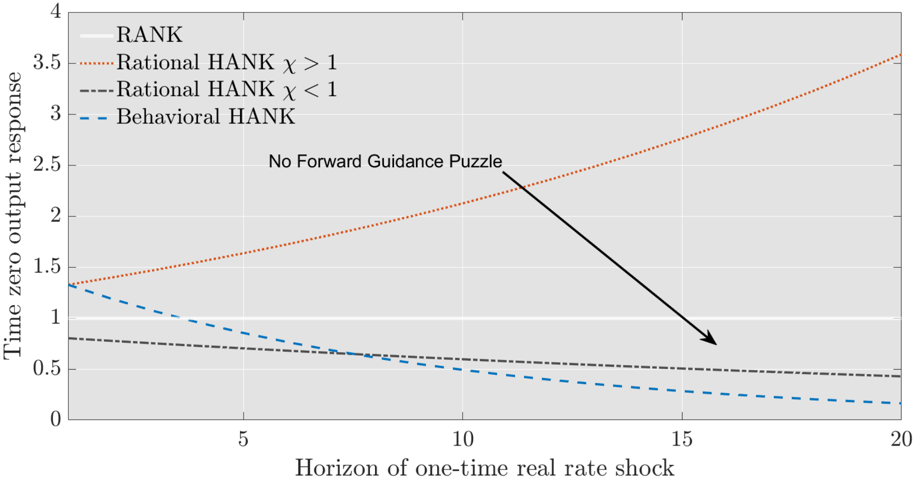

Facts 1 - 4

The behavioral HANK model can account for

Fact 1 transmission of monetary policy through indirect effects

Fact 2 no Forward Guidance Puzzle

Fact 4 higher MPC households more exposed to aggregate income fluctuations

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The behavioral HANK model can account for

Fact 1 transmission of monetary policy through indirect effects

Fact 2 no Forward Guidance Puzzle

Fact 3 stability at zero lower bound ▸ Determinacy under peg

⇒ similar intuition as for forward guidance puzzle

Fact 4 higher MPC households more exposed to aggregate income fluctuations

Further Analytical Results

- Behavioral HANK consistent with other empirical facts:
  - GE amplification carries over to fiscal policy $\Rightarrow$ positive fiscal multiplier on consumption (under constant real rate) ▸ Fiscal Multiplier
  - iMPCs in line with data ▸ iMPCs
  - Sticky wages $\Rightarrow$ hump-shaped responses and household expectations consistent with survey evidence ▸ Sticky wages

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- Comparison to existing models that are nested in our framework ⇒ no other model consistent with all the empirical facts simultaneously. ▸ Model comparison ▸ Myopia and Anchoring

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Full-Blown Behavioral HANK

- Standard incomplete markets set-up:
    - ex-ante identical households face idiosyncratic productivity e_{it} risk + borrowing constraints (endogenously binding)
    - self-insure by accumulating bonds B_{it} (now in positive net supply)

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- collapses to standard one-asset rational HANK for $\bar{m} = 1$

  McKay et al. (2016), Debortoli and Galí (2018)

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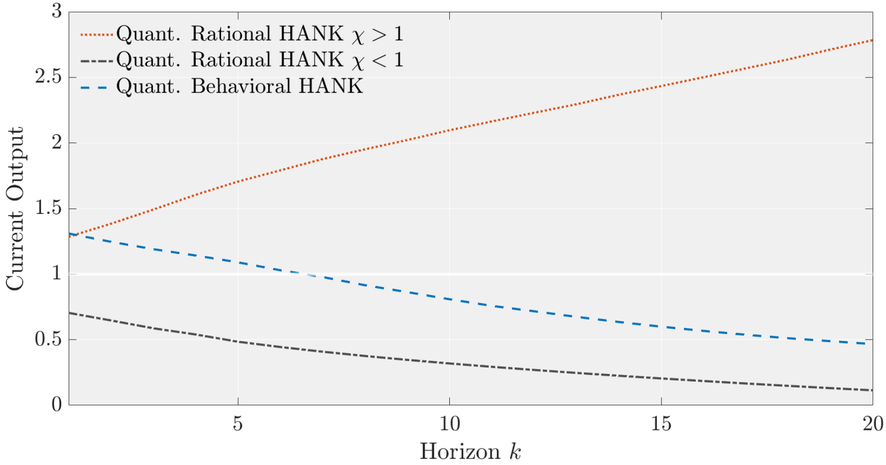
- Standard incomplete markets set-up:
  - ex-ante identical households face idiosyncratic productivity e_{it} risk + borrowing constraints (endogenously binding)
  - self-insure by accumulating bonds B_{it} (now in positive net supply)
- Bounded rationality: households anchor expectations to stationary equilibrium but cognitively discount deviations
- collapses to standard one-asset rational HANK for $\bar{m} = 1$

  McKay et al. (2016), Debortoli and Galí (2018)
- Calibration: high-MPC households more exposed to aggregate fluctuations (corresponds to $\chi > 1$ in tractable model) ▸ Calibration

Monetary Policy in quantitative behavioral HANK



Monetary policy amplification: ✓ ✗ ✓   No forward guidance puzzle: ✗ ✓ ✓

Results from Tractable Model carry over to Full-blown behavioral HANK

1. Transmission of monetary policy through indirect effects
2. No forward-guidance puzzle
3. Economy more stable at ELB
4. High-MPC households more exposed to aggregate income fluctuations

\+ Positive consumption response to government spending

Outline

1. Tractable Model
2. Analytical Results
3. Full-Blown Heterogeneity Model
4. **Monetary and Fiscal Policy Implications**

Negative Productivity Shock

Scenario:

- negative productivity shock: *potential output* (output in flex-price RANK) drops by 1% on impact, with $\rho = 0.9$

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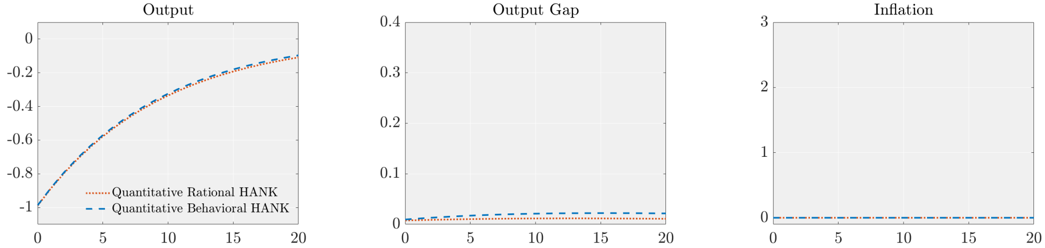
- for different monetary regimes: full-inflation stabilization vs. Taylor rule
- for different fiscal regimes: progressive taxes vs. less progressive taxes (not today)

▸ Details

Negative Productivity Shock: Full-Inflation Stabilization



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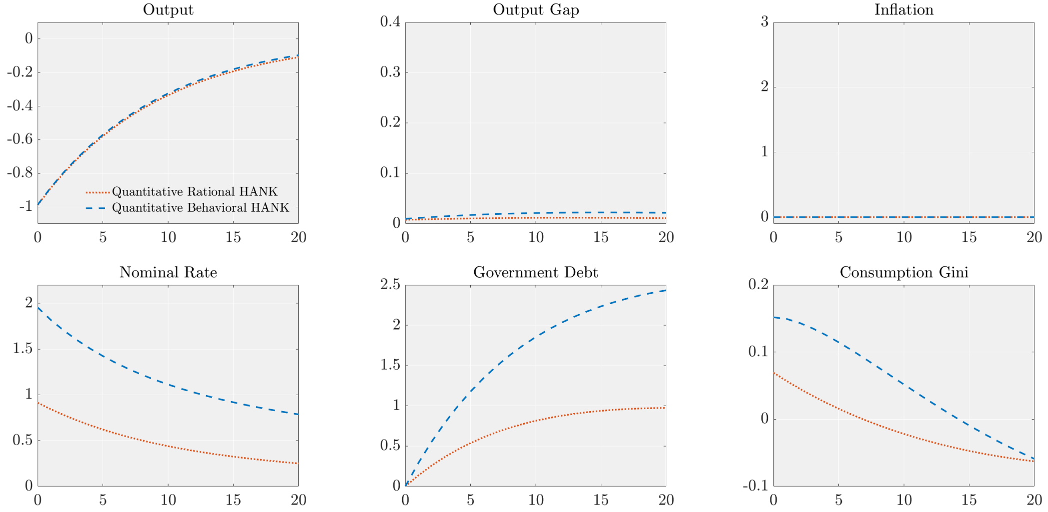
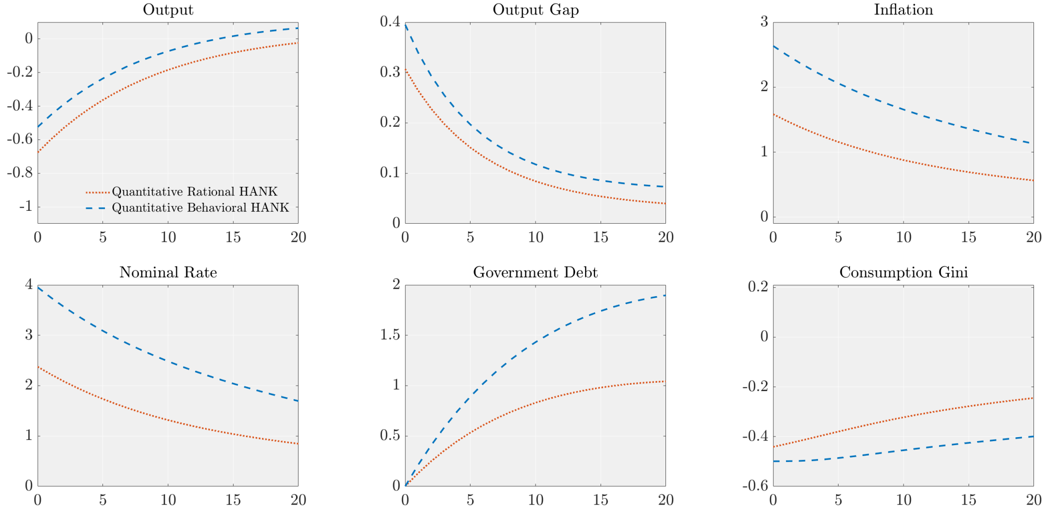


Negative Productivity Shock: Taylor Rule



Policy Implications: Take Aways

Behavioral HANK: monetary policy needs to act more strongly to stabilize inflation

⇒ implications for fiscal policy: government debt increases more

⇒ fiscal regime matters more ▸ Less Progressive Taxes

⇒ distributional consequences: stronger increase in inequality when inflation stabilizing

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- similar findings for cost-push shocks ▸ Cost Push

Extension: heterogeneous $\bar{m}$ ▸ Heterogeneous $\bar{m}$

Conclusion

The behavioral HANK model...

... is consistent with empirical facts about the transmission of monetary policy

... highlights strong trade-off between price stability vs. fiscal sustainability and distributional concerns after supply-side shocks

... can also account for other empirical patterns: fiscal multiplier, iMPCs...

Appendix

Households: Program of Family Head

$$V\left(B_t^U, \iota_t\right) = \max_{\{C_t^U, C_t^H, B_{t+1}^U, N_t^U, N_t^H, \iota_{t+1}\}} \left[(1-\lambda)\mathcal{U}\left(C_t^U, N_t^U\right) + \lambda\mathcal{U}\left(C_t^H, N_t^H\right)\right] + \beta\mathbb{E}_t^{BR} V\left(B_{t+1}^U, \iota_{t+1}\right)$$

subject to the flow budget constraints of unconstrained households

$$C_t^U + B_{t+1}^U + v_t \iota_{t+1} = W_t N_t^U + \iota_t(v_t + \tilde{D}_t) + s\frac{1+i_{t-1}}{1+\pi_t}B_t^U,$$

and the hand-to-mouth households

$$C_t^H = W_t N_t^H + T_t^H + \frac{1+i_{t-1}}{1+\pi_t}(1-s)\frac{1-\lambda}{\lambda}B_t^U.$$

with

$$\mathcal{U}(C_t^i, N_t^i) \equiv \begin{cases} \frac{(C_t^i)^{1-\gamma}}{1-\gamma} - \frac{(N_t^i)^{1+\varphi}}{1+\varphi}, & \text{if } \gamma \neq 1, \\ \log\left(C_t^i\right) - \frac{(N_t^i)^{1+\varphi}}{1+\varphi}, & \text{if } \gamma = 1. \end{cases}$$

Households: Optimality Conditions

Unconstrained households' bond Euler equation:

$$\frac{\partial \mathcal{U}(C_t^U, N_t^U)}{\partial C_t^U} \geqslant \beta \mathbb{E}_t^{BR}\left[R_t\left(s\frac{\partial \mathcal{U}(C_{t+1}^U, N_{t+1}^U)}{\partial C_{t+1}^U} + (1-s)\frac{\partial \mathcal{U}(C_{t+1}^H, N_{t+1}^H)}{\partial C_{t+1}^H}\right)\right]$$

Demand for shares:

$$\frac{\partial \mathcal{U}(C_t^U, N_t^U)}{\partial C_t^U} \geqslant \beta \mathbb{E}_t^{BR}\left[\frac{v_{t+1} + \tilde{D}_{t+1}}{v_t}\frac{\partial \mathcal{U}(C_{t+1}^U, N_{t+1}^U)}{\partial C_{t+1}^U}\right]$$

Labor-leisure equations of both types:

$$-\frac{\partial \mathcal{U}(C_t^i, N_t^i)}{\partial N_t^i} = W_t\frac{\partial \mathcal{U}(C_t^i, N_t^i)}{\partial C_t^i}.$$

back

Firms

- aggregate basket of individual goods, $j \in [0,1]$, $C_t = (\int_0^1 C_t(j)^{(\epsilon-1)/\epsilon} dj)^{\epsilon/(\epsilon-1)}$; $\epsilon > 1$: elasticity of substition

- demand of each firm: $C_t(j) = (P_t(j)/P_t)^{-\epsilon}$ with $P_t(j)/P_t$ being the individual price relative to the aggregate price index $P_t^{1-\epsilon} = \int_0^1 P_t(j)^{1-\epsilon} dj$

- production technology: $Y_t(j) = N_t(j)$; real marginal cost: W_t.

- assuming standard NK optimal subsidy financed by a lump-sum tax on firms yields total profits $D_t = Y_t - W_t N_t$ which are zero in steady state
  $\Rightarrow$ full-insurance steady state

- Linearized Phillips Curve:

$$\pi_t = \kappa \widehat{y}_t + \beta \bar{M}^f \mathbb{E}_t \pi_{t+1}$$

Government

- Fiscal policy taxes profits at rate τ^D and rebates these taxes as a transfer to H households: $T^H = \frac{\tau^D}{\lambda} D_t$
  - level of τ^D is key for the cyclicality of inequality
  - fiscal multiplier analysis: exogenous government spending financed by lump-sum tax on *all* households
- Monetary policy follows Taylor rule:

$$\widehat{i}_t = \phi_\pi \pi_t + \epsilon_t^{MP},$$

  - monetary policy shock ϵ_t^{MP} either AR(1) or i.i.d.

▸ back

Microfounding $\bar{m}$

Law of motion of (de-meaned) X_t: $X_{t+1} = \Gamma X_t + \varepsilon_{t+1}$
Household j receives a noisy signal of X_{t+1}, S^j_{t+1}, given by

$$S^j_{t+1} = \begin{cases} X_{t+1} & \text{with probability } p \\ X'_{t+1} & \text{with probability } 1-p \end{cases}$$

where X'_{t+1} is an i.i.d. draw from the unconditional distribution of X_{t+1}, which has an unconditional mean of zero.

Microfounding $\bar{m}$

The familiy head averages over all households. The *average* expectation of X_{t+1} is:

$$\begin{aligned}\mathbb{E}\left[X^e_{t+1}(S_{t+1})|X_{t+1}\right] &= \mathbb{E}\left[p \cdot S_{t+1}|X_{t+1}\right] \\ &= p \cdot \mathbb{E}\left[S_{t+1}|X_{t+1}\right] \\ &= p^2 X_{t+1}.\end{aligned}$$

Defining $\bar{m} \equiv p^2$ and since $X_{t+1} = \Gamma X_t + \varepsilon_{t+1}$, we have that the family head perceives the law of motion of X to equal

$$X_{t+1} = \bar{m}\left(\Gamma X_t + \varepsilon_{t+1}\right). \tag{1}$$

The boundedly-rational expectation of X_{t+1} is then given by

$$\mathbb{E}^{BR}_t\left[X_{t+1}\right] = \bar{m}\mathbb{E}_t\left[X_{t+1}\right].$$

▸ back

A Closer Look at Direct vs. Indirect Effects

Consumption function:

$$\hat{c}_t = [1-\beta(1-\lambda\chi)]\,\hat{y}_t - \frac{(1-\lambda)\beta}{\gamma}\hat{r}_t + \beta\bar{m}\delta(1-\lambda\chi)\mathbb{E}_t\hat{c}_{t+1}.$$

Indirect effects Ξ^{GE}: change in total consumption due to changes in total income for fixed real rates:

$$\Xi^{GE} = \frac{1-\beta(1-\lambda\chi)}{1-\beta\bar{m}\delta\rho(1-\lambda\chi)}.$$

$\Rightarrow$ about $70-80\%$, consistent with larger quantitative models (Kaplan et al. (2018)))

$\Rightarrow$ cognitive discounting reduces sensitivity to expected changes in the future ▸ back

Calibration Tractable Model

Parameter	Description	Value
γ	Risk Aversion	1
κ	Slope of NKPC	0.02
χ	Business-Cycle Exposure of H	1.5
λ	Share of H	0.33
s	Type-Switching Probability	$0.8^{1/4}$
β	Time Discount Factor	0.99
$\bar{m}$	Cognitive Discounting Parameter	0.85

back

Calibration Quantitative Model

Parameter	Description	Value
R	Steady State Real Rate (annualized)	2%
γ	Risk aversion	2
φ	Inverse of Frisch elasticity	2
μ	Markup	1.2
θ	Calvo Price Stickiness	0
ρ_e	Autocorrelation of idiosyncratic risk	0.966
σ_e^2	Variance of idiosyncratic risk	0.0384
$\tau(e)$	Tax shares	[0, 0, 1]
$d(e)$	Dividend shares	$[0, \frac{0.2}{0.5}, \frac{0.8}{0.25}]$
$\frac{B^G}{4Y}$	Total wealth	0.625

back

Fiscal Policy: Details

Debt rule:

$$T_t - \bar{T} = \vartheta \frac{B_{t+1} - \bar{B}}{\bar{B}}$$

$\vartheta = 0.05$

Household budget constraint:

$$C_{i,t} + \frac{B_{i,t+1}}{R_t} = B_{i,t} + W_t e_{i,t} N_{i,t} + D_t d(e) - \tau_t(e),$$

with

- progressive tax system: $\tau_t(e) = \frac{T_t}{0.25}$ if $e = e_{high}$ and 0 otherwise
- less-progressive taxes: $\tau_t(e) = e_t \frac{T_t}{\bar{e}}$

back

Fiscal Multipliers

The fiscal multiplier in the behavioral HANK model is given by

$$\frac{\partial \widehat{y}_t}{\partial g_t} = 1 + \frac{1}{1-\nu\mu}\frac{\zeta}{1+\frac{1}{\gamma}\frac{1-\lambda}{1-\lambda\chi}\phi\kappa}\left[\frac{\chi-1}{1-\lambda\chi}\left[\lambda + \bar{m}\mu(1-s-\lambda)\right] - \kappa\frac{1}{\gamma}\frac{1-\lambda}{1-\lambda\chi}(\phi-\mu)\right],$$

where

$$\nu \equiv \frac{\bar{m}\delta + \frac{1}{\gamma}\kappa\frac{1-\lambda}{1-\lambda\chi}}{1+\frac{1}{\gamma}\frac{1-\lambda}{1-\lambda\chi}\phi\kappa}. \tag{2}$$

Fiscal Multiplier II

Consider case with completely sticky prices: $\kappa = 0$

$$\frac{\partial \hat{y}_t}{\partial g_t} = 1 + \frac{\zeta}{1 - \bar{m}\delta\mu} \left[\frac{\chi - 1}{1 - \lambda\chi} [\lambda + \bar{m}\mu(1 - s - \lambda)] \right]$$

$\Rightarrow$ larger than 1 if and only if $\chi > 1$!

back

iMPCs

Proposition

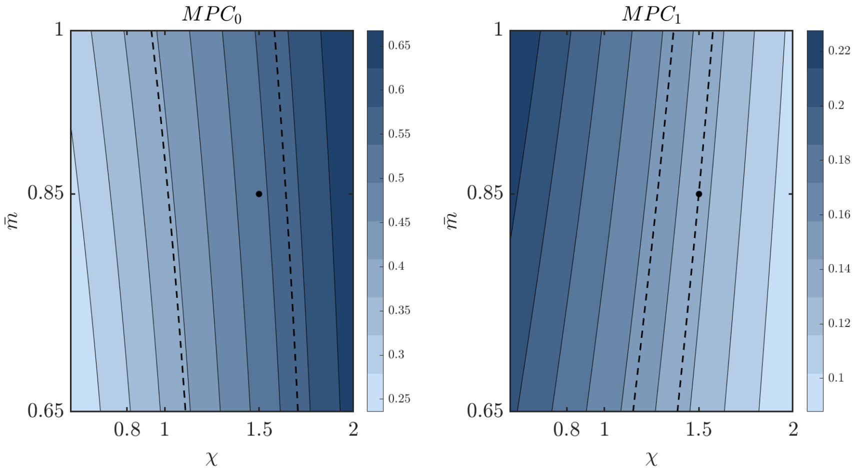
The intertemporal MPCs in the behavioral HANK model, i.e., the aggregate consumption response in period k to a one-time change in aggregate disposable income in period 0, are given by

$$MPC_0 \equiv \frac{d\hat{c}_0}{d\tilde{y}_0} = 1 - \frac{1-\lambda\chi}{s\bar{m}}\mu_2^{-1}$$

$$MPC_k \equiv \frac{d\hat{c}_k}{d\tilde{y}_0} = \frac{1-\lambda\chi}{s\bar{m}}\mu_2^{-1}\left(\beta^{-1}-\mu_1\right)\mu_1^{k-1}, \qquad \text{for } k > 0,$$

where the parameters μ_1 and μ_2 depend on the underlying parameters, including $\bar{m}$ and χ.

iMPCs Results



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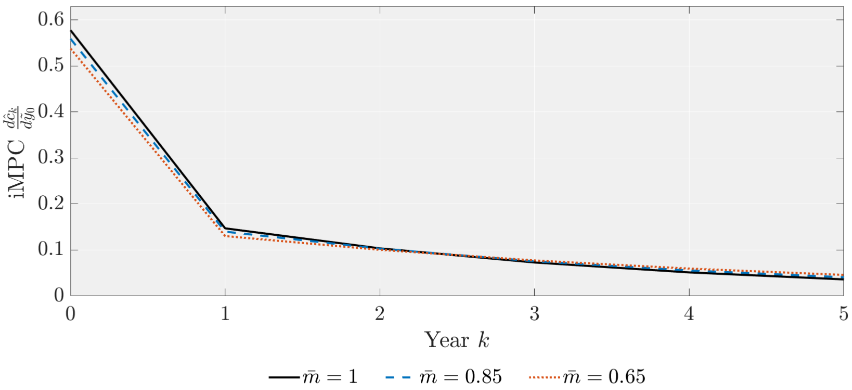
iMPCs for Longer Horizons



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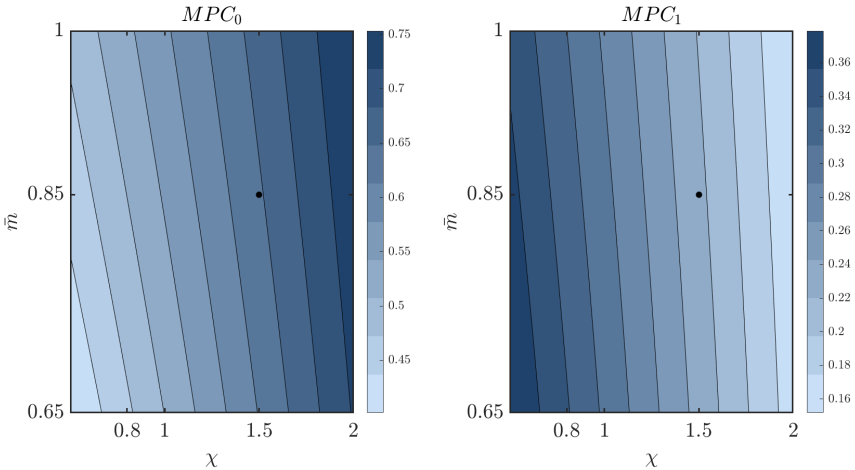
iMPCs for higher idiosyncratic risk $1 - s$



$\Rightarrow MPC_1$ decreases with $\bar{m}$ if idiosyncratic risk is high enough back

Taylor Principle Revisited

Taylor rule:

$$i_t = \phi \pi_t$$

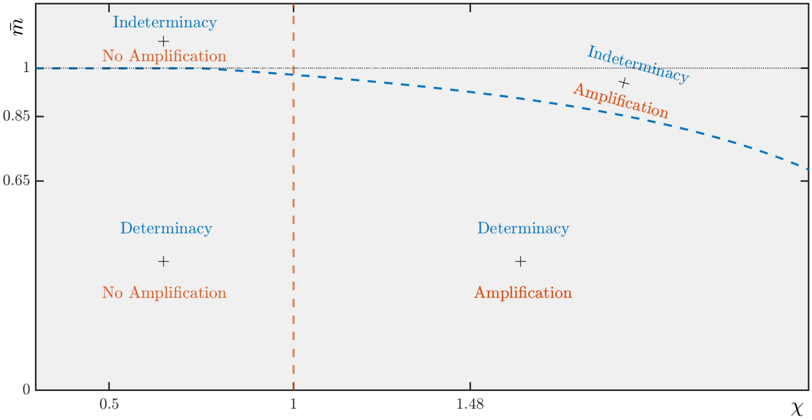
Condition for determinacy:

$$\phi > 1 + \frac{\delta \bar{m} - 1}{\frac{\kappa}{\gamma} \frac{1-\lambda}{1-\chi\lambda}}$$

- RANK/TANK: $\bar{m} = \delta = 1$: $\phi > 1$
- THANK $\bar{m} = 1$, $\chi = 1.5$, $\delta > 1 : \phi > 2.5$
- Behavioral HANK:
  - $\chi = 1.5$, $\bar{m} = 0.85 : \phi > -3$ (determinacy under a peg)

back

Nesting of Existing Models



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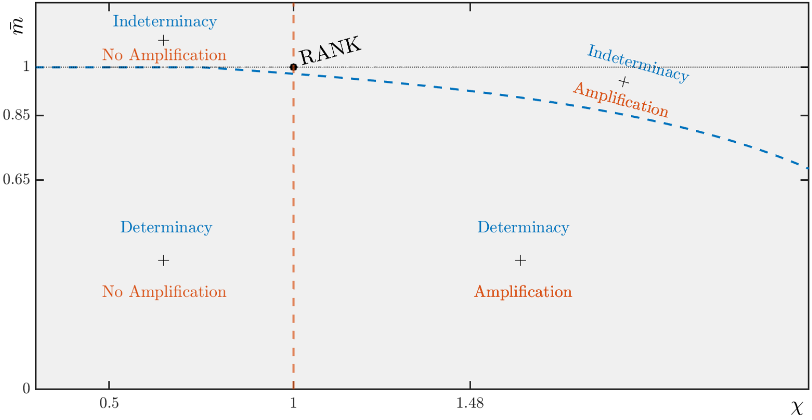

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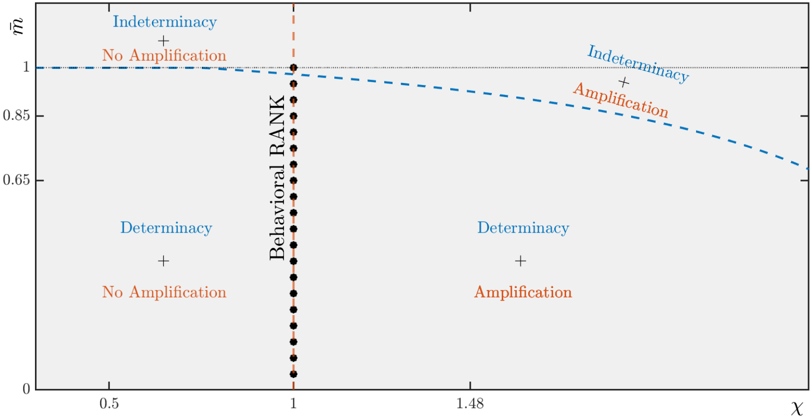

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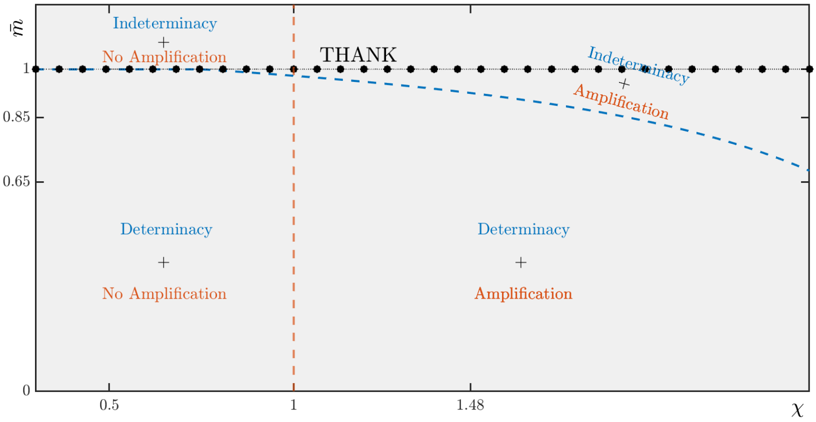

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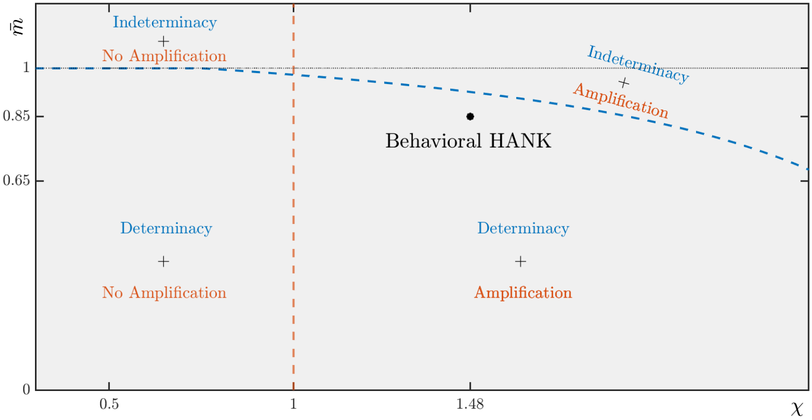


⇒ Only behavioral HANK achieves "Determinacy + Amplification"

‣ back

Introducing Sticky Wages

- Labor union allocates hours of households to firms and makes sure that U and H households work the same amount.
- Sticky wages: labor union faces Calvo friction $\Rightarrow$ wage Phillips Curve:

$$\pi_t^w = \beta \mathbb{E}_t \pi_{t+1}^w + \kappa_w \widehat{\mu}_t^w$$

π_t^w: wage inflation, κ_w: slope, $\widehat{\mu}_t^w$: wage markup, given by

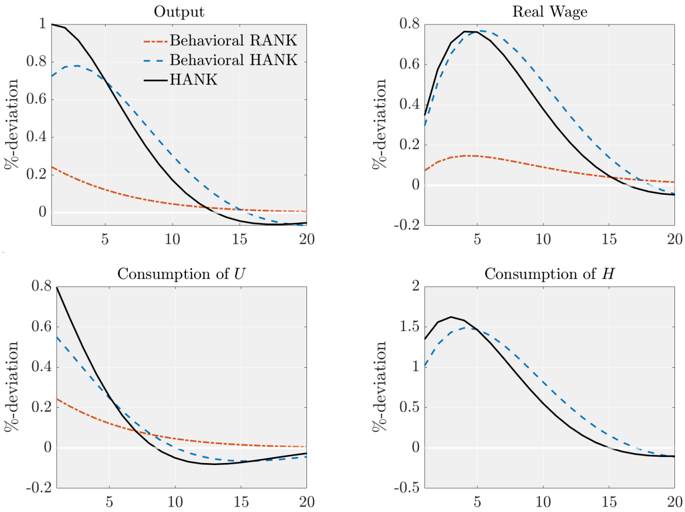
$$\widehat{\mu}_t^w = \gamma \widehat{c}_t + \varphi \widehat{n}_t - \widehat{w}_t .$$

- Interest-rate smoothing in Taylor rule (as in Auclert et al. (2020)):

$$\widehat{i}_t = \rho_i \widehat{i}_{t-1} + (1 - \rho_i) \phi \pi_t + \varepsilon_t^{MP}$$

$\Rightarrow$ How does the economy respond to an expansionary monetary policy shock?

Monetary Policy Shock



Why hump shapes?

Hump-shaped responses due to interaction of household heterogeneity, bounded rationality and sticky wages!

1. Calvo wage setting leads to hump-shape responses of real wage (in all models)
2. In HANK models, this causes hump-shape consumption of a subgroup of households
3. Cognitive discounting flattens consumption profile of unconstrained households:
   - impact response less strong because it dampens the FG component of persistent decline in interest rates
   - going forward, they learn that their idiosyncratic risk is still (or even more) relaxed

‣ back

Forecast Error Dynamics

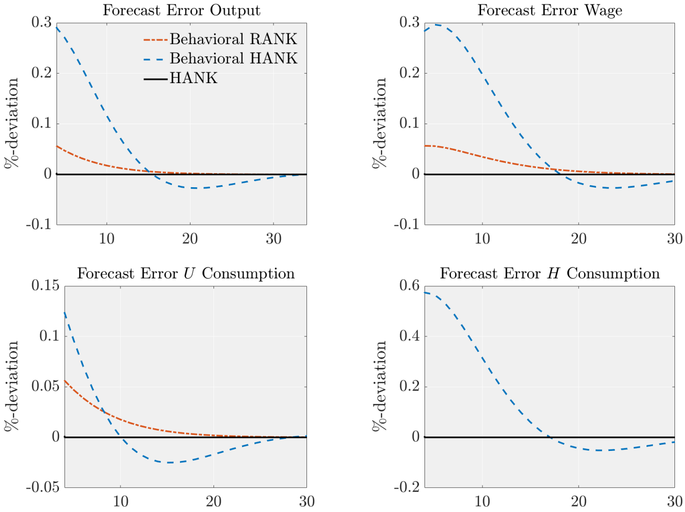
- 1-period ahead forecast error in period $t+h$ is defined as:

$$FE^{\widehat{x}}_{t+h+1|t+h} \equiv \widehat{x}_{t+h+1} - \bar{m}\mathbb{E}_{t+h}\left[\widehat{x}_{t+h+1}\right].$$

$\Rightarrow$ How do forecast errors evolve after shock?

- Full-info rational expectations: equal to zero in all periods *after* shock occurs
- Empirical evidence: persistent deviations from zero with initial underreaction, followed by delayed overshooting (Angeletos et al. (2021))

Forecast Error Dynamics



▸ back

Backward-Looking Anchor

Backward-looking anchor $X_t^d = X_{t-1}$ yields:

$$\mathbb{E}_t^{BR}\left[\widehat{x}_{t+1}\right] = (1-\bar{m})\widehat{x}_{t-1} + \bar{m}\mathbb{E}_t\widehat{x}_{t+1}$$

Backward-looking behavioral IS equation (with myopia and anchoring):

$$\widehat{y}_t = \underbrace{\bar{m}\delta}_{=\psi_f}\mathbb{E}_t\widehat{y}_{t+1} - \psi_c\frac{1}{\gamma}\left(\widehat{i}_t - \mathbb{E}_t\pi_{t+1}\right) + (1-\bar{m})\delta\widehat{y}_{t-1}.$$

$\Rightarrow$ reduced-form equivalence with models of incomplete information and learning

Angeletos and Huo (2021), Gallegos (2021)

▸ back

Heterogeneous $\bar{m}$

To estimate cognitive discounting and to test for heterogeneity in the degree of cognitive discounting, we follow Coibion and Gorodnichenko (2015)

$$x_{t+4} - \mathbb{E}_t^{e,BR} x_{t+4} = c^e + b^{e,CG} \left(\mathbb{E}_t^{e,BR} x_{t+4} - \mathbb{E}_{t-1}^{e,BR} x_{t+4} \right) + \epsilon_t^e, \tag{3}$$

estimate $b^{e,CG}$ for income groups of households, indexed by e.

$b^{e,CG} > 0$ is consistent with underreaction and the corresponding cognitive discounting parameter is approximately given by

$$\bar{m}^e = \left(\frac{1}{1 + b^{e,CG}} \right)^{1/4}. \tag{4}$$

Heterogeneous $\bar{m}$, Continued

Michigan Survey: asks households whether they expect unemployment to increase, decrease or to remain about the same over the next twelve months.

We translate these categorical unemployment expectation into numerical expectations (as in Carlson and Parkin (1975), Mankiw (2000) and Bhandari et al. (2019))

Let $q_t^{e,D}$, $q_t^{e,S}$ and $q_t^{e,U}$ denote shares of e in t thinking unemployment will go down, stay roughly the same, or go up. Assume shares are drawn from a cross-sectional distribution $\mathcal{N}\left(\mu_t^e, (\sigma_t^e)^2\right)$, threshold a such that when HH expects unemployment to remain within the range $[-a, a]$, responds that unemployment remains "about the same". We have

$$q_t^{e,D} = \Phi\left(\frac{-a-\mu_t^e}{\sigma_t^e}\right) \qquad q_t^{e,U} = 1 - \Phi\left(\frac{a-\mu_t^e}{\sigma_t^e}\right).$$

Heterogeneous $\bar{m}$, Continued

This yields

$$\sigma_t^e = \frac{2a}{\Phi^{-1}\left(1 - q_t^{e,U}\right) - \Phi^{-1}\left(q_t^{e,D}\right)}$$

$$\mu_t^e = a - \sigma_t^e \Phi^{-1}\left(1 - q_t^{e,U}\right)$$

Set $a = 0.5$.

Question is about the expected change in unemployment, add the actual unemployment rate at the time of the survey to μ_t^e.

Heterogeneous $\bar{m}$, Continued

Forecast revisions:

$$\mu_t^e - \mu_{t-1}^e$$

Four-quarter-ahead forecast errors (actual unemployment rate u_t from FRED):

$$u_{t+4} - \mu_t^e. \tag{5}$$

For the case of expected unemployment changes, we replace u_{t+4} with $(u_{t+4} - u_t)$ in equation (5).

Estimate

$$u_{t+4} - \mu_t^e = c^e + b^{e,CG} \left(\mu_t^e - \mu_{t-1}^e \right) + \epsilon_t^e \tag{6}$$

Problem: expectations in the forecast revisions are about unemployment at different points in time. To account for this, we instrument forecast revisions by the *main business cycle shock* obtained from Angeletos et al. (2020).

Heterogeneous $\bar{m}$: Empirical Results

	IV Regression			OLS		
	Bottom 25%	Middle 50%	Top 25%	Bottom 25%	Middle 50%	Top 25%
$\widehat{b}^{e,CG}$	0.85	0.75	0.63	1.22	1.10	0.90
s.e.	(0.471)	(0.453)	(0.401)	(0.264)	(0.282)	(0.247)
F-stat.	24.76	18.74	17.86	-	-	-
N	152	152	152	157	157	157

Note: This table provides the estimated $\widehat{b}^{e,CG}$ from regression (3) for different income groups. The first three columns show the results when the right-hand side in equation (3) is instrumented using the *main business cycle shock* from Angeletos et al. (2020) and the last three columns using OLS. Standard errors are robust with respect to heteroskedasticity and are reported in parentheses. The row "F-stat." reports the first-stage F-statistic for the IV regressions.

Heterogeneous $\bar{m}$: Empirical Results, Continued

From equation (4), we get $\bar{m}^e$ equal to 0.86, 0.87 and 0.88 for the bottom 25%, the middle 50% and the top 25%, respectively for the estimates from the IV regressions and 0.82, 0.83 and 0.85 for the OLS estimates. When estimating $\bar{m}^e$ using expected unemployment *changes* instead of the level, the estimated $\bar{m}^e$ equal 0.57, 0.59 and 0.64 for the IV regressions and 0.77, 0.80 and 0.86 for the OLS regressions.

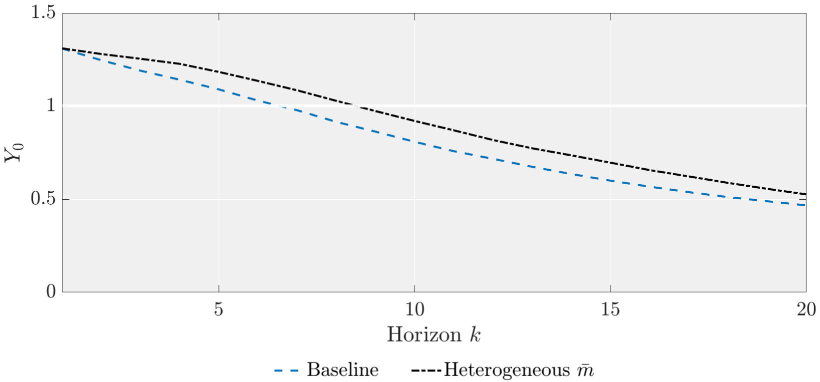
$\Rightarrow$ $\bar{m} = 0.85$ is a reasonable (but rather conservative) deviation from rational expectations

$\Rightarrow$ households with higher income tend to exhibit higher degrees of rationality

Inflation expectations: estimate cognitive discounting parameters of 0.70, 0.75 and 0.78 for the bottom 25%, the middle 50% and the top 25%.

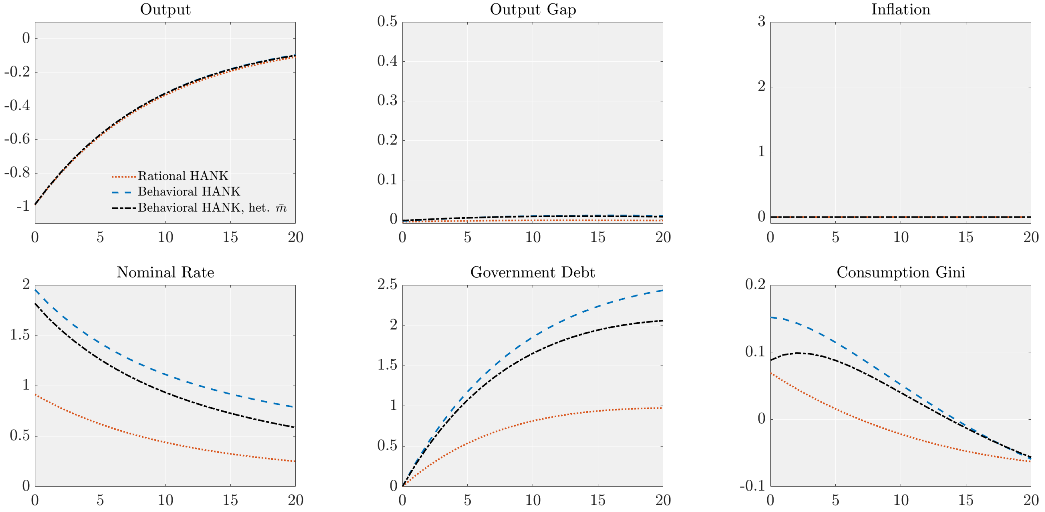
Heterogeneous $\bar{m}$: Model Implications

Implement in quantitative HANK: $\bar{m} \in \{0.8, 0.85, 0.9\}$ for the three different productivity-groups.

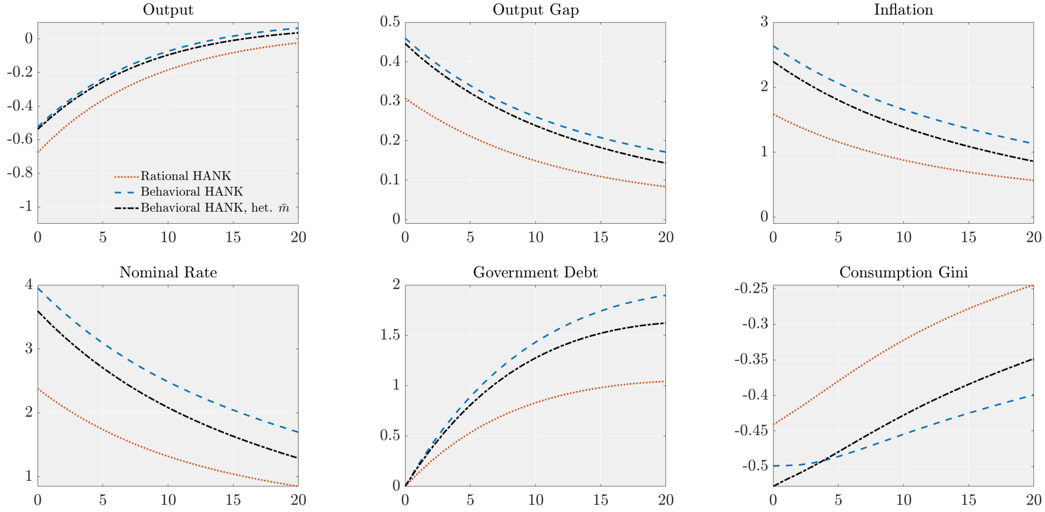


Monetary policy amplification ✓ Solve forward guidance puzzle ✓

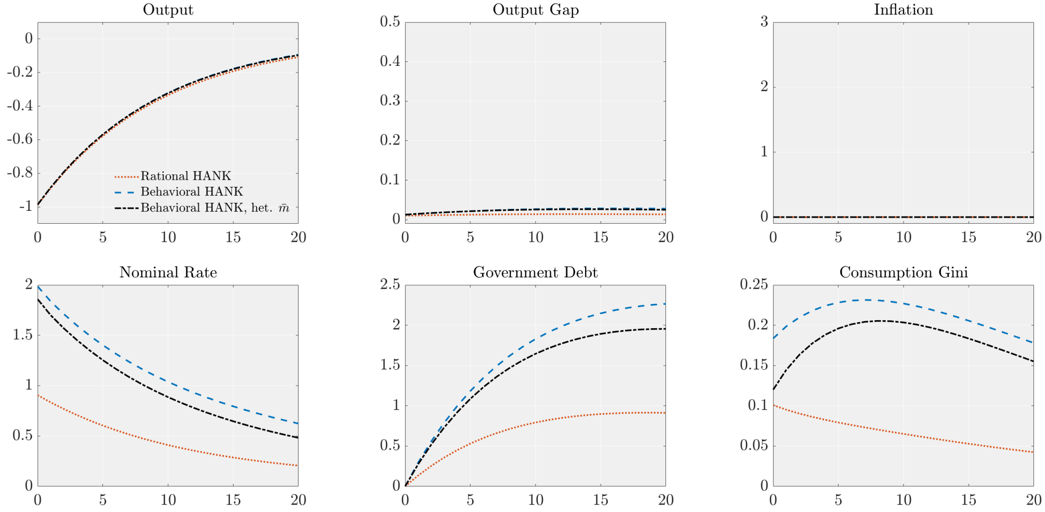
Negative Productivity Shock: Heterogeneous $\bar{m}$



Negative Productivity Shock - Taylor Rule: Heterogeneous $\bar{m}$



Negative Productivity Shock: Heterogeneous $\bar{m}$, "Flat" Taxes



Negative Prod. Shock - Taylor: Heterogeneous $\bar{m}$, "Flat" Taxes

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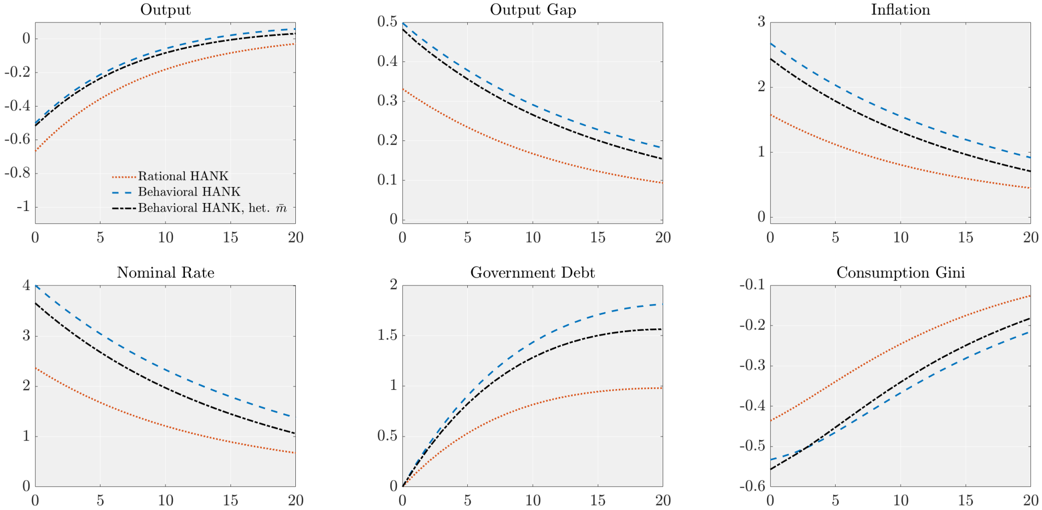
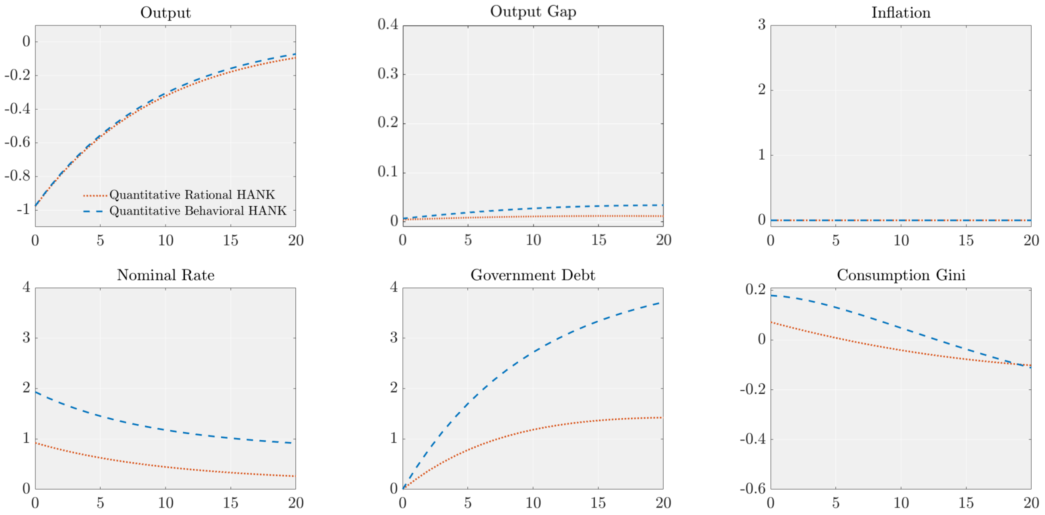


High Initial Debt



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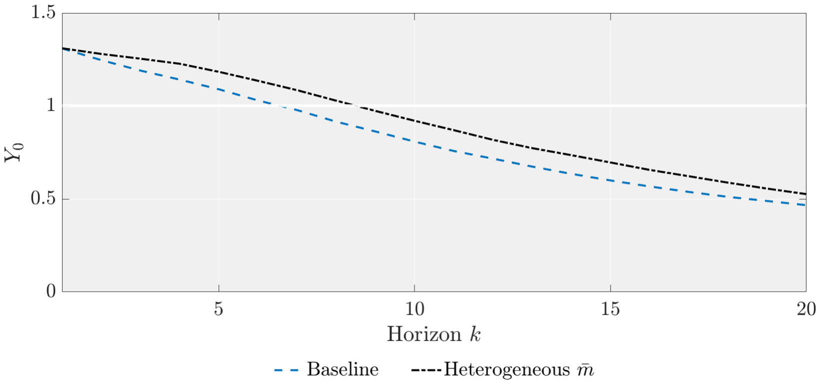
Extension: Heterogeneous Cognitive Discounting

We show that in the data:

- households of all income groups underreact
- but households with higher income slightly less ▸ Heterogeneous $\bar{m}$ in the data

$\Rightarrow$ model: $\bar{m} \in [0.8, 0.9]$ increasing function of individual productivity

Heterogeneous $\bar{m}$: Monetary Policy



Forward guidance is slightly more effective, but FG puzzle still resolved

Policy Implications with Heterogeneous $\bar{m}$

Heterogeneity in $\bar{m}$:

▸ Heterogeneous $\bar{m}$

- expectation channels are more powerful than with homogeneous $\bar{m}$

  $\Rightarrow$ trade-off is slightly smaller

- more productive households are less behavioral $\Rightarrow$ decrease consumption more in expectation of future tax increases

  $\Rightarrow$ more relevant with progressive taxes

- overall results are robust

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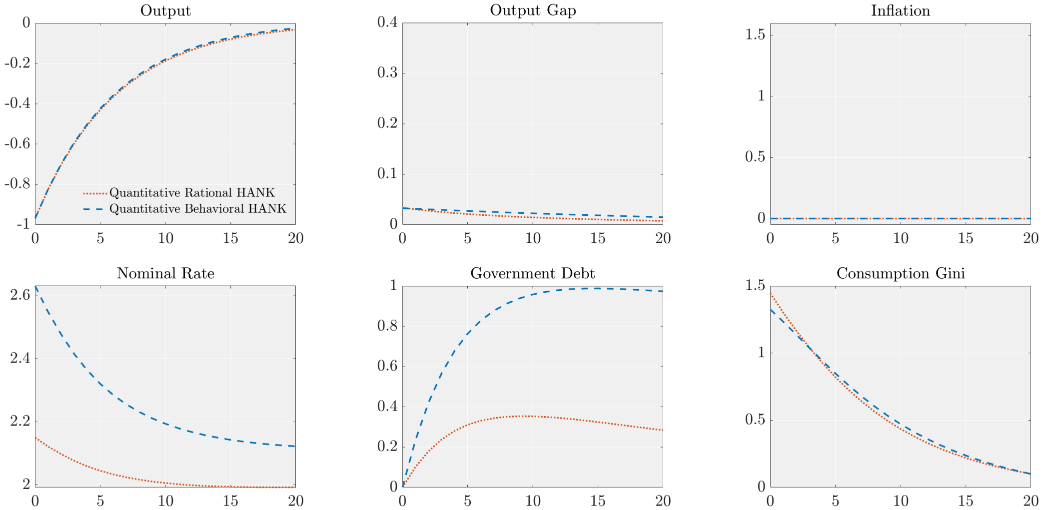
Cost-Push Shock



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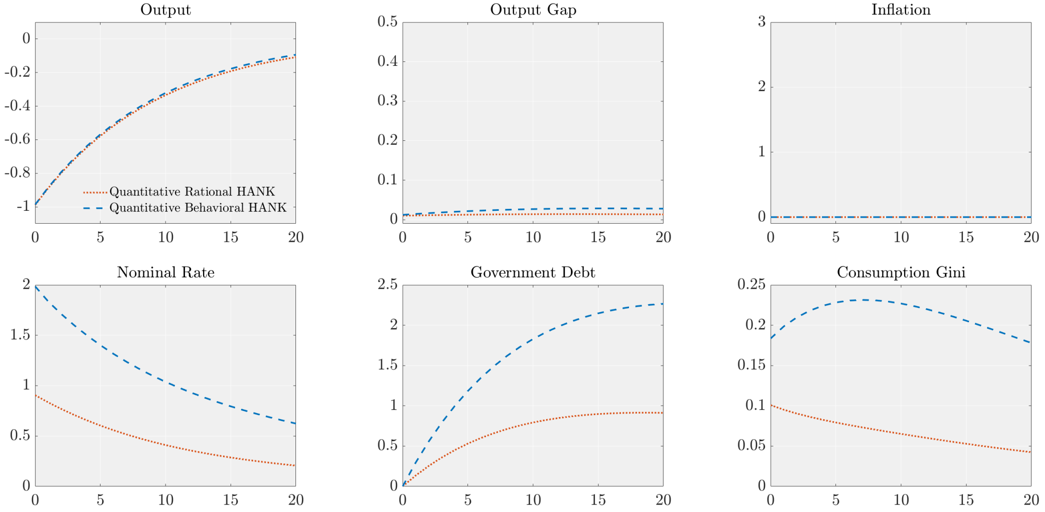
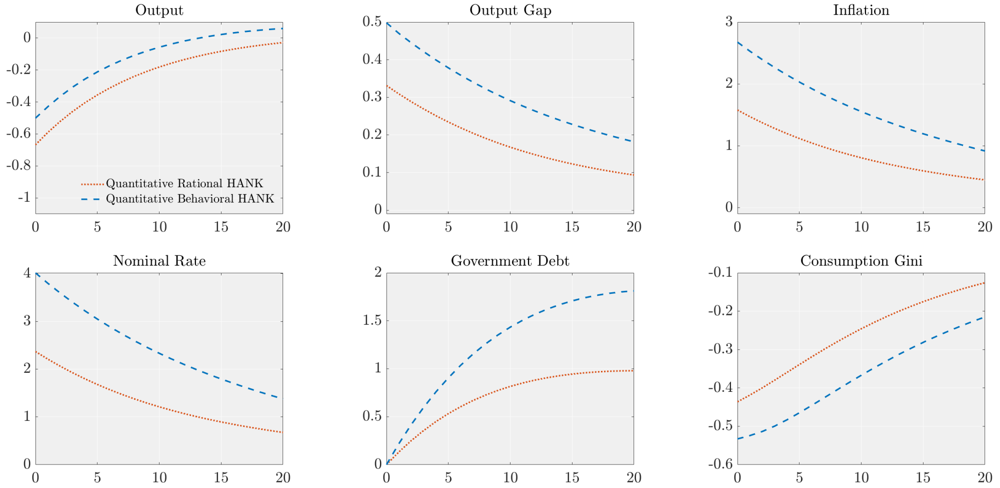
Less Progressive Taxes & Full-Inflation Stabilization



Less Progressive Taxes & Taylor Rule



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