A Behavioral Heterogeneous Agent New Keynesian Model

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$\Rightarrow$ accounting for these findings turns out to be challenging for existing macro models

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Today: Sketch of model, monetary policy, and supply shock

Literature

- HANK and TANK literature:
  - transmission of monetary policy through indirect general equilibrium effects
    Kaplan et al. (2018), Auclert (2019), Auclert et al. (2020), Bilbiie (2020))
  - positive fiscal multipliers on consumption
    Auclert et al. (2018), Galí et al. (2007), Bilbiie (2021), Hagedorn et al. (2019b)
  - resolution of forward guidance puzzle
    McKay et al. (2016, 2017), Hagedorn et al. (2019a)

  ... BUT: trade-off in HANK models: Werning (2015), Bilbiie (2021)

⇒ Contribution: overcome this tradeoff and account for all facts simultaneously

- Relaxation of full-info rational expectations to solve NK puzzles
  Wiederholt (2015), Angeletos and Lian (2018), Gabaix (2020)

⇒ Contribution: heterogeneity/incomplete markets, role of indirect effects

- Combination of household heterogeneity and deviation from FIRE
  Farhi and Werning (2019), Auclert et al. (2020). Broer et al. (2021), Angeletos and Huo (2021), Laibson et al. (2021), Gallegos (2021)

⇒ Contribution: analytical results, fiscal multipliers, amplification through GE

Model

Households

- Discrete time, infinite horizon
- Continuum of households, cognitive discounting (more later), 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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- Limited heterogeneity setup: 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, and MPCs
  - idiosyncratic risk of type switching: from U to H with prob. $1-s$
    $\Rightarrow$ self-insurance motive
  - full insurance within type; zero liquidity

▸ Details

Firms and Government

Firms:

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Government:

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

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

▸ Details

Equilibrium: Key Equations

Log-linearize around full-insurance, zero-liquidity steady state

- H consumption:

$$\widehat{c}_t^H = \chi \widehat{y}_t$$

  - χ depends on underlying parameters ▸ Details
  - χ measures the business-cycle exposure of high MPC households (Bilbiie (2020)
    $\Rightarrow \chi = 1.5$ as data suggests $\chi > 1$ (Auclert (2019), Patterson (2019))

- 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

Similar to Gabaix (2020), we introduce bounded rationality as cognitive discounting:

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

- $\mathbb{E}_t\left[\cdot\right]$: rational expectations (RE) 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, RE captured by $\bar{m} = 1$. ▸ Microfoundation
- Data: $\bar{m} \in [0.6, 0, 85] \Rightarrow \bar{m} = 0.85$ as upper bound
- Observationally equivalent with (some) models of incomplete information

  Angeletos and Lian (2022)

Behavioral HANK IS Equation

The behavioral HANK IS equation is given by

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

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- $\psi_{\mathbf{c}}$ is shaped by the business-cycle exposure of high MPC households χ:

$$\psi_{\mathbf{c}} = \frac{1-\lambda}{1-\chi\lambda}.$$

- $\psi_{\mathbf{f}}$ is shaped by the interaction of precautionary-savings dynamics and bounded rationality:

$$\psi_{\mathbf{f}} = \bar{m}\delta, \qquad \delta \equiv 1 + (\chi - 1)\frac{1-s}{1-\chi\lambda}.$$

▸ Calibration

Monetary Policy

Monetary Policy in behavioral HANK

We consider two monetary policy experiments:

(i) contemporaneous monetary policy shock (conventional MP shock)

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⇒ effects on output today?

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(i) GE amplification of conventional monetary policy shock if ▸ GE/PE decomposition

$$\psi_{\mathbf{c}} = \frac{1-\lambda}{1-\chi\lambda} > 1 \Leftrightarrow \chi > 1$$

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$$\underbrace{\bar{m}\delta}_{\psi_{\mathbf{f}}} + \underbrace{\frac{1}{\gamma} \frac{1-\lambda}{1-\lambda\chi} \kappa}_{\text{feedback from PC}} < 1, \text{ with } \delta \equiv 1 + (\chi - 1) \frac{1-s}{1-\chi\lambda}$$

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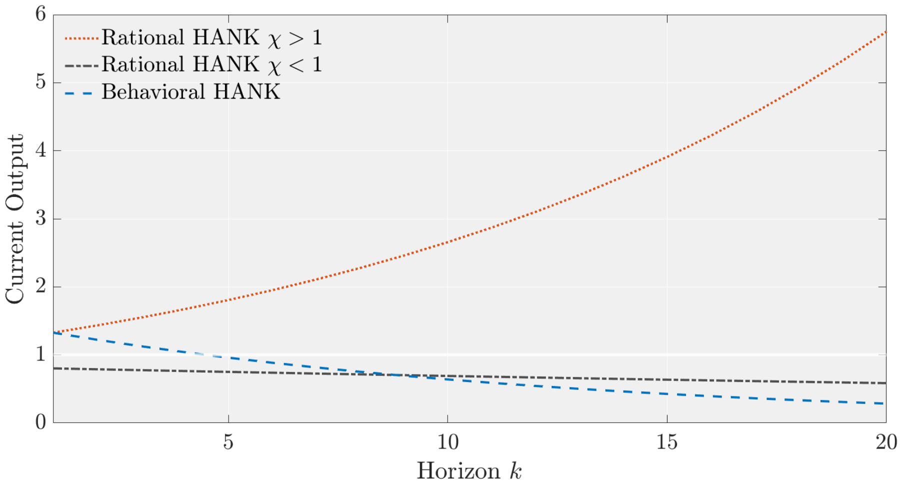
Note: With rational expectations ($\bar{m} = 1$), you cannot have both! Bilbiie (2021)

Monetary Policy in behavioral HANK



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

Further Results in Tractable Model

- Behavioral HANK consistent with other empirical facts:
  - GE amplification carries over to fiscal policy ⇒ positive fiscal multiplier on consumption (under constant real rate) ▸ Fiscal Multiplier
  - Determinacy under a peg ⇒ economy remains stable even with forever binding ELB ▸ Determinacy
  - iMPCs in line with data ▸ iMPCs
- Comparison to existing models that are nested in our framework ⇒ no other model consistent with all the empirical facts simultaneously. ▸ Model comparison
- Allowing for sticky wages ⇒ hump-shaped responses and household expectations consistent with survey evidence ▸ Sticky wages
- Equivalence result with models with incomplete information and learning as in Angeletos and Huo (2021) ▸ Myopia and Anchoring

Quantitative Model

Quantitative Behavioral HANK

Full-blown heterogeneity set-up:

- ex-ante identical households:
  - idiosyncratic productivity e_{it} risk + borrowing constraints
  - self-insure by accumulating bonds B_{it} (now in positive net supply)

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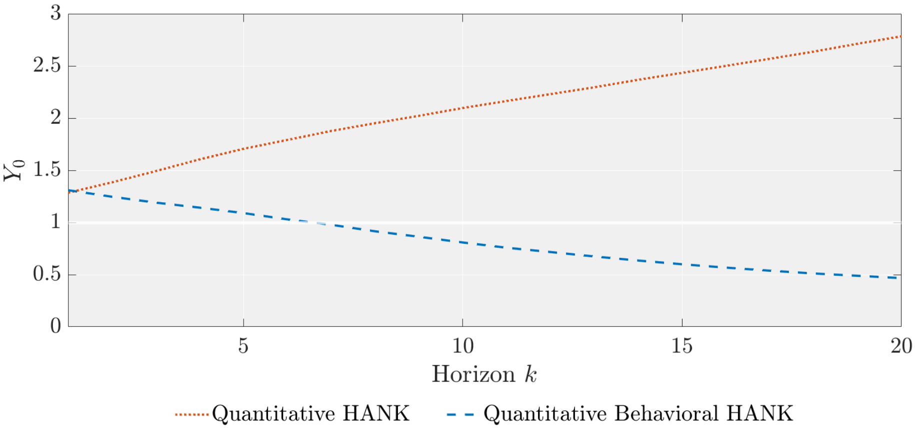
- Effects of conventional MP shocks and FG shocks on today's output?

Monetary Policy in quantitative behavioral HANK



Monetary policy amplification ✓ Solve forward guidance puzzle ✓

Quantitative behavioral HANK: Results

Results from tractable model carry over:

- GE amplification of conventional MP but no forward-guidance puzzle
- Economy more stable at ELB
- Positive consumption response to government spending

Extension:

- heterogeneity in bounded rationality ▸ Heterogeneous $\bar{m}$
  - we find that in the data higher income households are slightly more rational
  - make $\bar{m} \in [0.8, 0.9]$ an increasing function of individual productivity

    $\Rightarrow$ forward guidance puzzle still resolved, but FG is slightly more effective

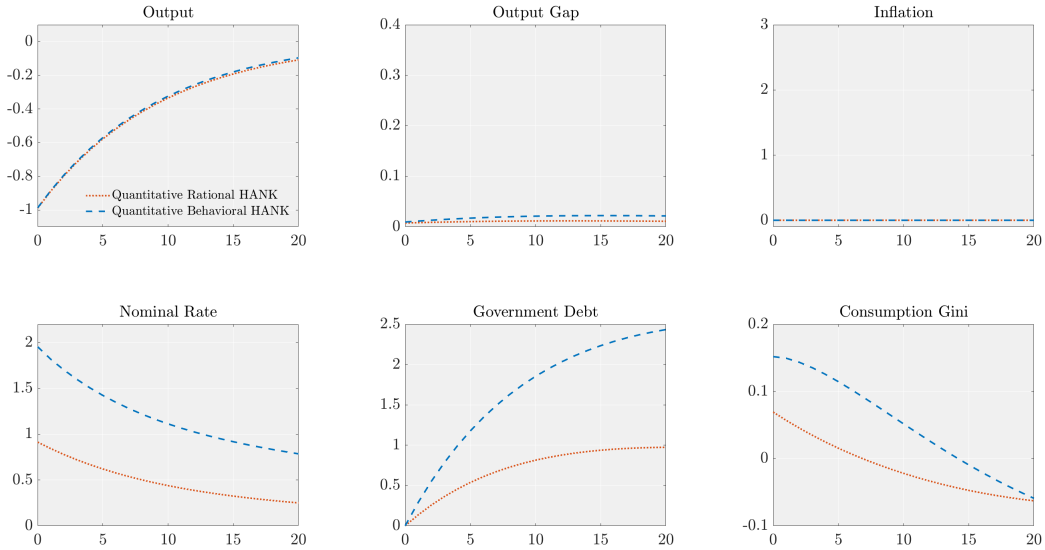
Policy Implications

Negative Productivity Shock

Consider the following scenario:

- Negative productivity shock such that *potential output* (output in flex-price RANK) drops by 1% on impact, with $\rho = 0.9$
- Monetary policy fully stabilizes inflation
- Compare quantitative behavioral HANK and rational HANK

Negative Productivity Shock



Policy Implications: Take Aways

Behavioral HANK model:

- future (expected) interest-rate hikes are less effective

$\Rightarrow$ monetary policy needs to act more strongly to stabilize inflation

$\Rightarrow$ implications for fiscal policy: government debt increases more $\Rightarrow$ especially when initial debt is high! High Debt

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▸ Taylor Rule

$\Rightarrow$ more pronounced tradeoff between aggregate efficiency + and price stability vs. inequality + fiscal sustainability

▸ Cost Push

Conclusion

- We propose a new framework for business cycle and policy analysis: the behavioral heterogeneous agent New Keynesian model
- The behavioral HANK model is consistent with recent empirical facts about the effectiveness and transmission of monetary and fiscal policy
- We offer analytical insights into the role of household heterogeneity and bounded rationality and show that the results carry over to a state-of-the-art HANK setup
- Behavioral HANK model shows that monetary policy needs to respond more strongly after inflationary shocks to stabilize inflation
- Can be extended along many dimensions (some are done in the paper) and used for many policy experiments

Thank you!

Appendix

Households

Unconstrained households:

- remain unconstrained with prob. s, become hand-to-mouth with prob. $1 - s$
- receive labor income + (after-tax) profits, have access to financial markets:

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

Hand-to-mouth households:

- receive labor income + transfers (financed by tax on profits), do not participate in financial markets:

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

⇒ "high MPC households"

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:

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

Demand for shares:

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

Labor-leisure equations of both types:

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

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

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

Business-Cycle Exposure χ

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

Intuition why consumption of H households moves more than 1-for-1 with output: output $\uparrow \Rightarrow$ labor demand $\uparrow \Rightarrow$ wages $\uparrow \Rightarrow$ profits $\downarrow \Rightarrow$. If $\tau^D < \lambda$: H households get wage increase fully, but not profit decrease $\Rightarrow \hat{c}_t^H > \hat{y}_t$

▸ 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

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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

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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: $\kappa = 0$

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

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

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iMPCs

Proposition

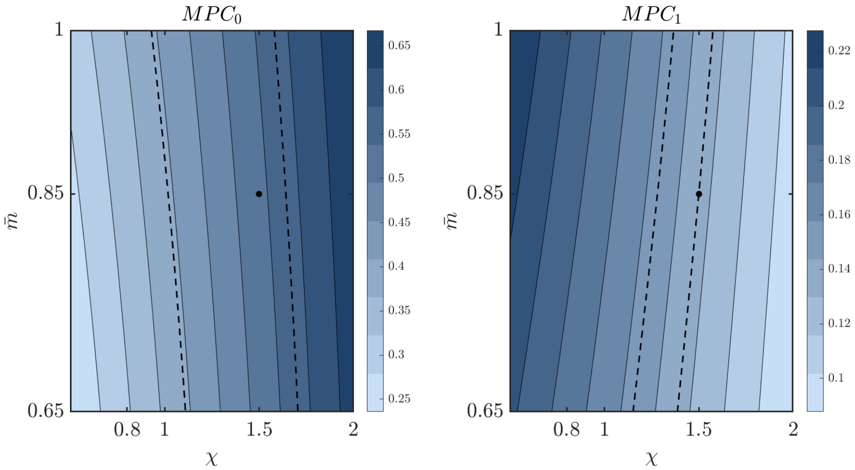
The intertemporal MPCs in the behavioral HANK model, i.e., the aggregate consumption response in period k to a one-time change in aggregate disposable income in period 0, are given by

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

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

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

iMPCs Results



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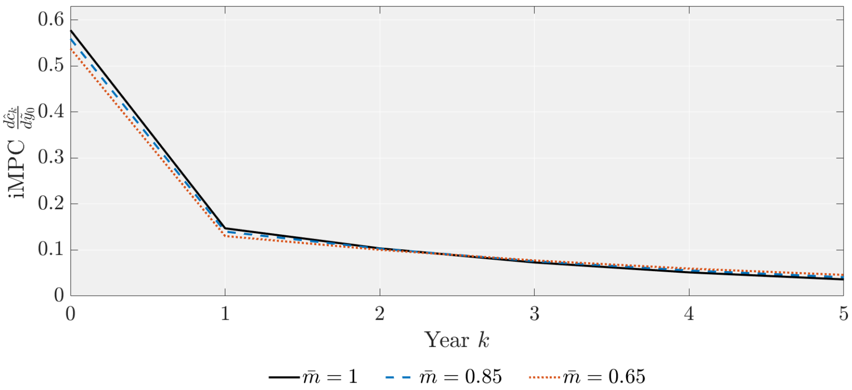
iMPCs for Longer Horizons



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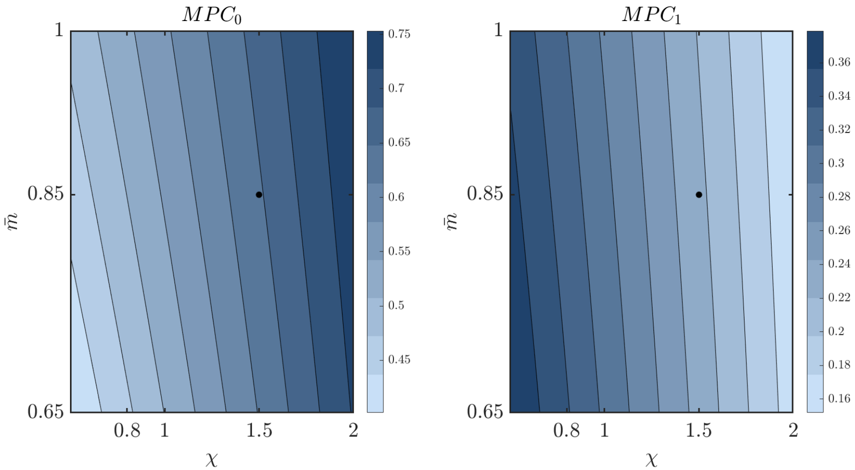
iMPCs for higher idiosyncratic risk $1 - s$



$\Rightarrow$ 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)

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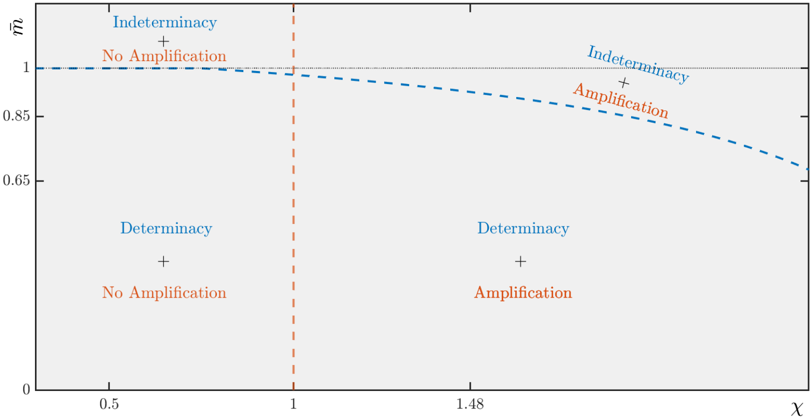
Nesting of Existing Models



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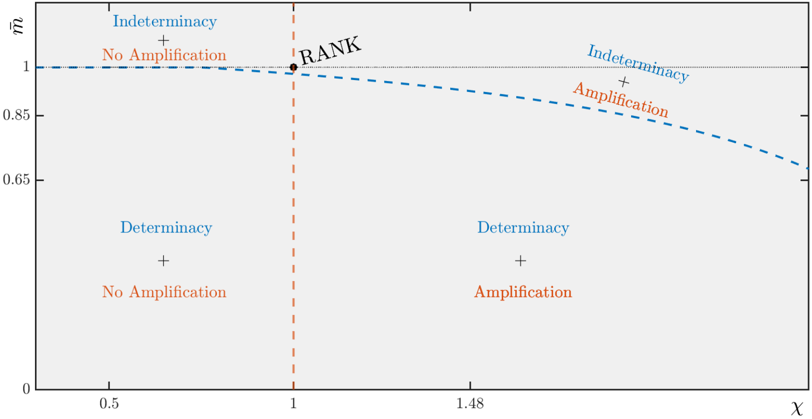
Nesting of Existing Models



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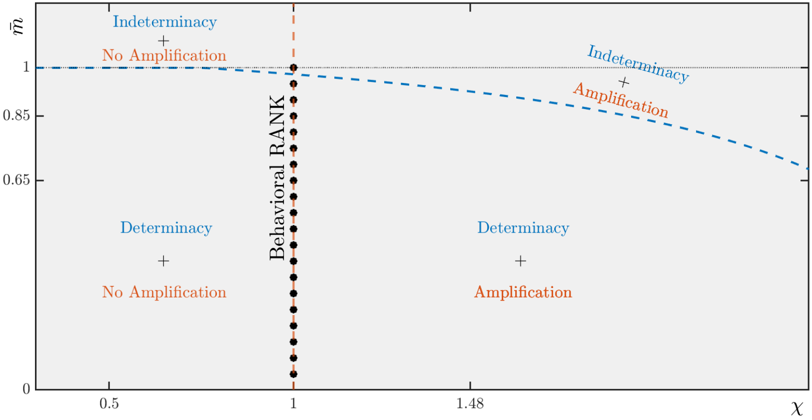
Nesting of Existing Models



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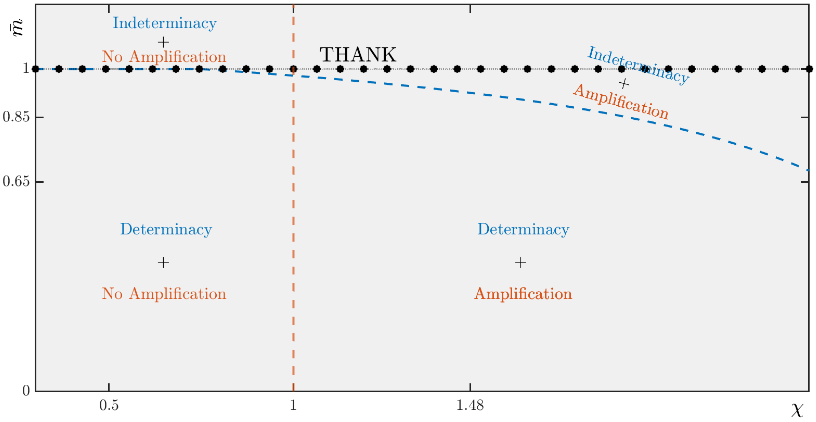
Nesting of Existing Models



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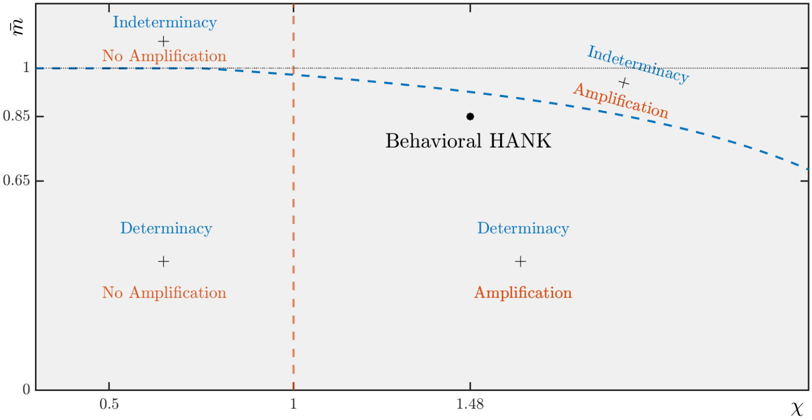
Nesting of Existing Models



$\Rightarrow$ Only behavioral HANK achieves "Determinacy + Amplification"

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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

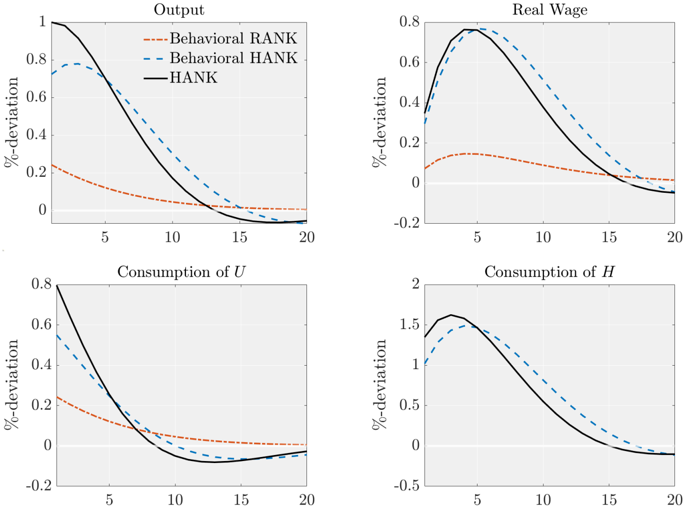
$$\widehat{\mu}_t^w = \gamma \widehat{c}_t + \varphi \widehat{n}_t - \widehat{w}_t.$$

- 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

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Forecast Error Dynamics

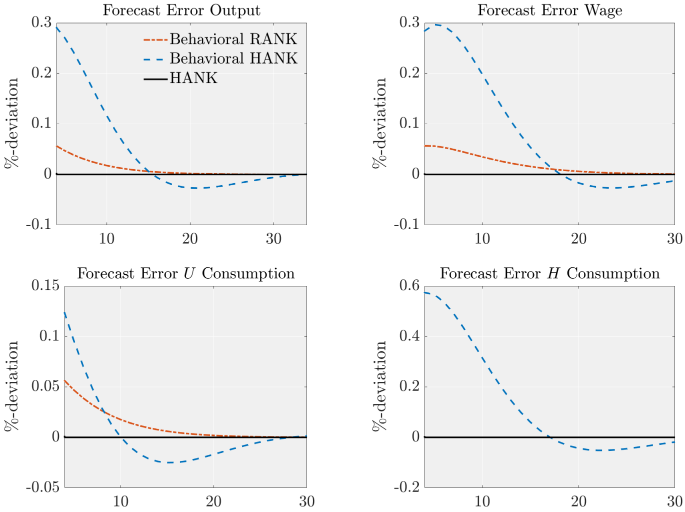
- 1-period ahead forecast error in period $t + h$ is defined as:

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

$\Rightarrow$ 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



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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)

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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.

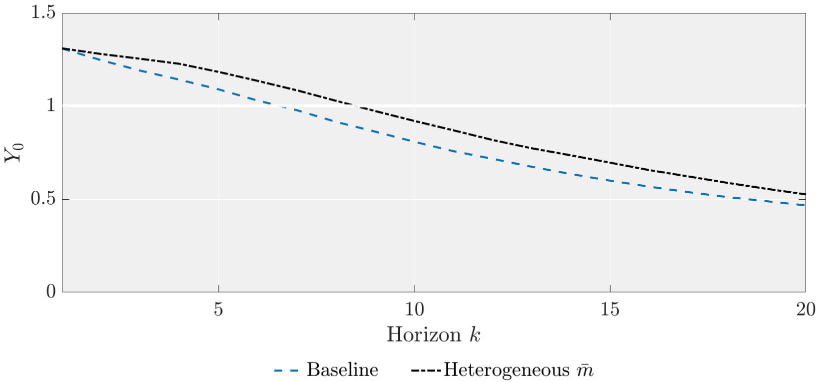
$\Rightarrow$ $\bar{m} = 0.85$ is a reasonable (but rather conservative) deviation from rational expectations

$\Rightarrow$ 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%.

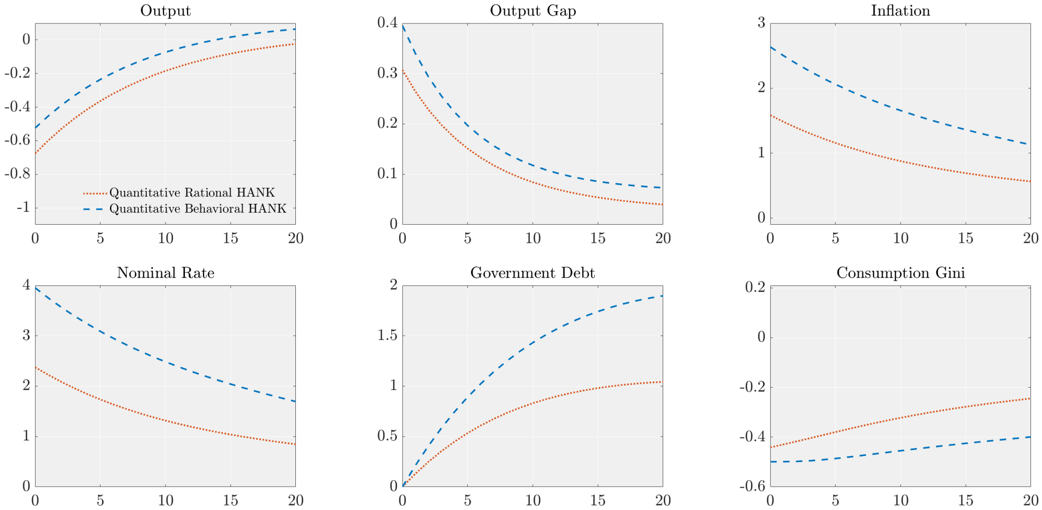
Heterogeneous $\bar{m}$: Model Implications

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 ✓ ▸ back

Productivity Shock - Taylor Rule



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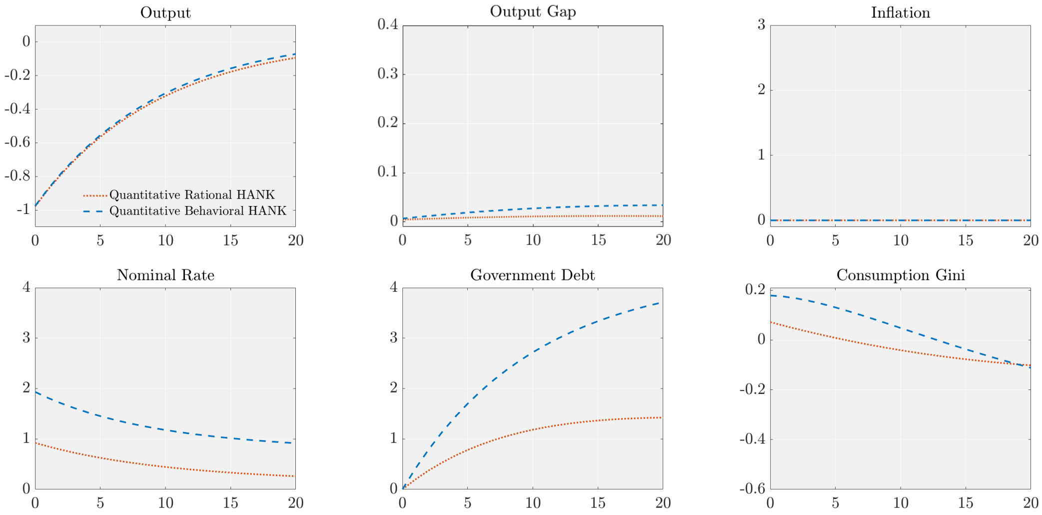
High Initial Debt



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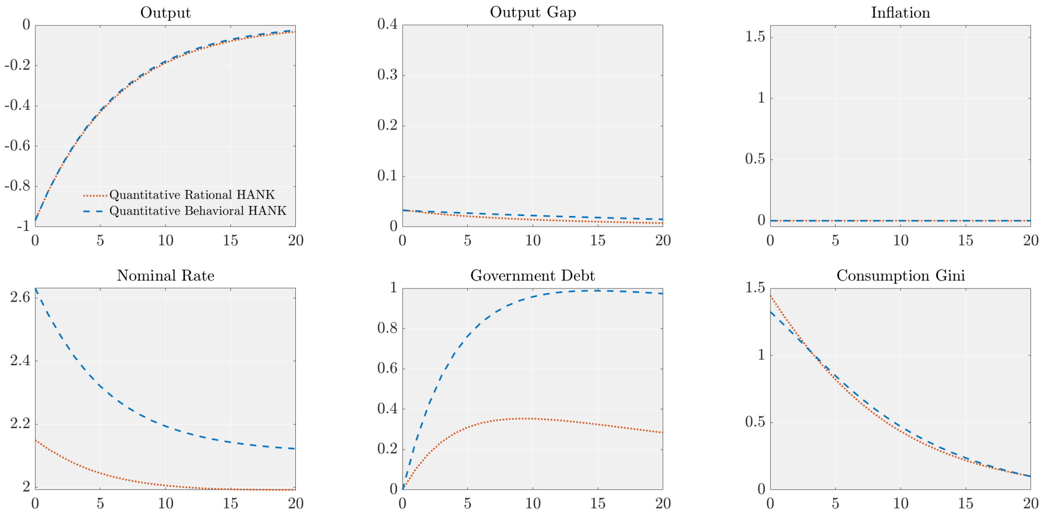
Cost-Push Shock



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