Quantitative Macroeconomics II

HANK models

Tobias Broer

HANK

Since Great Recession: strong interest in heterogeneous-agent NK (HANK) models. Why?

HANK

Since Great Recession: strong interest in heterogeneous-agent NK (HANK) models. Why?

1. Interaction Aggregate fluctuations / macro-policy $\Leftrightarrow$ inequality / individual risks
   - Welfare cost of BCs, cyclical inequality, changed transmission of shocks / policies
2. Keynesian demand-shortfall seems to have depressed output
   - NK demand effects: nominal rigidities, & monopolistic competition
   - High MPC out of income shocks for Keynesian multiplier

What is HANK?

- Builds on NK model (see Gali's textbook)
  1. Firm sector: NC production, Monopolistic competition, price setting friction (quadratic adj cost or Calvo-"fairy")
  2. Central Bank stabilises economy (Taylor rule for nominal interest rate)
  3. Government fiscal authority
- Replace rep HH by continuum of HH as in Bewley - Huggett - Aiyagari:
  - Idiosyncratic income risk
  - Incomplete markets (bonds, plus perhaps illiquid asset)

What is HANK?

- Builds on NK model (see Gali's textbook)
  1. Firm sector: NC production, Monopolistic competition, price setting friction (quadratic adj cost or Calvo-"fairy")
  2. Central Bank stabilises economy (Taylor rule for nominal interest rate)
  3. Government fiscal authority
- Replace rep HH by continuum of HH as in Bewley - Huggett - Aiyagari:
  - Idiosyncratic income risk
  - Incomplete markets (bonds, plus perhaps illiquid asset)
- "AiyaGali" !!

HANK: Early literature

- Oh and Reis (2012)
- Guerrieri and Lorenzoni (2017)
- McKay and Reis (2016)
- McKay et al. (2016)
- Werning (2015),
- Kaplan, Moll and Violante (2018)
- Den Haan et al. (2017)
- Bayer et al. (2017)
- Gornemann et al (unpublished)

Point of departure: Galí textbook model

Textbook NK model: Background

- 1970s: Stagflation, Lucas-critique of old-style macro models
- 1980s: Real-business-cycle revolution: microfoundations for household and firm behavior
- But: no role for monetary policy
- New-Keynesian economics: introduce frictions in RBC model that give role to monetary policy
- Firms have market power (so make profits), but cannot freely set prices
- Time-varying markups of price over marginal cost is key to aggregate fluctuations

Recap: NK textbook model

1. Rep HH: standard, choose consumption & labor supply
2. Firm sector
   - Final good: CES basket of many intermediate goods, downward-sloping demand for intermediate good i
   - Intermediate goods:
     - Production: $Y_i = L$ (no capital)
     - Monopolistic competition: set p_i taking aggregate price level P as given; implies optimal 'markup' of price over marginal cost is constant
     - Price setting friction (Calvo 83): can only reset p_i with probability $1 - \theta$; must satisfy demand at p_i
   - Implies: Markups fluctuate in response to aggregate shocks
3. Central Bank: Taylor rule - raise nominal interest rate when inflation is above target or output below its flex-price level
4. Government fiscal authority

Galí textbook model: Households

- The representative agent solves:

$$\begin{aligned} \max_{C_t, B_t, N_t} \quad & E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{C_t^{1-\sigma} - 1}{1-\sigma} - \frac{N_t^{1+\varphi}}{1+\varphi} \right) \\ \text{s.t.} \quad & P_t C_t + Q_t B_t \leq B_{t-1} + W_t N_t + P_t D_t \end{aligned}$$

Galí textbook model: Production side

- A competitive final goods producer assembles intermediate goods using the Dixit-Stiglitz aggregator $\rightarrow$ CES demand for intermediate goods:

$$Y_{it} = \left(\frac{P_{it}}{P_t} \right)^{-\epsilon} Y_t$$

- Intermediate goods producer i uses production technology

$$Y_{it} = N_{it}$$

- Calvo friction: Intermediate goods firms can only reset prices with probability $1 - \theta$
- A resetting firm maximizes the sum of expected discounted profits subject to the demand function

Galí textbook model: Government

- Fiscal authority does nothing
- Central bank follows Taylor rule:

$$\frac{1}{Q_t} = \frac{1}{\beta}\Pi_t^{\phi_\pi} e^{\nu_t}$$

$$\Rightarrow \qquad \hat{i}_t = \phi_\pi \pi_t^p + \nu_t$$

Galí textbook model: Summary of log-linearized equilibrium

$$
\begin{aligned}
\text{Phillips}: &\quad \pi_t^p = \beta E_t \pi_{t+1}^p + \lambda_p \hat{\omega}_t \\
\text{IS}: &\quad \hat{c}_t = E_t \hat{c}_{t+1} - \frac{1}{\sigma}(\hat{i}_t - E_t \pi_{t+1}) \\
\text{Taylor rule}: &\quad \hat{i}_t = \phi_\pi \pi_t^p + \nu_t \\
\text{Labor supply}: &\quad \hat{\omega}_t = \varphi \hat{n}_t + \frac{1}{\sigma}\hat{c}_t \\
\text{Market clearing}: &\quad \hat{c}_t = \hat{n}_t \\
\text{HH BC}: &\quad \hat{c}_t = \bar{S}(\hat{\omega}_t + \hat{n}_t) + (1 - \bar{S})\hat{d}_t \\
\text{Production} &\quad \hat{c}_t = \hat{n}_t
\end{aligned}
$$

where $\bar{S} = \frac{W_t N_t}{Y_t P_t} = \frac{\epsilon_p - 1}{\epsilon_p}$ is the steady state labor share

HANK: Motivation

1. Micro-consistency
   - Effect of interest rate changes
   - Average MPC out of transitory income changes
2. Novel Macro-implications
   - New responses to old questions
   - New questions to be asked
   - New model features that become important

Micro-consistency: RA model at odds with emp. evidence

1. Effect of interest rate changes
2. Average MPC out of transitory income changes

Generally:

- RANK: One permanent-income consumer, high intertemporal elasticity of substitution, low MPC
- HANK: Consumers with little / illiquid wealth have low IES, high MPC

Effect of interest rate changes: Data

- Weak reaction of aggregate consumption
- Individual reaction depends on portfolio of assets (Floden, Kilstroem, Sigurdsson, and Vestman 2016)
- Weak reaction of consumers with little wealth (Vissing-Jorgensen 2002)

Effect of interest rate changes: RANK vs HANK

- RANK:
  - Representative agent has substantial wealth, acts $\approx$ PIH-agent
  - Strong response to interest rate changes
- HANK:
  - Strong response by the wealthy
  - Weak reaction to interest rate changes by many consumers

Average MPC out of transitory income changes

- Why does this matter?

Average MPC out of transitory income changes

- Why does this matter?
- GE effects of shocks and policies strongly depend on MPC (e.g. Keynesian multiplier)
- Average MPC AND distribution matters, e.g. with heterogeneous income effects of shocks and policies

Average MPC out of transitory income changes: Data

- Kaplan and Violante (2022) for references
- 3 separate approaches:
  1. Quasi-experimental evidence on transfers (Johnson et al 2006; Parker, et al 2013) or lottery wins (Fagereng et al 2019; Golosov et al 2021)
  2. Survey instruments that pose hypothetical questions (Parker and Souleles 2019; Japelli and Pistaferri 2014)
  3. Semi-structural methods that identify transitory income change (Blundell, Pistaferri, and Preston, 2008; Ganong et al 2020)
- Survey Jappelli and Pistaferri (2010):
  1. sizeable average MPC out of small, unantic., transitory Δy
  2. larger MPCs for negative than for positive income shocks
  3. small MPCs out of announced future income gains
  4. strong heterogeneity in MPCs, correlated with access to liquidity

MPC out of transitory income changes: RANK vs HANK

- RANK:
  - Representative agent has substantial wealth
  - acts $\approx$ as a PIH-agent, MPC $\approx 1-\beta$
- HANK: Distribution of wealth
  - Constrained agents: MPC=1
  - Prudence / borrowing constraints: concave consumption function; MPC declines from 1 to $1-\beta$
  - Additional heterogeneity
    - Portfolios: "wealthy hand-to-mouth" with low liquid wealth
    - Discount factors: more constrained agents

Kaplan and Violante (2022)

- One-asset model can replicate average MPC when adding features
  - discount-factor heterogeneity
  - heterogeneous returns
  - behavioral features
- But: "missing middle" - too polarized wealth distribution
- Two-asset models
  - Illiquid asset (s.t. adjustment costs) plus bonds

  $\Rightarrow$ "wealthy hand-to-mouth"
  - Matches both average MPC and wealth-distribution

Macro-implications I: New responses to old questions

1. Effect and transmission of shocks: Kaplan, Moll, and Violante 2018 AER
2. Fiscal policy effects: Mitman et al 2019 (Broer et al 2023)
3. Determinacy of equilibrium
4. Optimal policy

1. Macro-dynamics: Kaplan, Moll, and Violante JEP 2018

- Builds on KMV AER 2018
- Same model, more shocks

1. Macro-dynamics: Kaplan, Moll, and Violante JEP 2018

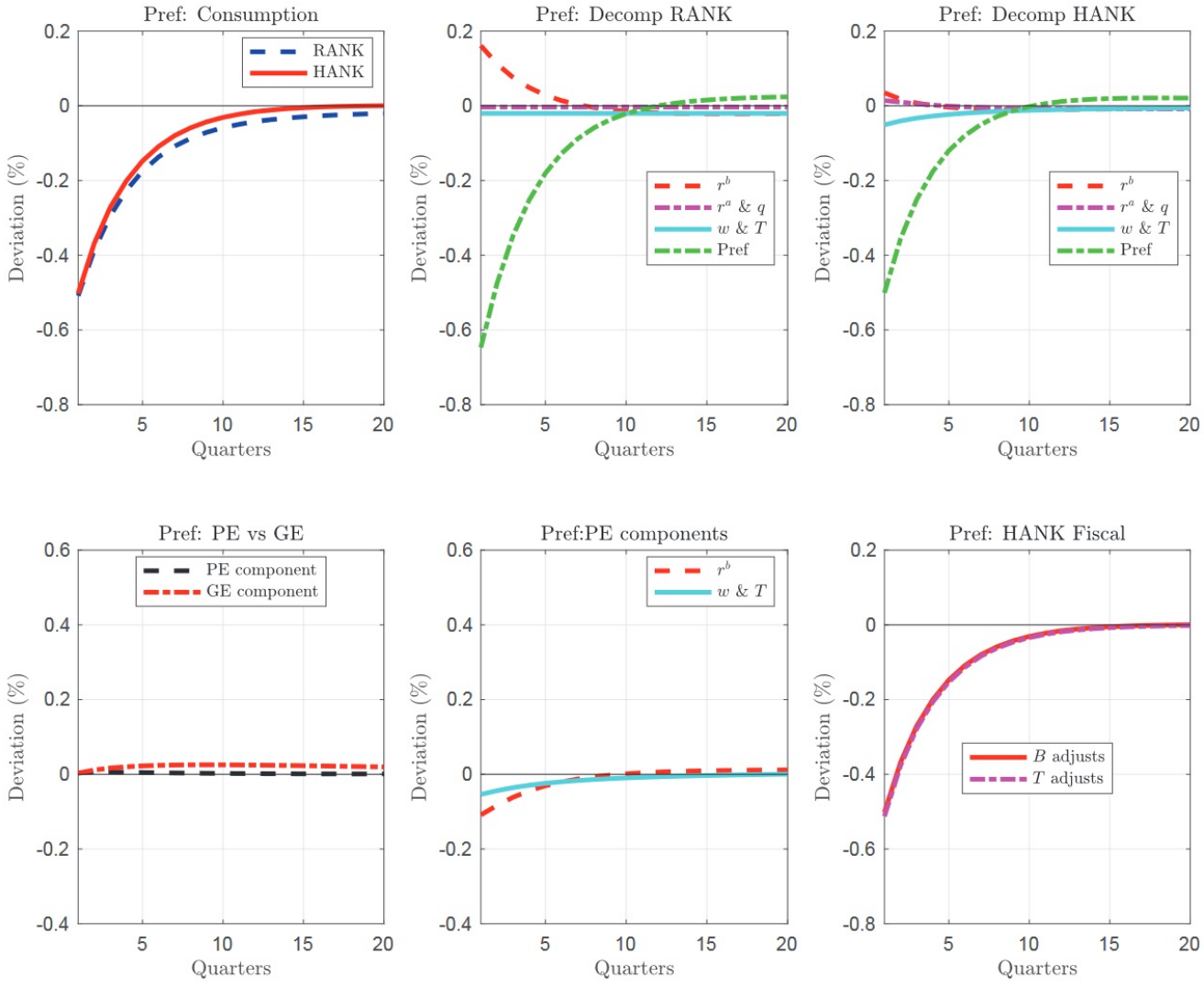
- Continuous time
- NK supply: CES aggregate of different. intermediate goods
  - Produced with K and L, sold under monop comp
  - Quadratic price adjustment costs (Rotemberg 1983)
- Continuum of HH, die with prob $1/180$
  - $\mathbb{E}_0 \int_0^\infty e^{-(\zeta+\rho)t} \left[\log c_t - \psi \frac{h_t^{\mathbf{1}+\mathbf{1}/\epsilon}}{1+1/\epsilon}\right] dt$
  - Trans. & pers. poisson shocks to idios. labor productivity
  - Trade 2 assets:
    1. Liquid riskless real gov. bonds $b_t > -b$, interest r_t^b with premium on borrowing
    2. Illiquid asset a_t, return r_t^a

       - comprises K and claims to profits of interm-goods firms - Transaction costs of withdrawals $d_t \neq 0$: > 0 and convex
- Gov finances G & lump-sum T with prop tax on L & debt B_t
- Monetary authority follows Taylor rule $i_t = \bar{r}^b + \psi \pi_t$

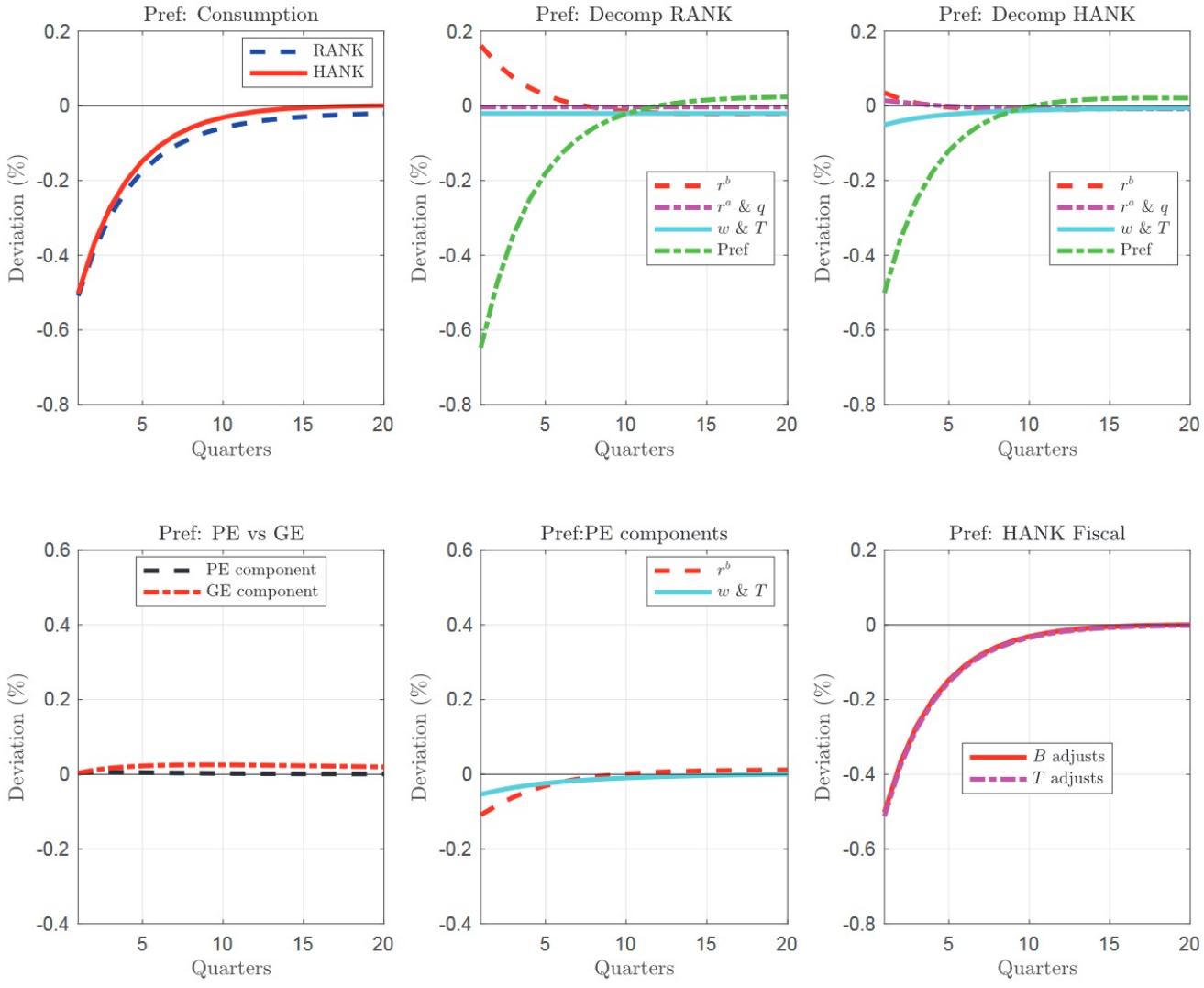
KMV JEP

1. Compare response of consumption to shocks, and their transmission, in RANK vs HANK
   - "Strong equivalence": Consumption response and transmission mechanism identical
   - vs. "Weak equivalence": Consumption response identical, but not transmission mechanism
2. Transmission: 3 dimensions
   - Decomposition of C response into shock $\{\nu_t\}$, equ prices $\{w_t, r_t^b, r_t^a, q_t\}$, and equ. transfers $\{T_t\}$
   - PE (HANK vs RANK, at p^{RANK}) vs GE (HANK at p^{GE} vs p^{RANK})
     $C^{HANK} - C^{RANK} =$
     $C^{HANK}(p^{GE}) - C^{HANK}(p^{RANK}) + C^{HANK}(p^{RANK}) - C^{RANK}$
   - Sensitivity to fiscal rule

Transmission of demand (disc factor) shocks

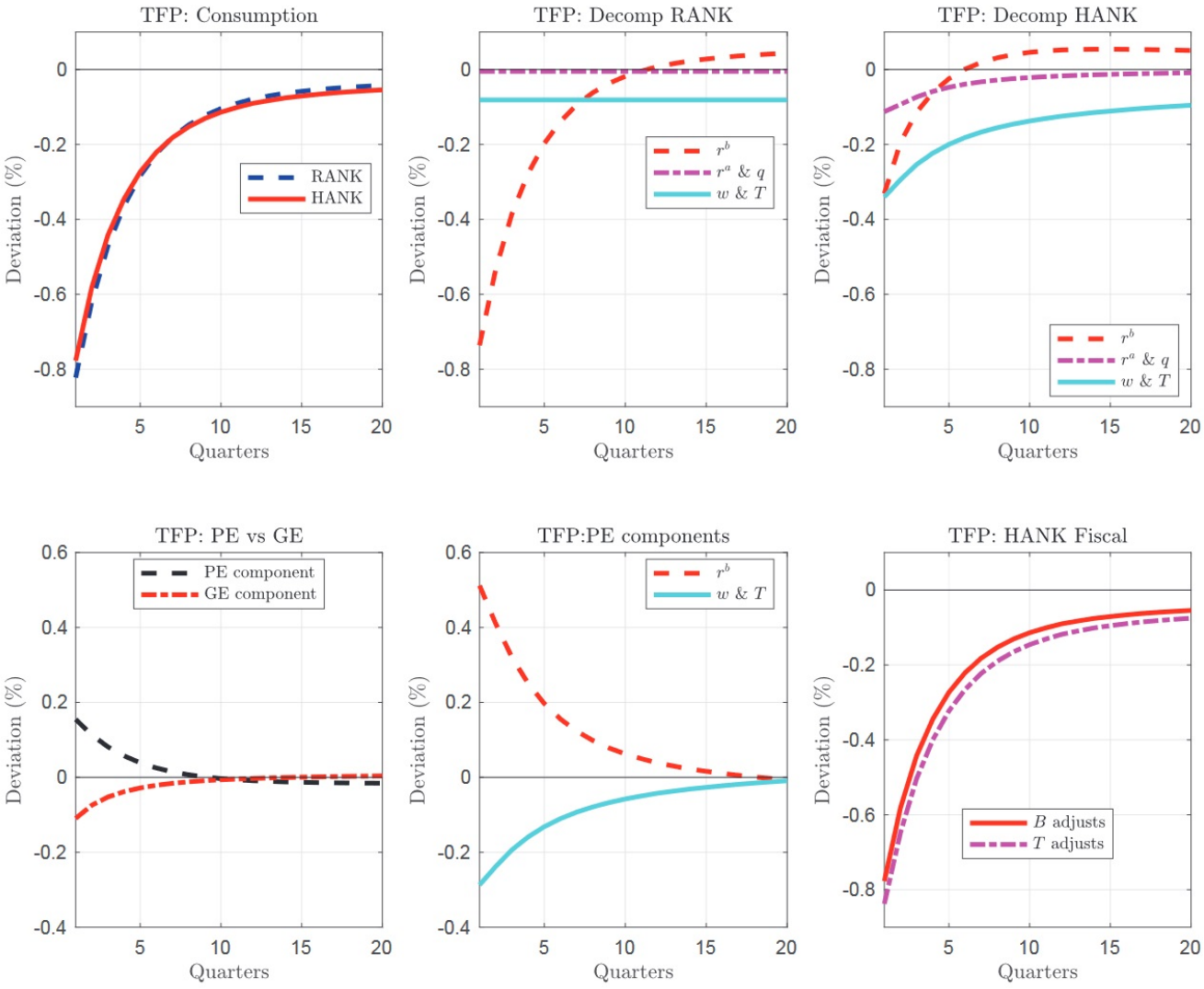


Transmission of demand (disc factor) shocks

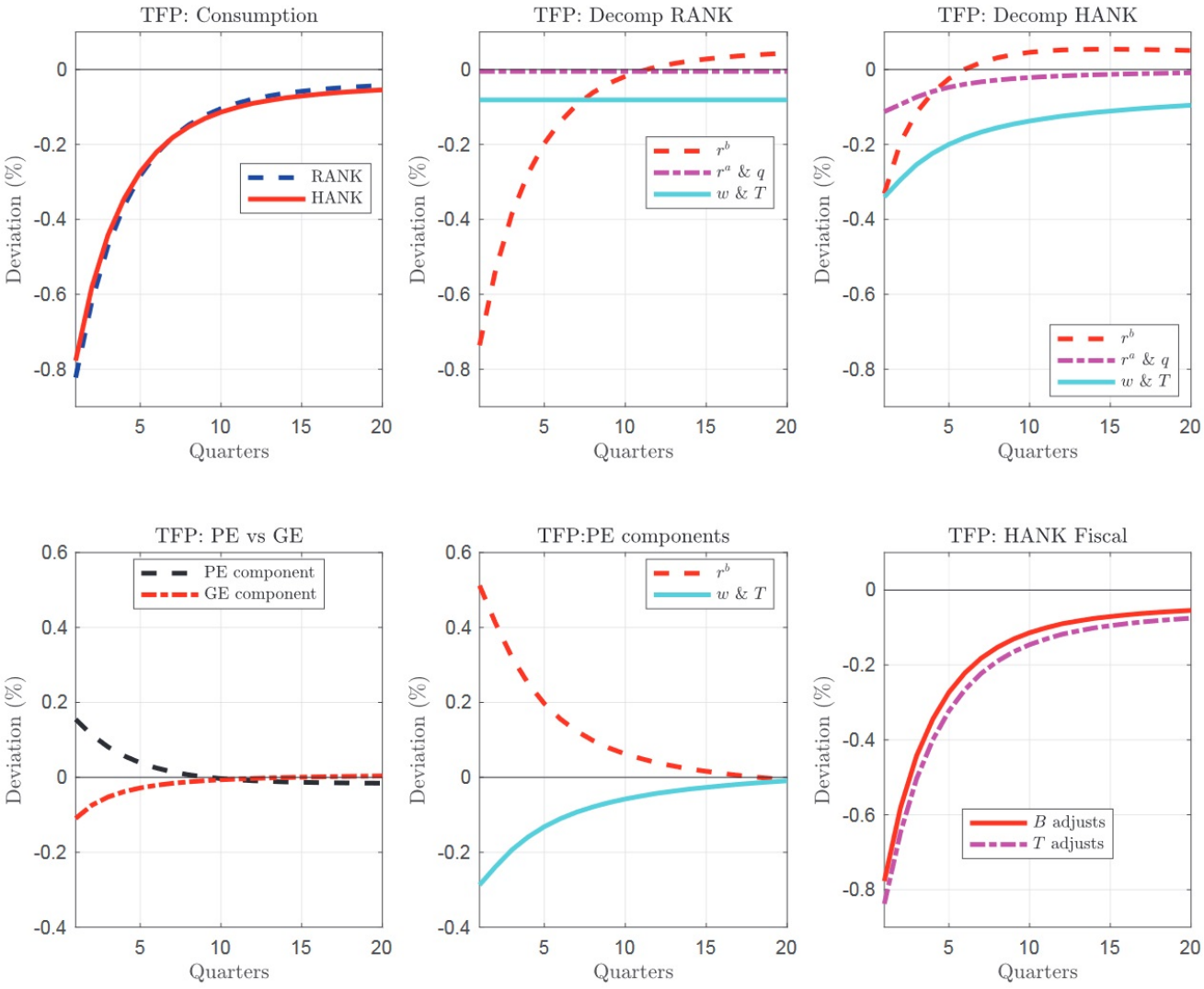


- "Strong" equivalence

Transmission of TFP shocks

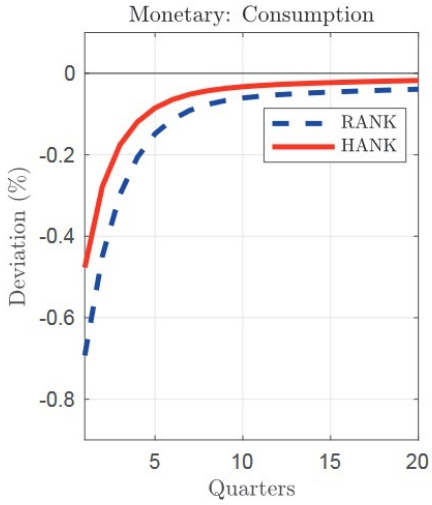


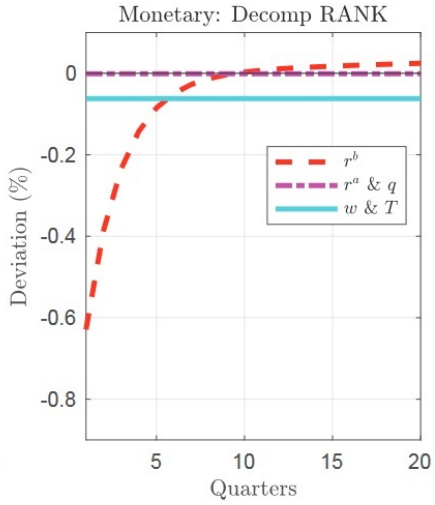
Transmission of TFP shocks

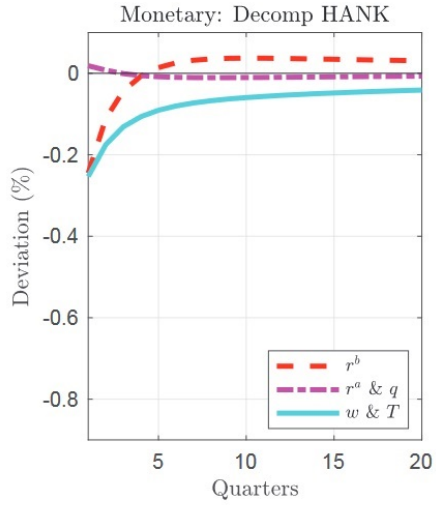


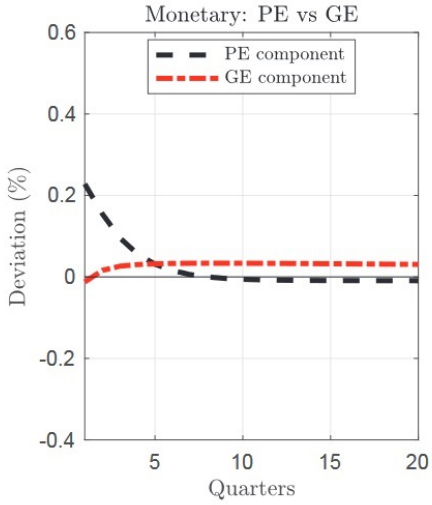
- "Weak" equivalence

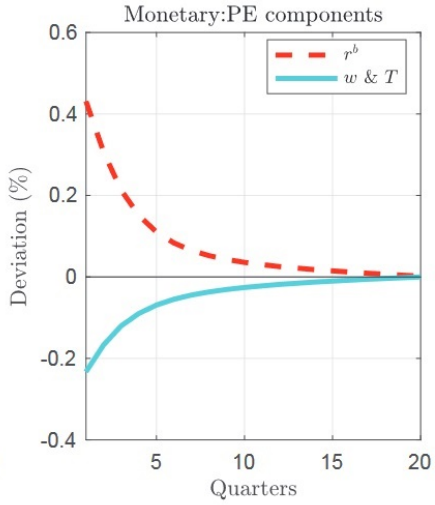
Transmission of MP shocks

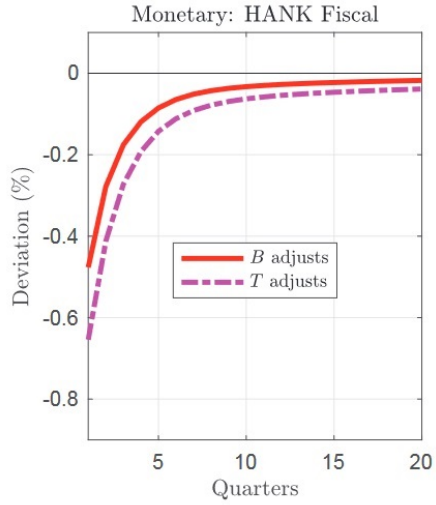




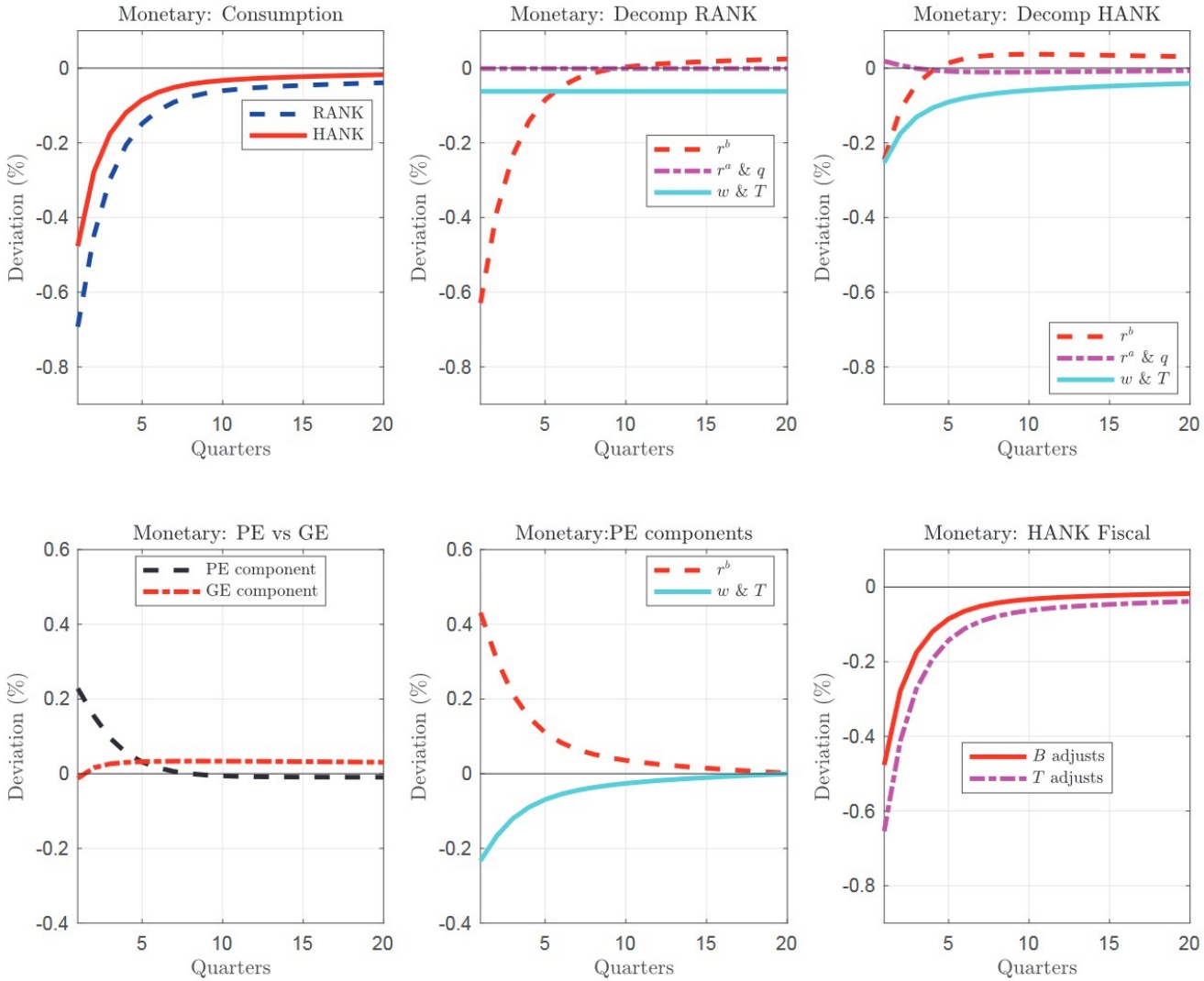








Transmission of MP shocks

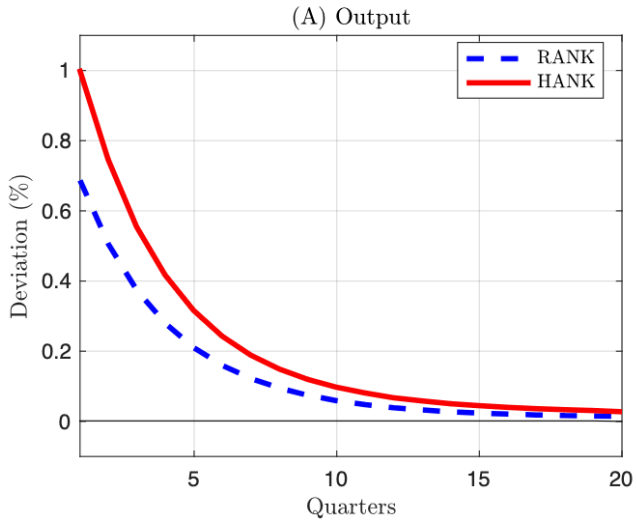


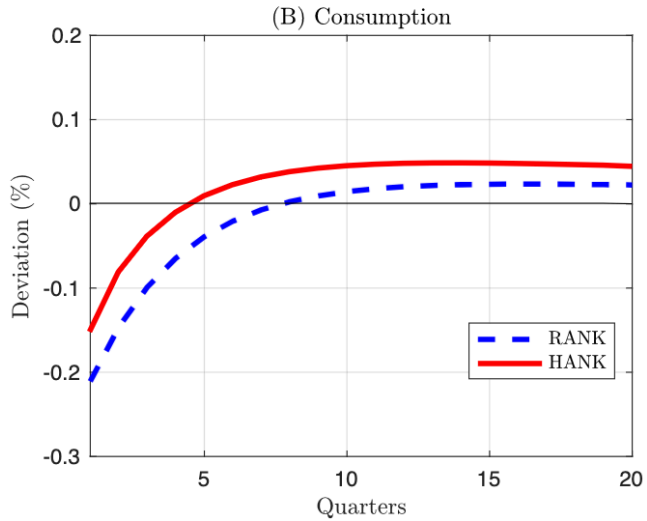
- Non-equivalence
- RANK: direct effect of r^b accounts for most

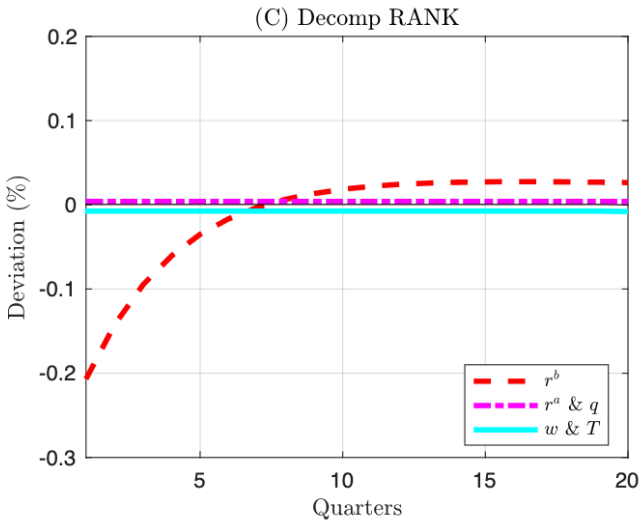
2. Fiscal policy in HANK

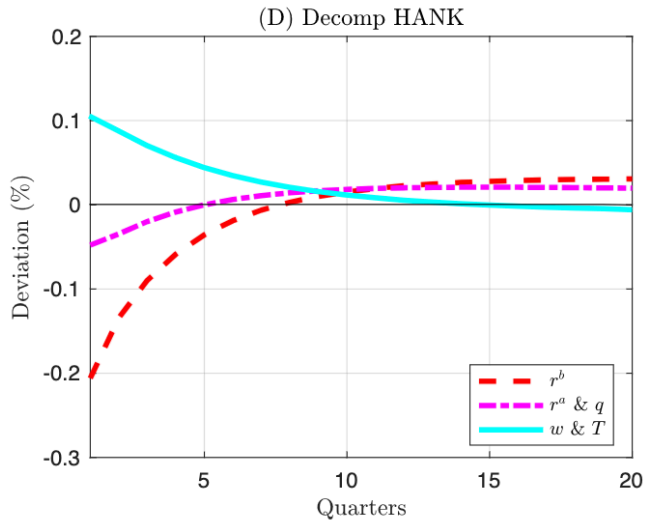
- "Fiscal multiplier" depends on
  - Effect of Government spending on demand
  - Effect of demand on output
- Need: Realistic MPC and nominal rigidity - HANK
- Other important features
  - Fiscal rule (Ricardian equvalence does not hold)
  - Monetary-policy rule

KMV JEP: Transmission of G shocks in HANK









Mitman et al "The Fiscal Multiplier"

Table II: Main Results: Consumption, Investment and Multipliers

	Normal Times					Liquidity Trap		
Experiment:	Benchmark		Taylor Rule		Transfer	Benchmark		Transfer
Financing:	Tax	Deficit	Tax	Deficit	Deficit	Tax	Deficit	Deficit
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Impact Mult.	0.61	1.34	0.54	0.66	0.66	0.73	1.39	0.86
Cumul Mult.	0.43	0.55	0.40	0.29	-0.3	0.48	0.51	-0.11
$100 \times \Delta C_0$	-2.7	1.4	-2.9	-0.4	5.2	-2.5	1.3	4.8
$100 \times \Delta I_0$	0.3	0.6	-0.02	-1.6	0.4	0.2	0.5	0.4
Decomposition of Consumption ($100 \times \Delta$)								
Direct G on C	1.2	1.2	1.2	1.2	0.0	1.2	1.2	3.9
Tax/Transfers	-3.1	0.5	-3.1	-0.2	4.6	-2.9	0.5	0.4
Indirect Income	-0.7	0.2	-0.8	-0.7	1.1	-0.6	0.0	0.8
Prices	-0.1	-0.5	-0.2	-0.8	-0.5	-0.2	-0.5	-0.4

Note - The table contains the impact and the cumulative multiplier $\overline{M}$ (using definition (60) for the last column and (A1) otherwise) as well as the initial consumption and investment responses, ΔC_0 and ΔI_0 (as a % of output). The last four rows show the decomposition of the initial aggregate consumption response (also multiplied by 100) into the direct G impact on C (Eq. 39), the effect of taxes/transfers (Eq. 40), indirect income effects (Eq. 41) and the price and interest rate effects (Eq. 42).

Broer, Druedahl,Harmenberg, berg: Stimulus effects of common fiscal policies

- One-asset HANK model with endogenous separations and sluggish vacancies
- Calibrated to response of JF and Sep rates to macro-shocks, and consumption response to unemployment

Broer et al: Transmission cycle

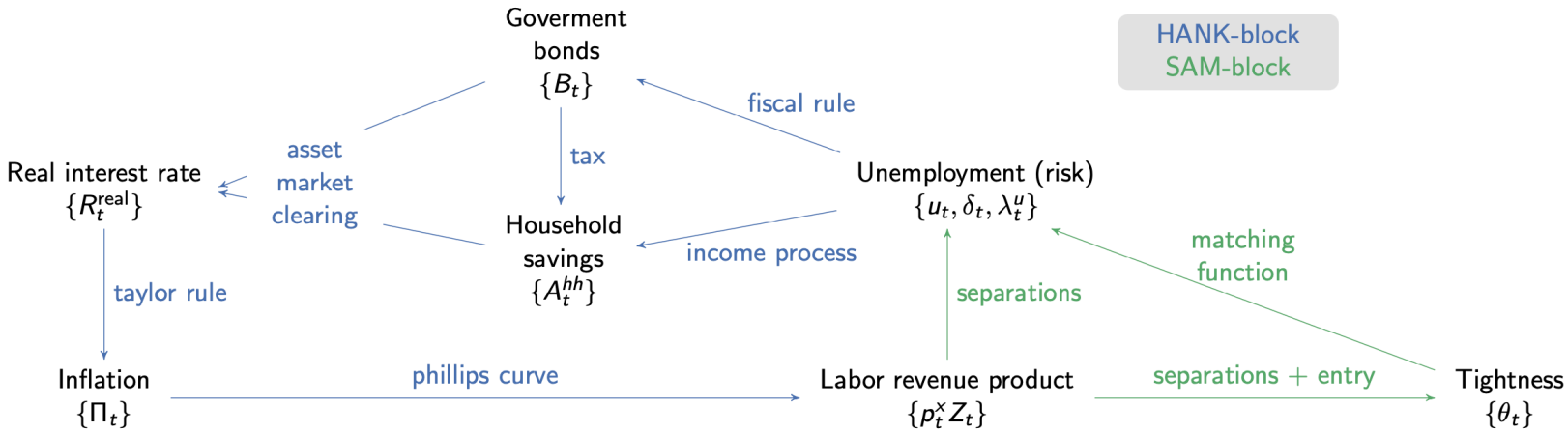


Figure 1: Model as a directed cycle graph with three separate blocks.

Broer et al: Cumulative fiscal multipliers

	G norm. [level]	**transfer**	**UI level**	**UI duration**	**retention**	**hiring**
Baseline	1.0 [1.01]	0.26	0.42	0.97	1.57	0.70
Full insurance	1.0 [0.71]	0.00	0.00	0.00	0.69	0.19
Fewer HtM	1.0 [0.82]	0.20	0.39	1.02	1.88	0.66
No Prec. sav.	1.0 [0.88]	0.27	0.25	0.77	1.54	0.69
More liquidity	1.0 [0.91]	0.20	0.32	0.68	1.54	0.68
Less liquidity	1.0 [1.20]	0.35	0.55	1.49	1.60	0.72
Near-zero liquidity	1.0 [12.19]	0.98	0.68	0.30	1.13	0.98

3. Determinacy in HANK

1. RANK model: price level is indeterminate, inflation is determinate under sufficiently responsive Taylor rule (if we rule out explosive paths of π_t)
2. HANK model: precautionary savings lead to determinacy of the price level (Hagedorn 2020)

4. Optimal policy

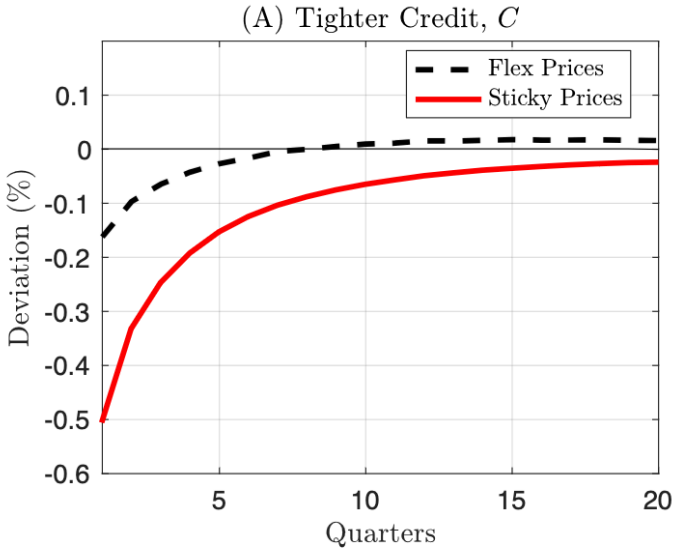
1. Challe, Acharya and Dogra (2020)
2. Bhandari, Evans, Golosov, and Sargent, Econometrica 2021
3. Redistribution becomes an important policy concern

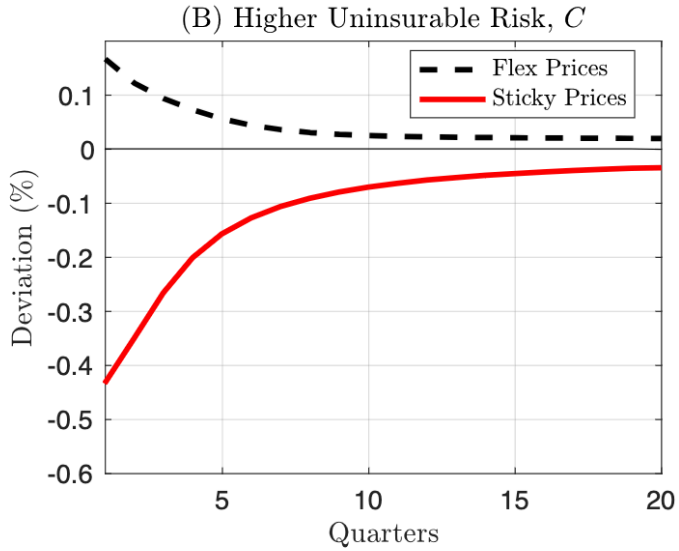
Macro-implications II: New questions to be asked

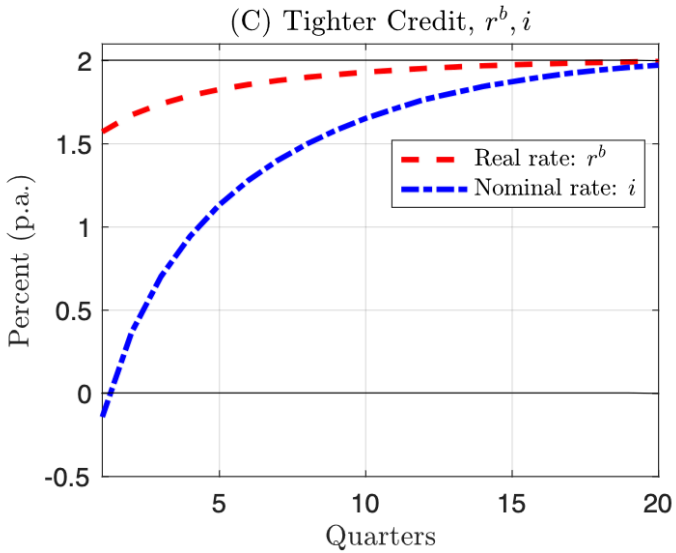
New microfoundation of demand shocks

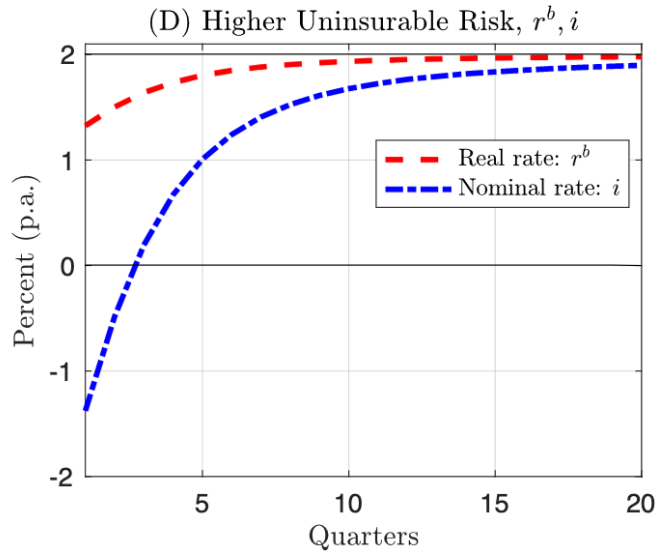
- Tighter credit limits (Guerrieri Lorenzoni 2017)
  Tightening in consumersâ borrowing capacity $\Rightarrow$ constrained consumers repay debt, unconstrained increase precautionary savings.
- Rise in idiosyncratic risk
  1. Den Haan et al 2017Increase in prec savings ($\downarrow C$)
  2. Bayer et al 2019: ... plus switch to liquid paper assets ($\downarrow I$)

KMV JPE: Transmission of credit / risk shocks in HANK









Heterogeneity in transmission

Redistributional effects of policies interact with MPC heterogeneity

- Patterson (AER 2023): Covariance of MPCs & elasticity of earnings to GDP across income distribution amplifies aggr. MPC
- Auclert (AER 2019): Heterog. MPCs change MP effects via
  1. Earnings heterogeneity channel of unequal income gains
  2. Fisher channel of unexp. inflation changes
  3. Interest rate exposure channel of real-interest rate changes

Aggregate effects of redistributional policies

- McKay and Reis (2016): Automatic stabilisers dampen US business cycles
- Ferriere and Navarro (2024): Financing through progressive taxes raises G-multiplier in HA model (as income-rich have less elastic labor supply) and U.S. post-WW II data
- Kekre (2024): Surprise unemployment benefit increases and extensions can stimulate output when the employed have lower MPCs and hold prec. buffers against unemployment
- Graves (2024): UI insurance dampens business cycles

Macro-implications III: Model features that become important

- timing and distribution of fiscal transfers (no Ric Eq)
- distribution of profits (Broer et al 2019, Kaplan and Violante 2018)
- cyclicality of income risk (Werning 2015, Acharya and Dogra 2019)
- incidence of labor market risk (Patterson 2019)
- source of nominal rigidity (Broer et al 2019)

HANK: Analytical characterizations

A step back: Why are HANK models difficult to solve?

- RANK: no analytical solution. But: simple characterization of aggregate C, N, Y, i, π (EE, PC, TR)
- HANK:
  1. C, N aggregate non-linear decision rules for c_i, n_i across continuous distribution Θ of b_i, A_i
  2. Θ matters for labor supply, savings (and, with capital, for prices next period)
- Can we simplify HANK if we are only intrested in aggregate macro outcomes?

Simple HANK models

- Alternative I: linear consumption rule with exogenous labor supply (Acharya and Dogra 2019)
- Alternative II: conditions such that individual allocation independent of aggregate quantities (Werning 2015)
- Alternative III: no-liquidity limit ($B, b = 0$), no capital: wealth distribution degenerate; can write EE for 'marginal saver"s c i.t.o. C (Broer et al (2019), Ravn and Sterck (2018))
- Alternative IV: simplify heterogeneity - "TANK" models (Bilbiie (various), Broer et al (2019), Gali and Debortoli (2018))

Next session

- Solution methods for HANK models
- Simple HANK / TANK models

Quantitative Macroeconomics II

HANK models

Tobias Broer

G. Kaplan and G. L. Violante. How much consumption insurance beyond self-insurance? *American Economic Journal: Macroeconomics*, 2(4):53–87, 2010. URL `http://ideas.repec.org/a/aea/aejmac/v2y2010i4p53-87.html`.

G. Kaplan and G. L. Violante. The marginal propensity to consume in heterogeneous agent models. *Annual Review of Economics*, 14:747–775, 2022.