Distributional Macroeconomics

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Asian Meeting of the Econometric Society

June 21, 2018

What do I mean by “Distributional Macroeconomics”?

- Study of macroeconomic questions in terms of distributions rather than just aggregates
    - typical example: distributions of income and wealth
- More technically: macroeconomic theories in which relevant state variable is a distribution
- Or “heterogeneous agent models” but I want to emphasize distributions
- What’s attractive about this approach?
    - conceptually: unified approach to macro and distribution
    - empirically: unified approach to micro and macro data

Main Message

- Hard to coherently think about macro if ignore distribution

- Instead, rich interaction:

distribution $\Longleftrightarrow$ macroeconomy

- Or perhaps more precisely:

macroeconomy is a distribution

Plan

1. Distribution in macroeconomics: a history of thought

2. Methods for "distributional macro" models: continuous time

3. An application of "distributional macro" from my own work: "Monetary Policy According to HANK"

- based on joint work with Yves Achdou, SeHyoun Ahn, Paco Buera, Andreas Fagereng, Jiequn Han, Martin Holm, Greg Kaplan, Jean-Michel Lasry, Pierre-Louis Lions, Gisle Natvik, Galo Nuño, Gianluca Violante, Tom Winberry, Christian Wolf

Distribution in Macro: A History of Thought

I find it useful to categorize macroeconomic theories as follows:

- before modern macro: 1930 to 1970
- 1st generation modern macro: 1970 to 1990
- 2nd generation modern macro: 1990 to financial crisis
- 3rd generation modern macro: after the financial crisis

Main drivers of evolution in modern macro era

1. better data
2. better computers & algorithms
3. current events (rising inequality, financial crisis)

(Warning: narrative won't be perfect – will point out failures)

Before Modern Macro: 1930 to 1970

1. Keynesian IS/LM
    - about aggregates, no role for inequality/distribution by design
2. Distribution does play role in growth theory
    - mostly factor income distribution – capital vs labor
      Kaldor, Pasinetti, other Cambridge UK theorists
    - rarely personal income or wealth distribution
      exceptions: Tobin, Stiglitz, Blinder
3. Disconnected empirical work on inequality (Kuznets)

First Generation Macro Theories: 1970 to 1990

Representative agent models, e.g. RBC model

- again no role for inequality/distribution by design
- advertised as "microfounded" but rep agent assumption cuts 1st generation theories from much of micro research

What's wrong with that?

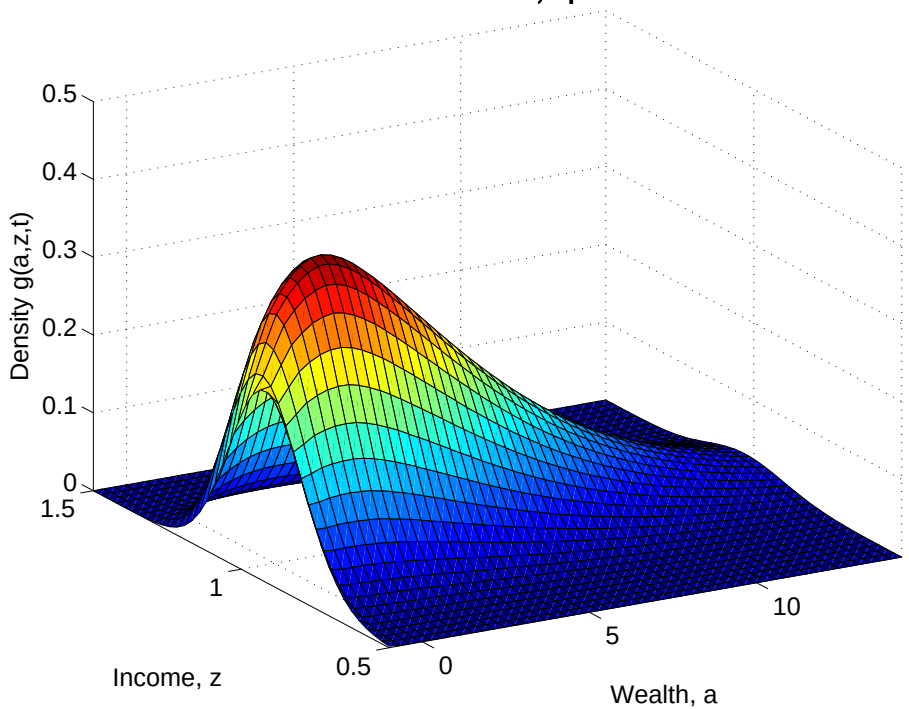
1. cannot speak to a number of important empirical facts, e.g.
    - unequally distributed growth
    - poorest hit hardest in recessions
2. cannot think coherently about welfare – "who gains, who loses?"

Second Generation Macro Theories: 1990 to 2008

Incorporate micro heterogeneity, particularly in income and wealth – early "heterogeneous agent models"

Aiyagari, Bewley, Huggett, Imrohoroğlu, Krusell-Smith, Den Haan,...

... represent economy with a distribution that moves over time, responding to macroeconomic shocks, policies



Can speak to facts on previous slide, useful for welfare analysis

Second Generation Theories: Inequality $\not\Rightarrow$ Macro

- Typical finding: heterogeneity doesn't matter much for macro agg's
  Krusell-Smith (1998) "approximate aggregation"
- Reason: linearity – rich = scaled version of poor
  Hence "inequality $\not\Rightarrow$ macro", but also a knife-edge result
- Interestingly, some more nuanced, cautionary results in literature:
  - even in KS98, extension where heterogeneity does matter (§4)
  - but gets lost, economists' perception = "inequality $\not\Rightarrow$ macro"
- Either way: in data, rich $\neq$ scaled version of poor, e.g. rich have
  - e.g. lower MPCs out of transitory income changes
- Note: some important contributions from 90s don't fit my narrative
  - Banerjee-Newman, Benabou, Galor-Zeira, Persson-Tabellini, ...

Third Generation Theories: after the Crisis

- 3rd generation theories take micro data more seriously
- Leads them to emphasize things like
  - household balance sheets
  - credit constraints
  - MPCs that are high on average but heterogeneous
  - non-homotheticities, non-convexities

  $\Rightarrow$ move away from knife-edge case
- Typical finding: distribution matters for macro
- Momentarily: an application from my own work (HANK)

Distribution in Macro: Summary

- Before modern macro: 1930 to 1970
  - it's complicated
- 1st generation: 1970 to 1990
  - representative agent models (RBC, New Keynesian etc)
  - no role for inequality by design
- 2nd generation: 1990 to financial crisis
  - early heterogeneous agent models
  - "macro $\Rightarrow$ inequality" but "macro $\not\Leftarrow$ inequality" (perception)
- 3rd generation: after the financial crisis
  - current heterogeneous agent models
  - rich interaction: "inequality $\Longleftrightarrow$ macro"

Distribution in Modern Macro: Summary

Janet Yellen speech "Macroeconomic Research After the Crisis"

`http://www.federalreserve.gov/newsevents/speech/yellen20161014a.htm`

- "Prior to the financial crisis, representative-agent models were the dominant paradigm for analyzing many macroeconomic questions [= 1st generation]."
- "However, a disaggregated approach seems needed to understand some key aspects of the Great Recession..."
- "While the economics profession has long been aware that these issues matter, their effects had been incorporated into macro models only to a very limited extent prior to the financial crisis [= 2nd generation]."
- "I am glad to now see a greater emphasis on the possible macroeconomic consequences of heterogeneity [= 3rd generation]."

Methods for Solving 3rd Generation Models: Continuous Time

Solving heterogeneous agent model as PDEs

- 3rd generation theories: richer economics, distribution matters
  - $\Rightarrow$ standard numerical solution methods may not work
  - need to carry around distribution – "can't do Krusell-Smith"
- One approach to make progress: solve het. agent model as PDEs
  1. Hamilton-Jacobi-Bellman equation for individual choices
  2. Kolmogorov Forward equation for evolution of distribution

  = application of "Mean Field Games" framework (Lasry-Lions)
- Apparatus is very general: applies to any heterogeneous agent model with continuum of atomistic agents
  1. heterogeneous households (Aiyagari, Bewley, Huggett,...)
  2. heterogeneous producers (Hopenhayn,...)

References

1. "Income and Wealth Distribution in Macroeconomics: A Continuous-Time Approach" (with Achdou, Han, Lasry & Lions)
    - discussion of computational advantages over discrete time
    - Codes: `http://www.princeton.edu/~moll/HACTproject.htm`
2. With aggregate shocks: "When Inequality Matters for Macro and Macro Matters for Inequality" (with Ahn, Kaplan, Winberry & Wolf)
    - Matlab toolbox: `https://github.com/gregkaplan/phact`

A nerdy version of my main message

Question: What is the central equation in macro?

- Likely answer of most macroeconomists: the Euler equation
- My answer: the Kolmogorov Forward equation
  - (closely followed by an Euler/Bellman equation for het agents)
  - again, macroeconomy is joint distribution of micro variables
  - not special to continuous time, analogous eq'n in discrete time

An Application of Distributional Macro Monetary Policy According to HANK

(with Greg Kaplan and Gianluca Violante)

(HANK = “Heterogeneous Agent New Keynesian” model)

How monetary policy works in RANK

- Total consumption response to a drop in real rates

$$C \text{ response} = \underbrace{\text{direct response to } r}_{>95\%} + \underbrace{\text{indirect effects due to } Y}_{<5\%}$$

- Direct response is everything, pure intertemporal substitution

- However, data suggest:

  1. Low sensitivity of C to r
  2. Sizable sensitivity of C to Y
  3. Micro sensitivity vastly heterogeneous, depends crucially on household balance sheets

How monetary policy works in HANK

- HANK delivers realistic distributions of household wealth and MPCs

$$C \text{ response} = \underbrace{\text{direct response to } r}_{\text{RANK: >95\%}\quad\text{HANK: <1/3}} + \underbrace{\text{indirect effects due to } Y}_{\text{RANK: <5\%}\quad\text{HANK: >2/3}}$$

- Overall effect depends crucially on fiscal response, unlike in RANK where Ricardian equivalence holds

HANK: a framework for monetary policy analysis

Households

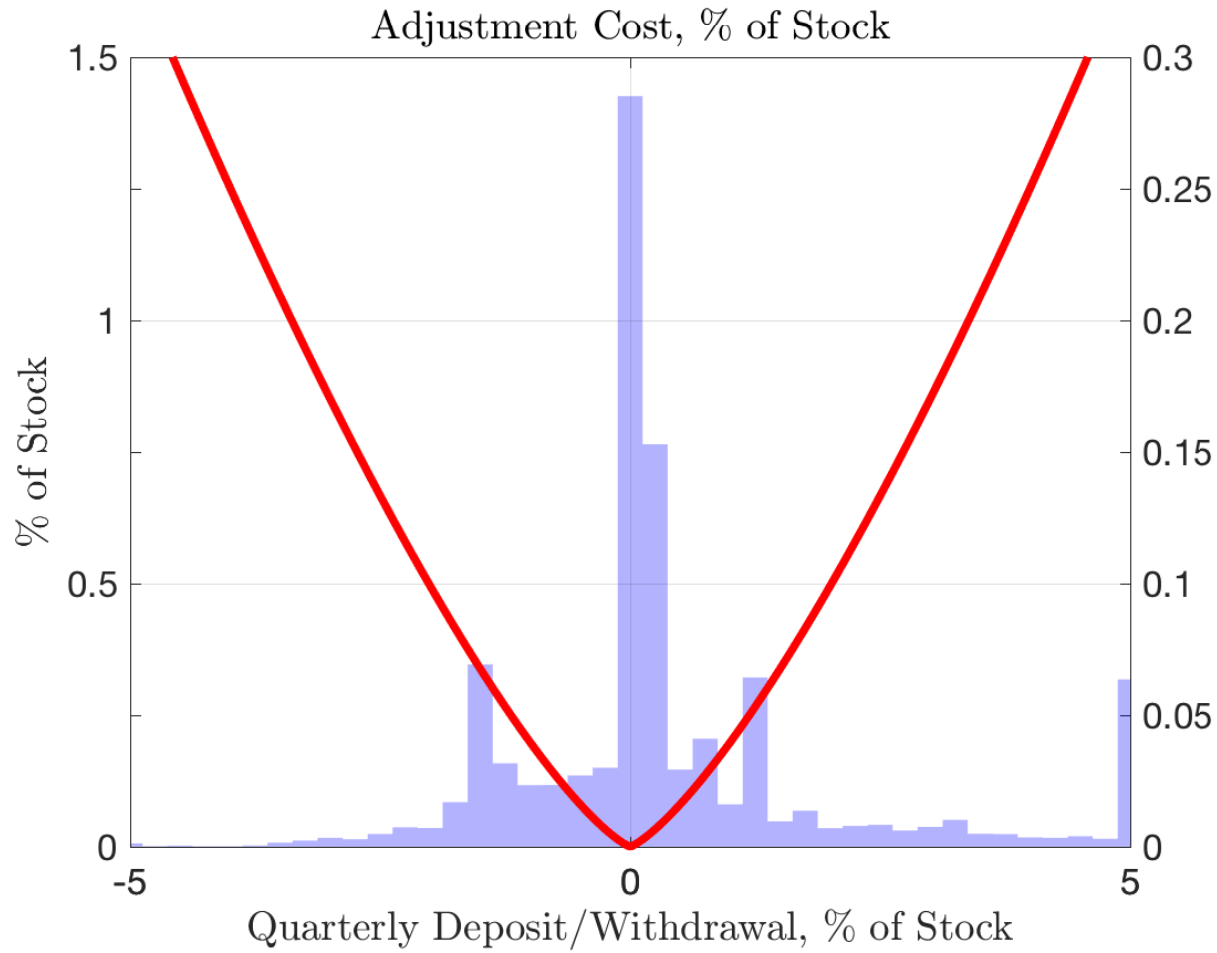
- Face uninsured idiosyncratic labor income risk
- Consume and supply labor
- Hold two assets: liquid and illiquid
- Budget constraints (simplified version)

$$\dot{b}_t = r^b b_t + w z_t \ell_t - c_t - d_t - \chi(d_t, a_t)$$
$$\dot{a}_t = r^a a_t + d_t$$

  - b_t: liquid assets
  - d_t: illiquid deposits ($\gtrless 0$)
  - a_t: illiquid assets
  - χ: transaction cost function

- In equilibrium: $r^a > r^b$
- Full model: borrowing/saving rate wedge, taxes/transfers

Kinked adjustment cost function $\chi(d, a)$



Remaining model ingredients

Firms

- monopolistically competitive intermediate-good producers
- quadratic price adjustment costs à la Rotemberg (1982)

Illiquid assets

- consist of both productive capital and equity = claim to profits
- pins down illiquid return

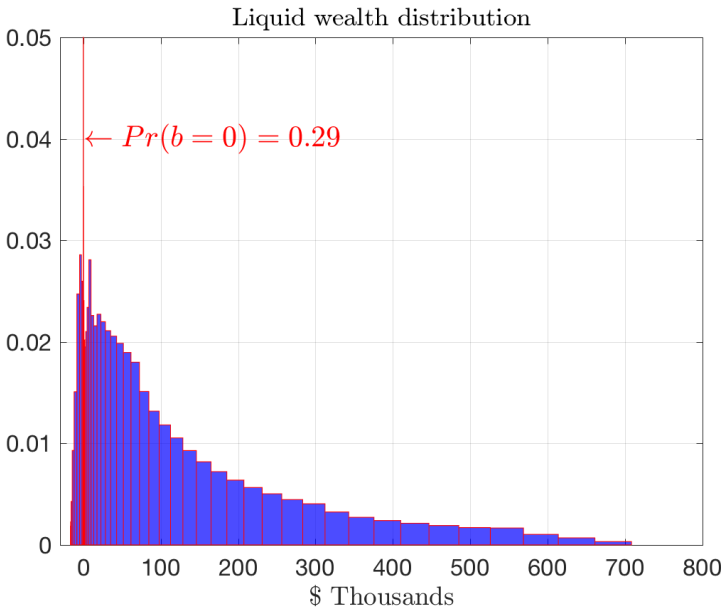
Government

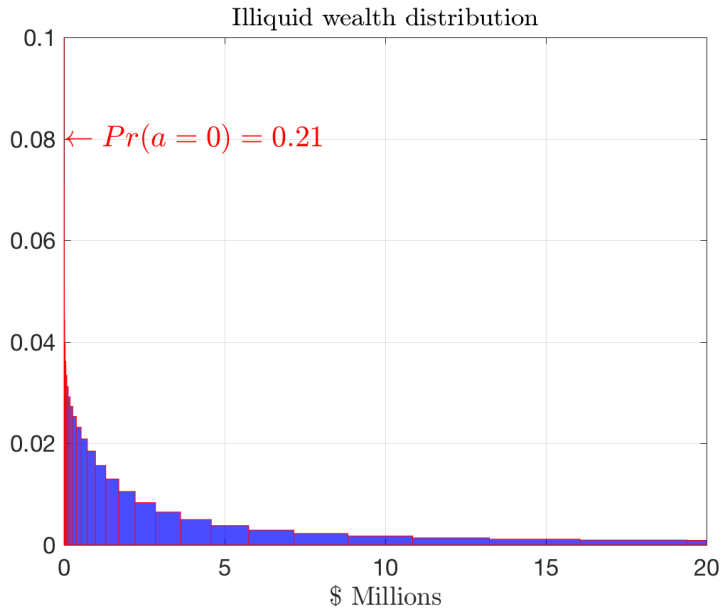
- issues liquid debt, spends, taxes

Monetary Authority

- sets nominal rate on liquid assets based on a Taylor rule

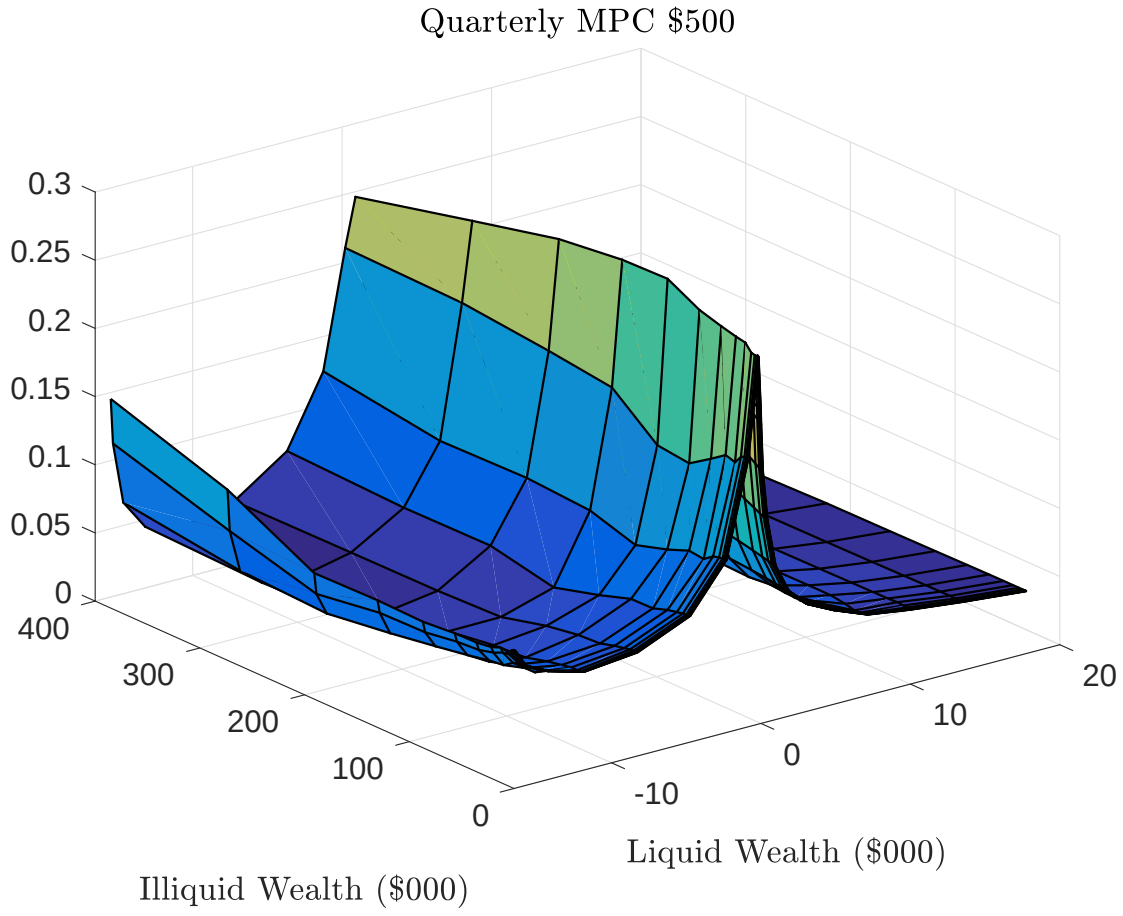
Model matches key feature of U.S. wealth distribution





	Data	Model
Mean illiquid assets (rel to GDP)	2.920	2.920
Mean liquid assets (rel to GDP)	0.260	0.263
Poor hand-to-mouth	10%	10%
Wealthy hand-to-mouth	20%	19%

Model generates high and heterogeneous MPCs

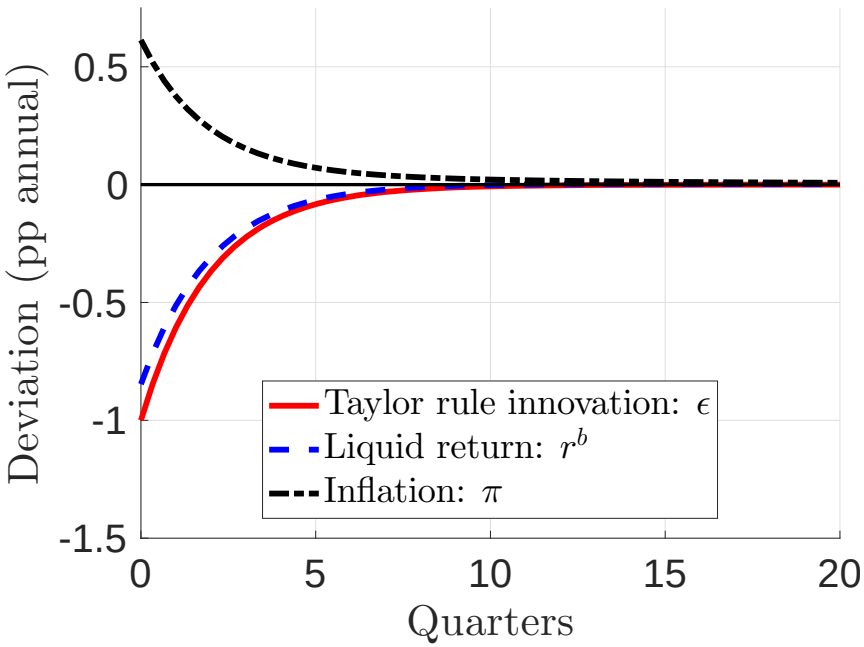


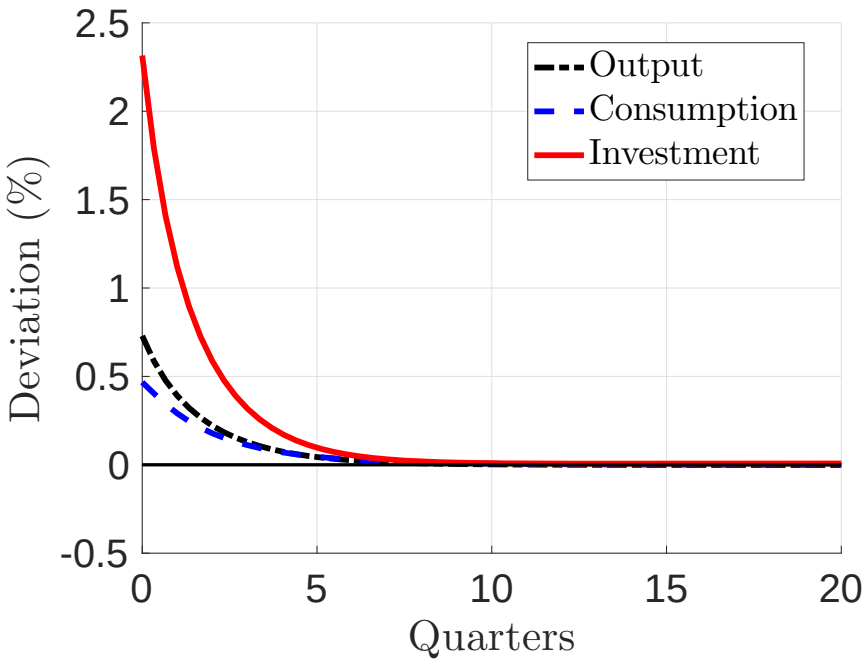
- Average quarterly MPC out of a $500 windfall: 16%

Transmission of monetary policy shock to C

Innovation $\epsilon < 0$ to the Taylor rule: $i = \bar{r}^b + \phi\pi + \epsilon$

- All experiments: $\epsilon_0 = -0.0025$, i.e. -1% annualized





Transmission of monetary policy shock to C

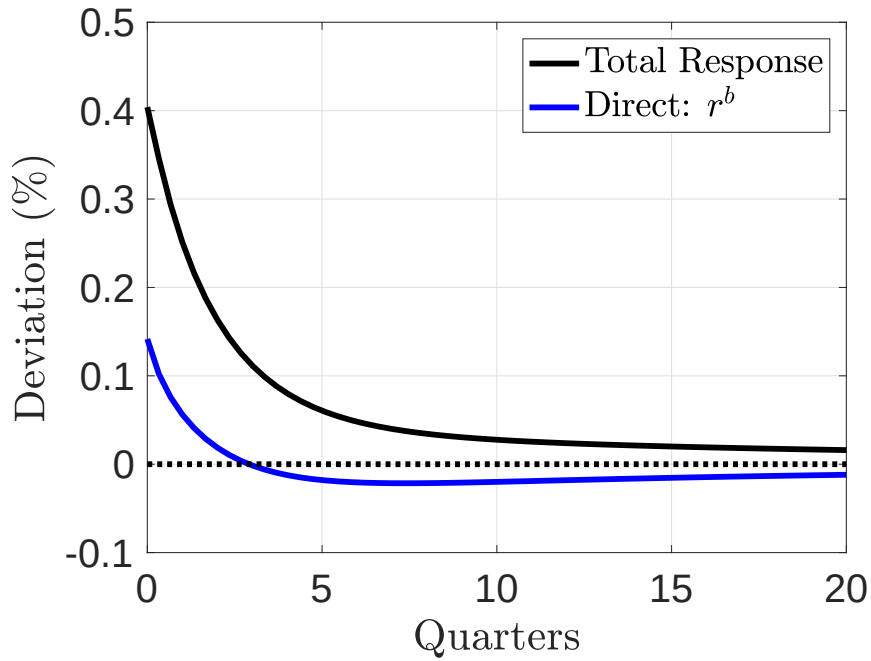
$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{\text{direct}} + \underbrace{\int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt}_{\text{indirect}}$$

Transmission of monetary policy shock to C

$$dC_0 = \int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt + \int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt$$

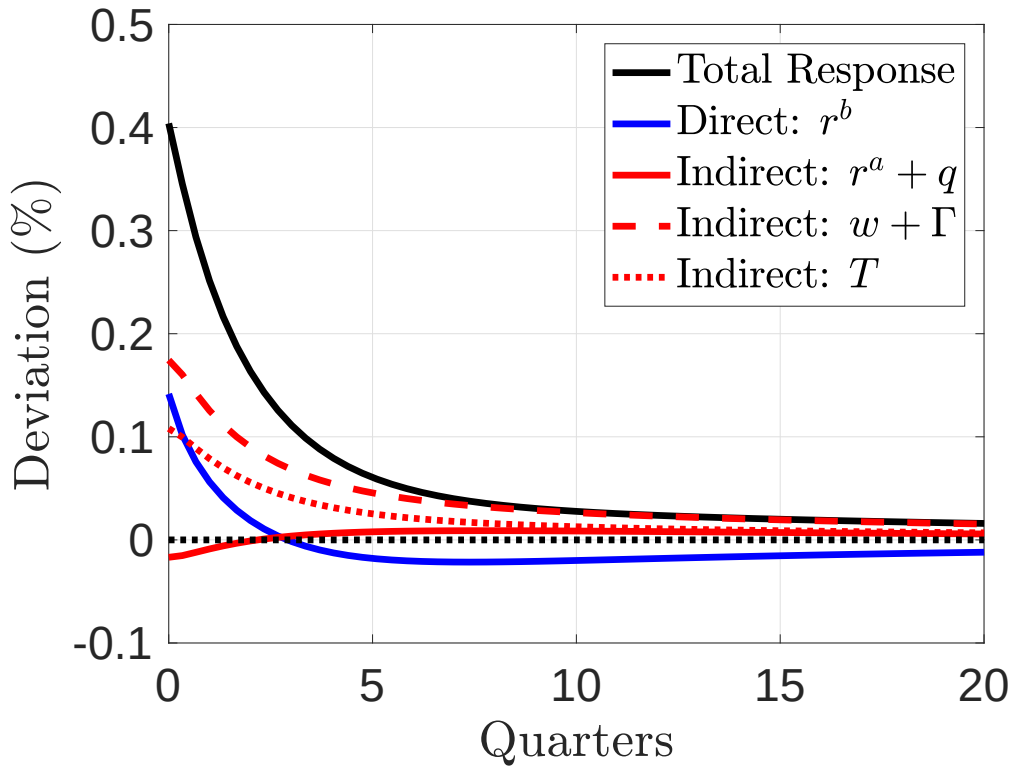
✓

Intertemporal substitution and income effects from $r^b \downarrow$



Transmission of monetary policy shock to C

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{19\%} + \underbrace{\int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt}_{81\%}$$



Role of fiscal response in determining total effect

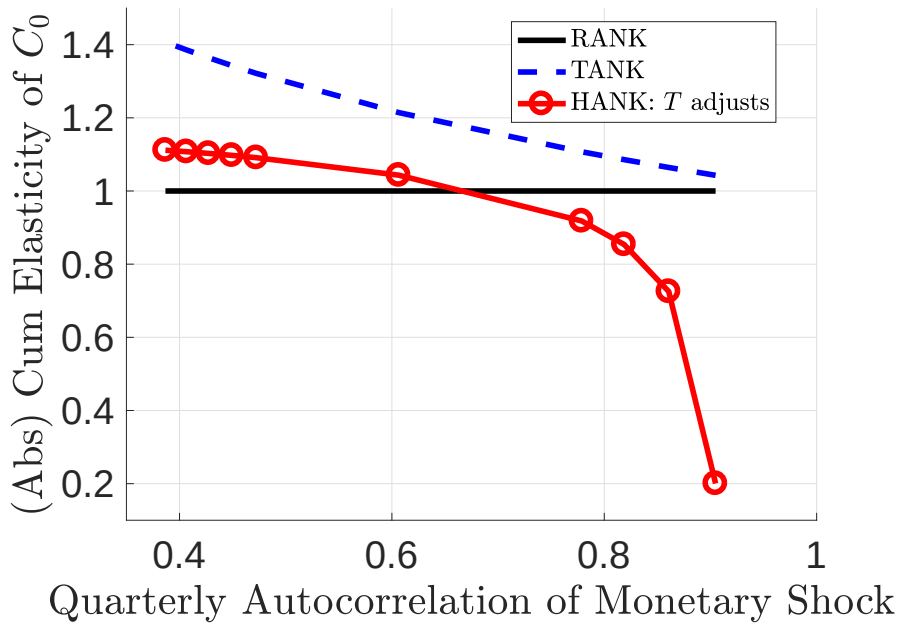
	T adjusts	G adjusts	B^g adjusts
	(1)	(2)	(3)
Elasticity of C_0 to r^b	-2.21	-2.07	-1.48
Share of Direct effects:	19%	22%	46%

- Fiscal response to lower interest payments on debt:
  - T adjusts: stimulates AD through MPC of HtM households
  - G adjusts: translates 1-1 into AD
  - B^g adjusts: no initial stimulus to AD from fiscal side

When is HANK $\neq$ RANK? Persistence

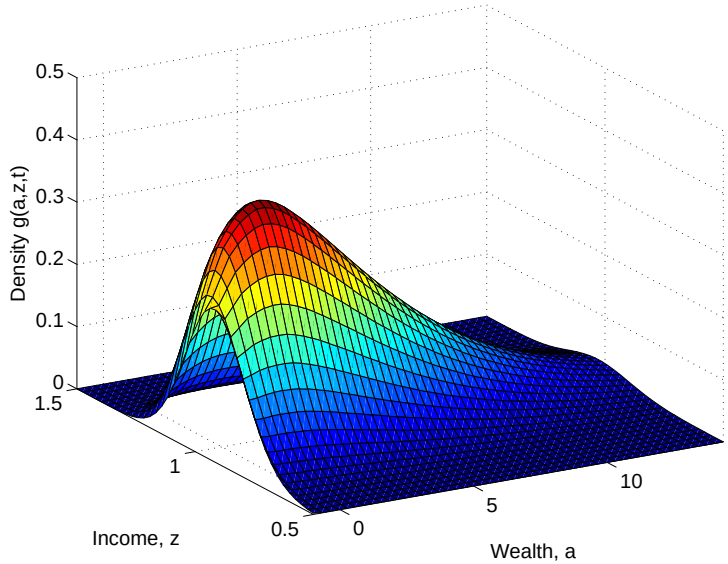
- RANK: $\frac{\dot{C}_t}{C_t} = \frac{1}{\gamma}(r_t - \rho) \Rightarrow C_0 = \bar{C} \exp\left(-\frac{1}{\gamma}\int_0^\infty (r_s - \rho) ds\right)$
- Cumulative r-deviation $R_0 := \int_0^\infty (r_s - \rho) ds$ is sufficient statistic
- Persistence η only matters insofar as it affects R_0

$$-\frac{d \log C_0}{d R_0} = \frac{1}{\gamma} = 1 \quad \textbf{for all } \eta$$



Distributional Macroeconomics: Summary

- Current macro research: economy = joint distribution of micro variables, not collection of aggregates



- Often: can't ignore distribution even if care only about aggregates
- Not yet part of policy makers' toolkit, but starting to change:
  - various central banks, other policy institutions currently developing their own 3rd generation frameworks
- Think in terms of Kolmogorov Forward not Euler equations!

Computational Advantages relative to Discrete Time

1. Borrowing constraints only show up in boundary conditions
   - FOCs always hold with "="
2. "Tomorrow is today"
   - FOCs are "static", compute by hand: $c^{-\gamma} = v_a(a, y)$
3. Sparsity
   - solving Bellman, distribution = inverting matrix
   - but matrices very sparse ("tridiagonal")
   - reason: continuous time $\Rightarrow$ one step left or one step right
4. Two birds with one stone
   - (KF) for distribution is "transpose problem" of (HJB) ("adjoint")
   - matrix in discrete (KF) is transpose of matrix in discrete (HJB)

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