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:

  \[ \text{distribution} \leftrightarrow \text{macroeconomy} \]

• 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?”
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

- Problem: in data, rich $\neq$ scaled version of poor, e.g. rich have
  - lower MPCs out of transitory income changes
  - higher saving rates out of permanent income, wealth

- 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

⇒ move away from knife-edge case

- Typical finding: distribution matters for macro
- Momentarily: an application from my own work (HANK)
• 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”

• 3rd generation: after the financial crisis
  • current heterogeneous agent models
  • rich interaction: “inequality \leftrightarrow macro”
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
  • ⇒ 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,...)
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

\[
C \text{ response} = \text{direct response to } r + \text{indirect effects due to } Y
\]

\[
>95\% \quad \text{and} \quad <5\%
\]

- 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

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

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

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

\[
\begin{align*}
\dot{b}_t &= r^b b_t + w z_t l_t - c_t - d_t - \chi(d_t, a_t) \\
\dot{a}_t &= r^a a_t + d_t
\end{align*}
\]

- \(b_t\): liquid assets
- \(d_t\): illiquid deposits \(\geq 0\)
- \(a_t\): illiquid assets
- \(\chi\): 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

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean illiquid assets (rel to GDP)</td>
<td>2.920</td>
<td>2.920</td>
</tr>
<tr>
<td>Mean liquid assets (rel to GDP)</td>
<td>0.260</td>
<td>0.263</td>
</tr>
<tr>
<td>Poor hand-to-mouth</td>
<td>10%</td>
<td>10%</td>
</tr>
<tr>
<td>Wealthy hand-to-mouth</td>
<td>20%</td>
<td>19%</td>
</tr>
</tbody>
</table>
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 $C$

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

- Direct
- Indirect
Transmission of monetary policy shock to $C$

$$dC_0 = \int_0^\infty \frac{\partial C_0}{\partial r^b_t} dr^b_t dt + \int_0^\infty \left[ \frac{\partial C_0}{\partial r^a_t} dr^a_t + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt$$

✓

Intertemporal substitution and income effects from $r^b$ ↓
Transmission of monetary policy shock to $C$

$$dC_0 = \int_0^\infty \frac{\partial C_0}{\partial r^b_t} dr^b_t dt + \int_0^\infty \left[ \frac{\partial C_0}{\partial r^a_t} dr^a_t + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt$$

19% and 81%
Role of fiscal response in determining total effect

<table>
<thead>
<tr>
<th></th>
<th>( T ) adjusts</th>
<th>( G ) adjusts</th>
<th>( B^g ) adjusts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Elasticity of ( C_0 ) to ( r^b )</strong></td>
<td>-2.21</td>
<td>-2.07</td>
<td>-1.48</td>
</tr>
<tr>
<td>Share of Direct effects:</td>
<td>19%</td>
<td>22%</td>
<td>46%</td>
</tr>
</tbody>
</table>

- 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 \( \text{HANK} \neq \text{RANK} \)? 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 \( \eta \) only matters insofar as it affects \( R_0 \)

\[
- \frac{d \log C_0}{d R_0} = \frac{1}{\gamma} = \frac{1}{r} \quad \text{for all } \eta
\]
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)
References: Some “Third Generation” Papers

• Ahn, Kaplan, Moll, Winberry & Wolf (2017) “When Inequality Matters for Macro and Macro Matters for Inequality”

• Auclert (2016) “Monetary Policy and the Redistribution Channel”

• Auclert & Rognlie (2016) “Inequality and Aggregate Demand”

• Bayer, Pham, Luetticke & Tjaden (2015) “Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk”

• Carroll, Slacalek & Tokuoka (2016) “The Distribution of Wealth and the Marginal Propensity to Consume”

• Den Haan, Rendahl & Riegler (2017) “Unemployment (fears) and Deflationary Spirals,”


• Guerrieri & Lorenzoni (2017) “Credit Crises, Precautionary Savings, and the Liquidity Trap”

• Kaplan, Moll & Violante (2017) “Monetary Policy According to HANK”
References: Some “Third Generation” Papers

- Hedlund, Karahan, Mitman & Ozkan (2017) “Monetary Policy, Heterogeneity and the Housing Channel”
- Oh & Reis (2012), “Targeted Transfers and the Fiscal Response to the Great Recession”
- Werning (2016), “Incomplete Markets and Aggregate Demand” (depends)
References: Other Academic Articles

• Aiyagari (1994) “Uninsured Idiosyncratic Risk and Aggregate Saving”


• Benabou (1996) “Inequality and Growth”

• Bewley (1986) “Stationary Monetary Equilibrium with a Continuum of Independently Fluctuating Consumers”


• De Nardi & Fella (2017) “Saving and Wealth Inequality”

• Den Haan (1996) “Heterogeneity, Aggregate Uncertainty, and the Short-Term Interest Rate”
References: Other Academic Articles

- Heathcote, Storesletten & Violante (2009) “Quantitative Macroeconomics with Heterogeneous Households”
- Krueger, Mitman & Perri (2016) “Macroeconomics and Household Heterogeneity”
- Tobin (1952) “Asset Holdings and Spending Decisions”
- Persson & Tabellini (1994) “Is Inequality Harmful for Growth?”
  http://economistsview.typepad.com/economistsview/2014/08/
  the-supply-side-case-for-government-redistribution.html


• Constâncio (2017) “Inequality and Macroeconomic Policies”

• Kaplan and Violante (2016) “Wealthy ‘hand-to-mouth’ households: key to understanding the impacts of fiscal stimulus”
  http://microeconomicinsights.org/
  wealthy-hand-to-mouth-households-key-to-understanding-the-impacts-of-fiscal-stimulus/

• Kocherlakota (2009) “Some Thoughts on the State of Macro”


• Olsen (2018) “How does the key policy rate operate?”
  https://www.bis.org/review/r181012c.htm

• Yellen (2016) “Macroeconomic Research After the Crisis”
  https://www.federalreserve.gov/newsevents/speech/yellen20161014a.htm