Distributional Macroeconomics

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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:

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

- Or perhaps more precisely:

  \[
  \text{macroeconomy is a distribution}
  \]
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 $\not\implies$ 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 $\not\implies$ 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 $\not\implies$ 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

⇒ 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 ⇒ inequality” but “macro ∉ inequality” (perception)

- **3rd generation**: after the financial crisis
  - current heterogeneous agent models
  - rich interaction: “inequality ↔ 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
  • ⇒ 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

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

>95%  <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

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

\[ \text{HANK: } <1/3 \quad \text{HANK: } >2/3 \]

• 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)

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

- \( b_t \): 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>

![Graphs showing liquid and illiquid wealth distributions]
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 $C$

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

✓

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

![Graph showing the transmission of monetary policy shock to consumption](image-url)
Transmission of monetary policy shock to $C$

$$dC_0 = \int_0^\infty \frac{\partial C_0}{\partial r^b_t} dt^b + \int_0^\infty \left[ \frac{\partial C_0}{\partial r^a_t} dt^a + \frac{\partial C_0}{\partial w_t} dw + \frac{\partial C_0}{\partial T_t} dT \right] dt$$

19% 
81%

![Graph demonstrating the transmission of monetary policy shock to C over time. The graph shows the deviations from baseline in percentage terms, with the total response, and direct and indirect effects indicated for different time periods.](image-url)
Role of fiscal response in determining total effect

<table>
<thead>
<tr>
<th></th>
<th>$T$ adjusts (1)</th>
<th>$G$ adjusts (2)</th>
<th>$B^g$ adjusts (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elasticity of $C_0$ to $r^b$</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 $R_0$

\[
- \frac{d \log C_0}{dR_0} = \frac{1}{\gamma} = 1 \quad \text{for all } \eta
\]
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)
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