Micro Jumps, Macro Humps: monetary policy and business cycles in an estimated HANK model

Adrien Auclert, Matt Rognlie and Ludwig Straub

Queen Mary, November 2020
This paper matches the micro and macro of monetary policy

**Q:** How should we model the effects of monetary policy?
Q: How should we model the effects of monetary policy?

"Macro time-series" approach
[CEE, ACEL, Mackowiak-Wiederholt, Smets-Wouters...]

- match **humps** in aggregates
- representative agent (RA)
- use habits, adj. costs, inattention

Output response to Romer-Romer shock

- match both humps and jumps
- revisit mon. transmission mechanism
- sources of business cycles
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• match micro “**jumps**” (MPCs)
• heterogeneous agents (HA)
• income risk + incomplete markets
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**This paper unifies the two:**
- match both humps and jumps
- revisit
  - mon. transmission mechanism
  - sources of business cycles
HA + inattention can match micro & macro

- Standard **RA supply side**:  
  - nominal rigidities, indexation 
  - investment adj. costs
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- **Household side as in HA:**
  - income risk + illiquid assets
  [Kaplan-Moll-Violante, Bayer et al]
  - *inattention* of households

What do we learn from matching micro & macro?

1. **Investment is key for monetary transmission**
   - \( I \uparrow \rightarrow Y \uparrow \rightarrow \text{amplified by households' MPCs} \)
   - state dependence: mon. pol. ∼/eight.osf/five.osf/percent.osf less powerful if \( I \) is constrained

2. **Investment is key for business cycles**
   [over and above findings from existing studies]
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**Estimate** to IRFs of mon. pol. shock:
[Rotemberg-Woodford, CEE, ACEL, MW, ...]

→ **hump**-shaped impulse responses
→ high **MPCs**
→ significant inattention
→ *(very)* small **direct effect** of \( r \) on \( C \)
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What do we learn from matching micro & macro?

1. **Investment** is key for **monetary transmission**  
   • $I \uparrow \rightarrow Y \uparrow \rightarrow$ amplified by households’ **MPCs**  
   • **state dependence**: mon. pol. $\sim 85\%$ less powerful if $I$ is constrained
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Monetary transmission

Representative agent, no flow

$r \rightarrow C \rightarrow Y$
Monetary transmission

Representative agent

In HA: monetary policy transmission operates through...

Any shocks that move \( r \), comove with & are amplified by...
Monetary transmission

Representative agent

Heterogeneous agents, no l
Monetary transmission

In HA: monetary policy transmission operates through
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- Representative agent
- Heterogeneous agents
Monetary transmission

Representative agent

Heterogeneous agents, estimated

Any shocks that move, comove with and are amplified by...
In HA: mon. pol. transmission operates through $l$
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Our paper brings together three literatures

1. **HA / tractable HA models** (with nominal rigidities)
   - **others:** McKay-Reis 2016, Guerrieri-Lorenzoni 2018, Auclert-Rognlie-Straub 2018, Acharya Dogra 2018, Bilbiie-Känzig-Surico 2019, Hagedorn-Manovskii-Mitman 2019, ...

2. **Estimation of RA/HA models**
   - **limited info:** Rotemberg-Woodford 1997, Christiano-Eichenbaum-Evans 2005, Altig-Christiano-Eichenbaum-Linde 2011, ...

3. **Deviations from rational expectations and monetary policy**
1. How we match micro jumps & macro humps

2. Inattentive HA model

3. Estimation

4. Result 1: Investment is the transmission mechanism

5. Result 2: Investment drives business cycles

6. Conclusion
How we match micro jumps & macro humps
Heterogeneous-agent models can match (i)MPCs

Standard **heterogeneous-agent** model in s.s.:

\[
V(\ell, s) = \max_{c, \ell'} u(c) + \beta \mathbb{E} \left[ V(\ell', s') \mid s \right] \\
\quad c + \ell' \leq (1 + r)\ell + ye(s) \\
\quad \ell' \geq 0
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**Key Q:** How does average agent dynamically react to unanticipated transitory shock to \(y\)?

→ **intertemporal MPCs**  
[Auclert-Rognlie-Straub 2018]
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**Intertemporal MPCs in the data**

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Intertemporal MPCs in the data

Data (FHN)

RA

HA

RA habits

HA habits

MPC out of unanticipated income \(\frac{\partial C}{\partial y}\)

\(0\)

0.05

0.1

0.15

0.2

0

2

4

6

8

Quarter
Inattention preserves (i)MPCs but introduces sluggishness

- Introduce aggregate risk in $r_t, y_t$
- Our approach to humps: **sticky expectations**
  
  
  - agents update expectations w/ Calvo $1 - \theta$
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• Introduce aggregate risk in $r_t$, $y_t$
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  $$V_t (\ell, s; k) = \max_{c, a'} u(c) + \beta \mathbb{E}_{t-k} \left[ \theta V_{t+1} (\ell', s', k+1) + (1 - \theta)V_{t+1} (\ell', s', 0) \right] \mid s$$

  $$c + \ell' \leq (1 + r_t)\ell + y_t e(s)$$

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  note: agents always see current $r_t$, $y_t$ → never violate borrowing constraint!

• Achieves two goals: (i)MPCs are unchanged around the s.s. → matches “micro jumps”

  (ii) beliefs about future path of aggregates sluggish → matches “macro humps”
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Inattentive HA model
• Discrete time with aggregate shocks

• **Heterogeneous-agent** household side
  • two assets + **sticky expectations**

• Standard **New-Keynesian** supply side
  • investment adjustment costs + nominal rigidities + indexation
  • fiscal rule changing labor taxes, monetary policy follows inertial Taylor rule
Households & financial intermediary

- Total wealth held by competitive & attentive financial intermediary, two liabilities:
  - liquid assets (deposits) $\ell_t$: short-term, pay rate $r^\ell_t = r_{t-1} - \xi$
  - illiquid assets $a_t$: pay rate $r^a_t$, households follow withdrawal rule $d(a_t^{\text{illiq}})$
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- Households are inattentive also w.r.t. value of $a^\text{illiq}_t$. Thus:
  $$V_{g,t}(\ell, a, a_{-k}, s; k) = \max_{c, \ell'} u(c) + \beta g E_{t-k} \left[ \theta V_{g,t+1}(\ell', a', a_{-k}, s', k + 1) + (1 - \theta) V_{g,t+1}(\ell', a', a', s', 0) | s \right]$$

\begin{align*}
c + \ell' & \leq (1 + r^\ell_t)\ell + Z_t \bar{e}_g e(s) + d_{g,t}(a_{-k}, k), \\
a' & = (1 + r^a_t)a - d_{g,t}(a_{-k}, k)
\end{align*}

- Allow for six household groups to capture heterogeneity in illiquid assets
Estimation
Two-step estimation procedure

• Split parameters into two categories:

1. Steady-state relevant parameters [income process, share of liquid assets, ...]
   → calibrate to micro moments, e.g. income distribution, **MPCs**

2. Impulse-response relevant parameters \( \theta, \phi, \zeta^p, \zeta^w, \rho^m, \sigma^m \)
   → **estimate** using either limited or full-information method
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• Today: match impulse responses to monetary policy shocks

  • data on $\{Y_t, C_t, I_t, N_t, P_t, W_t, r_t\}$
• Monetary impulse response [Ramey 2016]
• Jordà method using Romer-Romer shocks in original sample (69m3–96m12)
How do we simulate HA + info friction?

• Complicated model! HA + sticky expectations ...
• Expand “sequence-space Jacobian” method

[Auclert-Bardóczy-Rognlie-Straub 2019]
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  1. Use certainty equivalence → focus on small “MIT shocks”
  2. Break model into blocks: e.g. household block \( \{Y_t, r_t\} \mapsto \{C_t\} \)
  3. Compute each block’s Jacobians [sufficient for simulation!] e.g.
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\[
\begin{pmatrix}
    dC_0 \\
    dC_1 \\
    dC_2 \\
    \vdots
\end{pmatrix} =
\begin{pmatrix}
    M_{00} & M_{01} & M_{02} & \cdots \\
    M_{10} & M_{11} & M_{12} & \cdots \\
    M_{20} & M_{21} & M_{22} & \cdots \\
    \vdots & \vdots & \vdots & \ddots
\end{pmatrix}
\begin{pmatrix}
    dY_0 \\
    dY_1 \\
    dY_2 \\
    \vdots
\end{pmatrix} + \cdots
\]

• With sticky expectations: **manipulate the rational expectation Jacobian**!
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    dC_2 \\
    \vdots
\end{pmatrix} =
\begin{pmatrix}
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    M_{10} & (1 - \theta)M_{11} + \theta M_{00} & (1 - \theta)M_{12} + \theta(1 - \theta)M_{01} & \cdots \\
    M_{20} & (1 - \theta)M_{21} + \theta M_{10} & \cdots & \cdots \\
    \vdots & \vdots & \vdots & \ddots
\end{pmatrix}
\begin{pmatrix}
    dY_0 \\
    dY_1 \\
    dY_2 \\
    \vdots
\end{pmatrix} +
\]

- With sticky expectations: manipulate the rational expectation Jacobian!
The estimated impulse responses

<table>
<thead>
<tr>
<th>Output</th>
<th>Consumption</th>
<th>Investment</th>
<th>Hours (% of s.s.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent of s.s. output</td>
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</tr>
<tr>
<td>0</td>
<td>0.1</td>
<td>0</td>
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<tr>
<td>2</td>
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<table>
<thead>
<tr>
<th>Price level</th>
<th>Nominal wage</th>
<th>Nominal interest rate</th>
<th>Real interest rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percent</td>
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<tr>
<td>0</td>
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Data | 90% Confidence Interval | HA Model
Estimates point to significant inattention

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>std. dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta$</td>
<td>Stickiness of household expectations</td>
<td>0.935</td>
<td>(0.01)</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Investment adjustment cost</td>
<td>9.639</td>
<td>(2.428)</td>
</tr>
<tr>
<td>$\zeta^p$</td>
<td>Calvo price stickiness</td>
<td>0.926</td>
<td>(0.012)</td>
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<tr>
<td>$\zeta^w$</td>
<td>Calvo wage stickiness</td>
<td>0.899</td>
<td>(0.016)</td>
</tr>
<tr>
<td>$\rho^m$</td>
<td>Taylor rule inertia</td>
<td>0.890</td>
<td>(0.01)</td>
</tr>
<tr>
<td>$\sigma^m$</td>
<td>Standard deviation of monetary shock</td>
<td>0.057</td>
<td>(0.005)</td>
</tr>
</tbody>
</table>

• Somewhat more inattention than Coibion Gorodnichenko (2012)
  • find $0.80, 0.86$-$0.89$ for inflation expectations of households, prof. forecasters
  • distinction between updating expectations and acting on them?
How much does inattention matter?

- Sticky expectations are crucial for the hump shape!
Inattention informs the **composition** of consumption

Decompose [Auclert 2019, Kaplan-Moll-Violante 2018, ...]

\[
dC_t = \sum_s \frac{\partial C_t}{\partial r_s} dr_s + \sum_s \frac{\partial C_t}{\partial Y_s} dY_s + \ldots
\]

- **direct**
- **indirect**

Indirect effects largely driven by MPCs → mostly unaffected by inattention!

Direct effects strongly dampened by inattention
Inattention informs the **composition** of consumption

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*Indirect effects* largely driven by MPCs

→ mostly *unaffected by inattention!*

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- **Indirect effects** largely driven by MPCs
- → mostly **unaffected by inattention**!

**Direct effects** strongly **dampened by inattention**
Inattention informs the **composition** of consumption

**Decompose** [Auclert 2019, Kaplan-Moll-Violante 2018, ...]

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dC_t = \sum_s \frac{\partial C_t}{\partial r_s} dr_s + \sum_s \frac{\partial C_t}{\partial Y_s} dY_s + \ldots
\]

Indirect effects largely driven by **MPCs**

→ mostly **unaffected by inattention**!

Direct effects strongly **dampened by inattention**

→ intertemporal substitution \(\simeq\) irrelevant for \(C\)!
Result 1: Investment is the transmission mechanism
How is monetary policy transmitted in this model?

\[ r \quad Y \]
How is monetary policy transmitted in this model?

- Direct channels
- Indirect channels

Diagram:
- $r$ → $C$ → $Y$
- $I$ → $Y$
How is monetary policy transmitted in this model?

Direct channels
How is monetary policy transmitted in this model?

Direct channels & indirect channels
The role of investment in the transmission mechanism

Switching off investment entirely...

...dampens cumulative HA output by 85% and consumption by 70%!
The role of investment in the transmission mechanism

Switching off investment entirely...

...but has no effect on RA consumption!
Investment is the transmission mechanism in HA

In RA, Y is mostly driven by direct response of C!

Representative agent

Heterogeneous agents

In HA Y is driven by investment!
Result 2: Investment drives business cycles
Bayesian estimation of our inattentive HA model

- Enrich our model to include **7 standard shocks** [Smets Wouters 2007, JPT 2010, 2011, ...]
  - supply: TFP, $W$ markup, $P$ markup
  - demand: monetary policy, $G_t$, $C_t$, $I_t$
  - different: discount factor shock for $C_t$, risk premium shock for $I_t$

- Use **same model parameters** ...

... but **estimate all shock parameters** to 7 standard series

- To compare: apply same procedure to **RA with habit**
Consider baseline RA model

- Decompose forecast error variances $\text{Var}_t(Y_{t+h})$ at business cycle horizons:

In this estimated RA: it’s about **markup and TFP shocks** [as in Smets Wouters 2007]
Endogenous cov (C, I) in HA → investment shocks matter much more!

- Decompose forecast error variances $\text{Var}_t(Y_{t+h})$ at business cycle horizons:

![Graphs showing forecast error variances for output and consumption over different horizons, with shaded regions indicating the impact of various shocks.]

Replace RA with HA: investment shocks matter a lot more!
Why is this?

- Salient feature of the data: comovement of $\text{Cov}_t(C_{t+h}, I_{t+h})$ [Barro-King 1984]

In HA investment shocks generate endogenous comovement between $C$ and $I$. 
Conclusion
Conclusion

heterogeneity (micro jumps) + inattention (macro humps) ⇒ investment

\{ 
\begin{align*}
& \text{drives monetary transmission} \\
& \text{drives business cycles}
\end{align*}
\}
Extra slides
Illiquid account withdrawal rule

\[ d_{g,t}(a_{-k}, k) = \frac{r^{a,ss}}{1 + r^{a,ss}} a^e + \chi (a^e - (1 + r^{a,ss}) \bar{a}_g) \]

where

\[ a^e = a^e_t(a_{-k}, k) \equiv E_{t-k} [(1 + r_t^a) a|a_{-k}] \]

- First term \( \frac{r^{a,ss}}{1 + r^{a,ss}} a^e \) is annuity value of expected assets
- Second term is correction to hit long-term illiquid asset average \( \bar{a}_g \)
  - we choose \( \chi \) close to but not equal to 0, different choices have no discernible effect
Role of investment in estimated TA

- **TA** model (share of hand to mouth = 20%) is relatively close to **RA**
Without inattention, **investment much less important!**
What gets monetary transmission started?

- With long-term bonds, much less of a windfall from lower $r_t$
  - precise fiscal rule less crucial than with short-term bonds
Why does fiscal policy not matter more?

- With long-term bonds, much less of a windfall from lower $r_t$
  - precise fiscal rule less crucial than with short-term bonds
Stock market goes up, sluggish transmission to $C$

- shape & magnitude as in Chodorow-Reich Nenov Simsek (2019)