Monetary policy

NBER Heterogeneous-Agent Macro Workshop

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Today

Yesterday: The canonical HANK model & fiscal policy

Today: Monetary policy

We start by studying consumption in the closed economy

We keep our focus on real interest rate rules (also see what Taylor rules do)

Roadmap

1. Review of monetary policy in the standard NK model
2. Monetary policy in the canonical HANK model
3. Direct and indirect effects of monetary policy
4. Cyclical income risk

Review of monetary policy in the standard NK model

The NK model

- Recall the standard 3-equation NK model
  - separable preferences, sticky prices or wages, perfect foresight

$$c_t = c_{t+1} - \sigma^{-1}(i_t - \pi_{t+1}) \tag{EE}$$

$$\pi_t = \kappa c_t + \beta \pi_{t+1} \tag{NKPC}$$

$$i_t = \epsilon_t + \pi_{t+1} \tag{r-rule}$$

- Taylor rule instead of (r-rule): $i_t = \epsilon_t + \phi \pi_t$ (usually $\phi > 1$)
- What does a **monetary policy shock** do, e.g. $\epsilon_t \downarrow$?

  1. expansion in c_t so output y_t, inflation $\pi_t \uparrow$, nominal rate i_t ambiguous
  2. far out shocks to ϵ_t with large t have large effects (forward guidance "puzzle")

(1) One-time expansion

- Consider shock $\epsilon_t = (-\Delta, 0, 0, \ldots)$. Forward looking: $\pi_t = c_t = 0$ for $t > 0$
- From (EE), (NKPC), (r-rule)

$$c_0 = \sigma^{-1}\Delta > 0 \qquad \pi_0 = \kappa\sigma^{-1}\Delta > 0 \qquad i_0 = -\Delta < 0$$

- With Taylor rule, instead

$$c_0 = -\sigma^{-1} i_0 \qquad \pi_0 = \kappa c_0 \qquad i_0 = -\Delta + \phi\pi_0$$

$$c_0 = \frac{\sigma^{-1}\Delta}{1 + \kappa\phi\sigma^{-1}} > 0 \qquad \pi_0 = \frac{\sigma^{-1}\kappa\Delta}{1 + \kappa\phi\sigma^{-1}} > 0 \qquad i_0 = -\frac{\Delta}{1 + \kappa\phi\sigma^{-1}} < 0$$

- A plausible outcome. But is the **transmission mechanism** also plausible?
  - happens **entirely** through the **Euler equation** (intertemporal substitution)
  - no debt, no redistribution, no feedback from y_t to c_t $\leftarrow$ **want fo fix this**
  - also: no investment, no exchange rate $\leftarrow$ **fixes exist, but want to revisit them**

(2) Forward guidance in NK model

- Where the Euler equation really matters: **forward guidance**. E.g:

$$r_t \equiv i_t - \pi_{t+1} = \begin{cases} -\triangle & t = T \\ 0 & t \neq T \end{cases}$$

- At time of shock $\Rightarrow c_T = \sigma^{-1}\triangle$, $\pi_T = \kappa\sigma^{-1}\triangle$
- Then, solving (EE) and (NKPC) backwards from T

$$c_t = \sigma^{-1}\triangle \qquad \pi_t = \kappa \sum_{k=0}^{T-t} \beta^k \sigma^{-1}\triangle \qquad \textit{for all } t \leq T$$

- Transmission to c_t **independent** of T. Transmission to π_t **growing** in T!
  - e.g. $\beta = 0.99$ and $T = 20$ quarters then $\frac{\pi_0}{\pi_T} = \frac{1-\beta^T}{1-\beta} = 18$!
  - "Forward guidance puzzle" from Del Negro et al. (2013)
  - gets even worse at ZLB!

Summary: two issues

- To summarize, two key issues with the standard NK model:
  - **transmission channel:** 100% through Euler equation, seems implausible
  - **output response:** Euler equation "too forward looking"
- A major goal of the early HANK literature was to solve these two issues
  - Auclert (2019), Kaplan et al. (2018): wealth distribution + high MPCs $\Rightarrow$ redistribution channels of m.p., substitution effects less important for C
  - McKay et al. (2016): borrowing constraints imply that C is less forward looking. Could help deliver "discounting" in the Euler equation? Something like:

$$c_t = \delta c_{t+1} - \sigma^{-1}(i_t - \pi_{t+1}) \qquad \text{with } \delta < 1 \tag{DEE}$$

Next: What HANK actually does!

Monetary policy in the canonical HANK model

Setting up the model

- Take canonical HANK model, but abstract from fiscal policy
    - $T = \tau = G = B = 0$
    - but allow agents to borrow from each other: $\underline{a} < 0$ (as in Huggett model)
    - Later bring back govtt to study monetary-fiscal interactions
- Real rate rule: monetary policy sets r_t^{ante} directly
- Related to the above, want to ask two questions:
    1. What's the output response relative to RA? (Magnitude? Any "discounting"?)
    2. What are the transmission channels relative to RA?

We'll start with 1.

Back to our equilibrium conditions

Under these assumptions, the canonical HANK model can just be written as:

$$\max_{c_{it}} \; \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(u(c_{it}) - v\left(N_t\right)\right)$$

$$c_{it} + a_{it} \leq (1 + r_{t-1}^{ante}) a_{it-1} + s_{it} Y_t$$

$$a_{it} \geq \underline{a}$$

with

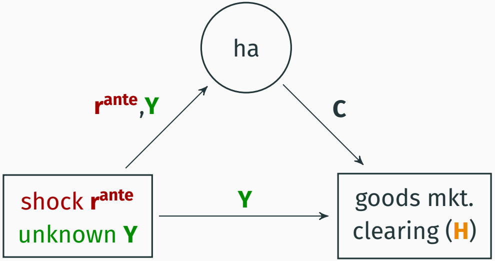
$$C_t \equiv \int c_{it} di = Y_t = N_t$$

$$A_t \equiv \int a_{it} di = 0$$

That's it!

DAG of this model

Let's visualize this as a DAG:



Here again, simple fixed point:

$$\mathcal{C}_t\left(\{r_s^{ante}, Y_s\}\right) = Y_t$$

Ex-ante vs ex-post r

- In practice, we usually write `HetBlocks` with "ex-post r" convention, i.e. here:

$$\max_{c_{it}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(u(c_{it}) - v\left(N_t\right)\right)$$

$$c_{it} + a_{it} \leq (1 + r_t)a_{it-1} + s_{it}Y_t$$

$$a_{it} \geq \underline{a}$$

- This is more general: allows us to handle valuation effects (see next lecture)
- Here there are no valuation effects, so we just have

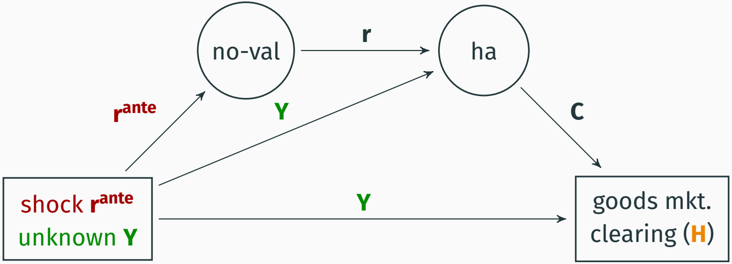
$$r_t = r_{t-1}^{ante} \quad t \geq 1$$

$$r_0 = r_{ss}$$

- This adds one "no valuation" block to the DAG

DAG including the valuation block

Our new DAG is:



Using a `CombineBlock`, we can just let SSJ do the convolution for us, ie define

$$\mathcal{C}_t\left(\{r_s^{ante}, Y_s\}\right) \equiv \mathcal{C}_t^{post}\left(\{r_j\left(r_s^{ante}\right), Y_s\}\right)$$

So that we are back to our simple fixed point:

$$\mathcal{C}_t\left(\{r_s^{ante}, Y_s\}\right) = Y_t$$

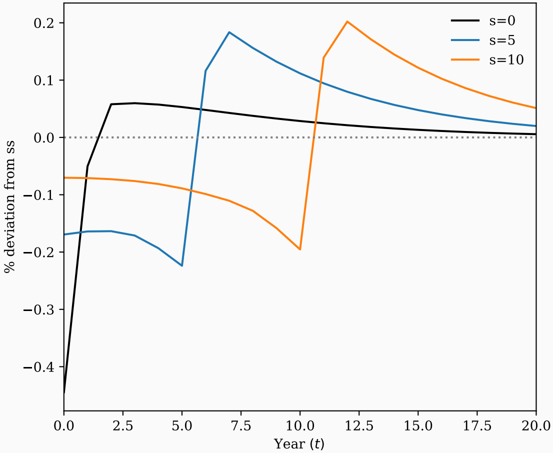
Jacobians again

- As in fiscal lecture, let's linearize this sequence space equation
- Define $d\mathbf{r} \equiv \left(dr_0^{ante}, dr_1^{ante}, \ldots\right)$, and let $d\mathbf{Y} = (dY_0, dY_1, \ldots)$ as before. Define Jacobian $\mathbf{M}^r \equiv \left(\partial \mathcal{C}_t / \partial r_s^{ante}\right)_{t,s}$ capturing direct effect of r on C. Then:
$$d\mathbf{Y} = \mathbf{M}^r d\mathbf{r} + \mathbf{M} d\mathbf{Y}$$
- Almost like the IKC, except that partial eqbm demand shock is no longer coming from fiscal policy, $d\mathbf{G} - \mathbf{M}d\mathbf{T}$, but instead from monetary policy!
- Just as with fiscal, the PE demand shock has zero NPV (Why?)
- General solution uses same linear mapping $\mathcal{M}$ (recall "$(I - \mathrm{M})^{-1}$")
$$d\mathbf{Y} = \mathcal{M}\mathbf{M}^r d\mathbf{r}$$

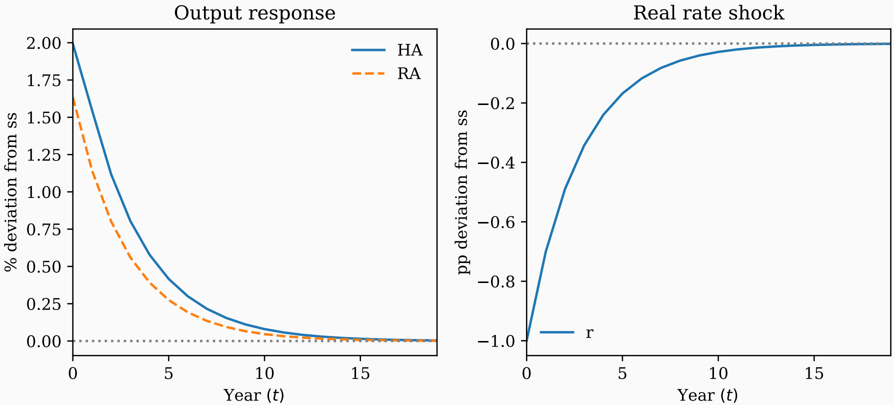
Next: Let's visualize $\mathbf{M}^r$; then the solution $d\mathbf{Y}$ for an AR(1) shock to $d\mathbf{r}$

Columns of Jacobian $\mathbf{M}^r$

- $\mathbf{M}^r$ is our old friend from Lecture 2



Monetary policy shock in HA (AR(1) with $\rho = 0.7$)



- HA $>$ RA! Interesting! But why?

Benchmark result with zero liquidity

- One way to make progress is to simplify the model $\Rightarrow$ ZL model: $\underline{a} \to 0$
- Recall that for low β only Euler equation of agents in income state $\overline{s}$ holds

$$(Y_t \overline{s})^{-\sigma} = \beta (1 + r_t) \mathbb{E}_t \left[\left(Y_{t+1} s' \right)^{-\sigma} | \overline{s} \right]$$

  where $\overline{s}$ is income state attaining $\overline{\rho} \equiv \max_s \mathbb{E} \left[(s'/s)^{-\sigma} | s \right]$

- Hence, we always have

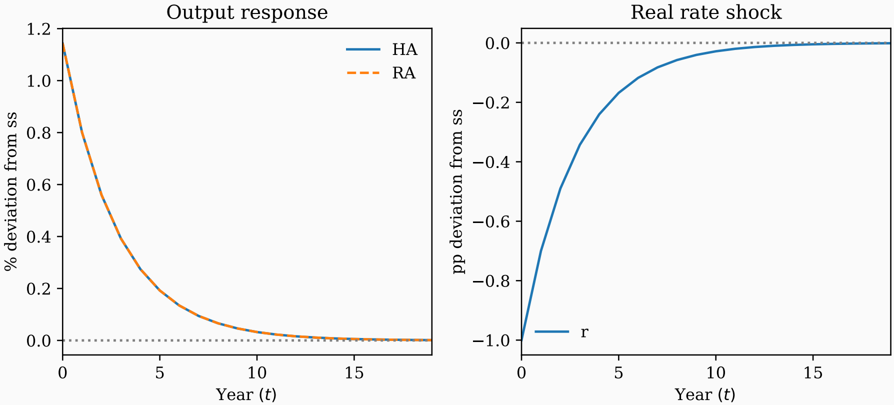
$$Y_t^{-\sigma} = \beta (1 + r_t) \overline{\rho} (Y_{t+1})^{-\sigma} \quad \Rightarrow \quad y_t = y_{t+1} - \sigma^{-1} (r_t - \log (\beta \overline{\rho}))$$

- **This is like our representative agent Euler equation!**
  - just with effective discount factor $\beta \overline{\rho}$

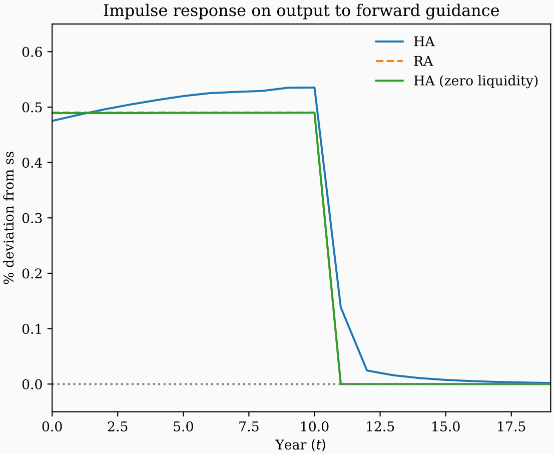
  $\rightarrow$ Werning (2015)'s **neutrality result** for zero liquidity and acyclical income risk

- In particular: No discounting in log-linearized Euler equation!

Neutrality for monetary policy in the ZL limit



Neutrality also implies the forward guidance puzzle is not solved by HA



Summary: Output response of monetary policy in HA

- No robust result that HA $\neq$ RA !
  - In fact here, with zero liquidity, we show that HA $=$ RA
  - Forward guidance can be equally powerful
- But how can that be, given that HA breaks the Euler equation?
- **Next: study transmission channels**

Direct and indirect effects of monetary policy

Direct and indirect effects

- To see what's going on, let's go back to our IKC-like equation:

$$d\mathbf{Y} = d\mathbf{C} = \underbrace{\mathbf{M}^r \cdot d\mathbf{r}}_{\text{Direct effect}} + \underbrace{\mathbf{M} \cdot d\mathbf{Y}}_{\text{Indirect effect}}$$

- **Two competing effects** of market incompleteness! direct $\downarrow$, indirect $\uparrow$

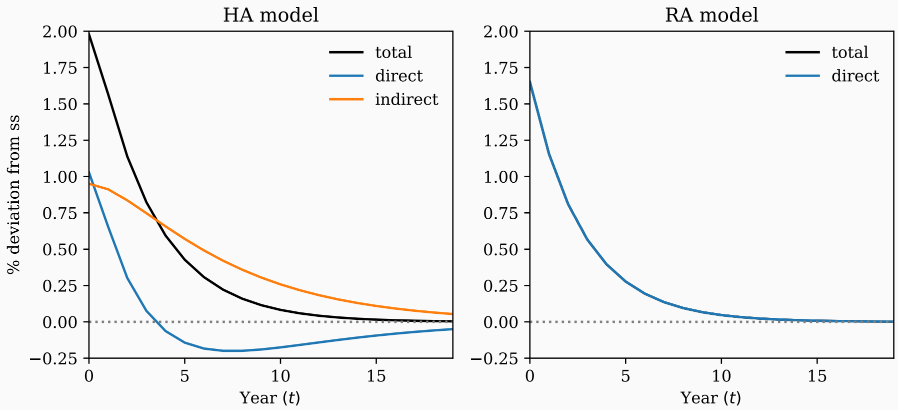
  [Kaplan et al. (2018) showed this in their two-asset HA model]

- Why? High MPCs make C more sensitive to Y but also **less sensitive to** r!
  - cf Auclert (2019): substitution effect of dr scales with $-\sigma^{-1}(1 - MPC)$
  - In ZL model above, can actually prove that $\mathbf{M}^r = -\sigma^{-1}(\mathbf{I} - \mathbf{M})$ so [new result!]

$$d\mathbf{C} = -\sigma^{-1}(\mathbf{I} - \mathbf{M}) \cdot d\mathbf{r} + \mathbf{M} \cdot d\mathbf{Y}$$

Decomposition into direct and indirect effects

- Let's implement $d\mathbf{C} = \mathbf{M}^r d\mathbf{r} + \mathbf{M} \cdot d\mathbf{Y}$ in our canonical HA model:



Takeaway so far

1. HA model does not imply robustly different output response
2. But it *does* change transmission: indirect effects are more important!

- This is the main result in KMV. Why do we care about that per se?
  - KMV: labor & financial market institutions matter more than we thought
  - We'll see other reasons for why we should care in the next lecture
- Before going there, let's see how we can make HA and RA really *different*
- Recall that so far, we have assumed **acyclical income risk**, i.e.

$$\text{sd}(\log y_{it}) = \text{sd}(\log s_i), \text{ independent of } Y_t$$

- This turns out to be a critical assumption. Let's relax it now.

Cyclical income risk

Introducing cyclical income risk

- We can introduce cyclical income risk by adopting different allocation rule. For instance take Auclert and Rognlie (2018)

$$n_{it} = Y_t \frac{(s_{it})^{\zeta \log Y_t}}{\mathbb{E}\left[s^{1+\zeta \log Y_t}\right]} \equiv Y_t \Gamma\left(s_{it}, Y_t\right)$$

- Distribution of income $y_{it} \equiv s_{it} n_{it}$ now reacts to monetary policy

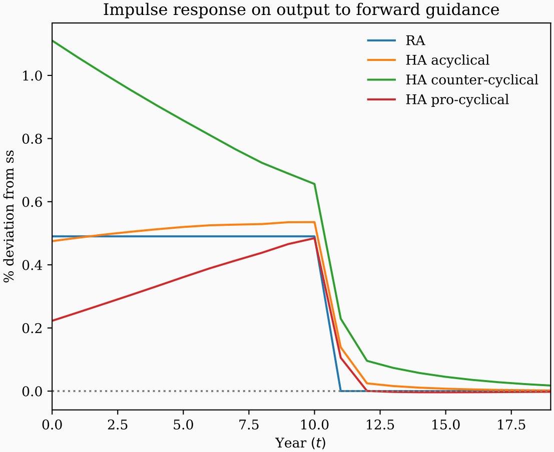
$$\text{sd}\left(\log y_{it}\right) = \left(1 + \zeta \log Y_t\right) \text{sd}\left(\log s_i\right)$$

  - $\zeta > 0$: procyclical inequality and income risk
  - $\zeta < 0$: countercyclical inequality and income risk
  - $\zeta = 0$ is benchmark from above (acyclical inequality & risk)

- Matters because:
  - current shocks redistribute between different MPCs ("cyclical inequality")
  - future shocks change income risk ("cyclical risk")

How does cyclical income risk change forward guidance?

- Consider a r_T shock with three calibrations for ζ in HA model



Zero liquidity limit with cyclical income risk

▸ details

- What's going on? In ZL limit, we get an **exact** discounted Euler equation

$$y_t = \delta \mathbb{E}_t [y_{t+1}] - \sigma^{-1} \cdot \mathrm{Cst} \cdot (r_{t+1} - \log(\beta \overline{\rho}))$$

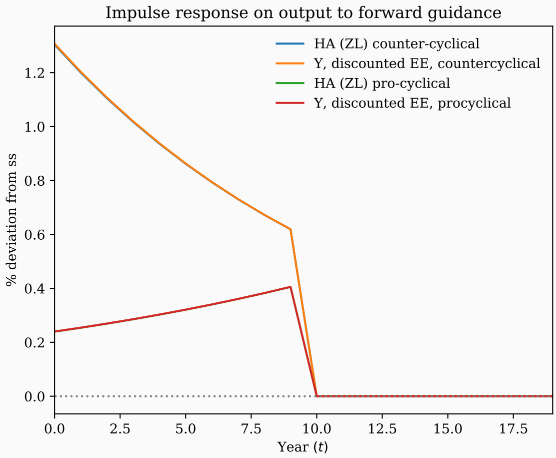
where δ depends on $\gamma(s)$, elasticity of Γ in state s wrt Y, relative to that for $\overline{s}$

1. Dynamic discounting ($\delta < 1$) $\Leftrightarrow \gamma(s) < \gamma(\overline{s})$ on average
   - "procyclical income risk", not commonly used, exception below
2. Dynamic amplification ($\delta > 1$) $\Leftrightarrow \gamma(s) > \gamma(\overline{s})$ on average
   - "countercyclical risk", more common
   - Microfound w/ u: Ravn and Sterk (2017), den Haan et al. (2018), Challe (2020)
   - Lots of evidence: Storesletten et al. (2004), Guvenen et al. (2014)
3. Dynamic neutrality ($\delta = 1$) $\Leftrightarrow \gamma(s) = \gamma(\overline{s})$
   - "acyclical risk", ie Werning benchmark

- Why? Precautionary savings. Think about logic of discounted Euler equation.

Forward guidance in the ZL model

- In the empirically plausible case, the fwd guidance puzzle is **aggravated**!
  Bilbiie (2019), Acharya and Dogra (2020)



Indirect ways to make income risk cyclical

- In richer models income of agents typically involves multiple components,

$$y_{it} = \frac{W_t}{P_t} n_{it} s_{it} - \underbrace{\tau_{it}}_{\text{taxes}} + \underbrace{T_{it}}_{\text{transfers}}$$

- These also matter for cyclicality of income risk
- For example, suppose taxes are set to keep balanced budget, $\tau_t \equiv \int \tau_{it} di = r_t B$ and transfers T_t are dividends from firms with sticky prices
  $\Rightarrow$ both τ_t and T_t fall after expansionary r_t (why?)
- If τ_t allocated to highest income state and T_t to all $\Rightarrow$ procyclical risk!
- These are the assumptions in McKay et al. (2016).
  - Reason why that paper "solves" the forward guidance puzzle!

Summary

- Cyclical income risk matters
- Procyclical income risk $\Rightarrow$
  - smaller effects of monetary policy in HA relative to RA
  - solves forward guidance puzzle
  - not empirically supported
- Countercyclical income risk is empirically more plausible, amplifies HA relative to RA, but aggravates forward guidance puzzle!

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Zero liquidity limit with cyclical income risk

back

- Take ZL model with cyclical income risk. Euler for $\bar{s}$:

$$\left(Y_t \Gamma\left(\bar{s}, Y_t\right)\right)^{-\sigma} = \beta\left(1 + r_t\right) \mathbb{E}_t\left[\left(Y_{t+1} \Gamma\left(s', Y_{t+1}\right)\right)^{-\sigma} | \bar{s}\right]$$

- Log-linearize around steady state $\Rightarrow$

$$y_t = \delta \mathbb{E}_t\left[y_{t+1}\right] - \sigma^{-1} \gamma(\bar{s})^{-1}\left(r_t - \log\left(\beta \bar{\rho}\right)\right)$$

where, if $\gamma\left(s\right) \equiv 1 + \frac{\Gamma_Y Y}{\Gamma}$ is the elasticity of income wrt Y for agent in s:

$$\delta \equiv \bar{\rho}^{-1} \mathbb{E}\left[\left(s/\bar{s}\right)^{-\sigma} \frac{\gamma\left(s\right)}{\gamma\left(\bar{s}\right)} | \bar{s}\right] = \sum \omega\left(s\right) \frac{\gamma\left(s\right)}{\gamma\left(\bar{s}\right)} \qquad \text{where } \sum_s \omega(s) = 1$$

- What matters is cyclicality of $y(\bar{s})$ relative to other income states
- Example with two states: $\delta = 1 - \omega + \omega \frac{\gamma_L}{\gamma_H}$ with $\omega \in (0, 1)$