11. Monetary Policy in HANK

Adv. Macro: Heterogenous Agent Models

Jeppe Druedahl, Raphaël Huleux

2025

Summing Up What We Did So Far:

Aggregate Consumption Function in HANK

- Under some assumptions (real rate rule, real bond, no lump-sum transfers), we can derive a simpler consumption function
- In this case, $C_t^{hh} = C^{hh}(\{Y_s - T_s\}_{s=0}^{\infty})$ depends only on net income!
- If $\mathbf{Y} = C^{hh}(\mathbf{Y} - \mathbf{T}) + \mathbf{G}$, we thus have $d\mathbf{Y} = d\mathbf{G} + \mathbf{M}(d\mathbf{Y} - d\mathbf{T})$
- The sequence space Jacobian $\mathbf{M}$ tells us everything we need to know to understand output response to a monetary policy shock!

Plan for Today

Monetary policy!

- Derive equivalent of IKC for Monetary Policy in HANK
- Main results of KMV (2018) (Key paper in the literature)
- Study deviations from rational expectations
- Exercise
- **Dedicate last hour to the 2nd assignment.**

Introduction

Introduction

- **Last Time:**
  - Fiscal policy in the canonical HANK model
- **Today:**
  - Other pillar of stabilization policy: **Monetary policy**
  - Will use as example to study alternatives to **rational expecations** (RE) in HANK
- **Literature:**
  - *Seminal paper*: Kaplan, Moll, Violante (2018) »Monetary policy according to HANK«
  - Auclert Rognlie, Straub (2020) »Micro jumps, macro humps«
  - Alves, Kaplan, Moll, Violante (2020) »A further look at the propagation of monetary policy shocks in HANK«

Monetary Policy in HANK

Monetary Policy

- Introducing heterogeneous agents into the standard NK model **fundamentally** changes the transmission of Fiscal Policy
  - *Potentially* more effective
  - Important whether policy is deficit financed or tax financed
- What about monetary policy?

Model

- **Last time**: Canonical HANK model
- Very close to standard **NK** except for:
  - HA instead of RA
  - Sticky wages
  - Government
- Today: Monetary policy - don't really need a government?
  - Issue: If we remove government no liquidity for households to save in
    - Fine in RA, issue in HA with borrowing constraint at $a = 0$
  - **Solution:** Firm equity

Households

- **Household problem:**

$$
\begin{aligned}
v_t(z_t, a_{t-1}) &= \max_{c_t} \frac{c_t^{1-\sigma}}{1-\sigma} - \varphi \frac{\ell_t^{1+\nu}}{1+\nu} + \beta \mathbb{E}_t \left[v_{t+1}(z_{t+1}, a_t) \right] \\
\text{s.t. } a_t + c_t &= (1 + r_t^a) a_{t-1} + Z_t z_t + \chi_t \\
\log z_{t+1} &= \rho_z \log z_t + \psi_{t+1} \quad , \psi_t \sim \mathcal{N}(\mu_\psi, \sigma_\psi), \ \mathbb{E}[z_t] = 1 \\
a_t &\geq 0
\end{aligned}
$$

- with $Z_t = w_t \ell_t$ - real labor income
- **decisions:** Consumption-saving, c_t (and a_t)
- **Union decision:** Labor supply, ℓ_t
- **Aggregate Consumption:** $C_t^{hh} = \int c_t d\mathcal{D}_t$
- **Consumption function:** $C_t^{hh} = C^{hh}\left(\{r_s^a, Z_s, \chi_s\}_{s=0}^{\infty}\right)$

Firms

- **Production and profits:**

$$Y_t = L_t$$
$$\Pi_t = Y_t - w_t L_t$$

- Optimize subject to demand curve (monopolistic competition)
- **First order condition:**

$$w_t = \frac{1}{\mu}$$

- where $\mu > 1 =$ markup - firms make positive profits in equilibrium

Mutual fund I

- Mutual fund collect households savings A_t and invest in firm equity
- Firm j has ownership shares $\upsilon_{j,t}$ with price $p^D_{j,t}$
- If you own shares in the firm you get profits/dividends $\Pi_{j,t}$
- Shares sum to 1, $\int \upsilon_{j,t} dj = 1$
- Firms are gonna be symmetric in eq., $p^D_{j,t} = p^D_t$
- Total value of firm equity is then $\int p^D_t \upsilon_{j,t} dj = p^D_t$

Mutual fund II

- **Problem**:

$$\max_{\upsilon_{j,t}} \int \left(\Pi_{j,t+1} + p^D_{j,t+1}\right) \upsilon_{j,t} - \left(1 + r^a_{t+1}\right) A_t$$

- **Subject** to balance sheet:

$$\int p^D_{j,t} \upsilon_{j,t} dj = A_t$$

- **FOC**:

$$p^D_t = \frac{\Pi_{t+1} + p^D_{t+1}}{1 + r_t}$$

- where $r_t = E_t r^a_{t+1}$ the ex-ante interest rate
- Price of equity can be written as (assume $r_t = r$): $p^D_t = \sum_{s=0}^{\infty} (1+r)^{-s} \Pi_{t+s}$
  - Asset price today reflect discounted sum of future profits
- Valuation effects: As with nominal gov bonds:

$$1 + r^a_t = \begin{cases} \frac{\Pi_0 + p^D_0}{p^D_{ss}} & t = 0 \\ 1 + r_{t-1} & t > 0 \end{cases}$$

Union

- Everybody works the same:

$$\ell_t = L_t^{hh}$$

- Maximization subject to wage adjustment cost imply a **New Keynesian Wage (Phillips) Curve** (NKWPC or NKWC)

$$\pi_t^w = \kappa \left(\varphi \left(L_t^{hh} \right)^{\nu} - \frac{1}{\mu} \left(1 - \tau_t \right) w_t \left(C_t^{hh} \right)^{-\sigma} \right) + \beta \pi_{t+1}^w$$

Central bank

- Two options for monetary policy
- **1.** Government bonds are nominel, CB chooses nominel interest rate:

$$i_t = i_{ss} + \phi\pi_t$$

- And fisher equation links nominal rate i to real rate r:

$$1 + r_t = \frac{1 + i_t}{1 + \pi_{t+1}}$$

- **2. Alternative:** Real rate rule. CB chooses real rate r_t directly

$$r_t = r_{ss} + (\phi - 1)\,\pi_t$$

Market clearing

1. Asset market: $p_t^D = A_t^{hh}$
2. Labor market: $L_t = L_t^{hh}$
3. Goods market: $Y_t = C_t^{hh}$

The consumption function

- Model features a consumption function:

$$C_t^{hh} = C_t^{hh}\left(\{r_s^a, Z_s\}_{s=0}^{\infty}\right) \Rightarrow \boldsymbol{C}^{hh} = C^{hh}\left(\boldsymbol{r}^a, \boldsymbol{Z}\right)$$

- Linearize around steady state:

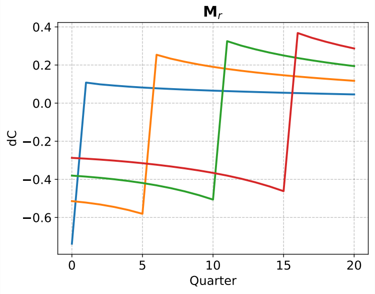
$$d\boldsymbol{C} = \boldsymbol{M} d\boldsymbol{Z} + \boldsymbol{M}_{r^a} d\boldsymbol{r}^a$$

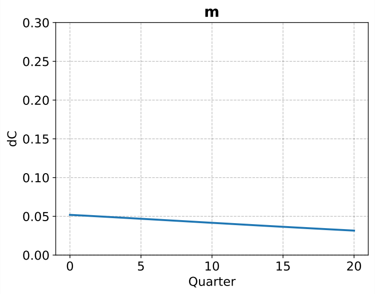
- As discussed in last lecture, can split overall effect of asset returns $d\boldsymbol{r}^a$ into intertemporal substitution effect (ex-ante r) and a capital gain effect at time 0:

$$d\boldsymbol{C} = \boldsymbol{M} d\boldsymbol{Z} + \boldsymbol{M}_r d\boldsymbol{r} + \boldsymbol{m} dcap_0$$

- Note: $\boldsymbol{m}$ is a vector not matrix (multiplies onto scalar $dcap_0$, not vector)

Interest rate Jacobians





Monetary policy in sequence-space

- Write real labor income as $Z_t = w_t L_t = \frac{1}{\mu} Y_t \Rightarrow d\boldsymbol{Z} = \frac{1}{\mu} d\boldsymbol{Y}$
- Linearize goods market clearing:

$$d\boldsymbol{Y} = \boldsymbol{M}_r d\boldsymbol{r} + \frac{1}{\mu}\boldsymbol{M} d\boldsymbol{Y} + \boldsymbol{m} dcap_0$$

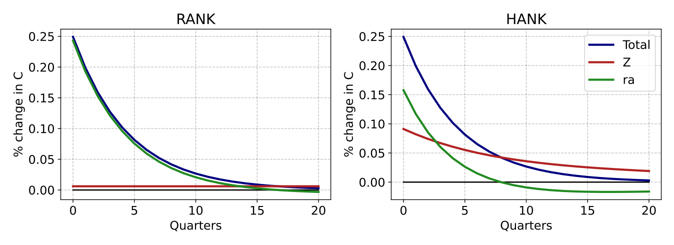
- For small capital gains, solution is:

$$d\boldsymbol{Y} = \left(\boldsymbol{I} - \frac{1}{\mu}\boldsymbol{M}\right)^{-1} \boldsymbol{M}_r d\boldsymbol{r} \equiv \mathcal{M}\boldsymbol{M}_r d\boldsymbol{r}$$

- Note: **can** multiplier invert this PV of columns in $\frac{1}{\mu}\boldsymbol{M}$ is not 1 when $\mu > 1$!)
- Monetary policy operates through:
  - **Direct** (partial eq., $\boldsymbol{M}_r$) effect
  - **Indirect** (general eq., $\boldsymbol{M}$) effect
- **Q1**: Sign? Positive/negative?
- **Q2**: Do you expect the effects of monetary policy on output to be larger in HANK than RANK?

HANK-RANK equivalence

- Assume logarithmic utility $u(c) = \log(c)$
- **Proposition**: Above model features **exact** equivalence between RANK and HANK for the response of aggregates w.r.t a monetary policy shock (*Werning 2015*)
- **... but transmission channel is different**
- Decompose $d\boldsymbol{Y}$ into direct and indrect effect using $d\boldsymbol{Y}^j = \boldsymbol{M}^j_{r^a} d\boldsymbol{r^a} + \boldsymbol{M}^j d\boldsymbol{Z}$ for $j \in \{HA, RA\}$



HANK-RANK equivalence

- In basic HANK model:
  - Monetary policy has same effectiveness as in RANK
  - But transmission different: Indirect income effects more important than in RANK
- Exact **equivalence** is the product of a number of simplifying assumptions:
  - Linear production function
  - No investment
  - Log utility
  - Equal incidence of labor income
  - No government debt
- How does the effectiveness of monetary policy look in more realistic models?
  - Kaplan, Moll, Violante (2018) »Monetary policy according to HANK«
  - Auclert Rognlie, Straub (2020) »Micro jumps, macro humps«

KMV 2018

Monetary policy according to HANK

- Kaplan, Moll, Violante (2018) is a seminal paper in the HANK litterature
    - The term HANK originates from this paper
- They study the transmission of monetary policy in medium scale HANK model
- Follows Kaplan & Violante (2014) closely
    - See lecture 2
    - Household can hold both liquid and illiquid assets
    - Model features both **poor** and **wealthy** Hand-to-mouth households

Household problem

- Households solve (here converted to discrete time, paper in cont. time):

$$V_t\left(a_{t-1}, b_{t-1}, z_t\right) = \max_{c_t, a_t, b_t} u\left(c_t, \ell_t\right) + \beta E_t V_{t+1}\left(a_t, b_t, z_{t+1}\right)$$

$$b_t + c_t = (1-\tau_t) w_t z_t \ell_t + \left(1 + r_t^b\right) b_{t-1} - d_t - \chi(d_t, a_{t-1})$$

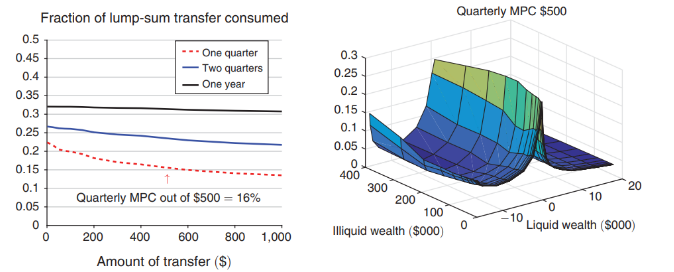
$$a_t = \left(1 + r_t^a\right) a_{t-1} + d_t$$

$$b_t \geq -\bar{b} \quad a_t \geq 0.$$

- with b_t=liquid asset, a_t=illiquid assets, d_t=deposits into illiquid asset, $\chi(d_t, a_{t-1})$ a convex cost
- Return on illiquid asset r_t^a Return on liquid asset r_t^b
  - Household will prefer to hold a_t due to superior return
  - But not good for consumption smoothing as they have to pay adjustment cost to use a_t for smoothing against shocks
  - Some HHs will be wealthy hand-to-mouth

MPCs

- 1) MPCs for different sizes of stimulus checks, 2) MPCs across the wealth distribution



Direct vs indirect effects

- Amplification in HANK (elasticity of $C^{HANK} = -2.9$ vs $C^{RANK} = -2.07$)
- Baseline HANK: Indirect effects account for majority of transmission ($\approx 80\%$)

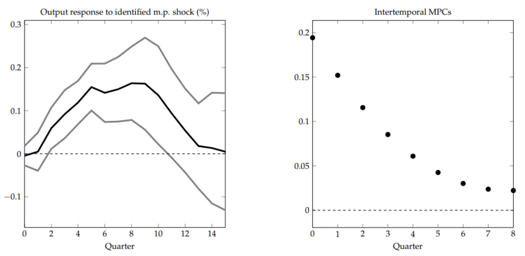
TABLE 7—DECOMPOSITION OF THE EFFECT OF MONETARY SHOCK ON AGGREGATE CONSUMPTION

	Baseline (1)	$\omega = 1$ (2)	$\omega = 0.1$ (3)	$\frac{\varepsilon}{\theta} = 0.2$ (4)	$\phi = 2.0$ (5)	$\frac{1}{\nu} = 0.5$ (6)
Change in r^b (pp)	−0.28	−0.34	−0.16	−0.21	−0.14	−0.25
Elasticity of Y	−3.96	−0.13	−24.9	−4.11	−3.94	−4.30
Elasticity of I	−9.43	7.83	−105	−9.47	−9.72	−9.79
Elasticity of C	−2.93	−2.06	−6.50	−2.96	−3.00	−2.87
Partial eq. elasticity of C	−0.55	−0.45	−0.99	−0.57	−0.59	−0.62
Component of percent change in C due to						
Direct effect: r^b	19	22	15	19	20	22
Indirect effect: w	51	56	51	51	51	38
Indirect effect: T	32	38	19	31	31	45
Indirect effect: r^a and q	−2	−16	15	−2	−2	−4

Expectations

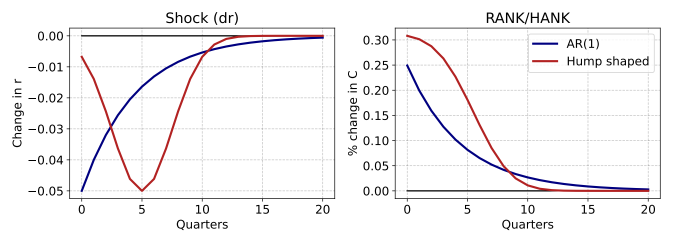
Micro Jumps, Macro Humps

- Auclert, Rognlie and Straub (2020) »Micro jumps, macro humps«
- Estimate parameters in quantitative HANK model to match estimated effects of causal monetary policy shock
- Main hurdle: Empirical response of C, Y is hump-shaped to monetary policy shock.
- Want a model that simultaneously match hump-shaped agg. response to r and iMPC moment



The problem

- Standard model does **not** give hump shaped for C to standard shock
- Does not matter if **shock** is hump shaped or not



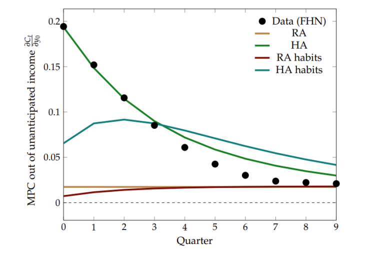
The solution: RANK

- Solution in RANK litterature: Habits in utility function:

$$\sum_{t=0}^{\infty} \beta^t u\left(C_t - \gamma C_{t-1}\right)$$

$$\Rightarrow u'\left(C_t - \gamma C_{t-1}\right) = \beta R_{t+1} u'\left(C_{t+1} - \gamma C_t\right)$$

- Generates persistence in C response to shocks because household don't want to deviate too much from last periods consumption level
- **However**: Does not work in HANK because it kills iMPCs:



Deviations from alternative expectations

- Solution: **Deviate** from **rational expecations** (RE)
- Assume households have imperfect expecations about **changes** in **aggregate variables** (Z, r)
  - Implies that steady state is unaffected
  - Still rational expecations w.r.t idiosyncratic income shocks
- Will only implement this to first-order (e.g. linear approximations)
  - Much more difficult if we want full non-linear solution

Income Jacobian

- Example: Response of aggregate consumption $\boldsymbol{C}$ to change in agg. income $\boldsymbol{Z}$

$$d\boldsymbol{C} = \boldsymbol{M} d\boldsymbol{Z}$$

- where $\boldsymbol{M}$ is jacobian with rational expectations:

$$\boldsymbol{M} = \begin{bmatrix} \frac{\partial C_0}{\partial Z_0} & \frac{\partial C_0}{\partial Z_1} & \frac{\partial C_0}{\partial Z_2} & \cdots \\ \frac{\partial C_1}{\partial Z_0} & \frac{\partial C_1}{\partial Z_1} & \frac{\partial C_1}{\partial Z_2} & \cdots \\ \frac{\partial C_2}{\partial Z_0} & \frac{\partial C_2}{\partial Z_1} & \frac{\partial C_2}{\partial Z_2} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

- Note that elements above diagonal are affected by expectations (i.e. they concern the **future**)
  - Elements on and below diagonal reflect changes in income **today** or in the **past** (known by HHs)

Expectations matrix

- Introduce expectations matrix $\boldsymbol{E}$:

$$\boldsymbol{E} = \begin{bmatrix} 1 & * & * & * & \cdots \\ 1 & 1 & * & * & \cdots \\ 1 & 1 & 1 & * & \cdots \\ 1 & 1 & 1 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

- Element t, s ($E_{t,s}$) captures average date-t exp. about shock to Z at date s.
  - $E_{t,s} dZ_s$ is then the expected value of dZ_s at date t
  - First column: Exp. of HHs at all dates w.r.t dZ_0
  - Second column: Exp. of HHs at all dates w.r.t dZ_1...
- How to get jacobian $\hat{\boldsymbol{M}}$ associated with $\boldsymbol{E}$?

Stylized Example I

- Expectations matrix:

$$\boldsymbol{E} = \begin{bmatrix} 1 & 0.4 & 0.3 & \cdots \\ 1 & 1 & 0.6 & \cdots \\ 1 & 1 & 1 & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

- At $t = 0$ expected path of $d\boldsymbol{Z}$ is $\{1 \cdot dZ_0, 0.4 \cdot dZ_1, 0.3 \cdot dZ_2\}$
- At $t = 1$ expected path of $d\boldsymbol{Z}$ is $\{1 \cdot dZ_0, 1 \cdot dZ_1, 0.6 \cdot dZ_2\}$
- What is response of $\boldsymbol{C}$?
- Period 0 with RE:

$$dC_0 = \frac{\partial C_0}{\partial Z_0} dZ_0 + \frac{\partial C_0}{\partial Z_1} dZ_1 + \frac{\partial C_0}{\partial Z_2} dZ_2 + \dots$$

- With alternative $\boldsymbol{E}$:

$$d\hat{C}_0 = \frac{\partial C_0}{\partial Z_0} dZ_0 + 0.4 \cdot \frac{\partial C_0}{\partial Z_1} dZ_1 + 0.3 \cdot \frac{\partial C_0}{\partial Z_2} dZ_2 + \dots$$

Stylized Example II

- $d\hat{C}_0$ simple to get. What about $d\hat{C}_1$?
- With RE we have:

$$dC_1 = \frac{\partial C_1}{\partial Z_0} dZ_0 + \frac{\partial C_1}{\partial Z_1} dZ_1 + \frac{\partial C_1}{\partial Z_2} dZ_2 + \dots$$

- With Alternative $\boldsymbol{E}$:

$$d\hat{C}_1 = \underbrace{\frac{\partial C_1}{\partial Z_0} dZ_0}_{\text{Past shock}} + \underbrace{0.4 \frac{\partial C_1}{\partial Z_1} dZ_1 + (1-0.4) \frac{\partial C_0}{\partial Z_0} dZ_1}_{\text{Shock "today"}} + \underbrace{0.3 \frac{\partial C_1}{\partial Z_2} dZ_2 + (0.6-0.3) \frac{\partial C_0}{\partial Z_1} dZ_2}_{\text{Future shock}}$$

- Intuition:
  - Past shock: Fully known, so standard effect
  - Present shock: Weighted average of forward looking RE part and »myopic« surprise
  - Future shock: Initial RE part from period 0 (weight: 0.3) and revision of expectations (weight: $0.6 - 0.3$)

General formula

- At first glance seems hard to implement
- ... but we have a general formula to get $\hat{\boldsymbol{M}}$ given $\boldsymbol{E}$
- $\hat{\boldsymbol{M}}$ matrix with expectations matrix $\boldsymbol{E}$:

$$\hat{M}_{t,s} = \sum_{\tau=0}^{\min\{t,s\}} \underbrace{\left(E_{\tau,s} - E_{\tau-1,s}\right) M_{t-\tau,s-\tau}}_{\text{date-}t\text{ effect of date-}\tau\text{ expectation revision of date-}s\text{ shock}}$$

- with $E_{-1,s} = 0$ by convention
- **Fast** and **easy** to implement

Examples

- Examples:

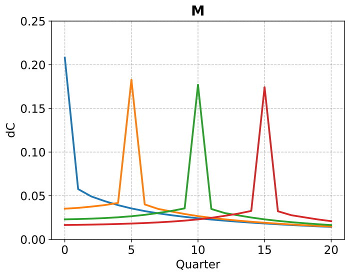
$$\boldsymbol{E}^{\text{RE}} = \begin{bmatrix} 1 & 1 & 1 & 1 & \cdots \\ 1 & 1 & 1 & 1 & \cdots \\ 1 & 1 & 1 & 1 & \cdots \\ 1 & 1 & 1 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}, \qquad \boldsymbol{E}^{\text{Myopic}} = \begin{bmatrix} 1 & 0 & 0 & 0 & \cdots \\ 1 & 1 & 0 & 0 & \cdots \\ 1 & 1 & 1 & 0 & \cdots \\ 1 & 1 & 1 & 1 & \cdots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

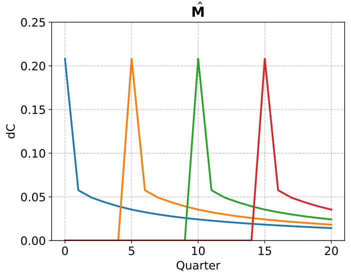
- Two extremes:
  - **Rational** expectations: Households are fully informed about the future path of Z from the moment the shock manifests
  - **Myopic** expectations: Households are not forward looking w.r.t aggregates. Every change in Z is a surprise.
- Implied jacobians:

$$\hat{\boldsymbol{M}}^{\text{RE}} = \boldsymbol{M} = \begin{bmatrix} \frac{\partial C_0}{\partial Z_0} & \frac{\partial C_0}{\partial Z_1} & \frac{\partial C_0}{\partial Z_2} & \cdots \\ \frac{\partial C_1}{\partial Z_0} & \frac{\partial C_1}{\partial Z_1} & \frac{\partial C_1}{\partial Z_2} & \cdots \\ \frac{\partial C_2}{\partial Z_0} & \frac{\partial C_2}{\partial Z_1} & \frac{\partial C_2}{\partial Z_2} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}, \qquad \hat{\boldsymbol{M}}^{\text{Myopic}} = \begin{bmatrix} \frac{\partial C_0}{\partial Z_0} & 0 & 0 & \cdots \\ \frac{\partial C_1}{\partial Z_0} & \frac{\partial C_0}{\partial Z_0} & 0 & \cdots \\ \frac{\partial C_2}{\partial Z_0} & \frac{\partial C_1}{\partial Z_0} & \frac{\partial C_0}{\partial Z_0} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix}$$

Jacobians

- Jacobian of C w.r.t Z





Solving GE with non-RE expecations

- Given some exp. matrix $\boldsymbol{E}$ we can construct alternative jacobians $\hat{\boldsymbol{M}}, \hat{\boldsymbol{M}}_r$
- Solve for GE using these jacobians instead of RE jacobians $\boldsymbol{M}, \boldsymbol{M}_r$ ($\boldsymbol{X}$=shock):

$$\boldsymbol{H}(\boldsymbol{U}, \boldsymbol{X}) = 0 \Rightarrow d\boldsymbol{U} = -\hat{\boldsymbol{H}}_U^{-1} \hat{\boldsymbol{H}}_X d\boldsymbol{X}$$

- In our example:

$$\boldsymbol{Y} - \boldsymbol{C}\left(\boldsymbol{r}, \frac{1}{\mu}\boldsymbol{Y}\right) = 0$$
$$\Rightarrow d\boldsymbol{Y} = \left(\boldsymbol{I} - \frac{1}{\mu}\hat{\boldsymbol{M}}\right)^{-1} \hat{\boldsymbol{M}}_r d\boldsymbol{r}$$

- where $-\hat{\boldsymbol{H}}_U^{-1} = \left(\boldsymbol{I} - \frac{1}{\mu}\hat{\boldsymbol{M}}\right)^{-1}$ and $\hat{\boldsymbol{H}}_X = -\hat{\boldsymbol{M}}_r$

Non-RE expecations in GEModelTools

- How to implement in GEModelTools?
  - Currently no built in way to handle
- Work around (see exercise):
  1. Compute all Jacobians for household block
     - `model._compute_jac_hh()`
     - If using RA/TA instead of HA must manually compute jac
  2. Construct Expectation matrix $\boldsymbol{E}$ and compute $\hat{\boldsymbol{M}}$ by modyfing RE jacobians in `model.jac_hh`
  3. Overwrite jacobians `model.jac_hh` with $\hat{\boldsymbol{M}}$ for each output/input to household block
  4. Compute all Jacobians w.r.t unknowns and shocks, but **not** for household block
     - `model.compute_jacs(skip_hh=True,skip_shocks=False)`
     - GEModelTools will automatically use whatever jacobian is in `model.jac_hh` to construct Jacobians $\boldsymbol{H}_U, \boldsymbol{H}_Z$
  5. Solve for IRFs:
     - `model.find_IRFs(shocks=[x])`

Back to Auclert, Rognlie, Straub (2020) - Sticky expectations

- Auclert, Rognlie, Straub (2020) use **sticky information/expectations** (Mankiw and Reis (2002))
- Only a fraction $1-\theta$ of HHs update their information set about the aggregate economy each period
  - Only learn full path of shock $d\boldsymbol{r}, d\boldsymbol{Z}$ if you update
  - 1. period: $1-\theta$ update and learn full path
  - 2. period: $\theta(1-\theta)$ update, so $1-\theta+\theta(1-\theta)=1-\theta^2$ have full info
- Expectations matrix:

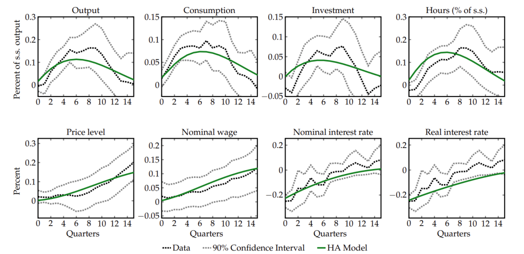
$$\boldsymbol{E}=\begin{pmatrix}1 & 1-\theta & 1-\theta & \dots \\ 1 & 1 & 1-\theta^2 & \dots \\ 1 & 1 & 1 & \dots \\ \vdots & \vdots & \vdots & \ddots\end{pmatrix}$$

Sticky expectations

- Properties:
  - Response of consumption at 0 to Z_1 is $(1-\theta)\frac{\partial C_0}{\partial Z_1}$
  - Response of consumption at 1 to $Z_1$is $(1-\theta)\frac{\partial C_1}{\partial Z_1}+\theta\frac{\partial C_0}{\partial Z_0}$ and so forth
- $\theta=0$ gives us RE, $\theta=1$ gives us myopic behavior.
- Since households perfectly observe income changes **today and in past** iMPCs are preserved
  - **Unlike** habit formation

Estimation

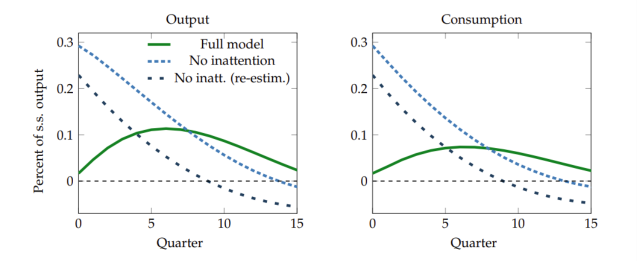
- Auclert, Rognlie, Straub (2020) fomulate full HANK model with:
  - Investment
  - Sticky wages + prices
  - Government
- Estimate parameters to match empirical evidence on causally identified monetary policy shock in the US (Romer & Romer shock)



- Estimate $\theta = 0.935 \Rightarrow$ **Large** deviation from RE

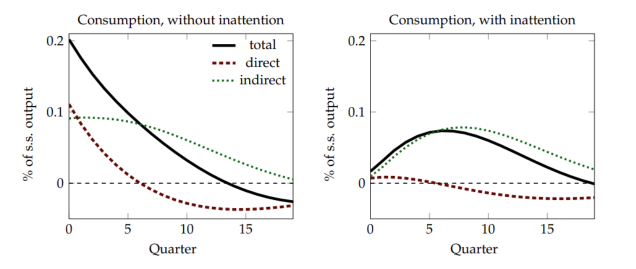
RE vs. Non-RE

- Why we need sticky expectations in order to match empirical response



Direct and indirect effects

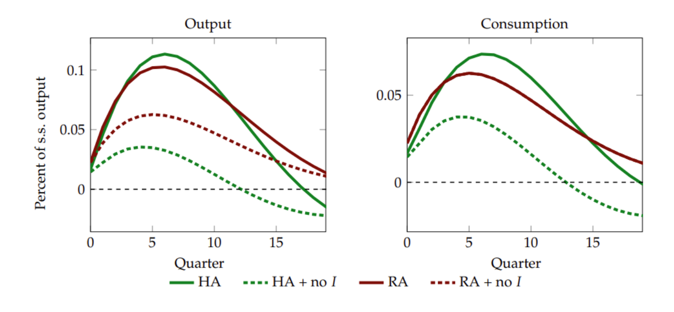
- Can decompose C into direct and indirect as before



- In the estimated model with sticky expectations indirect effect is by far the most important driver of consumption

Importance of Investment

- Importance of indirect effects in HANK partly comes from *investment*



Summing-Up

1. We can use our SSJ machinery to include deviations from RE
2. To do so, we just need define an expectation matrix, and recompute the Jacobian accordingly
3. This allows HANK models to match the observed "hump-shape" in the data

Exercise

Exercise

Consider the HANK model described in section 2

1. Compare a monetary policy shock in HANK and RANK. Decompose the response in HANK into direct and indirect effects using the household Jacobians
2. Solve for a monetary policy shock in HANK and RANK with myopic expectations w.r.t $\boldsymbol{r}$, $\boldsymbol{Z}$,only $\boldsymbol{r}$ and only $\boldsymbol{Z}$
3. Solve for a monetary policy shock in HANK and RANK with sticky expectations w.r.t $\boldsymbol{r}$, $\boldsymbol{Z}$,only $\boldsymbol{r}$ and only $\boldsymbol{Z}$
4. Consider a model where household hold nominal government debt instead. Relax the borrowing constraint to -1, $\underline{a} = -1$ and solve for a monetary policy shock (assume rational expectations). Does the presence of household debt amplify or dampen the effects of monetary policy?

Summary

Summary and next week

- **Today:**
  - Monetary policy in HANK
  - Alternatives to rational expecations, and how to implement them using jacobians
- **Next week:** HANK + unemployment risk in GE (**JD**)
- **Homework:**
  1. Work on exercise