HANK

Heterogeneous Agent New Keynesian Models

Distributional Macroeconomics

Part II of ECON 2149

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Macroeconomic Policy with Distributions

Most macroeconomic policies can be classified as one of

1. Monetary policy

2. Fiscal policy

This lecture: “distributional macro” perspective changes how to think about both of these

Fiscal Policy

- Main differences from rep agent models
  - high MPCs
  - violations of Ricardian equivalence
- Some useful references
  - Kaplan and Violante (2014) "A Model of the Consumption Response to Fiscal Stimulus"
  - Hagedorn, Manovskii and Mitman (2017) "The Fiscal Multiplier"
- These models are already used for actual policy advice
  - Penn Wharton Budget Model `http://budgetmodel.wharton.upenn.edu/`
  - PWBM dynamic OLG $\approx$ lifecycle Aiyagari ("2nd generation")
  - compare `http://budgetmodel.wharton.upenn.edu/dynamic-olg/` with Krueger-Mitman-Perri "Macroeconomics and Household Heterogeneity"
  - Wonder what Trump thinks of heterogeneous agent models? `https://www.whitehouse.gov/articles/issues-penn-wharton-budget-model/` (mostly about other stuff)

HANK: Heterogeneous Agent New Keynesian models

- Combine two workhorses of modern macroeconomics:
  - New Keynesian models Gali, Gertler, Woodford
  - Bewley models Aiyagari, Bewley, Huggett
- Will present Kaplan-Moll-Violante incarnation, but many others
  - see related literature at end of slides
- Framework for quantitative analysis of aggregate shocks and macroeconomic policy
- Three building blocks
  1. Uninsurable idiosyncratic income risk
  2. Nominal price rigidities
  3. Assets with different degrees of liquidity
- Today: Transmission mechanism for conventional monetary policy

How monetary policy works in RANK

- Total consumption response to a drop in real rates

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

- 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

- Once matched to micro data, HANK delivers realistic:
  - wealth distribution: small direct effect
  - MPC distribution: large indirect effect (depending on ΔY)

$$C \text{ response} = \underbrace{\text{direct response to } r}_{\substack{\text{RANK: >95\%} \\ \text{HANK: <1/3}}} + \underbrace{\text{indirect effects due to } Y}_{\substack{\text{RANK: <5\%} \\ \text{HANK: >2/3}}}$$

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

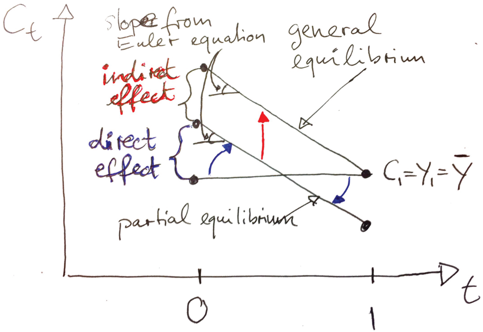
Decomposition into Direct and Indirect Effects

The Decomposition in a Two-Period Model

- Just to understand, consider even simpler two-period model
  - households solve

$$\max_{C_0,C_1} U(C_0) + \beta U(C_1) \quad \text{s.t.} \quad C_0 + \frac{C_0}{1+r} = Y_0 + \frac{Y_1}{1+r}$$

  - market clearing $C_0 = Y_0$, $C_1 = Y_1$; long-run anchoring $Y_1 = \bar{Y}$
  - monetary policy: drop r from $\beta(1+r) = 1$ to $\beta(1+r) < 1$



More General RANK Models

- Paper: simple calibrated version in infinite-horizon RANK model

- Direct effects $> 95\%$

- This result is very general and holds in any model with representative agent's Euler equation at its core

HANK

HANK: a framework for monetary policy analysis

Households

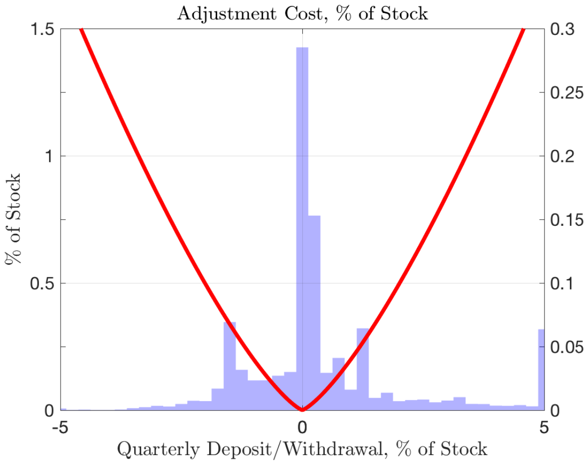
- Face uninsured idiosyncratic labor income risk
- Consume and supply labor
- Hold two assets: liquid and illiquid
- Budget constraints (simplified version)

$$\dot{b}_t = r^b b_t + w z_t \ell_t - c_t - d_t - \chi(d_t, a_t)$$
$$\dot{a}_t = r^a a_t + d_t$$

  - b_t: liquid assets
  - d_t: illiquid deposits ($\gtrless 0$)
  - a_t: illiquid assets
  - χ: 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

Illiquid assets: $a = k + qs$

- No arbitrage: $r^k - \delta = \frac{\Pi + \dot{q}}{q} := r^a$

Firms

- Monopolistic intermediate-good producers $\rightarrow$ final good
- Rent illiquid capital and labor services from hh
- Quadratic price adjustment costs à la Rotemberg (1982)

Government

- Issues liquid debt (B^g), spends (G), taxes and transfers (T)

Monetary Authority

- Sets nominal rate on liquid assets based on a Taylor rule

Summary of market clearing conditions

- Liquid asset market

$$B^h + B^g = 0$$

- Illiquid asset market

$$A = K + q$$

- Labor market

$$N = \int z\ell(a, b, z)d\mu$$

- Goods market:

$$Y = C + I + G + \chi + \Theta + \text{borrowing costs}$$

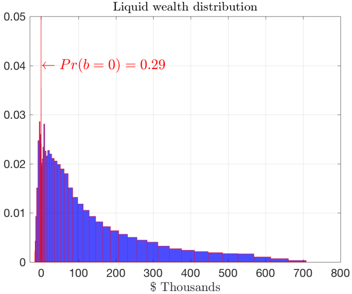
Parameterization

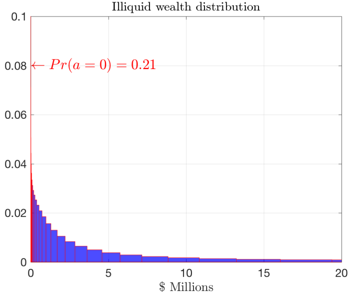
Three key aspects of parameterization

1. Measurement and partition of asset categories into: ▸ 50 shades of K
    - Liquid (cash, bank accounts + government/corporate bonds)
    - Illiquid (equity, housing)
2. Income process with leptokurtic income changes ▸ income process
    - Nature of earnings risk affects household portfolio
3. Adjustment cost function and discount rate ▸ adj cost function
    - Match mean liquid/illiquid wealth and fraction HtM

- Production side: standard calibration of NK models
- Standard separable preferences: $u(c, \ell) = \log c - \frac{1}{2}\ell^2$

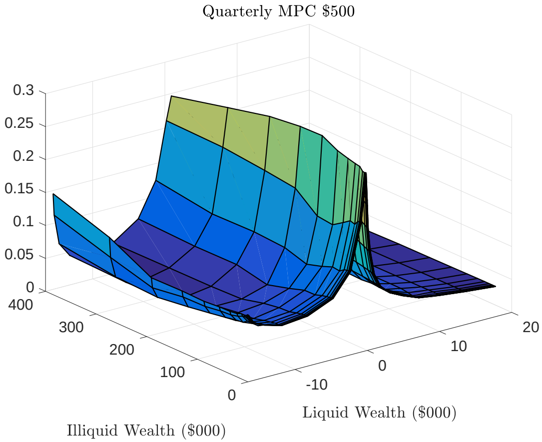
Model matches key feature of U.S. wealth distribution





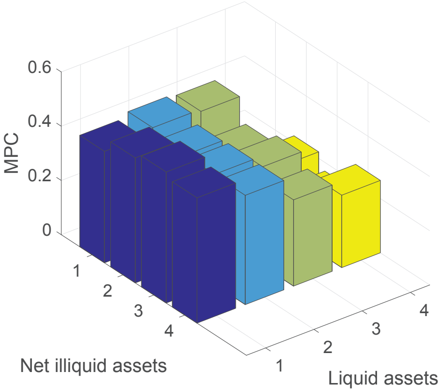
	Data	Model
Mean illiquid assets (rel to GDP)	2.920	2.920
Mean liquid assets (rel to GDP)	0.260	0.263
Poor hand-to-mouth	10%	10%
Wealthy hand-to-mouth	20%	19%

Model generates high and heterogeneous MPCs



- Average quarterly MPC out of a $500 windfall: 16%

Evidende on MPCs – Norwegian Lotteries



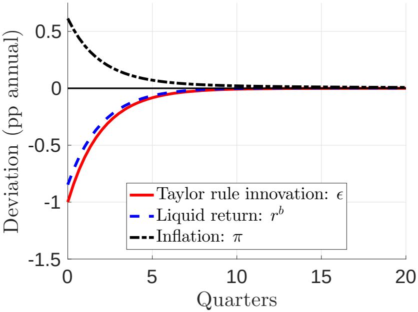
Source: Fagereng, Holm and Natvik (2016)

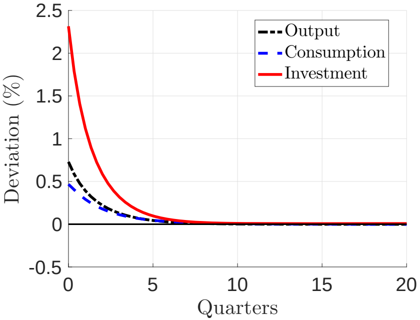
Results

Transmission of monetary policy shock to C

Innovation $\epsilon < 0$ to the Taylor rule: $\quad i = \bar{r}^b + \phi\pi + \epsilon$

- All experiments: $\epsilon_0 = -0.0025$, i.e. -1% annualized





Transmission of monetary policy shock to C

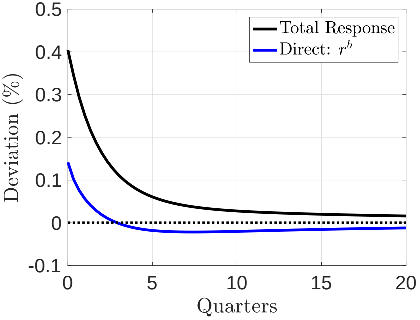
$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{\text{direct}} + \underbrace{\int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt}_{\text{indirect}}$$

Transmission of monetary policy shock to C

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

✓

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

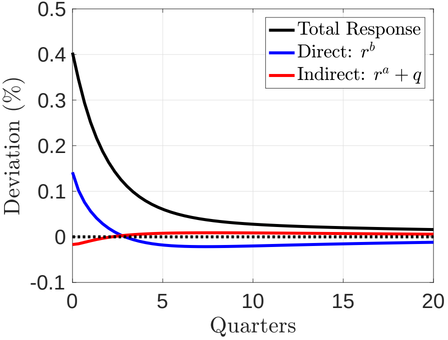


Transmission of monetary policy shock to C

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

$\checkmark$

Portfolio reallocation effect from $r^a - r^b \uparrow$

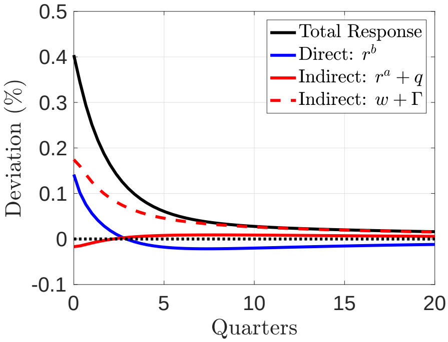


Transmission of monetary policy shock to C

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

$\checkmark$

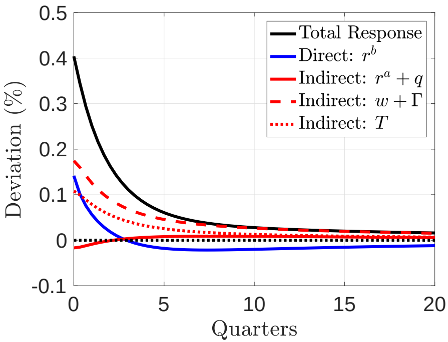
Labor demand channel from $w \uparrow$



Transmission of monetary policy shock to C

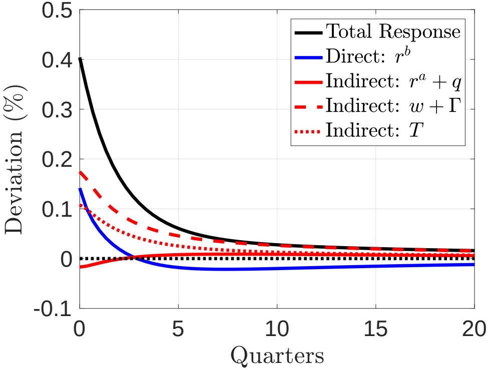
$$dC_0 = \int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt + \int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \underbrace{\frac{\partial C_0}{\partial T_t} dT_t}_{\checkmark} \right] dt$$

Fiscal adjustment: $T \uparrow$ in response to $\downarrow$ in interest payments on B

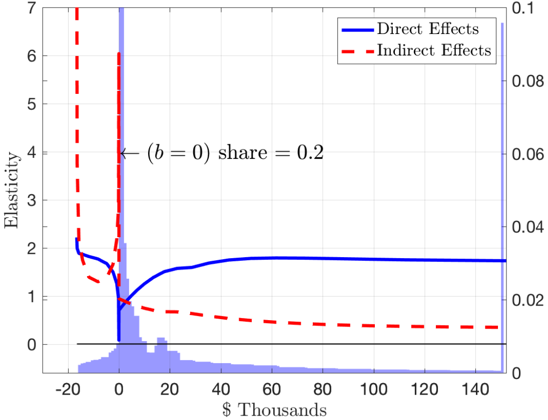


Transmission of monetary policy shock to C

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t^b} dr_t^b dt}_{19\%} + \underbrace{\int_0^\infty \left[\frac{\partial C_0}{\partial r_t^a} dr_t^a + \frac{\partial C_0}{\partial w_t} dw_t + \frac{\partial C_0}{\partial T_t} dT_t \right] dt}_{81\%}$$

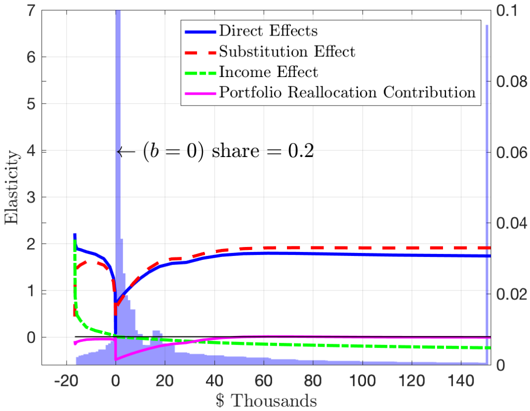


Monetary transmission across liquid wealth distribution



- Total change = c-weighted sum of (direct + indirect) at each b

Why small direct effects?



- Intertemporal substitution: (+) for non-HtM
- Income effect: (-) for rich households
- Portfolio reallocation: (-) for those with low but >0 liquid wealth

Role of fiscal response in determining total effect

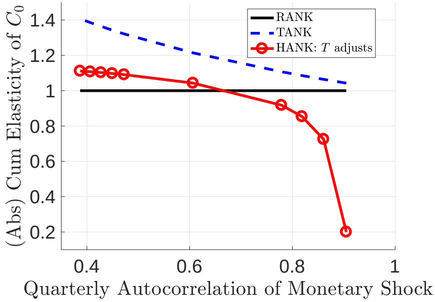
	T adjusts (1)	G adjusts (2)	B^g adjusts (3)
Elasticity of C_0 to r^b	-2.21	-2.07	-1.48
Share of Direct effects:	19%	22%	46%

- 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

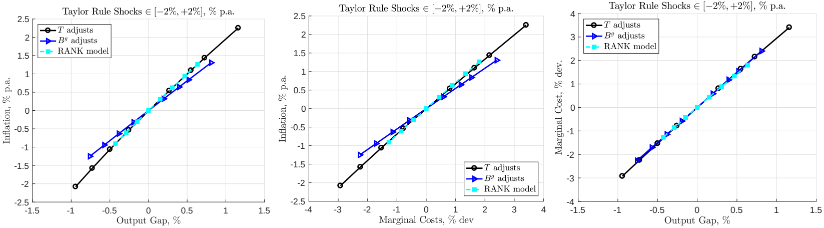
When is HANK $\neq$ RANK? Persistence

- 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 η only matters insofar as it affects R_0

$$-\frac{d \log C_0}{d R_0} = \frac{1}{\gamma} = 1 \quad \textbf{for all } \eta$$

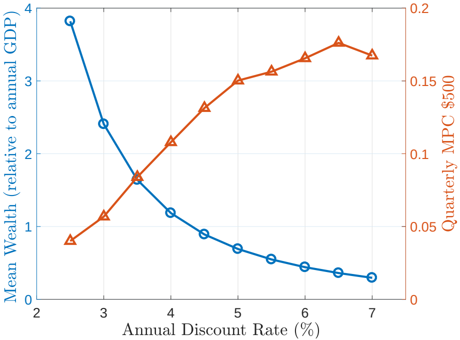


In Contrast, Inflation-Output Tradeoff same as in RANK

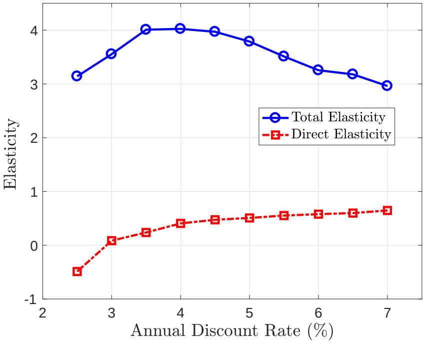


(a) Inflation-Output Gap (b) Inflation-Marginal Cost (c) Marginal Cost-Output

Comparison to One-Asset HANK Model



(d) Average MPC and Wealth-to-GDP Ratio



(e) Total and Direct Effects

Monetary transmission in RANK and HANK

ΔC	$=$	direct response to r	$+$	indirect GE response
		RANK: 95%		RANK: 5%
		HANK: 1/3		HANK: 2/3

- RANK view:
  - High sensitivity of C to r: intertemporal substitution
  - Low sensitivity of C to Y: the RA is a PIH consumer
- HANK view:
  - Low sensitivity to r: income effect of wealthy offsets int. subst.
  - High sensitivity to Y: sizable share of hand-to-mouth agents

$\Rightarrow$ **Q:** Is Central Bank less in control of C than we thought?

- Work in progress: perturbation methods $\Rightarrow$ estimation, inference

HANK's friends (other papers in this literature)

1. New Keynesian models with limited heterogeneity

   Campell-Mankiw, Gali-LopezSalido-Valles, Iacoviello, Bilbiie,

   Challe-Matheron-Ragot-Rubio-Ramirez, Broer-Hansen-Krusell-Öberg

2. Bewley models with sticky prices

   Oh-Reis, Guerrieri-Lorenzoni, Ravn-Sterk, Gornemann-Kuester-Nakajima,

   DenHaan-Rendal-Riegler, Bayer-Luetticke-Pham-Tjaden, McKay-Reis, Wong,

   McKay-Nakamura-Steinsson, Huo-RiosRull, Werning, Luetticke, Auclert, Auclert-Rognlie

- Very useful: Werning's "as if" result. In benchmark HANK model
  - direct and indirect effects exactly offset each other
  - overall effect same as in RA model
  - true even though incomplete markets $\Rightarrow$ smaller direct effects
  - same logic as in spender-saver (TANK) model

$$-\frac{d\log C_0}{dr_0} = \frac{1}{\gamma\eta}\left[\underbrace{(1-\Lambda)\frac{\eta}{\rho+\eta}}_{\text{direct response to } r} + \underbrace{(1-\Lambda)\frac{\rho}{\rho+\eta}+\Lambda}_{\text{indirect effects due to } Y}\right].$$

Open Questions

- Loads left to do! Just see Janet Yellen's speech:

  `http://www.federalreserve.gov/newsevents/speech/yellen20161014a.htm`

  - "the various linkages between heterogeneity and aggregate demand are not yet well understood, either empirically or theoretically."
  - "More broadly, even though the tools of monetary policy are generally not well suited to achieve distributional objectives, it is important for policymakers to understand and monitor the effects of macroeconomic developments on different groups within society."
- Two more or less random examples of great questions:
  1. Does inequality affect level of aggregate consumption/saving?

     some progress in Auclert and Rognlie (2016) "Inequality and Aggregate Demand"
  2. How does housing/mortgages affect monetary transmission?

     some progress in Hedlund-Karahan-Mitman-Ozkan (2016) "Monetary Policy, Heterogeneity and the Housing Channel"
- Particularly useful: empirical evidence but through lens of model

Illiquid return and monopoly profits

- Illiquid assets = part capital, part equity

$$a = k + qs$$

  - k: capital, pays return $r - \delta$
  - s: shares, price q, pay dividends $\omega\Pi = \omega(1-m)Y$

- Arbitrage:

$$\frac{\omega\Pi + \dot{q}}{q} = r - \delta := r^a$$

- Remaining $(1-\omega)\Pi$? Scaled lump-sum transfer to hh's:

$$\Gamma = (1-\omega)\frac{z}{\bar{z}}\Pi$$

- Set $\omega = \alpha \Rightarrow$ neutralize asset redistribution from markups

$$\text{total illiquid flow} = rK + \omega\Pi = \alpha mY + \omega(1-m)Y = \alpha Y$$

$$\text{total liquid flow} = wL + (1-\omega)\Pi = (1-\alpha)Y$$

Monetary Policy in Benchmark NK Models

Goal:

- Introduce decomposition of C response to r change

Setup:

- Prices and wages perfectly rigid $= 1$, GDP=labor $=Y_t$
- Households: CRRA(γ), income Y_t, interest rate r_t

$$\Rightarrow \quad C_t(\{r_s, Y_s\}_{s\geq 0})$$

- Monetary policy: sets time path $\{r_t\}_{t\geq 0}$, special case

$$r_t = \rho + e^{-\eta t}(r_0 - \rho), \quad \eta > 0 \tag{$*$}$$

- Equilibrium: $C_t(\{r_s, Y_s\}_{s\geq 0}) = Y_t$
- Overall effect of monetary policy

$$-\frac{d \log C_0}{d r_0} = \frac{1}{\gamma\eta}$$

Monetary Policy in RANK

- Decompose C response by totally differentiating $C_0(\{r_t, Y_t\}_{t\geq 0})$

$$dC_0 = \underbrace{\int_0^\infty \frac{\partial C_0}{\partial r_t} dr_t dt}_{\text{direct response to } r} + \underbrace{\int_0^\infty \frac{\partial C_0}{\partial Y_t} dY_t dt}_{\text{indirect effects due to } Y} .$$

- In special case $(*)$

$$-\frac{d \log C_0}{dr_0} = \frac{1}{\gamma\eta}\left[\underbrace{\frac{\eta}{\rho+\eta}}_{\text{direct response to } r} + \underbrace{\frac{\rho}{\rho+\eta}}_{\text{indirect effects due to } Y} \right].$$

- Reasonable parameterizations $\Rightarrow$ very small indirect effects, e.g.
    - $\rho = 0.5\%$ quarterly
    - $\eta = 0.5$, i.e. quarterly autocorr $e^{-\eta} = 0.61$

$$\Rightarrow \quad \frac{\eta}{\rho+\eta} = 99\%, \qquad \frac{\rho}{\rho+\eta} = 1\%$$

What if some households are hand-to-mouth?

- "Spender-saver" or Two-Agent New Keynesian (TANK) model
- Fraction Λ are HtM "spenders": $C_t^{sp} = Y_t$
- Decomposition in special case $(*)$

$$-\frac{d \log C_0}{d r_0} = \frac{1}{\gamma \eta} \left[\underbrace{(1-\Lambda)\frac{\eta}{\rho+\eta}}_{\text{direct response to } r} + \underbrace{(1-\Lambda)\frac{\rho}{\rho+\eta} + \Lambda}_{\text{indirect effects due to } Y} \right].$$

- $\Rightarrow$ indirect effects $\approx \Lambda = 20\text{-}30\%$

What if there are assets in positive supply?

- Govt issues debt B to households sector
- Fall in r_t implies a fall in interest payments of $(r_t - \rho)\, B$
- Fraction λ^T of income gains transferred to spenders
- Initial consumption restponse in special case $(*)$

$$-\frac{d \log C_0}{d r_0} = \frac{1}{\gamma\eta} \quad + \quad \underbrace{\frac{\lambda^T}{1-\lambda}\frac{B}{\bar{Y}}}_{\text{fiscal redistribution channel}} \quad .$$

- Interaction between non-Ricardian households and debt in positive net supply matters for overall effect of monetary policy

Fifty shades of K

	Liquid	Illiquid	Total
Non-productive	Household deposits net of revolving debt Corp & Govt bonds $B^h = 0.26$	$0.6\times$ net housing $0.6\times$ net durables $\omega A = 0.79$	1.05
Productive		Indirectly held equity Directly held equity Noncorp bus equity $0.4\times$ housing, durables $(1-\omega)A = 2.13$	2.13 K
Total	$-B^g = 0.26$	$A = 2.92$	3.18

- Quantities are multiples of annual GDP
- Sources: Flow of Funds and SCF 2004

back

Leptokurtic earnings changes (Guvenen et al.)

Key idea: normally distributed jumps = kurtosis at discrete time intervals

Moment	Data	Model	Moment	Data	Model
Variance: annual log earns	0.70	0.70	Frac 1yr change $< 10\%$	0.54	0.56
Variance: 1yr change	0.23	0.23	Frac 1yr change $< 20\%$	0.71	0.67
Variance: 5yr change	0.46	0.46	Frac 1yr change $< 50\%$	0.86	0.85
Kurtosis: 1yr change	17.8	16.5			
Kurtosis: 5yr change	11.6	12.1			

back

Description		Value	Target / Source
Preferences			
λ	Death rate	1/180	Av. lifespan 45 years
γ	Risk aversion	1	
φ	Frisch elasticity (GHH)	1	
ρ	Discount rate (pa)	4.8%	Internally calibrated
Production			
ε	Demand elasticity	10	Profit share 10 %
α	Capital share	0.33	
δ	Depreciation rate (p.a.)	7%	
θ	Price adjustment cost	100	Slope of Phillips curve, $\varepsilon/\theta = 0.1$
Government			
τ	Proportional labor tax	0.25	
T	Lump sum transfer (rel GDP)	\$6,900	6% of GDP
$\bar{g}$	Govt debt to annual GDP	0.233	government budget constraint
Monetary Policy			
ϕ	Taylor rule coefficient	1.25	
r^b	Steady state real liquid return (pa)	2%	
Illiquid Assets			
r^a	Illiquid asset return (pa)	5.7%	Equilibrium outcome
Borrowing			
r^{borr}	Borrowing rate (pa)	7.9%	Internally calibrated
$\underline{b}$	Borrowing limit	\$16,500	$\approx 1\times$ quarterly labor inc
Adjustment Cost Function			
χ_0	Linear term	0.04383	Internally calibrated
χ_1	Coef on convex term	0.95617	Internally calibrated
χ_2	Power on convex term	1.40176	Internally calibrated
$\bar{a}$	Min a in denominator	\$360	Internally calibrated