Lecture 7

Heterogeneity in New Keynesian Models

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EC417

Today: heterogeneity in New Keynesian models

Two parts:

- Simple form of heterogeneity with **complete markets**
  - Extends the model with **wage rigidity** and heterogeneous **utility**
  - Ben Moll would not call this a heterogeneous agent model (and he's right)
- Heterogeneous agent models with **incomplete markets**
  - Two Agent New Keynesian Model (TANK)
  - Heterogeneous Agent New Keynesian Model (HANK)

Model overview

Firms:

- Produce differentiated goods, reset their prices with prob $(1-\theta)$
- Use **differentiated labor** as inputs in production

Households:

- Members with varying disutility of labor, varying **labor specialty**
- **Unions** set the labor-income maximizing wage for each speciality
- Two types of involuntary unemployment:
  - Higher wage reduces employment: **structural unemployment**
  - Sticky **nominal wage** (calvo wage setting): cyclical unemployment

Model overview

- New Keynesian Phillips Curve

$$\pi_t = \kappa_p \tilde{y}_t + \Lambda \tilde{\omega}_t + \beta \mathbb{E}_t \left(\pi_{t+1} \right)$$

- Dynamic IS Equation

$$\tilde{y}_t = \mathbb{E}_t \left(\tilde{y}_{t+1} \right) - \frac{1}{\sigma} \left(i_t - \mathbb{E}_t (\pi_{t+1}) - r_t^n \right)$$

- Wage Phillips Curve

$$\pi_t^w = \beta \mathbb{E}_t \left(\pi_{t+1}^w \right) - \kappa_w \varphi \widehat{u}_t^w$$

  - New: unemployment gap, involuntary

- Monetary policy rule:

$$i_t = \rho + \phi_\pi \pi_t + \phi_y \tilde{y}_t + v_t$$

Firms

Firm faces same market structure as before:

- Produce goods that are CES-aggregated by consumers:

$$Y_{i,t+k|t} = \left(\frac{P_{it}}{P_{t+k}} \right)^{-\varepsilon_p} Y_{t+k}$$

- Are able to update their price with probability $(1 - \theta_p)$. Hence:

$$P_{it}^* = \arg\max_{P_{it}} \sum_{k=0}^{\infty} \theta_p^k \mathbb{E}_t Q_{t,t+k} \left(P_{i,t} Y_{i,t+k} - W_{t+k} L_{t+k} \right)$$

New: labor input is **differentiated**, continuum of types j:

$$L_{it} = \left[\int_0^1 L_{ijt}^{1-\frac{1}{\epsilon_w}} \right]^{\frac{\epsilon_w}{\epsilon_w - 1}} \text{ and } Y_{it} = A_t L_{it}^{1-\alpha}$$

Households

Representative household with heterogeneous members, two dimensions:

- Type of labor specialty (indexed by $j \in [0, 1]$)
- Disutility of labor (indexed by $s \in [0, 1]$)

  $\Rightarrow$ household member represented by coordinate (j,s) on unit square

- Perfect risk sharing within the continuum of household members
  - Identical consumption $\rightarrow$ differs from Aiyagari-Bewley-Huggett (Jane)
- Households face **wage stickiness**
  - Each labor specialty can reset wage at t with probability $(1 - \theta_w)$

Household

Household member's instantaneous utility:

$$U = \left(\frac{C_{jst}^{1-\sigma}}{1-\sigma} - \mathbb{I}_{jst} \chi s^{\varphi} \right) Z_t$$

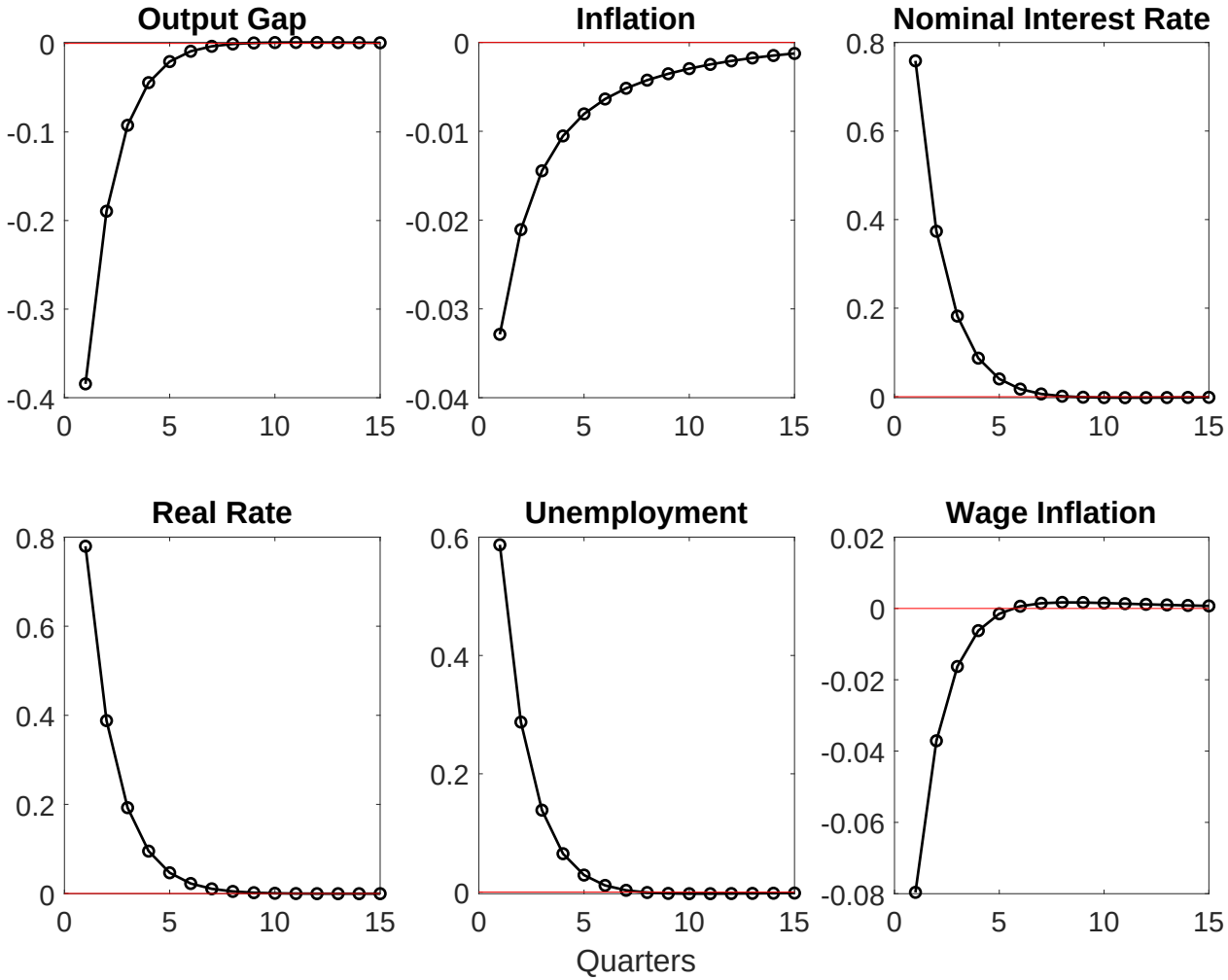
- $\mathbb{I}_{jst}$ is the indicator function for employment participation of j,s
- Risk sharing: $C_{jst} = C_t$ and $B_{jst} = B_t$
- Budget constraint:

$$P_t C_t + Q_t B_t \leq B_{t-1} + \int_0^1 W_{jt} L_{jt} dj + Profits_t$$

- Z_t measures **preference** shocks (steady state =1)

Labor specialty j can only update wage with probability $1 - \theta_w$

Impulse responses: monetary policy shock



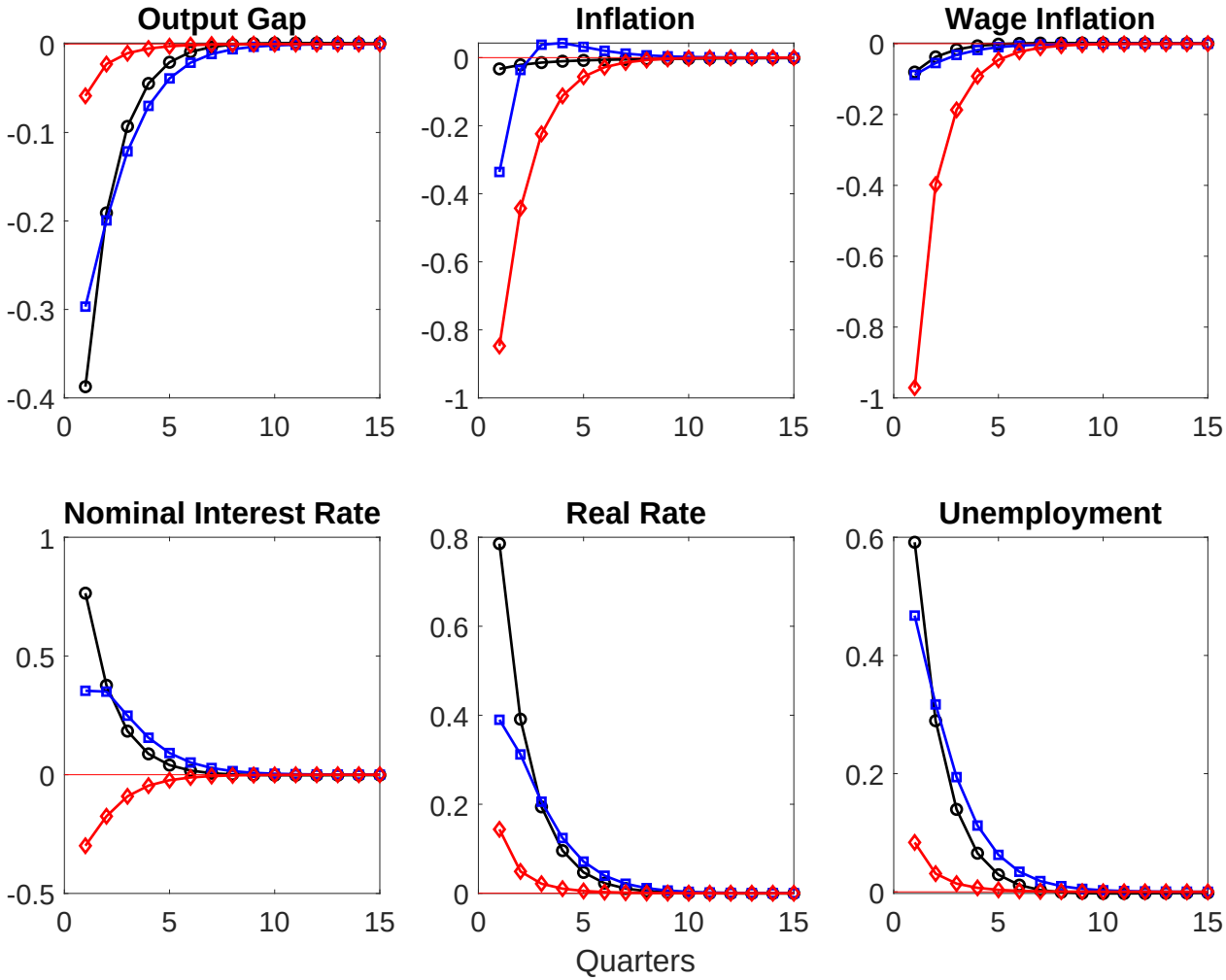
Impulse responses to 25 basis point contractionary monetary policy shock

Baseline calibration, inflation, money growth, interest rates multiplied by 4.

Intuition

- Monetary policy shock raises the nominal interest rate
- Higher interest rate lowers demand
- Inflation does not fall sufficiently: positive output gap
- Lower demand for goods: lower demand for labor
- Wage falls insufficiently: reduction in labor
- Wage still high: labor supply exceeds labor demand: unemployment

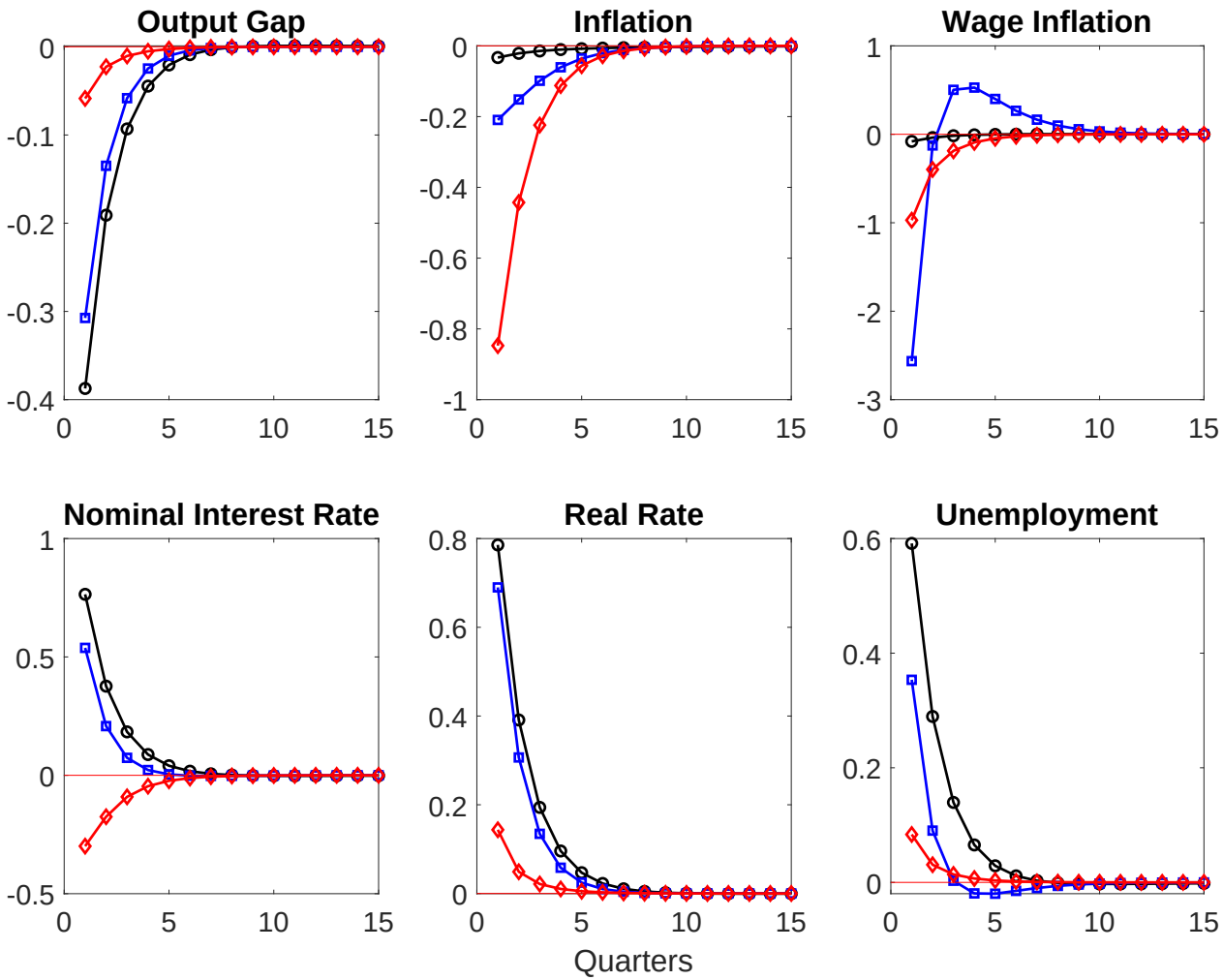
Monetary policy shock - low price rigidity



Impulse responses to 25 basis point contractionary monetary policy shock

Black-circled: baseline. Blue-squared: $\theta_p = 0.1$. Red-diamond: $\theta_p = \theta_w = 0.1$.

Monetary policy shock - low wage rigidity



Impulse responses to 25 basis point contractionary monetary policy shock

Black-circled: baseline. Blue-squared: $\theta_w = 0.1$. Red-diamond: $\theta_p = \theta_w = 0.1$.

Intuition

- Low price or wage rigidity: output gap response quite similar
- Main effect is on resp. price and wage inflation
- The other source of rigidity has large effects on its own:
  - No wage rigidity: sticky prices cause demand reduction (like before), but also reduce need for wage adjustment (real wage)
  - No price rigidity: sticky wages reduce employment, but also reduce need for price adjustment (price is markup over marginal cost)

This term

Part I: Shocking theory of the business cycle

- Introduction to business cycles ✓
- Real Business Cycle (RBC) Model ✓
- New Keynesian DSGE Models ✓

Part II: Perspectives on business cycles and steady states ⇐

- Heterogeneity versus homogeneity and the effect of policy
- Endogenous growth and persistent effects of recessions
- Aggregate shocks? Firm-heterogeneity and the business cycle
- (Interesting steady states: firms, productivity, market power)

DSGE Paradigm

Key features:

1. **Representative** household makes optimal intertemporal decisions $\Leftarrow$
2. Business cycles are **transitory** deviations from the long-term trend
3. Macroeconomic fluctuations are driven by **aggregate** shocks
4. The source of fluctuations are **shocks** (random disturbances)

Heterogeneous versus homogeneous agents

Remember from Jane's part of the course:

- Consumption can be expressed as a function of current income
- Elasticity of consumption w.r.t. current income:
  marginal propensity to consume
- Models with representative, forward looking agents have low MPCs
- Heterogeneous agent models can have higher (data-consistent) MPCs
- High MPCs amplify the real effect of monetary (or fiscal) policy

Today

- A refresher of undergraduate macroeconomics
- New Keynesian Cross in Representative Agent NK-DSGE
- Two Agent New Keynesian Model (TANK)
- Heterogeneous Agent New Keynesian Model (HANK)

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Keynesian cross

(Back to) undergraduate economics:

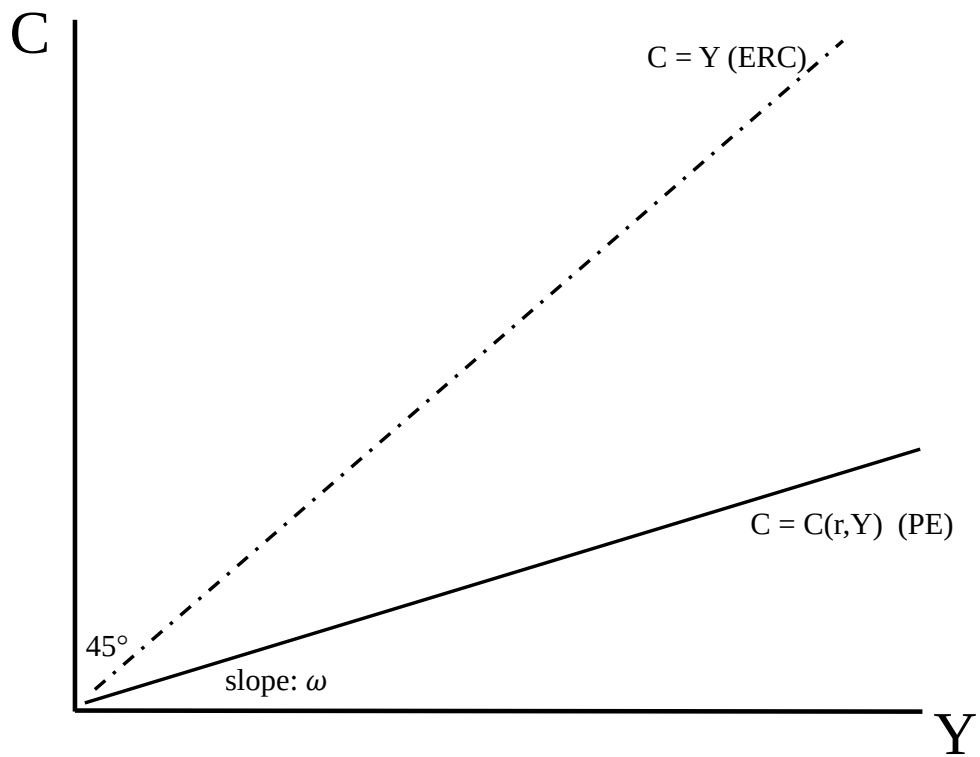
- Assume consumption C depends on: output Y ($\uparrow$), real rate r ($\downarrow$)
- The consumption function $C(Y, r)$ has $0 < C'_Y < 1$ and $C'_r < 0$
- Abstract from aggregate supply, prices are fixed
- Economy's resource constraint (ERC) is $C = Y$
- Effect of a negative shock to the real interest rate:
  - $r \downarrow$ causes $C \uparrow$ which causes $Y \uparrow$
  - Increase in income $Y \uparrow$ causes further $C \uparrow$, causing further $Y \uparrow$
  - Total change in output/consumption: sum of $C'_r(1 + C'_y + C'^2_y +, ..)$

$$\frac{\mathrm{d}C}{\mathrm{d}r} = \underbrace{\frac{C'_r}{1 - C'_y}}_{\textit{multiplier}}$$

Keynesian cross

The Keynesian cross is a graphical representation of this

- Notation: Ω is the multiplier, $\omega = C'_y$, $\Omega_D = C'_r$
- Similar analysis applies to fiscal spending



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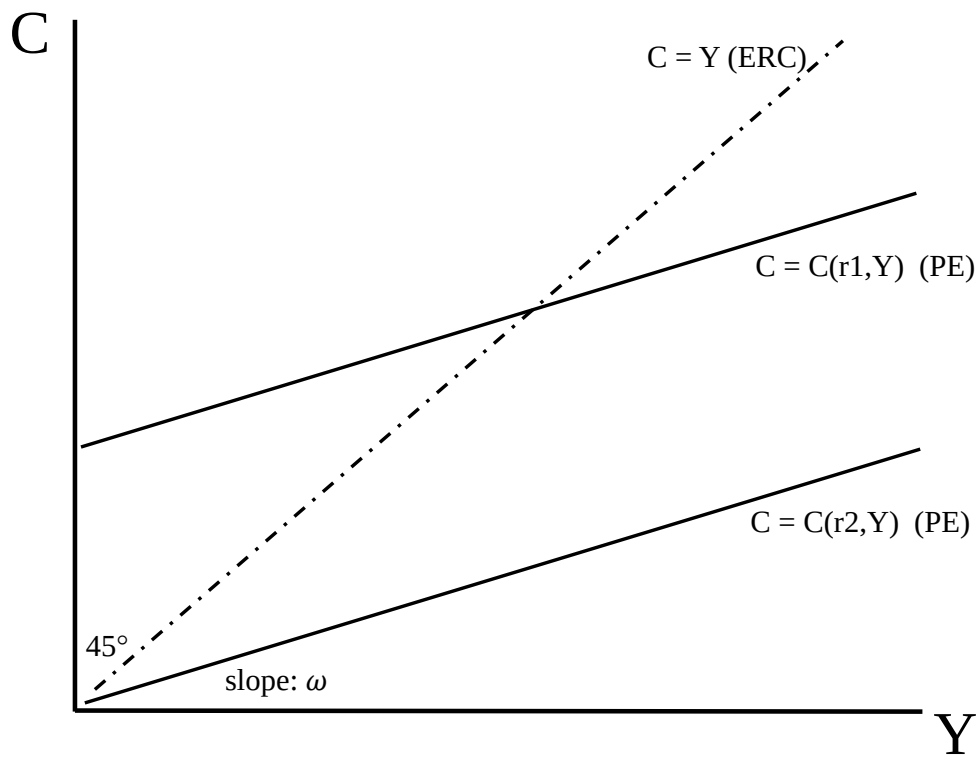

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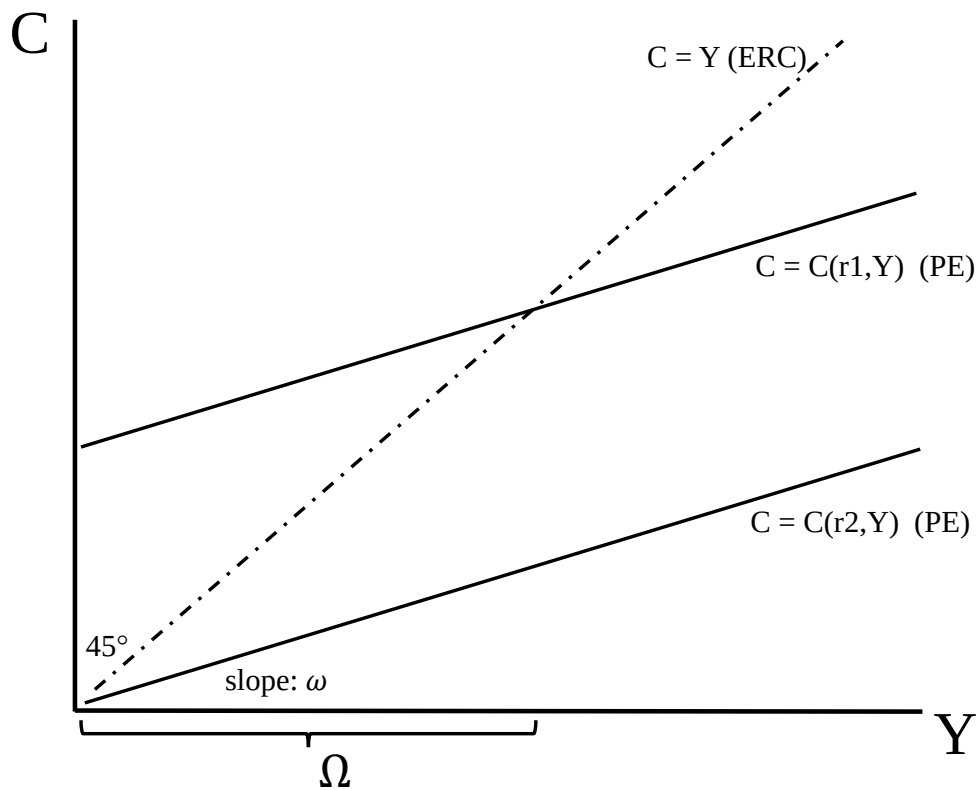

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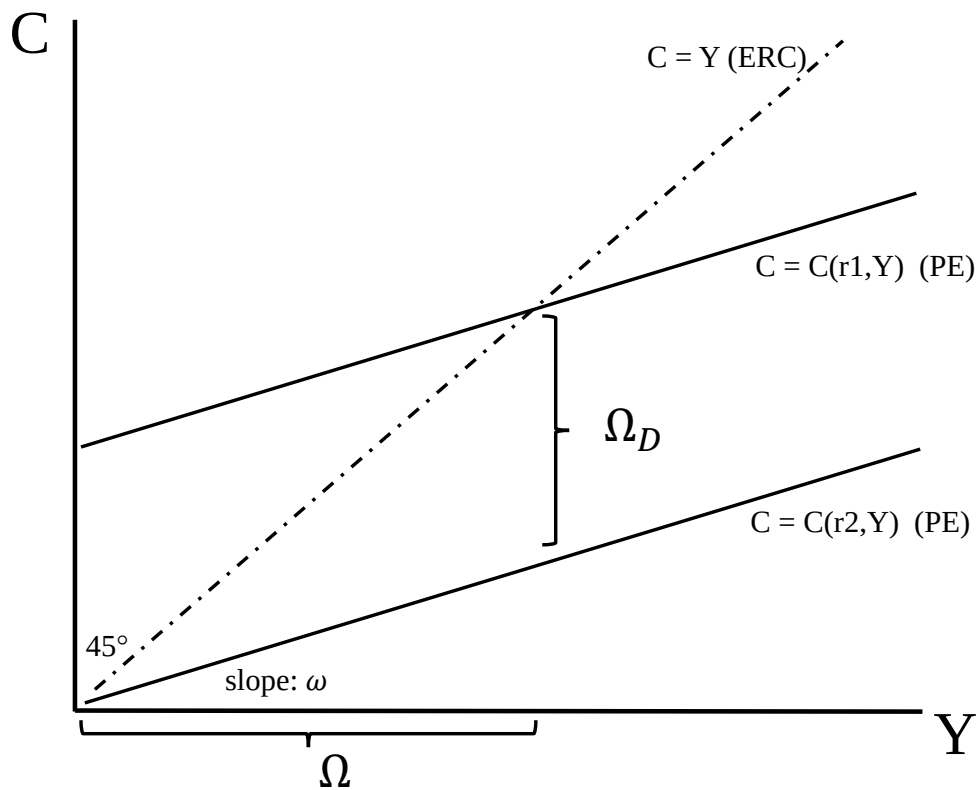


Monetary policy in RANK

How does this look in a conventional New Keynesian model?

- Consumption is optimized intertemporally along the Euler equation:

$$C_t^{-\sigma}{}_t = \beta \mathbb{E}_t \left[Q_t \frac{P_t}{P_{t+1}} C_{t+1}^{-\sigma} \right] = \beta \mathbb{E}_t \left[R_t C_{t+1}^{-\sigma} \right]$$

- Log-linearized:

$$\widehat{c}_t = -\sigma r_t + \mathbb{E}_t[\widehat{c}_{t+1}]$$

- The effect of monetary policy is a **substitution effect**
  - Real interest rate is price of consumption today vs tomorrow
  - Changes to real rate therefore change savings $\Rightarrow$ aggr. demand
  - No **wealth effect** / amplification through Keynesian channel

Monetary policy in RANK

With quite some algebra (see Bilbiie 2020), can show that:

$$c_{jt} = (1-\beta)y_{jt} - \sigma\beta r_t + \beta\mathbb{E}_t c_{jt+1}$$

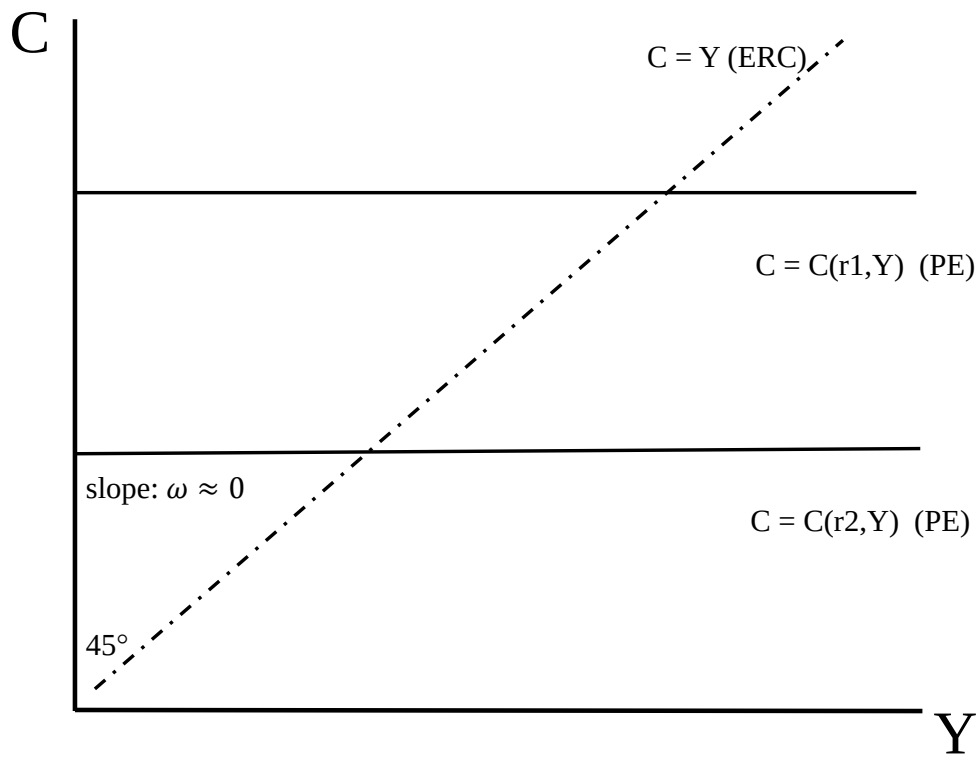
Use exogenous persistence of shocks p, s.t. $\mathbb{E}_t[c_{jt+1}] = pc_{jt}$ (see PS5)

The consumption function can be written as:

$$\begin{aligned} c_{jt} &= (1-\beta)y_{jt} - \sigma\beta r_t + \beta p c_{jt} \\ &= \frac{1-\beta}{1-\beta p} y_{jt} - \frac{\sigma}{1-\beta p}\beta r_t \end{aligned}$$

- For a one-off shock ($p = 0$), the MPC is $1 - \beta \approx 0$

New Keynesian cross



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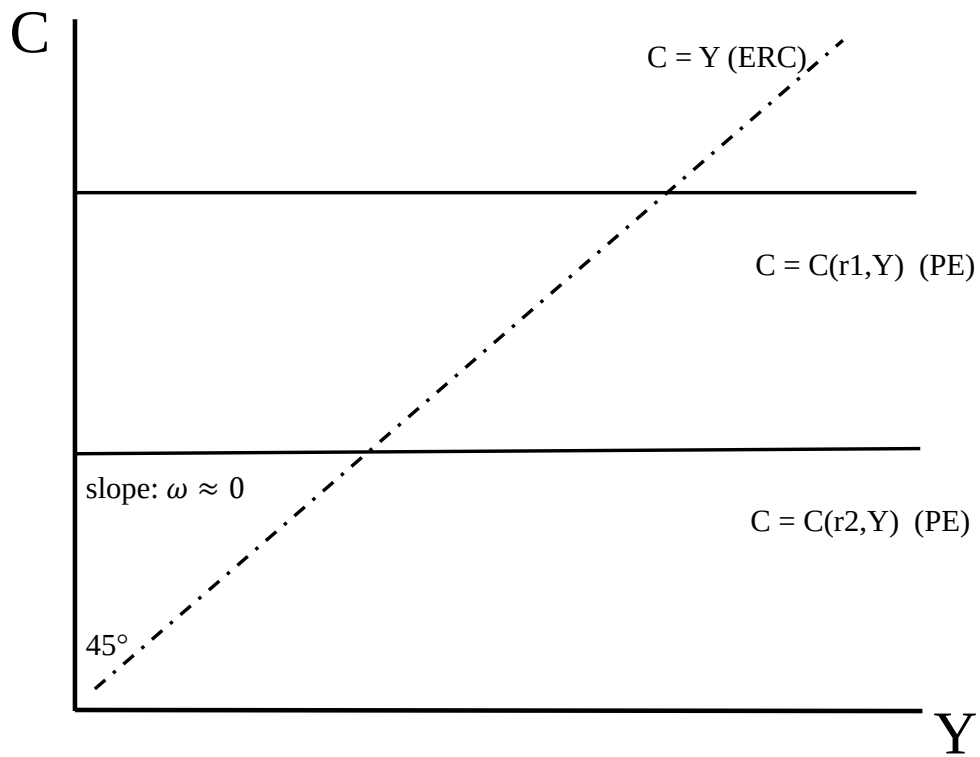

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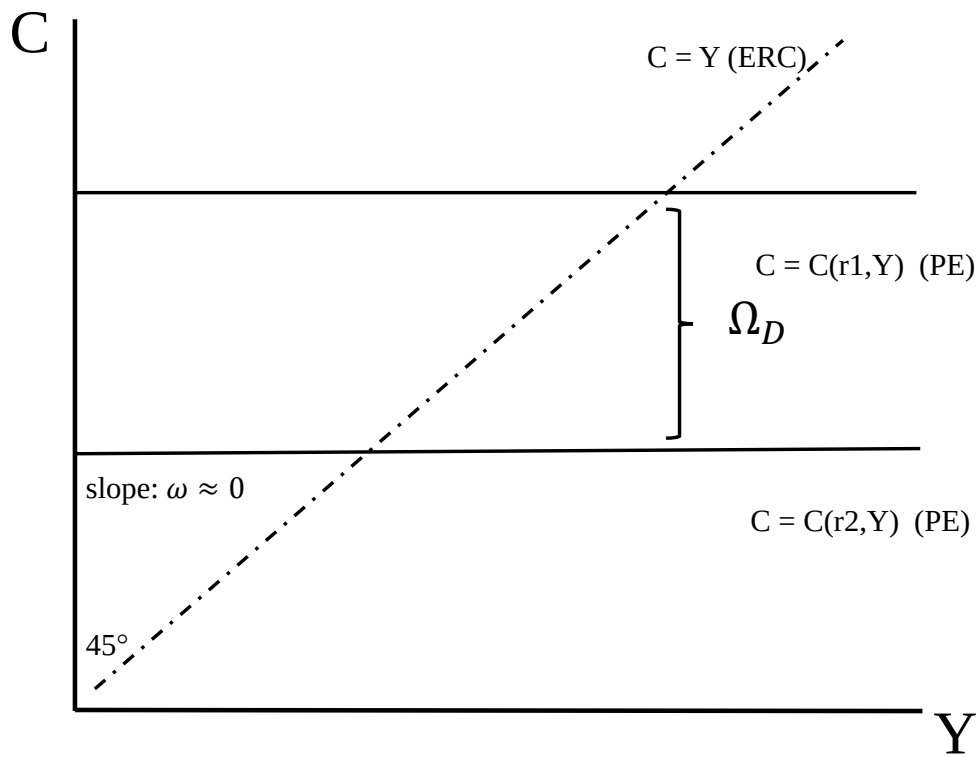

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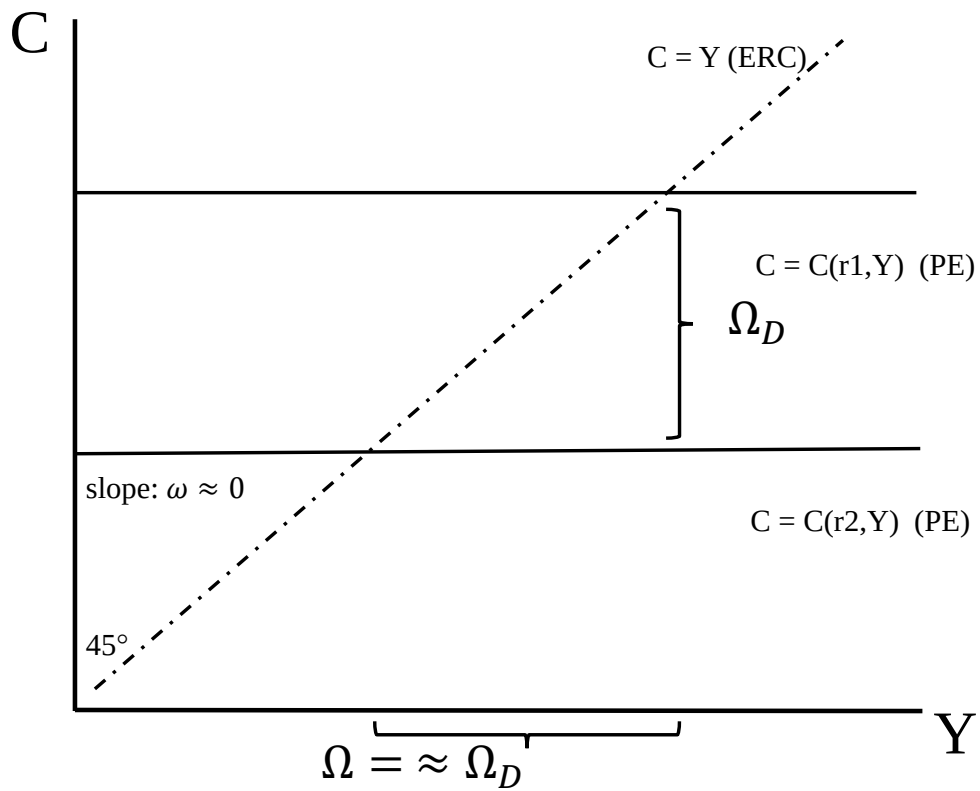

Monetary policy in RANK

Why is the amplification so small?

- Because of the permanent income hypothesis
  - Only changes in permanent income significantly affect consumption
  - Temporary rate shock does not significantly affect lifetime income
  - MPC out of transitory income shocks is tiny
- But consumption change from intertemporal subst. is substantial
  - Kaplan, Moll, Violante: direct effect (intertemporal substitution) drives 90% of consumption response in broad class of NK-DSGE models
- In the data: intertemporal consumption response is **weak**

MPCs in the data

Recent stream of research: estimate MPCs causally

- Quasi-experimental data on effect of transitory income shocks
- Parker et al. (2006, 2013): timing of Bush tax rebates
  - 2001 Bush tax rate retroactive cuts: households sent cheques
  - Sequence based on last 2-digits of social security number (4 mo)
  - Consumer expenditure survey (CEX): questions added on rebate
- Find marginal propensity to consume of 20-40%
- Control group: informed but not received $\Rightarrow$ news about future rebate does not much to consumption, but receipt does!

MPCs in the data

Table 1 Empirical Estimates of the Marginal Propensity to Consume (MPC) out of Transitory Income

	Consumption Measure				
Authors	Nondurables	Durables	Total PCE	Horizon*	Event/Sample
Agarwal and Quian (2013)			0.90	10 Months	Growth Dividend Program Singapore 2011
Blundell, Pistaferri, and Preston (2008)‡	0.05				Estimation Sample: 1980–92
Browning and Collado (2001)			~ 0		Spanish ECPF Data, 1985–95
Coronado, Lupton, and Sheiner (2005)			0.36	1 Year	2003 Tax Cut
Hausman (2012)			0.6–0.75	1 Year	1936 Veterans' Bonus
Hsieh (2003)‡	~ 0		0.6–0.75		CEX, 1980–2001
Jappelli and Pistaferri (2013)	0.48				Italy, 2010
Johnson, Parker, and Souleles (2009)	~ 0.25			3 Months	2003 Child Tax Credit
Lusardi (1996)‡	0.2–0.5				Estimation Sample: 1980–87
Parker (1999)	0.2			3 Months	Estimation Sample: 1980–93
Parker, Souleles, Johnson, and McClelland (2013)	0.12–0.30		0.50–0.90	3 Months	2008 Economic Stimulus
Sahm, Shapiro, and Slemrod (2010)			$\sim 1/3$	1 Year	2008 Economic Stimulus
Shapiro and Slemrod (2009)			$\sim 1/3$	1 Year	2008 Economic Stimulus
Souleles (1999)	0.045–0.09	0.29–0.54	0.34–0.64	3 Months	Estimation Sample: 1980–91
Souleles (2002)	0.6–0.9			1 Year	The Reagan Tax Cuts of the Early 1980s

Notes: *: The horizon for which consumption response is calculated is typically 3 months or 1 year. The papers which estimate consumption response over the horizon of 3 months typically suggest that the response thereafter is only modest, so that the implied cumulative MPC over the full year is not much higher than over the first three months. ‡: elasticity.

Source: Carroll et al. (2017)

MPCs during COVID

Coibion, Gorodnichenko, Weber (2020):

- Effect of CARES $1200 transfers on consumption
- Large scale survey: ask households how they spent transfer
  - 15% responds that they (mostly) spent it
  - 33% mostly saved transfer, 52% paid down debt
  - On average: 40% of transfer spent on consumption

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TANK

Simple way to embed this in the NK-DSGE model: two agents

- Ignore micro found.: **assume** frac. λ hand-to-mouth consumers
- Remaining household fraction $1 - \lambda$ optimize dynamically ("savers")
- Hand-to-mouth households have MPC of 1: $\lambda \approx$ macro MPC
- Firms-side is as in the RANK model with flexible wages:

$$\pi_t = \kappa \tilde{y}_t + \beta \mathbb{E}_t[\pi_{t+1}]$$

Model here: simplified version of Gali, Lopez-Salido and Valles (2007)

Fiscal interaction

In this type of model, monetary policy works through different channels

- Intertemporal substition effect remains, declines in Λ
- Additional indirect effect through **labor income**
  - Transitory increase in employment? Puts money in H-t-M pockets
  - Potency of monetary policy depends on labor market effect
  - RANK: MPC out of such income would be low (hence no effect)
- Additional indirect effect through **fiscal policy**
  - Expansionary monetary policy eases gov. budget constraint
  - Lower taxes? Again additional money in H-t-M pockets

TANK: Saving households

Optimization problem for the dynamically optimizing households:

$$\max_{C_t^s, L_t^s, B_t^s} \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i \left(\frac{(C_{t+i}^s)^{1-\sigma}}{1-\sigma} - \chi \frac{(L_{t+i}^s)^{1+\varphi}}{1+\varphi} \right) \right]$$

$$\text{s.t. } C_t^s = \frac{W_t}{P_t} L_t^s - \frac{Q_t B_t^s - B_{t-1}^s}{P_t} + PR_t^s - T_t^s$$

First order conditions:

$$\frac{W_t}{P_t} = \chi (L_t^s)^{\varphi} (C_t^s)^{\sigma}$$

$$1 = \beta \mathbb{E}_t \left[Q_t \frac{P_t}{P_{t+1}} \frac{{C_{t+1}^s}^{-\sigma}}{C_t^{s\,-\sigma}} \right] = \mathbb{E}_t \left[\underbrace{\lambda_{t,t+1}}_{\text{real SDF}} R_t \right]$$

TANK: Hand-to-mouth households

Optimization problem for the hand-to-mouth households:

$$\max_{C_t^h, L_t^h, B_t^h} \mathbb{E}_t \left[\sum_{i=0}^{\infty} \beta^i \left(\frac{(C_{t+i}^h)^{1-\sigma}}{1-\sigma} - \chi \frac{(L_{t+i}^h)^{1+\varphi}}{1+\varphi} \right) \right]$$

$$\text{s.t. } C_t^h = \frac{W_t}{P_t} L_t^h - T_t^h$$

First order condition:

$$\frac{W_t}{P_t} = \chi (L_t^h)^{\varphi} (C_t^h)^{\sigma}$$

TANK: Household aggregation

Aggregate consumption and employment:

$$\begin{aligned} C_t &= \lambda C_t^h + (1-\lambda) C_t^s \\ L_t &= \lambda L_t^h + (1-\lambda) L_t^s \end{aligned}$$

To simplify aggregation/linearization, assume that in steady state:

$$C^h = C^s = C \quad \text{such that} \quad L^h = L^s = N$$

- (This can be achieved through taxation: T^s vs T^h)

Long-linearize consumption equations (assume $\sigma = 1$):

$$\begin{aligned} \widehat{c}_t^s &= -(\widehat{i} - \mathbb{E}_t[\pi_{t+1}]) + \mathbb{E}_t[\widehat{c}_{t+1}^s]) \\ \widehat{c}_t^h &= \frac{WN}{PC}(\widehat{w}_t - \widehat{p}_t + \widehat{l}_t^h) - \frac{Y}{C}\widehat{t}_t^h \end{aligned}$$

TANK: IS Curve

From the consumption conditions

$$\widehat{c}_t = \mathbb{E}_t[\widehat{c}_{t+1}] - \tilde{\sigma}(\widehat{i} - \mathbb{E}_t[\pi_{t+1}]) - \Omega_n \mathbb{E}_t[\Delta \widehat{n}_{t+1}] + \Omega_g \mathbb{E}_t[\widehat{t}_{t+1}]$$

(requires much algebra: see Gali, Valles and Lopiz-Salido (2007) appendix)

New channels:

- $\tilde{\sigma} = (1-\lambda)\varphi_\sigma \quad \Rightarrow$ intuition: λ diminishes intertemporal sub.
- $\Omega_n = \lambda \varphi_n \quad \Rightarrow$ intuition: $\mathbb{E}_t \Delta \widehat{n}_{t+1} \uparrow$ means $\widehat{n}_t \downarrow$,
  - Hand-to-mouth simply consume labor income (hence increases in λ)
- $\Omega_g = \lambda \varphi_g \quad \Rightarrow$ intuition: $\mathbb{E}_t \Delta \widehat{t}_{t+1} \uparrow$ means $\widehat{t}_t \downarrow$,
  - Hand-to-mouth consume after-tax income (hence increases in λ)
- In RANK the MPC of these last 2 is small (Ω_g, $\Omega_n \to 0$ as $\lambda \to 0$)

Fiscal Policy

Government budget constraint:

$$P_t T_t + B_t Q_t = B_{t-1} + P_t G_t$$

- Government tax $T_t = \lambda T_t^h + (1-\lambda) T_t^s$
- Assume constant government debt and spending is constant
- Lump-sum taxes are adjusted to maintain balanced budget, deviations equal across households:

$$\widehat{t}_t = \widehat{t}_t^h = \widehat{t}_t^s$$

- **Monetary policy will affect taxes**:

$$\widehat{t}_t = \frac{B}{PG} \widehat{i}_t$$

  - Decline in interest rates reduces taxes as cost of borrowing falls
  - Stimulates consumption hand-to-mouth: amplifies consumption

Monetary policy

Assume a simple inflation targeting Taylor rule:

$$i_t = \rho + \phi_\pi \pi_t + v_t$$

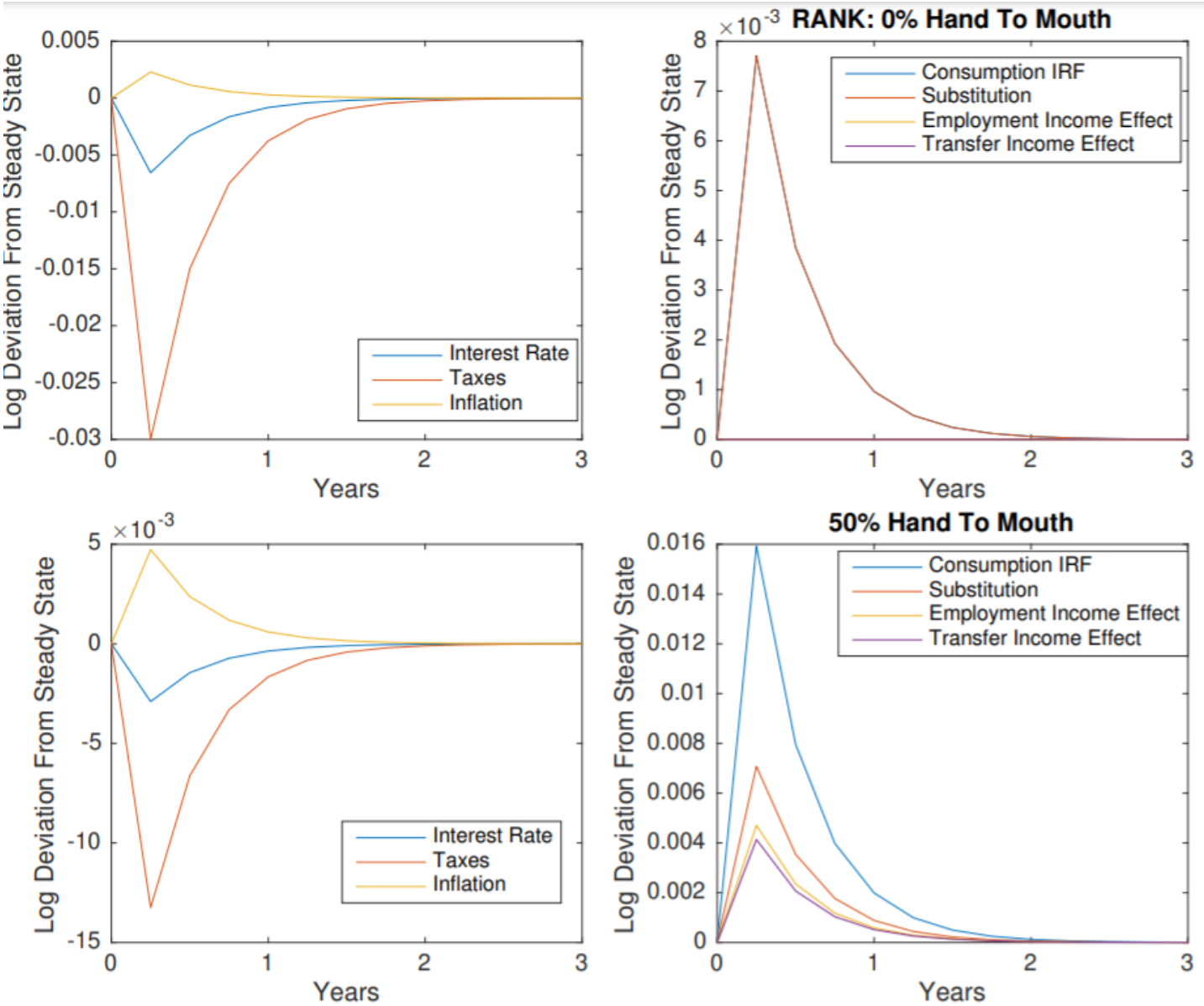
Market clearing condition:

$$Y_t = C_t + G_t$$

Overview

$$
\begin{aligned}
\widehat{c}_t &= \mathbb{E}_t[\widehat{c}_{t+1}] - \tilde{\sigma}(\widehat{i} - \mathbb{E}_t[\pi_{t+1}]) - \Omega_n \mathbb{E}_t[\Delta \widehat{n}_{t+1}] + \Omega_g \mathbb{E}_t[\widehat{t}_{t+1}] \\
\pi_t &= \kappa \tilde{y}_t + \beta \mathbb{E}_t[\pi_{t+1}] \\
\tilde{y} &= \widehat{c} \varphi_c \\
\widehat{t}_t &= (B/GP)\widehat{i}_t \\
\widehat{i}_t &= \phi_\pi \pi_t + \widehat{v}_t \\
\widehat{v}_t &= \rho_v \widehat{v}_{t-1} + \epsilon_t
\end{aligned}
$$

IRF to monetary policy shock



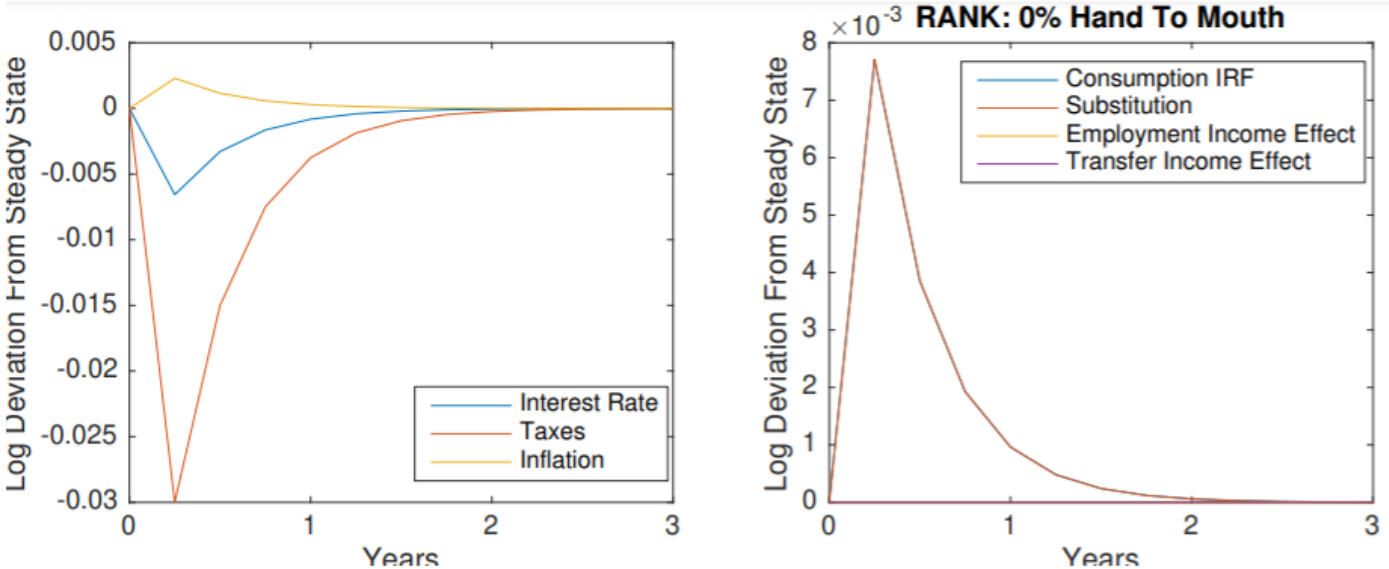
TANK model: effect of shock almost twice as large than substitution effect

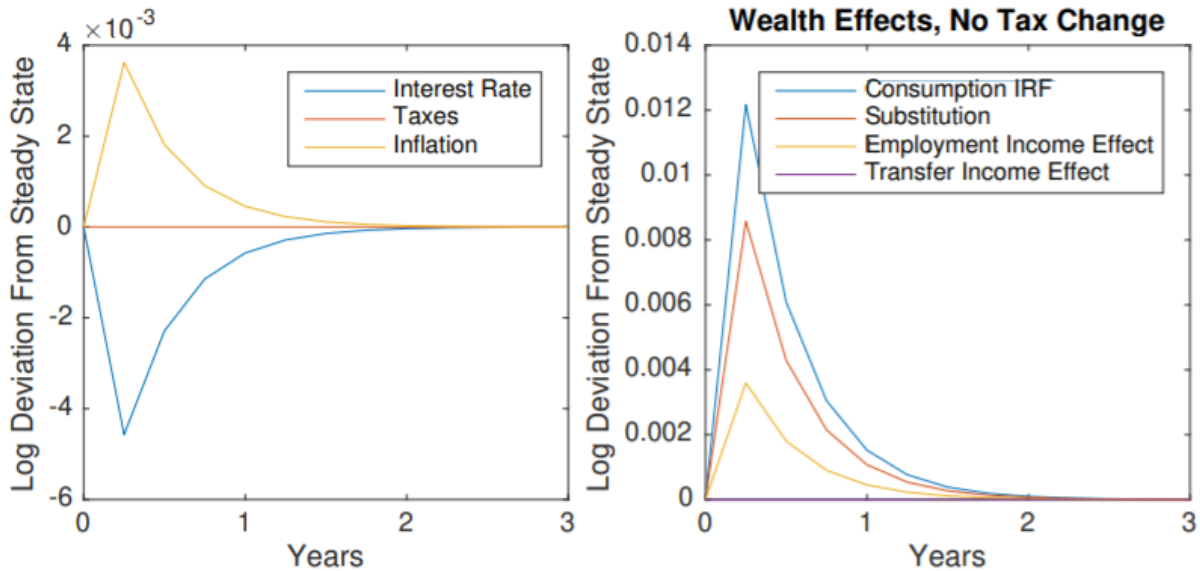
Intuition/summary

Monetary policy shock lowers nominal interest rate

- Substitution effect: optimizing agents increase demand today (Euler)
- Increased demand requires more labor: increases labor income H-t-M
- Government reduces taxation because its borrow costs drop
- Both labor and tax income raises consumption by H-t-M
  - Optimizing household has almost no response to increase in income
- Overall monetary policy effect about twice as large when $\lambda = 0.50$

IRF to monetary policy shock, no fiscal interaction





Constant tax: substitution effect more important, still amplification

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How to micro-found higher MPC?

Deviations from the PIH can be obtained with two ingredients:

- Precautionary savings
  - Uncertainty induces households to save for bad states
  - Standard derivation of PIH: removed through quadratic utility
- Liquidity constraints
  - If constraint binds: act as hand-to-mouth consumer
  - Constraint households don't obey RANK Euler equation
- With **idiosyncratic income risk**:
  - Households accumulate buffer to insure against shocks that push them to borrowing constraint
  - Low asset holders: look like hand to mouth because strong precautionary motive. High asset holders: close to PIH behavior

Problem: not high enough MPC

Idiosyncratic risk is important

- Greater than aggregate risk, so high precautionary savings
- But with realistic calibration, agents **out save** their constraints
- Only hand-to-mouth are the young and those with recent large shock
- Overall: 10% hand-to-mouth. Gives MPC below empirical evidence

Wealthy hand to mouth

Kaplan and Violante (2014): introduce the **wealthy hand-to-mouth**

- Empirical observation: high-wealth households have **illiquid assets**
  - Housing equity, but simultaneously credit card debt etc.
  - Survey of consumer finances: 10% poor hand-to-mouth
  - As well as 7-26% wealthy hand-to-mouth (depending on def. illiquid)
- Hence, sum of all hand-to-mouth agents can create realistic MPCs

Wealthy hand to mouth

Kaplan, Moll, Violante (2018):

- Model with realistically calibrated idiosyncratic risk
- Endogenous (through precautionary savings, borrowing constraints)
- Two assets: high return asset (illiquid) and low return asset (liquid)
- Wealthy households afraid of facing illiquidity constraint: mutes intertemporal substitution, amplifies indict channels

Takeaways:

- Adding idiosyncratic income risk allows realistic MPCs in NK-DSGE
- This can amplify effect of monetary policy and creates new transmission channels & fiscal policy interactions

Optional references

Bilbiie (2020), *The New Keynesian Cross*, Journal of Monetary Economics

Gali, Lopez-Salido, Valles (2007), *Understanding the Effects of Government Spending on Consumption*, Journal of the European Economic Association

Kaplan, Moll, Violante (2018), *Monetary Policy According to HANK*, American Economic Review

What have we done?

- Revised the Keynesian Cross from undergrad, in NK-DSGE ✓
- Analysed a two-agent New Keynesian model (TANK) ✓
- Looked at mechanisms and new interactions in HANK models ✓