# Should monetary policy care about redistribution? Optimal fiscal and monetary policy with heterogeneous agents

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# Introduction

- Monetary policy generates redistributive effects through various channels. (Bewley, 1983; McKay et al. 2016; Gornemann et al. 2016; Kaplan et al. 2018; Nuño and Moll 2018; Auclert 2019)
- Research question: Should monetary policy care about redistribution or only focus on monetary objectives (and leave redistribution to fiscal policy)?
- What we do:
  - Compute optimal fiscal and monetary Ramsey policy with commitment in a quantitative HANK model (het-agent (HA) economy with capital, aggregate shocks and nominal rigidities).
  - **Fiscal policy**: linear labor and capital taxes, lump-sum transfer and one-period nominal public debt.
  - **Monetary policy**: nominal interest rate.

# How we do it

Computing Ramsey policies in HANK is challenging. We do so thanks to a methodological contribution.

- Extensive use of the Lagrangian approach (Marcet and Marimon, 2019). Well adapted for HANK model.
- **Not enough**. To quantify, we derive a "truncated representation" of het-agent model. (LeGrand and Ragot 2020)
- Allows for simple and accurate quantitative investigation.

# Results' preview

- **Theoretical results.**
  - Irrelevance result: No redistributive role for monetary policy when linear capital and labor taxes are available, for both TFP shock and public spending shock. (in the spirit of Correia, Nicolini, Teles 2008; and Correia et al. 2013)
- **Quantitative results.**
  1. **Fiscal policy**: Heterogeneity matters. Optimal capital tax is much less volatile in HA economy compared to RA, public debt is more volatile.
  2. **Monetary policy**: Even with incomplete fiscal tools (no optimal capital tax), inflation has little role to play for redistribution.
- Different from Bhandari, Evans, Golosov and Sargent (2020). Explanation below...

Literature

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# Outline of the presentation

1. The environment
2. Optimal fiscal-monetary policy
3. Truncated representation
4. Numerical Simulations

# 1 - The environment- Preferences

- Unit mass of agents facing uninsurable productivity risk
- Idiosyncratic productivity levels $y \in \mathcal{Y}$: constant discrete first-order Markov process.
- Aggregate state $Z_t$ that affects TFP. First-order Markov process.
- GHH utility function over consumption and labor supply:

$$U(c,l) = u\left(c - \chi^{-1}\frac{l^{1+1/\varphi}}{1+1/\varphi}\right).$$

# Program

$$\max_{\left(a_t^i, c_t^i, l_t^i\right)_{t\geq 0}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t^i, l_t^i),$$

$$c_t^i + a_t^i = (1 + r_t)a_{t-1}^i + w_t y_t^i l_t^i + T_t$$

$$a_t^i \geq -\bar{a}(= 0),\ c_t^i > 0,\ l_t^i > 0$$

where,

- Labor tax: $w_t = (1 - \tau_t^L)\tilde{w}_t$
- Capital tax: $r_t = (1 - \tau_t^K)\tilde{r}_t$
- Lumpsum transfer: $T_t$

# Production

Standard NK production sector with capital.

- Aggregator of intermediate goods. Elasticity of substitution $\varepsilon$.
- Intermediary firms production function : $y = Z\tilde{k}^{\alpha}\tilde{l}^{1-\alpha}$.
- Rotemberg adjustment cost, parameter $\kappa$.
- Pricing kernel to price profits $M_t$.
- Generates a Phillips curve ($\Pi_t = \frac{P_t}{P_{t-1}}$),

$$\Pi_t(\Pi_t - 1) = \frac{\varepsilon - 1}{\kappa}(\zeta_t - 1) + \beta \mathbb{E}_t \Pi_{t+1}(\Pi_{t+1} - 1)\frac{Y_{t+1}}{Y_t}\frac{M_{t+1}}{M_t}.$$

# Asset markets

- Three assets:
  - Capital shares with pre-tax tax net rate $\tilde{r}_t^K$.
  - Public debt $B_{t-1}$ with pre-tax gross real rate $\tilde{R}_{t-1}^{B,N}/\Pi_t$, which depends on current inflation.
  - Monopoly rents (taxed away).
- Risk-neutral fund collects capital and public debt and issues claims to agents with rate $\tilde{r}_t$ (and borrowing limits) (Gornemann, Kuester, Nakajima, 2016)

  $\rightarrow$ no actual portfolio choice by agents.

# Government

Has to finance exogenous $G_t$ and transfers $T_t$. Fiscal tools:

- Distorting taxes on capital and labor ($\tau_t^K$ and $\tau_t^L$)
- Public debt issuance $B_t$
- Corporate tax

Market clearing

# 2 - Optimal fiscal-monetary policy

- Aggregate welfare criterion: $\sum_{t=0}^{\infty} \beta^t \int_i \omega_t^i U(c_t^i, l_t^i)\ell(di)$. Additive with weights $(\omega_t^i)$.
- **Ramsey program:** Find fiscal and monetary policy that maximizes aggregate welfare among competitive equilibria. I.e. maximize aggregate welfare subject to all constraints and borrowing limits.
- **Monetary-fiscal instruments**:

$$\left(\tau_t^L, \tau_t^K, T_t, B_t, \tilde{R}_t^{B,N}\right)_{t\geq 0}.$$

See program

# The Lagrangian approach

- Rich framework for normative questions.

→ Rely on Lagrangian approach of Marcet and Marimon (2020): **Factorization of the Lagrangian**. See factorization

- Note: **Slater's condition** raises no problem here (FOCs in our problem = limits of FOCs with infinitely concave penalty functions).
- Two Lagrange multipliers of interest:
  - $\lambda_t^i$: on agents' Euler equation. $\lambda_t^i > 0$ when the planner perceives excess savings.
  - $\mu_t$: on government budget constraint.

# A transformation

Key concept: social valuation of liquidity for agent $i$, denoted by $\psi_t^i$.

$$\psi_t^i \equiv \underbrace{\omega_t^i U_c(c_t^i, l_t^i)}_{\text{Direct effect}} - \underbrace{U_{cc}(c_t^i, l_t^i)\left(\lambda_t^i - (1+r_t)\lambda_{t-1}^i\right)}_{\text{Saving incentives}}$$
$$- \underbrace{\left(\left(\gamma_t - \gamma_{t-1}\right)\Pi_t\left(\Pi_t - 1\right) - \frac{\varepsilon - 1}{\kappa}\gamma_t\left(\zeta_t - 1\right)\right) Y_t \omega_t^i U_{cc}(c_t^i, l_t^i)}_{\text{Change in pricing kernel}}$$

$\rightarrow$ Benefit, from planner's perspective, of transferring an extra unit of consumption to agent $i$.

Related concept: net social valuation.

$$\hat{\psi}_t^i = \psi_t^i - \mu_t.$$

# Real economy $\kappa = 0$ : Ramsey - FOCs

- Euler equation (unconstrained $i$) for $\hat{\psi}^i$

$$\hat{\psi}_t^i = \beta \mathbb{E}_t \left[ (1 + r_{t+1}) \hat{\psi}_{t+1}^i \right].$$

- Capital tax: $\underbrace{\int_i \hat{\psi}_t^i a_{t-1}^i \ell(di)}_{\text{net redistributive effects}} = \underbrace{- \int_i \lambda_{t-1}^i U_c(c_t^i, l_t^i) \ell(di)}_{\text{savings distortions}}.$

- Transfer $T$ : $\underbrace{\int_i \hat{\psi}_t^i \ell(di)}_{\text{net redistributive effects}} = 0.$

- Labor tax: $\underbrace{\int_i \hat{\psi}_t^i y_t^i l_t^i \ell(di)}_{\text{net redistributive effects}} = \underbrace{\varphi \mu_t \left( L_t - (1 - \alpha) \frac{Y_t}{w_t} \right)}_{\text{labor supply distortions}}.$

$\rightarrow$ transparent results thanks to the $\hat{\psi}^i$.

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# Nominal economy with all fiscal tools

## An irrelevance result

With the full menu of fiscal tools, the planner exactly reproduces the real-economy allocation ($\kappa = 0$) and there is no further role for monetary policy.

**Intuition.** There are sufficient independent instruments to cancel the mark-up wedge of firms. Inflation variations are costly, thus $\Pi_t = 1$. (Correia, Nicolini, and Teles, 2008)

**Question.** What happens with missing fiscal instruments?
With fixed $\tau^K$, possible redistributive role for monetary policy. FOCs computed in the paper → need for quantitative investigation.

# 3 - Truncated representation

$$\left\{y_{-\infty}, ..., y_{-N}, y_{-N+1}, .., y_{-1}, y_0\right\} = y^i$$

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$$\{y_{-\infty}, ..., y_{-N} \underset{\Gamma^*}{\underset{\uparrow}{,}} \underbrace{y_{-N+1}, .., y_{-1}, y_0}_{y^N}\} = y^i$$

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$$\{\underbrace{y_{-\infty}, ..., y_{-N}}_{\sim \xi_{y^N}} \underset{\Gamma^*}{\underset{\uparrow}{,}} \underbrace{y_{-N+1}, .., y_{-1}, y_0}_{y^N}\} = y^i$$

# Truncation (cont'd)

Assume that agents having history $y^N$, have period utility (history-specific preference shifters):

$$\xi_{y^N} U(c, l)$$

## Construction of the $\xi$s

The $\xi$s can be constructed such that, at the steady-state:

- Allocations of the truncated equilibrium are averages of Bewley allocations (among agents with same truncated history).

$\rightarrow$ Same steady-state aggregate quantities and prices in both equilibria.

Formulation of a Ramsey program. See program See Algorithm

See LeGrand and Ragot 2020 for convergence properties.

# 4 - Numerical Simulations

The strategy

1. Calibrate a Bewley model with a relevant fiscal system
2. Truncate the model, $N = 5$.
3. Find the $\omega_{y^N}$ such the actual fiscal system is optimal at the *steady-state* (Inverse optimal approach, Bargain and Keane, 2010; Bourguignon and Amadeo, 2015; Heathcote and Tsujiyama, 2017; Chang et al. 2018).
4. Optimal dynamics after TFP shocks and G shocks.
   - HA economy with full set of instruments
   - HA economy with constant capital tax
   - Complete-market economy

| | | |
|---|---|---|
| | **Preference and technology** | |
| $\beta$ | Discount factor | $0.99$ |
| $\alpha$ | Capital share | $0.36$ |
| $\delta$ | Depreciation rate | $0.025$ |
| $\bar{a}$ | Credit limit | $0$ |
| $\chi$ | Scaling param. labor supply | $0.068$ |
| $\varphi$ | Frisch elasticity labor supply | $0.5$ |
| | **Shock process** | |
| $\rho_z$ | Autocorrelation TFP | $0.95$ |
| $\sigma_z$ | Standard deviation TFP shock | $0.31\%$ |
| $\rho_y$ | Autocorrelation idio. income | $0.99$ |
| $\sigma_y$ | Standard dev. idio. income | $14\%$ |
| $Y$ | Number idio. states | $5$ |
| | **Tax system** | |
| $\tau^K$ | Capital tax | $36\%$ |
| $\tau^L$ | Labor tax | $28\%$ |
| $T$ | Transfer over GDP | $8\%$ |
| $B/Y$ | Public debt over yearly GDP | $60\%$ |
| $G/Y$ | Public spending over yearly GDP | $12.4\%$ |
| | **Monetary parameters** | |
| $\kappa$ | Price adjustment cost | $100$ |
| $\varepsilon$ | Elasticity of sub. | $6$ |

We have $5^5 = 3125$ truncated histories.

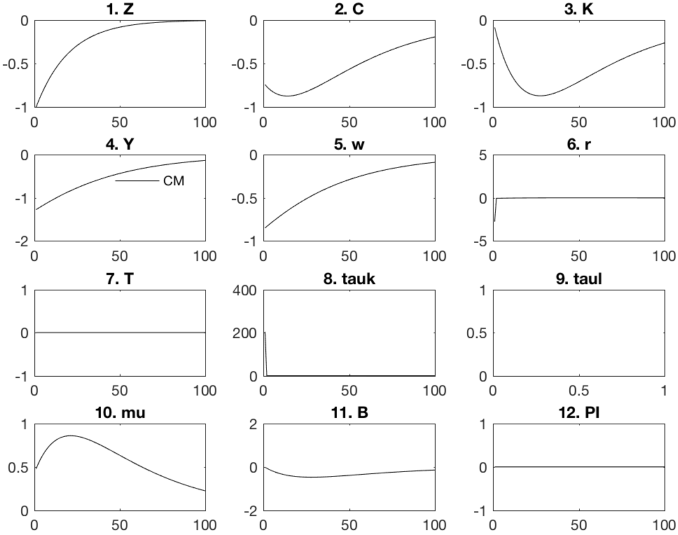
References

# Distribution

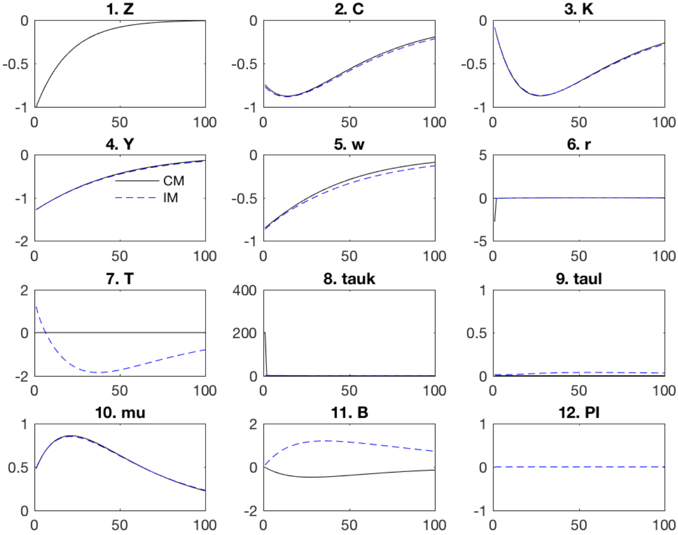
| | Data | | Model |
|---|---|---|---|
| Wealth statistics | PSID, 06 | SCF, 07 | |
| Q1 | $-0.9$ | $-0.2$ | $0.0$ |
| Q2 | $0.8$ | $1.2$ | $0.1$ |
| Q3 | $4.4$ | $4.6$ | $3.5$ |
| Q4 | $13.0$ | $11.9$ | $15.1$ |
| Q5 | $82.7$ | $82.5$ | $81.3$ |
| Top 5% | $36.5$ | $36.4$ | $37.8$ |
| Top 1% | $30.9$ | $33.5$ | $10.7$ |
| Gini | $0.77$ | $0.78$ | $0.77$ |

Pareto weights

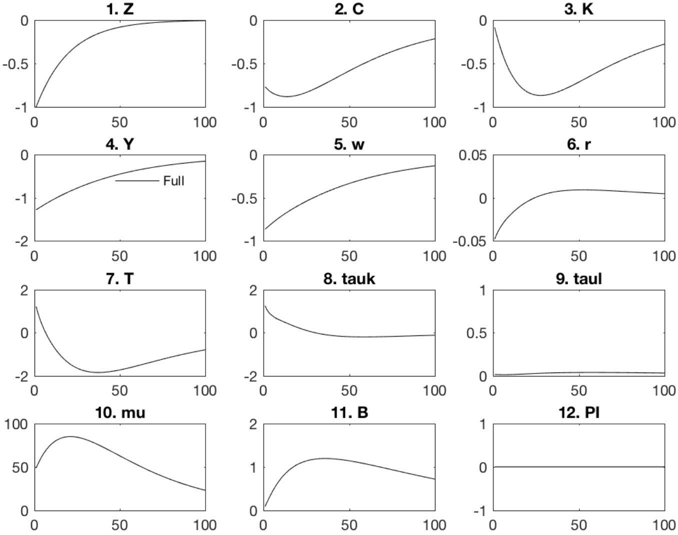
# Complete markets (negative TFP shock)



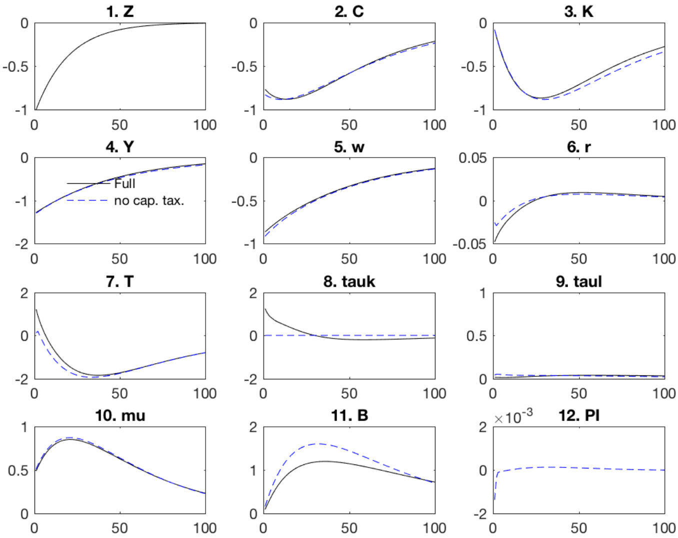
# complete markets vs Full set incomplete markets



# Full-set incomplete-market economy



# Missing capital tax vs. full-set (incomplete markets)



# Second-order moments

| | | CM | Full | No cap.tax |
|---|---|---|---|---|
| $C$ | Mean | 0.7543 | 0.7542 | 0.7542 |
| | Std | 0.0259 | 0.0266 | 0.0269 |
| $K$ | Mean | 11.0557 | 11.0536 | 11.0535 |
| | Std | 0.0268 | 0.0270 | 0.0288 |
| $Y$ | Mean | 1.1760 | 1.1759 | 1.1759 |
| | Std | 0.0264 | 0.0268 | 0.0274 |
| $\tau^K$ | Mean | 0.0009 | 0.3600 | 0.3600 |
| | Std | 0.8855 | 0.0145 | 0.0000 |
| $\tau^L$ | Mean | 0.0000 | 0.2800 | 0.2800 |
| | Std | 0.0000 | 0.0016 | 0.0015 |
| $B$ | Mean | $-10.9327$ | 2.8435 | 2.8424 |
| | Std | 0.0146 | 0.0462 | 0.0541 |
| $T$ | Mean | 0.0000 | 0.0941 | 0.0941 |
| | Std | 0.0000 | 0.0610 | 0.0637 |
| $\pi$ | Mean | 0.0000 | 0.0000 | 0.0000 |
| | Std | 0.0000 | 0.0000 | 0.0007 |
| $corr(\tau^K, Y)$ | | $-0.2085$ | $-0.4868$ | 0.0000 |
| $corr(\tau^L, Y)$ | | 0.9273 | $-0.6374$ | $-0.9249$ |
| $corr(B, Y)$ | | $-0.8349$ | $-0.7592$ | $-0.8291$ |
| $corr(Y, Y_{-1})$ | | 0.9776 | 0.9781 | 0.9785 |
| $corr(B, B_{-1})$ | | 0.9992 | 0.9996 | 0.9994 |

# Discussion

Why is monetary policy so different compared to Bhandari, Evans, Golosov and Sargent (2020)?

- Different setup. Here, capital and occasionally binding credit constraints.
- Different quantitative exercise. Here, perturbation around a steady state. BEGS: transition between an initial and final stochastic distribution.

→ Last channel is the most important. Similar large effects of the capital tax in the transition in Dyrda and Pedroni (2018).

# Robustness checks

- Validation of the truncation method. Comparison with Reiter See here and Boppart, Krusell, Mitman.
- Public spending shock. See here
- Fixed labor tax and fixed labor and capital taxes.
- Solve optimal policy in the transition.

# Conclusion : Main take-aways

1. **Irrelevance result** for the monetary policy when the full set of fiscal tools is available. Confirmed in simulations.
2. **Incomplete markets matter.** Public debt is more volatile and capital tax volatility is reduced by two orders of magnitude.
3. **Importance of public debt.** Even in absence of capital tax, shock is mostly smoothed out by public debt.
4. **Monetary policy.** Even in absence of capital tax, monetary policy plays a very little role (though theoretically possible).

# Literature

Go back

- Interactions between monetary and fiscal policies (no idiosyncratic risk): Chari and Kehoe (1999), Aiyagari, Marcet, Sargent, and Seppälä (2002), Bhandari, Evans, Golosov and Sargent (2017), Correia, Nicolini, and Teles (2008) and Correia, et al. (2013).
- Monetary policy in het-agent economies with nominal frictions: Bilbiie (2008), McKay, Nakamura and Steinsson (2016), Gornemann, Kuester and Nakajima (2017), Kaplan, Moll, and Violante (2018), Nuño and Moll (2018), Auclert (2019).
- Optimal policy in HA model Acikgoz et al. (2018), Dyrda and Pedroni, (2019), LeGrand and Ragot, (2020)
- Closest paper: Bhandari, Evans, Golosov and Sargent (2020).

# Ramsey program formulation

Go back

$$\max_{(w_t, r_t, \tilde{w}_t, \tilde{r}_t^K, \tilde{R}_t^{B,N}, \tau_t^K, \tau_t^L, B_t, K_t, L_t, \Pi_t, (a_t^i, c_t^i, l_t^i)_i)_{t\geq 0}} \mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \int_i \omega_t^i U(c_t^i, l_t^i)\ell(di)\right],$$

$$G_t + B_{t-1} + r_t(B_{t-1} + K_{t-1}) + w_t L_t + T_t = B_t + (1 - \frac{\kappa}{2}\pi_t^2)Y_t - \delta K_{t-1}.$$

for all $i \in \mathcal{I}$: $a_t^i + c_t^i = (1 + r_t)a_{t-1}^i + w_t y_t^i l_t^i + T_t,$

$$a_t^i \geq -\bar{a},$$

$$U_c(c_t^i, l_t^i) = \beta \mathbb{E}_t \left[U_c(c_{t+1}^i, l_{t+1}^i)(1 + r_{t+1})\right] + \nu_t^i,$$

$$l_t^{i,1/\varphi} = \chi w_t y_t^i,$$

$$\Pi_t(\Pi_t - 1) = \frac{\varepsilon - 1}{\kappa}(\zeta_t - 1) + \beta \mathbb{E}_t \Pi_{t+1}(\Pi_{t+1} - 1)\frac{Y_{t+1}}{Y_t}\frac{M_{t+1}}{M_t},$$

$$K_t + B_t = \int_i a_t^i \ell(di),\ L_t = \int_i y_t^i l_t^i \ell(di),$$

$$r_t = (1 - \tau_t^K)\frac{\tilde{r}_t^K K_{t-1} + (\frac{\tilde{R}_{t-1}^{B,N}}{\Pi_t} - 1)B_{t-1}}{K_{t-1} + B_{t-1}}$$

Pricing kernel $M_t = \int_i \omega_t^i U_c(c_t^i, l_t^i)\ell(di)$.

# Factorization

Go back

The objective of the Ramsey program can be rewritten as maximizing:

$$J = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \int_i \Big[\omega_t^i U(c_t^i, l_t^i) - \left(\omega_t^i \lambda_t^i - (1+r_t)\lambda_{t-1}^i \omega_{t-1}^i\right) U_c(c_t^i, l_t^i)$$
$$- \left((\gamma_t - \gamma_{t-1})\Pi_t\left(\Pi_t - 1\right) - \frac{\varepsilon - 1}{\kappa}\gamma_t\left(\zeta_t - 1\right)\right) Y_t M_t\Big] \ell(di),$$

with budget constraints (i.e. no expectations in constraints).

$$G_t + B_{t-1} + r_t(B_{t-1} + K_{t-1}) + w_t L_t + T_t = B_t + (1 - \frac{\kappa}{2}\pi_t^2)Y_t - \delta K_{t-1}.$$

for all $i \in \mathcal{I}$: $a_t^i + c_t^i = (1+r_t)a_{t-1}^i + w_t y_t^i l_t^i + T_t,$

$$a_t^i \geq -\bar{a},$$
$$l_t^{i,1/\varphi} = \chi w_t y_t^i,$$
$$K_t + B_t = \int_i a_t^i \ell(di),\ L_t = \int_i y_t^i l_t^i \ell\left(di\right),$$

# Projected model

Go back

Ramsey problem:

$$\max \mathbb{E}_0 \left[ \sum_{t=0}^{\infty} \beta^t \sum_{y^N \in \mathcal{Y}^N} S_{t,y^N} \omega_{y^N} \xi_{y^N} U(c_{t,y^N}, l_{t,y^N}) \right]$$

subject to individual constraints:

$$\xi_{y^N} U_c(c_{t,y^N}, l_{t,y^N}) = \mathbb{E} \sum_{y^{N'} \in \mathcal{Y}^N} \Pi_{y^N, y^{N'}, t+1} \xi_{y^{N'}} U_c(c_{t+1,y^{N'}}, l_{t+1,y^{N'}}) + \nu_{t,y^N},$$

$$c_{t,y^N} + a_{t,y^N} = w_t l_{t,y^N} y_{y^N} + (1 + r_t)\, \tilde{a}_{t,y^N} + T_t,$$

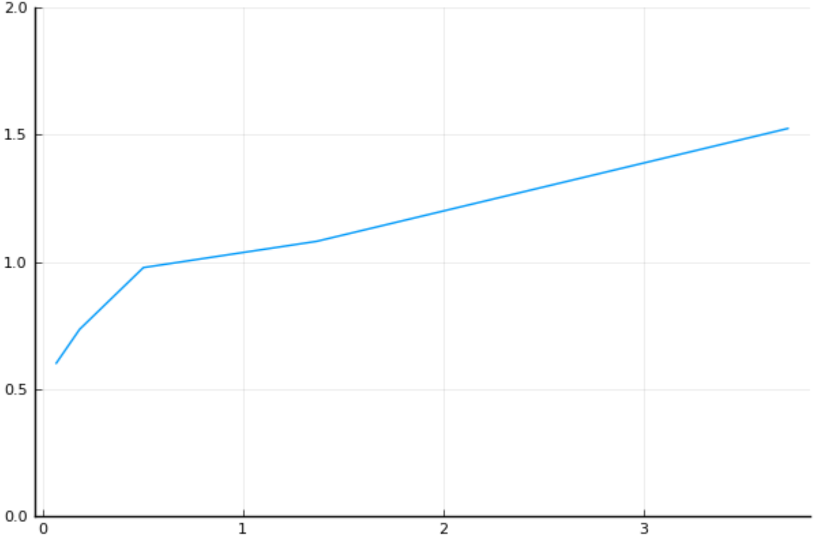
$$\tilde{a}_{t,y^N} = \sum_{\tilde{y}^N \in \mathcal{Y}^N} \Pi_{\tilde{y}^N y^N, t} \frac{S_{t-1,\tilde{y}^N}}{S_{t,y^N}} a_{t-1,\tilde{y}^N},$$

$$l_{t,y^N} = \left(\chi y_{y^N} w_t\right)^{\phi}.$$

$$a_{t,y^N} \geq 0$$

# Pareto weights vs. current productivity

Go back



# Public spending shocks

Go back

| | | CM | Full | No cap.tax |
|---|---|---|---|---|
| $C$ | Mean | 0.7541 | 0.7540 | 0.7540 |
| | Std | 0.0105 | 0.0113 | 0.0129 |
| $K$ | Mean | 11.0541 | 11.0509 | 11.0508 |
| | Std | 0.0082 | 0.0089 | 0.0109 |
| $Y$ | Mean | 1.1758 | 1.1756 | 1.1756 |
| | Std | 0.0037 | 0.0047 | 0.0063 |
| $L$ | Mean | 0.3334 | 0.3333 | 0.3333 |
| | Std | 0.0012 | 0.0023 | 0.0037 |
| $\tau^K$ | Mean | 0.0000 | 0.3600 | 0.3600 |
| | Std | 22.8698 | 0.0780 | 0.0000 |
| $\tau^L$ | Mean | 0.0000 | 0.2800 | 0.2800 |
| | Std | 0.0000 | 0.0017 | 0.0036 |
| $B$ | Mean | -10.9399 | 2.8441 | 2.8436 |
| | Std | 0.0098 | 0.0293 | 0.0543 |
| $T$ | Mean | 0.0000 | 0.0941 | 0.0941 |
| | Std | 0.0000 | 0.0502 | 0.0546 |
| $\pi$ | Mean | 0.0000 | 0.0000 | 0.0000 |
| | Std | 0.0000 | 0.0000 | 0.0027 |

# Comparison Reiter vs Truncation

Go back

| | | Reiter | Trunc |
|---|---|---|---|
| GDP | mean | 1.1757 | 1.1757 |
| | std | 0.0242 | 0.0239 |
| C | mean | 0.7541 | 0.7541 |
| | std | 0.0240 | 0.0240 |
| K | mean | 11.0514 | 11.0510 |
| | std | 0.0265 | 0.0261 |
| L | mean | 0.3333 | 0.3333 |
| | std | 0.0120 | 0.0119 |
| B | mean | 2.8436 | 2.8436 |
| | std | 0.0000 | 0.0000 |
| $\tau^L$ | mean | 0.2800 | 0.2800 |
| | std | 0.0086 | 0.0085 |
| corr(C,Y) | | 0.9784 | 0.9904 |
| corr(K,Y) | | 0.8550 | 0.8484 |
| corr(L,Y) | | 0.9998 | 0.9998 |
| corr(B,Y) | | -0.0000 | 0.0000 |
| corr($\tau^L$,Y) | | -0.9978 | -0.9977 |
| corr(Y,$Y_{-1}$) | | 0.9816 | 0.9812 |

Table: Reiter and Truncation - Constant public debt, labor tax adjust

# Ramsey in the truncated model (cont'd) Go back

**Resolution algorithm** for Ramsey policies in our economy.

1. Solve the "true" Bewley model (i.e., without aggregate shocks) for a given fiscal-monetary policy.
2. Construct the truncated model, and compute the $\xi$s.
3. If *truncated* Ramsey optimality conditions hold, stop. Otherwise, go back to Step 1 with updated policy.

→ Projected model always consistent with a Bewley model.

→ Perturbation computed around a steady state that exists.

# Market clearing

Go back

- Governmental budget constraint (Chamley, 1986)

$$G_t + B_{t-1} + r_t\left(B_{t-1} + K_{t-1}\right) + w_t L_t + T_t = B_t + \left(1 - \frac{\kappa}{2}\pi_t^2\right) Y_t - \delta K_{t-1}.$$

- Financial market clearing:

$$\int a_t^i \ell(di) = K_t + B_t.$$

- Goods market clearing:

$$\int c_t^i \ell(di) + G_t + K_t = Z_t K_{t-1}^{\alpha} L_t^{1-\alpha} + (1-\delta) K_{t-1}$$

- Labor market clearing $L_t = \int_i y_t^i l_t^i \ell\left(di\right)$.

**Equilibrium:** For given prices and fiscal policy, individual allocations solve agents' program; factor prices are consistent with firms' behavior; government budget is balanced; markets clear.

# Calibration

Go back **Standard Calibration** (Period = quarter)

- **Preferences:** Frisch el. labor $\varphi = 0.5$, (Chetty, et al. 2011), $\beta = 0.99$
- **Production:** $Z_t = \exp(z_t)$ with $z_t = \rho_z z_{t-1} + \sigma_z \varepsilon_t^z$. $\rho_z = 0.95$ and $\sigma_z = 0.31\%$, such that std dev. of $z$ is $1\%$ (den Haan, 2010).
- **Productivity risk:** $\log y_t = \rho_y \log y_{t-1} + \sigma_y \varepsilon_t^y$ with $\rho_y = 0.99$ and $\sigma_y = 0.14$. (Krueger et al. 2018).
- **Taxes:** $\tau^K = 36\%$ , $\tau^L = 28\%$, $T/Y = 8\%$. Yields debt-to-GDP $B/Y = 60\%$ and public spending-to-$G/Y = 12.4\%$. (Trabandt and Uhlig, 2011)

→ Gini for wealth = 0.77, average capital-to-GDP = 2.5.

→ Using Rouwenhorst (1995), 5 states with constant transitions.