The Intertemporal Keynesian Cross

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This paper

Q: How does the macroeconomy propagate shocks?

- what micro moments are important?

- Recent literature: **MPCs** are crucial for **PE** effects
  - Idea: for **PE impact response to shocks**, want models to be consistent with evidence on C response to Y
  - Applications: fiscal policy [Kaplan-Violante], monetary policy [Auclert], house prices [Berger et al], …

- In GE, C now and in future affects everyone's Y
  - Here: "**intertemporal MPCs**" (**iMPCs**) are crucial for the **GE impulse response**

Application: When is the fiscal multiplier large?

- Lots of theory + empirical work. Two workhorse models:

1. **Representative-agent (RA)** models
   - **response of monetary policy** is key
   - large when at ZLB

   [Eggertsson 2004; Christiano-Eichenbaum-Rebelo 2011]

2. **Two-agent (TA)** models
   - aggregate **MPC** is key
   - large when deficit financed, effects not persistent

   [Galí-López-Salido-Vallés 2007; Coenen et al 2012; Farhi-Werning 2017]

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New: **Heterogeneous-agent (HA)** models

$\rightarrow$ **iMPCs** are key, can be used for calibration

$\rightarrow$ large and persistent Y effect when deficit financed

Our contribution: Interaction of iMPCs and deficit-financing

1. **Benchmark model,** allows for RA, TA, HA
   - without capital & constant-real-rate monetary policy
   - multiplier $=$ function of **iMPCs** and **deficits** *only*

     $= \mathbf{1}$ if zero deficits or flat iMPCs (RA) [Woodford 2011]

     $> \mathbf{1}$ if **deficit-financed** and **realistic iMPCs** (HA, TA?)

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    - large & persistent Y effects, despite these extra elements
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3. Role of **iMPCs** for the **GE effects of other shocks**
   - Today (not in paper): monetary policy

Outline

1. The intertemporal Keynesian Cross
2. iMPCs in models vs. data
3. Fiscal policy in the benchmark model
4. Fiscal policy in the quantitative model
5. Other shocks

The intertemporal Keynesian Cross

Model overview

- GE, discrete time $t = 0 \ldots \infty$, no aggregate risk (MIT shocks)
- Mass 1 of households:
  - idiosyncratic shocks to skills e_{it}, various market structures
  - real pre-tax income $y_{it} \equiv W_t / P_t e_{it} n_{it}$
  - **after tax income** $z_{it} \equiv y_{it} - T_t(y_{it}) \equiv \tau_t y_{it}^{1-\lambda}$ [Bénabou, HSV]

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  - **government spending** G_t
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- Supply side:
  - linear production function $Y_t = N_t$
  - flexible prices $\Rightarrow$ $P_t = W_t$
  - sticky $W_t \Rightarrow \pi_t^w = \kappa^w \int N_t(v'(n_{it}) - \frac{\partial z_{it}}{\partial n_{it}} u'(c_{it}))di + \beta \pi_{t+1}^w$

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rationing

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- Government sets:
  - **tax revenues** $T_t = \int (y_{it} - z_{it})\, di$ rationing
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  - monetary policy: fixed real rate $= r$
- Supply side: relax later
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Nesting four types of households

Household i solves

$$\max \mathbb{E} \left[\sum \beta^t \left\{ u\left(c_{it}\right) - v\left(n_{it}\right) \right\} \right]$$

$$c_{it} + a_{it} = \left(1 + r\right) a_{it-1} + z_{it}$$

- RA: no risk in e (or complete markets)
- TA: share μ of agents with $c_{it} = z_{it}$
- HA-std: one asset model, with constraint $a_{it} \geq 0$
- HA-illiq: simplified two asset model
    - **illiquid** account a^{illiq} = **fixed** no. of bonds (+ capital)
    - **liquid** account a_{it} = all **remaining** bonds + ra^{illiq}

The aggregate consumption function

▸ Eq definition

- Given $\{a_{i0}\}$ and r, **aggregate consumption function** is

$$C_t = \int c_{it} di = \mathcal{C}_t \left(\{Z_s\}_{s=0}^{\infty} \right)$$

[Farhi Werning 2017, Kaplan Moll Violante 2017, ...]

with $Z_t \equiv$aggregate after-tax labor income

$$Z_t \equiv \int z_{it} di = Y_t - T_t$$

- $\mathcal{C}$ summarizes the heterogeneity and market structure
- Equilibrium defined as usual

Intertemporal MPCs

- An output path $\{Y_t\}_{t=0}^{\infty}$ is part of equilibrium $\Leftrightarrow$

$$Y_t = G_t + \mathcal{C}_t\left(\{Y_s - T_s\}\right) \quad \forall t \geq 0$$

- Impulse response to shock $\{dG_t, dT_t\}$

$$dY_t = dG_t + \sum_{s=0}^{\infty} \underbrace{\frac{\partial \mathcal{C}_t}{\partial Z_s}}_{\equiv M_{t,s}} \cdot (dY_s - dT_s) \tag{1}$$

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$\rightarrow$ Response $\{dY_t\}$ entirely characterized by $\{M_{t,s}\}$!

- *partial equilibrium* derivatives, **"intertemporal MPCs"**
- how much of income change at date s is spent at date t
- $\sum_{t=0}^{\infty}(1+r)^{s-t} M_{t,s} = 1$

The intertemporal Keynesian cross

- Stack objects: $\mathbf{M} = \{M_{t,s}\} = \left\{\frac{\partial \mathcal{C}_t}{\partial Z_s}\right\}$, $d\mathbf{Y} = \{dY_t\}$, etc
- Rewrite equation (1) as

$$d\mathbf{Y} = d\mathbf{G} - \mathbf{M}d\mathbf{T} + \mathbf{M}d\mathbf{Y}$$

- This is an **intertemporal Keynesian cross**
    - entire complexity of model is in **M**
    - with **M** from data, could get $d\mathbf{Y}$ without model simulations!

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- This is an **intertemporal Keynesian cross**
  - entire complexity of model is in $\mathbf{M}$
  - with $\mathbf{M}$ from data, could get $d\mathbf{Y}$ without model simulations!
- When unique, solution is

$$d\mathbf{Y} = \mathcal{M} \cdot (d\mathbf{G} - \mathbf{M}d\mathbf{T})$$

where $\mathcal{M}$ is (essentially) $(I - \mathbf{M})^{-1}$

iMPCs in models vs. data

Measuring aggregate iMPCs using individual iMPCs

- Object of interest: **(aggregate) iMPCs**

$$M_{t,s} = \frac{\partial \mathcal{C}_t}{\partial Z_s}$$

where $C_t = \int c_{it} di$ and $Z_s = \int z_{is} di$

- Direct evidence on $M_{t,s}$ is hard to come by for general s
- More work on column $s = 0$ (unanticipated income shock)
  - Can write

$$M_{t,0} = \int \underbrace{\frac{z_{i0}}{Z_0}}_{\text{income weight}} \cdot \underbrace{\frac{\partial c_{it}}{\partial z_{i0}}}_{\text{individual iMPC}} di$$

$\rightarrow$ aggregate iMPCs are **weighted individual iMPCs**

Obtain date-0 iMPCs from cross-sectional microdata

- Two sources of evidence on $\frac{\partial c_{it}}{\partial z_{i0}}$:

1. Fagereng Holm Natvik (2018) measure in Norwegian data

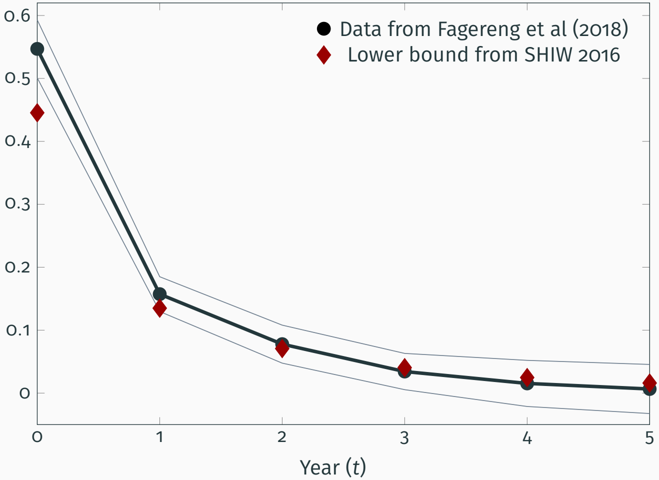
$$c_{it} = \alpha_i + \tau_t + \sum_{k=0}^{5} \gamma_k \text{lottery}_{i,t-k} + \theta x_{it} + \epsilon_{it}$$

   - Weighting by income in year of lottery receipt $\Rightarrow M_{t,0}$

2. Italian survey data (SHIW 2016) on $\frac{\partial c_{i0}}{\partial z_{i0}}$

   - Lower bound for $M_{t,0}$ using distribution of MPCs
   - Example: income-weighted average of $(1 - MPC_i)MPC_i \Rightarrow$ lower bound for $M_{1,0}$

iMPCs in the data



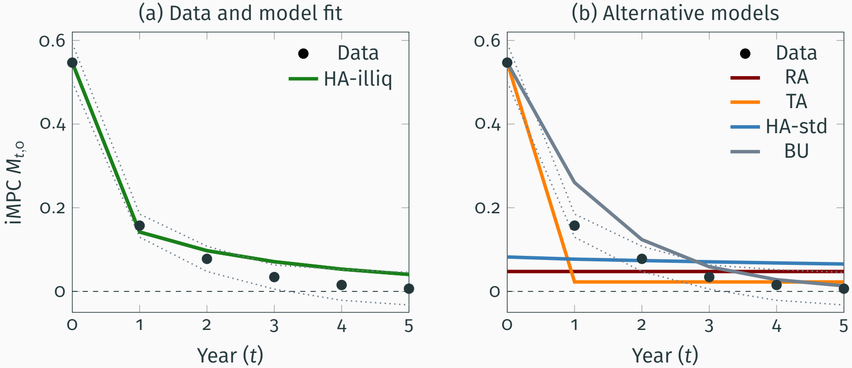
- Annual $M_{0,0}$ consistent with evidence from other sources

Compare iMPCs across models

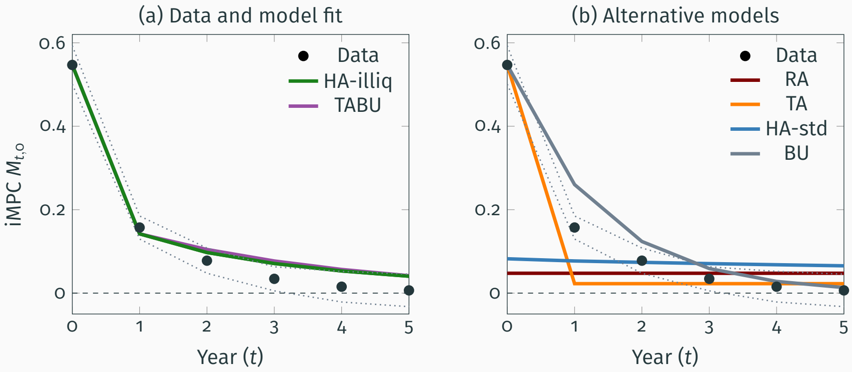
▸ Calibration

- RA
- TA: share of hand-to-mouth calibrated to match $M_{0,0}$
- HA-std: one-asset HA, standard calibration
- **HA-illiq**: two-asset HA calibrated to match $M_{0,0}$
- . . . and for fun:
  - BU: bonds-in-utility model, calibrated to match $M_{0,0}$
    [Michaillat Saez 2018; Hagedorn 2018; Kaplan Violante 2018]

iMPCs across models



iMPCs across models including TABU

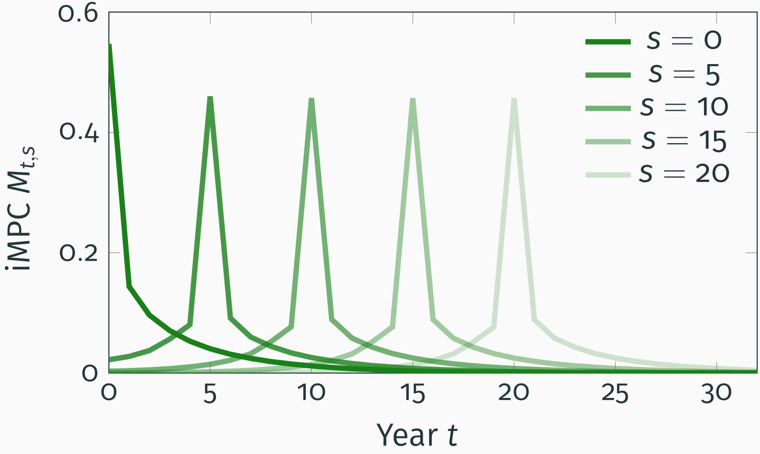


What about non-date-0 iMPCs?

- Existing evidence useful for response to date-0 income shocks, $\{M_{t,0}\}$
- What about response to future shocks?

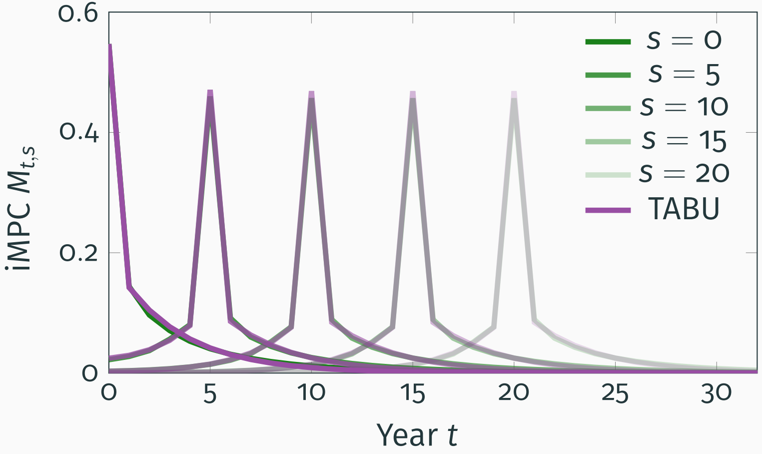
$\rightarrow$ rely on calibrated **HA-illiq** model to fill in the blanks!

Response of HA-illiq to other income shocks



Not entirely arbitrary → TABU is very similar!

▸ Durables



Fiscal policy in the benchmark model

Fiscal policy in the benchmark model

- Recall **intertemporal Keynesian cross:**

$$d\mathbf{Y} = d\mathbf{G} - \mathbf{M} \cdot d\mathbf{T} + \mathbf{M} \cdot d\mathbf{Y}$$

- $d\mathbf{Y}$ entirely determined by iMPCs $\mathbf{M}$ and fiscal policy $(d\mathbf{G}, d\mathbf{T})$

- Next: Characterize role of iMPCs for
  1. balanced budget policies, $d\mathbf{G} = d\mathbf{T}$
  2. deficit-financed policies

The balanced-budget unit multiplier

- With **balanced budget**, $d\mathbf{G} = d\mathbf{T} \Rightarrow$ **multiplier of 1:**

$$d\mathbf{Y} = d\mathbf{G}$$

- Similar reasoning already in Haavelmo (1945)

- Generalizes Woodford's RA results
  - heterogeneity irrelevant for balanced budget fiscal policy
  - similar to Werning (2015)'s result for monetary policy

- Proof: $d\mathbf{Y} = d\mathbf{G}$ is unique solution to

$$d\mathbf{Y} = (I - \mathbf{M}) \cdot d\mathbf{G} + \mathbf{M} \cdot d\mathbf{Y}$$

Deficit-financed fiscal policy

- With deficit financing $d\mathbf{G} \neq d\mathbf{T}$ we have

$$d\mathbf{Y} = d\mathbf{G} + \underbrace{\mathcal{M} \cdot \mathbf{M} \cdot (d\mathbf{G} - d\mathbf{T})}_{d\mathbf{C}}$$

  Consumption $d\mathbf{C}$ depends on **primary deficits** $d\mathbf{G} - d\mathbf{T}$

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- Example: TA model with deficit financing

$$d\mathbf{Y} = d\mathbf{G} + \frac{\mu}{1-\mu}(d\mathbf{G} - d\mathbf{T})$$

  - consumption $d\mathbf{C}$ depends only on **current** deficits
  - **initial multiplier** can be large $\in \left[1, \frac{1}{1-\mu}\right] \dots$
  - but **cumulative multiplier** is $= 1$!

$$\frac{\sum(1+r)^{-t} dY_t}{\sum(1+r)^{-t} dG_t} = 1$$

Simulate model responses for more general shocks

▸ Impulse

- Parametrize: $dG_t = \rho_G dG_{t-1}$ and $dB_t = \rho_B (dB_{t-1} + dG_t)$
  - vary **degree of deficit-financing** ρ_B

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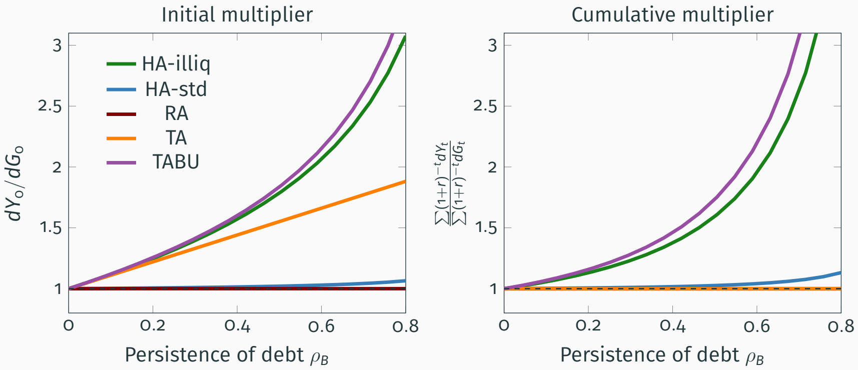


Calibration: $\rho_G = 0.7$

Fiscal policy in the quantitative model

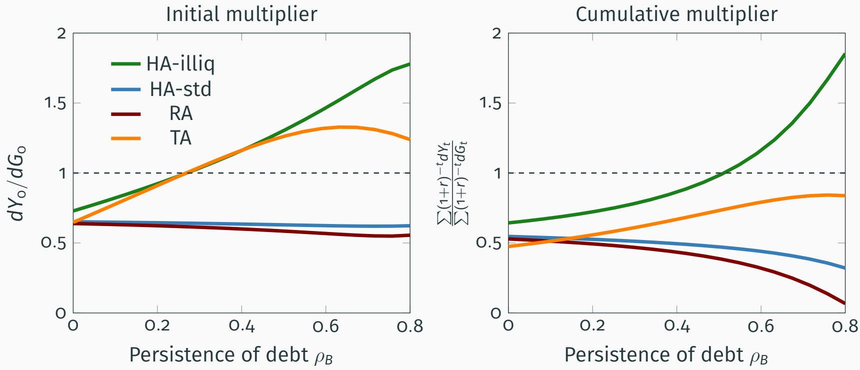
Adding new elements to the HA-illiq model . . .

▸ Calibration

- **Government:**
  - gov spending shock, $dG_t = \rho_G dG_{t-1}$
  - fiscal rule, $dB_t = \rho_B \left(dB_{t-1} + dG_t \right)$
  - Taylor rule, $i_t = r_{ss} + \phi \pi_t$, $\phi > 1$
- **Supply side:**
  - Cobb-Douglas production, $Y_t = K_t^{\alpha} N_t^{1-\alpha}$
  - K_t subject to quadratic capital adjustment costs
  - sticky prices à la Calvo, $\pi_t = \kappa^p mc_t + \frac{1}{1+r_t} \pi_{t+1}$
- **Two reasons for lower multipliers:**
  - distortionary taxation & crowding-out of investment

iMPCs *still* a crucial determinant of response!

▸ Impulse



Calibration: $\rho_G = 0.7$, $\kappa^w = \kappa^p = 0.1$, $\phi = 1.5$

Other shocks

What can we learn for other shocks? – back to benchmark

- Aggregate consumption may depend on **other shocks** θ,

$$C_t = \mathcal{C}_t\left(\{Z_s\}, \theta\right)$$

[e.g. deleveraging, inequality, preferences, **mon. policy**]

- Can generalize intertemporal Keynesian cross as

$$d\mathbf{Y} = d\mathbf{G} - \mathbf{M}d\mathbf{T} + \underbrace{\mathbf{C}_\theta d\theta}_{\equiv \partial \mathbf{C}} + \mathbf{M}d\mathbf{Y}$$

$\rightarrow$ **iMPCs also determine propagation of other shocks**

$$d\mathbf{Y} = d\mathbf{G} + \mathcal{M}\mathbf{M}(d\mathbf{G} - d\mathbf{T}) + \mathcal{M}\partial\mathbf{C}$$

Monetary policy experiment

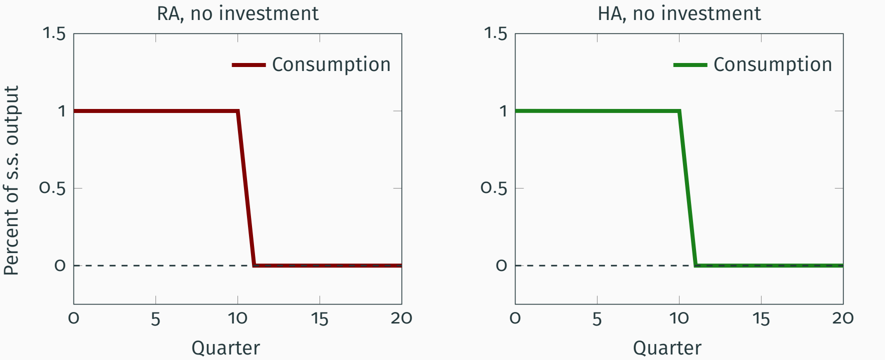
- Economy starts in steady state
- Monetary policy sets $\{r_t\}$ according to

$$r_t = \begin{cases} r & t \neq T \\ r - dr & t = T \end{cases}$$

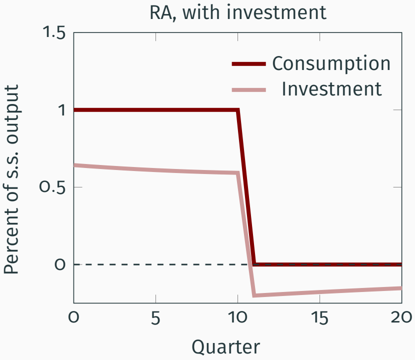
  with shock at **horizon** $t = T$

- **Next:** Compare responses
  - **RA** vs **HA-illiq** (matching iMPCs)
  - **investment** vs **no investment** ($\delta = 0$, ∞ adj. costs)

No investment: **RA** $\sim$ **HA** (Werning 2015)



With investment: **HA** is amplified, $\gg$ **RA**



$\rightarrow$ "Forward guidance is more powerful than you think!"

M matters for **M**acro !

$\rightarrow$ crucial for GE propagation

$\rightarrow$ new insights for fiscal policy

New avenues:
- more evidence on **M**
- implications for other shocks

Extra slides

Unions

back

- Mass 1 of unions. Each union k
  - employs every individual, $n_i \equiv \int n_{ik} dk$
  - produces task $N_k = \int e_i n_{ik} di$ from member hours
  - pays common wage w_k per efficient unit of work e
  - requires that all individuals work $n_{ik} = N_k$
- Final good firms aggregate $N \equiv \left(\int_0^1 N_k^{\frac{\epsilon-1}{\epsilon}} dk \right)^{\frac{\epsilon}{\epsilon-1}}$
- Union k sets w_{kt} each period to maximize

$$\max_{w_{kt}} \sum_{\tau \geq 0} \beta^{\tau} \left\{ \int \left\{ u\left(c_{it+\tau}\right) - v\left(n_{it+\tau}\right) \right\} di - \frac{\psi}{2} \left(\frac{w_{kt+\tau}}{w_{kt+\tau-1}} \right)^2 \right\}$$

- $\Rightarrow$ nonlinear wage Phillips curve

$$\left(1+\pi_t^w\right) \pi_t^w = \frac{\epsilon}{\psi} \int N_t \left(v'\left(n_{it}\right) - \frac{\epsilon-1}{\epsilon} \frac{\partial z_{it}}{\partial n_{it}} u'\left(c_{it}\right) \right) di + \beta \pi_{t+1}^w \left(1+\pi_{t+1}^w\right)$$

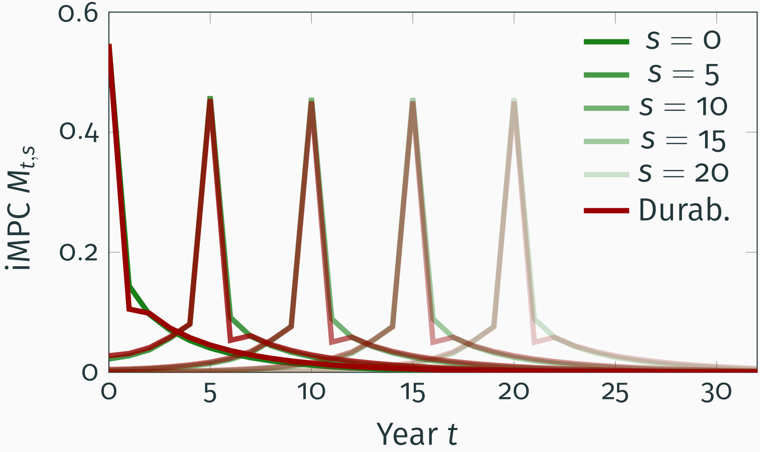
Equilibrium definition

back

- Given $\{G_t, T_t\}$, a **general equilibrium** is a set of prices, household decision rules and quantities s.t. at all t:
  1. firms optimize
  2. households optimize
  3. fiscal and monetary policy rules are satisfied
  4. the goods market clears

iMPCs for model with durables

back



Calibration: homothetic durables model with $d_{it} = 0.1 \cdot c_{it}$ and $\delta_D = 20\%$

Calibration for benchmark model

back

- Preferences: $u(c) = \frac{c^{1-\frac{1}{\nu}}}{1-\frac{1}{\nu}}$, $v(n) = b\frac{n^{1+\frac{1}{\phi}}}{1+\frac{1}{\phi}}$
- Income process: $\log e_t = \rho_e \log e_{t-1} + \sigma\epsilon_t$

Parameter	Parameter	HA-illiq	HA-std
ν	EIS	0.5	
ϕ	Frisch	1	
ρ_e	Log e persistence	0.91	
σ	Log e st dev	0.92	
λ	Tax progressivity	0.181	
G/Y	Spending-to-GDP	0.2	
A/Z	Wealth-to-aftertax income	8.2	
B/Z	Liquid assets to aftertax income	0.15	8.2
β	Discount factor	0.80	0.92
r	Real interest rate	0.05	
κ^w	Wage flexibility	0.1	

Calibration for quantitative model

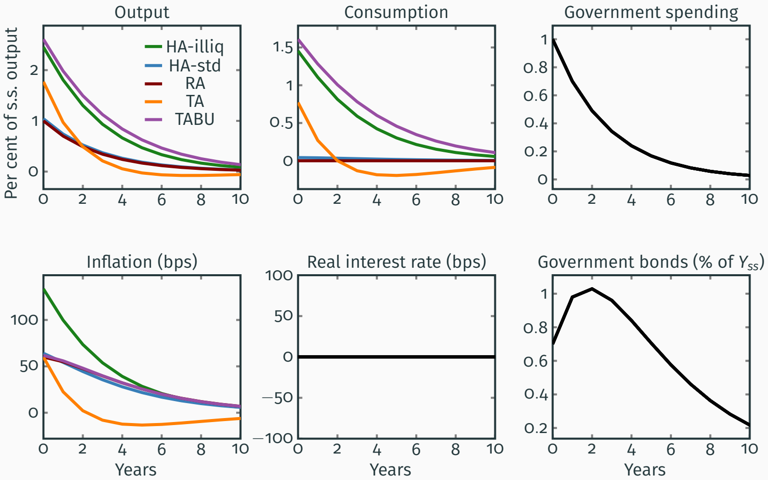
back

- As in benchmark model, plus:

Parameter	Parameter	
α	Capital share	0.33
B/Y	Debt-to-GDP	0.7
K/Y	Capital-to-GDP	2.5
μ	SS markup	1.015
δ	Depreciation rate	0.08
ϵ_I	Invest elasticity to q	4
κ^p	Price flexibility	0.1
κ^w	Wage flexibility	0.1
ϕ	Taylor rule coefficient	1.5

Impulse responses in benchmark model

▸ back



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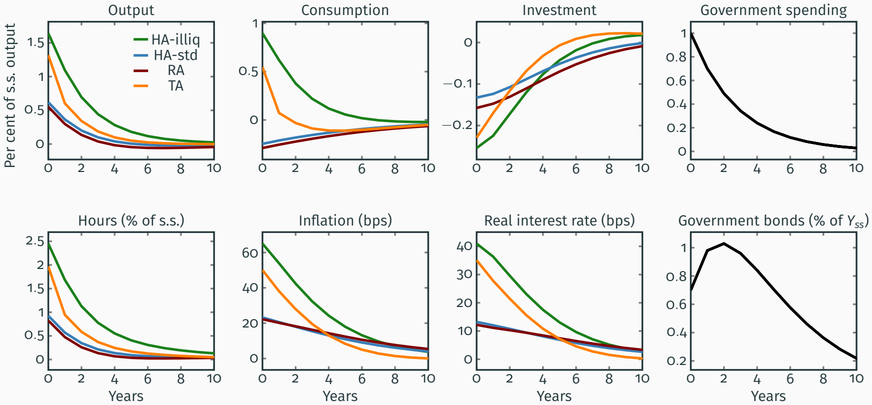
Impulse responses in quantitative model

back



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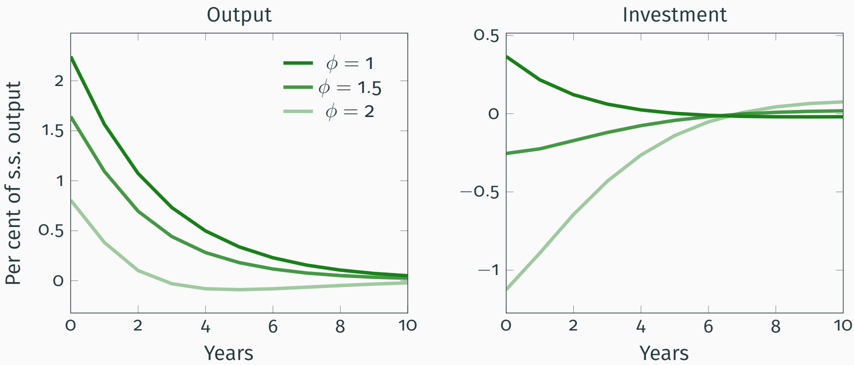
True unless very responsive Taylor rule

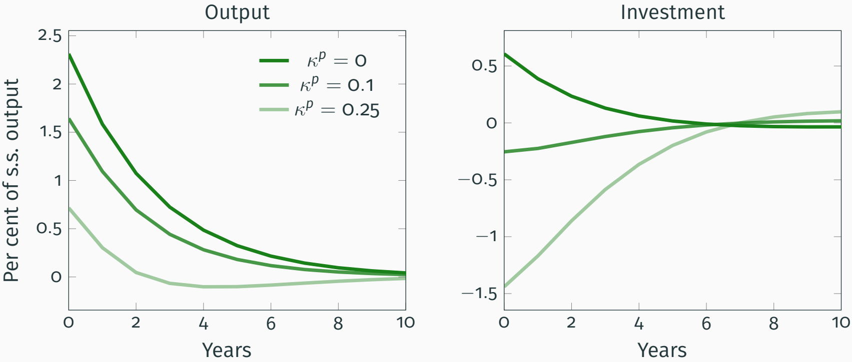
back



Calibration: $\rho_G = 0.7$, $\kappa^w = \kappa^p = 0.1$, $\rho_B = 0.5$, and vary ϕ in Taylor rule

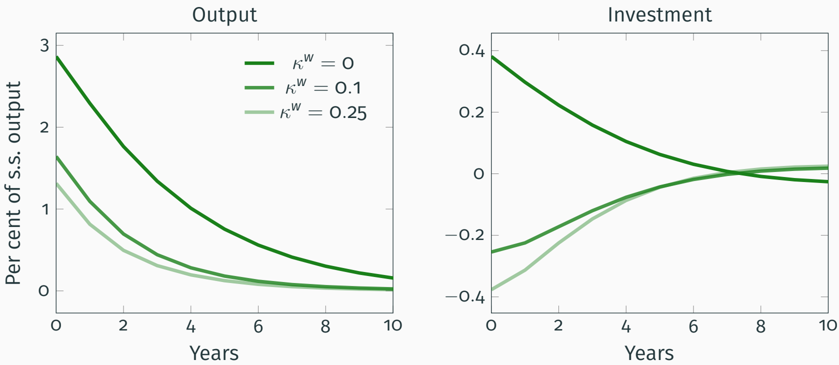
True even with more flexible prices (unless *very* flexible)

back



Calibration: $\rho_G = 0.7$, $\kappa^w = 0.1$, $\rho_B = 0.5$, $\phi = 1.5$, and vary κ^p in price Phillips curve

True even with more flexible wages (unless *very* flexible) ▸ back



Calibration: $\rho_G = 0.7$, $\kappa^p = 0.1$, $\rho_B = 0.5$, $\phi = 1.5$, and vary κ^w in wage Phillips curve