Managing an Energy Shock: Fiscal and Monetary Policy

Adrien Auclert, Hugo Monnery, Matthew Rognlie, and Ludwig Straub

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Energy prices and aggregate demand

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- Existing models to study these Q are **representative Agent (RA)** NK-SOE:
  [Blanchard-Gali 2007, Blanchard-Riggi 2009, Bodenstein et al 2011 ...]
  - shock leads to **expenditure switching, raising domestic demand**
  - magnitude governed by a certain elasticity of substitution χ
  - **real income decline not affecting demand** much if at all
  - little trade-off for monetary policy: raise rates to limit boom & inflation

Heterogeneous agents provide a new perspective

Today: Revisit by embedding **Heterogeneous Agents (HA)** in NK-SOE model

[Fast growing literature: De Ferra-Mitman-Romei, Zhou, Guo-Ottonello-Perez, Auclert-Rognlie-Souchier-Straub, Pieroni, Chan-Diz-Kanngiesser...]

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- **fiscal policy**: powerful in isolation ...
  - $\rightarrow$ but may have huge **negative externalities**!

Roadmap

1. Model
2. The energy shock: RA vs HA
3. Implications for inflation
4. Managing the energy shock: Monetary policy
5. Managing the energy shock: Fiscal policy

Model

Model overview: Gali-Monacelli + Energy + HANK

▸ Details

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1: Introduce one extra good: **energy** E (in addition to Foreign and Home)

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- SOE households consume E, elasticity of sub. χ. E not used in production
- Energy trades at world price P^*_{Et} — this is what we shock

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3: Standard **nominal wage rigidity**, various scenarios for mon policy

- Later, allow for real-wage stabilization motive ($\sim$ Blanchard-Gali)

Consumer demand and price-setting

- Each household has 2-tier CES demand, so consumption of E, F and H is

$$c_{iEt} = \alpha_E \left(\frac{P_{Et}}{P_t}\right)^{-\eta_E} c_{it}$$

$$c_{iFt} = \alpha_F \left(\frac{P_{Ft}}{P_{HFt}}\right)^{-\eta} \left(\frac{P_{HFt}}{P_t}\right)^{-\eta_E} c_{it}$$

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- For now: flexible prices, linear production $Y_t = N_t$, home markup μ

$$P_{Et} = P^*_{Et} \cdot \mathcal{E}_t \qquad P_{Ft} = 1 \cdot \mathcal{E}_t \qquad P_{Ht} = \mu \cdot W_t$$

where $\mathcal{E}_t$ is nominal exchange rate ($\mathcal{E}_t \uparrow$ is nominal depreciation)

Household consumption behavior

- c_{it} is determined by **intertemporal problem** of **HA**

$$\max_{\{c_{it}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left\{ \frac{c_{it}^{1-\sigma}}{1-\sigma} - v(N_t) \right\}$$

$$c_{it} + a_{it+1} = (1 + r_t^p) a_{it} + e_{it} \frac{W_t}{P_t} N_t \qquad a_{it+1} \geq 0 \qquad C_t \equiv \int c_{it} di$$

  - a_{it} = position in domestic mutual fund, r_t^p is return
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$$C_{Ht}^* = (\alpha_E + \alpha_F) \left(\frac{P_{Ht}}{\mathcal{E}_t P^*} \right)^{-\gamma} C^*$$

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- Domestic production and market clearing:

$$Y_t = N_t = C_{Ht} + C_{Ht}^*$$

Monetary policy and assets

- Three types of assets
  - nominal home & foreign bonds in zero net supply
  - shares in H firms $v_t = (v_{t+1} + \text{div}_{t+1})/(1 + r_t)$ in positive supply
  - asset market clearing $A_t = v_t + NFA_t$

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- Domestic central bank sets nominal rate i_t on nominal home bonds
  - for now, it targets constant CPI-based real interest rate, $i_t = r + \pi_{t+1}$
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- Mutual fund & foreigners invest freely in all assets
  - equalized $\mathbb{E}$ returns $\Rightarrow$ return on mutual fund is $r^p_{t+1} = r \; \forall t \geq 0$
  - UIP holds

$$1 + i_t = (1 + r)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \qquad 1 + r = (1 + r)\frac{Q_{t+1}}{Q_t}$$

so in our baseline the real exchange rate $Q \equiv \frac{\mathcal{E}_t}{P_t}$ is held constant

The energy shock: RA vs HA

Feeding in the shock

- Tentative calibration to a European country
- AR(1) shock to P^*_{Et}, impact 100%, persistence 0.95 quarterly
- Consider:
  - **Representative agent (RA)**
  - **Heterogeneous agents (HA)**
- Monetary policy: raises nominal rate to stabilize real rate (for now)

Textbook RA complete markets model

- In **RA** with complete markets and Q constant $\Rightarrow C_t = C$ [Backus-Smith]

$$Y_t = (1 - \alpha_E - \alpha_F)\left(\frac{P_{Ht}}{P_{HFt}}\right)^{-\eta}\left(\frac{P_{HFt}}{P_t}\right)^{-\eta_E} C + (\alpha_E + \alpha_F)\left(\frac{P_{Ht}}{\mathcal{E}_t}\right)^{-\gamma} C^*$$

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- Linearize around SS with $Y = C = C^* = Q = P_E^* = 1$:

$$dY_t = \frac{\alpha_E}{1-(\alpha_E+\alpha_F)} \cdot \chi \cdot dP_{Et}^*$$

  where χ is weighted average elasticity of substitution:

$$\chi = (1-\alpha_E-\alpha_F)\left(\frac{\alpha_F}{1-\alpha_E}\eta + \left(1-\frac{\alpha_F}{1-\alpha_E}\right)\eta_E\right) + (\alpha_E+\alpha_F)\gamma$$

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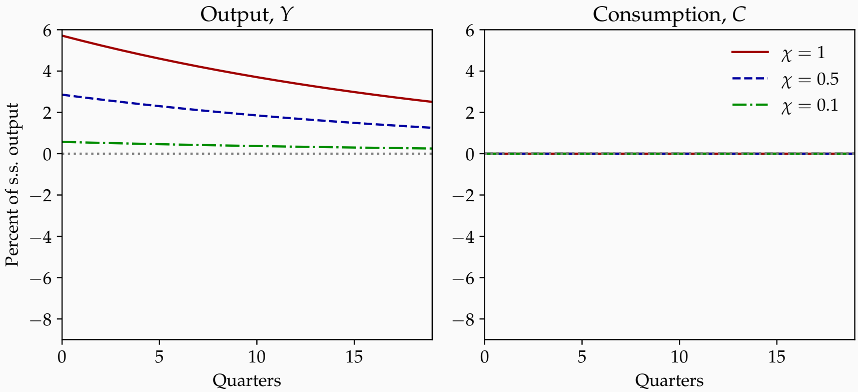
- Pure expenditure switching: **domestic boom!**
- In relatively closed economy $\chi \simeq \eta_E$ so quite low

RA: Output and consumption

▸ Energy input

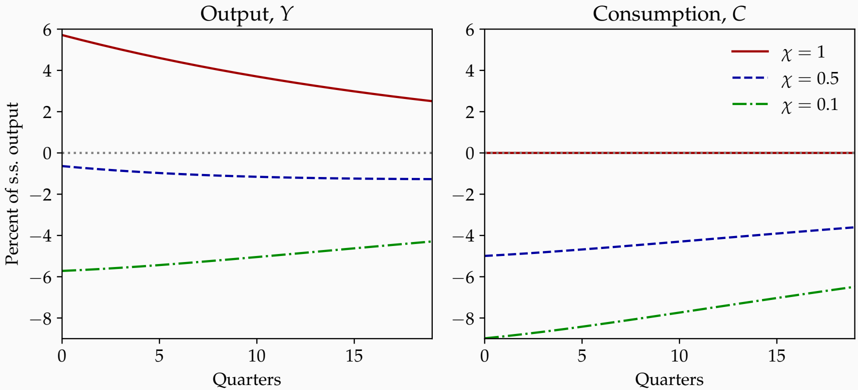
- **RA: boom** due to expenditure switching! Scales in χ.
- With energy in production: same GDP + C (gross output different).



HA: Output and consumption

International Keynesian Cross

- **HA**: Higher MPCs $\Rightarrow$ negative income effect; any movement in Y is amplified.
- $\chi = 1$: these forces offset each other, **HA = RA** ! [Cole-Obstfeld] Lower $\chi \Rightarrow$ bust.



Implications for inflation

Slower passthrough for quantification

- For quantification, allow for price and *real* wage stickiness

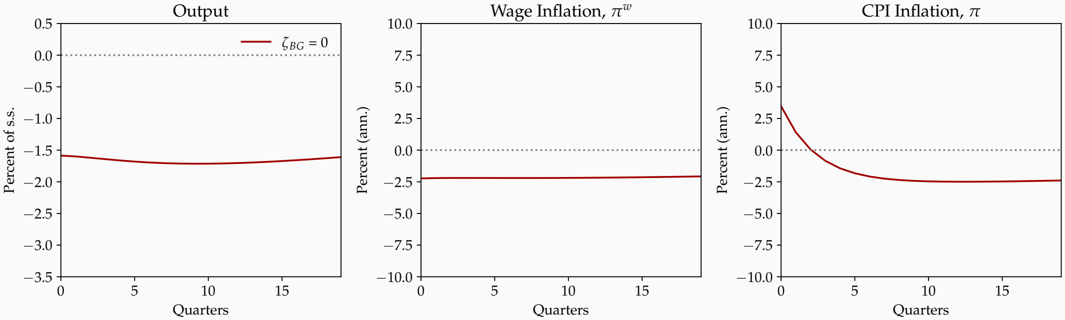
1. Slow passthrough of exchange rate into energy and foreign goods
    - "pricing to market" nominal rigidities $\to$ standard Phillips curves
2. Wage Phillips curve with real rigidity a la Blanchard-Gali

$$\pi_{wt} = \kappa_w \left(\frac{v'(N_t)}{u'(C_t)\mu_w (W_t/P_t)^{1+\zeta}} - 1 \right) + \beta \pi_{wt+1}$$

- $\zeta = 0$: only nominal wage rigidity
- $\zeta > 0$: both nominal and real wage rigidity

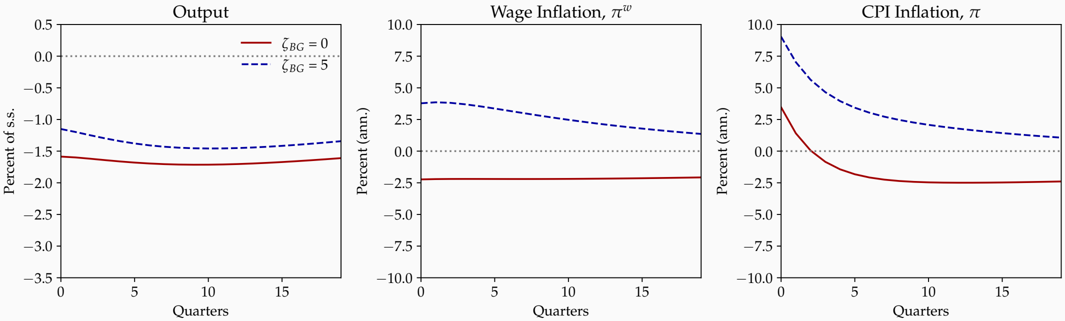
Effect of energy shock: output and inflation

- With $\zeta = 0$: energy price shock is negative domestic demand shock
- Why? $W/P \downarrow$, but $N, C \downarrow\downarrow$. Nominal wages fall (deflation)



Effect of Blanchard-Gali real wage rigidity

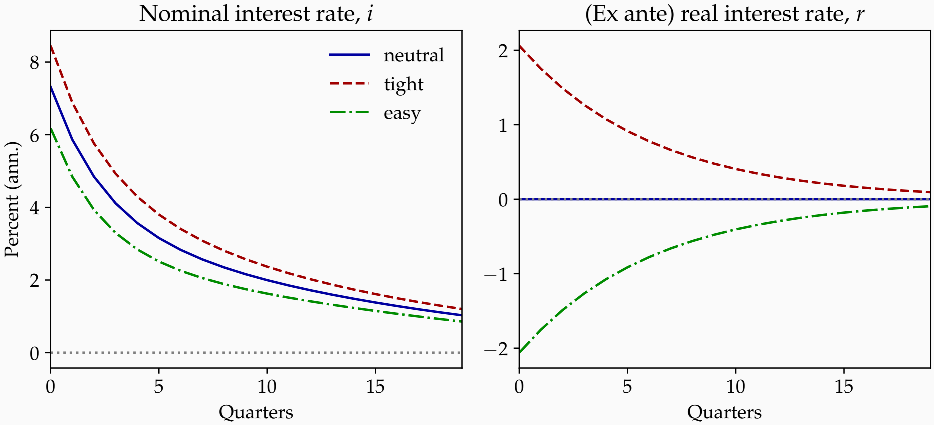
- With $\zeta > 0$: energy price shock is a stagflationary shock
- Wage setters averse to $W/P \downarrow$. Get **price-wage spiral** ! Important today?



Managing the energy shock: Monetary policy

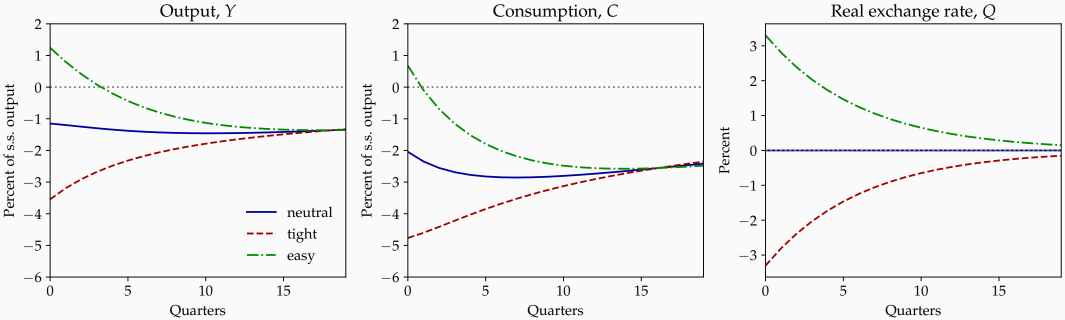
Monetary policy: three scenarios

- Three scenarios for monetary policy



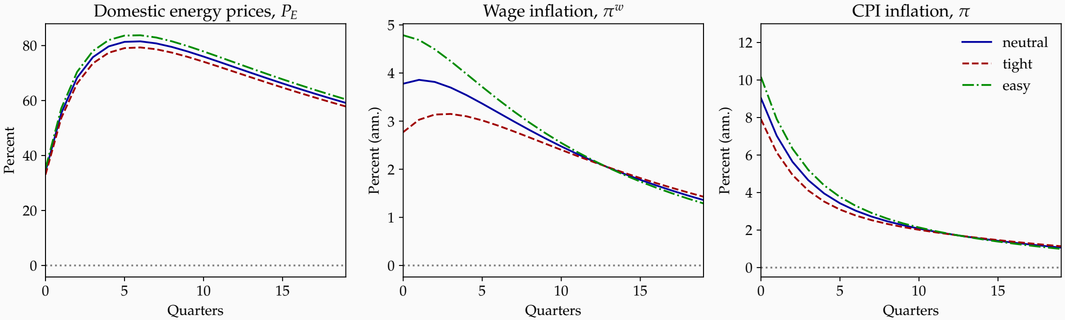
Monetary policy: Output and consumption

- Tight monetary policy causes deeper recession (as expected)



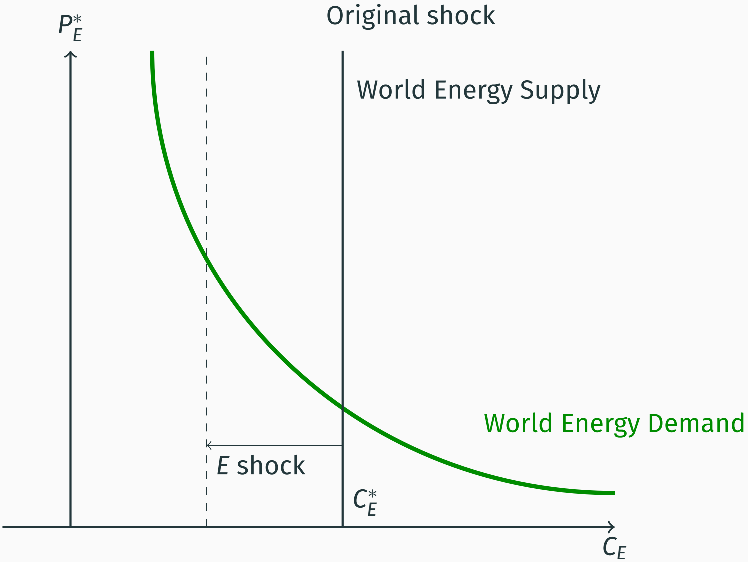
Monetary policy: Inflation

- Tight monetary policy not that effective against imported inflation
  - Can only appreciate the exchange rate so much without collapse in output



Microfounding P_E^* in world economy

▸ Dynamic supply



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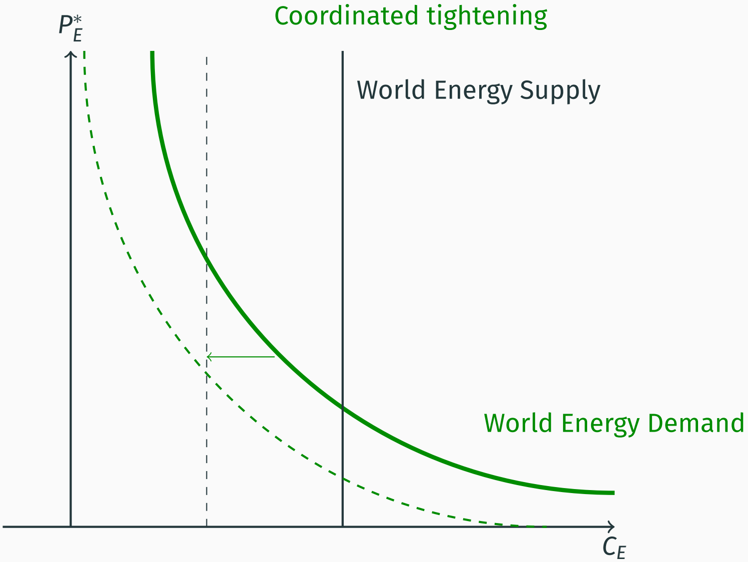

Monetary policy: Coordination

- **Positive spillover** from domestic $i \uparrow$: brings down P_E^* for everyone else.

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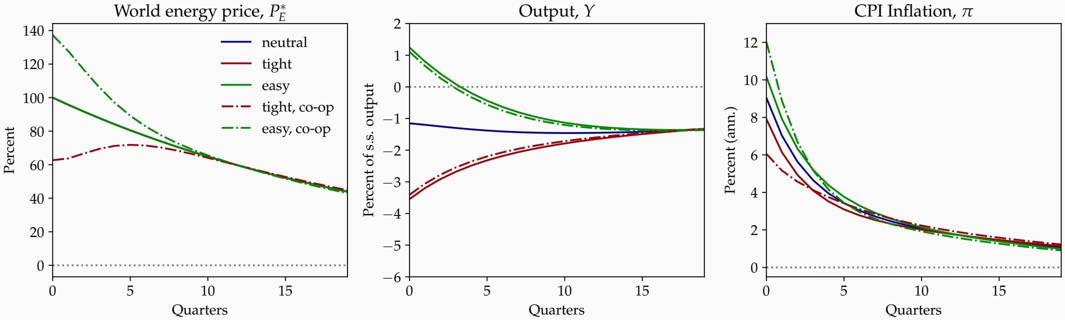
- Coordination problem. If continuum of SOE's consume E and all hike:



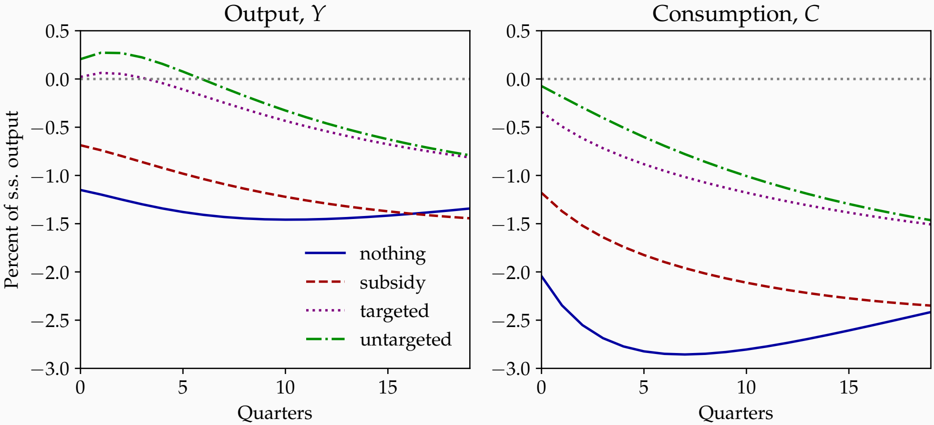
Managing the energy shock: Fiscal policy

Fiscal policy

- Next: **fiscal policy**
- Compare:
  - price subsidy
  - targeted transfers (based on usual level of E consumption)
  - untargeted transfers
- All initially deficit financed

Fiscal policy (uncoordinated): output and consumption

- All three policies effectively mitigate consumption decline...



Fiscal policy (uncoordinated): inflation

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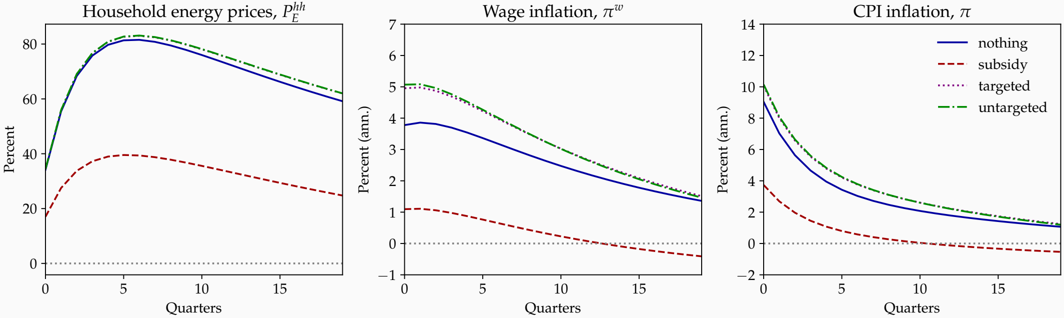
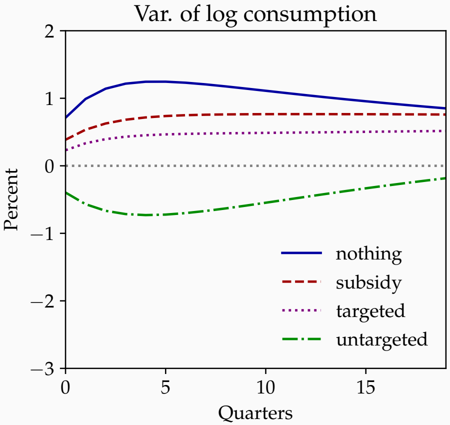
- Transfer programs are inflationary...
- ... but subsidy seems like a silver bullet?



Fiscal policy (uncoordinated): inequality

- All programs seem to reduce inequality (var of log consumption)



Fiscal policy (coordinated): inflation

- Subsidy is a disaster if everyone uses it. No one adjusts E consumption!
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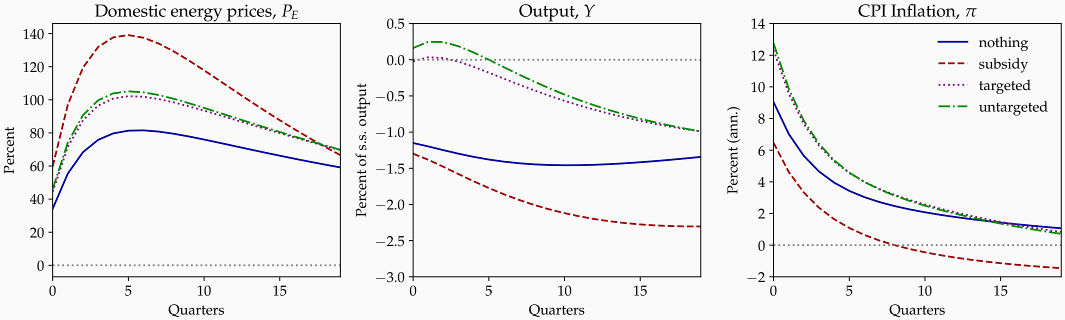
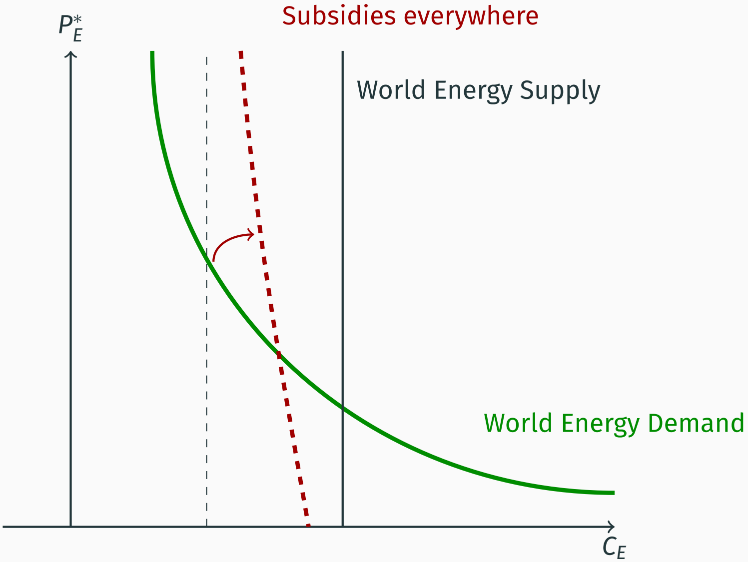
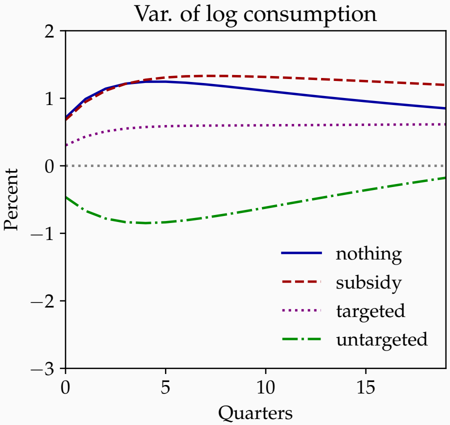


World economy equilibrium with subsidies



Fiscal policy (coordinated): inequality

- Even the inequality benefits are gone if everyone subsidizes energy.



Conclusion

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- Use **open economy HA model** to speak to current energy price shock
- **Negative demand shock** given low short-run elasticity of substitution
  - Adding real wage concerns, shock is even **stagflationary**
- **Monetary tightening** alone does little, but has **positive externalities**

  → Want major countries to hike together
- **Fiscal support** alone is very powerful, but hugely **negative externalities**

  → Developing countries with less fiscal space may bear the cost. Do less?

Appendix

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- For now: flexible prices, linear production $Y_t = N_t$, home markup μ

$$P_{Et} = P^*_{Et} \cdot \mathcal{E}_t \qquad P_{Ft} = 1 \cdot \mathcal{E}_t \qquad P_{Ht} = \mu \cdot W_t$$

where $\mathcal{E}_t$ is nominal exchange rate ($\mathcal{E}_t \uparrow$ is nominal depreciation)

Household consumption behavior

- c_{it} is determined by **intertemporal problem** of **HA**

$$\max_{\{c_{it}\}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta_i^t \left\{ \frac{c_{it}^{1-\sigma}}{1-\sigma} - v(N_t) \right\}$$

$$c_{it} + a_{it+1} = (1 + r_t^p) a_{it} + e_{it} \frac{W_t}{P_t} N_t \qquad a_{it+1} \geq 0 \qquad C_t \equiv \int c_{it} di$$

  - $a_{it} =$ position in domestic mutual fund, r_t^p is return
  - W_t is sticky, so income $\frac{W_t}{P_t} N_t$ taken as given by households

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- Domestic production and market clearing:

$$Y_t = N_t = C_{Ht} + C_{Ht}^*$$

Monetary policy and assets

back

- Three types of assets
  - nominal home & foreign bonds in zero net supply
  - shares in H firms $v_t = (v_{t+1} + \text{div}_{t+1})/(1 + r_t)$ in positive supply
  - asset market clearing $A_t = v_t + NFA_t$

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- Domestic central bank sets nominal rate i_t on nominal home bonds
  - for now, it targets constant CPI-based real interest rate, $i_t = r + \pi_{t+1}$
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- Interest rate on foreign bonds is constant $r^* = r$
- Mutual fund & foreigners invest freely in all assets
  - equalized $\mathbb{E}$ returns $\Rightarrow$ return on mutual fund is $r^p_{t+1} = r\ \forall t \geq 0$
  - UIP holds

$$1 + i_t = (1 + r)\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \qquad 1 + r = (1 + r)\frac{Q_{t+1}}{Q_t}$$

so in our baseline the real exchange rate $Q \equiv \frac{\mathcal{E}_t}{P_t}$ is held constant

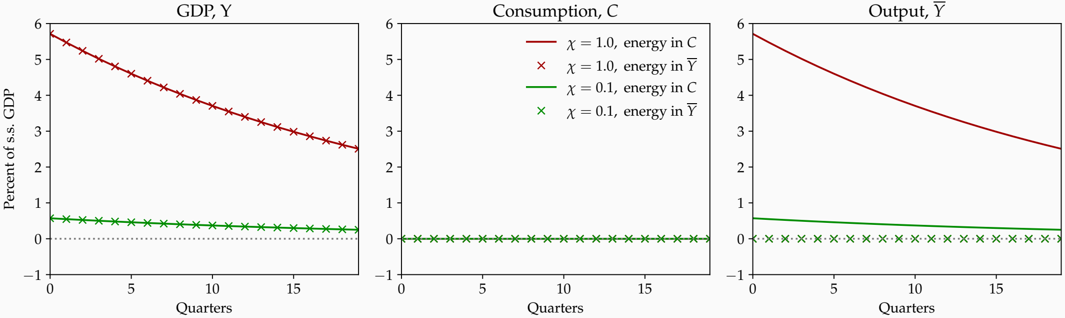
Calibration

- The energy shock: 100% AR(1) shock with (quarterly) persistence 0.96
- Consumption shares: $\alpha_F = 0.26$, $\alpha_E = 0.04$
- Elasticities of substitution: $\eta_E = 0.1$, $\eta = 0.5$, $\gamma = 0.5$
- Unions: $\zeta = 5$, $\theta_W = 0.91$
- Importers: $\theta_E = 0.65$, $\theta_F = 0.9$. Entirely foreign owned.

Aside: RA with energy in output

back

- Same predictions for output + consumption if energy is input to production. Gross output is unchanged.



The incomplete market representative agent

- Drop international risk-sharing, consider incomplete-market RA
- Given st. state $r = \beta^{-1} - 1$ and variable perfect foresight income stream Z_t

$$\max_{\{C_t\}} \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\sigma}}{1-\sigma}$$

$$C_t + A_t = (1+r)A_{t-1} + Z_t$$

- Given A_{-1}, consumption is function of Z_t ...

$$C_t = \mathcal{C}_t\left(\{Z_0, Z_1, Z_2, \ldots\}\right)$$

- What does this function look like in the RA case?

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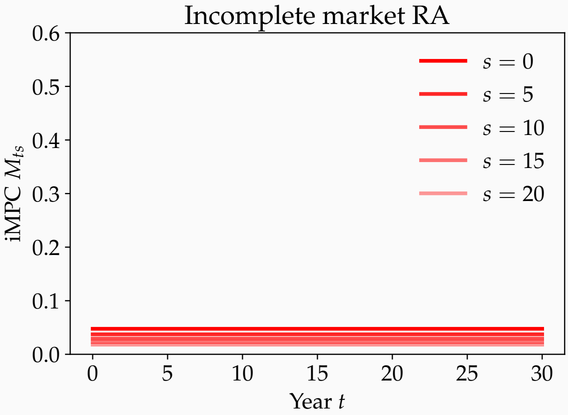
$\rightarrow$ Perfect consumption smoothing, **very small** C **responses to** Z **shocks**!

- Responses to income shocks at various dates, **intertemporal MPCs**



Heterogeneous agents

- Now add **idiosyncratic productivity shocks** e_{it} + **borrowing constraint**

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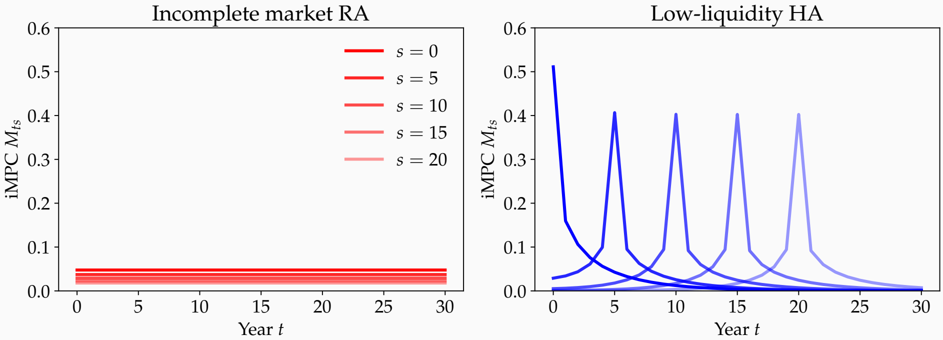
- Feed in small Z_t shocks again ...

Consumption responses to income shocks in HA vs RA

- Responses to income shocks at various dates in HA vs RA (if low liquidity)

[Auclert-Rognlie-Straub 2018]



Matrix of intertemporal MPCs

◂ iMPCs-back

- Can stack responses into matrix **M** as columns, "MPC matrix"
- Then, for any given path $d\mathbf{Z} = (dZ_0, dZ_1, dZ_2, \ldots)'$, consumption path is

$$d\mathbf{C} = \mathbf{M} \cdot d\mathbf{Z}$$

  - a bit like undergraduate macro, where $\Delta C = \text{mpc} \cdot \Delta Y$

- Proof of international keynesian cross follows three steps:

[Simplified case with zero liquidity, otherwise also include MPC from capital gains]

1. observe that real income is $Z_t = \frac{W_t}{P_t} N_t = \frac{P_{Ht}}{P_t} Y_t$
2. linearize the consumption equation around ss with $P_H/P = Y = 1$

$$d\mathbf{C} = \mathbf{M} d\left(\frac{\mathbf{P}_H}{\mathbf{P}}\right) + \mathbf{M} d\mathbf{Y}$$

3. use demand system to relate $d\left(\frac{\mathbf{P}_H}{\mathbf{P}}\right)$ to $d\mathbf{P}_E^*$ and $d\mathbf{Y}$ to $d\mathbf{C}$

Back

Proposition

In the HA model, $d\mathbf{Y}$ solves an "international Keynesian cross"

$$d\mathbf{Y} = \underbrace{\frac{\alpha_E}{1-(\alpha_E+\alpha_F)}\chi d\mathbf{P}_{\mathbf{E}}^*}_{\text{Expenditure switching}} - \underbrace{\alpha_E \mathbf{M} d\mathbf{P}_{\mathbf{E}}^*}_{\text{Real income}} + \underbrace{(1-(\alpha_E+\alpha_F))\mathbf{M}d\mathbf{Y}}_{\text{Multiplier}}$$

where $d\mathbf{P}_{\mathbf{E}}^*$ is the energy price shock and $M_{t,s} \equiv \frac{\partial \mathcal{C}_t}{\partial Y_s}$ is the matrix of iMPCs

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- Entire role of heterogeneity encoded in $\mathbf{M}$ matrix, RA corresponds to $\mathbf{M} = 0$

The International Keynesian cross

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- Entire role of heterogeneity encoded in $\mathbf{M}$ matrix, RA corresponds to $\mathbf{M} = 0$
- When $\chi = 1$, last two terms cancel, so HA=RA

[related: Cole-Obstfeld, Werning, Auclert-Rognlie-Straub, Auclert-Rognlie-Souchier-Straub]

Dynamic energy supply

◂ Back

- Energy suppliers
  - endowed with $\overline{E}_t$
  - can adjust "inventory" $I^E_{i,t+1} = I^E_{i,t} + \left(\overline{E}_t - E_{it}\right)$
  - maximize

$$\sum_{j=0}^{\infty} \left(\frac{1}{1+r^*}\right)^j \left[P^*_{E,t+j} E_{i,t+j} - \frac{\Gamma}{2}\left(I^E_{i,t+1}\right)^2\right]$$

- Optimal inventory

$$I^E_{i,t+1} = \frac{\left(\frac{1}{1+r^*}\right) P^*_{E,t+1} - P^*_{E,t}}{\Gamma}$$

built up when future price is expected to be high relative to today