Optimal Monetary Response to Tariffs in HANK

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  - Existing work studies question in a RANK economy.
  - Want to extend to HANK.

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- Today: Model to capture some of these intuitions
  - Highlight central bank's motives to inflate/deflate
  - Numerical results
    - ★ *Sign* of optimal policy response determined by how fiscal revenue is spent

Literature

Open Economy (Optimal) Monetary Policy

- Bianchi & Coulibaly (2025), Monacelli (2025), Bergin & Corsetti (2023), Auray et al (2024), Kalemli-Özcan et al (2025)

Optimal Monetary Policy in HANK

- Dàvila & Schaab (2023), Nuño & Thomas (2021), Nuño & Moll (2018)

Open Economy HANK

- Auclert et al (2024), Guo et al (2020), de Ferra et al (2020)

Distributional Consequences of Trade

- Carroll & Hur (2023, 2020), Borusyak & Jaravel (2021)

Outline

Model Environment

Adapt model of Bianchi & Coulibaly to heterogeneous agent economy, in continuous time for mathematical and computational tractability. Model features:

1. Home and foreign consumption goods
2. Households subject to idiosyncratic Poisson productivity shocks
3. Standard New Keynesian production block
4. A fiscal authority that collects tariff and income tax revenues, issues debt, distributes subsidies to firms, and distributes transfers to households
5. A monetary authority that optimally sets interest rates.

Households

- Measure 1 of households, indexed by i
- Consume home and foreign goods aggregated according to

$$(c_{i,t})^{\frac{\gamma-1}{\gamma}} = \omega(c^h_{i,t})^{\frac{\gamma-1}{\gamma}} + (1-\omega)\left(c^f_{i,t}\right)^{\frac{\gamma-1}{\gamma}}$$

- Receive disutility from labor $n_{i,t}$
- Can save in home denominated bonds $(b_{i,t})$ subject to borrowing constraint ϕ
- Household productivity z evolves according to Poisson process with transition intensities $\lambda_{j,j'}$

Household HJB

Household optimization problem is then

$$\rho V_t(b_t, z_{jt}) = \max_{c_t^f, c_t^h, n_t} u(c_t^f, c_t^h) - g(n_t) + \frac{\partial V_t}{\partial b_t}\dot{b}_t + \sum_{j' \neq j} \lambda_{j,j'} \left[V_t(j') - V_t(j) \right] + \frac{\partial V_t}{\partial t}$$

subject to

$$\dot{b}_t = r_t b_t + (1 - \tau_n) z_t w_t n_t + T_t + D_t - p_t^h c_t^h - p_t^f (1 + \tau_t) c_t^f$$
$$b_t \geq \phi$$

Household FOC's

Household FOC's expressed as

$$c_t^f = c_t^h \left(\frac{\omega}{1-\omega} (1+\tau_t) \frac{p_t^f}{p_t^h} \right)^{-\gamma}$$

$$g'(n_t) = \frac{w_t z_t}{p_t^h} u_h(c_t^h, c_t^f)$$

$$u_h(c_t^h, c_t^f) = \frac{\partial V(b_t, z_t)}{\partial b_t}$$

- Foreign consumption decreasing in $(1+\tau_t)\frac{p_t^f}{p_t^h}$ and preference share for home ω_i.

▸ Sources of Suboptimality

KFE

Distribution of households $f_t(b_t, z_{jt})$ satisfies the KFE

$$\frac{\partial f_t(b_t, z_{jt})}{\partial t} = -\frac{\mathrm{d}}{\mathrm{d}b_t}[s_t(b_t, z_{jt})f_t(b_t, z_{jt})] - f_t(b_t, z_{jt})\sum_{j' \neq j}\lambda_{jj'} + \sum_{j' \neq j}\lambda_{j'j}f_t(b_t, z_{jt})$$

Define generator $\mathcal{A}$ and adjoint $\mathcal{A}^*$ in usual way and satisfy

$$\rho V_t = u(c_t^f, c_t^h) - g(n_t) + \mathcal{A}V_t + \frac{\partial V_t}{\partial t}$$
$$\frac{\partial f_t}{\partial t} = \mathcal{A}^* f_t$$

Firms

- Standard NK production block with Rotemberg pricing and linear production. Will highlight 2 relevant equations:
- NKPC:

$$(r_t - \frac{\dot{N}_t}{N_t})\pi_t = \frac{\epsilon}{\theta}(m_t - 1) + \dot{\pi}_t$$

- ϵ elasticity of production, θ Rotemberg parameter, m_t marginal cost, π_t the PPI
- Dividends:

$$\frac{D_t}{P_t^h} = (1 + S)Y_t - m_t Y_t - \Theta(\pi_t)$$

Government

Government issues debt, collects tariff and income tax revenue, issues a production subsidy to firms, and issue lump sum transfers

$$\dot{B}_t = rB_t + T_t + Sp_t^h Y_t - \tau_t p_t^f \int c_t^f \, \mathrm{d}f_t(b_t, z_t) - \tau^n w_t \int n_t \, \mathrm{d}f_t(b_t, z_t)$$

Specification of fiscal policy requires rule for 2 of B, τ_n, and T, third adjusts. Baseline: assume T_t adjusts

Rest of the World

- ROW comprised of small open economies $k \in (0,1)$
- Each country produces a single foreign variety, aggregates into C^f

$$\left(C_{k,t}^f\right)^{\frac{\vartheta-1}{\vartheta}} = \int \left(C_{k,t}^j\right)^{\frac{\vartheta-1}{\vartheta}} \mathrm{d}j$$

$$C_{k,t}^{\frac{\gamma-1}{\gamma}} = \omega \left(C_{k,t}^h\right)^{\frac{\gamma-1}{\gamma}} + (1-\omega)\left(C_{k,t}^f\right)^{\frac{\gamma-1}{\gamma}}$$

Solving foreign representative household's problem yields

$$p \equiv \frac{p_t^h}{p_t^f} = A^*\left(N_t - C_t^h\right)^{\frac{1}{\vartheta}}$$

where ϑ is the export demand elasticity. For now, abstract from ToT manipulation $\implies \vartheta = \infty$

Equilibrium

Given an initial distribution bond holdings and idiosyncratic states $f_0(b_0, z_0)$, an exogenous relative price p, sequences of government policy for S, T_t, B_t, $\tau_{n,t}$, and τ_t, a specification for monetary policy r_t, a competitive equilibrium requires finding (sequences of) household policy functions s_t, n_t c_t^h, c_t^f and value functions V_t, solutions for the firms' problem $n_{j,t}$, $y_{j,t}$, $p_{j,t}^h$, Y_t, N_t, prices w_t, and measures $f_t(b_t, z_t)$ such that

1. Given prices and interest rates, the HJB holds
2. Given the savings function $s_t(b_t, z_t)$, f_t solves the KFE
3. Given wages, $n_{j,t}$ solves the firm cost minimization problem and $p_{j,t}^h$ solves the price setting problem
4. Given a specification for 3 of S, T_t, B_t, and τ_t^n, the fourth is determined by the government budget constraint
5. Markets clear
    1. Labor market: $N_t = n_{j,t} = \int n \, \mathrm{d}f_t(b_t, z_t)$
    2. Bond market: $B_t = \int b_t \, \mathrm{d}f_t(b_t, z_t)$
    3. Goods: $\underbrace{Y_t - \frac{\theta}{2}\pi_t^2 Y_t - C_t^h}_{\text{Exports}} = \underbrace{pC_t^f}_{\text{Imports}}$

Outline

Ramsey Optimal Policy Problem

The timeless Ramsey plan solves the following problem, requiring choosing paths of allocations, prices, distributions, multipliers, and the instrument (r_t) that maximize social welfare subject to all equilibrium conditions

$$\min_{\{\eta_{j,t}\}_{j=1}^{9}} \max_{r_t, c_t^f, c_t^h, n_t, C_t^f, N_t, \pi_t, w_t, V_t, f_t} \mathcal{L}(f_0)$$

where

$$\mathcal{L} \equiv \int_0^\infty e^{-\rho t} \Big\{ \int_{z_1}^{z_J} \int_{\phi}^{\infty} \Big[u(c_t^h, c_t^f) - g(n_t) \Big] f_t + \eta_{1,t}(b,z) \underbrace{\Big[\mathcal{A}^* f_t - \frac{\partial f_t}{\partial t} \Big]}_{\text{KFE}} +$$

$$\eta_{2,t}(b,z) \underbrace{\Big[u(c_t^f, c_t^h) - g(n_t) + \mathcal{A} V_t + \frac{\partial V_t}{\partial t} - \rho V_t \Big]}_{\text{HJB}} + \eta_{3,t} \underbrace{\Big[\pi_t (r_t - \frac{\dot{N}_t}{N_t}) - \frac{\epsilon}{\theta}(w_t - 1) - \dot{\pi}_t \Big]}_{\text{NKPC}} +$$

$$\underbrace{\eta_{4,t}[b_t - B_t] f_t + \eta_{5,t}[n_t z_t - N_t] f_t + \eta_{6,t}[c_t^f - C_t^f] f_t}_{\text{Market Clearing}} + \eta_{7,t}(b,z) \underbrace{\Big[g'(n_t) - \frac{(1-\tau^n) w_t z_{j,t}}{p_t^h} u_h(c_t^h, c_t^f) \Big]}_{\text{Labor/Leisure}}$$

$$\eta_{8,t}(b,z) \underbrace{\Big[u_h(c_t^h, c_t^f) - \frac{\partial V}{\partial b_t} \Big]}_{\text{Home Consumption}} + \eta_{9,t}(b,z) \underbrace{\Big[u_f(c_t^h, c_t^f) - \frac{\partial V}{\partial b_t} p(1+\tau_t) \Big]}_{\text{Foreign Consumption}} \mathrm{d}b\,\mathrm{d}z \Big\} \mathrm{d}t + \underbrace{\mathcal{T}(\eta_{2,0}, \eta_{3,0})}_{\text{Timeless Penalty}}$$

▸ Mathematical Preliminaries ▸ Planner FOCs

Planner HJB

FOC with respect to density f gives rise to a planner's HJB equation, where $\eta_{1,t}$ is the social value function

$$\rho\eta_{1,t} = u(c_t^h, c_t^f) - g(n_t) + \mathcal{A}\eta_{1,t} + \frac{\mathrm{d}\eta_{1,t}}{\mathrm{d}t} + \underbrace{\eta_{4,t}(b_t - B_t) + \eta_{5,t}(n_t - N_t) + \eta_{6,t}(c_t^f - C_t^f)}_{\text{Pecuniary Externality Terms}}$$

- Capture that the planner internalizes how individual savings, labor, and foreign consumption affect market clearing prices, redistributed profits, and tariff revenues

Planner Choice of Foreign Consumption

Planner's FOC for aggregate foreign consumption reflects fiscal externality

$$\eta_{6,t} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} \underbrace{\frac{\partial s_t}{\partial T} \frac{\partial T}{\partial C^f}}_{\text{Marginal Effect of Transfers}} \underbrace{\left(\frac{\partial \eta_{1,t}}{\partial b} + \frac{\partial V_t}{\partial b} \frac{\eta_{2,t}}{f_t} \right)}_{\text{Planner Marginal Value}} f_t \, \mathrm{d}b \, \mathrm{d}z$$

- $\eta_{6,t}$ is a pecuniary fiscal externality, novel to this environment
- $\eta_{6,t} > 0 \implies$ positive social value of increasing demand for foreign consumption.
- "Covariance" between marginal effect of adjusting fiscal variable and planner weight determines strength of this motive

Other HH Choice FOC | Other Aggregates FOC | A Targeting Rule

Outline

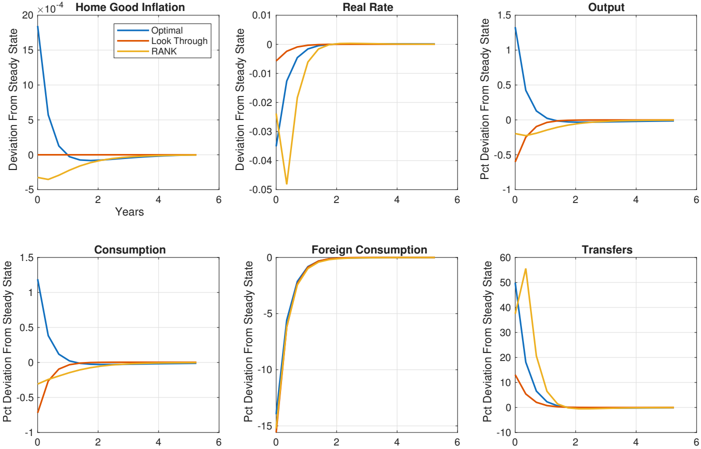
Numerical Results

- Calculate fully nonlinear, perfect foresight impulse responses to a 10% tariff shock that fully decays after 2 years.
- Compare optimal policy to "look-through" policy (setting $\pi_t = 0 \forall t$) and RANK

Computational Algorithm   Calibration

Numerical Results- Aggregate Outcomes

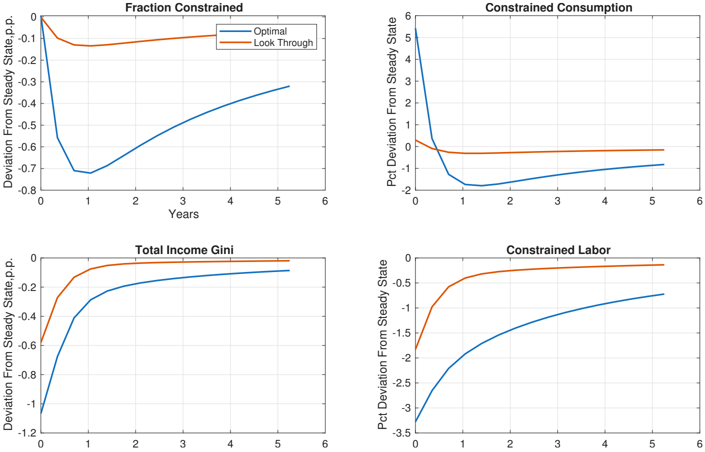
Figure: Response of Aggregate Variables



Optimal policy expansionary

Numerical Results- Distributional Outcomes

Figure: Optimal vs Look Through Policy, Distributional



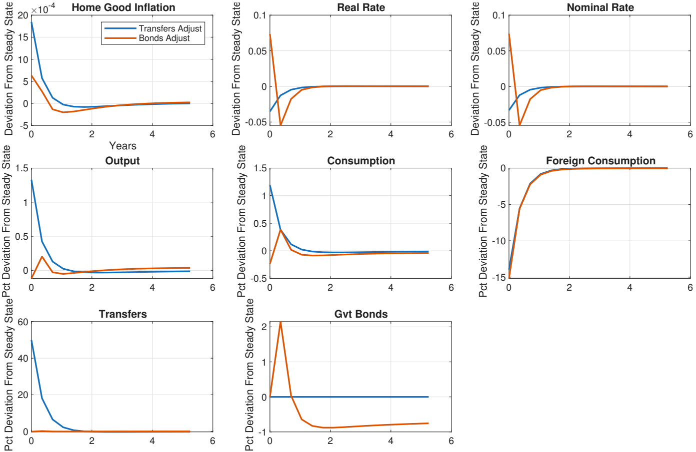
Powerful fiscal externality! Expansionary policy $\implies$ higher foreign consumption $\implies$ higher transfers $\implies$ better distributional outcomes

Failure of Ricardian Equivalence

- Ricardian equivalence fails in this class of model $\implies$ which fiscal variable adjusts matters for equbm outcomes.
- As a baseline, assumed transfers adjusted.
- Calculate same transition paths for optimal policy as before, under assumption that transfers or bonds adjust.
  - Planner has different FOC

Varying Adjustment- Aggregate Outcomes

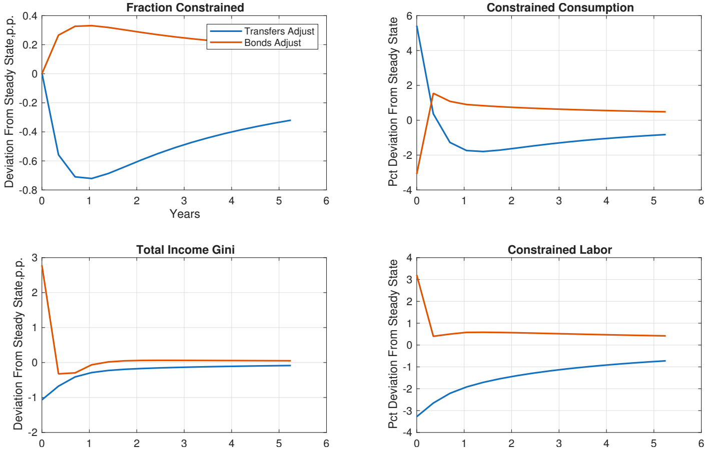
Figure: Varying Adjustment, Aggregates



Sign of policy response affected by which variable adjusts! Bonds adjust ≈ RANK

Varying Adjustment- Distributional Outcomes

Figure: Varying Adjustment, Distributional



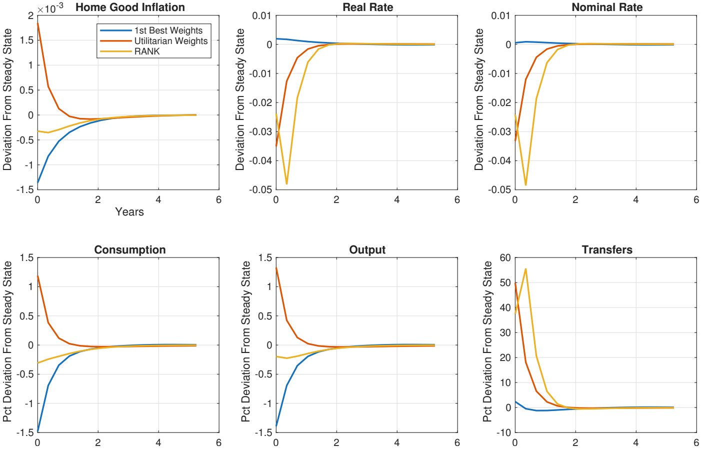
Direct transfers very powerful!

“Efficient” Initial Conditions

- Planner can inflate because existing economy is inefficient *and* because tariff induces new inefficiencies
- Abstract from the former by finding Pareto weights φ such that pre-tariff steady state is efficient
  - φ will be *increasing* in wealth
- Solve for transition path in response to shock

“Efficient” Initial Conditions

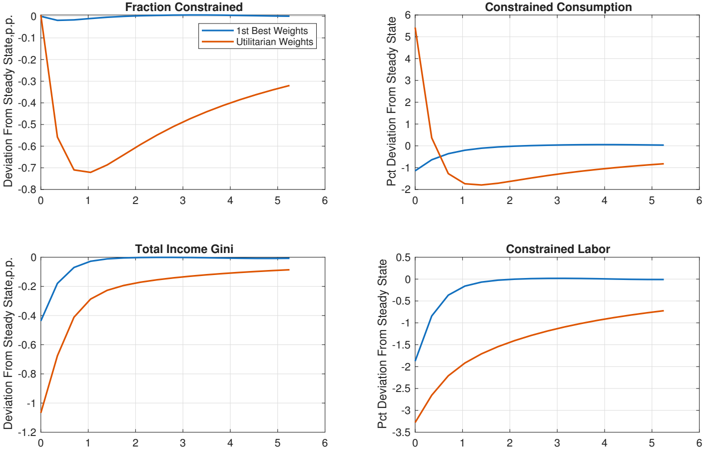
Figure: First Best vs Utilitarian Weights, Aggregate Variables



No rate cut- planner does not like the redistribution transfers induce

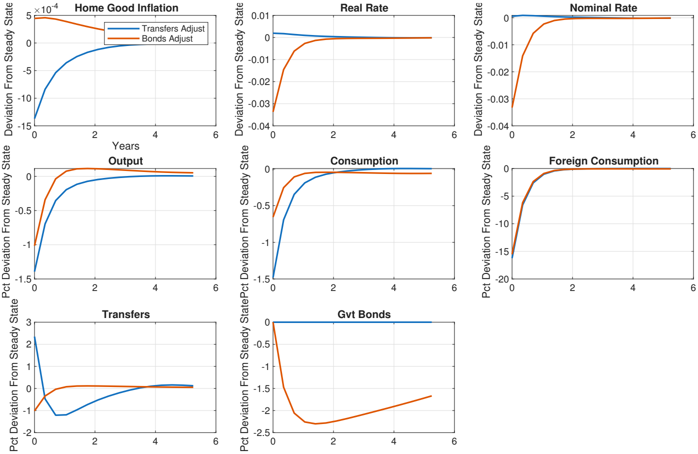
"Efficient" Initial Conditions

Figure: First Best vs Utilitarian Weights, Distributional Variables



"Efficient" Initial Conditions, Changing Adjustment

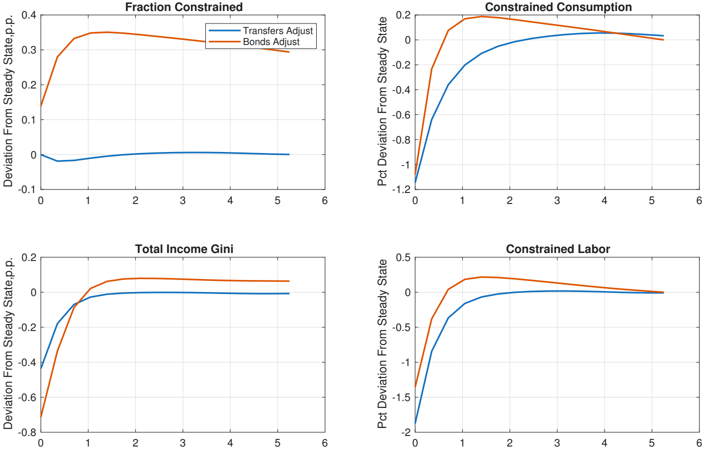
Figure: First Best vs Utilitarian Weights, Aggregate Variables



Minimal difference between bonds adjusting with utilitarian and "first best" weights

“Efficient” Initial Conditions, Changing Adjustment

Figure: First Best vs Utilitarian Weights, Distributional Variables



Conclusion

Household heterogeneity alters optimal monetary response to tariffs

- How fiscal policy adjusts affects signs and magnitudes of monetary policy response, direct transfers feature strongest incentive to inflate
- Optimal allocations feature redistribution because planner has direct preference for redistribution *and* because poor have high MPC

Next Steps

- Richer fiscal instruments
- Welfare decomposition to understand where gains from (Davila & Schaab 2025)
- Think more carefully about international saving/borrowing

Appendices

Mathematical Preliminaries

- Optimization problem is in a function space. Need a generalized notion of derivatives to solve.
- Gâteaux derivatives in the function space $L^2(\Phi)$ (as in Nuño & Thomas):

$$\delta W[f;h] = \lim_{\alpha \to 0} \frac{W[f+\alpha h] - W[f]}{\alpha} = \frac{\mathrm{d}}{\mathrm{d}\alpha} W[f+\alpha h]|_{\alpha=0}$$

  where h is any function in the same space as f.
- The Lagrangian functional for the optimization problem

$$\max W[f]$$
$$\text{s.t.} \quad G[f] = 0$$

  is defined as $\mathcal{L}[f] = W[f] + \int_\Phi \eta G[f]$ where $\eta \in L^2(\Phi)$ is the Lagrange multiplier
- Necessary condition for optimality: Gâteaux derivative of Lagrangian for any function h in the function space is 0

$$\delta \mathcal{L}[f;h] = 0, \quad \forall h \in L^2(\Phi)$$

Solution to Planner's Problem

The planner's problem's solution is characterized by

$$\rho\eta_{1,t} = u(c_t^h, c_t^f) - g(n_t) + \mathcal{A}\eta_{1,t} + \frac{\mathrm{d}\eta_{1,t}}{\mathrm{d}t} + \eta_{4,t}(b_t^h - B_t) + \eta_{5,t}(n_t - N_t) + \eta_{6,t}(c_t^f - C_t^f)$$

$$\frac{\partial \eta_{2,t}}{\partial t} = \mathcal{A}^*\eta_{2,t} + \frac{\partial \eta_{8,t}}{\partial b} p + \frac{\partial \eta_{9,t}}{\partial b}(1+\tau)p$$

$$0 = u_f(c_t^h, c_t^f) - \frac{\partial \eta_{1,t}}{\partial b}(p(1+\tau)) + \frac{\eta_{9,t}}{f_t} u_{ff}(c_t^h, c_t^f) - \frac{\eta_{7,t}}{f_t} u_{hf}(c_t^h, c_t^f) + \frac{\eta_{8,t}}{f_t} u_{fh}(c_t^h, c_t^f) + \eta_{6,t}$$

$$0 = u_h(c_t^h, c_t^f) - \frac{\partial \eta_{1,t}}{\partial b} p + \frac{\eta_{9,t}}{f_t} u_{fh}(c_t^h, c_t^f) - \frac{\eta_{7,t}}{f_t} u_{hh}(c_t^h, c_t^f) + \frac{\eta_{8,t}}{f_t} u_{hh}(c_t^h, c_t^f)$$

$$0 = -g'(n_t) + z_t w_t \frac{\partial \eta_{1,t}}{\partial b} + \eta_{7,t}\frac{g''(n_t)}{f_t} + z\eta_{5,t}$$

$$\eta_{3,t}\pi_t = \int_{z_1}^{z_J}\int_{\phi}^{\infty} (B_t - b_t^h)\frac{\partial \eta_{1,t}}{\partial b} f_t + (B_t - b_t^h)\frac{\partial V_t}{\partial b}\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z$$

$$\eta_{3,t}\frac{\epsilon}{\theta} = \int_{z_1}^{z_J}\int_{\phi}^{\infty} (1-\tau^n)(z_t n_t - N_t)\left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b}\eta_{2,t}\right) - (1-\tau^n) z u_h(c^f, c^h)\eta_{7,t}\,\mathrm{d}b\,\mathrm{d}z$$

$$\dot{\eta}_{3,t} = \int_{z_1}^{z_J}\int_{\phi}^{\infty} \frac{\partial \eta_{1,t}}{\partial b}(N_t\theta\pi_t) f_t + \frac{\partial V_t}{\partial b}(N_t\theta\pi_t)\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z + \eta_{3,t}(\rho - r + \frac{\dot{N}_t}{N_t})$$

$$\eta_{4,t} = \int_{z_1}^{z_J}\int_{\phi}^{\infty} \frac{\partial \eta_{1,t}}{\partial b}\frac{\partial s_t^h}{\partial B} f_t + \frac{\partial V_t}{\partial b}\frac{\partial s_t^h}{\partial B}\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z$$

$$\eta_{5,t} = \int_{z_1}^{z_J}\int_{\phi}^{\infty} \frac{\partial \eta_{1,t}}{\partial b}\left(1 - m_t - \frac{\theta}{2}\pi_t^2\right) f_t + \frac{\partial V_t}{\partial b}\left(1 - m_t - \frac{\theta}{2}\pi_t^2\right)\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z + \frac{(\dot{\eta}_{3,t}\pi_t - \eta_{3,t}\rho\pi_t + \dot{\pi}\eta_{3,t})}{N_t}$$

$$\eta_{6,t} = \int_{z_1}^{z_J}\int_{\phi}^{\infty} \frac{\partial \eta_{1,t}}{\partial b}\tau p f_t + \frac{\partial V_t}{\partial b}\tau p \eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z$$

◂ Lagrangian

Numerical Algorithm

Algorithm is somewhat novel and a combination of Nuño & Thomas (2022) and Nuño & Moll (2018). Double fixed point structure:

- Inner loop solves for the competitive equilibrium in the standard way, for a given guess of planner multipliers and inflation
- Outer loop uses planner FOC's to verify the guess of inflation and multipliers

Similar structure for both stationary equilibrium and transitional dynamics.

◂ Numerical Results

Sources of Suboptimality Induced by Tariffs

Tariffs distort 3 margins in this model

- Intratemporal consumption distribution: Relative price of foreign consumption $\uparrow$.
- Intratemporal labor leisure margin: Consumption more expensive, induces income/substitution effects in labor/leisure margin.
- Intertemporal margin: Suppose tariffs constant. Take discrete time HANK Euler equation

$$(c_{i,t}^h)^{-\sigma}\mathcal{C}_{i,\tau} = \mathbb{E}\left[\beta R_{t+1}(c_{i,t+1}^h)^{-\sigma}\mathcal{C}_{i,\tau}\right] + \lambda_{i,t}$$

  In RANK, multiplier on constraint λ is 0 and time invariant scaling factor $\mathcal{C}_{i,\tau}$ cancels $\implies$ same EE regardless of tariff level. Can show this is not true in HANK!

  - Intuition is that consumption is more expensive, so more costly to be constrained $\implies$ save more today

FOCs

Characterizing Optimal Policy

Can derive some theoretical results about this economy, even in the absence of closed form solution for optimal policy problem:

Proposition (Inefficiency With $\tau = 0$)

Even if $\tau = 0$, the solution to the planner's problem remains inefficient (unlike in RANK), relative to both the first best allocation and the constrained efficient allocation.

Sketch of Proof

The constrained efficient allocation with $\tau = 0$ is equivalent to one where $\eta_{2,t} = \eta_{3,t} = \eta_{6,t} = \eta_{7,t} = \eta_{8,t} = \eta_{9,t} = 0$. This would necessitate that the pecuniary externalities are also 0 ($\eta_{4,t} = \eta_{5,t} = 0$) and social and private values coincide. But this is inconsistent with the planner's foc for aggregate B. Targeting

Fiscal Externalities

Proposition (Fiscal Externality)

The presence of the fiscal externality implies the socially optimal level of foreign consumption is higher than the optimal level of foreign consumption in its absence

Sketch of Proof
Socially optimal foreign consumption satisfies

$$\int_{z_1}^{z_J}\int_{\phi}^{\infty}\frac{\partial s^h}{\partial T}\frac{\partial T}{\partial C^f}\left(\frac{\partial \eta_{1,t}}{\partial b}+\frac{\partial V_t}{\partial b}\frac{\eta_{2,t}}{f_t}\right)f_t\,\mathrm{d}b\,\mathrm{d}z=\int_{z_1}^{z_J}\int_{\phi}^{\infty}\left[\frac{\partial \eta_{1,t}}{\partial b}p(1+\tau)-u_f(c_t^h,c_t^f)+\mathcal{H}_t^f\right]f_t\,\mathrm{d}b\,\mathrm{d}$$

If instead of being redistributed to households, tariff revenue was thrown into the sea, the LHS of the above would be 0 ($\frac{\partial s^h}{\partial T}\frac{\partial T}{\partial C^f}=0$). Satisfying this new equality would require lower foreign consumption.

Endogenous Relative Price

Now allow for relative price p to be endogenous and time-varying. Assume relative price takes form

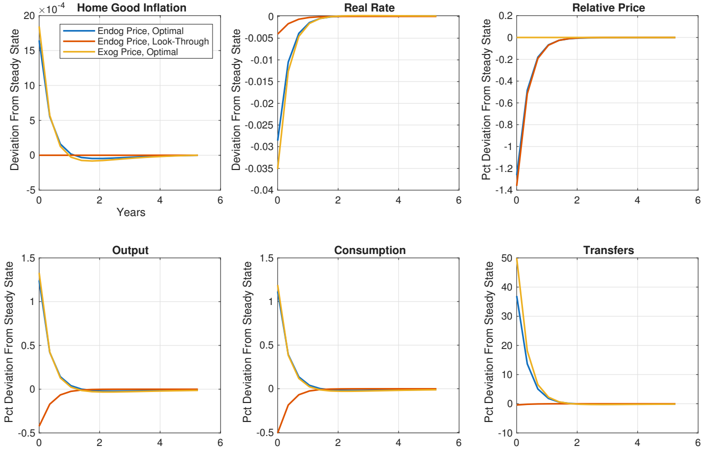
$$p_t = A(N_t - C_t^h)^{\frac{1}{\vartheta}}$$

Obtained by modeling ROW as continuum of small open economies, each produce a foreign variety aggregated into composite C^f with elasticity ϑ

Mechanism

Endogenous Relative Price

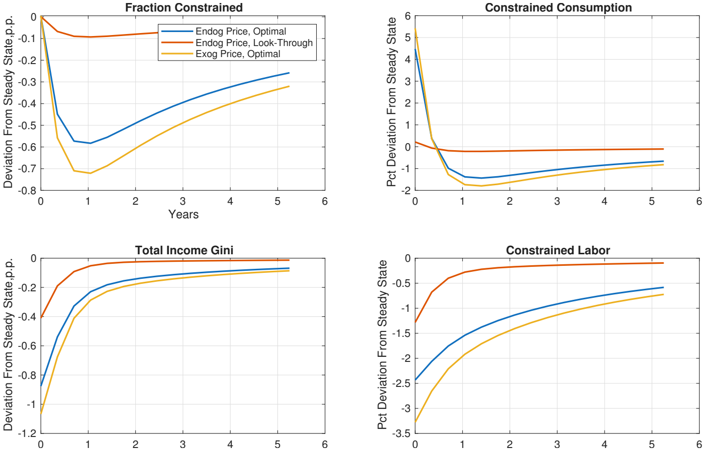
Figure: Endogenous Relative Price, Aggregates



Endogenous price $\implies$ weaker expansion; terms of trade motive relatively weak

Endogenous Relative Price

Figure: Endogenous Relative Price, Distributional Outcomes



Weaker expansion $\implies$ worse distributional outcomes

Abstracting From Redistribution

- Want to abstract from planner's redistributive motive, which is necessarily subjective
- Is planner only expanding because it's redistributive (via transfers) and they have a preference for redistribution?
- Assume planner has ad-hoc welfare function

$$\tilde{W}_0 = \int_0^\infty e^{-\rho t} \mathbb{E}_{f_0(b,z)} [u(C_t^f, C_t^h) - g(N_t)] \, \mathrm{d}t$$

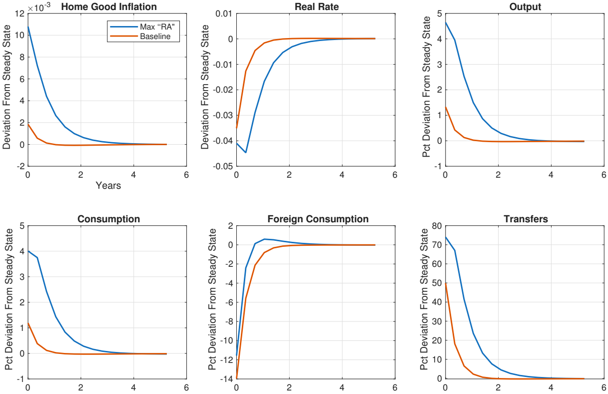
  - Maximize welfare of fictitious representative agent
  - Planner has same constraints as before
- Roughly captures a planner with traditional dual mandate

Mechanism

Abstracting From Redistribution

Calculate optimal policy response to same shock as before

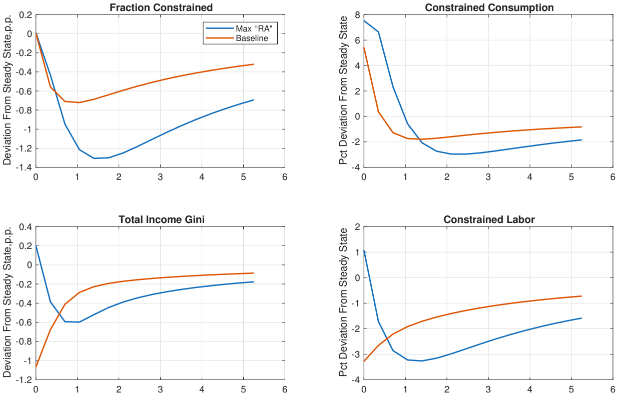
Figure: Aggregate Outcomes



Optimal policy still expansionary, but weaker than in baseline model.
Redistribution still beneficial because poor have high MPC

Abstracting From Redistribution

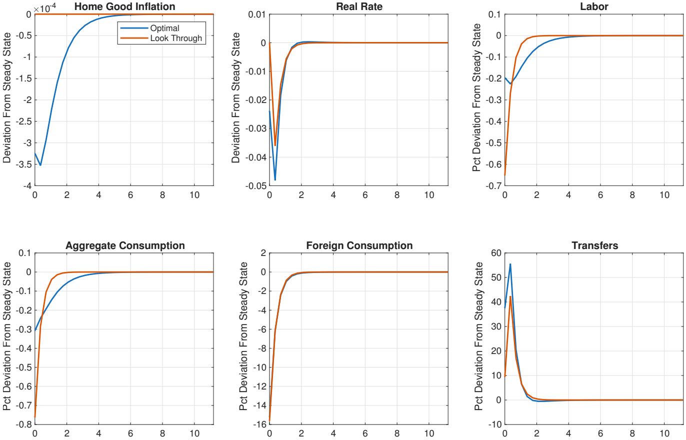
Figure: Distributional Outcomes



Outcomes of poor noticeably worse, planner doesn't *directly* want to redistribute towards them ▸ Other Numerical Experiments

Optimal vs Look Through, RANK

Figure: Optimal vs Look Through Policy, RANK



Household Choices

Planner's FOC for individual household choices

$$0 = u_f(c_t^h, c_t^f) - \frac{\partial \eta_{1,t}}{\partial b}(p(1+\tau)) + \eta_{6,t} + \frac{\eta_{9,t}}{f_t} u_{ff}(c_t^h, c_t^f) - \frac{\eta_{7,t}}{f_t} u_{hf}(c_t^h, c_t^f) + \frac{\eta_{8,t}}{f_t} u_{fh}(c_t^h, c_t^f)$$

$$0 = u_h(c_t^h, c_t^f) - \frac{\partial \eta_{1,t}}{\partial b} + \frac{\eta_{9,t}}{f_t} u_{fh}(c_t^h, c_t^f) - \frac{\eta_{7,t}}{f_t} u_{hh}(c_t^h, c_t^f) + \frac{\eta_{8,t}}{f_t} u_{hh}(c_t^h, c_t^f)$$

$$0 = -g'(n_t) + z_t w_t (1-\tau^n) \frac{\partial \eta_{1,t}}{\partial b} + z\eta_{5,t} + \eta_{7,t} \frac{g''(n_t)}{f_t}$$

Return

Planner Choice of Prices

Planner's FOC for inflation, and wages, and interest rates

$$\dot{\eta}_{3,t} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} (N_t \theta \pi_t) \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) \mathrm{d}b \, \mathrm{d}z + \eta_{3,t} (\rho - r + \frac{\dot{N}_t}{N_t})$$

$$\eta_{3,t} \frac{\epsilon}{\theta} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} (1 - \tau^n)(z_t n_t - N_t) \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) - (1 - \tau^n) z u_h (c^f, c^h) \eta_{7,t} \, \mathrm{d}b \, \mathrm{d}z$$

$$\eta_{3,t} \pi_t = \int_{z_1}^{z_J} \int_{\phi}^{\infty} (B_t - b_t) \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) \mathrm{d}b \, \mathrm{d}z$$

Return

Planner Choice of Aggregates

Final 3 FOC quantify the pecuniary externalities

$$\eta_{4,t} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) \frac{\partial s_t^h}{\partial B} \, \mathrm{d}b \, \mathrm{d}z$$

$$\eta_{5,t} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) \frac{\partial s_t^h}{\partial N} \, \mathrm{d}b \, \mathrm{d}z + \frac{(\dot{\eta}_{3,t} \pi_t - \eta_{3,t} \rho \pi_t + \dot{\pi} \eta_{3,t})}{N_t}$$

$$\eta_{6,t} = \int_{z_1}^{z_J} \int_{\phi}^{\infty} \left(\frac{\partial \eta_{1,t}}{\partial b} f_t + \frac{\partial V_t}{\partial b} \eta_{2,t} \right) \frac{\partial s_t^h}{\partial T} \frac{\partial T}{\partial C^f} \, \mathrm{d}b \, \mathrm{d}z$$

▸ Return

A Targeting Rule

Like Davila & Schaab (2023), I combine the planner's FOC to obtain a targeting rule

Proposition

Optimal interest rate policy is determined by the following equation

$$0 = \mathbb{E}_{f_t}\left[(1-m_t)u_h\right] - \mathbb{E}_{f_t}\left[\frac{\theta}{2}\pi_t^2 u_h\right] - \frac{\Omega_2}{\Omega_1}\mathbb{E}_{f_t}\left[\frac{\partial s^h}{\partial B}u_h\right] - \frac{\Omega_2}{\Omega_1}\mathbb{E}_{f_t}\left[\frac{\partial s^h}{\partial B}\frac{\partial s^h}{\partial C^f}u_h\right] +$$
$$+ \frac{1}{N_t}\left(\frac{\dot{\eta}_{3,t}}{\eta_{3,t}} - \rho + \frac{\dot{\pi}_t}{\pi_t}\right)\mathbb{E}_{f_t}\left[(B-b)u_h\right] - \frac{\Omega_2}{\Omega_1}\int\int\left[(1+\tau)\frac{\partial s^h}{\partial B}\right]u_h\eta_{2,t} +$$
$$\int\int\frac{1}{N_t}\left(\frac{\dot{\eta}_{3,t}}{\eta_{3,t}} - \rho + \frac{\dot{\pi}_t}{\pi_t}\right)\left[B-b\right]u_h\eta_{2,t} + \left[(1-m_t) - \frac{\theta}{2}\pi_t^2\right]u_h\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z$$

where Ω_1 and Ω_2 are (endogenous and generally positive) constants

The planner must balance all of these "motives", which are generically in the form of marginal utility weighted averages ▸ Other Theoretical Results

Planner Motives

- Output Gap Motive: $\mathbb{E}_{f_t}\left[(1-m_t)u_h\right]$
- Inflation Costs Motive: $\mathbb{E}_{f_t}\left[\frac{\theta}{2}\pi_t^2 u_h\right]$
- Savings Demand Motive: $\mathbb{E}_{f_t}\left[\frac{\partial s^h}{\partial B}u_h\right]$
- Tariff Revenue: $\mathbb{E}_{f_t}\left[\frac{\partial s^h}{\partial B}\frac{\partial s^h}{\partial C^f}u_h\right]$
- Redistributive $\mathbb{E}_{f_t}\left[(B-b)u_h\right]$
- Distributional Penalties:

$$\int\int\left[(1+\tau)\frac{\partial s^h}{\partial B}\right]u_h\eta_{2,t}+\frac{1}{N_t}\left(\frac{\dot{\eta}_{3,t}}{\eta_{3,t}}-\rho+\frac{\dot{\pi}_t}{\pi_t}\right)[B-b]\,u_h\eta_{2,t}+$$
$$\left[(1-m_t)-\frac{\theta}{2}\pi_t^2\right]u_h\eta_{2,t}\,\mathrm{d}b\,\mathrm{d}z$$

All of the planner's motives have an associated distributional penalty: the gains of some households must be penalized to force the planner to obey private optimality conditions

RANK vs HANK; Closed vs Open

Table: Presence of Policy Motives

Motive	Closed RANK	Open RANK	Closed HANK	Open HANK
Output Gap	✓	✓	✓	✓
Inflation Costs	✓	✓	✓	✓
Savings Demand/IES	✓	✓	✓	✓
Tariff Revenue		✓		✓
Redistribution			✓	✓
Penalties			✓	✓

Calibration

Table: Parameter Values

		Parameter	Value
Household	Effective Discount Factor	ρ	0.0417
	Risk Aversion	σ	1
	Frisch Elasticity	κ	1
	Borrowing Limit	ϕ	-0.25
	Persistence Idiosyncratic Shock	ρ_z	0.914
	Std. Idiosyncratic Shock	σ_z	0.2063
	No. of St. Dev Idiosyncratic Shock	m_z	2.0
	Preference Weight, Home Goods	ω	0.7
	Trade Elasticity	γ	2
	Relative Price	p	1
Firms	Intermediate Firm Elasticity	θ	10
	Adj. Cost Parameter	ϵ	100
Gvt.	Debt to GDP ratio	B_{perc}	1.4
	Labor Tax	τ_n	0.3
	Firm Subsidy	s	$\frac{1}{\epsilon-1}$

Very rough for now! Return

Abstracting From Redistribution

- Show some of planner's new optimality conditions, as they offer some insights into planner's decision. Planner HJB:

$$\rho\eta_{1,t} = \underbrace{u(C_t^h, C_t^f) - g(N_t)}_{\text{Flow payoff depends on aggregates}} + \mathcal{A}\eta_{1,t} + \frac{\mathrm{d}\eta_{1,t}}{\mathrm{d}t} + \eta_{4,t}(b_t^h - B_t) + \eta_{5,t}(z_t n_t - N_t) + \eta_{6,t}(c_t^f - C_t^f) + \eta_{10,t}(c_t^h - C_t^h)$$

  and envelope condition

$$\mathcal{M}\frac{\partial \eta_{1,t}}{\partial b} = \eta_4 + \eta_5 \frac{\partial n_t}{\partial b} + \eta_6 \frac{\partial c_t^f}{\partial b} + \eta_{10} \frac{\partial c_t^h}{\partial b}$$

- Before: This expression *plus* marginal private value of wealth $\frac{\partial V_t}{\partial b}$
- Now: Planner does not care about marginal private value of wealth, only how wealth affects consumption/savings/leisure decisions. Relatively flat over distribution.

Return

New Planner Motive

- Endogenous price $\Longrightarrow$ planner motive to manipulate terms of trade
- How planner reacts to terms of trade motive depends on the following expression:

$$\mathbb{E}_{f_t}\left[\frac{\partial p}{\partial N}\left(\underbrace{\tau C_t^f}_{\uparrow \text{ Transfers}} - \underbrace{(1+\tau_t)c_t^f}_{\text{Consumption Cost}}\right)u_h\right]$$

New Planner Motive

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- How planner reacts to terms of trade motive depends on the following expression:

$$\mathbb{E}_{f_t}\left[\frac{\partial p}{\partial N}\left(\underbrace{\tau C_t^f}_{\uparrow \text{ Transfers}} - \underbrace{(1+\tau_t)c_t^f}_{\text{Consumption Cost}}\right)u_h\right]$$

- Expansionary policy raises relative price
- Makes foreign good more expensive, but increases tariff revenue
- Generally will push against expansion, but if c_t^f is particularly small for high marginal utility households, may lead to increased expansion

Return

Heterogeneous ω_i

- Indirect interaction between household heterogeneity/tariffs through heterogeneous ω_i, affects all planner motives
- Rewrite marginal utility

$$u_h(c^h_{i,t}, c^f_{i,t}) = (c^h_{i,t})^{-\sigma}\mathcal{C}_{i,\tau}$$

$$\mathcal{C}_{i,\tau} = \omega_i\left(\omega_i + (1-\omega_i)\Theta_{i,\tau}^{\frac{\gamma-1}{\gamma}}\right)^{\frac{\gamma(1-\sigma)}{\gamma-1}-1}$$

$$\Theta_{i,\tau} = \left(\frac{1-\omega_i}{\omega_i(1+\tau_t)p}\right)^{\gamma}$$

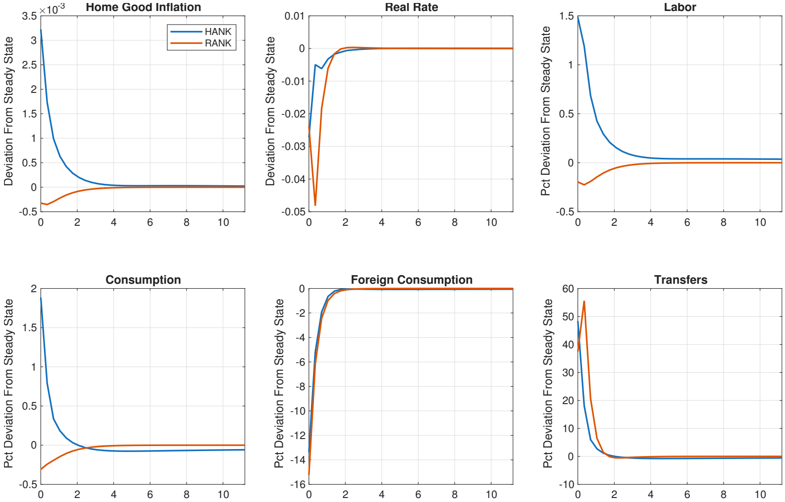
  Marginal utility of consumption $\uparrow$ in tariff
- If $\omega_i = \omega \forall i$, all household marginal utility scaled upwards by same amount
- If foreign consumption share $1-\omega_i$ depends on i, the weight placed on the welfare of high foreign consumption share households increases with the tariff
- Heterogeneity in exposure to tariffs therefore major determinant of *normative* response

▶ Return

HANK vs RANK

Compare Optimal HANK and RANK policy

Figure: Optimal Policy, HANK vs RANK



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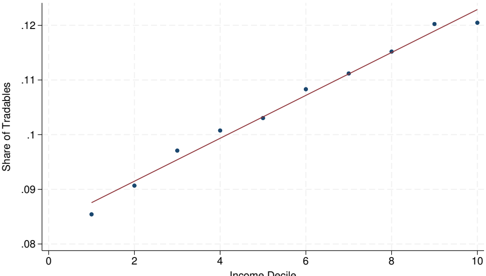
“Non-Homothetic” Preferences

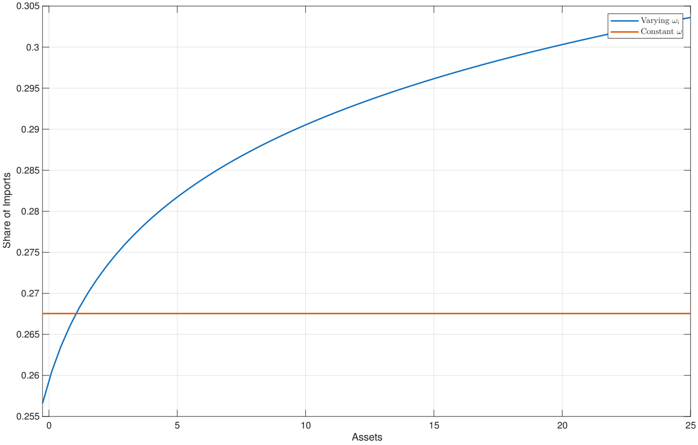
- Use CEX data from 2004-2013 to calibrate expenditure weights ω_i– generates behavior equivalent to non-homothetic preferences over home and foreign good
- Import shares obtained from I/O tables for a (fairly) disaggregated set of goods and services
- Find shares are rising in income, maybe counterintuitive but other papers have found similar result in US w/ similar methodology (Borusyak & Jaravel 2021)

Figure: Import Share on Tradables



"Non-Homothetic" Preferences

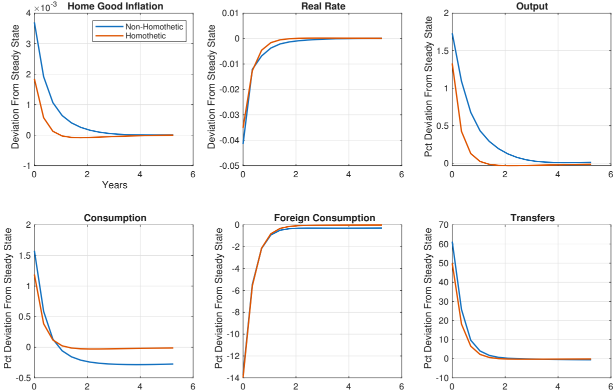
Figure: STEADY STATE IMPORT SHARES, HETEROGENEOUS ω_i



Target same *average* import share as baseline model, similar variation in shares as in data ▸ Mechanism

"Non-Homothetic" Preferences

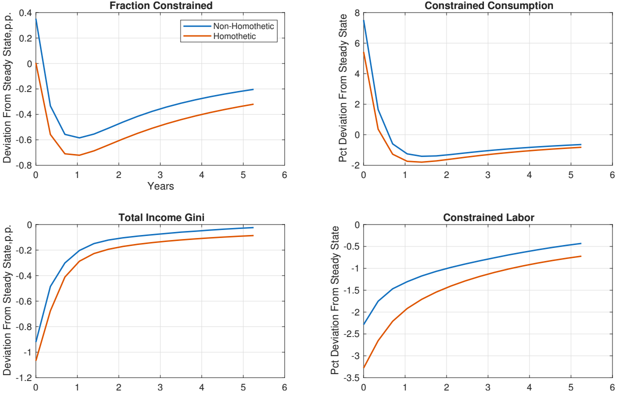
Figure: Non-Homothetic vs Homothetic, Aggregates



Expenditure channel quantitatively weak, main difference in response of aggregate output/labor

“Non-Homothetic” Preferences

Figure: Non-Homothetic vs Homothetic, Distributional



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