Exchange Rates and Monetary Policy with Heterogeneous Agents:
Sizing up the Real Income Channel

Adrien Auclert, Matt Rognlie, Martin Souchier, and Ludwig Straub

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Exchange rates and aggregate demand

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   • e.g. due to capital flows or monetary policy
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- closed economy literature: misses important features of the data!
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→ Revisit by embedding Heterogeneous Agents (HA) in NK-SOE model
  1. through which new channels are exchange rates transmitted?
  2. do these new channels amplify / mitigate transmission to output?
  3. new policy implications?
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Exciting literature: [Farhi-Werning, Cugat, De Ferra-Mitman-Romei, Giagheddu, Zhou, Kekre-Lenel, Guo-Ottonello-Perez]
What we find

- Compare to Gali-Monacelli RA. Response to exchange rate depreciation:
  - governed by two key parameters: trade elasticity $\chi$, openness $\alpha$
  - output boom, due to \textit{expenditure switching channel}, scales in $\chi$
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   • real income channel: higher import prices ($< 0$)
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   → depends on $\chi$: $HA = RA$ when $\chi = 1$, $HA < RA$ when $\chi < 1$ [similar for monetary policy]
   • realistically small $\chi$ (short-run elasticity) → contractionary depreciation
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More in the paper: monetary policy, simple model of the “J curve”, het. cons. baskets, endog. UIP spreads
Empirical evidence on contractionary depreciations

- Extend Vicondoa (2019, JIE) to include consumption

(VAR on a panel of emerging market economies with 11 real and financial variables. 25 bps unexpected contractionary shock to the U.S. int. rate, measured from Fed Funds futures contracts. 90% confidence bands.)
Roadmap

1. HANK meets Gali-Monacelli
2. Capital flows and exchange rates
3. Managing contractionary depreciations
HANK meets Gali-Monacelli
Model overview

- Discrete time, small open economy (SOE) model
  - No aggregate uncertainty + small shocks (first order perturb. wrt aggregates)

- Two goods
  - “Home”: $H$, produced at home. Price $P_{Ht}$ at home, $P^*_H$ abroad
  - “Foreign”: $F$, produced abroad. Price $P_{Ft}$ at home, $P^*_F \equiv 1$ abroad
  - Consumed in bundles. Price $P_t$ of bundle at home, $P^*_t \equiv 1$ abroad
  - Nominal rigidities in wages, allow for two “pricing paradigms” (PCP & DCP)

- Two types of agents
  - Continuum of foreign countries each have a representative foreign agent
  - Mass 1 of domestic households, subject to idiosyncratic income risk
Households’ consumption behavior

- Foreign households have fixed real C*.
Households’ consumption behavior

• Foreign households have fixed real $C^*$. Domestic HA: intertemporal problem

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

$$c_{it} + a_{it+1} = (1 + r^p_t)a_{it} + e_{it}\frac{W_t}{P_t}N_t \quad a_{it+1} \geq 0 \quad C_t \equiv \int c_{it} \, di$$

• $a_{it} =$ position in domestic mutual fund
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- with **RA:** complete markets across hh & countries \( \Rightarrow C_t^{-\sigma} = \beta (1 + r_{t+1}^p) C_{t+1}^{-\sigma} \)
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- Both domestic & foreign have CES bundle, solve intratemporal problem

$$C_{Ht} = (1 - \alpha) \left( \frac{P_{Ht}}{P_t} \right)^{-\eta} C_t \quad C_{Ht}^* = \alpha \left( \frac{P_{Ht}^*}{P^*} \right)^{-\gamma} C^*$$
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• Domestic production and market clearing: $Y_t = N_t = C_{Ht} + C_{Ht}^*$
Prices and nominal rigidities

• Exchange rates: nominal $\mathcal{E}_t$, real $Q_t \equiv \mathcal{E}_t/P_t$, ↑ is depreciation

• Standard nominal wage rigidity

\[
\pi_{wt} = \kappa_w \left( \frac{v' (N_t)}{\mu_w W_t/P_t} - 1 \right) + \beta \pi_{wt+1}
\]

[Erceg-Henderson-Levin, Auclert-Rognlie-Straub]

• For now, flexible prices everywhere else: at home ...

\[
P_{Ft} = \mathcal{E}_t \quad P_{Ht} = \mu \cdot W_t
\]

• ... and abroad (as in producer currency pricing, PCP)

\[
P_{Ht}^* = \frac{P_{Ht}}{\mathcal{E}_t}
\]

• Will consider dollar currency pricing (DCP) later
Monetary policy and assets

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

- Domestic central bank sets nominal rate $i_t$ on nominal home bonds
  - for now, it targets constant CPI-based real interest rate, $i_t = r + \pi_{t+1}$

- Interest rate on foreign bonds is $i^*_t$, shocks to $i^*_t \equiv$ shocks to $\beta$ abroad

- Mutual fund & foreigners invest freely in all assets
  - equalized $\mathbb{E}$ returns $\Rightarrow$ return on mutual fund is $r^p_{t+1} = r_t \quad \forall t \geq 0$
  - UIP holds
    $$1 + i_t = (1 + i^*_t) \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}$$
    $$1 + r = (1 + i^*_t) \frac{Q_{t+1}}{Q_t}$$
Benchmark model calibration

- Calibrate $\alpha = 0.40$ and balanced trade as in Gali-Monacelli
- Initial mutual fund portfolio invested 100% in domestic stocks
- **Allow for general substitution elasticities** $\eta, \gamma$ for now
- Quarterly persistence of $i_t^*$ and m.p. shocks $\epsilon_t$ of $\rho = 0.85$
- Standard calibration for HA part
  - EIS $\sigma^{-1} = 1$
  - target Peruvian data on MPCs and income risk
  - $\beta$ heterogeneity to get reasonable average MPC & distribution

- Note: **HA model already stationary**, no need for debt-elastic interest rate

[Schmitt-Grohe Uribe 2003]

[Hong 2020]
Capital flows and exchange rates
• Consider a temporary shock $i_t^* \uparrow$

$\rightarrow$ Effect on path of real exchange rate: (long-run PPP)

$$dQ_t = \sum_{s \geq t} \frac{di_{t+s}^*}{(1 + r)^{s-t+1}}$$

so $Q_t \uparrow$, $\frac{P_{ht}}{P_t} \downarrow$, and $\frac{P_{ht}}{\varepsilon_t} \downarrow$ (real depreciation)
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→ Effect on demand for home goods:

$$Y_t = (1 - \alpha) \left( \frac{P_{Ht}}{P_t} \right)^{-\eta} C_t + \alpha \left( \frac{P_{Ht}}{\epsilon_t} \right)^{-\gamma} C^*$$
Setup

- Consider a temporary shock $i_t^* \uparrow$

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- **Next:** RA, then HA
Textbook RA complete markets model

- In RA: complete markets + r constant ⇒ $C_t = C$

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

$$dY_t = \frac{\alpha}{1 - \alpha} \left( \underbrace{\eta (1 - \alpha)}_{H \text{ exp. switching}} + \underbrace{\gamma}_{F \text{ exp. switching}} \right) dQ_t$$

$\chi$ is trade elasticity: sum of elasticities of imports and exports to $P_F/P_H$ [as in Marshall-Lerner condition]
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• Linearize around SS with $Y = C = C^* = Q = 1$:

$$dY_t = \frac{\alpha}{1 - \alpha} \left( \eta (1 - \alpha) + \gamma \right) dQ_t$$

• Write $\chi \equiv \eta (1 - \alpha) + \gamma$, bold for time paths:

$$dC = 0 \quad \quad dY = \frac{\alpha}{1 - \alpha} \chi dQ$$

$\chi$ is **trade elasticity**: sum of elasticities of imports and exports to $P_F/P_H$

[as in Marshall-Lerner condition]
Representative agent: Exchange rate shock

\( (i^*_t \text{ shock of quarterly persistence } \rho = 0.85 \text{ and impact effect of 1% on } Q.) \)
What changes with heterogeneous agents?

- In HA, $C_t$ is affected by $\frac{W_t}{P_t}N_t$ and $r_t^p$ (through dividends):

$$\frac{W_t}{P_t}N_t = \frac{1}{\mu \frac{P_{Ht}}{P_t}}Y_t$$

$$\text{div}_t = \left(1 - \frac{1}{\mu}\right)\frac{P_{Ht}}{P_t}Y_t$$

so that only aggregate real income matters:

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- Two effects of the exchange rate
  - relative price $\frac{P_{Ht}}{P_t}$ falls → **real income channel**
  - production $Y_t$ changes → (Keynesian) **multiplier channel**

To linearize, define derivatives $M_t$, $s \equiv \frac{\partial C_t}{\partial Y_s}$ (Jacobian). These are "intertemporal MPCs" out of $Y$. Stack as $M_t$. [Auclert Rognlie Straub /two.osf/zero.osf/one.osf/eight.osf]
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[Auclert Rognlie Straub 2018]
**Proposition**

\[ \frac{dY}{dY} \text{ solves an “international Keynesian cross”} \]

\[
\frac{dY}{\frac{\alpha}{1 - \alpha} \chi dQ} - \alpha M dQ + (1 - \alpha) M dY
\]

- Use this to solve the model & decompose sources of effects on \( dY \)
## International Keynesian cross

<table>
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- Use this to solve the model & decompose sources of effects on \( dY \)
- Entire role of heterogeneity encoded in \( M \) matrix, RA corresponds to \( M = 0 \)
General equilibrium neutrality result for $\chi = 1$

- Benchmark result when $\chi = 1$:

  **Proposition**

  $\chi = 1 \implies dY^{HA} = dY^{RA} = \frac{\alpha}{1-\alpha} \chi dQ$

  *Heterogeneity is **irrelevant** for the aggregate effects of exchange rates*

- **Multiplier channel** undoes **real income channel**, $\frac{P_{Ht}}{P_t} Y_t = \text{const}$
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- Intuition: Marshall-Lerner condition, net exports unchanged if $\chi = 1$
- More generally, for $dQ \geq 0$, can show $dY^{HA} < dY^{RA}$ if and only if $\chi < 1$.  

Contractionary devaluations in output for low $\chi$

- When $\chi$ is small, the fall in consumption overwhelms expenditure switching:

→ Open economy HA model can generate **contractionary depreciations**!
HA vs incomplete markets: sizing up the real income channel

(Incomplete market model is non-stationary, here assuming $Q_\infty = Q_{-1} = 1$.)

[For incomplete markets RA model, see also: Corsetti Pesenti 2001, Tille 2001, Corsetti Dedola Leduc 2008]
Dollar currency pricing (DCP)

• So far: **producer currency pricing (PCP)**

• Alternative: **dominant (or dollar) currency pricing (DCP)**
  
  → export prices set in international currency: $P^*_{Ht} = \text{const.}$

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• Two effects in our HA model:

  1. **standard effect**: less expenditure switching by \( F \Rightarrow dY \downarrow 
  
  2. **profit effect**: greater margins from exporting \( \Rightarrow \) dividends rise, \( dY \uparrow \)

• Both can dominate, depends on magnitude of \( \chi \) vs MPC out of dividends
Managing contractionary depreciations
How should monetary policy respond to capital flows?

- Consider situation with unexpected capital outflows, $Q$ depreciates ($i_t^* \uparrow$)
- With low $\chi$, the shock itself is initially contractionary

Q: What should a monetary policymaker do to stabilize output?
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**Q What should a monetary policymaker do to stabilize output?**

• Not clear! Dilemma:
  1. Fight the **depreciation** with monetary tightening. Exacerbates contraction?
  2. Fight the **contraction** with monetary easing. Exacerbates depreciation?
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- **Next:** Investigate both rationales
  + compare weak real income channel ("AE") vs strong ("EM")
  + by varying import price pass through
Fighting the depreciation: Effect of exchange rate stabilization

- Fighting the depreciation beneficial later, **contractionary** at first!
- Trading one evil (contractionary depreciation) for another (contractionary monetary policy)  
  [Gourinchas 2018, Kalemli-Özcan 2019]
Fighting the contraction: Effect of monetary easing

- Monetary easing helps in the short run... but worsens the long run!
What policy fully stabilizes output?

- Monetary easing with weak real income channel!
Very different for with strong real income channel

- **Monetary tightening with strong real income channel!**
- Stable (or even appreciating...) exchange rate
- Could explain why monetary policy typically less countercyclical in EMs
Conclusion
Conclusion

**HA + NK-SOE ⇒**

- real income channel
- contractionary depreciation for plausibly small short-run trade elasticity
- new perspectives on navigating contractionary depreciations

+ more results in the paper: monetary policy, J curve, het. cons baskets, UIP wedges, …
Preferences

• In baseline, consumption $c_{it}$ aggregates $H$ and $F$ with elasticity $\eta$,

$$c_{it} = \left(1 - \alpha\right)^{\frac{1}{\eta}} \left(\frac{c_{iHt}}{c_{iFt}}\right)^{\frac{\eta - 1}{\eta}} + \alpha^{\frac{1}{\eta}} \left(\frac{c_{iFt}}{c_{iHt}}\right)^{\frac{\eta - 1}{\eta}}$$

and preferences across goods $j$ produced in countries $k$ are

$$c_{iHt} = \left(\int_0^1 c_{iHt} (j) \left(\frac{\epsilon - 1}{\epsilon}\right) dj\right)^{\frac{1}{\epsilon + 1}} c_{iFt} = \left(\int_0^1 c_{ikt} \left(\frac{\gamma - 1}{\gamma}\right) dk\right)^{\frac{1}{\gamma + 1}} c_{ikt} = \left(\int_0^1 c_{ikt} (j) \left(\frac{\epsilon - 1}{\epsilon}\right) dj\right)^{\frac{1}{\epsilon + 1}}$$

with $\epsilon > 1$, $\gamma > 0$ and $\eta > 0$. Budget constraint:

$$\int_0^1 P_{Ht} (j) c_{iHt} (j) dj + \int_0^1 \int_0^1 P_{kt} (j) c_{ikt} (j) djd k + a_{it+1} \leq (1 + r^p_t) a_{it} + e_{it} \frac{W_t}{P_t} N_t$$

• Demand for good $j$ in country $k$ by consumer $i$:

$$c_{ikt} (j) = \alpha \left(\frac{P_{kt} (j)}{P_{kt}}\right)^{-\epsilon} \left(\frac{P_{kt}}{P_{ft}}\right)^{-\gamma} \left(\frac{P_{ft}}{P_t}\right)^{-\eta} c_{it}$$
Contractionary devaluations in output for low $\chi$

Output, RA complete markets

Output, RA incomplete markets

Percent of s.s. vs. Quarters
Two-agent model

TA model

HA model

\( \chi = 1 \)
\( \chi = 0.5 \)
\( \chi = 0.1 \)
The “stealing demand from the future” effect

- The effect comes from a **current account deficit** after monetary easing:
  1. Real income effect: import prices rise
  2. Interest rate effect: agents front-load spending (intertemporal substitution!)
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- Effects are only balanced by increased exports if $\chi = 2 - \alpha$. 
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- CA deficit $\leadsto$ falling NFA $\leadsto$ agents eventually spend less to rebuild NFA

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"Stealing demand from future" is similar to recent closed economy papers [McKay Wieland /zero.osf/zero.osf/zero.osf, Caballero Simsek /zero.osf/zero.osf/zero.osf, Mian Straub Su/f_i /zero.osf/zero.osf/one.osf] ... but one big difference: monetary easing here can have negative NPV. Present value ($dY$) $< 0$ $\iff$ $\chi < 1 - \alpha$. 

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The “stealing demand from the future” effect

• The effect comes from a **current account deficit** after monetary easing:
  1. Real income effect: import prices rise
  2. Interest rate effect: agents front-load spending (intertemporal substitution!)
• Effects are only balanced by increased exports if $\chi = 2 - \alpha$.
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... but one big difference: monetary easing here can have negative NPV

Present value $(dY) < 0 \iff \chi < 1 - \alpha$
1. Nonhomothetic Stone-Geary to capture heterogeneity in real income effect

\[ C_t = \left( (1 - \alpha)^{\frac{1}{\eta}} C_{Ht}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} (C_{Ft} - C_F)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}} \]

2. Realistic passthrough of exchange rate to domestic & foreign consumer prices
   - Add domestic price rigidities

\[ \pi_{Ht} = \kappa_H \left( \frac{\mu_H W_t / Z_t}{P_{Ht}} - 1 \right) + \beta \pi_{Ht+1} \]

   - Add flexibility of dollar export prices

\[ \pi_{Ht}^* = \kappa_X \left( \frac{P_{Ht} / \varepsilon_t}{P_{Ht}^*} - 1 \right) + \beta \pi_{Ht+1}^* \]

   - Allow foreign retailers to repatriate profits from dollar sales

3. Allow for currency mismatch in NFA (\( f_Y \equiv \text{asset-liability mismatch/GDP} \))
   - Debt held by households via mutual fund, or by government and then rebated
Benchmark model fit

**MPC**

**Share of aggregate consumption**

Benchmark

Data
### Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Benchmark</th>
<th>Quantitative</th>
<th>Parameter</th>
<th>Benchmark</th>
<th>Quantitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma)</td>
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<td>1</td>
<td>(\mu)</td>
<td>1.03</td>
<td>1.028</td>
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<tr>
<td>(\psi)</td>
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<td>s.s. nfa</td>
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<tr>
<td>(\eta)</td>
<td>(\frac{0.1,0.5,1,2-\alpha}{2-\alpha})</td>
<td>4</td>
<td>(\sigma_e)</td>
<td>0.6</td>
<td>0.6</td>
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<tr>
<td>(\gamma)</td>
<td>(\eta)</td>
<td>(\eta)</td>
<td>(\rho_e)</td>
<td>0.92</td>
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<td>(\theta_w)</td>
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<tr>
<td>(\beta)</td>
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<td>0.953</td>
<td>(\theta_p)</td>
<td>0</td>
<td>0.75</td>
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<tr>
<td>(\Delta)</td>
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<td>0.067</td>
<td>(\theta_X)</td>
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<tr>
<td>(\alpha)</td>
<td>0.4</td>
<td>0.323</td>
<td>(\theta_I)</td>
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<td>0</td>
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<tr>
<td>(\zeta)</td>
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<td>0.114</td>
<td>(\phi)</td>
<td>n.a.</td>
<td>1.5</td>
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## Calibration targets

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Benchmark model</th>
<th>Quantitative Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average MPC</td>
<td>0.632</td>
<td>0.636</td>
<td>0.637</td>
</tr>
<tr>
<td>Std of MPC</td>
<td>0.152</td>
<td>0.151</td>
<td>0.149</td>
</tr>
<tr>
<td>Average tradable share</td>
<td>0.400</td>
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<tr>
<td>Std of tradable share</td>
<td>0.042</td>
<td>n.a.</td>
<td>0.042</td>
</tr>
</tbody>
</table>
Calibration outcomes

MPC

Import share

Share of aggregate consumption

Import share against MPC
Delayed substitution model

- Ratio $x = \frac{CH}{CF}$ is a state variable, updated a la Calvo with parameter $\theta$

- Static outcome ($\theta = 0$)
  \[ x_t = \frac{\alpha}{1 - \alpha} \left( \frac{P_{Ht}}{P_{Ft}} \right)^{-\eta} \]

- Dynamic ($\theta > 0$) outcome with log utility [general case in paper]
  \[
  d \log x_t^* = -\eta (1 - \beta \theta) d \log \frac{P_{Ht}}{P_{Ft}} + \beta \theta d \log x_{t+1}^*
  \]
  \[
  d \log x_t = (1 - \theta) d \log x_t^* + \theta d \log x_{t-1}
  \]

  Long-run elasticity is $\eta$, short-run is $< \eta$, depends on shock duration

- Same assumption for $\gamma$ (exports slow to adjust)
Calibration of $\eta$, $\gamma$ and $\theta$

- Use tariff change evidence in Boehm, Levchenko, and Pandalai-Nayar
• Use tariff change evidence in Boehm, Levchenko, and Pandalai-Nayar
Quantitative model behaves like a low-elasticity model

Consumption $C$

Output volume $Y$

Net exports $NX$

Net foreign asset position $nfa$

Real exchange rate $Q$

Real interest rate $r$
Comparative statics

<table>
<thead>
<tr>
<th></th>
<th>Bench.</th>
<th>Low $\alpha$</th>
<th>High MPC</th>
<th>Full DCP</th>
<th>Low passthru</th>
<th>Homothetic</th>
<th>High ST elast.</th>
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</thead>
<tbody>
<tr>
<td>$dY_0$</td>
<td>- 0.36</td>
<td>- 0.27</td>
<td>- 0.40</td>
<td>- 0.31</td>
<td>- 0.09</td>
<td>- 0.32</td>
<td>- 0.30</td>
</tr>
<tr>
<td>PDV of $dY$</td>
<td>- 2.03</td>
<td>- 2.38</td>
<td>- 1.15</td>
<td>- 1.25</td>
<td>- 1.01</td>
<td>- 1.51</td>
<td>- 0.25</td>
</tr>
</tbody>
</table>

(Response to $i_t^*$ shock of quarterly persistence $\rho = 0.8$ and impact effect of 1% on $Q$.)
Assuming a gross currency debt position in the NFA of 50% of annual GDP:

<table>
<thead>
<tr>
<th></th>
<th>Benchmark</th>
<th>Mutual fund</th>
<th>Government</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>lump-sum</td>
<td>prop tax</td>
<td>+ deficit-fin.</td>
</tr>
<tr>
<td>$dY_0$</td>
<td>- 0.71</td>
<td>- 0.63</td>
<td>- 0.46</td>
</tr>
<tr>
<td>PDV of $dY$</td>
<td>- 3.18</td>
<td>- 3.17</td>
<td>- 3.21</td>
</tr>
</tbody>
</table>

(Response to $i_t^*$ shock of quarterly persistence $\rho = 0.8$ and impact effect of 1% on $Q$.)
Amplification from non-homothetic demand

Output

Percent of s.s.

Homothetic model
Non-homothetic model

Quarters

Foreign interest rate $r^*$

Percent

Quarters
Amplification from currency mismatch on balance sheet

Household balance sheets

Government debt (50% of annual GDP)

\(dY\), percent of s.s.

Quarters

Benchmark

25% of annual GDP

50% of annual GDP

Proportional (\(\lambda = 0\)), deficit (\(\rho_B = 0.8\))

Proportional (\(\lambda = 0\)), \(t = 0\) tax. (\(\rho_B = 0\))

Lump-sum (\(\lambda = 1\)), \(t = 0\) tax. (\(\rho_B = 0\))