The Transmission of Foreign Demand Shocks

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Motivation

- Many believe **shocks to foreign demand** are important for business cycle fluctuations in small open economies...
- ...but often not so in DSGE models (Justiniano and Preston 2010)

Motivation

- Many believe **shocks to foreign demand** are important for business cycle fluctuations in small open economies...
- ...but often not so in DSGE models (Justiniano and Preston 2010)
- **Why this discrepancy?**
  - *What is the transmission mechanism of foreign demand shocks?*
  - *What can stabilization policies achieve in the face of foreign demand shocks?*
- **This paper**: An **open-economy** Heterogeneous Agent New Keynesian model (HANK) compared to a Representative Agent New Keynesian (RANK) model

Insights

1. **Data:** Drop in foreign demand leads to drop in consumption in SOE
2. **RANK:** Counter-factually implies increase in consumption
   + counter-factual negative covariance of tradable/non-tradable consumption
3. **HANK:** Implies drop in consumption, consistent with the data
   $\Rightarrow$ *larger role for demand shocks in international business cycles*
4. Fiscal policy poor at stabilizing foreign demand shocks: It over-stimulates the non-tradable sector and under-stimulates the tradable sector

   Monetary policy or (fiscal) devaluations work by depreciating the terms of trade

Intuition: Decomposition of domestic consumption

- **RANK:** Gali and Monacelli (2005) (no international risk-sharing)
  HANK: + incomplete domestic asset market
- Response of domestic consumption $\boldsymbol{C}$ to foreign demand $\boldsymbol{Y}^*$:

$$d\boldsymbol{C} = \left[\boldsymbol{M} + \frac{\alpha}{1-\alpha}\boldsymbol{M}\boldsymbol{G}^{-Q,Y} + \boldsymbol{M}^r\boldsymbol{G}^{r,Y}\right]\boldsymbol{G}^{Y,Y^*}d\boldsymbol{Y}^*.$$

  - $d\boldsymbol{X} = (dX_0, dX_1, \dots)'$: Sequence of deviations from steady state of X
  - $\boldsymbol{G}^{X,Z}$ captures GE response of X to Z, "$\boldsymbol{G}^{X,Z} > 0$"
  - Y is GDP, Q is real exchange rate (RER), r is real interest rate, $1-\alpha$ is home bias
  - $\boldsymbol{M}$: Intertemporal MPCs, "$\boldsymbol{M} \geq 0$"
  - $\boldsymbol{M}^r$: Consumption response to the real interest rate, "$\boldsymbol{M}^r < 0$"

HANK and RANK imply opposite sign of consumption

$$d\boldsymbol{C} = \Big[\overbrace{\boldsymbol{M}}^{\text{Labor income}>0} + \overbrace{\frac{\alpha}{1-\alpha}\boldsymbol{M}\boldsymbol{G}^{-Q,Y}}^{\text{Real income}>0} + \overbrace{\boldsymbol{M}^{r}\boldsymbol{G}^{r,Y}}^{\text{Intertemporal sub.}<0} \Big] \overbrace{\boldsymbol{G}^{Y,Y^*} d\boldsymbol{Y}^*}^{<0}.$$

- **RANK:** MPCs are very close to zero, i.e. $M \approx 0 \quad \Rightarrow \quad \underline{dC > 0}$
  - **Intertemporal sub.:** Lower foreign demand $\Rightarrow$ lower domestic inflation $\Rightarrow$ CB lowers rates $\Rightarrow$ higher consumption
- **HANK:** Realistic MPCs, i.e. $M > 0 \quad \Rightarrow \quad \underline{dC < 0}$
  - **Labor income:** Lower foreign demand $\Rightarrow$ lower labor income for domestic workers $\Rightarrow$ lower consumption
  - **Real income:** Lower foreign demand $\Rightarrow$ depreciation of the RER $\Rightarrow$ domestic households are poorer in real terms $\Rightarrow$ lower consumption

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Related literature

1. **Empirical studies of foreign demand shocks:** Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016). *Confirm and summarize existing results with new method*

2. **Foreign demand shocks in small to large-scale RANK models:** Lubik and Schorfheide (2007), Justiniano and Preston (2010), Christiano, Trabandt, and Walentin (2011), Adolfson et al. (2013), and Bergholt (2015). *Incomplete domestic asset market*

3. **Open-economy HANK models**: De Ferra, Mitman, and Romei (2020), Giagheddu (2020), Auclert et al. (2021b), Zhou (2021), Bayer et al. (2022), Chen et al. (2022), Guo, Ottonello, and Perez (2020), and Oskolkov (2021). *Foreign demand shock*

4. **Fiscal policy and fiscal devaluations:** Farhi, Gopinath, and Itskhoki (2014), Auclert, Rognlie, and Straub (2018), Hagedorn, Manovskii, and Mitman (2019). *SOE HANK*

Roadmap

Data

Model

Calibration

Transmission

Policy

Conclusion

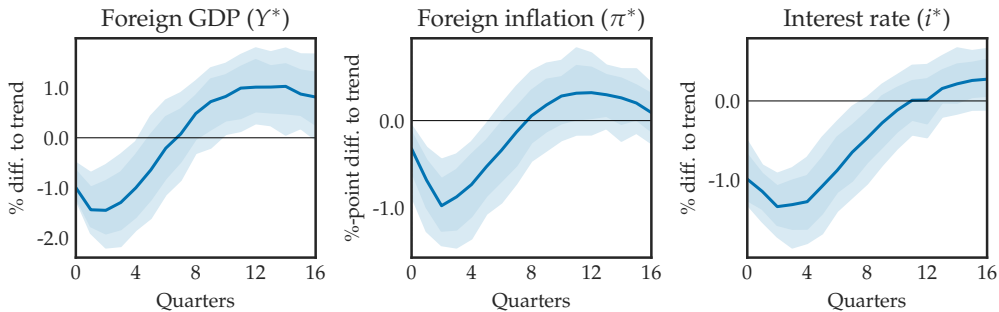
Empirical strategy

- We use **pooled local projections** and identify foreign demand shocks using **sign and zero restrictions** based on Plagborg-Møller and Wolf (2021)
- **Identification** builds on two steps:
  1. Standard **small open economy (SOE)** assumption: The domestic economy is affected by the foreign economy, but *not* vice versa
  2. **Sign restrictions on the foreign variables**: A foreign demand shock moves foreign output, inflation, and the nominal interest rate in the *same direction*

Data

- **Data:** 38 OECD countries from when quarterly data is available to 2019:Q4
  - Small open economies (SOEs): 31
  - Remaining: G7 countries (only for constructing "foreign economy")
- **Trade-weighted country i specific "foreign economy"** $(Y^*_{i,t}, \pi^*_{i,t}, i^*_{i,t})'$ (excluding foreign countries where country i is "central" trading partner)
- Variables are de-trended

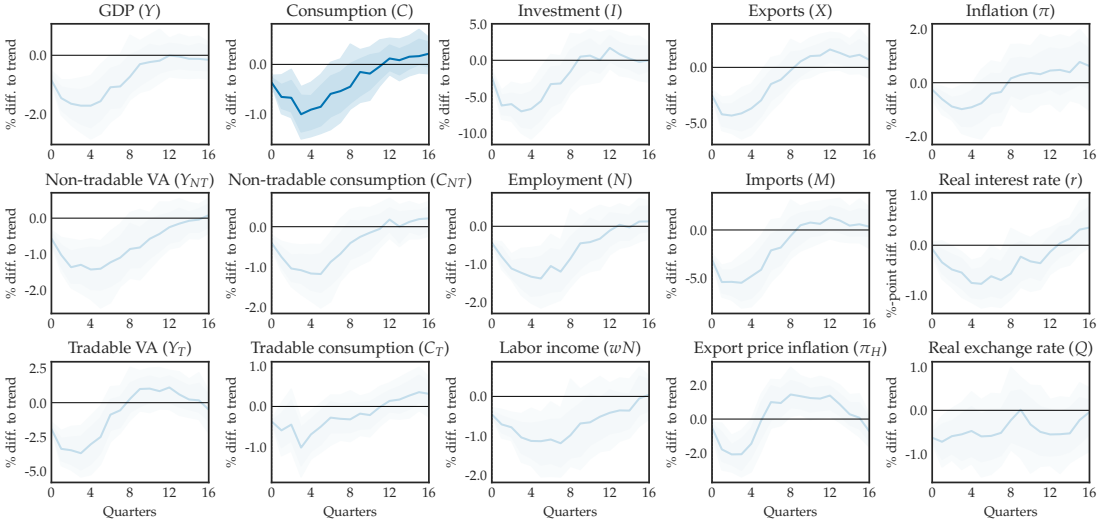
Response of the foreign economy



3 main empirical observations

- Empirical evidence for **domestic economy** yields 3 main observations:
  I. Consumption falls
  II. Consumption of tradables and non-tradables both fall
  III. Foreign demand important for variance of domestic variables
- Similar results when changing a battery of choices

Response of the domestic economy



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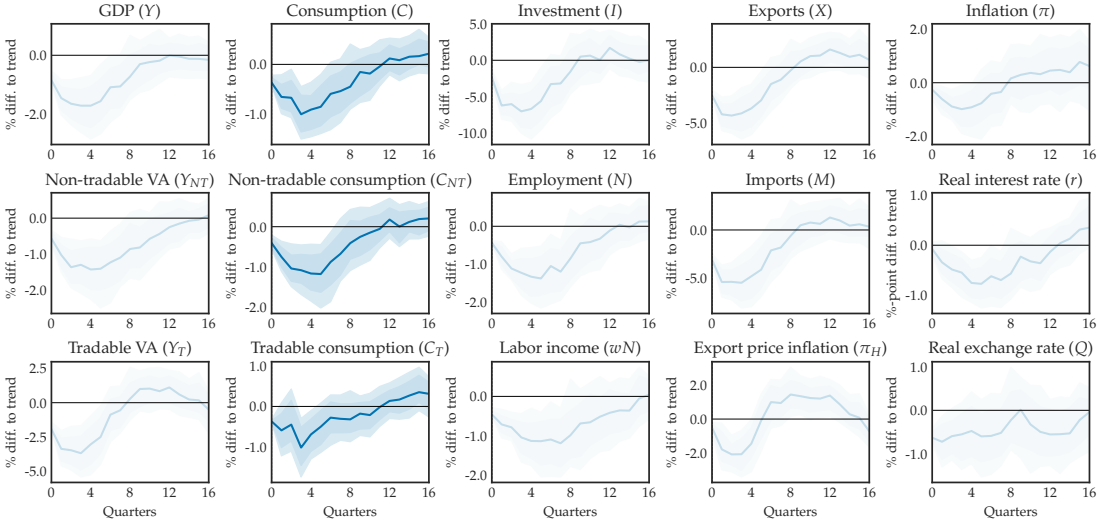

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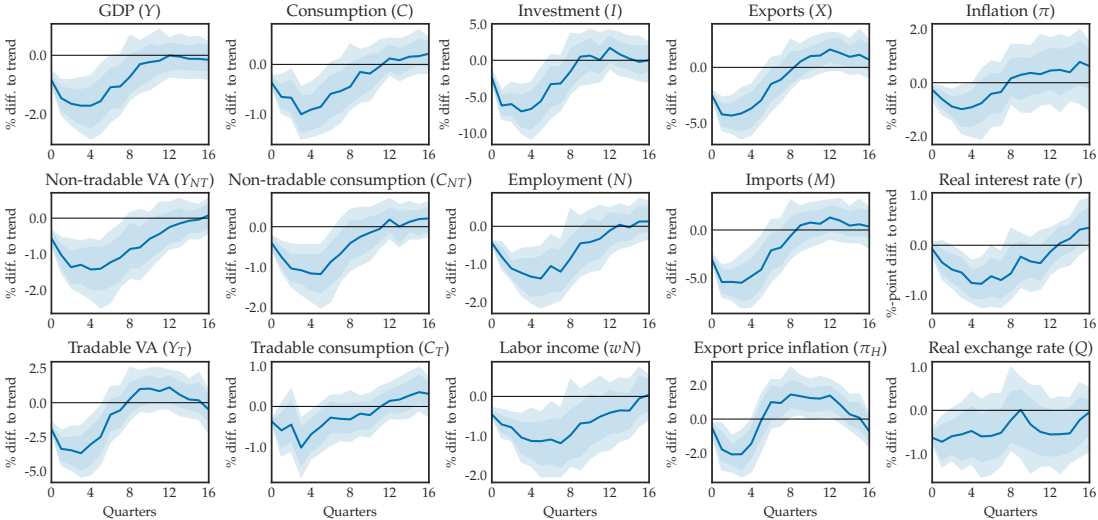

Foreign demand shocks are important

- **Q:** How much of the domestic variance is explained by the shock?
- **A:** Variance decomposition

Y	C
29.8	22.3
(17.7, 44.4)	(8.5, 26.8)

Table: Forecast error variance decomposition (FEVD) of foreign demand shocks

Roadmap

Overview of model

Gali and Monacelli (2005) with **incomplete asset markets**

- Tradable good and non-tradable good
- Government follows a fiscal rule with initially fixed tax rate
- Central bank follows an inertial Taylor rule in PPI (or fixed exchange rate)
- Input-output structure in production with capital + labor + intermediate goods
- Price and wage stickiness (with indexation)
- Capital and labor adjustment costs
- Dynamic export elasticity (Drozd, Kolbin, and Nosal 2021)
- Costly external financing of investment (Gomes 2001)
- Portfolio adjustment costs $\rightarrow$ UIP deviations (Bacchetta and Van Wincoop 2021)

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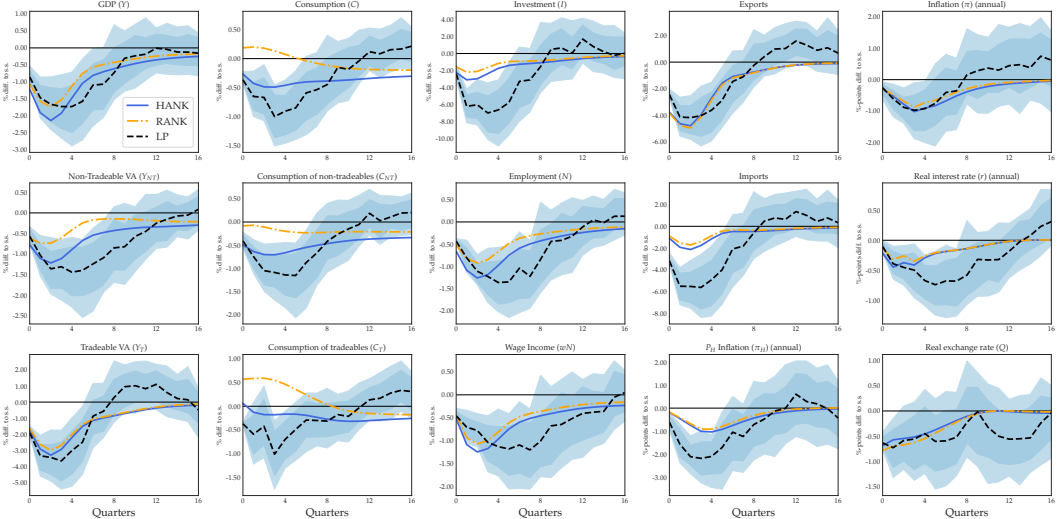
Step 1: External Calibration (details)

- **Ratios:** Calibrate to average OECD small open economy (government, expenditure shares, IO)
- **Households:** Discount factors match $\frac{\text{wealth}}{\text{income}} = 10$ and annual MPC $= 0.51$
  Standard preferences and income process
- **Elasticities in production, mark-ups, interest rate:**
  Calibrate to standard values

Step 2: IRF matching to LP (details)

- **Shock:** Feed in foreign demand shock from LP
- **Targets:**
  - Key variables from empirical LP
  - **Excluding** consumption, both aggregate and tradable/non-tradable
- **Parameters:** Price adjustment costs, real adjustment costs, monetary policy rule, demand and export elasticities

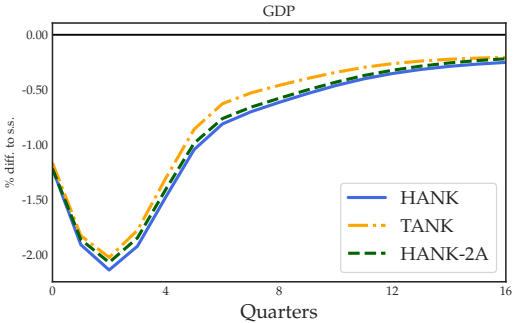
Fit of HANK and RANK

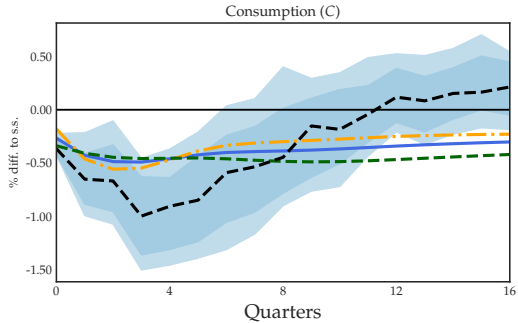


Takeaways from fit

- **Only HANK gives fall in consumption**.
- **Missing:**
  1. Some responses too weak
  2. Some responses not persistent enough
- **Bells-and-whistles:**
  - **Dynamic export elasticity** $\rightarrow$ Too short-lived export response
  - **Costly external financing** $\rightarrow$ Too weak investment response
  - **Portfolio adjustment cost** $\rightarrow$ Too weak real exchange rate
  - **Input-output** $\rightarrow$ Too weak non-tradeable sector VA

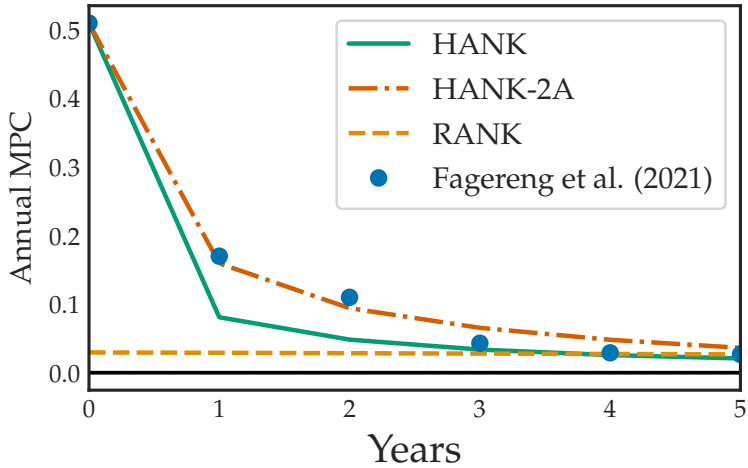
TANK or Two-Asset-HANK changes little



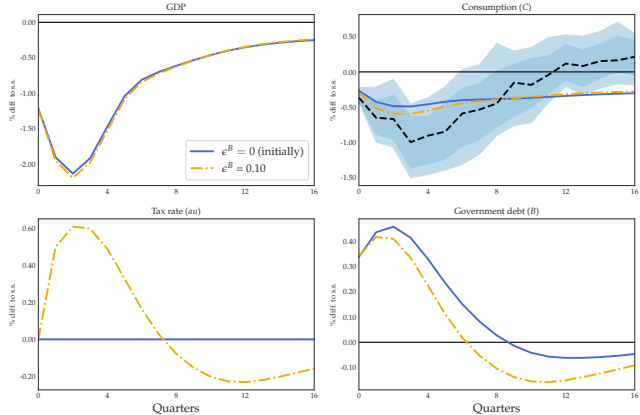


- **Two-agents (TANK)** $\rightarrow$ Less persistence in consumption.
- **Two-assets (HANK-2A)** $\rightarrow$ More persistence in consumption.

Two-Asset-HANK matches intertemporal MPCs



Alternative debt rules $\tau = \tau_{ss} + \epsilon^B \frac{B_{t-1} - B_{ss}}{Y_{ss}}$

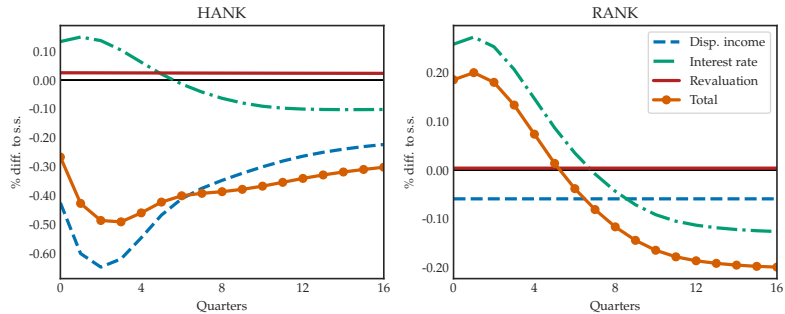


Consumption falls more, but tax rate increases...

Roadmap

I. Opposite consumption sign in HANK and RANK

- Decomposition of consumption response:



- **RANK:** Response is determined by r through intertemporal substitution
- **HANK:** Response is driven by changes in disposable income

II. Co-movement of tradables vs. non-tradables

- Empirically, we observed that $\text{Cov}(C_T, C_{NT}) > 0$
- In both HANK and RANK, CES demand for C_T, C_{NT} gives:

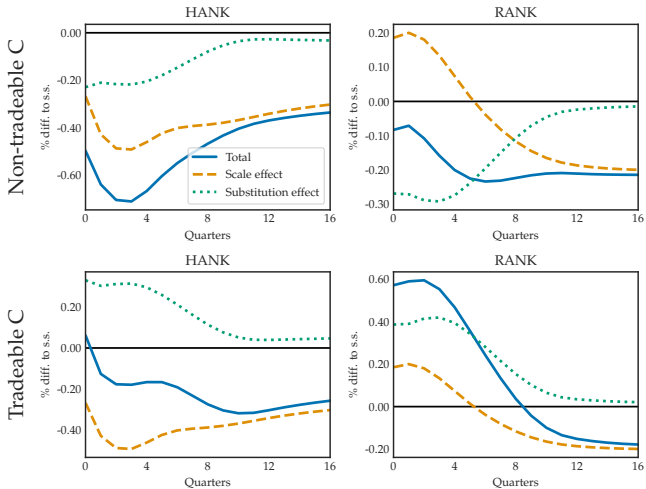
$$dC_T = \underbrace{-\alpha_T \eta_{T,NT} d\left(\frac{P_T}{P}\right)}_{\text{substitution effect}} + \underbrace{\alpha_T dC}_{\text{scale effect}},$$

$$dC_{NT} = \underbrace{-(1-\alpha_T) \eta_{T,NT} d\left(\frac{P_{NT}}{P}\right)}_{\text{substitution effect}} + \underbrace{(1-\alpha_T) dC}_{\text{scale effect}}.$$

- Positive co-movement requires that the scale effect ($C \downarrow$) dominates the substitution effect from movements in relative prices ($\frac{P_T}{P_{NT}} \downarrow$)

II. Co-movement of tradables vs. non-tradables

- **RANK:** Substitution effect $>$ scale effect
  $\Rightarrow \text{Cov}(C_T, C_{NT}) < 0$
- **HANK**: Scale effect $>$ substitution effect
  $\Rightarrow \text{Cov}(C_T, C_{NT}) > 0$



III. Can foreign demand shocks be important?

- Justiniano and Preston (2010): Foreign shocks explain $< 5\%$ of SOE variables
- **Unconditional data**: $\text{Cov}(C_t, C_t^*)$ and $\text{Cov}(C_t, Y_t)$ are strongly positive
- **Our model results show** (following a foreign demand shock):
  - **RANK:** $\text{Cov}(C_t, C_t^*) < 0$ and $\text{Cov}(C_t, Y_t) < 0$
  - **HANK:** $\text{Cov}(C_t, C_t^*) > 0$ and $\text{Cov}(C_t, Y_t) > 0$
- **HANK**: *Foreign demand shocks are better suited to account for domestic business-cycle fluctuations of international origin*

The case of a fixed exchange rate

- **Floating:** Taylor rule is crucial to obtain $i_t \downarrow$, $r_t \downarrow$, and $C_t \uparrow$ in RANK
- **Fixed**: Nominal UIP condition + Fisher equation give the same:

$$1 + i_t = 1 + i_t^* \quad \Leftrightarrow \quad 1 + r_t = \frac{1 + i_t^*}{1 + \pi_{t+1}}.$$

  - Our empirical foreign demand shock includes $i_t^* \downarrow$
  - UIP forces domestic central bank to lower i_t, so $r_t \downarrow$ (unless $\pi_{t+1} \downarrow\downarrow$)
  - Our model-based findings are confirmed with a fixed exchange rate

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Stabilization policy

- **One aim of stabilization policy**: Help households smooth consumption irrespective of which sector they work in
- **Problem**: Different shocks affect households' income differently depending on which sector they work in

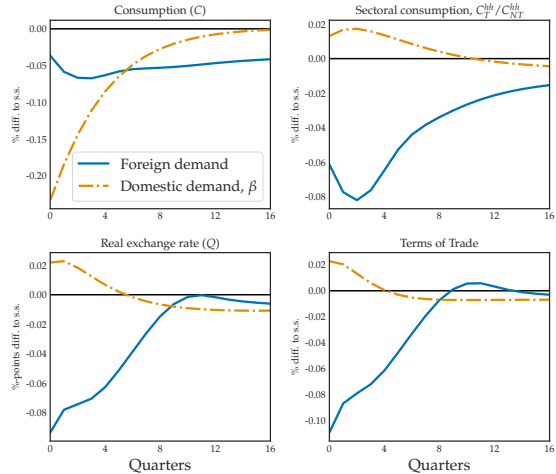
What happens to C_T^{hh} / C_{NT}^{hh}?

C_T^{hh} = consumption of households in *tradeable* sector

C_{NT}^{hh} = consumption of households in *non-tradeable* sector

Compare domestic and foreign demand shocks

- **Scaling:** Cumulative impact on consumption of -1%
- **Foreign demand ↓:** Households in *tradeables* hit worst. Appreciation.
- **Domestic demand ↓ (β ↑):** Households in *non-tradeables* hit worst. Depreciation.



Cumulative multipliers of shocks and policies

	C^{hh}	C_T^{hh}	C_{NT}^{hh}	RER	ToT
Foreign demand	-1.00	-1.42	-0.68	$\downarrow$	$\downarrow$
Domestic demand, β	-1.00	-0.96	-1.03	$\uparrow$	$\uparrow$
Government spending, G	1.00	0.55	1.34	$\downarrow$	$\downarrow$
Uniform transfers, T	1.00	0.60	1.31	$\downarrow$	$\downarrow$
Monetary policy, i	1.00	1.49	0.62	$\uparrow$	$\uparrow$

- **Domestic demand:** Mix of fiscal and monetary policy required for balance
- **Foreign demand:** Monetary policy get balance right alone

Options in fixed exchange regime

- **Nominal devaluation**: Works directly due to depreciation.
  May not be a viable or attractive option in practice.
- **Fiscal devaluation** a la Farhi, Gopinath, and Itskhoki (2014) also works well:
  1. Employment and investment subsidy ↑ (reducing domestic production costs)
  2. VAT ↑ (affects terms of trade as levied on imports, but not exports)

	C^{hh}	C_T^{hh}	C_{NT}^{hh}	RER	ToT
Foreign demand	-1.00	-1.38	-0.71	↓	↓
Domestic demand, β	-1.00	-0.90	-1.08	↑	↑
Nominal devaluation	1.00	2.02	0.22	↑	↑
Fiscal devaluation	1.00	1.94	0.28	↓	↑

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Conclusion

- **Data:** Foreign demand shocks induce positive co-movement of consumption across countries and across types of goods in the data and are important drivers of business cycles
- **Theory:** An open-economy HANK model can account for these findings, while standard RANK models cannot
- **Policy:** Conventional fiscal policy tools under-stimulate the tradable sector and are not well-suited to counteract such shocks
  - Challenge for countries with peg / currency union
  - A fiscal devaluation may be a way out for such countries

Empirical strategy (Back)

- **IRFs** $\{\beta_h\}_{h=0}^{H}$ estimated (with OLS) from **pooled LP regressions**:

$$Z_{j,t+h} = \beta_h X_{j,t} + \sum_{k=1}^{p} \delta_{h,k} X_{j,t-k} + \varepsilon_{j,t,h},$$

  where $X_{j,t} = (Z_{j,t}, Y^*_{j,t}, \pi^*_{j,t}, i^*_{j,t})'$, and $Z_{j,t}$ denote domestic variables (e.g., GDP), and $Y^*_{j,t}, \pi^*_{j,t}, i^*_{j,t}$ denote country-specific foreign variables.
- We only **keep rotations of the IRFs satisfying our identifying assumptions**.
- We similarly estimate responses for the country-specific foreign variables.

Sign restrictions: Implementation (Back)

- Our implementation of sign restrictions builds on Rubio-Ramírez, Waggoner, and Zha (2010) and Arias, Rubio-Ramírez, and Waggoner (2018).
- The 4×4 matrix of horizon-h impulse responses is:

$$C_h \equiv \begin{pmatrix} \beta_{1,h} & \beta^Y_{1,h} & \beta^\pi_{1,h} & \beta^r_{1,h} \\ \beta_{2,h} & \beta^Y_{2,h} & \beta^\pi_{2,h} & \beta^r_{2,h} \\ \beta_{3,h} & \beta^Y_{3,h} & \beta^\pi_{3,h} & \beta^r_{3,h} \\ \beta_{4,h} & \beta^Y_{4,h} & \beta^\pi_{4,h} & \beta^r_{4,h} \end{pmatrix}$$

- The structural horizon-h impulse response matrix is $\Theta_h = C_h B Q$, where Q is an 4×4 orthogonal matrix and BB' is the Cholesky decomposition of the covariance matrix.

Sign restrictions: Implementation (Back)

1. Draw Q from the subspace consistent with the imposed zero restrictions.
2. Use Q to compute $\Theta_h = C_h B Q$.
3. If the following conditions are satisfied, keep the draw of Q:

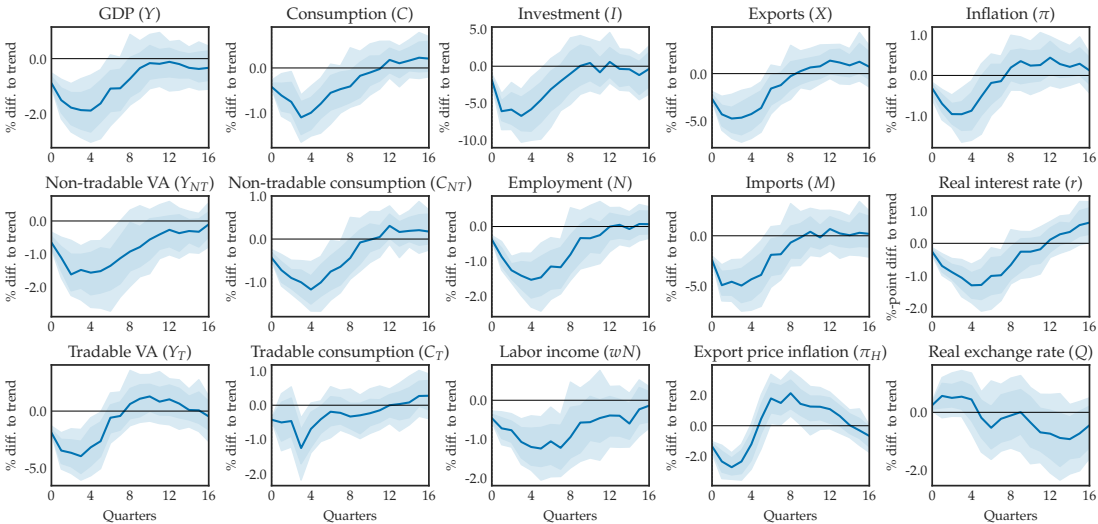
$$S_j \Theta e_j \geq 0, \quad j = 1, 2, 3, 4,$$
$$Z_j \Theta e_j = 0, \quad j = 1, 2, 3, 4,$$

   where $\Theta \equiv (\Theta_0', \Theta_1', \ldots, \Theta_H')'$, and S_j and Z_j are matrices set to impose the chosen restrictions.
4. If enough draws of Q are accepted, stop. Otherwise, return to 1.

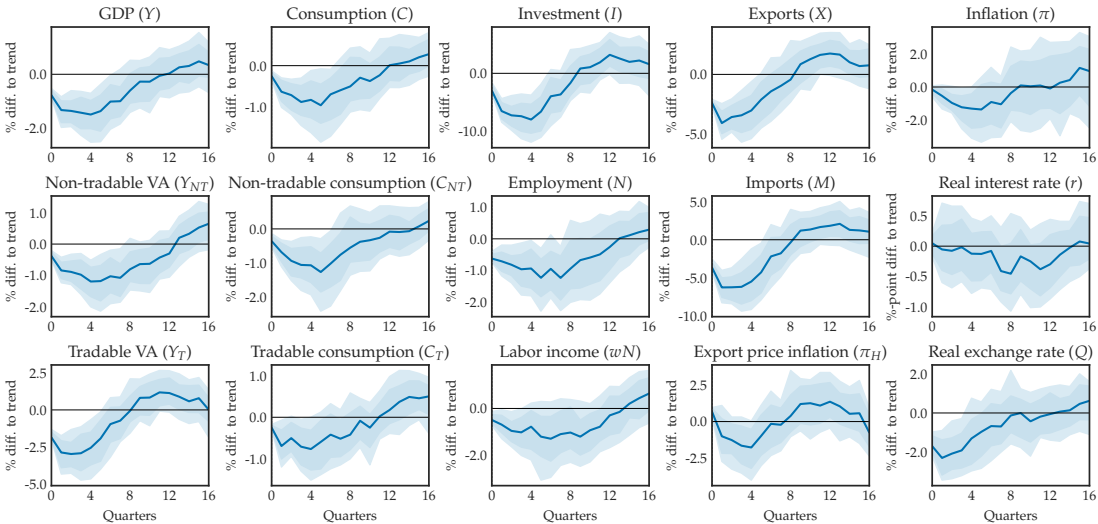
Robustness (Back)

1. **Exchange rate regime:** Similar results for *fixed* and *floating* countries
2. **No sign-restrictions:** Similar results when regressing domestic variables directly against $Y^*_{j,t}$ (with lags) and a time-fixed effect.
3. **Common shocks:** Similar (more imprecise) results when including time-fixed effects or OECD GDP on the RHS
4. **Different sign restrictions**: Similar results when using imports instead of GDP
5. **Detrending:** Similar results with HP or Hamilton filter
6. **Specification:** Similar results with more lags and when using a structural VAR model instead of LP

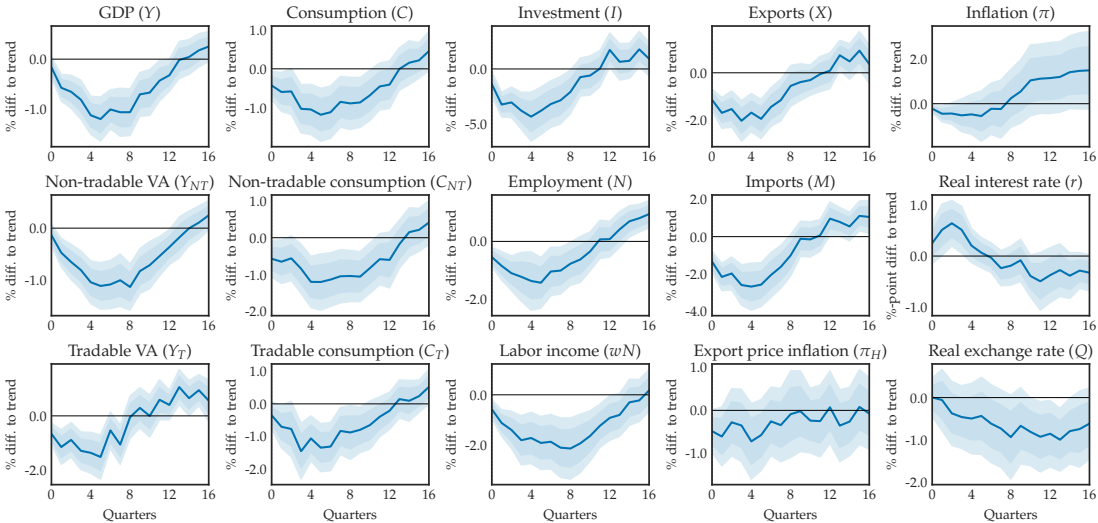
Fixed countries only (Back)



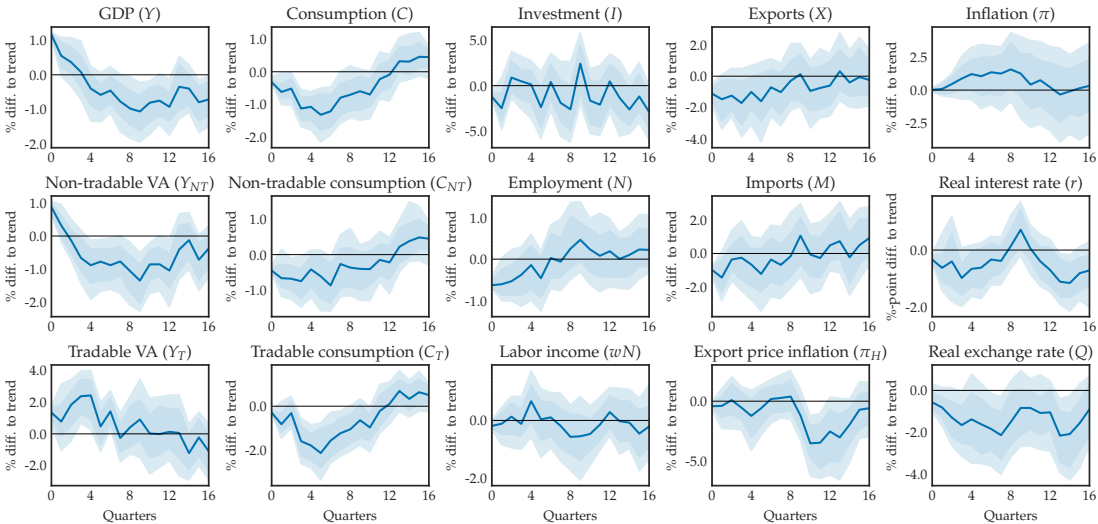
Floating countries only (Back)



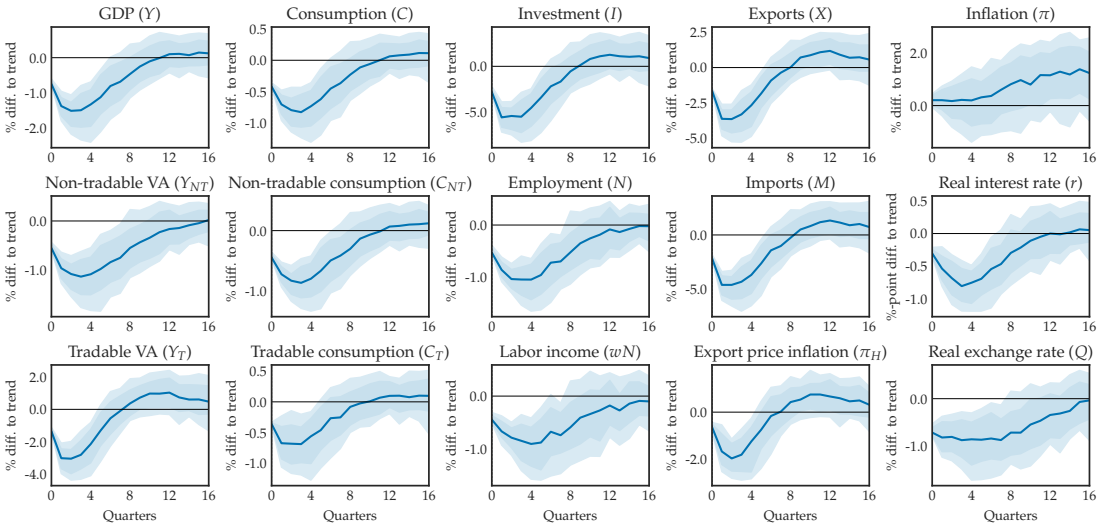
No sign restrictions (Back)



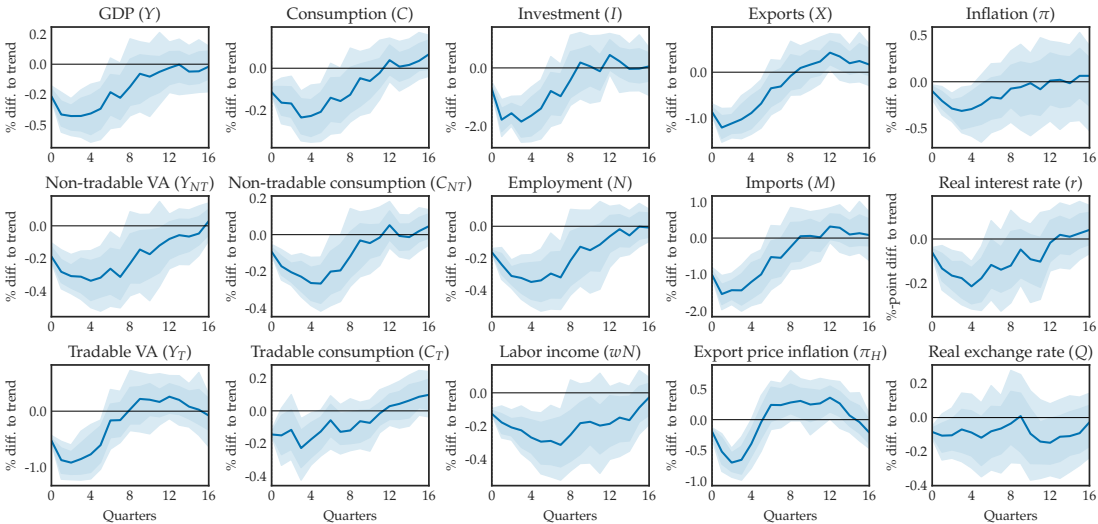
Time-fixed effects (Back)



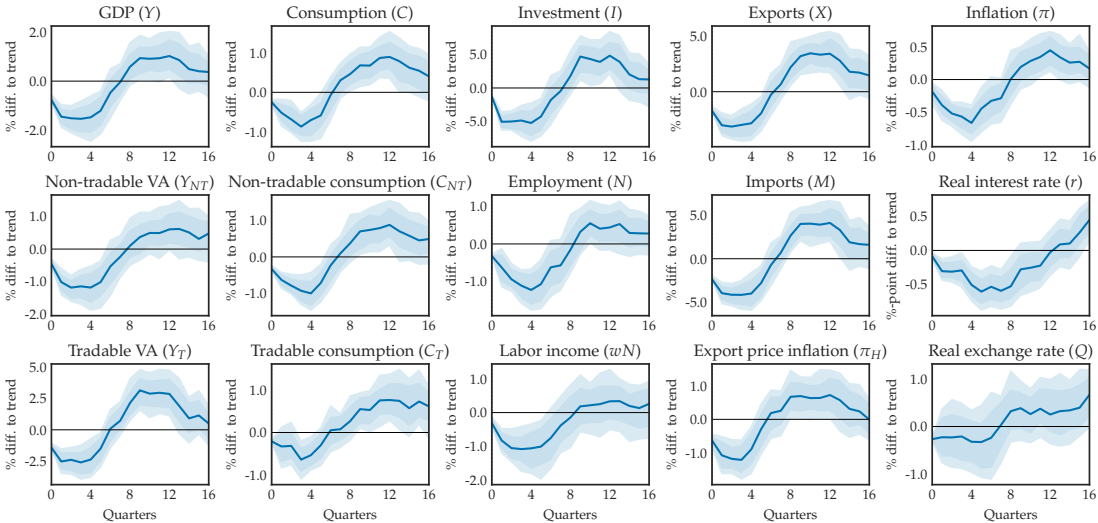
SVAR (Back)


GDP (Y)
Consumption (C)
Investment (I)
Exports (X)
Inflation (π)
Non-tradable VA (Y_{NT})
Non-tradable consumption (C_{NT})
Employment (N)
Imports (M)
Real interest rate (r)
Tradable VA (Y_T)
Tradable consumption (C_T)
Labor income (wN)
Export price inflation (π_H)
Real exchange rate (Q)
% diff. to trend
%-point diff. to trend
Quarters

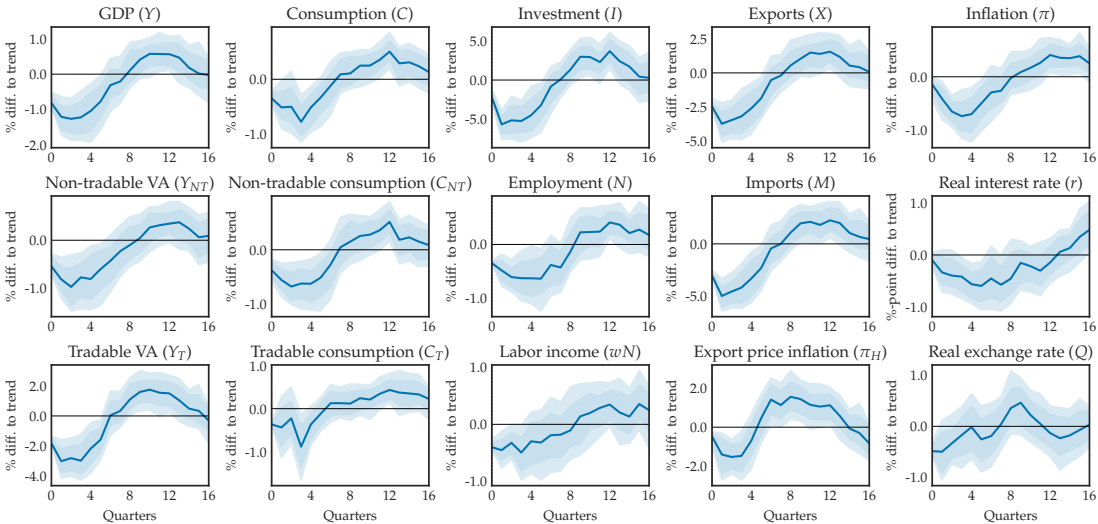
Shocking imports (Back)



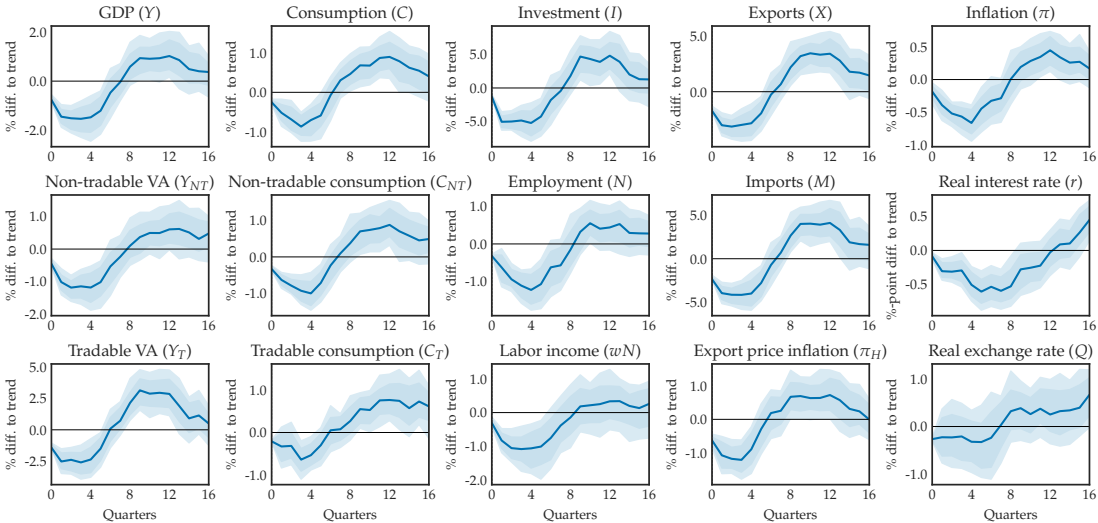
Hamilton filter (Back)



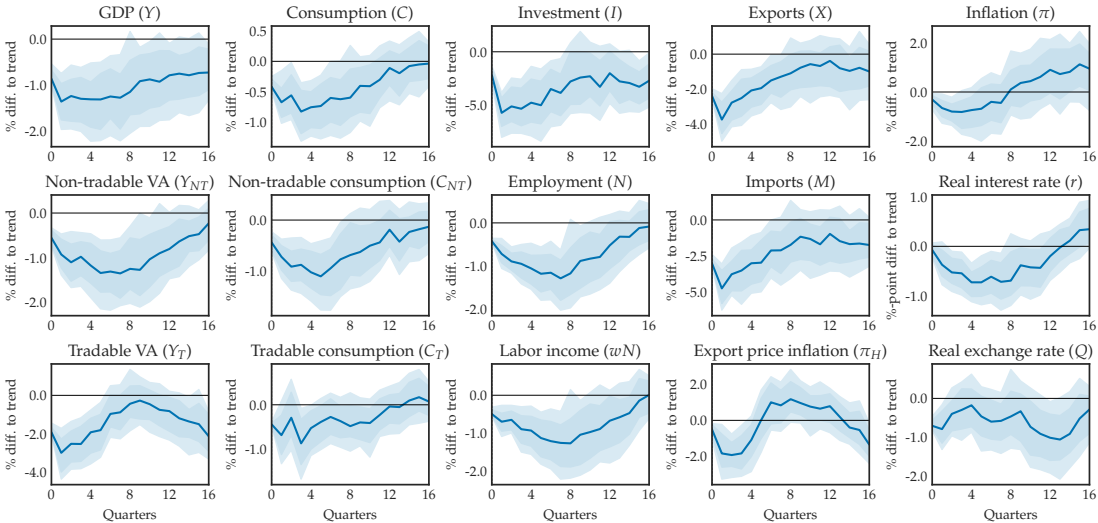
HP filter (Back)



More lags (Back)



OECD GDP (Back)



Data (Back)

- The **frequency is quarterly**.
- **Sample:** 31 ”small” and 7 ”large” OECD countries.
  - Largest SOE: Spain
  - All OECD countries with data starting in 1996 or earlier.
- For most countries data starts in the early-mid 1990s.
- Variables are **detrended** by a country-specific regression on $(1, t, t^2, t^3, t^4)$.

Countries (Back)

Large countries	Canada, France, Germany, Italy, Japan, United Kingdom, United States of America
Small countries	Australia, Austria, Belgium, Chile, Colombia, Costa Rica, Czech Republic, Denmark, Estonia, Finland, Greece, Hungary, Iceland, Ireland, Israel, Latvia, Lithuania, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Slovenia, South Korea, Spain, Sweden, Switzerland, Turkey.

Variable description (Back)

Variable	Description	Transformation
Y	GDP	Log
C	Consumption	Log
I	Investment	Log
X	Exports	Log
M	Imports	Log
Y_T	Tradable VA	Log
Y_{NT}	Non-tradable VA	Log
C_T	Tradable consumption	Log
C_{NT}	Non-tradable consumption	Log
Q	Real effective exchange rate	Log
P	Consumer price index	—
i	Short nominal interest rate	—
NX	Net exports	$NX = X - M$
π	Inflation	$\pi = P/P_{-4}$
r	Short real interest rate	$r = (1+i)/(1+\pi_{+4}) - 1$

Exchange rate terms (Back)

- E_t: Nominal exchange rate (domestic currency units per foreign currency unit)

  $E_t \uparrow$ = *depreciation* = *more* domestic currency required.

  $E_t \downarrow$ = *appreciation* = *less* domestic currency required.

- P_t: Domestic price level
- P_t^*: Foreign price level
- $Q_t = E_t \frac{P_t^*}{P_t}$: Real exchange rate
- $P_{H,t}, P_{F,t}$: Price of home and foreign good in *domestic* currency
- $P_{H,t}^* = \frac{P_{H,t}}{E_t}, P_{F,t}^* = \frac{P_{F,t}}{E_t}$: Price of home and foreign good in *foreign* currency
- $ToT_t = \frac{P_{F,t}^*}{P_{H,t}^*}$: Terms of trade

Household problem (Back)

- **States:** Assets (a_{t-1}), earnings (e_t), discount factors (β_t^k), and sector (s)
- **Recursive problem:**

$$V_t^{s,k}(e_t, a_{t-1}) = \max_{c_t, a_t} u(c_t) - \nu(n_t) + \beta_t^k \mathbb{E}_t \left[V_{t+1}^{s,k}(e_{t+1}, a_t) \right] \text{ s.t.}$$

$$c_t + a_t = (1 + r_t^a) a_{t-1} + (1 - \tau_t) w_{s,t} n_{s,t} e_t + T_t$$

$$\ln e_t = \rho_e \ln e_{t-1} + \epsilon_t^e, \quad \epsilon_t^e \sim \mathcal{N}\left(0, \sigma_e^2\right),$$

$$a_t \geq 0.$$

- Union chooses labor supply (alternatively GHH preferences)
- **RANK:** Collapses to aggregate Euler-equation (still no international risk-sharing).

Portfolio choice (Back)

- **Domestic households save in a mutual fund with three assets:** Domestic bonds, foreign bonds, and domestic shares.

$$A_t = B_t + B_t^* + p_t^D.$$

- Full arbitrage between domestic bonds and shares.
- **Sluggish arbitrage between foreign and domestic bonds** $\Rightarrow$

$$(1 + r_t^*) \frac{Q_{t+1}}{Q_t} + \underbrace{\phi^{B^*} \left(\frac{B_t^* - B_{t-1}^*}{A_{ss}^*} \right) - \beta \phi^{B^*} \left(\frac{B_{t+1}^* - B_t^*}{A_{ss}^*} \right)}_{\text{real UIP deviation}} = 1 + r_t$$

Optimal CES demand functions (Back)

- Choice between tradables and non-tradables:

$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t} \right)^{-\eta_{T,NT}} C_t,$$

$$C_{NT,t} = (1 - \alpha_T) \left(\frac{P_{NT,t}}{P_t} \right)^{-\eta_{T,NT}} C_t.$$

- Choice between foreign tradables and domestic tradables:

$$C_{F,t} = \alpha_F \left(\frac{P_{F,t}}{P_{T,t}} \right)^{-\eta_{H,F}} C_{T,t},$$

$$C_{H,t} = (1 - \alpha_F) \left(\frac{P_{H,t}}{P_{T,t}} \right)^{-\eta_{H,F}} C_{T,t}.$$

Production + price and wage setting in each sector (Back)

- **Production firms:** CES of capital-labor good and intermediate good
  Monopolistic competition with Rotemberg price adj. costs $\Rightarrow$
  New Keynesian Phillips Curve with indexation.
- **Intermediate good:** CES of own good, other sector good, and foreign good
- **Capital-labor**: CES of capital and labor.
- **Labor firm**: Convex labor adj. cost.
- **Capital firm**: Convex investment adj. cost + cost of external financing.
- **Unions:** Wage adj. cost $\Rightarrow$ New Keynesian Wage Phillips Curve with indexation.

Price and wage stickiness (Back)

Producers in sector s face a virtual Rotemberg price adjustment cost with indexation to past inflation as in Ascari and Rossi (2012):

$$\frac{\theta_s^P}{2}\left(\frac{1+\pi_{s,t}}{(1+\pi_{s,t-1})^{\varpi}}-1\right)^2 Z_{s,t}.$$

Union j in sector s maximizes the discounted sum of future utility of its members less a Rotemberg adjustment cost on nominal wages:

$$\sum_{t=0}^{\infty}\beta_t^U\left(\int\left\{u\left(c_{i,s,t}\right)-\nu\left(n_{i,s,t}\right)\right\}d\mathcal{D}_t-\frac{\theta_s^W}{2}\left(\frac{W_{s,t}^j}{W_{s,t-1}^j}-1\right)^2\right).$$

Adjustment costs (Back)

Labor firms maximize

$$r_{s,t}^{L} L_{s,t} - w_{s,t} L_{s,t} - \phi^{L} g\left(\frac{L_{s,t}}{L_{s,t-1}}\right) L_{s,t-1}$$

where $g\left(\frac{x'}{x}\right) = \frac{1}{2}\left(\frac{x'}{x} - 1\right)^2$ is a quadratic adjustment.
Capital firms maximize

$$r_{s,t}^{K} K_{s,t} - I_{s,t} - \kappa\left(D_{s,t}\right) - \phi^{I} g\left(\frac{I_{s,t}}{I_{s,t-1}}\right) I_{s,t-1}$$

where $\frac{\partial \kappa}{\partial D_{s,t}} = \tanh\left(\kappa^{I}\left(\frac{D_{s,t}}{D_{s,ss}} - 1\right)\right)$.

Dynamic export elasticity (Back)

Foreign demand for home tradables is given by an Armington relation:

$$C^*_{H,t} = \alpha^* \left(\hat{p}^*_t\right)^{-\eta^*} C^*_t,$$

where

$$\hat{p}^*_t = \left(\hat{p}^*_{t-1}\right)^{\rho^*} \left(\frac{P^*_{H,t}}{P^*_{F,t}}\right)^{1-\rho^*}.$$

Government and central bank (Back)

- **Government:**
  - **Expenses:** Government consumption and transfers.
    (constant share to domestic tradables, no foreign tradables)
  - **Revenues:** Income tax proportional to labor income.
  - **Financing:** Initial purely with bonds, later adjust tax rate so $B_t \to B_{ss}$.
- **Central bank:**
  - **Floating:** Inertial Taylor rule responding to PPI inflation.
  - **Fixed:** Set interest rate so $E_t = E_{ss}$ always.

Solution method (Back)

- **Steady state:** Zero inflation and a balanced net foreign asset position.
- **Households' problem**: Solved using the EGM from Carroll (2006)
- **Jacobian**: Found using the "fake news algorithm" from Auclert et al. (2021a).
- **Impulse-responses:** Full non-linear transition path using Broydens' method.
  Interest rate eventually decreasing in NFA
  $\rightarrow$ speed-up convergence + necessary for stationarity in RANK

Calibration (Back)

Parameter	Description	Value	Target/source
	Households		
$1/\sigma$	Intertemporal elasticity of substitution	0.5	Standard value
φ	Frisch elasticity	0.5	Chetty et al. (2011)
$\bar{\beta}$ (HANK)	Mean discount factor	0.979	$\frac{A}{Income} = 2.5$ (annual)
$\bar{\beta}$ (RANK)	Mean discount factor	0.995	$r = 2\%$ p.a.
$\Delta\beta$	Discount factor dispersion	0.02	$MPC = 0.51$ (annual)
ρ_e	Persistence of idiosyncratic income	0.95	Standard value
σ_e	Std. of idiosyncratic income	0.25	Standard value
s_T	Share of households working in tradeable sector	0.30	OECD average
$\eta^{T,NT}$	Elasticity of sub. between C_T and C_{NT}	1.5	Akinci (2011)
$\eta^{H,F}$	Elasticity of sub. between C_F and C_H	1.5	Gallaway, McDaniel, and Rivera (2003)
α_T	Share of tradeables in home basket	0.41	OECD average
α_F	Share of foreign tradeables in home basket	0.42	$\frac{C_F}{Imports} = 25\%$
α^*	Size of export market	0.39	$\frac{Exports}{GDP} = 39\%$
	Government and monetary policy		
$\frac{G}{GDP}$	Public consumption to GDP	0.17	17%
$\frac{B}{GDP}$	Government debt to GDP	0.95	95% (annual)
s_T^G	Share of G going to tradeables	0.2	Cardi and Restout (2021)

Table: Calibration of the domestic economy

Calibration (Back)

Parameter	Description	Value	Target/source
	Production and intermediate goods		
α_T^X	Intermediate goods share	0.71	$\frac{P_T^X X_T}{P_T^X X_T + W_T N_T + r_T^K K_T} = 0.71$
α_{NT}^X	Intermediate goods share	0.46	$\frac{P_{NT}^X X_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}} = 0.46$
α_T^K	Capital share	0.35	$\frac{r_T^K K_T}{P_T^X X_T + W_T N_T + r_T^K K_T} = 0.10$
α_{NT}^K	Capital share	0.33	$\frac{r_{NT}^K K_{NT}}{P_{NT}^X X_{NT} + W_{NT} N_{NT} + r_{NT}^K K_{NT}} = 0.18$
η_x	Elasticity of sub. between intermediate goods	0.5	See text
η_{KL}	Elasticity of sub. between capital and labor	0.5	Gechert et al. (2022)
δ_K	Deprecation rate of capital	5.2% p.a.	Auclert, Rognlie, and Straub (2020)
	Market Power		
$\epsilon_T^P, \epsilon_{NT}^P$	Elasticity of substitution for final goods	6	Markup=20%
$\epsilon_T^w, \epsilon_{NT}^w$	Elasticity of substitution for labor	6	Markup=20%

Table: Sectoral calibration

Estimation procedure (Back)

We solve the following minimization problem:

$$\min_{\boldsymbol{\Psi}} \left(\boldsymbol{\Lambda}\left(\boldsymbol{\Psi}\right) - \hat{\boldsymbol{\Lambda}}\right)' \boldsymbol{W} \left(\boldsymbol{\Lambda}\left(\boldsymbol{\Psi}\right) - \hat{\boldsymbol{\Lambda}}\right)$$

- $\boldsymbol{\Psi}$: Parameters
- $\hat{\boldsymbol{\Lambda}}$: LP IRFs (first 12 quarters)
- $\boldsymbol{\Lambda}\left(\boldsymbol{\Psi}\right)$: Model IRFs evaluated at $\boldsymbol{\Psi}$ (first 12 quarters)
- $\boldsymbol{W}$: Weight matrix containing the inverse of the variances of the estimated impulse responses

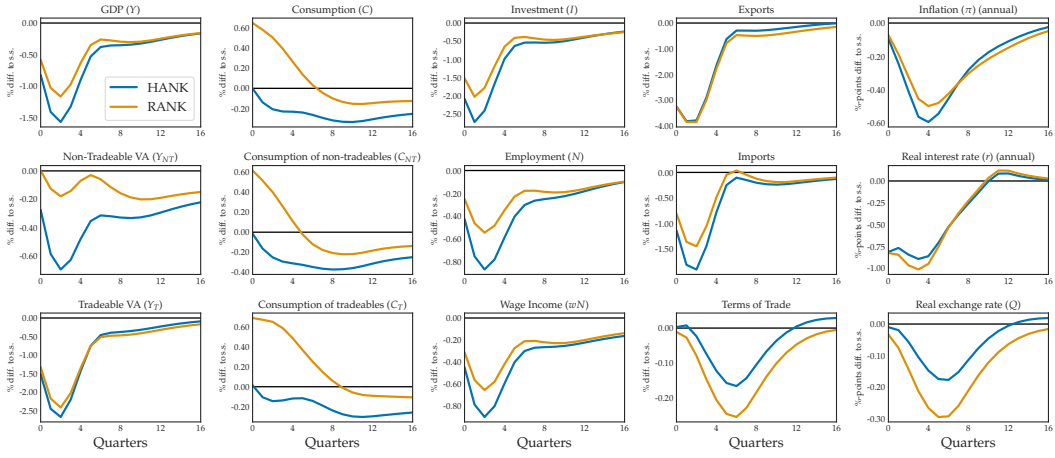
Targets and parameters (Back)

- **Targets:**
  - Value added in tradable and non-tradable sector
  - Investment, employment, and labor compensation
  - Inflation rate, real interest rate, and real exchange rate
  - Exports and domestic export price
- **Parameters:**
  - Price and wage adjustment cost and indexation factor in both sectors
  - Taylor coefficient on inflation and interest rate inertia
  - Investment and labor adjustment cost
  - Investment risk-premium cost and portfolio adjustment cost
  - Armington elasticity and dynamic trade elasticity

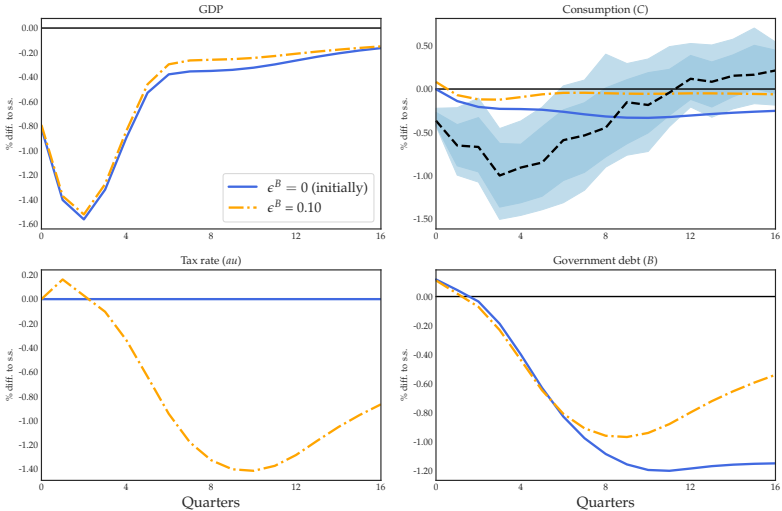
Estimated parameters (Back)

	Parameter name	Value	S.E.
θ_T^P	Rotemberg price parameter	0.07	-
θ_{NT}^P	Rotemberg price parameter	0.07	-
θ_T^W	Rotemberg wage parameter	0.05	-
θ_{NT}^W	Rotemberg wage parameter	0.00	-
ϖ	Inflation indexation	0.66	-
ϖ^W	Wage indexation	0.81	-
ϕ^π	Taylor coeff. on inflation	1.34	-
ρ^r	Interest rate smoothing	0.14	-
ϕ^N	Employtment adj. cost	1.79	-
ϕ^I	Investment adj. cost	5.58	-
κ^I	Investment risk-premium elasticity	0.29	-
ϕ^{B^*}	UIP deviation	1.11	-
η^*	Armington elasticity	2.98	-
ρ^*	Dynamic export elasticity	0.78	-

Domestic responses under a fixed exchange rate (Back)



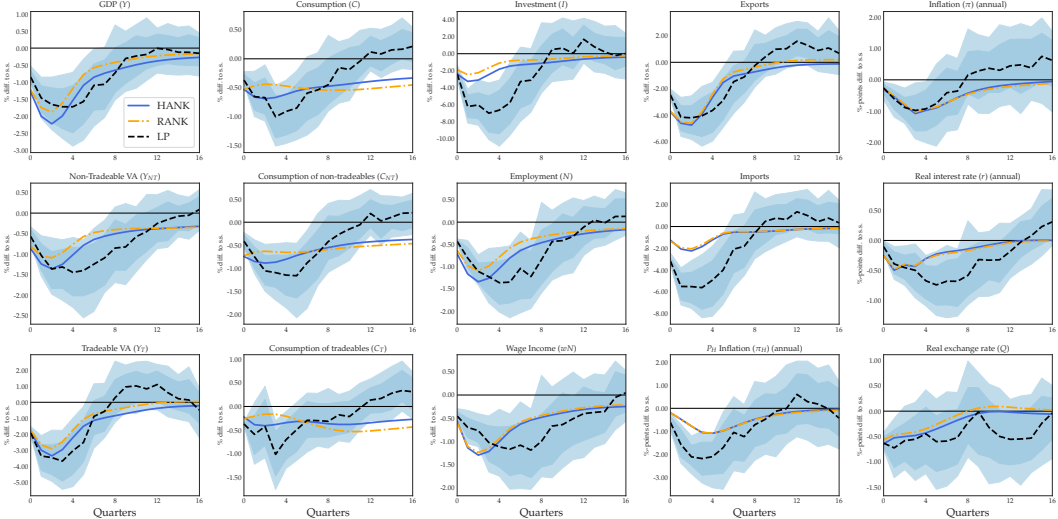
Debt rule under fixed: $\tau = \tau_{ss} + \epsilon^B \frac{B_{t-1} - B_{ss}}{Y_{ss}}$



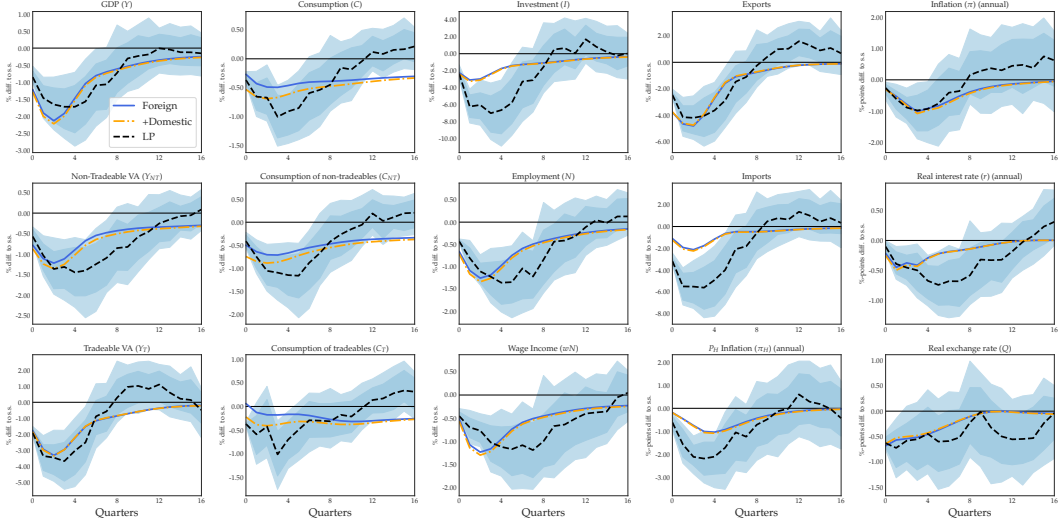
Variances and covariances (Back)

	$\frac{\text{var}(Y)}{\text{var}(Y^{\text{data}})}$	$\frac{\text{var}(C)}{\text{var}(C^{\text{data}})}$	$\frac{\text{cov}(C,Y)}{\text{cov}(C^{\text{data}},Y^{\text{data}})}$
HANK	1.17	0.59	0.73
RANK	0.73	0.10	-0.08

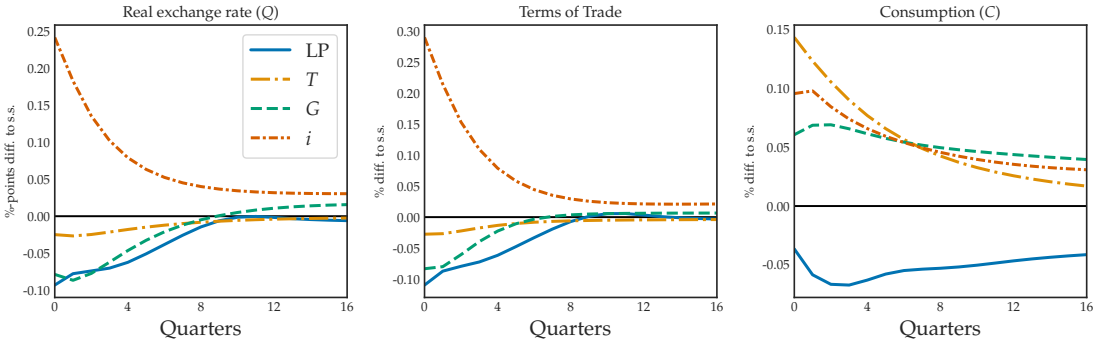
HANK+RANK with foreign+domestic demand shock



HANK with foreign+domestic demand shock



RER and ToT under a floating exchange rate (Back)



RER and ToT under a fixed exchange rate (Back)