Lecture 10: I-HANK

Adv. Macro: Heterogenous Agent Models

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Plan

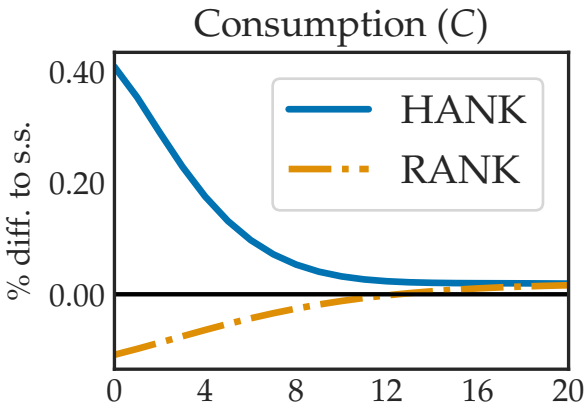
- **Topic:** Open economy HANK model
- **I-HANK: I**nternational **H**eterogenous **A**gent **N**ew-**K**eynesian
- We will be talking about the paper

  The Transmission of Foreign Demand Shocks
- Joint work with Jeppe Druedahl, Søren Hove Ravn, and Laura Sunder-Plassmann
- **1st hour:** Jacob Marott Sundram (paper)
- **2nd hour:** Nicolai Waldstrøm (solution + code)

The paper

- We study **foreign demand shocks** in small open economies (SOEs)
- **Stylized empirical result:** **Higher** consumption in the SOE
- **Representative agent (RANK) model:** **Lower** consumption
- **Heterogeneous agent (HANK) model:** **Higher** consumption
- Also gives co-movement of consumption of tradeables and non-tradeables
- Fiscal policy cannot stabilize all households at the same time, while monetary policy can
- **Takeaway:** Foreign demand shocks are important

Main result



Motivation

- **Business cycle co-move** a lot (Backus, Kehoe, and Kydland 1992)
- **Foreign demand shocks** are intuitively and empirically important
  - Canova (2005), Eickmeier (2007), Mumtaz and Surico (2009), Charnavoki and Dolado (2014), and Feldkircher and Huber (2016)
- But in NK models, foreign demand shocks are **unimportant** and deliver counter-intuitive IRFs
  - Bergholt (2015), Justiniano and Preston (2010), Lubik and Schorfheide (2007), Christiano, Trabandt, and Walentin (2011), and Adolfson et al. (2013)

Agenda

1. Motivating empirics
2. Stylized model
3. Full model

Motivating empirics

5 stylized facts

- We establish 5 stylized empirical results regarding the transmission of foreign demand shocks:
  1. GDP increases
  2. Aggregate consumption increases
  3. Exports and imports *both* increase
  4. Consumption of tradeable and non-tradeable goods co-moves positively
  5. Foreign demand explains a large share of the variance of domestic variables
- These results are found in the existing literature

Empirical strategy

- **Panel data local projections** to get IRFs $\{\beta_h\}_{h=0}^{H-1}$:

$$Z_{it+h} = \beta_h Y_{it}^* + \sum_{j=1}^{p} \gamma_{h,j} Z_{i,t-j} + \sum_{j=1}^{p} \delta_{h,j} Y_{i,t-j}^* + X_{th} + \varepsilon_{ith}.$$

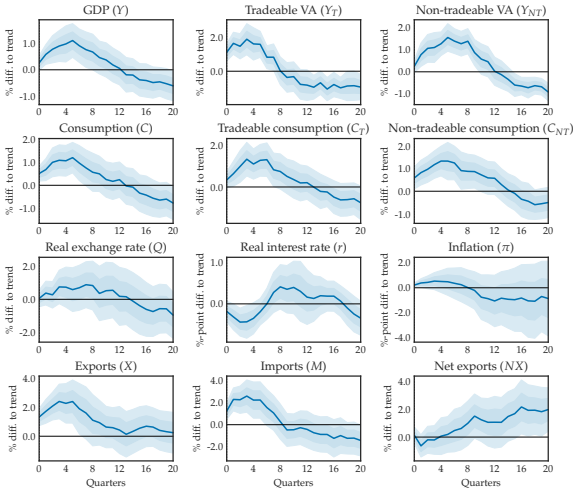
  - Z_{it}: Domestic outcome
  - Y_{it}^*: Measure of foreign demand (Baseline: Trade-weighted foreign GDP)
  - X_{th}: Time fixed effects

- **Identification:** SOE + time fixed effects

Data

- **Sample:** 39 "small" and 7 "large" OECD countries
  - Largest SOE: Canada
  - All OECD countries with quarterly NA data starting at least in 1996
- The frequency is quarterly and for most countries data starts in the early-mid 1990's
- Variables are detrended by a country-specific regression on $(1, t, t^2, t^3, t^4)$

Response of the SOE



Forecast error variance decomposition

- **Q:** How much of the variance in the SOE is explained by the shock?
- **Method:** Gorodnichenko and Lee (2020)

h	Y	C	X	M	NX
4	22.2 (20.4,24.2)	21.9 (20.6,23.6)	16.9 (15.1,19.2)	15.2 (12.6,18.0)	14.8 (12.6,17.5)
8	28.7 (26.2,31.7)	26.4 (24.6,28.6)	22.7 (20.4,25.2)	19.8 (16.6,23.2)	20.9 (18.3,24.3)
∞	22.2 (18.2,25.9)	18.9 (16.0,21.3)	16.5 (10.3,20.5)	17.1 (12.6,20.4)	10.5 (6.1,14.2)

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

Robustness

- We do various robustness checks:
  1. **Structural VAR:** SVAR
  2. **Variables:** HP filter, Hamilton filter, shocking imports, only large economies on RHS, and weights based on GDP
  3. **LP specification:** More lags, no time FE, time $\times$ region FE, only floating countries, only fixed countries, and starting sample in 1996
- The results are very robust: Virtually all relevant significance carries over to all specifications

Stylized model

Stylized model: Idea

- We can show the main mechanism at work in a stylized model á la Gali and Monacelli (2005) with a generalized household block
- Let $d\boldsymbol{X} = (dX_0, dX_1, \ldots, dX_T)'$ denote the sequence of deviations from steady state of a variable X
- We look at shifts in foreign demand, $d\boldsymbol{Y}^*$

Stylized model: Market clearing

- Domestic market clearing + CES demand + $C^* = Y^*$ gives

$$\begin{aligned} d\boldsymbol{Y} &= d\boldsymbol{C}_{H,t} + d\boldsymbol{C}^*_{H,t} \\ &= (1-\alpha) d\boldsymbol{C} + \alpha d\boldsymbol{Y}^* + \frac{\alpha}{1-\alpha}\chi d\boldsymbol{Q}. \end{aligned}$$

- Y is production, C is consumption, and Q is the real exchange rate
- $C_{H,t}$ and $C^*_{H,t}$ are consumption of home goods at home and abroad
- $1-\alpha \in (0,1)$ is the home bias and χ is the total trade elasticity

Stylized model: Consumption

- General consumption function $\mathcal{C}_t\left(\left\{Y_s^{hh}, r_s\right\}\right)$ nests HANK and RANK
- **Linearize:**

$$d\boldsymbol{C} = \underbrace{\boldsymbol{M} d\boldsymbol{Y}^{\boldsymbol{hh}}}_{\text{Income}} + \underbrace{\boldsymbol{M}^{r} d\boldsymbol{r}}_{\text{Intertemporal sub.}} .$$

- Note that "$\boldsymbol{M} > 0$" and "$\boldsymbol{M}^{r} < 0$"
- Household income is given by

$$d\boldsymbol{Y}^{hh} = d\boldsymbol{Y} - \frac{\alpha}{1-\alpha} d\boldsymbol{Q}.$$

Stylized model: Last parts

- Sticky wages + Taylor rule + UIP gives

$$d\mathbf{Q} = -\boldsymbol{G}^{Q,Y} d\mathbf{Y},$$
$$d\mathbf{r} = -\boldsymbol{G}^{r,Q} d\mathbf{Q}.$$

- "$\boldsymbol{G}^{Q,Y} > 0$" and "$\boldsymbol{G}^{r,Q} > 0$"

Stylized model: Key result

Proposition

The response of domestic consumption ($d\boldsymbol{C}$) to foreign demand ($d\boldsymbol{Y}^*$) is

$$d\boldsymbol{C} = \boldsymbol{G}^{C,Y}\boldsymbol{G}^{Y,Y^*}d\boldsymbol{Y}^*,$$

where

$$\boldsymbol{G}^{C,Y} \equiv \boldsymbol{M} + \frac{\alpha}{1-\alpha}\boldsymbol{M}\boldsymbol{G}^{Q,Y} + \boldsymbol{M}^r\boldsymbol{G}^{r,Q}\boldsymbol{G}^{Q,Y},$$

and $\boldsymbol{G}^{Y,Y^*}$ is a known function of the structural parameters of the model.

Stylized model: RANK

- RANK ("$M \approx 0$"):

$$d\boldsymbol{C} \approx \boldsymbol{M}^{r}\boldsymbol{G}^{r,Q}\boldsymbol{G}^{Q,Y}\boldsymbol{G}^{Y,Y^*}d\boldsymbol{Y^*} < 0.$$

- **Note:** "$M^r < 0$" and all other matrices are "positive"
- The channel is **intertemporal substitution**
- **Mechanism:** Foreign demand shock $\Rightarrow$ Demand for domestic goods $\Rightarrow$ Higher domestic inflation $\Rightarrow$ CB hikes rates $\Rightarrow$ Lower consumption

Stylized model: HANK

- HANK ("$M > 0$"):

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

- **Mechanism:** Foreign demand shock $\Rightarrow$ Demand for domestic goods ...
  - **Labor income:** $\cdots \Rightarrow$ Higher labor income for domestic workers $\Rightarrow$ Higher consumption
  - **Real income:** $\cdots \Rightarrow$ Higher inflation $\Rightarrow$ Appreciation of the RER $\Rightarrow$ Domestic households are richer in real terms $\Rightarrow$ Higher consumption

Stylized model: Conclusion

- Foreign demand shocks lead to **lower consumption in RANK** due to intertemporal substitution...
- ...but **higher consumption in HANK** due to income channels
- The latter is consistent with empirics
- Purely **qualitative**. What about quantitatively? $\Rightarrow$ Bigger model

Full model

Full model: Setup

- Full model = Baseline model + Tradeables and non-tradeables + Intermediate inputs + Public sector + 3-equation NK foreign economy
- Shock **before:** $dY^* \uparrow$
- Shock **now:** $\beta^* \downarrow$, causing $dY^* \uparrow$, $d\pi^* \uparrow$ and $dr^* \uparrow$ *endogenously*

Full model: Setup

- **Households:**
  - "Canonical HANK" (Auclert, Rognlie, and Straub 2018, Auclert et al. 2021b)
  - Uninsurable idiosyncratic income shocks + borrowing constraint
  - Heterogeneous discount factors
  - Domestic/foreign tradeable good and non-tradeable good

Full model: Household problem

- **States:** Assets (a_{t-1}), idiosyncratic earnings (e_t), discount factor (β), and sector (s). β and s are permanent.

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

s.t.

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

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

$$a_t \geq 0.$$

Full model: RANK

- Previous slide holds in HANK model
- In RANK model, there is complete markets with perfect risk-sharing and no preference heterogeneity, giving a representative agent following a standard Euler equation:

$$u'(C_t) = (1 + r^a_{t+1})\bar{\beta}_t u'(C_{t+1}).$$

- This model is non-stationary, so we adjust UIP by adding Γ_t:

$$1 + r_t = (1 + r^*_t)\frac{Q_{t+1}}{Q_t}\Gamma_t, \quad \Gamma_t \equiv \exp\left\{-\varepsilon^D\left(\frac{Q_t B^*_t}{GDP_{ss}} - \frac{Q_{ss}B^*_{ss}}{GDP_{ss}}\right)\right\}.$$

Full model: CES split

- Split between tradeables and non-tradeables:

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

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

- Split between foreign tradeables and domestic tradeables:

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

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

Full model: Setup

- **Firms:**
  - Production with labor and intermediate goods (IO)
  - Import of intermediate goods
  - Price adjustment costs $\Rightarrow$ New Keynesian Phillips Curve
- **Unions:** Wage adjustment costs $\Rightarrow$ New Keynesian Wage Phillips Curve
- **Central bank:** Taylor rule that reacts to producer prices
- **Government:** Finances public consumption, transfers and services debt using bonds and lump sum taxes

Full model: The foreign economy

- Foreign economy is its own model!
- Specifically, it is a RANK model, see Galí (2015):
  - Euler equation
  - Labor supply curve
  - Standard supply side with a NKPC
  - Taylor rule

Full model: Solution method

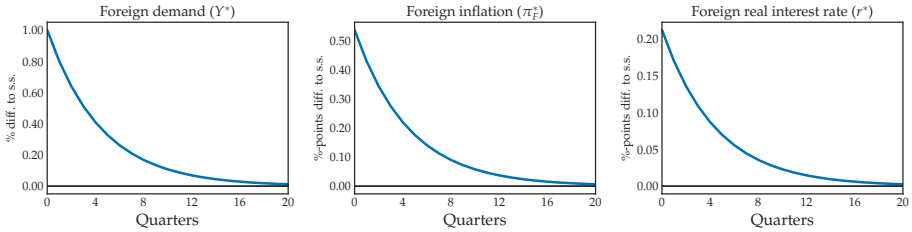
- We solve the households' problem using EGM of Carroll (2006)
- We use the "fake news algorithm" from Auclert et al. (2021a) to compute the Jacobian of the HH problem around a deterministic steady with zero inflation and no NFA position
- We solve for the full non-linear transition path to each shock using Broyden's method

Full model: Calibration

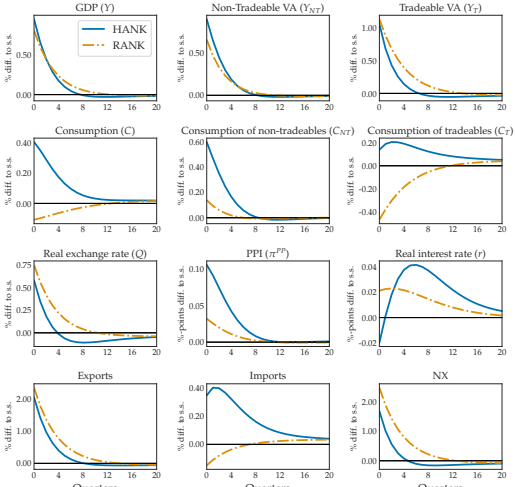
- We use a quarterly calibration and match the average SOE in the OECD
- Household calibration is standard
  - Match annual MPC $= 0.55$ (Fagereng, Holm, and Natvik 2021)
- Sectoral calibration matches OECD averages
- Public sector calibration is standard
- IO calibration matches OECD IO tables
- Phillip curve calibration follows the literature
- Foreign economy calibration follows the NK literature

Full model: Foreign demand shock

- β^* (foreign demand) shock in the **foreign** economy:

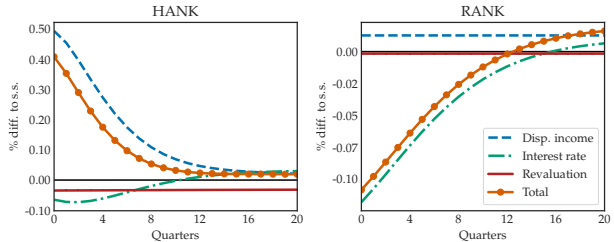


Full model: Domestic response to shock



Full model: Consumption decomposition

- Decompose C responses using linearized consumption function



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

Full model: C_T, C_{NT} setup

- Recall that in the LP $\text{Cov}(C_T, C_{NT}) > 0$
- We have CES demand for C_T, C_{NT}:

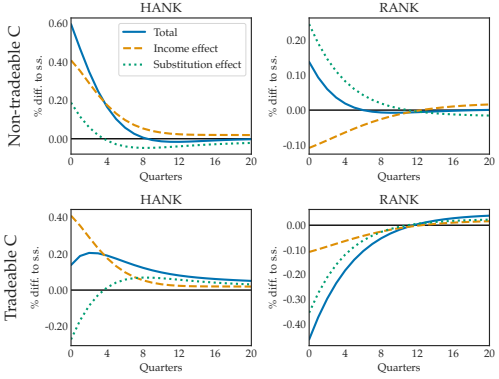
$$C_{T,t} = \alpha_T \left(\frac{P_{T,t}}{P_t} \right)^{-\eta_{T,NT}} C_t,$$

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

- Positive co-movement occurs when income effect (C_t) dominates the substitution effect from relative price movements ($\frac{P_{T,t}}{P_t}, \frac{P_{NT,t}}{P_t}$)

Full model: C_T, C_{NT} co-movement

- Income effect also generates C_T, C_{NT} co-movement in HANK, consistent with empirical evidence



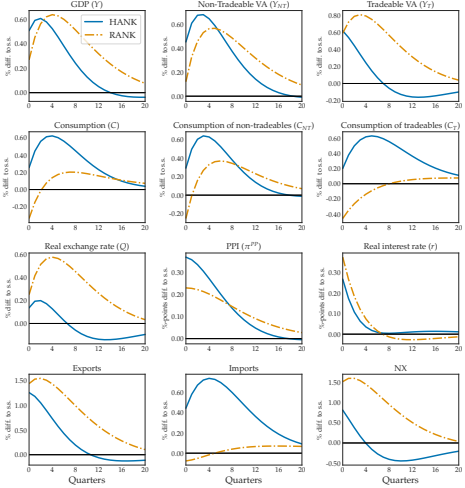
Full model: Fixed exchange rate

- With a floating exchange rate we get $dC^{RA} < 0$ because of Taylor rule
- Does this carry over to a fixed exchange rate?
- Yes! UIP condition + Fisher equation:

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

- If domestic prices are sticky enough ($\Delta\pi_{t+1}$ small) then $i^* \uparrow \Rightarrow r \uparrow$
- i^* increases in the foreign demand shock, hence implying $dC^{RA} < 0$
- Note here that micro-founding the foreign economy is essential

Full model: Fixed exchange rate IRFs



Stabilization policy: Setup

- Foreign demand shocks are important, but how do you stabilize them?
- Trade-off between stabilizing households employed in both sectors?
- We consider the effects of foreign demand shocks and policy shocks meant to stabilize them on consumption of households in both sectors

Stabilization policy: Results

	Floating				Fixed			
	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$	C	C_T^{hh}	C_{NT}^{hh}	$\frac{C_T^{hh}}{C_{NT}^{hh}}$
Foreign demand, β^*	-1.00	-1.23	-0.90	1.37	-1.00	-0.95	-1.02	0.92
Domestic demand, β	-1.00	-0.69	-1.14	0.60	-1.00	-0.71	-1.13	0.63
Public transfers, T	1.00	0.57	1.19	0.48	1.00	0.64	1.16	0.55
Public spending, G	1.00	0.01	1.44	0.01	1.00	0.23	1.34	0.17
Monetary policy, i	1.00	0.95	1.02	0.93	-	-	-	-
Nominal devaluation	-	-	-	-	1.00	1.05	0.98	1.07
Fiscal devaluation	-	-	-	-	1.00	1.03	0.99	1.04

Table: Cumulative effects of demand shocks and policy instruments.

Stabilization policy: Takeaways

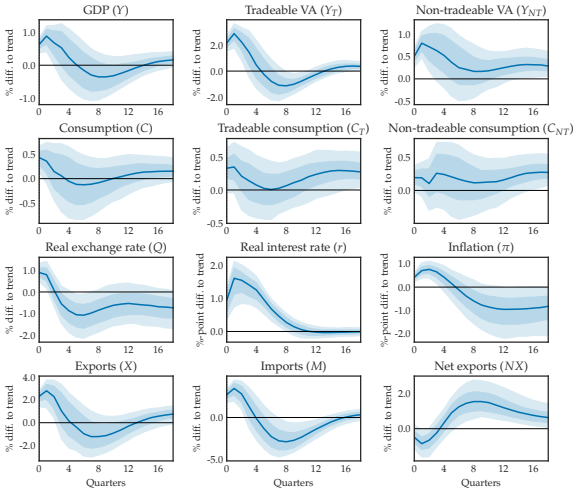
- Domestic "demand" shocks (β, T, G) are tilted towards non-tradeables
- Foreign demand shocks are tilted towards tradeables (or $\sim$ symmetric)
- Thus, we cannot stabilize foreign demand shocks with fiscal policy
- However, i affects sectors symmetrically and can thus be used to stabilize
- Creates an issue for countries with fixed exchange rates
- We show that a fiscal devaluation yields results similar to monetary policy

Conclusion

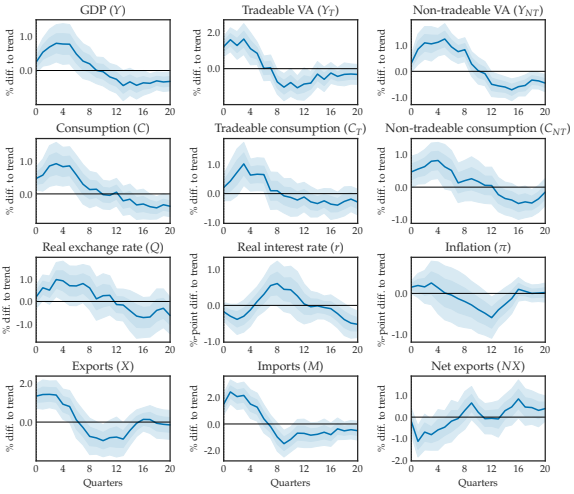
- We study **foreign demand shocks** in small open economies (SOEs)
- **Local projections:** Higher consumption in the SOE
- HANK matches this, RANK does not
- HANK also matches observed co-movement in the consumption of tradeables and non-tradeables
- **Key channel:** Income effects
- Fiscal policy cannot stabilize households in both sectors at the same time; monetary policy can

Thank you!

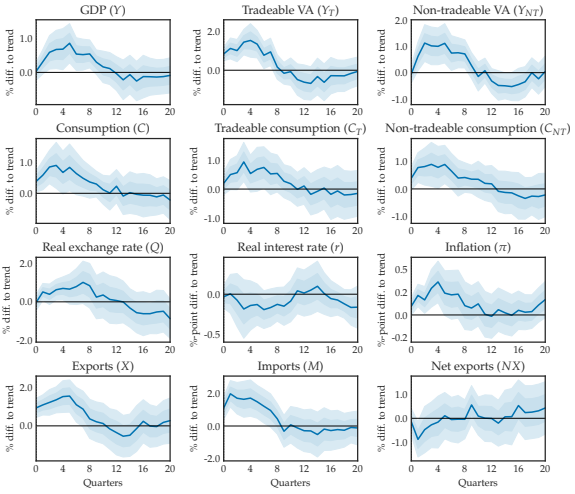
SVAR (Back)


GDP (Y)
Tradeable VA (Y_T)
Non-tradeable VA (Y_{NT})
Consumption (C)
Tradeable consumption (C_T)
Non-tradeable consumption (C_{NT})
Real exchange rate (Q)
Real interest rate (r)
Inflation (π)
Exports (X)
Imports (M)
Net exports (NX)
% diff. to trend
%-point diff. to trend
Quarters

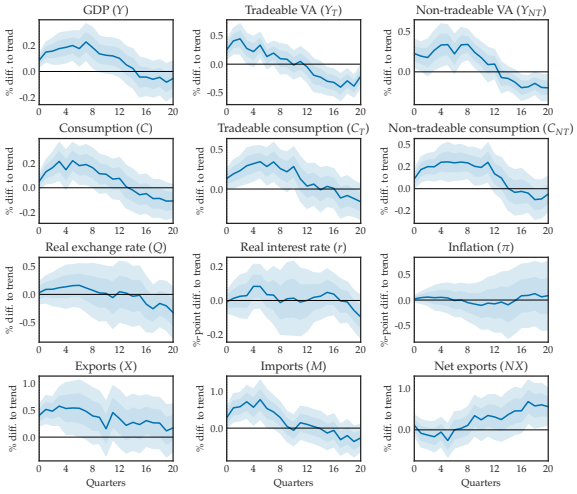
HP filter (Back)



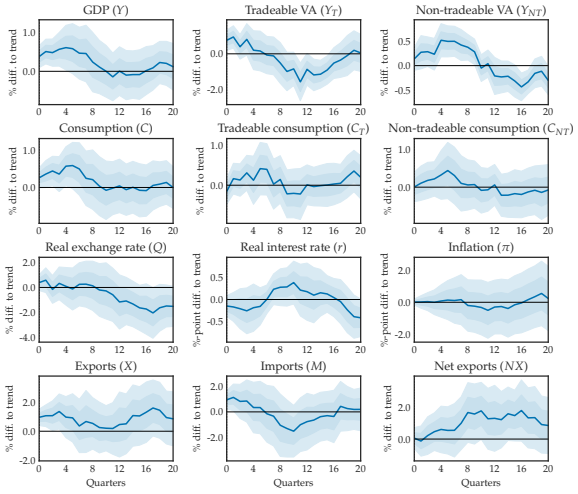
Hamilton filter (Back)



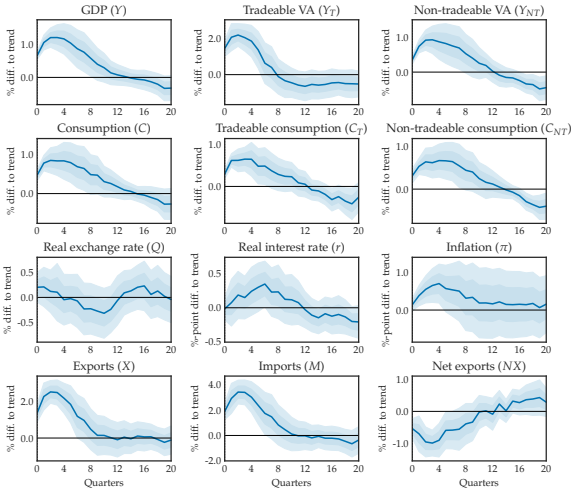
Shocking imports (Back)



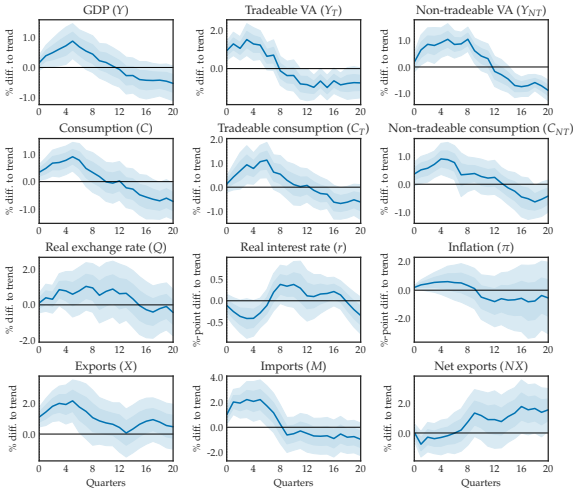
Only large economies on RHS (Back)



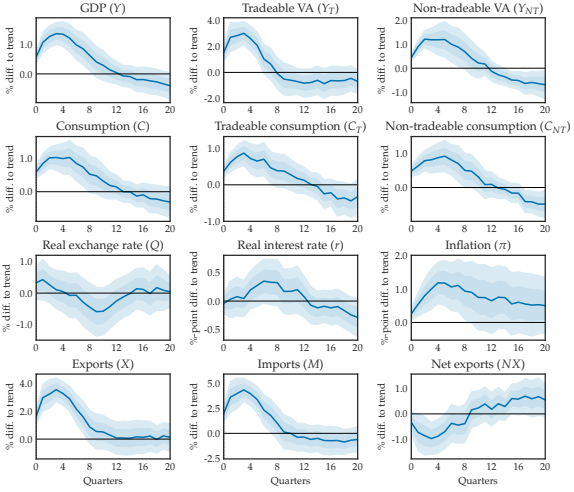
Weights based on GDP (Back)



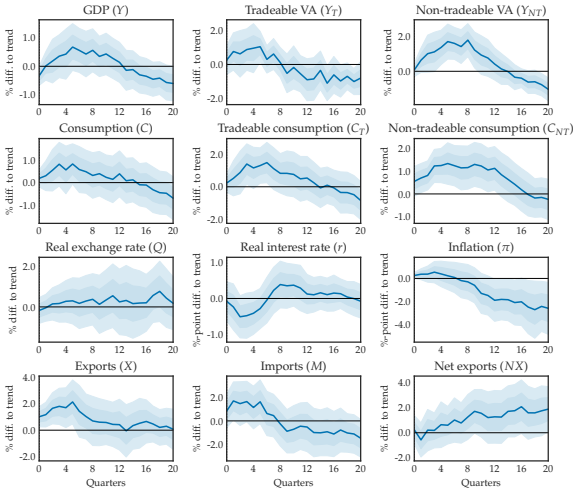
More lags (Back)



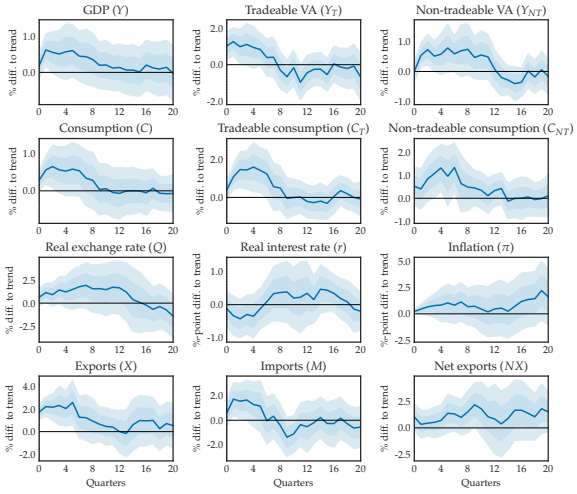
No time fixed effects (Back)



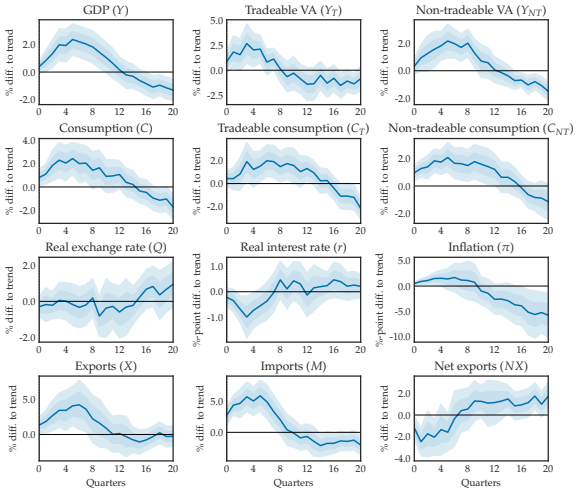
Time × region fixed effects (Back)



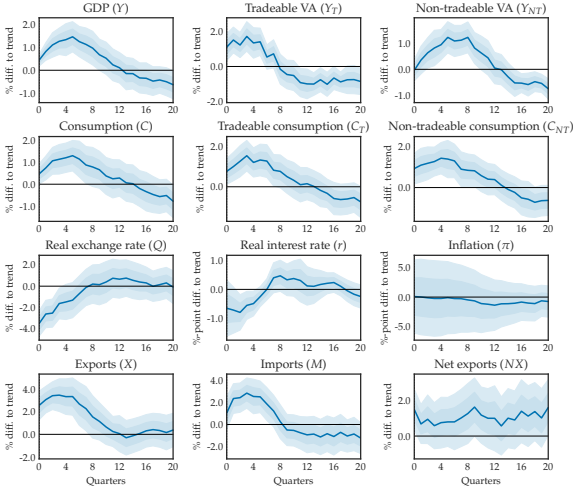
Floating countries only (Back)



Fixed countries only (Back)



Starting sample in 1996 (Back)



Countries (Back)

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

Variable description (Back)

Variable	Description	Transformation
Y	GDP	Log
C	Consumption	Log
I	Investment	Log
X	Exports	Log
M	Imports	Log
Y_T	Tradeable VA	Log
Y_{NT}	Non-tradeable VA	Log
C_T	Tradeable consumption	Log
C_{NT}	Non-tradeable 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	$r = (1 + i)/(1 + \pi_{+4}) - 1$

Table: Variable description

Calibration I (Back)

Parameter	Description	Value	Target
$1/\sigma$	EIS	0.5	Standard value
$\tilde{\beta}$ (HANK)	Mean discount factor	0.972	$\frac{A}{GDP} = 3$ (annual)
$\tilde{\beta}$ (RANK)	Mean discount factor	0.995	$r = 2\%$ p.a.
$\Delta\beta$	Discount factor dispersion	0.02	$MPC = 0.55$ (annual)
ρ^e	persistent 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	0.35	OECD average
η_T	Elasticity of sub. between C_T and C_{NT}	1.5	See text
η	Elasticity of sub. between C_F and C_H	1.5	See text
α_T	Share of tradeables in home basket	0.41	OECD average
α	Share of foreign tradeables in home basket	0.33	$\frac{CF}{Imports} = 30\%$
$\frac{G}{GDP}$	Public consumption	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 (2022)
ϕ^π	Taylor rule coefficient	1.5	Standard value
ρ^i	Degree of interest rate smoothing	0.85	Standard value

Calibration II (Back)

Parameter	Description	Value	Target
α_T^X	Intermediate goods share	0.79	$\frac{P_T^X X_s}{P_s^X X_s + W_s N_s} = 0.8$
α_{NT}^X	Intermediate goods share	0.59	$\frac{P_s^X X_s}{P_s^X X_s + W_s N_s} = 0.6$
Θ_T^X	Share of own final goods in X_T	0.65	65%
Θ_{NT}^X	Share of own final goods in X_{NT}	0.65	65%
η_x	Elasticity of sub. between intermediate goods	0.5	See text
ϵ_T^P, ϵ_{NT}^P	Elasticity of substitution for final goods	11	Markup=10%
ϵ_T^w, ϵ_{NT}^w	Elasticity of substitution for labor	11	Markup=10%
θ_T^P, θ_{NT}^P	Rotemberg price parameter	73.3	Slope of NKPC = 0.15
θ_T^w, θ_{NT}^w	Rotemberg wage parameter	366.6	Slope of NKWPC = 0.03
$1/\sigma^*$	EIS	0.5	Standard value
φ^*	Frisch elasticity	0.5	Standard value
β^*	Discount factor	0.995	$r^* = 2\%$ p.a.
ϕ^*	Taylor rule coefficient	1.5	Standard value
ϵ^*	Elasticity of substitution for final goods	11	Markup=10%
θ^*	Rotemberg price parameter	366.6	Slope of NKPC = 0.03
η^*	Export elasticity	1.5	See text