Real Exchange Rate Dynamics Beyond Business Cycles

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Martin Evans (1960-2021)

- Exchange rates
  - Microstructure of the foreign exchange markets (Evans and Lyons (2001, 2008), Evans (2002), ...)
  - Exchange-Rate Dynamics (2011)

- Incomplete markets and portfolio choices, external positions and capital flows (Evans and Hnatkovska (2007, 2012, 2014), Evans (2014, 2017), ...)

- Inflation, inflation expectations, inflation regime switching (Evans (1991, 1998); Evans and Wachtel (1993, 1995), Evans and Lewis (1994), ...)

Outline

Outline

Real Exchange Rate Dynamics

- RER: fundamental variable in international finance and economics. Many open questions (Froot and Rogoff, 1995; Engle et al, 2008; Itskhoki, 2021) and extensive existing research
  - Daily to quarterly variations: Evans and Lyons (2002), Bacchetta and Van Wincoop (2006, 2010), Gabaix and Maggiori (2015), Lilley et al (2020), ...
  - Business cycle variations: BKK (1992), Chari et al (2002), Heathcote and Perri (2002), Corsetti et al (2008), Rabanal et al (2011), Itskhoki and Mukhin (2021), ...
  - Long-run variations: Harrod (1933), Balassa (1964), Samuelson (1964), Asea and Mendoza (1994), Rogoff (1996), ...
  - Medium-term variations: Canzoneri, Cumby, and Diba (1999), Lane and Milesi-Ferretti (2004), Ricci et al (2013), Gourinchas and Rey (2007), Berka, Devereux, Engle (2018), ...
- This paper:
  - empirical analyses at medium-term frequencies using 200+ year time series (Lothian and Taylor, 2008)
  - a neoclassical transmission mechanism to explain empirical results

Main Findings

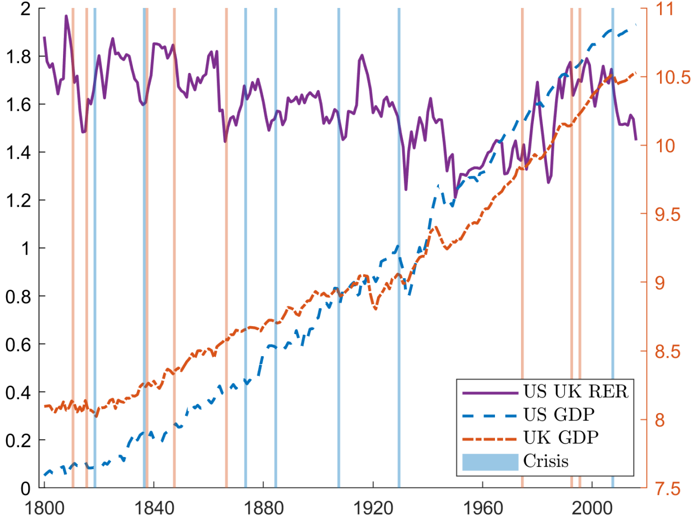
- Empirical results:
  - Real exchange rate appreciates upon positive "productivity" shocks
    - Backus-Smith puzzle
    - Persistent medium run effects
  - Reversal during banking crises
    - Effects dependent on financial conditions

- Neoclassical transmission mechanism
  - Incomplete markets + production and investment + relatively high elasticity of substitution between traded goods ($\theta \geq 2.5$)
  - Persistent positive productivity shock leads to more investment demand ("making hay where the sun shines"), consumption demand, and more borrowing
  - Substitution of foreign traded goods for home traded goods
  - The mechanism dampened at borrowing constraint

Outline

Real Exchange Rate Dynamics: Data

Figure: US/UK Real Exchange Rate, GDP, and Banking Crises



Real Exchange Rate Dynamics: Facts

- Nominal exchange rate: £1 = $\$S_t$. Real exchange rate

$$\mathscr{E}_t = \frac{S_t \hat{P}_t}{P_t} \text{ and } \varepsilon_t = \log \mathscr{E}_t$$

- Control for secular trends: low frequency dynamics co-int. test

$$\varepsilon_t^{\text{LR}} = \underset{(0.367)}{0.624} + \underset{(0.118)}{0.558}\, \hat{y}_t^{\text{trend}} - \underset{(0.079)}{0.439}\, y_t^{\text{trend}}$$

and

$$gap_t = \varepsilon_t - \varepsilon_t^{\text{LR}}$$

- Medium run dynamics:

$$\Delta\varepsilon_t = \begin{bmatrix} \beta_1 & \beta_2 \end{bmatrix} \begin{bmatrix} y_t^{Cycle} \\ \hat{y}_t^{Cycle} \end{bmatrix} + \gamma gap_{t-1} + e_t \tag{1}$$

$$\begin{bmatrix} y_t^{Cycle} \\ \hat{y}_t^{Cycle} \end{bmatrix} = \begin{bmatrix} \alpha_{11} & \alpha_{12} \\ \alpha_{21} & \alpha_{22} \end{bmatrix} \begin{bmatrix} y_{t-1}^{Cycle} \\ \hat{y}_{t-1}^{Cycle} \end{bmatrix} + \begin{bmatrix} \psi_1 \\ \psi_2 \end{bmatrix} \Delta\varepsilon_{t-1} + \begin{bmatrix} v_t \\ \hat{v}_t \end{bmatrix} \tag{2}$$

Real Exchange Rate Dynamics: Unconditional Estimates

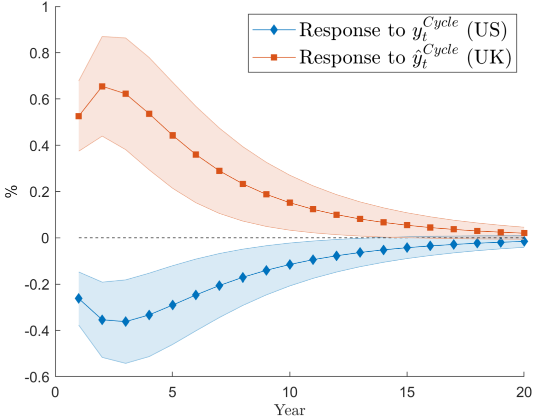
I: Estimates Equation	$\Delta\varepsilon_t$	y_t^{Cycle} (US)	$\hat{y}_t^{Cycle}$ (UK)
	(i)	(ii)	(iii)
Regressors			
y^{Cycle} (US)	-0.262*	0.496***	-0.003
	(0.147)	(0.082)	(0.052)
$\hat{y}^{Cycle}$ (UK)	0.526***	0.278***	0.536***
	(0.159)	(0.099)	(0.095)
gap	-0.175***		
	(0.034)		
$\Delta\varepsilon$		0.043	0.063***
		(0.033)	(0.024)
SEE	0.064	0.033	0.025
R^2	0.137	0.388	0.324

II: Variance Contribution	Horizon (years)				
	1.	5.	10.	15.	20.
GDP Contribution	0.062	0.167	0.217	0.192	0.144
(standard error)	(0.019)	(0.024)	(0.030)	(0.036)	(0.025)
Trend GDP Contribution	0.011	0.036	0.082	0.099	0.077
(standard error)	(0.007)	(0.012)	(0.019)	(0.027)	(0.023)

Notes: Panel I reports estimates of (1) and (2). Estimates are computed by OLS from annual data 1802-2016 (215 observations), and robust standard errors are shown in parenthesis below the coefficient estimates. Statistical significance at the 10, 5 and 1% levels is indicated by *, ** and ***, respectively. Panel II reports the estimated contribution of US and UK GDP (trend and cyclical components) to the variance of the real depreciation rate over horizons from one to 20 years, and the variance contributions of the trend components in US and UK GDP alone.

Real Exchange Rate Dynamics: Facts

Figure: Real Exchange Rate Response



Notes: The figure plots the dynamic response of the log real exchange rate to a shock that induces a one percent increase in either y_t^{Cycle} (US: diamonds) or $\hat{y}_t^{Cycle}$(UK: squares).

Real Exchange Rate Dynamics: State-Dependent Estimates

- With banking crises (Reinhart and Rogoff, 2008):

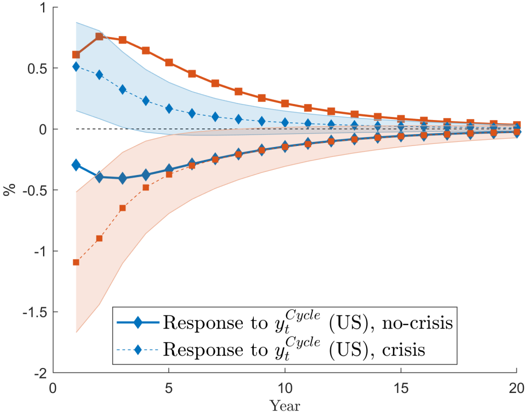
$$\Delta\varepsilon_t = \left(\begin{bmatrix} \beta_1 & \beta_2 \end{bmatrix} + \begin{bmatrix} \beta_1^{\text{diff}} & \beta_2^{\text{diff}} \end{bmatrix} s_t\right) \begin{bmatrix} y_t^{Cycle} \\ \hat{y}_t^{Cycle} \end{bmatrix} + \left(\gamma + \gamma^{\text{diff}} s_t\right) gap_{t-1} + e_t$$

I: Estimates		Real Depreciation Rate Equation:	
		No Crisis	Difference in Crisis
Regressors			
y^{Cycle} (US)		-0.294*	0.806**
		(0.155)	(0.386)
$\hat{y}^{Cycle}$ (UK)		0.609***	-1.702***
		(0.163)	(0.589)
gap		-0.148***	-0.313***
		(0.034)	(0.097)
SEE	0.063		
R^2	0.183		

II: Variance Contribution	Horizon (years)				
	1.	5.	10.	15.	20.
GDP Contribution	0.068	0.185	0.234	0.201	0.149
(standard error)	(0.021)	(0.026)	(0.032)	(0.038)	(0.026)
Trend GDP Contribution	0.009	0.032	0.075	0.091	0.072
(standard error)	(0.006)	(0.012)	(0.018)	(0.027)	(0.023)

Real Exchange Rate Dynamics: Facts

Figure: Conditional Real Exchange Rate Responses



Notes: The figure plots the dynamic response of the log real exchange rate to a shock that induces a one percent increase in either y_t^{Cycle} (US: diamonds) or $\hat{y}_t^{Cycle}$(UK: squares). Solid plots for responses in no-crisis years, dashed plots for crisis years.

Summary of robustness of empirics

- Robust to error correction specification in first difference ECM in Diffs
- No structural breaks in estimates across exchange-rate regimes Regimes

Outline

The Model: Preferences

- Standard IRBC two countries, two-traded goods with home bias in consumption

$$\mathscr{C}(a,b) = \left(\alpha^{\frac{1}{\theta}} a^{\frac{\theta-1}{\theta}} + (1-\alpha)^{\frac{1}{\theta}} b^{\frac{\theta-1}{\theta}}\right)^{\frac{\theta}{\theta-1}}$$

  and in investment
- Incomplete markets: bond denominated in US consumption baskets

$$C_t + q_t^b b_t \leq d_t + w_t + b_{t-1}$$
$$b_t \geq \underline{b}\xi_t$$

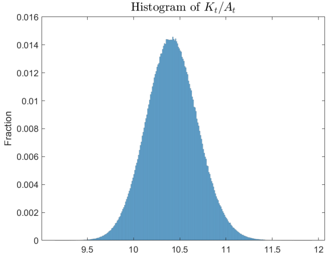
- Persistent productivity shocks:

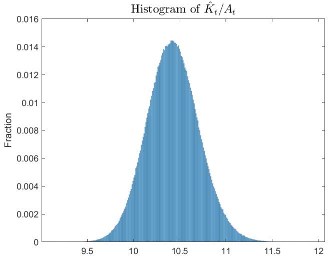
$$\log A_t = \log A_{t-1} + \rho \log\left(\hat{A}_{t-1}/A_t\right) + \varepsilon_t$$
$$\log \hat{A}_t = \log \hat{A}_{t-1} + \rho \log\left(A_{t-1}/\hat{A}_{t-1}\right) + \hat{\varepsilon}_t$$

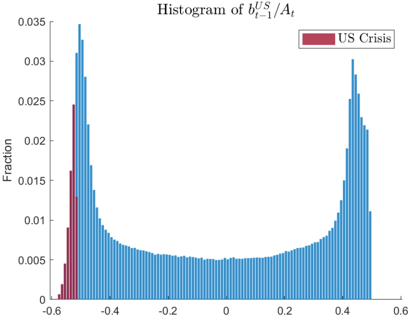
- Borrowing limits: $\log \xi_t = \rho_\xi \log(\xi_{t-1}) + (1-\rho_\xi)\frac{\log(A_t)+\log(\hat{A}_t)}{2}$
- Five continuous state variables (six with two bonds): global solution

The Model: Stationary Recursive Equilibria

Figure: Histograms of Normalized State Variables

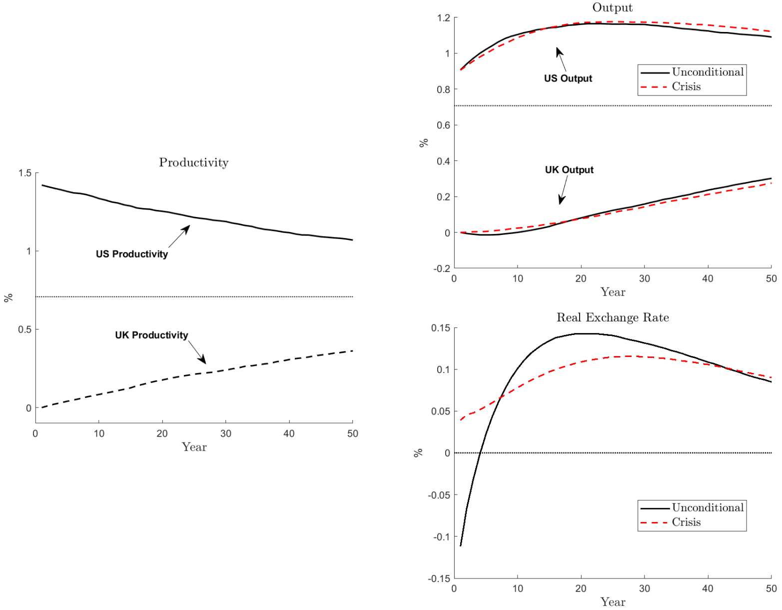




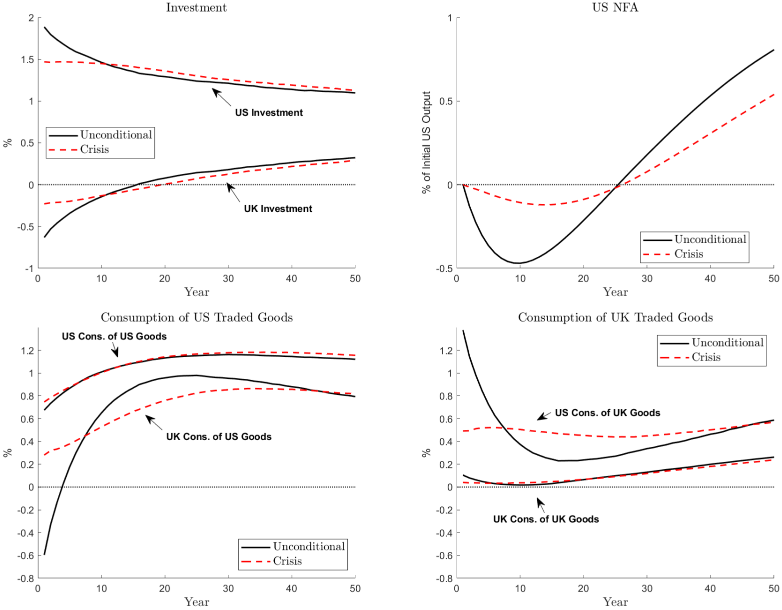


Outline

A neoclassical mechanism: IRFs to US Prod. Shock



A neoclassical mechanism: IRFs to US Prod. Shock



Additional results

- Results (neoclassical transmission; reversal at borrowing constraints) robust to a wide range of trade elasticity ($\theta \geq 2.5$, Broda and Weinstein (2006), Feenstra et al (2018)) Details
- Not HBS: HBS effect does not produce the correct sign of conditional response Details
- Not low trade elasticity: mechanisms that rely on low trade elasticity (Corsetti et al, RES, 08) do not produce the correct sign of conditional responses Details
- Investment is key: endowment economy cannot generate the unconditional appreciation Details
- Robust to stationary productivity processes - albeit with less persistent responses Details
- Robust to investment with imperfect home bias Details
- Resolve Backus-Smith puzzle Details

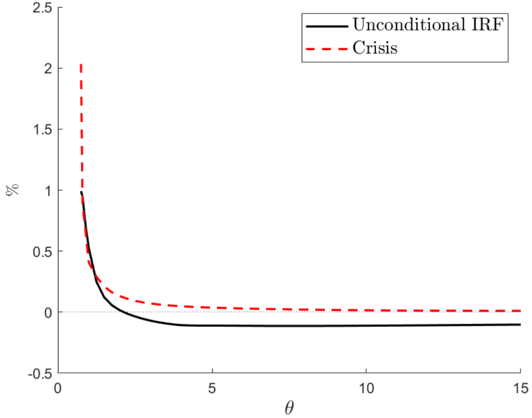
Outline

Conclusions

- New empirical facts about real exchange dynamics in medium-term frequencies
- New transmission mechanism
- State-dependent dynamics
- More medium-term variations to be explained!

Trade Elasticities

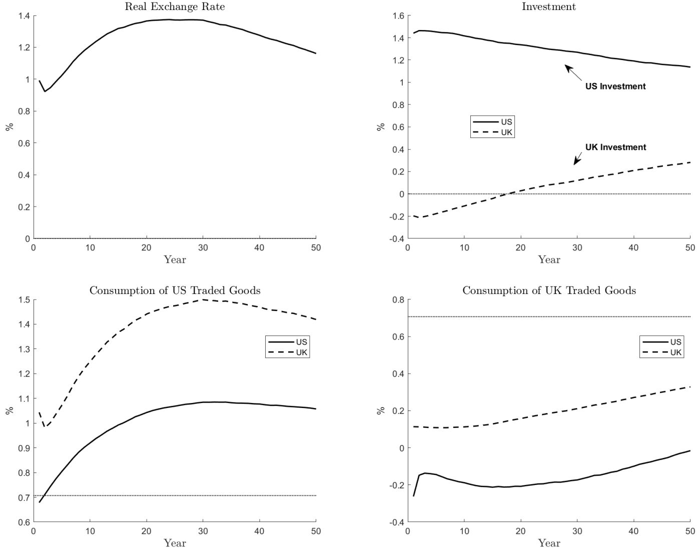
Figure: Comparative Statics in Trade Elasticity



Notes: Plotted are **Impact responses** of real exchange rate as functions of the trade elasticity, θ.

Back

IRFs to positive US prod. shocks - low trade elasticity ($\theta = 0.75$)



- Require depreciation to generate a negative income effect to clear US goods market when θ is low Back

Traded and non-traded goods

- Traded and non-traded

$$\mathscr{C}_t = \left(\lambda^{\frac{1}{\kappa}} \left(C_t^T \right)^{\frac{\kappa-1}{\kappa}} + (1-\lambda)^{\frac{1}{\kappa}} \left(C_t^{NT} \right)^{\frac{\kappa-1}{\kappa}} \right)^{\frac{\kappa}{\kappa-1}}$$

- Price indices

$$P_t = \left(\lambda (P_t^{\mathrm{T}})^{1-\kappa} + (1-\lambda)(P_t^{\mathrm{NT}})^{1-\kappa} \right)^{\frac{1}{1-\kappa}}$$

$$P_t^{\mathrm{T}} = \left(\alpha (P_t^{\mathrm{US}})^{1-\theta} + (1-\alpha)(P_t^{\mathrm{UK}})^{1-\theta} \right)^{\frac{1}{1-\theta}}$$

- Decomposition

$$\mathscr{E}_t = \frac{S_t \hat{P}_t}{P_t} = \underbrace{\left[\frac{S_t \hat{P}_t^{\mathrm{T}}}{P_t^{\mathrm{T}}} \right]}_{\mathrm{ToT}} \underbrace{\left[\frac{\left(\hat{\lambda} + \left(1-\hat{\lambda}\right) (\hat{P}_t^{\mathrm{NT}}/\hat{P}_t^{\mathrm{T}})^{1-\kappa} \right)^{\frac{1}{1-\kappa}}}{\left(\lambda + (1-\lambda)(P_t^{\mathrm{NT}}/P_t^{\mathrm{T}})^{1-\kappa} \right)^{\frac{1}{1-\kappa}}} \right]}_{\mathrm{HBS}}$$

- Non-traded productivity: $A_t^{\mathrm{NT}} = A_t$ or $A_t^{\mathrm{NT}} = \xi_t$

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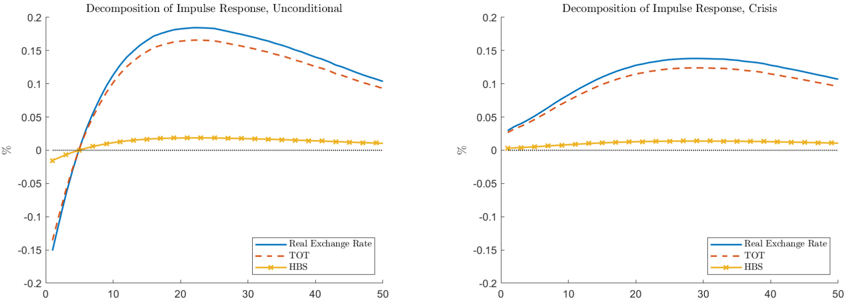
Traded and non-traded goods: **perfectly** correlated A_t^{NT} and A_t

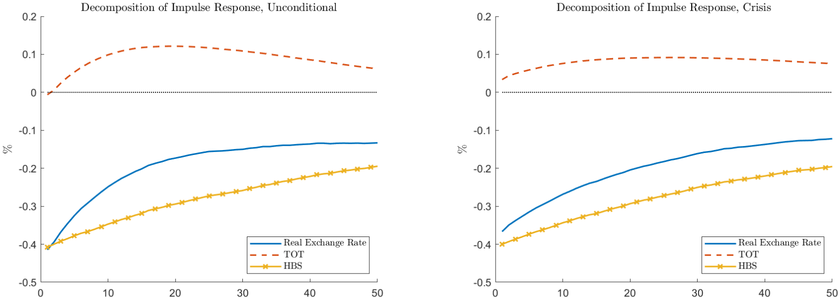
Figure: IRFs of Real Exchange Rate - Decomposition



- HBS effects are muted with perfectly correlated A_t^{NT} and A_t

HBS effects: **imperfectly** correlated A_t^{NT} and A_t

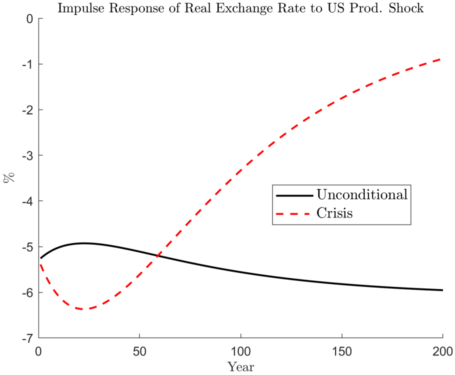
Figure: IRFs of Real Exchange Rate - Decomposition



- HBS effects do not generate the empirical conditional responses
- TOT effects still see the conditional responses

Back

Mechanisms that rely on low trade elasticity do not produce the correct conditional responses

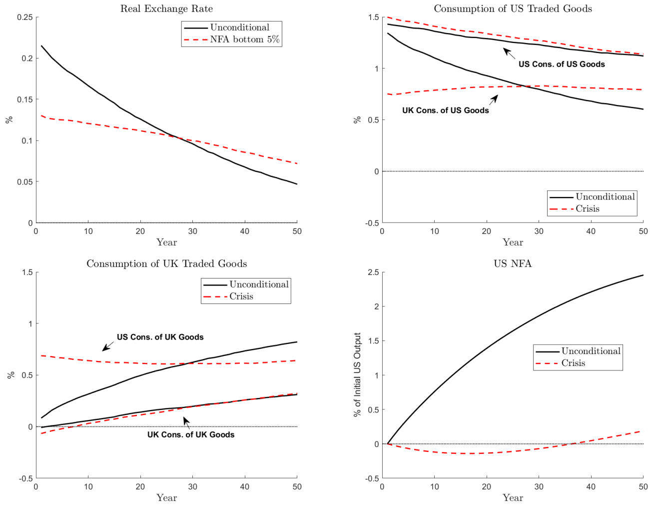


Notes: $\theta = 0.4 < \frac{2\alpha - 1}{2\alpha}$.

- Relies on that income effect dominates substitution effect; but income effect is larger close to the borrowing constraint

Back

Endowment economy (no investment)

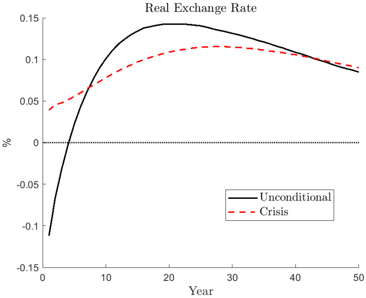


Notes: same parameterization as the benchmark

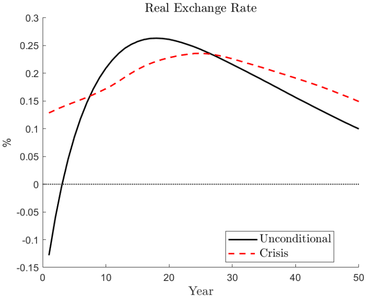
Back

Stationary productivity processes

$$\log A_t = \rho_A \log A_{t-1} + \varepsilon_t, \quad \rho_A = 0.98$$



(a) Benchmark - cointegrated productivity process

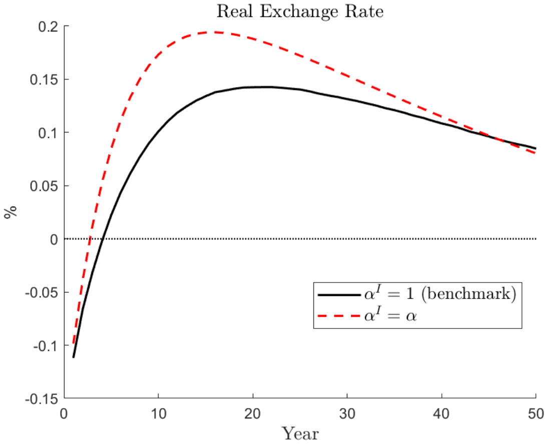


(b) Stationary productivity processes

Back

Imperfect investment home bias

$$I_t = \left(\left(\alpha^I\right)^{\frac{1}{\theta}} \left(I_t^{\mathrm{US}}\right)^{\frac{\theta-1}{\theta}} + \left(1-\alpha^I\right)^{\frac{1}{\theta}} \left(I_t^{\mathrm{UK}}\right)^{\frac{\theta-1}{\theta}} \right)^{\frac{\theta}{\theta-1}}$$



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Back-Smith correlation under different market structures

Economy	RER-Output Corr $corr\left(\Delta \log Y_{t+1}, \Delta \log \mathscr{E}_{t+1}\right)$	Backus-Smith Corr $corr\left(\Delta \log C_{t+1} - \Delta \log \hat{C}_{t+1}, \Delta \log \mathscr{E}_{t+1}\right)$
Specifications		
Complete Markets	0.519	1.000
Incomplete Markets (2 bonds)	-0.478	-0.707
Incomplete Markets (1 bond)	-0.444	-0.632
Financial Autarky	0.705	1.000

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Cointegration test

Table: p-value of tests for the stationarity of ε_t and gap_t

	ADF test (H0: unit root)		KPSS test (H0: stationary)
	w/ constant	wo/ constant	
ε_t	0.167	0.451	< 0.01
gap_t	2.13E-05	7.37E-07	> 0.1

Notes: Reported are p-values of each test. Optimal lags selected based on AIC

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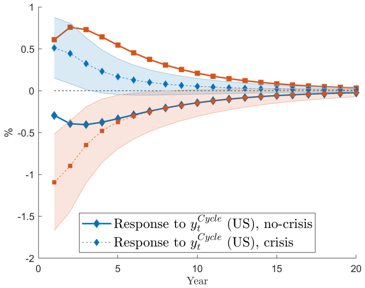
Error-correction specification in first difference: estimation

	Benchmark	Benchmark Lag(4)	Diff	Diff Lag(4)
$y^{Cycle}(US)$	-0.294**	-0.333***		
	(0.123)	(0.116)		
$\times crisis$	0.806**	0.726*		
	(0.399)	(0.408)		
$y^{Cycle}(UK)$	0.609***	0.615***		
	(0.157)	(0.152)		
$\times crisis$	-1.702***	-1.665***		
	(0.591)	(0.580)		
$\Delta y(US)$			-0.099	-0.121
			(0.131)	(0.135)
$\times crisis$			1.318**	1.267**
			(0.618)	(0.603)
$\Delta y(UK)$			0.339**	0.319**
			(0.151)	(0.151)
$\times crisis$			-1.068**	-1.053**
			(0.481)	(0.488)
L.gap	-0.148***	-0.064***	-0.157***	-0.151***
	(0.032)	(0.023)	(0.030)	(0.029)
$\times crisis$	-0.313***	-0.177**	-0.316***	-0.312***
	(0.091)	(0.079)	(0.088)	(0.106)
N	216	216	216	216
R^2	0.183	0.116	0.161	0.152

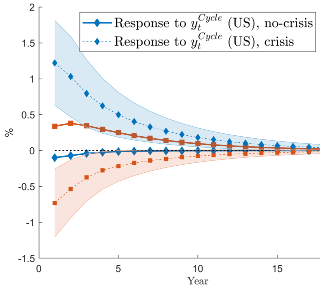
Notes: HAC (Bartlett kernel with bandwidth 4) standard errors in parenthesis
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Back

Error-correction specification in first difference: IRFs



(a) Benchmark



(b) First Difference

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Testing for structural breaks

	Real Depreciation Rate Equation: $\Delta\varepsilon$	
	(1) Baseline	(2) Testing breaks
Regressors		
y^{Cycle}(US)	-0.294*	-0.296*
	(0.155)	(0.158)
$\times crisis$	0.806**	1.481
	(0.386)	(0.935)
$\times crisis \times 1(1914-1948)$		-
$\times crisis \times 1(1949-1971)$		-
$\times crisis \times 1(1972-2016)$		1.601
		(2.350)
y^{Cycle}(UK)	0.609***	0.609***
	(0.163)	(0.167)
$\times crisis$	-1.702***	-2.147***
	(0.589)	(0.625)
$\times crisis \times 1(1914-1948)$		-0.705
		(0.737)
$\times crisis \times 1(1949-1971)$		-
$\times crisis \times 1(1972-2016)$		-1.111
		(3.233)
gap	-0.148***	-0.144***
	(0.034)	(0.0355)
$\times crisis$	-0.313***	-0.316***
	(0.097)	(0.0995)
R-squared	0.183	0.188
F-statistics (all triple interaction coefs = 0)	-	0.51

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