Mussa Puzzle Redux

Implications for Optimal Monetary and Exchange Rate Policy

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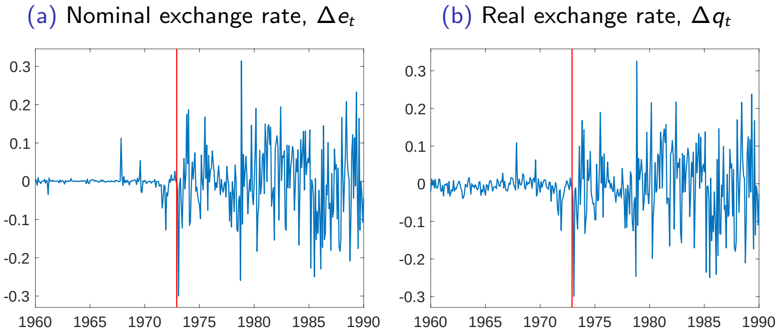
Mussa Puzzle

- *Real* exchange rate (RER):

$$\mathcal{Q}_t = \frac{\mathcal{E}_t P_t^*}{P_t} \quad \text{or in log changes} \quad \Delta q_t = \Delta e_t + \pi_t^* - \pi_t$$



Note: US vs the rest of the world (G7 countries except Canada plus Spain), monthly.

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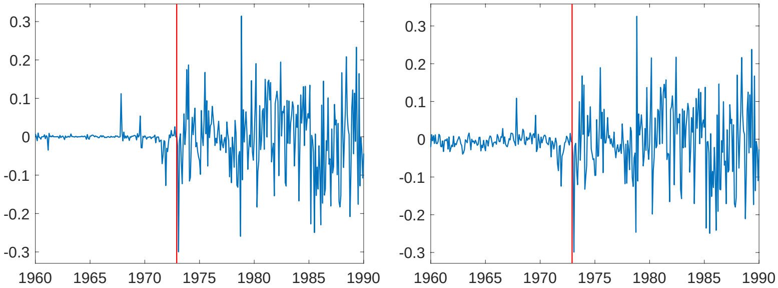
- Mussa puzzle is some of the most convincing evidence for monetary non-neutrality (Nakamura and Steinsson, 2018)

(a) Nominal exchange rate, Δe_t (b) Real exchange rate, Δq_t



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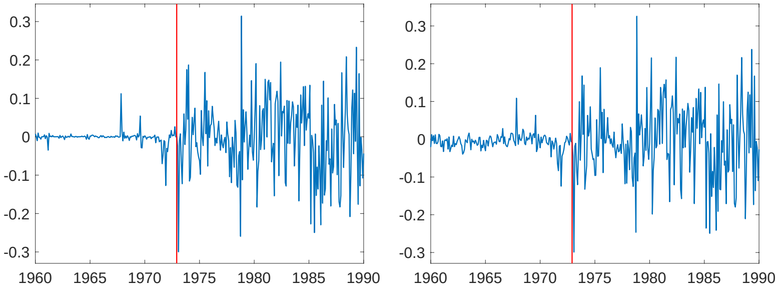

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- We argue instead: monetary policy transmission via *risk premia*

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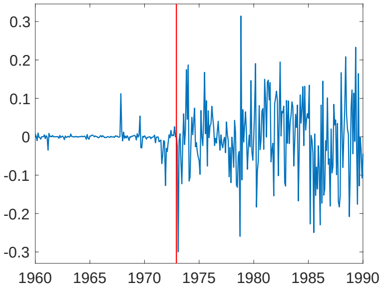
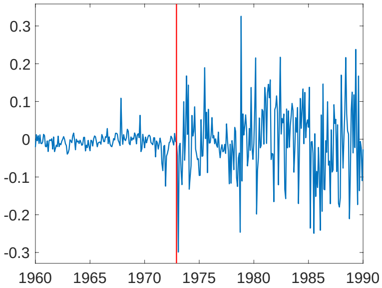


(b) Real exchange rate, Δq_t



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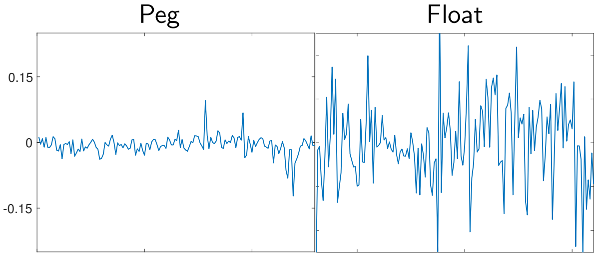
Mussa Puzzle Redux

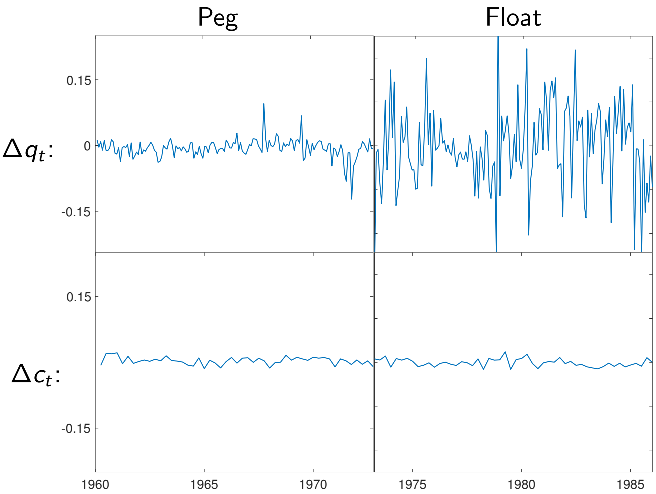
Δq_t:



$\Rightarrow$ ✗ IRBC (flex prices)

$q_t = e_t + p_t^* - p_t$

Mussa Puzzle Redux



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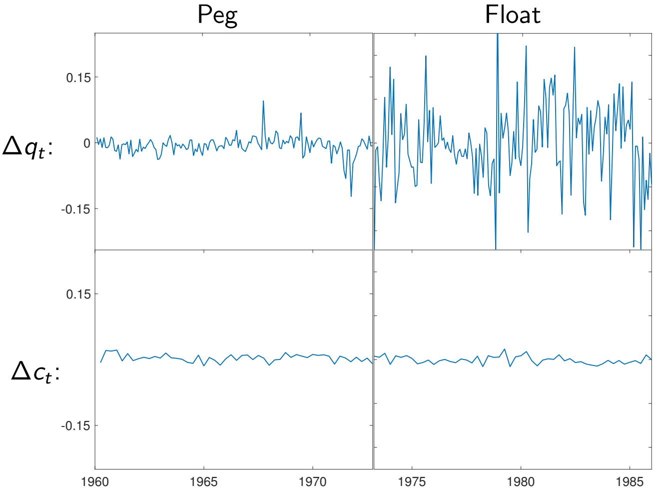
$q_t = e_t + p_t^* - p_t$

$\Rightarrow$ ✗ NKOE (sticky prices)

$\sigma(c_t - c_t^*) - q_t = z_t$

Mussa Puzzle Redux



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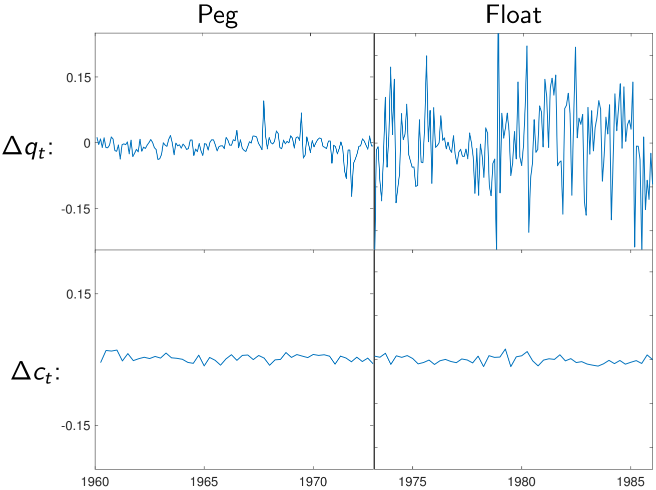
$\Downarrow$

✓ ER Disconnect

$$i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = \hat{\psi}_t$$

Mussa Puzzle Redux



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$\Downarrow$ ✓ Mussa Redux

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$$i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1} = \hat{\psi}_t$$

Related Literature

1. **Empirical evidence**
   Frenkel & Levich (1975), Mussa (1986), Stockman (1983, 1988), Baxter & Stockman (1989), Bordo (1993), Flood & Rose (1995), Colacito & Croce (2013), Bergin, Glick & Wu (2014), Devereux & Hnatkovska (2014), Berka, Devereux & Engel (2018)

   — combine evidence on prices, quantities and asset prices

2. **Falsification of "conventional" models**
   Dedola & Leduc (2001), Chari, Kehoe & McGrattan (2002), Duarte (2003), Monacelli (2004), Kollmann (2005)

   — derive & estimate sufficient statistic for a large class of models

3. **Alternative model of non-neutrality**
   Krugman (1991), Davis, Nalewaik, Willen (2000), Jeanne & Rose (2002), Devereux & Engel (2002), Alvarez, Atkeson & Kehoe (2007, 2009), Bacchetta, Tille & van Wincoop (2012), Gabaix & Maggiori (2015)

   — GE model with asset pricing endogenous to monetary policy

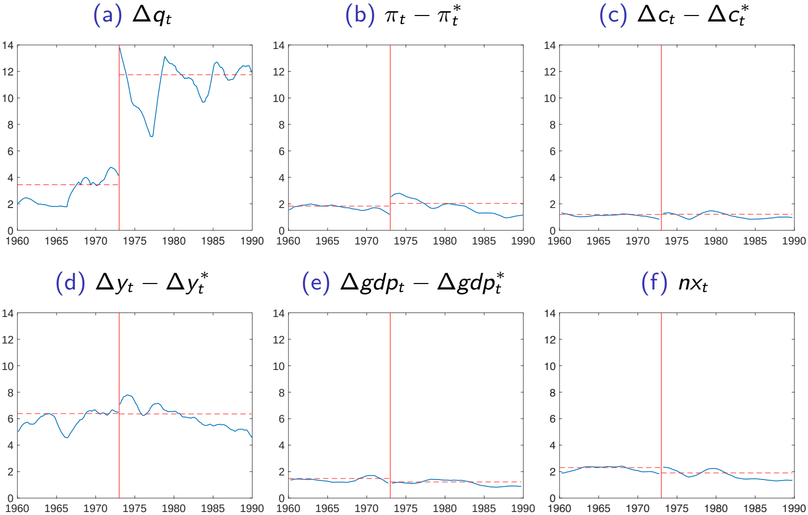
Roadmap

1. Empirical patterns
2. Falsification of “conventional” models
3. Alternative model of non-neutrality
4. Quantitative evaluation
5. Optimal Policy

EMPIRICAL PATTERNS

Macroeconomic Volatility

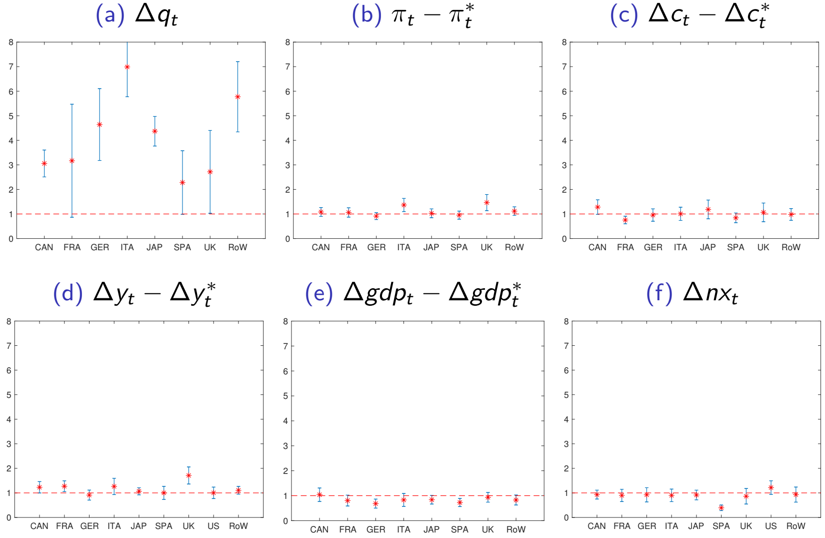
Figure: Standard deviations (triangular moving average)



Data Zoom in Quarterly ToT Asset Prices

Cross-Country Evidence

Figure: Ratios of std under float vs. peg (with 90% HAC conf. intervals)



▸ nx-gdp ▸ correlations

THEORY

General Model Setup

- Two-country Open Economy model
- Home Households:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{1}{1+\varphi} L_t^{1+\varphi} \right)$$

$$\text{s.t.} \quad P_t C_t + \sum\nolimits_{j \in J_t} \Theta_t^j B_{t+1}^j \leq W_t L_t + \sum\nolimits_{j \in J_{t-1}} e^{-\zeta_t^j} D_t^j B_t^j + \Pi_t + T_t$$

- CES aggregator with home bias parameter $\gamma \in (0, \frac{1}{2})$:

$$C_t = \left[\int_0^1 \left((1-\gamma)^{\frac{1}{\theta}} e^{-\frac{\gamma}{\theta}\xi_t} C_{Ht}(i)^{\frac{\theta-1}{\theta}} + \gamma^{\frac{1}{\theta}} e^{\frac{1-\gamma}{\theta}\xi_t} C_{Ft}(i)^{\frac{\theta-1}{\theta}} \right) \mathrm{d}i \right]^{\frac{\theta}{\theta-1}}$$

- Production: e.g. $Y_t(i) = e^{a_t} L_t(i)$
- Monetary policy: 'float' is $\pi_t \equiv 0$ and 'peg' is $\Delta e_t \equiv 0$

Equilibrium Conditions

1. International risk sharing (financial market):

$$\mathbb{E}_t\Big\{\sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) - \Delta q_{t+1}\Big\} = \hat{\psi}_t$$
$$\equiv -\mathbb{E}_t\tilde{\zeta}_{t+1} + RP_t$$

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2. Intertemporal budget constraint:

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3. Goods market:
   - allow for PCP/LCP/DCP and sticky wages ▸ details
   - any monetary rule, any shocks, any degree of openness γ

Definition (Conventional models): *monetary regime has real effects via sticky prices only, and* **no** *effect on the risk premium* $\hat{\psi}_t$.

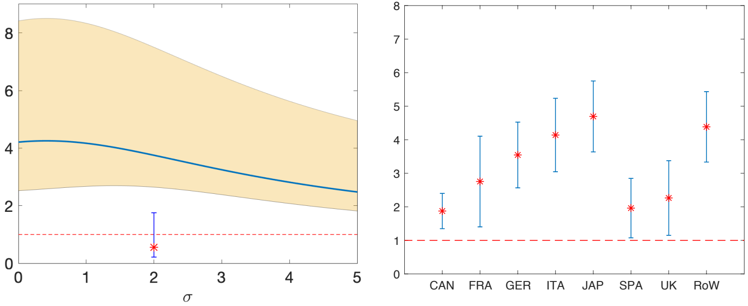
Empirical Falsification

- **Proposition 1**: *In the Cole-Obstfeld case $\sigma = \theta = 1$, in conventional models the equilibrium relationship*

$$z_t \equiv \sigma(c_t - c_t^*) - q_t$$

does **not** *depend on the exchange rate regime.* ▸ IRF

Figure: Ratio of $\mathrm{std}\big(\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t\big)$ under float vs. peg



$\Rightarrow$ Need a model with risk premium $\hat{\psi}_t$ endogenous to MP ▸ show

ALTERNATIVE MODEL OF NON-NEUTRALITY

Alternative Model

- Emphasize financial frictions instead of nominal rigidities
  - switch off nominal rigidities altogether

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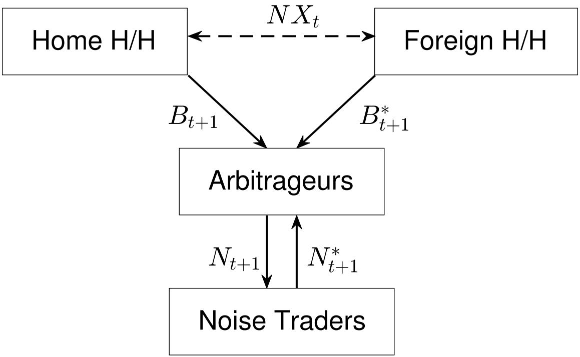

Financial Market Equilibrium

- Financial intermediaries invest in a **carry trade** strategy:

$$\max_{d^*_{t+1}} \mathbb{E}_t \left\{ -\frac{1}{\omega} \exp\left(-\omega \frac{\tilde{R}^*_{t+1}}{P^*_{t+1}} d^*_{t+1} \right) \right\}, \quad \tilde{R}^*_{t+1} \equiv R^*_t - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

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- **Lemma 2**: (i) *Optimal portfolio choice:* ▸ *details*

$$d^*_{t+1} = -\frac{i_t - i^*_t - \mathbb{E}_t \Delta e_{t+1}}{\omega \sigma_e^2}, \quad \sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$$

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(ii) *Equilibrium in the financial market:* ▸ *details*

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- Monetary regime changes $\sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$
  — a source of **non-neutrality**, even without nominal rigidities

General Equilibrium

1. International risk sharing:

$$\mathbb{E}_t\left\{\sigma(\Delta c_{t+1}-\Delta c^*_{t+1})-\Delta q_{t+1}\right\}=\chi_1\psi_t-\chi_2 b_{t+1},\quad \chi_1,\chi_2\propto\omega\sigma_e^2$$

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$$\beta b_{t+1} - b_t = nx_t = \gamma\left(\hat{\theta} q_t - (c_t - c_t^*) - \tilde{\xi}_t\right)$$

3. Goods market clearing:

$$c_t - c_t^* = \kappa_a(a_t - a_t^*) - \gamma\kappa_q q_t$$

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Proposition 2: *A change in the NER regime results in:*

a) *an arbitrary large increase in volatility of both nominal and real exchange rates* ▸ details ▸ IRF

b) *a vanishingly small change in macro variables when* $\gamma\approx 0$ *(partial and general equilibrium channels)* ▸ show

Additional Evidence

"Overidentification"

1. Forward premium puzzle ▸ show
    - UIP and CIP both hold under peg (Frankel and Levich 1975)
    - UIP puzzle under float (Colacito and Croce 2013)

2. Backus-Smith puzzle ▸ show
    - $\mathrm{corr}(\Delta q, \Delta c - \Delta c^*)$ switches sign: $+$ under peg, $-$ under float (Colacito and Croce 2013, Devereux and Hnatkovska 2014)

3. Balassa-Samuelson effect ▸ show
    - no explanatory power under float (Engel 1999)
    - works well under peg (Berka, Devereux and Engel 2018)

4. Reserves and Turnover in FX market ▸ show ▸ show

QUANTITATIVE EVALUATION

Quantitative Framework

- Sticky wages and LCP sticky prices (on/off)
- Capital with adjustment costs
- Pricing-to-market & intermediate inputs
- Shocks:
  1. Productivity a_t or monetary shocks ε_t^m
  2. Taste shock ξ_t
  3. Financial shock ψ_t
- Taylor rule with a weight on nominal exchange rate

$$i_t = \rho_m i_{t-1} + (1-\rho_m)[\phi_\pi \pi_t + \delta_e (e_t - \bar{e})] + \varepsilon_t^m$$

  — size of shocks calibrated to yield $\mathrm{std}(\Delta e_t) = 0.12$ under float

  — ER regime δ_e calibrated to change $\mathrm{std}(\Delta e_t)$ eightfold

- Standard calibration ▸ show

Results

Table: Standard deviations

	Δq_t			$\sigma(\Delta c_t - \Delta c_t^*) - q_t$			Δgdp_t			$i_t - i_t^*$		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Data	1.8	9.9	**5.6**	2.5	10.7	**4.3**	1.1	0.9	**0.8**	0.3	0.5	**1.7**

▸ Var Decomp ▸ std ▸ corr

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Models without UIP shock $\hat{\psi}_t$:												
IRBC	15.4	15.4	1.0	9.3	9.3	1.0	15.0	15.0	1.0	0.4	1.4	3.3
NKOE-*a*	4.2	12.8	3.0	11.3	10.8	1.0	17.7	11.7	0.7	0.4	0.9	2.2
NKOE-*m*	1.5	11.3	7.5	2.0	2.0	1.0	7.8	8.2	1.0	0.7	1.3	1.9

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Models with exogenous financial shock $\hat{\psi}_t$:												
IRBC	11.0	11.0	1.0	13.6	13.6	1.0	2.5	2.5	1.0	1.7	0.4	0.2
NKOE-*a*	2.2	11.9	5.3	14.0	13.2	0.9	14.5	2.1	0.1	2.1	0.4	0.2
NKOE-*m*	2.1	11.8	5.7	13.9	13.1	0.9	8.6	1.8	0.2	2.3	0.4	0.2

Var Decomp std corr

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Models with endogenous financial shock $\chi_1(\sigma_e^2)\cdot\psi_t$:												
IRBC	3.0	11.0	3.6	1.5	13.6	9.1	2.5	2.5	1.0	0.2	0.4	1.9
NKOE-*a*	1.7	11.9	6.9	1.2	13.2	11.1	1.9	2.1	1.1	0.2	0.4	2.5
NKOE-*m*	1.4	11.8	8.2	0.5	13.1	27.3	1.5	1.8	1.2	0.3	0.4	1.6

Var Decomp · std · corr

OPTIMAL POLICY

Alternative Models

Segmented markets

(This paper, Jeanne-Rose'02, AAK'09)

IRBC/NKOE

Alternative Models

Segmented markets
(This paper, Jeanne-Rose'02, AAK'09)

Expectation errors & Heterogeneous beliefs
(Gourinchas-Tornell'04, Bacchetta-vanWincoop'06)

Financial frictions
(Gabaix-Maggiori'15, Bruno-Shin'15, Brunnermeier-Sannikov'15)

Risk premium under complete markets
(Verdelhan'10, Colacito-Croce'11, Farhi-Gabaix'16)

Convenience yield (BiU)
(Engel'16, Valchev'16, JKL'18)

IRBC/NKOE

Policy Tradeoff

1. Financial market:

$$\mathbb{E}_t\Big\{\sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) - \Delta q_{t+1}\Big\} = \chi_1(\sigma_e^2) \cdot \psi_t$$

2. Goods market, e.g. assuming PCP/sticky wages:

$$\Delta q_t = \beta \mathbb{E}_t \Delta q_{t+1} - \hat{k}_R \cdot \big[(c_t - c_t^*) + \gamma \kappa_q q_t - \kappa_a \tilde{a}_t\big]$$

$$\text{where} \quad \hat{k}_R = \begin{cases} \kappa, & R = \text{peg} \\ \frac{1}{2\gamma}\kappa, & R = \text{float} \end{cases} \quad \text{and} \quad \kappa = \frac{(1-\lambda)(1-\beta\lambda)}{\lambda}(\sigma + \varphi)$$

Policy Tradeoff

1. Financial market:

$$\mathbb{E}_t\Big\{\sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) - \Delta q_{t+1}\Big\} = \chi_1(\sigma_e^2) \cdot \psi_t$$

2. Goods market, e.g. assuming PCP/sticky wages:

$$\Delta q_t = \beta \mathbb{E}_t \Delta q_{t+1} - \hat{k}_R \cdot \big[(c_t - c_t^*) + \gamma\kappa_q q_t - \kappa_a \tilde{a}_t\big]$$

where $\hat{k}_R = \begin{cases} \kappa, & R = \text{peg} \\ \frac{1}{2\gamma}\kappa, & R = \text{float} \end{cases}$ and $\kappa = \frac{(1-\lambda)(1-\beta\lambda)}{\lambda}(\sigma + \varphi)$

- Government policy:
  - Taylor rule: $i_t = \rho_m i_{t-1} + (1-\rho_m)[\phi_\pi \pi_t + \delta_e(e_t - \bar{e})] + \varepsilon_t^m$
  - Asset market intervention: details

$$B_{t+1} + D_{t+1} + N_{t+1} + F_t = 0 \quad \text{and} \quad B^*_{t+1} + D^*_{t+1} + N^*_{t+1} + F^*_t = 0$$

Optimal Policy

- With both policy tools (MP and FM interventions):
  - the government can address both risk sharing and output gap
  - use QE to offset noise-trader (currency demand) shocks
  - use monetary policy for inflation/output gap stabilization

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  - pegs and partial pegs are useful to improve risk sharing
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  - the government can address both risk sharing and output gap
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  - at the cost of greater inflation volatility/output gap

- Alternative objectives in the goods/financial market:
  - encourage exchange rate volatility to reduce the arbitrage activity in the fin. market, relaxing implementability constraints

Conclusion

- Mussa puzzle is prime evidence of monetary non-neutrality
- We argue, however, that it is a weak test of nominal rigidities
  - — sticky prices are not sufficient (and neither necessary)
- Instead, emphasize monetary policy transmission via risk premia in segmented financial markets
- Important for reassessing arguments in favor of float vs peg and, more broadly, optimal policy in an open economy

APPENDIX

Data

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- Two datasets:
  1. IMF's International Financial Statistics: monthly data on exchange rates, inflation, production index, discount rates and total share prices
  2. OECD: quarterly data on consumption, GDP and trade
     - real variables, seasonally-adjusted
     - net exports: $nx \equiv (X - M)/(X + M)$
     - log changes are annualized for comparability
- Dating the end of Bretton Woods:
  - 1973:02 as the benchmark
  - "Nixon shock" in 1971:08 for robustness
  - 1967–1971: a few jumps in NER
- Countries: France, Germany, Italy, Japan, Spain, and the U.K. Also Canada.

Macroeconomic Volatility

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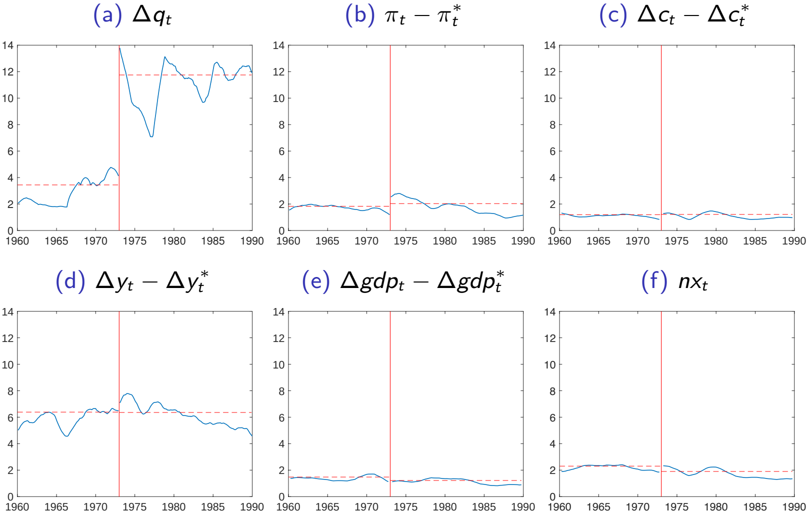
Figure: Standard deviations (triangular moving average)



Macroeconomic Volatility

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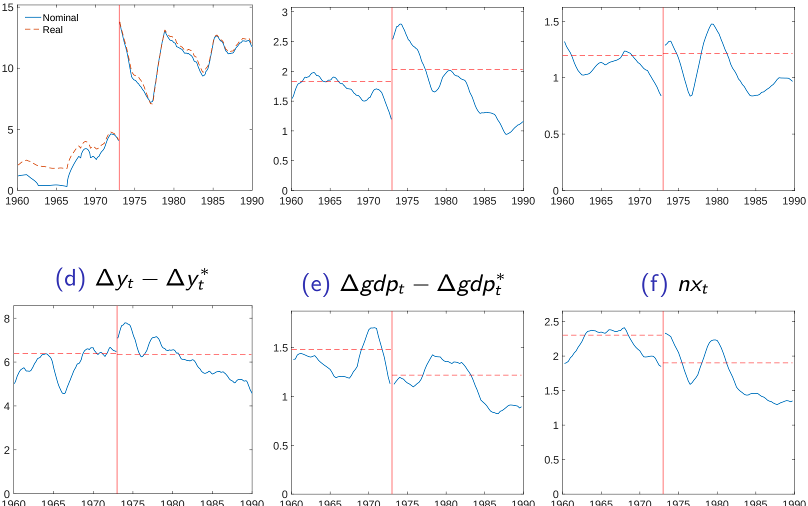
Figure: Standard deviations (triangular moving average)

(a) Δq_t (b) $\pi_t - \pi_t^*$ (c) $\Delta c_t - \Delta c_t^*$ (d) $\Delta y_t - \Delta y_t^*$ (e) $\Delta gdp_t - \Delta gdp_t^*$ (f) nx_t



Macroeconomic Volatility

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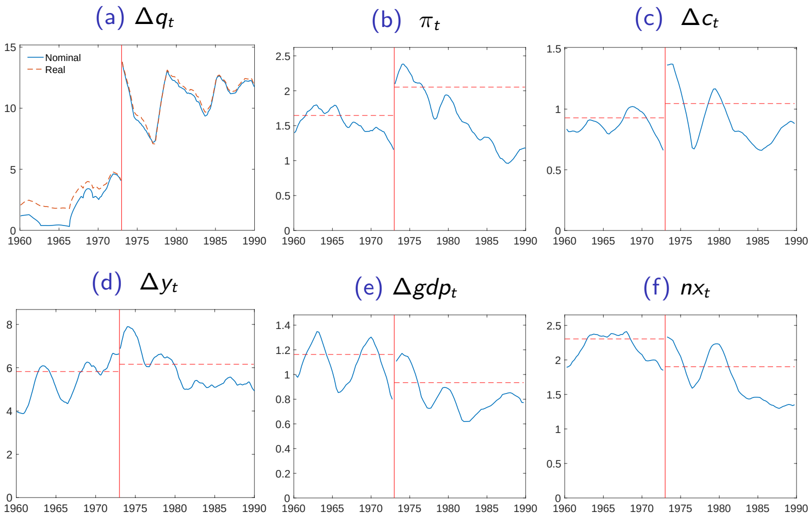
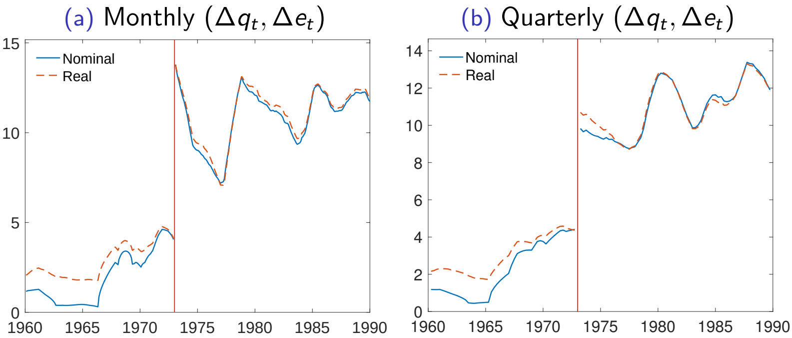
Figure: Standard deviations (triangular moving average)



Monthly vs. Quarterly Series



Note: Triangular moving average correlations, treating 1973:01 as the end point for the two regimes

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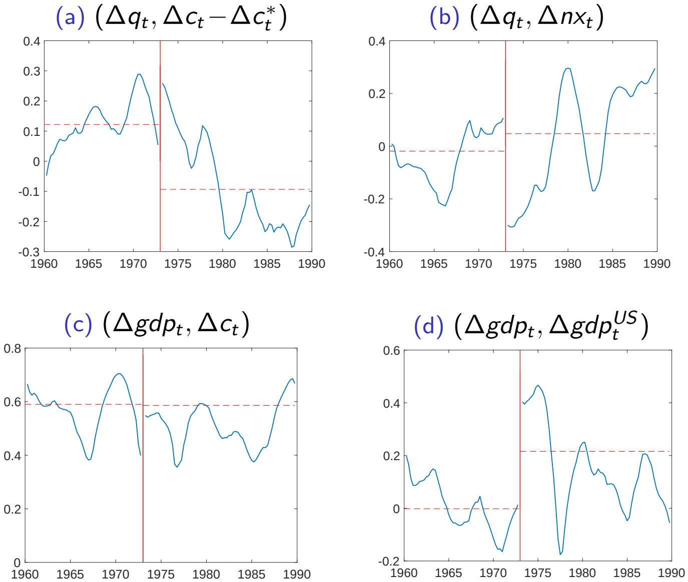
Correlations



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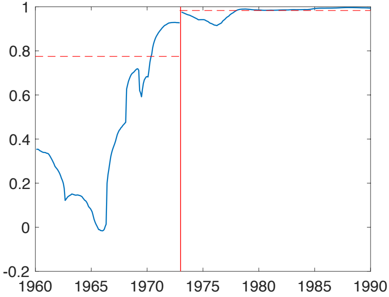
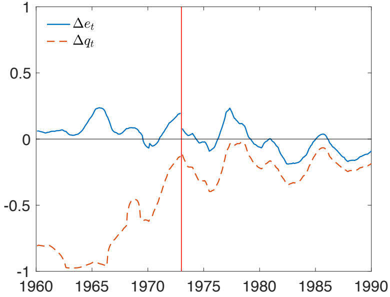
Correlations

(a) $(\Delta q_t, \Delta e_t)$



(b) $(\bullet, \pi_t - \pi_t^*)$



Note: Triangular moving average correlations, treating 1973:01 as the end point for the two regimes

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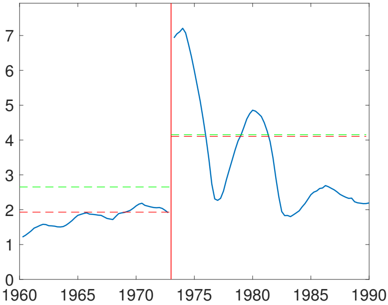
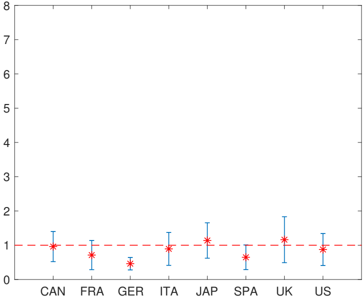
Terms of Trade Volatility

(a) U.S., quarterly data



(b) All countries, annual data



Note: blue and red lines in (a) are constructed for the aggregate ToT, while the green line corresponds to the non-petrolium ToT.

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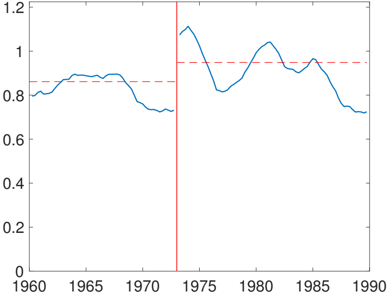
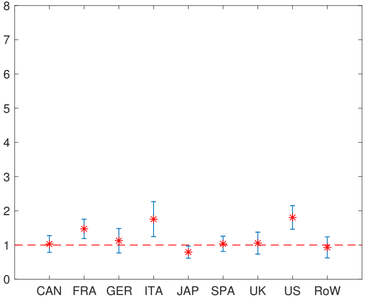
Alternative Measure of NX

Figure: Std of NX-to-GDP

(a) Moving average



(b) Ratio of std: float vs. peg



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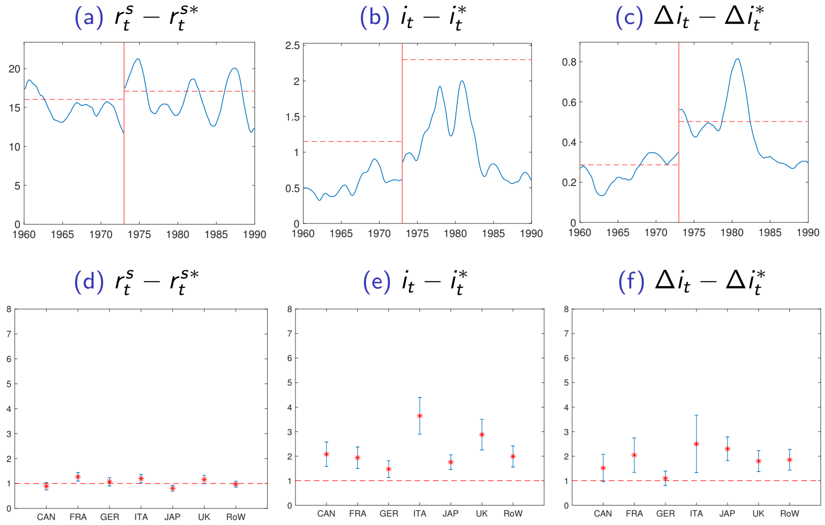
Asset Prices

Figure: Std of stock market returns and discount rates

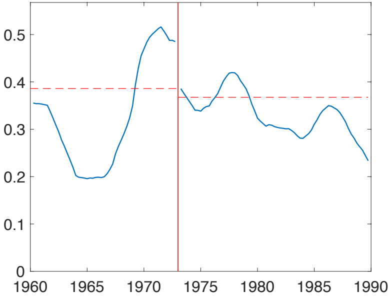


reserves turnover back to slides

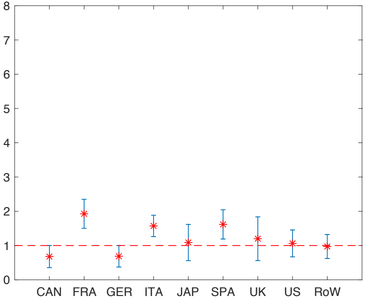
Reserves

Figure: std $\left(\Delta \frac{\text{FX reserves}}{\text{GDP}}\right)$ (quarterly data from IMF IFS)

(a) Aggregate



(b) Individual countries



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	Δe_t			Δq_t			$\pi_t - \pi_t^*$			$\Delta c_t - \Delta c_t^*$		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Canada	0.8	4.4	5.7*	1.5	4.7	3.0*	1.3	1.4	1.1	0.8	1.1	0.9
France	3.4	11.8	3.5*	3.7	11.8	3.2*	1.3	1.3	1.0	1.2	0.9	0.7*
Germany	2.4	12.3	5.0*	2.7	12.5	4.7*	1.4	1.3	0.9	1.3	1.2	0.9
Italy	0.5	10.4	18.8*	1.5	10.4	6.9*	1.4	1.9	1.3*	1.0	1.1	1.0
Japan	0.8	11.7	13.8*	2.7	11.9	4.4*	2.7	2.8	1.0	1.1	1.3	1.2
Spain	4.4	10.8	2.5*	4.7	10.8	2.3*	2.7	2.6	0.9	1.2	1.0	0.8
U.K.	4.1	11.5	2.8*	4.4	12.0	2.7*	1.7	2.5	1.5*	1.4	1.5	1.1
RoW	1.2	9.8	8.0*	1.8	9.9	5.6*	1.3	1.4	1.1	0.9	0.9	1.0

	$\Delta gdp_t - \Delta gdp_t^*$			$\Delta y_t - \Delta y_t^*$			Δnx_t			$\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t$		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Canada	1.0	1.0	1.0	3.8	4.9	1.3	1.7	1.6	0.9	2.4	4.5	1.9*
France	1.2	1.0	0.8	5.3	5.6	1.1	1.5	1.4	0.9	4.4	12.2	2.7*
Germany	1.8	1.2	0.7*	6.7	6.0	0.9	1.8	1.7	0.9	3.9	13.7	3.5*
Italy	1.5	1.3	0.8	8.1	9.7	1.2	2.5	2.2	0.9	2.8	11.4	4.1*
Japan	1.5	1.3	0.8	5.5	5.0	0.9	2.4	2.2	0.9	2.8	13.1	4.7*
Spain	1.6	1.2	0.7*	10.1	10.4	1.0	5.4	2.1	0.4*	5.8	11.4	2.0*
U.K.	1.4	1.4	0.9	3.9	6.0	1.5*	2.2	1.9	0.9	5.2	11.8	2.2*
RoW	1.1	1.0	0.8	3.9	3.5	0.9	1.1	1.0	0.9	2.5	10.7	4.3*

	π_t			Δc_t			Δgdp_t			Δy_t		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Canada	1.3	1.4	1.1	0.8	0.9	1.1	0.9	0.9	1.0	4.1	5.1	1.2
France	1.1	1.3	1.2*	0.9	0.8	0.9	0.9	0.6	0.6*	4.2	5.4	1.3*
Germany	1.2	1.1	0.9	1.0	1.0	1.0	1.5	1.0	0.7	6.2	5.7	0.9
Italy	1.0	2.1	2.0*	0.7	0.8	1.2	1.3	1.0	0.8	7.5	9.5	1.3*
Japan	2.6	2.9	1.1	1.0	1.3	1.3	1.1	1.1	0.9	4.6	4.9	1.1
Spain	2.5	2.5	1.0	1.0	0.7	0.7	1.4	0.7	0.5*	10.1	10.1	1.0
U.K.	1.6	2.6	1.6*	1.2	1.4	1.2	1.0	1.3	1.2	3.5	5.9	1.7*
U.S.	0.9	1.3	1.5*	0.7	0.8	1.1	0.9	1.0	1.1	2.9	2.9	1.0

Correlations

	$\Delta q_t, \Delta e_t$		$\Delta q_t, \Delta c_t - \Delta c_t^*$		$\Delta q_t, \Delta nx_t$		$\Delta gdp_t, \Delta gdp_t^*$		$\Delta c_t, \Delta c_t^*$		$\Delta c_t, \Delta gdp_t$	
	peg	float	peg	float	peg	float	peg	float	peg	float	peg	float
Canada	0.77	0.92	0.03	−0.07	0.01	0.05	0.31	0.47	0.40	0.25	0.28	0.57
France	0.96	0.99	0.05	−0.08	0.23	0.12	0.09	0.30	−0.24	0.29	0.51	0.48
Germany	0.87	0.99	0.04	−0.19	−0.06	0.00	−0.01	0.28	−0.11	0.11	0.57	0.58
Italy	0.54	0.97	0.07	−0.13	0.02	−0.01	0.04	0.17	−0.18	0.13	0.64	0.45
Japan	0.76	0.98	0.21	−0.00	0.03	0.21	−0.08	0.24	0.11	0.23	0.70	0.71
Spain	0.83	0.96	−0.09	−0.18	−0.06	0.16	0.05	0.09	−0.06	0.05	0.56	0.63
U.K.	0.94	0.96	0.09	−0.10	−0.39	−0.16	−0.11	0.30	−0.02	0.22	0.59	0.71
RoW	0.80	0.98	0.05	−0.19	−0.20	0.21	−0.03	0.39	−0.11	0.31	0.68	0.72

International Equilibrium

1. International risk sharing for $j \in J_t \cap J_t^*$

$$\mathbb{E}_t \left\{ \left[\left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} - \left(\frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \frac{\mathcal{Q}_t}{\mathcal{Q}_{t+1}} e^{\tilde{\zeta}_{t+1}^j} \right] \frac{D_{t+1}^j}{P_{t+1}/P_t} \right\} = 0$$

2. Country budget constraint

$$\mathcal{B}_{t+1} - \mathcal{R}_t \mathcal{B}_t = \overbrace{P_{Ht} C_{Ht}^* - \mathcal{E}_t P_{Ft}^* C_{Ft}}^{=NX_t} = \frac{\gamma P_t^\theta C_t}{(\mathcal{E}_t P_{Ft}^*)^{\theta-1}} \left[\mathcal{S}_t^{\theta-1} \mathcal{Q}_t^\theta \frac{C_t^*}{C_t} - 1 \right]$$

- where $\mathcal{B}_{t+1} \equiv \sum_{j \in J_t} \Theta_t^j B_{t+1}^j$ is NFA position
- terms of trade $\mathcal{S}_t \equiv \frac{\mathcal{E}_t P_{Ft}^*}{P_{Ht}} \approx \mathcal{Q}_t^{\frac{1}{1-2\gamma}}$

3. Open economy Phillips curve: e.g. under PCP

$$\Delta q_t = \beta \mathbb{E}_t \Delta q_{t+1} - k_R \Big[\underbrace{(c_t - c_t^*) + \gamma \kappa_q q_t - \kappa_a \tilde{a}_t}_{\text{relative excess demand}} \Big]$$

$$k_R = \begin{cases} \kappa, & R = \text{peg} \\ \frac{1}{2\gamma}\kappa, & R = \text{float} \end{cases} \quad \text{and} \quad \kappa = \frac{(1-\lambda)(1-\beta\lambda)}{\lambda}(\sigma + \varphi)\ldots$$

back

- **Complete markets**: $j \in J_t \cap J_t^*$ for each state of the world

$$\sigma(\Delta c_t - \Delta c_t^*) = \Delta q_t - \Delta \tilde{\zeta}_t$$

Cointegration Relationship

Limiting cases

- **Complete markets**: $j \in J_t \cap J_t^*$ for each state of the world

$$\sigma(\Delta c_t - \Delta c_t^*) = \Delta q_t - \Delta\tilde{\zeta}_t$$

- **Financial autarky**: $NX_t \equiv 0$ results in

$$c_t - c_t^* = \frac{2(1-\gamma)\theta - 1}{1 - 2\gamma} q_t$$

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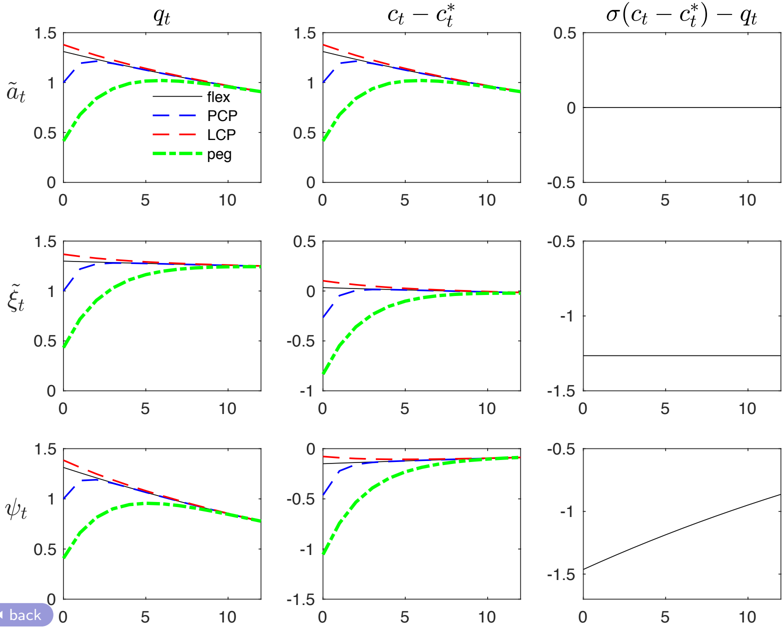
IRF under Alternative Regimes



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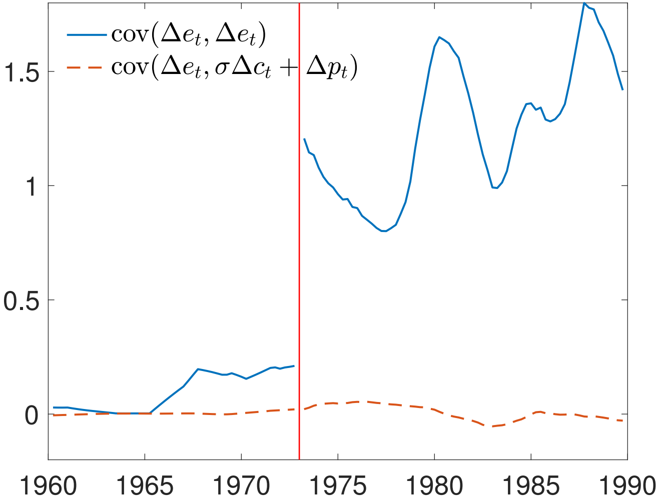
NER and SDF



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Segmented Financial Markets

1. Households in each country hold local-currency bonds only, B_{t+1} and B^*_{t+1} respectively: $J_t \cap J^*_t = \emptyset$

$$\frac{B_{t+1}}{R_t} = B_t + NX_t(\mathcal{Q}_t), \qquad \frac{B^*_{t+1}}{R^*_t} = B^*_t - NX_t(\mathcal{Q}_t)$$

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2. Noise (liquidity) traders with an exogenous demand

$$\frac{N^*_{t+1}}{R^*_t} = n\left(e^{\psi_t} - 1\right) \quad \text{and} \quad \frac{N_{t+1}}{R_t} = -\mathcal{E}_t \frac{N^*_{t+1}}{R^*_t}$$

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3. Financial intermediaries invest in a **carry trade** strategy:

$$\max_{d^*_{t+1}} \mathbb{E}_t \left\{ -\frac{1}{\omega} \exp\left(-\omega \frac{\tilde{R}^*_{t+1}}{P^*_{t+1}} d^*_{t+1} \right) \right\}, \quad \tilde{R}^*_{t+1} \equiv R^*_t - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

— m symmetric intermediaries with total demand $\frac{D^*_{t+1}}{R^*_t} = m \cdot d^*_{t+1}$ for foreign bond and $\frac{D_{t+1}}{R_t} = -\mathcal{E}_t \frac{D^*_{t+1}}{R^*_t}$ for home bond

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— m symmetric intermediaries with total demand $\frac{D^*_{t+1}}{R^*_t} = m \cdot d^*_{t+1}$ for foreign bond and $\frac{D_{t+1}}{R_t} = -\mathcal{E}_t \frac{D^*_{t+1}}{R^*_t}$ for home bond

- Market clearing: $B^*_{t+1} + D^*_{t+1} + N^*_{t+1} = 0$

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Segmented Financial Markets

1. **Households** in each country hold local-currency bonds only, B_{t+1} and B^*_{t+1} respectively: $J_t \cap J^*_t = \emptyset$

$$\frac{B_{t+1}}{R_t} = B_t + NX_t(\mathcal{Q}_t), \qquad \frac{B^*_{t+1}}{R^*_t} = B^*_t - NX_t(\mathcal{Q}_t)$$

2. **Noise (liquidity) traders** with an exogenous demand

$$\frac{N^*_{t+1}}{R^*_t} = n\left(e^{\psi_t} - 1\right) \quad \text{and} \quad \frac{N_{t+1}}{R_t} = -\mathcal{E}_t \frac{N^*_{t+1}}{R^*_t}$$

3. **Lemma 2**: *Optimal portfolio choice of intermediaries:*

$$d^*_{t+1} = \frac{i^*_t - i_t + \mathbb{E}_t \Delta e_{t+1}}{\omega \sigma_e^2}$$

where $i_t \equiv \log R_t$ *and* $\sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$.

- Market clearing: $B^*_{t+1} + D^*_{t+1} + N^*_{t+1} = 0$ back back

Portfolio Choice

- Objective function of arbitrageurs:

$$\max_{d^*} \mathbb{E}_t \left\{ -\frac{1}{\omega} \left(-\omega(1 - e^{x^*_{t+1}}) e^{-\pi^*_{t+1}} \frac{d^*}{P^*_t} \right) \right\}, \; x^*_{t+1} \equiv i_t - i^*_t - \Delta e_{t+1}$$

- Short periods: $(x^*_{t+1}, \pi^*_{t+1}) \to (\mathrm{d}\mathcal{X}_t, \mathrm{d}\mathcal{P}_t)$ follows a Brownian motion
- From Ito's lemma:

$$\max_{d^*} -\frac{1}{\omega} \exp \left\{ \left[\omega \left(\mu_{1t} + \frac{1}{2}\sigma_e^2 + \sigma_{e\pi^*} \right) \frac{d^*}{P^*_t} + \frac{\omega^2 \sigma_e^2}{2} \left(\frac{d^*}{P^*_t} \right)^2 \right] \mathrm{d}t \right\}$$

- Solution:

$$\frac{d^*}{P^*_t} = -\frac{\mu_{1t} + \frac{1}{2}\sigma_e^2 + \sigma_{e\pi^*}}{\omega \sigma_e^2}$$

- Adopt asymptotics $\sigma_e^2 \approx 0$ and $\omega\sigma_e^2/m = \text{const}$:

$$\frac{1}{\omega\sigma_e^2/m} \left(i_t - i^*_t - \mathbb{E}_t \Delta e_{t+1} \right) = \frac{n}{\beta}\psi_t - \bar{Y} b_{t+1}$$

back

Exchange Rate Process

- **Lemma 3**: *Assuming* $\tilde{a}_t, \psi_t \sim AR(1)$ *with coefficient* ρ,
  (i) *equilibrium exists under both peg and floating regimes,*
  (ii) *RER follows an ARMA(2,1) process,* show
  (iii) $q_t = q_t^{\psi} + q_t^{a}$, *where in the limiting case* $\rho = 1$

$$q_t^a = \eta_a \, \tilde{a}_t,$$

$$(1 - \delta L)\, q_t^{\psi} = \frac{\beta\delta\eta_{\psi}}{1 - \beta\delta}\left(1 - \beta^{-1}L\right)\sigma_e^2 \, \psi_t,$$

where $\delta = \delta(\sigma_e^2) \in (0, 1]$ *and* $\delta \to 1$ *as* $\sigma_e^2 \to 0$.

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Exchange Rate Process

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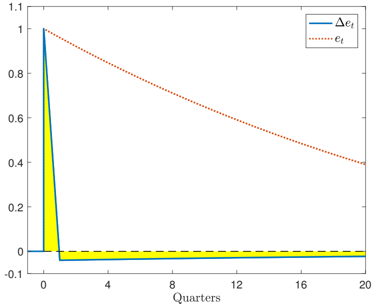
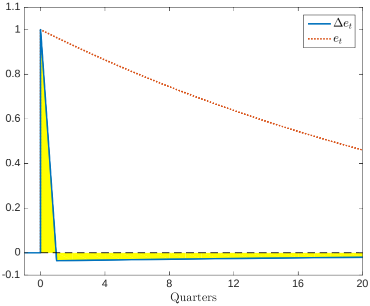
(a) IRF to ψ_t



(b) IRF to $\tilde{a}_t$



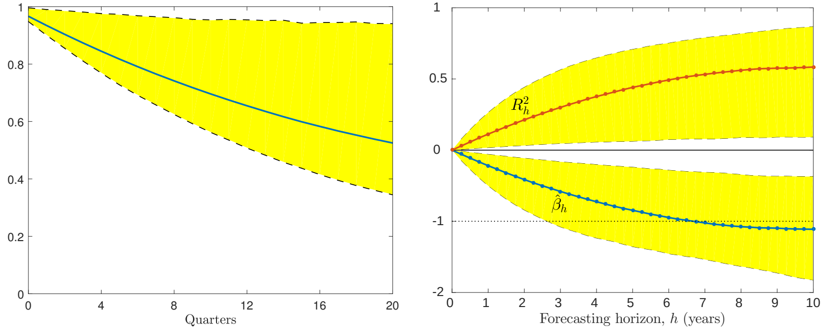
- persistent ψ_t and $\tilde{a}_t$ shocks both lead to a near-random-walk exchange rate response ▸ predictability
- when $\chi_1 \propto \omega\sigma_e^2 \gg 0$: ψ_t dominates the variance of Δq_t
- when $\chi_1 \propto \omega\sigma_e^2 \approx 0$: Δq_t only responds to $\tilde{a}_t$ shocks

Exchange Rate Properties

Near-random-walkness

(a) Surprise component

(b) Predictive regressions



- cf. evidence from Eichenbaum, Johannsen & Rebel (2018)

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Macro Volatility

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1. **Consumption** — goods market clearing:

$$c_t - c_t^* = \kappa_a(a_t - a_t^*) - \gamma\kappa_q q_t$$

   — when γ is small, $(a_t - a_t^*)$ is the main driver of $(c_t - c_t^*)$ independently of the volatility of Δq_t

   — similar results apply to other macro variables

2. **Inflation** — under float $\mathrm{std}(\pi_t) = 0$ and under peg:

$$\mathrm{std}(\pi_t) = \mathrm{std}(\Delta q_t) = \frac{\kappa_a}{\hat{\theta} + \gamma\kappa_q}\mathrm{std}(\Delta\tilde{a}_t)$$

3. **Interest rates** — from the household Euler equations:

$$i_t - i_t^* = \mathbb{E}_t\Big\{\sigma(\Delta c_{t+1} - \Delta c_{t+1}^*) + (\pi_{t+1} - \pi_{t+1}^*)\Big\}$$

Calibration

β	discount factor	0.99
σ	inverse of the IES	2
γ	openness of economy	0.035
φ	inverse of Frisch elasticity	1
ϕ	intermediate share in production	0.5
ϑ	capital share	0.3
δ	capital depreciation rate	0.02
θ	elasticity of substitution between H and F goods	1.5
ϵ	elasticity of substitution between different types of labor	4
λ_w	Calvo parameter for wages	0.85
λ_p	Calvo parameter for prices	0.75
ρ	autocorrelation of shocks	0.97
ρ_r	Taylor rule: persistence of interest rates	0.95
ϕ_π	Taylor rule: reaction to inflation	2.15

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Calibration

- Shocks are calibrated to match
  - $\mathrm{std}(\Delta e_t) = 12\%$ $\longrightarrow \sigma_\psi$
  - $\mathrm{corr}(\Delta q_t, \Delta c_t - \Delta c_t^*) = -0.4$ $\longrightarrow \sigma_a, \sigma_m$
  - $\mathrm{corr}(\Delta q_t, \Delta nx_t) = -0.1$ $\longrightarrow \sigma_\xi$
  - $\mathrm{corr}(\Delta gdp_t, \Delta gdp_t^*) = 0.3$ $\longrightarrow \rho_{a,a^*}, \rho_{m,m^*}$

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Calibration

	σ_n	σ_ξ	σ_a	σ_m	ρ_{a,a^*}	κ	ϕ_e
Models w/o financial shock:							
IRBC	0.00	13.8	8.1	–	0.28	11	13.0
NKOE-1	0.00	20.7	5.7	–	0.30	7	1.8
NKOE-2	0.00	4	–	0.75	0.29	22	5.1
Models w/ exogenous financial shock:							
IRBC	0.61	3.37	1.41	–	0.30	15	14.5
NKOE-1	0.59	2.80	1.01	–	0.35	7.5	3.7
NKOE-2	0.59	1.23	–	0.15	0.42	20	3.6
Models w/ endogenous financial shock:							
IRBC	0.61	3.37	1.41	–	0.30	15	0.25
NKOE-1	0.59	2.80	1.01	–	0.35	7.5	0.03
NKOE-2	0.59	1.23	–	0.15	0.42	20	0.08

Results

Table: Variance decomposition in models w/ endogenous ψ_t

	peg			float		
	ψ	ξ	a/m	ψ	ξ	a/m
Real exchange rate:						
IRBC	1	23	76	92	3	5
NKOE-1	1	22	77	97	1	2
NKOE-2	1	4	95	97	1	2
Consumption:						
IRBC	0	1	99	15	1	84
NKOE-1	0	1	99	10	0	90
NKOE-2	0	1	99	13	0	87

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Results: Standard Deviations

	Δnx_t			Δs_t			$\pi_t - \pi_t^*$			$\Delta c_t - \Delta c_t^*$		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Data	1.1	1.0	0.9	3.8	3.8	1.0	1.3	1.4	1.1	0.9	0.9	1.0
Models without UIP shock $\hat{\psi}_t$:												
IRBC	1.1	1.1	1.0	3.5	3.5	1.0	14.1	3.9	0.3	10.3	10.3	1.0
NKOE-1	1.5	1.7	1.1	1.3	9.1	7.0	3.4	1.9	0.6	5.9	7.3	1.2
NKOE-2	0.4	0.4	1.0	1.4	9.7	7.0	0.4	1.5	3.8	1.1	5.9	5.4
Models with exogenous financial shock $\hat{\psi}_t$:												
IRBC	1.3	1.3	1.0	2.5	2.5	1.0	9.8	1.4	0.1	2.3	2.3	1.0
NKOE-1	1.4	1.0	0.7	1.3	9.5	7.3	1.3	0.5	0.4	6.0	1.5	0.3
NKOE-2	0.9	1.0	1.1	1.3	9.6	7.4	1.2	0.5	0.4	5.0	1.3	0.3
Models with endogenous financial shock $\chi_1(\sigma_e^2) \cdot \psi_t$:												
IRBC	0.3	1.3	4.3	0.7	2.5	3.6	1.6	1.4	0.9	1.8	2.3	1.3
NKOE-1	0.3	1.0	3.3	1.1	9.5	8.6	0.4	0.5	1.2	1.1	1.5	1.4
NKOE-2	0.1	1.0	10.0	1.3	9.6	7.4	0.2	0.5	2.5	0.8	1.3	1.6

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Results: Correlations

	$\Delta q_t, \Delta e_t$		$\Delta q_t, \Delta c_t - \Delta c_t^*$		$\Delta q_t, \Delta nx_t$		$\Delta gdp_t, \Delta gdp_t^*$		$\Delta c_t, \Delta c_t^*$		$\Delta c_t, \Delta gdp_t$	
	peg	float	peg	float	peg	float	peg	float	peg	float	peg	float
Data	0.80	0.98	0.05	−0.40	−0.10	0.20	−0.03	0.30	−0.11	0.31	0.68	0.72
Models without UIP shock $\hat{\psi}_t$:												
IRBC	0.86	0.99	0.91	0.91	−0.10	−0.10	0.30	0.30	0.34	0.34	0.99	0.99
NKOE-1	0.67	0.99	0.27	0.70	−0.10	−0.50	0.36	0.30	0.65	0.42	0.91	0.97
NKOE-2	0.97	0.99	0.54	0.99	−0.10	0.08	0.95	0.30	0.98	0.32	1.00	1.00
Models with exogenous financial shock $\hat{\psi}_t$:												
IRBC	0.86	0.99	−0.40	−0.40	0.93	0.93	0.30	0.30	0.15	0.15	0.88	0.88
NKOE-1	0.81	1.00	−0.88	−0.40	0.89	0.93	0.60	0.30	−0.06	0.32	0.99	0.84
NKOE-2	0.82	1.00	−0.89	−0.40	0.92	0.97	0.51	0.30	−0.10	0.26	1.00	0.79
Models with endogenous financial shock $\chi_1(\sigma_e^2) \cdot \psi_t$:												
IRBC	0.98	1.00	0.92	−0.40	−0.10	0.93	0.30	0.30	0.39	0.16	0.99	0.88
NKOE-1	0.98	1.00	0.84	−0.40	−0.10	0.93	0.44	0.30	0.54	0.32	0.96	0.84
NKOE-2	1.00	1.00	0.94	−0.40	−0.10	0.97	0.66	0.30	0.70	0.26	0.99	0.79

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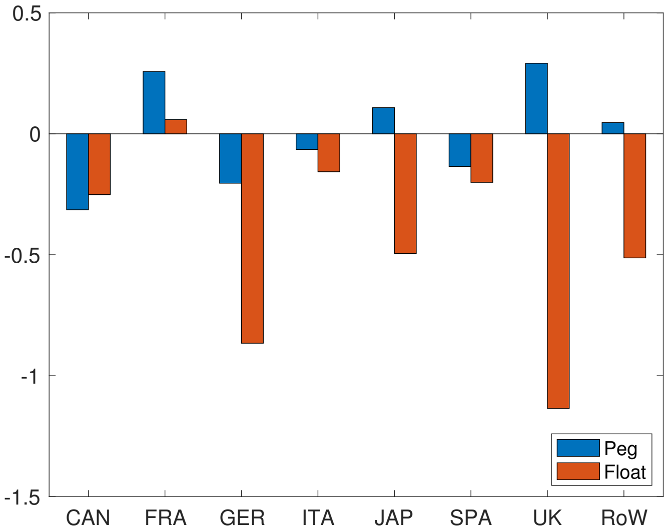
UIP Puzzle



Note: slope coefficient from $\Delta e_{t+1} = \alpha + \beta(i_t - i_t^*) + \varepsilon_{t+1}$, monthly data.

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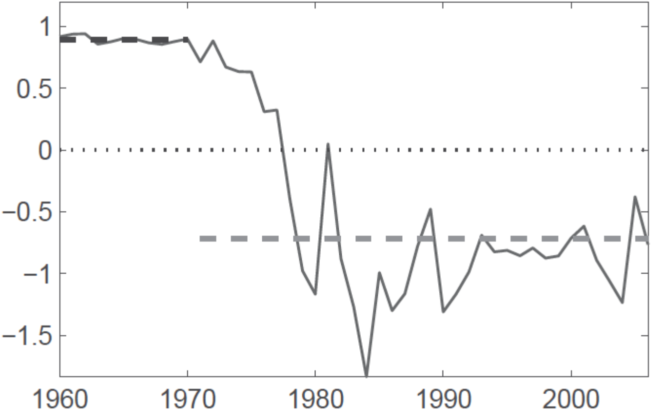
UIP Puzzle



Note: moving average UIP coefficient from Colacito & Croce (JF'2013) for U.K. vs. U.S., 1930-2006

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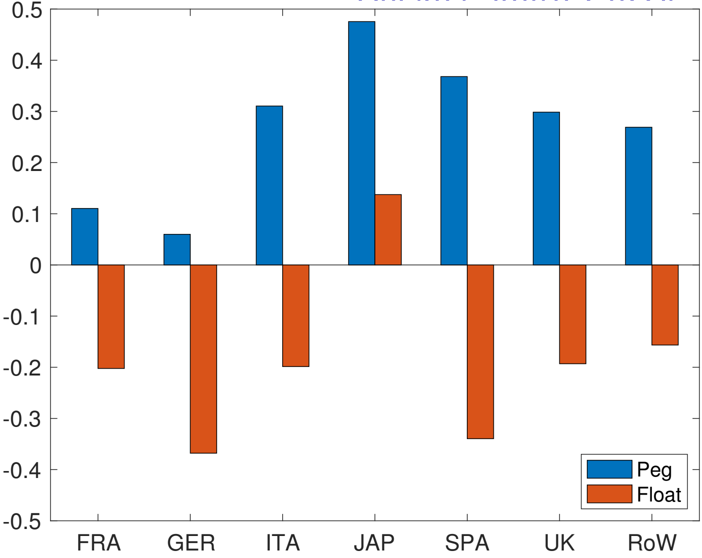
Backus-Smith Puzzle



Note: corr$(\Delta q_t, \Delta c_t - \Delta c_t^*)$, annual data.

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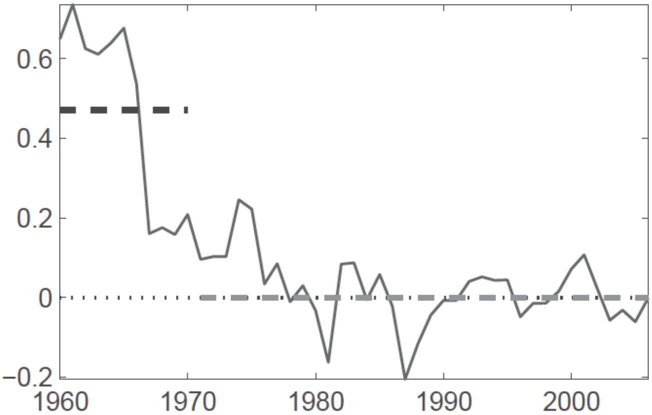
Backus-Smith Puzzle



Note: moving average Backus-Smith correlation
from Colacito & Croce (JF'2013) for U.K. vs. U.S., 1930-2006

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Balassa-Samuelson Effect

	Pool		
	1a	1b	1c
TFP	**0.43*** **	–	–
	(0.067)		
TFP_T	–	**0.50*** **	$\boxed{\textbf{0.76}^{***}}$
		(0.059)	(0.062)
TFP_N	–	-0.09	**-0.29*** **
		(0.08)	(0.078)
$RULC$	–	–	**0.43*** **
			(0.079)
$\overline{R}^2$	0.25	0.41	0.57
N	117	117	117
HT	–	–	–

Note: from Berka, Devereux & Engel (AER'2018) for Eurozone

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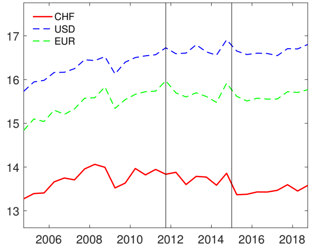
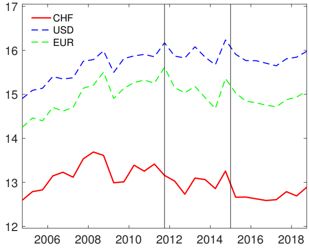
CHF Turnover

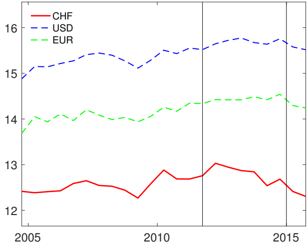
(a) Total



(b) Spot



(c) $\leq$ 1 month derivatives



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