Mussa Puzzle Redux

Oleg Itskhoki
itskhoki@Princeton.edu

Dmitry Mukhin
dmitry.mukhin@Yale.edu

Princeton University
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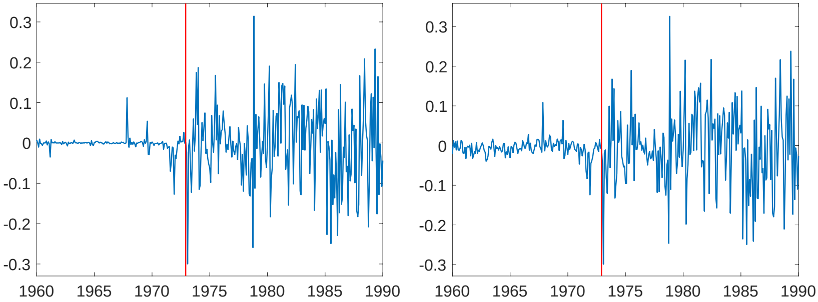
Mussa Puzzle

- *Real* exchange rate (RER):

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

: Nominal exchange rate, Δe_t : Real exchange rate, Δq_t



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

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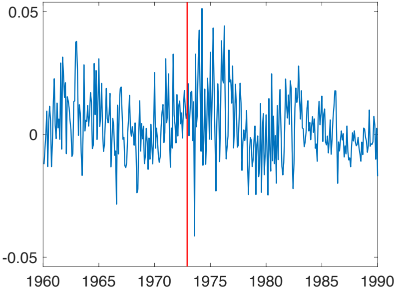
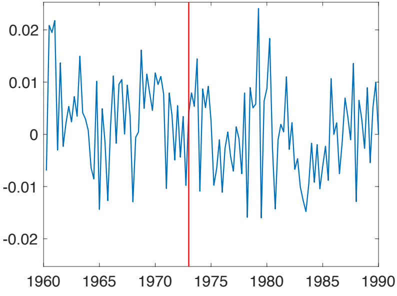
: Inflation rate, π_t



: Consumption growth, Δc_t



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

Mussa Puzzle Redux

- Mussa puzzle is some of the most convincing evidence for monetary non-neutrality (Nakamura and Steinsson, 2018)
  - with monetary neutrality, *real* exchanger rate should not be affected by a change in the monetary rule
  - timing and the sharp discontinuity in the behavior of ERs

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- We argue this latter conclusion is not supported by the data: no contemporaneous change in properties of macro variables
  1. neither nominal, like inflation
  2. nor real, like consumption, output or net exports

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  Is it an extreme form of *neutrality*? or disconnect?
- The combined evidence does not favor sticky prices over flexible prices, but rather rejects both types of models

Intuition

- Real exchange rate:

$$q_t = e_t + p_t^* - p_t \tag{1}$$

  ✗ IRBC (flex prices): no change in Δq_t, change in $\pi_t - \pi_t^* \propto \Delta e_t$

  ✓ NKOE (sticky prices): change in $\Delta q_t \propto \Delta e_t$

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- ‘Cointegration’ relationship between consumption and RER:

$$\varsigma(c_t - c_t^*) = q_t - \zeta_t \qquad (2)$$

  1. generally derives from international risk sharing condition, but does not rely on (perfect) risk sharing
  2. under a variety of circumstances ζ_t does not depend on exchange rate regime
  3. falsifies both sticky-price and flexible-price models

Relationship with ER Disconnect

- Define exchange rate disconnect as combination of:
  1. Meese-Rogoff (1983) puzzle
  2. PPP puzzle (Rogoff 1996)
  3. Terms-of-Trade puzzle (Engel 1999, Atkeson-Burstein 2008)
  4. Backus-Smith (1993) puzzle
  5. Forward-premium puzzle (Fama 1984)

- Itskhoki and Mukhin (2017) propose a solution with emphasis:
  1. Home bias in consumption
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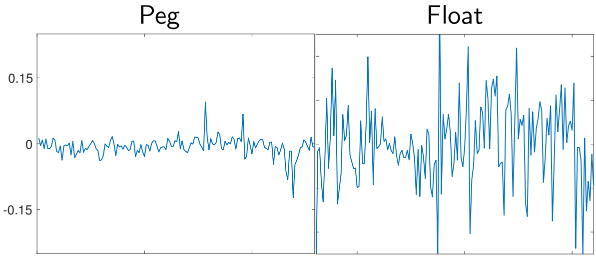
- This is insufficient to explain Mussa puzzle, which involves a sharper experiment — a change in the monetary regime
  - even under the "disconnect conditions," a switch in the monetary regime would result in a change in macro volatility

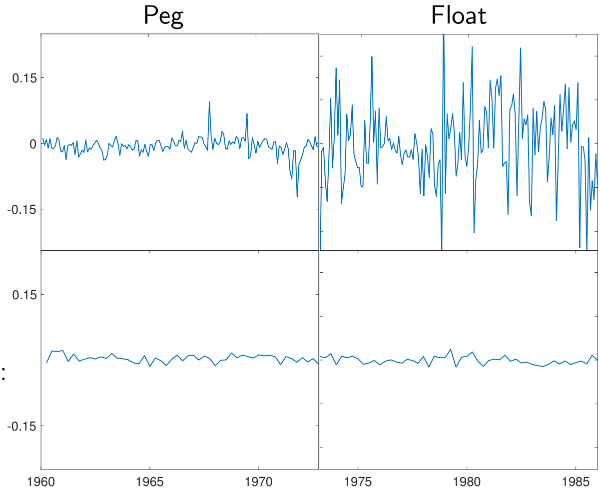
Relationship with ER Disconnect



Δq_t:

$\Rightarrow$ ✗ IRBC (flex prices)

Relationship with ER Disconnect



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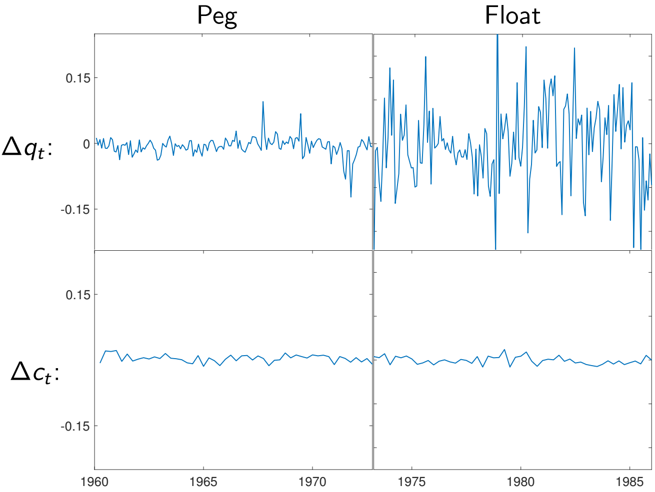

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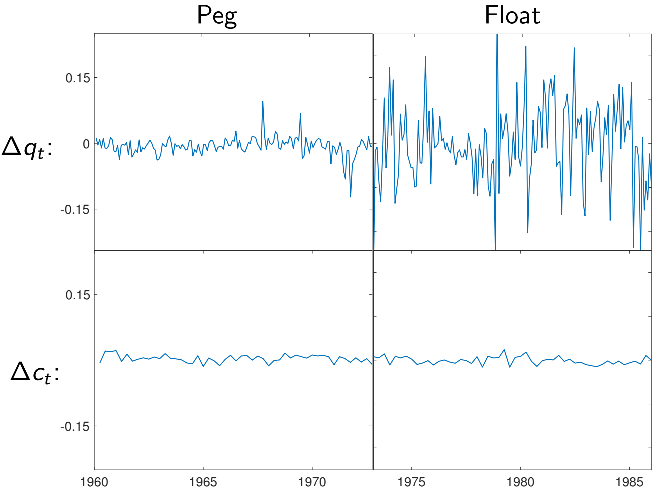
$\Downarrow$

✓ ER Disconnect

Relationship with ER Disconnect



⇒ ✗ IRBC (flex prices)

⇒ ✗ NKOE (sticky prices)

⇓ ✓ Mussa Redux

⇓ ✓ ER Disconnect

- Segmented financial markets
  - a particular type of financial friction
  - ER risk is held in a concentrated way by specialized financiers, and is not smoothly distributed across agents in the economy

- Modified UIP conditions:

$$\frac{i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1}}{\omega \sigma_e^2} = \psi_t - \chi b_{t+1}$$

where $\sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$ and $\omega \sigma_e^2$ is the price of ER risk

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- Nominal ER volatility is consequential for real allocations
  - — an alternative source of monetary non-neutrality
  - — this mechanism is sufficient to explain the Mussa puzzle
  - — sticky prices are neither necessary, nor sufficient

Related literature

- Empirics:
  - Mussa (1986), Baxter and Stockman (1989), Flood and Rose (1995)

- Theory:
  - Jeanne and Rose (2002), Monacelli (2004), Kollmann (2005), Alvarez, Atkeson and Kehoe (2007)

- Additional empirical moments:
  - Colacito and Croce (2013), Devereux and Hnatkovska (2014), Berka, Devereux and Engel (2018)

EMPIRICAL PATTERNS

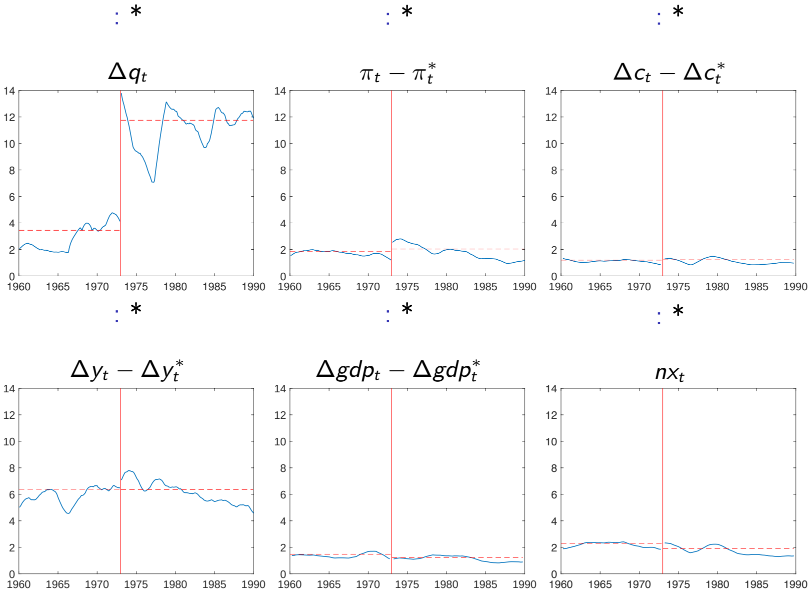
Data

- Two datasets:
  1. IFM's International Financial Statistics: monthly data on exchange rates, inflation and production index
  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 to make measures of volatility comparable across variables

- Dating the end of Bretton Woods:
  - — "Nixon shock" in 1971:08 and the end of BW in 1973:02
  - — 1967–1971: a number of devaluations (UK, Spain, France) and a revaluation (Germany)

- Countries: France, Germany, Italy, Japan, Spain and the UK. Also Canada.

Macroeconomic volatility



Note: triangular moving average estimates of standard deviations over time, 1973:01 as a break point.

Macroeconomic volatility

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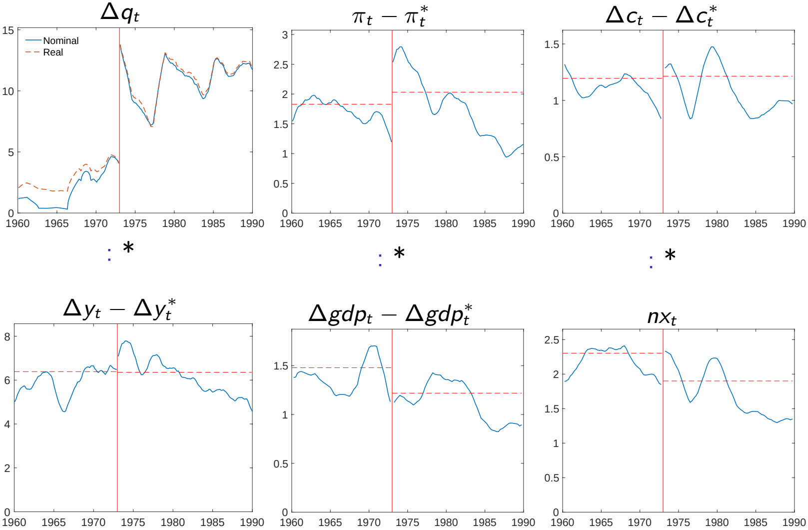

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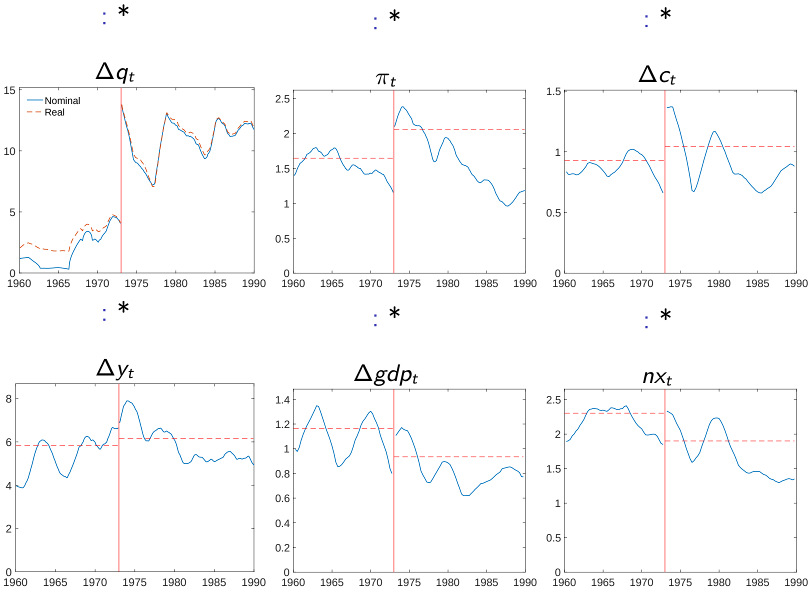

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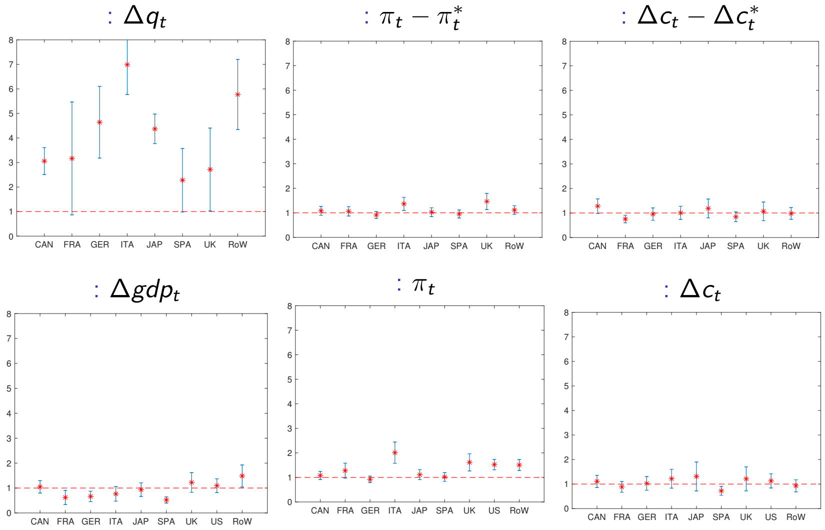
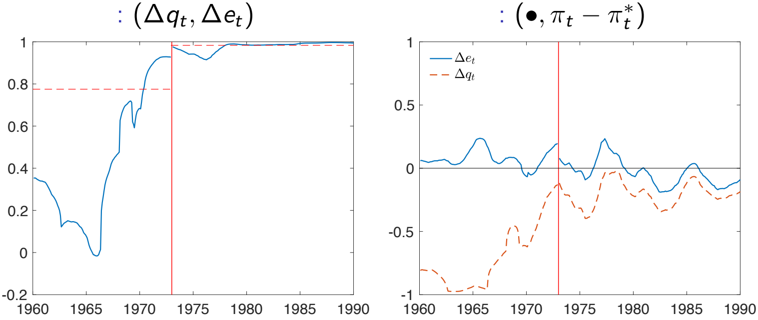
Change in Macro Volatility



*Ratios of standard deviations under floating (≥73:02) and peg (≤71:08) regimes with 90% HAC conf. intervals

Correlations



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

CONVETIONAL MODELS: FALSIFICATION

'Conventional' Models

- **Definition**: *if prices were flexible, a switch in the monetary regime would not affect real variables*
  - hence, only sticky-price version can be considered
- Log-linear approximate solution
  - 'conventional'
  - second-order (risk premia) terms are small
  - we allow for risk-sharing wedges instead

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- Two-country New Keynesian Open Economy model
  - with producer-currency (PCP) Calvo price stickiness
  - with productivity and ‘financial’ shocks
  - flexible wages, no capital, no intermediates

- Monetary policy (‘primal approach’):
  - Foreign: inflation targeting $\pi_t^* \equiv 0$
  - Home: ‘float’ is $\pi_t \equiv 0$ and ‘peg’ is $\Delta e_t \equiv 0$

Model setup I

- Households:

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

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

  - CES aggregator across products with elasticity $\theta > 1$
  - home bias with expenditure share on foreign varieties $\gamma \in (0, \frac{1}{2})$

- Optimality conditions:

$$C_t^{\sigma} L_t^{\varphi} = W_t / P_t,$$

$$C_{Ft}(i) = \gamma e^{\tilde{\xi}_t} \left(\frac{P_{Ft}(it)}{P_t} \right)^{-\theta} C_t,$$

$$\Theta_t^j = \beta \mathbb{E}_t \left\{ \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} e^{-\zeta_{t+1}^j} D_{t+1}^j \right\}$$

and $P_t C_t = P_{Ht} C_{Ht} + P_{Ft} C_{Ft}$

Model setup II

- Production:

$$Y_t(i) = e^{a_t} L_t(i) \quad \Rightarrow \quad MC_t = e^{-a_t} W_t$$

- Profits:

$$\Pi_t(i) = \big(P_{Ht}(i) - MC_t\big)\big(\overbrace{C_{Ht}(i) + C^*_{Ht}(i)}^{=Y_t(i)}\big)$$

- Calvo price setting:

$$\bar{P}_{Ht}(i) = \arg\max \, \mathbb{E}_t \sum_{k=0}^{\infty} (\beta\lambda)^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+k}} \Pi_{t+k}(i)$$

- Domestic and export prices:

$$P_{Ht}(i) = \begin{cases} P_{H,t-1}(i), & \text{w/prob } \lambda \\ \bar{P}_{Ht}, & \text{o/w} \end{cases} \quad \text{and} \quad P_{Ht}(i)^* = P_{Ht}(i)/\mathcal{E}_t$$

International Equilibrium

1. International risk sharing

2. Country budget constraint

3. Open economy Phillips curve

International Equilibrium

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

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

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

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

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   - terms of trade $\mathcal{S}_t \equiv \frac{\mathcal{E}_tP_{Ft}^*}{P_{Ht}} \approx \mathcal{Q}_t^{\frac{1}{1-2\gamma}}$

3. Open economy Phillips curve
   - another relationship that links C_t/C_t^* and $\mathcal{Q}_t$
   - only condition that directly depends on the monetary regime

Cointegration Relationship

Limiting cases

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

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

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

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

- **Cole-Obstfeld**:

$$\sigma = \frac{1-2\gamma}{2(1-\gamma)\theta - 1} \qquad \text{(in particular, } \sigma = \theta = 1\text{)}$$

General Case

- Log-linearized dynamic equilibrium system:

$$\mathbb{E}_t\left\{\sigma(\Delta c_{t+1} - \Delta c^*_{t+1}) - \Delta q_{t+1}\right\} = \psi_t,$$

$$\beta b_{t+1} - b_t = \gamma\left[\tfrac{2(1-\gamma)\theta-1}{1-2\gamma} q_t - (c_t - c^*_t) + \tilde{\xi}_t\right]$$

$$\Delta q_t = \beta\mathbb{E}_t\Delta q_{t+1} - k_R\left[(c_t - c^*_t) + \gamma\kappa_q q_t - \kappa_a\tilde{a}_t\right]$$

  — where $\psi_t \equiv -\mathbb{E}_t\Delta\zeta_{t+1}$ is the UIP shock

  — slope of the open economy Phillips curve: ‣ show

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

General Case

- Log-linearized dynamic equilibrium system:

$$\sigma(c_t - c_t^*) - q_t = -\frac{\psi_t}{1-\rho} + m_t, \qquad \Delta m_t = u_t$$

$$\beta b_{t+1} - b_t = \gamma \left[\tfrac{2(1-\gamma)\theta - 1}{1-2\gamma} q_t - (c_t - c_t^*) + \tilde{\xi}_t \right]$$

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Empirical Falsification

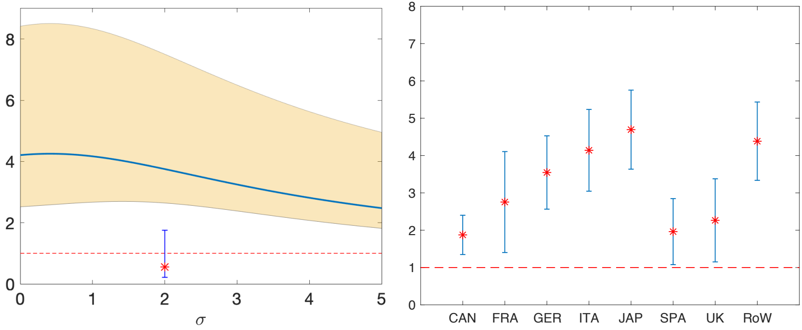
- **Proposition 1**: *Eqm relationship between $(c_t - c_t^*)$ and q_t does* **not** *depend on the exchange rate regime under any of:*
  1. *international financial autarky*
  2. *complete asset markets (with risk-sharing wedges)*
  3. *generalized Cole-Obstfeld case*
  4. *in the limit of both fully fixed and fully flexible prices*
  5. *in the limit of perfect patience,* $\beta \to 1$
  6. *in the limit of persistent shocks,* $\rho \to 1$

- The process for $\sigma(c_t - c_t^*) - q_t$ is independent of the ER regime
- In particular, $\mathrm{var}\big(\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t\big)$ should not change

Empirical Falsification

Figure: Change in $\mathrm{std}\big(\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t\big)$ from peg to float

: Different values of σ : Across countries, $\sigma = 2$

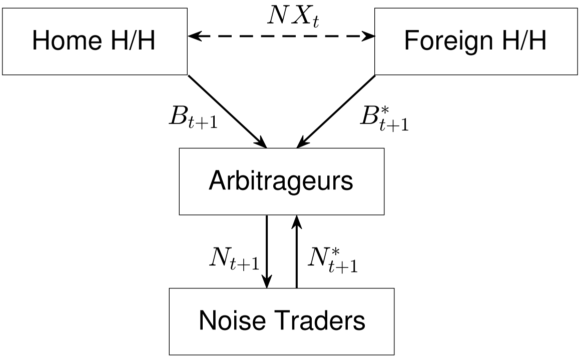


Note: Ratio of $\mathrm{std}\big(\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t\big)$ under float vs under peg with HAC 90% confidence intervals

ALTERNATIVE MODEL OF NON-NEUTRALITY

Alternative Model

- Emphasize financial frictions instead of nominal rigidities
  - switch off nominal rigidities altogether
- A particular model of UIP deviations:
  - segmented asset markets
  - limits to arbitrage and risk premium



Segmented Financial Market

Three types of agents

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

$$\frac{B_{t+1}}{R_t} - B_t = NX_t \quad \text{and} \quad \frac{B^*_{t+1}}{R^*_t} - B^*_t = -NX_t/\mathcal{E}_t$$

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

$$\max_{d^*_{t+1}} \mathbb{E}_t \Big\{ -\tfrac{1}{\omega} \exp\Big(-\omega \tfrac{\tilde{R}^*_{t+1}}{P^*_{t+1}} \tfrac{d^*_{t+1}}{R^*_t} \Big) \Big\} \quad \text{where} \quad \tilde{R}^*_{t+1} = R^*_t - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

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

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

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

$$\max_{d^*_{t+1}} \mathbb{E}_t \Big\{ -\tfrac{1}{\omega} \exp\Big(-\omega \tfrac{\tilde{R}^*_{t+1}}{P^*_{t+1}} \tfrac{d^*_{t+1}}{R^*_t} \Big) \Big\} \quad \text{where} \quad \tilde{R}^*_{t+1} = R^*_t - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$$

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

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

- **Lemma 2**: (i) *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 $i_t - i^*_t \equiv \log \frac{R_t}{R^*_t}$ *and* $\sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$.

- **Lemma 2**: (i) *Optimal portfolio choice of intermediaries:*

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

(ii) *Equilibrium in the financial market:*

$$i_t - i^*_t - \mathbb{E}_t \Delta e_{t+1} = \chi_1 \psi_t - \chi_2 b_{t+1}$$

where $\chi_1 = \frac{n}{m}\omega\sigma_e^2$ *and* $\chi_2 = \frac{\bar{Y}}{m}\omega\sigma_e^2$.

- Exchange rate regime changes $\sigma_e^2 \equiv \mathrm{var}_t(\Delta e_{t+1})$, and hence affects equilibrium in the financial market
  — a source of **non-neutrality**, even without nominal rigidities

Exchange Rate Process

- **Lemma 3**: *RER follows an ARMA(2,1) process*

$$
\begin{aligned}
(1-\delta L)q_t = & \frac{1}{1+\gamma\sigma\kappa_q}\frac{\beta\delta}{1-\beta\rho\delta}\Bigg[(1-\beta^{-1}L)\chi_1\psi_t \\
& + \left(\frac{(\beta\delta)^{-1}-1}{1+\frac{\varsigma}{1+\gamma\sigma\kappa_q}}(1-\rho\delta L)+(1-\rho)(1-\beta^{-1}L)\right)\sigma\kappa_a\tilde{a}_t\Bigg]
\end{aligned}
$$

where $\delta \in (0,1]$ *and* $\delta \to 1$ *as* $\chi_2 \to 0$*.*

Exchange Rate Process

- **Lemma 3**: *RER follows an ARMA(2,1) process*

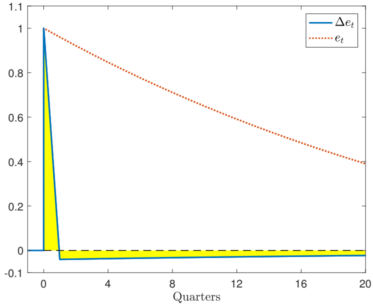
$$(1-\delta L)q_t = \frac{1}{1+\gamma\sigma\kappa_q}\frac{\beta\delta}{1-\beta\rho\delta}\Bigg[(1-\beta^{-1}L)\chi_1\psi_t + \left(\frac{(\beta\delta)^{-1}-1}{1+\frac{\varsigma}{1+\gamma\sigma\kappa_q}}(1-\rho\delta L)+(1-\rho)(1-\beta^{-1}L)\right)\sigma\kappa_a\tilde{a}_t\Bigg]$$

where $\delta \in (0,1]$ *and* $\delta \to 1$ *as* $\chi_2 \to 0$.

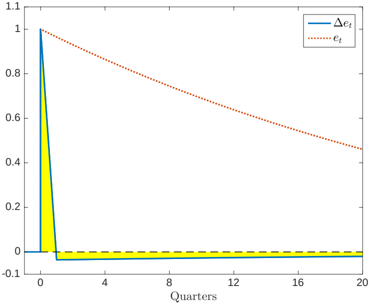
- **Proposition 2**: *A change in the ER regime results in:*
  1. *an increase in volatility of both nominal and real exchange rates, arbitrary large when* $\beta\rho \approx 1$
  2. *a change in the behavior of the other macro variables, which is vanishingly small when* $\gamma \approx 0$.

Exchange Rate Process

: IRF to ψ_t



: IRF to $\tilde{a}_t$



- persistent ψ_t and $\tilde{a}_t$ shocks both lead to a near-random-walk exchange rate response ▸ show
- when $\chi_1 > 0$: ψ_t dominates the variance of Δq_t as $\beta\rho \to 1$
- when $\chi_1 = 0$: Δq_t only responds to $\tilde{a}_{t+1}$ shocks

Macro Volatility

1. **Consumption**

2. **Inflation**

Macro Volatility

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
   - $\mathrm{corr}(\Delta c_t - \Delta c_t^*, \Delta q_t) > 0$ under the peg and < 0 under the float, provided ρ sufficiently large and γ sufficiently small
   - similar results apply to other macro variables

2. **Inflation**

Macro Volatility

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
   - $\mathrm{corr}(\Delta c_t - \Delta c_t^*, \Delta q_t) > 0$ under the peg and < 0 under the float, provided ρ sufficiently large and γ sufficiently small
   - similar results apply to other macro variables

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

$$\mathrm{std}(\pi_t) = \mathrm{std}(\Delta q_t) = \frac{\sigma\kappa_a}{1 + \gamma\sigma\kappa_q + \varsigma}\mathrm{std}(\tilde{a}_t)$$

Additional Evidence

'Overidentification'

1. Forward premium puzzle
   - UIP and CIP both hold under peg (Frankel and Levich 1975)
   - Forward Premium 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
   - holds no explanatory power under float (Engel 1999)
   - works well under peg (Berka, Devereux and Engel 2018)

QUANTITATIVE EVALUATION

Quantitative Framework

- Sticky wages and LCP sticky prices (on/off)
- Taylor rule with a weight on nominal exchange rate
  — ER regime calibrated to change $\mathrm{std}(\Delta e_t)$ eightfold
- Pricing-to-market and intermediate inputs
- Capital with adjustment costs
- Shocks:
  1. Productivity or monetary shocks
  2. Taste shock ξ_t
  3. Financial shock ψ_t
- Standard calibration ▸ show

Results

Table: Macroeconomic volatility

	Δq_t			π_t			Δc_t			Δgdp_t		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Models without UIP shock ψ_t:												
IRBC	15.4	15.4	1.0	12.7	3.2	0.2	9.1	9.1	1.0	15.0	15.0	1.0
NKOE-1	4.2	12.8	3.0	3.1	1.8	0.6	7.1	6.8	1.0	17.7	11.7	0.7
NKOE-2	1.5	11.5	7.4	1.3	1.3	1.0	5.0	5.2	1.0	8.1	8.4	1.0

correlations

Results

Table: Macroeconomic volatility

	Δq_t			π_t			Δc_t			Δgdp_t		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Models without UIP shock ψ_t:												
IRBC	15.4	15.4	1.0	12.7	3.2	0.2	9.1	9.1	1.0	15.0	15.0	1.0
NKOE-1	4.2	12.8	3.0	3.1	1.8	0.6	7.1	6.8	1.0	17.7	11.7	0.7
NKOE-2	1.5	11.5	7.4	1.3	1.3	1.0	5.0	5.2	1.0	8.1	8.4	1.0
Models with exogenous UIP shock:												
IRBC	11.0	11.0	1.0	10.2	0.9	0.1	1.8	1.8	1.0	2.5	2.5	1.0
NKOE-1	2.2	11.9	5.3	1.4	0.4	0.3	5.8	1.3	0.2	14.5	2.1	0.1
NKOE-2	2.1	11.8	5.7	1.3	0.3	0.2	5.8	1.1	0.2	8.6	1.8	0.2

▸ correlations

Results

Table: Macroeconomic volatility

	Δq_t			π_t			Δc_t			Δgdp_t		
	peg	float	ratio	peg	float	ratio	peg	float	ratio	peg	float	ratio
Models without UIP shock ψ_t:												
IRBC	15.4	15.4	1.0	12.7	3.2	0.2	9.1	9.1	1.0	15.0	15.0	1.0
NKOE-1	4.2	12.8	3.0	3.1	1.8	0.6	7.1	6.8	1.0	17.7	11.7	0.7
NKOE-2	1.5	11.5	7.4	1.3	1.3	1.0	5.0	5.2	1.0	8.1	8.4	1.0
Models with exogenous UIP shock:												
IRBC	11.0	11.0	1.0	10.2	0.9	0.1	1.8	1.8	1.0	2.5	2.5	1.0
NKOE-1	2.2	11.9	5.3	1.4	0.4	0.3	5.8	1.3	0.2	14.5	2.1	0.1
NKOE-2	2.1	11.8	5.7	1.3	0.3	0.2	5.8	1.1	0.2	8.6	1.8	0.2
Models with endogenous UIP shock:												
IRBC	3.0	11.0	3.6	1.4	0.9	0.7	1.6	1.8	1.1	2.5	2.5	1.0
NKOE-1	1.7	11.9	6.9	0.4	0.4	1.0	1.1	1.3	1.1	1.9	2.1	1.1
NKOE-2	1.4	11.8	8.2	0.2	0.3	1.5	0.9	1.1	1.2	1.5	1.8	1.2

▸ correlations

Results

Table: Variance decomposition

	peg			float		
	ψ	ξ	a or m	ψ	ξ	a or 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

Conclusion

- Mussa facts are some of the most prominent pieces of evidence of monetary non-neutrality

- We argue, however, that it is not directly suggestive of nominal rigidities
  - a weak test of nominal rigidities (and monetary vs productivity shocks), as it rejects both types of 'conventional' models

- Yet, it is highly suggestive of an alternative source of non-neutrality arising via the financial market
  - a particular type of financial friction
  - namely, segmented financial market, whereby *nominal* exchange rate risk is held in a concentrated way

- Important for reassessing the argument in favor of peg/float

APPENDIX

	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

Price dynamics

- Open economy Phillips curve:

$$(1-\beta L^{-1})\Big[\underbrace{\pi_t - \pi_t^* - 2\gamma\Delta e_t}_{=\pi_{Ht}-\pi^*_{Ft}}\Big] = \kappa\Big[(c_t - c_t^*) + \gamma\kappa_q q_t - \kappa_a \tilde{a}_t\Big]$$

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Price dynamics

- Open economy Phillips curve:

$$(1-\beta L^{-1})\big[\underbrace{\pi_t-\pi_t^*-2\gamma\Delta e_t}_{=\pi_{Ht}-\pi^*_{Ft}}\big]=\kappa\big[(c_t-c_t^*)+\gamma\kappa_q q_t-\kappa_a\tilde{a}_t\big]$$

- **Lemma 1**: *The equilibrium dynamics of the RER:*

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

under both monetary regimes, $R\in\{float, peg\}$, where

$$k_R=\begin{cases}\frac{\kappa}{\sigma}, & R=peg,\\ \frac{1}{2\gamma}\frac{\kappa}{\sigma}, & R=float.\end{cases}$$

  — Recall that under peg $\Delta e_t=\pi_t^*\equiv 0$ and $\Delta q_t=-\pi_t$, and under float $\pi_t=\pi_t^*\equiv 0$ and $\Delta q_t=\Delta e_t$

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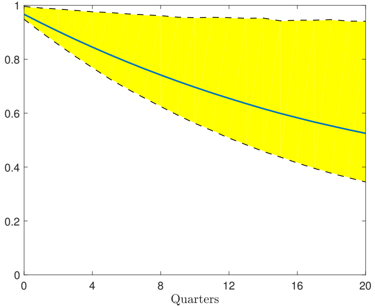
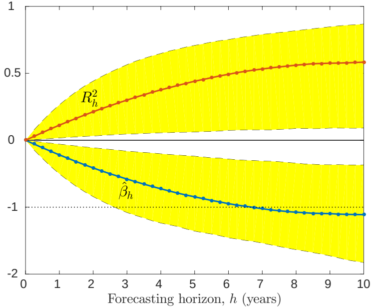
Exchange Rate Properties

Near-random-walkness

: Surprise component



: Predictive regressions



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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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Simulations

	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	5.71	10.6	–	0.30	7	1.8
NKOE-2	0.00	4.38	–	0.77	0.30	22	5.3
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

Note: in all calibrations, shocks are normalized to obtain $\text{std}(\Delta e_t) = 12\%$. Parameter ϕ_e in the Taylor rule is calibrated to generate 8 times fall in $\text{std}(\Delta e_t)$ between monetary regimes. When possible, relative volatilities of shocks are calibrated to match $\text{cor}(\Delta q_t, \Delta \tilde{c}_t) = -0.4$ under the float and $\text{cor}(\Delta q_t, \Delta nx_t) = -0.1$ under the peg. The cross-country correlation of productivity/monetary shocks matches $\text{cor}(\Delta gdp_t, \Delta gdp_t^*) = 0.3$ under the float. Capital adjustment parameter ensures that $\frac{\text{std}(\Delta i_t)}{\text{std}(\Delta gdp_t)} = 2.5$ under the float. The moments are calculated by simulating the model for $T = 100,000$ quarters.

Simulated Correlations

Panel B: correlations

	$\Delta q_t, \Delta e_t$		$\Delta q_t, \Delta c_t - \Delta c_t^*$		$\Delta q_t, \Delta nx_t$		$\Delta gdp_t, \Delta gdp_t^*$		$\Delta c_t, \Delta c_t^*$		$\Delta c_t, \Delta gdp_t$		β^{UIP}	
	peg	float	peg	float	peg	float	peg	float	peg	float	peg	float	peg	float
Models w/o financial shock:														
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	0.8	0.9
NKOE-1	0.67	0.99	0.28	0.70	−0.10	−0.49	0.38	0.31	0.65	0.41	0.91	0.97	0.3	1.0
NKOE-2	0.96	0.99	0.49	0.99	−0.10	0.05	0.95	0.30	0.97	0.33	1.00	1.00	1.0	1.0
Models w/ exogenous financial shock:														
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	0.0	−1.3
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	−0.1	−1.6
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	−0.1	−2.2
Models w/ endogenous financial shock:														
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	1.0	−1.4
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	1.0	−1.6
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	1.0	−2.3

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Correlations

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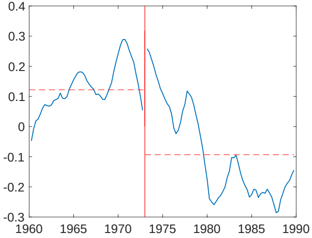
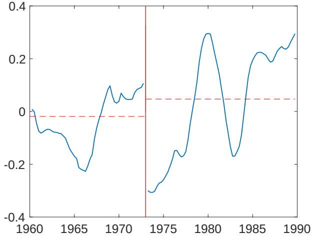
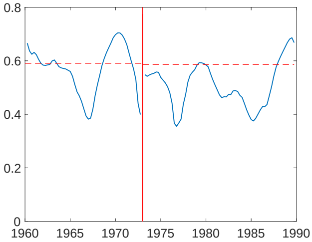
: $(\Delta q_t, \Delta c_t - \Delta c_t^*)$



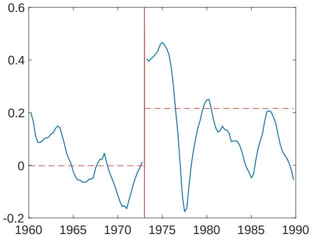
: $(\Delta q_t, \Delta nx_t)$



: $(\Delta gdp_t, \Delta c_t)$



: $(\Delta gdp_t, \Delta gdp_t^{US})$



Model Setup III

- Fiscal authority:

$$T_t = \sum_{j \in J_{t-1}} \left(1 - e^{-\zeta_t^j}\right) D_t^j B_t^j$$

- Monetary authority:

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

— limiting case: (i) $\phi_\pi \to \infty \Rightarrow \pi_t \equiv 0$ or (ii) $\phi_e \to \infty \Rightarrow \Delta e_t \equiv 0$

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- Market clearing in labor and product market:

$$L_t = e^{-a_t} \int_0^1 Y_t(i) \mathrm{d}i \quad \text{and} \quad C_{Ht}(i) + C_{Ht}^*(i) = Y_t(i)$$

and financial market:

$$B_{t+1}^j + B_{t+1}^{j*} = 0 \quad \forall j \in J_t \cap J_t^* \quad \text{given price } \Theta_t^j$$