Mussa Puzzle

- **Real exchange rate (RER):**

\[ Q_t = \frac{E_t P^*_t}{P_t} \]

or in log changes

\[ \Delta q_t = \Delta e_t + \pi^*_t - \pi_t \]

: Nominal exchange rate, \( \Delta e_t \)

: Real exchange rate, \( \Delta q_t \)

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

- **Real exchange rate (RER):**

\[ Q_t = \frac{\varepsilon_t P_t^*}{P_t} \]

or in log changes

\[ \Delta q_t = \Delta e_t + \pi_t^* - \pi_t \]

: Inflation rate, \( \pi_t \)

: Consumption growth, \( \Delta c_t \)

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

- The combined evidence does not favor sticky prices over flexible prices, but rather rejects both types of models
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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

Is it an extreme form of neutrality? or disconnect?
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Intuition

- Real exchange rate:

\[ q_t = e_t + p_t^* - p_t \]  \hspace{1cm} (1)

- IRBC (flex prices): no change in \( \Delta q_t \), change in \( \pi_t - \pi_t^* \propto \Delta e_t \)
- NKOE (sticky prices): change in \( \Delta q_t \propto \Delta e_t \)

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

• Real exchange rate:

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

• ‘Cointegration’ relationship between consumption and RER:

\[ \varsigma(c_t - c_t^*) = q_t - \zeta_t \]  

1. generally derives from international risk sharing condition, but does not rely on (perfect) risk sharing
2. under a variety of circumstances \( \zeta_t \) 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)
  5. Forward-premium puzzle (Fama 1984)

• Itskhoki and Mukhin (2017) propose a solution with emphasis:
  1. Home bias in consumption
  2. ‘Financial’ shocks as the main driver of exchange rates
  3. Taylor rule inflation targeting
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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

Δ$q_t$:

⇒ \text{IRBC (flex prices)}

Mussa Redux

ER Disconnect
Relationship with ER Disconnect

\[ \Delta q_t : \]

\[ \Delta c_t : \]

\[ \Rightarrow \text{IRBC (flex prices)} \]

\[ \Rightarrow \text{NKOE (sticky prices)} \]
Relationship with ER Disconnect

\[ \Delta q_t: \]

\[ \Delta c_t: \]

\[ \Rightarrow \text{IRBC (flex prices)} \]

\[ \Rightarrow \text{NKOE (sticky prices)} \]

\[ \downarrow \]

✓ ER Disconnect
Relationship with ER Disconnect

\[ \Delta q_t : \]

\[ \Delta c_t : \]

\[
\begin{array}{c}
1960 \quad 1965 \quad 1970 \quad 1975 \quad 1980 \quad 1985 \\
\downarrow \quad \downarrow \end{array}
\]

\[ \Rightarrow \quad \text{IRBC (flex prices)} \]

\[ \Rightarrow \quad \text{NKOE (sticky prices)} \]

\[ \checkmark \quad \text{Mussa Redux} \]

\[ \checkmark \quad \text{ER Disconnect} \]
Mussa Puzzle Redux
Resolution

• **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 \( \sigma_e^2 \equiv \text{var}_t(\Delta e_{t+1}) \) and \( \omega \sigma_e^2 \) is the price of ER risk
Mussa Puzzle Redux

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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:

• Theory:
  — Jeanne and Rose (2002), Monacelli (2004), Kollmann (2005), 

• 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

\[ \Delta q_t \]

\[ \pi_t - \pi_t^* \]

\[ \Delta c_t - \Delta c_t^* \]

\[ \Delta y_t - \Delta y_t^* \]

\[ \Delta gdp_t - \Delta gdp_t^* \]

\[ nx_t \]

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

\[ \Delta q_t \]

\[ \pi_t - \pi_t^* \]

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\[ \Delta gdp_t - \Delta gdp_t^* \]

\[ nx_t \]

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

\[ \Delta q_t \]
\[ \pi_t \]
\[ \Delta c_t \]
\[ \Delta y_t \]
\[ \Delta gdp_t \]
\[ nx_t \]

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

\[ \Delta q_t \]

\[ \pi_t - \pi^*_t \]

\[ \Delta c_t - \Delta c^*_t \]

\[ \Delta gdp_t \]

\[ \pi_t \]

\[ \Delta c_t \]

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

\[ (\Delta q_t, \Delta e_t) \]

\[ (\bullet, \pi_t - \pi^*_t) \]

Note: Triangular moving average correlations, treating 1973:01 as the end point for the two regimes.
CONVENTIONAL 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
‘Conventional’ Models

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  - 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

- 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:

\[
\max E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{1}{1-\sigma} C_t^{1-\sigma} - \frac{1}{1+\varphi} L_t^{1+\varphi} \right)
\]

s.t. \( P_t C_t + \sum_{j \in J_t} \Theta_j^t B_{t+1}^j \leq W_t L_t + \sum_{j \in J_{t-1}} e^{-\zeta_t^j} D_t^j B_t^j + \Pi_t + T_t \)

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

• Optimality conditions:

\[
C_t^\sigma L_t^\varphi = W_t / P_t,
\]

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

\[
\Theta_t^j = \beta E_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} e^{-\zeta_{t+1}^j} D_{t+1}^j \right\}
\]

and \( P_t C_t = P_{Ht} C_{Ht} + P_{Ft} C_{Ft} \)
Model setup II

- Production:
  \[ Y_t(i) = e^{a_t L_t(i)} \implies MC_t = e^{-a_t} W_t \]

- Profits:
  \[ \Pi_t(i) = (P_{Ht}(i) - MC_t)(C_{Ht}(i) + C^{*}_{Ht}(i)) \]

- 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 $j \in J_t \cap J^*_t$

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

2. Country budget constraint

3. Open economy Phillips curve
International Equilibrium

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

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

2. Country budget constraint

$$B_{t+1} - R_t B_t = P_{Ht} C_{Ht}^* - \mathbb{E}_t P_{Ft}^* C_{Ft} = \gamma P_t^\theta \frac{C_t}{\left( \mathbb{E}_t P_{Ft}^* \right)^{\theta-1}} \left[ e^{\tilde{\xi}_t} S_t^{\theta-1} Q_t^\theta \frac{C_t^*}{C_t} - 1 \right]$$

where $B_{t+1} \equiv \sum_{j \in J_t} \Theta_t^j B_{t+1}^j$ is NFA position

— terms of trade $S_t \equiv \frac{\mathbb{E}_t P_{Ft}^*}{P_{Ht}} \approx Q_t^{\frac{1}{1-2\gamma}}$

3. Open economy Phillips curve
International Equilibrium

1. International risk sharing — for \( j \in J_t \cap J^*_t \)

\[
\mathbb{E}_t \left\{ \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} - \left( \frac{C^*_{t+1}}{C^*_t} \right)^{-\sigma} \frac{Q_t}{Q_{t+1}} e^{\tilde{\xi}_{t+1}} \right] \frac{D^j_{t+1}}{P_{t+1}/P_t} \right\} = 0
\]

2. Country budget constraint

\[
B_{t+1} - R_t B_t = P_{Ht} C^*_{Ht} - \mathcal{E}_t P^*_{Ft} C^*_{Ft} = \frac{\gamma P^\theta_t C_t}{(\mathcal{E}_t P^*_{Ft})^{\theta-1}} \left[ e^{\tilde{\xi}_t} S_{t}^{\theta-1} Q^\theta_t \frac{C^*_{t}}{C_t} - 1 \right]
\]

where \( B_{t+1} \equiv \sum_{j \in J_t} \Theta_t^j B^j_{t+1} \) is NFA position

- terms of trade \( S_t \equiv \frac{\mathcal{E}_t P^*_{Ft}}{P_{Ht}} \approx Q_t^{1-2\gamma} \)

3. Open economy Phillips curve

- another relationship that links \( C_t/C^*_t \) and \( Q_t \)
- only condition that directly depends on the monetary regime
Cointegration Relationship

Limiting cases

- **Financial autarky:** \( \mathcal{N}X_t \equiv 0 \) 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:**

\[
\sigma = \frac{1 - 2\gamma}{2(1 - \gamma)\theta - 1} \quad \text{(in particular, } \sigma = \theta = 1)\]
General Case

- Log-linearized dynamic equilibrium system:

\[
E_t \{ \sigma(\Delta c_{t+1} - \Delta c^*_t) - \Delta q_{t+1} \} = \psi_t,
\]

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

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

- where \( \psi_t \equiv -E_t \Delta \zeta_{t+1} \) is the UIP shock

- slope of the open economy Phillips curve:

\[
k_R = \begin{cases} 
\kappa, & R = \text{peg} \\
\frac{1}{2\gamma} \kappa, & R = \text{float}
\end{cases}
\]

\[
\kappa = \frac{(1-\lambda)(1-\beta \lambda)}{\lambda} (\sigma + \varphi)...
\]
General Case

- Log-linearized dynamic equilibrium system:

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

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

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

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- slope of the open economy Phillips curve:

\[ k_R = \begin{cases} 
\kappa, & R = \text{peg} \\
\frac{1}{2\gamma} \kappa, & R = \text{float} 
\end{cases} \quad \text{and} \quad \kappa = \frac{(1-\lambda)(1-\beta \lambda)}{\lambda} (\sigma + \varphi) \ldots \]
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, \(\text{var}(\sigma(\Delta c_t - \Delta c_t^*) - \Delta q_t)\) should not change
Empirical Falsification

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

- Different values of $\sigma$
- Across countries, $\sigma = 2$

Note: Ratio of $\text{std}(\sigma(\Delta c_t - \Delta c^*_t) - \Delta q_t)$ 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

```
Home H/H    Foreign H/H
  \[NX_t\]
  \[B_{t+1}\]    \[B_t^*\]
  \[N_t+1\]    \[N_t^{*}\]

Arbitrageurs
Noise Traders
```

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 $J_t \cap J^*_t = \emptyset$

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

  $$\frac{B_{t+1}}{R_t} - B_t = NX_t \quad \text{and} \quad \frac{B_{t+1}^*}{R_t^*} - B_t^* = -NX_t/E_t$$

- **Noise (liquidity) traders** with an exogenous demand:

  $$\frac{N_{t+1}}{R_t^*} = n(e^{\psi_t} - 1) \quad \text{and} \quad \frac{N_{t+1}}{R_t} = -E_t \frac{N_{t+1}^*}{R_t^*}$$
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  $$\frac{N^*_t}{R^*_t} = n (e^{\psi_t} - 1) \quad \text{and} \quad \frac{N_t}{R_t} = -E_t \frac{N^*_t}{R^*_t}$$

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

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

  - $m$ symmetric intermediaries
  - $D^*_{t+1} = md^*_{t+1}$ foreign bond and $\frac{D_{t+1}}{R_t} = -E_t \frac{D^*_{t+1}}{R^*_t}$ home bond
Segmented Financial Market

Three types of agents

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

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- **Noise (liquidity) traders** with an exogenous demand:

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

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

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

  - $m$ symmetric intermediaries
  - $D^*_{t+1} = md^*_{t+1}$ foreign bond and $\frac{D^*_{t+1}}{R_t} = -E_t \frac{D^*_{t+1}}{R^*_t}$ 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 \( \sigma_e^2 \equiv \text{var}_t(\Delta e_{t+1}) \).
Segmented Financial Market

Equilibrium

• **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 \( \sigma_e^2 \equiv \text{var}_t (\Delta e_{t+1}) \).

(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 \( \sigma_e^2 \equiv \text{var}_t (\Delta e_{t+1}) \), 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

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

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

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

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 \( \gamma \approx 0 \).
• persistent $\psi_t$ and $\tilde{a}_t$ shocks both lead to a **near-random-walk exchange rate response**

• when $\chi_1 > 0$: $\psi_t$ dominates the variance of $\Delta q_t$ as $\beta \rho \to 1$

• when $\chi_1 = 0$: $\Delta q_t$ only responds to $\tilde{a}_{t+1}$ shocks
1  Consumption

2  Inflation

Macro Volatility

\[ c_t - c^*_t = \kappa a_t (a_t - a^*_t) - \gamma \kappa q_t \]

\[ when \gamma \text{ is small, } (a_t - a^*_t) \text{ is the main driver of } (c_t - c^*_t) \text{ independently of the volatility of } \Delta q_t \]

\[ \text{corr} (\Delta c_t - \Delta c^*_t, \Delta q_t) < 0 \text{ under the peg and } > 0 \text{ under the float, provided } \rho \text{ sufficiently large and } \gamma \text{ sufficiently small} \]

\[ \text{similar results apply to other macro variables} \]

\[ \text{Inflation} - \text{under float} \]

\[ \text{std}(\pi_t) = \text{std}(\Delta q_t) = \sigma \kappa a_t + \gamma \sigma \kappa q_t + \varsigma \text{std}(\tilde{a}_t) \]
Macro Volatility

1 Consumption — goods market clearing:

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

- when \( \gamma \) is small, \((a_t - a_t^*)\) is the main driver of \((c_t - c_t^*)\) independently of the volatility of \(\Delta q_t\)
- \(\text{corr}(\Delta c_t - \Delta c_t^*, \Delta q_t) > 0\) under the peg and \(< 0\) under the float, provided \(\rho\) sufficiently large and \(\gamma\) sufficiently small
- similar results apply to other macro variables

2 Inflation

Inflation — under float \(\text{std}(\pi_t) = 0\) and under peg:

\[ \text{std}(\pi_t) = \text{std}(\Delta q_t) = \sigma_{\kappa_a} 1 + \gamma \sigma_{\kappa_q} + \varsigma \text{std}(\tilde{a}_t) \]
Macro Volatility

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

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

- when \( \gamma \) is small, \( (a_t - a_t^*) \) is the main driver of \( (c_t - c_t^*) \) independently of the volatility of \( \Delta q_t \)

- \( \text{corr}(\Delta c_t - \Delta c_t^*, \Delta q_t) > 0 \) under the peg and \( < 0 \) under the float, provided \( \rho \) sufficiently large and \( \gamma \) sufficiently small

- similar results apply to other macro variables

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

\[ \text{std}(\pi_t) = \text{std}(\Delta q_t) = \frac{\sigma \kappa_a}{1 + \gamma \sigma \kappa_q + \varsigma} \text{std}(\tilde{a}_t) \]
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
   - \( \text{corr}(\Delta q, \Delta c - \Delta c^*) \) 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 $\text{std}(\Delta e_t)$ eightfold
- Pricing-to-market and intermediate inputs
- Capital with adjustment costs
- Shocks:
  1. Productivity or monetary shocks
  2. Taste shock $\xi_t$
  3. Financial shock $\psi_t$
- Standard calibration
Results

Table: Macroeconomic volatility

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<tr>
<th>Δ$q_t$</th>
<th>$\pi_t$</th>
<th>Δ$c_t$</th>
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Models without UIP shock $\psi_t$:

Models with exogenous UIP shock:

Models with endogenous UIP shock:
## Results

### Table: Macroeconomic volatility

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*Correlations:*

- IRBC: $\psi_t$ (15.4, 15.4, 1.0)
- NKOE-1: $\psi_t$ (4.2, 12.8, 3.0)
- NKOE-2: $\psi_t$ (1.5, 11.5, 7.4)

**Note:** The table entries are values for different models and their respective volatility measures.
## Results

### Table: Macroeconomic volatility

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### Correlations

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## Results

### Table: Variance decomposition

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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
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Price dynamics

- Open economy Phillips curve:

\[
(1 - \beta L^{-1}) \left[ \pi_t - \pi_t^* - 2\gamma \Delta e_t \right] = \kappa \left[ (c_t - c_t^*) + \gamma \kappa q q_t - \kappa a \tilde{a}_t \right]
\]

\[
= \pi_{Ht} - \pi_{Ft}
\]
Price dynamics

• Open economy Phillips curve:

\[
(1 - \beta L^{-1}) \left[ \pi_t - \pi_t^* - 2\gamma \Delta e_t \right] = \kappa \left[ (c_t - c_t^*) + \gamma \kappa_q q_t - \kappa_a \tilde{a}_t \right]
\]

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

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

under both monetary regimes, \( R \in \{ \text{float, peg} \} \), where

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

— 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 \( \Delta q_t = \Delta e_t \)
Exchange Rate Properties

Near-random-walkness

: Surprise component

: Predictive regressions

\[ R^2_h \]

\[ \hat{\beta}_h \]
### Calibration

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<th>Symbol</th>
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<td>$\epsilon$</td>
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<td>$\lambda_p$</td>
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<tr>
<td>$\rho_r$</td>
<td>Taylor rule: persistence of interest rates</td>
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<tr>
<td>$\phi_\pi$</td>
<td>Taylor rule: reaction to inflation</td>
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### Simulations

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<th>$\sigma_n$</th>
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<th>$\sigma_a$</th>
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<th>$\rho_{a,a^*}$</th>
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<tr>
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<td>3.37</td>
<td>1.41</td>
<td>–</td>
<td>0.30</td>
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<td>1.01</td>
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<td>0.35</td>
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<td>–</td>
<td>0.15</td>
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<tr>
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<td>0.61</td>
<td>3.37</td>
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<td>NKOE-1</td>
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<td>0.42</td>
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<td>0.08</td>
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</table>

Note: in all calibrations, shocks are normalized to obtain $\text{std}(\Delta e_t) = 12\%$. Parameter $\phi_e$ 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 $\text{cor}(\Delta q_t, \Delta n_{xt}) = -0.1$ 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**

<table>
<thead>
<tr>
<th></th>
<th>$\Delta q_t, \Delta e_t$</th>
<th>$\Delta q_t, \Delta c_t - \Delta c_t^*$</th>
<th>$\Delta q_t, \Delta n_x_t$</th>
<th>$\Delta gdp_t, \Delta gdp_t^*$</th>
<th>$\Delta c_t, \Delta c_t^*$</th>
<th>$\Delta c_t, \Delta gdp_t$</th>
<th>$\beta_{UIP}$</th>
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<tr>
<td>IRBC</td>
<td>0.86 0.99</td>
<td>0.91 0.91</td>
<td>$-0.10$ $-0.10$</td>
<td>0.30 0.30</td>
<td>0.34 0.34</td>
<td>0.99 0.99</td>
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<td>NKOE-1</td>
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<td>0.28 0.70</td>
<td>$-0.10$ $-0.49$</td>
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<td>0.97 0.33</td>
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<td><strong>Models w/ exogenous financial shock:</strong></td>
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<tr>
<td>IRBC</td>
<td>0.86 0.99</td>
<td>$-0.40$ $-0.40$</td>
<td>0.93 0.93</td>
<td>0.30 0.30</td>
<td>0.15 0.15</td>
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<tr>
<td>NKOE-1</td>
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<td>0.89 0.93</td>
<td>0.60 0.30</td>
<td>$-0.06$ 0.32</td>
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<tr>
<td>NKOE-2</td>
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<td>$-0.89$ $-0.40$</td>
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<tr>
<td>IRBC</td>
<td>0.98 1.00</td>
<td>0.92 $-0.40$</td>
<td>$-0.10$ 0.93</td>
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<td>0.94 $-0.40$</td>
<td>$-0.10$ 0.97</td>
<td>0.66 0.30</td>
<td>0.70 0.26</td>
<td>0.99 0.79</td>
<td>1.0 $-2.3$</td>
</tr>
</tbody>
</table>
Correlations:

1. $(\Delta q_t, \Delta c_t - \Delta c_t^*)$

2. $(\Delta q_t, \Delta n_x_t)$

3. $(\Delta gdp_t, \Delta c_t)$

4. $(\Delta gdp_t, \Delta gdp_t^{US})$
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:
  \[
  i_t = \rho_m i_{t-1} + (1 - \rho_m) \left[ \phi_\pi \pi_t + \phi_e (e_t - \bar{e}) \right] + \sigma_m \epsilon_t^m
  \]
  - limiting case: (i) \( \phi_\pi \to \infty \) \( \Rightarrow \pi_t \equiv 0 \) or (ii) \( \phi_e \to \infty \) \( \Rightarrow \Delta e_t \equiv 0 \)
Model Setup III

- Fiscal authority:
  \[ T_t = \sum_{j \in J_{t-1}} (1 - e^{-\zeta_t^j}) D_t^j B_t^j \]

- Monetary authority:
  \[ i_t = \rho_m i_{t-1} + (1 - \rho_m) [\phi_\pi \pi_t + \phi_\varepsilon (e_t - \bar{e})] + \sigma_m \varepsilon_t^m \]
  Limiting case: (i) \( \phi_\pi \to \infty \Rightarrow \pi_t \equiv 0 \) or (ii) \( \phi_\varepsilon \to \infty \Rightarrow \Delta e_t \equiv 0 \)

- Market clearing in labor and product market:
  \[ L_t = e^{-a_t} \int_0^1 Y_t(i) di \text{ and } C_{Ht}(i) + C^*_H(i) = Y_t(i) \]

  and financial market:
  \[ B_{t+1}^j + B_{t+1}^{j*} = 0 \quad \forall j \in J_t \cap J_t^* \quad \text{given price } \Theta_t^j \]