Mussa Puzzle Redux

Oleg Itskhoki
itskhoki@Princeton.edu

Dmitry Mukhin
dmitry.mukhin@Yale.edu

Rutgers University
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Mussa Puzzle

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

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

or in log changes

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

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

(b) 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

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

(a) Inflation rate, \( \pi_t \)

(b) 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, RER 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?
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Is it an extreme form of neutrality?

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

- Real exchange rate:

\[ q_t = e_t + p_t^* - p_t \]  (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 \( \Delta q_t \propto \Delta e_t \)

\[ \Delta q_t \neq e_t + p_t^* - p_t \]

**generally derives from international risk sharing condition, but does not rely on (perfect) risk sharing**

\[ \Delta q_t \] 

does not depend on exchange rate regime

\[ \Delta q_t \] 

falsifies both sticky-price and flexible-price models
Intuition

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

• Cointegration relationship between consumption and RER:

\[ \varsigma(c_t - c_t^*) = q_t - \zeta_t \]  \hspace{1cm} (2)

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

- Exchange rate disconnect is a 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

- 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.
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Relationship with ER Disconnect

\[ \Delta q_t: \]

\[ \begin{array}{c|c|c}
1960 & 1965 & 1970 \\
\hline
-0.15 & 0 & 0.15 \\
\end{array} \]

⇒ IRBC (flex prices)

\[ \begin{array}{c|c|c}
1975 & 1980 & 1985 \\
\hline
-0.15 & 0 & 0.15 \\
\end{array} \]

⇒ NKOE (sticky prices)

Mussa Redux

ER Disconnect
Relationship with ER Disconnect

\[ \Delta q_t : \]

\[ \Delta c_t : \]

⇒ \( \times \) IRBC (flex prices)

⇒ \( \times \) NKOE (sticky prices)
Relationship with ER Disconnect

\[ \Delta q_t: \]

\[ \Delta c_t: \]

⇒ \( \times \) IRBC (flex prices)

⇒ \( \times \) NKOE (sticky prices)

\( \downarrow \)

✓ ER Disconnect
Relationship with ER Disconnect

\[ \Delta q_t: \]

\[ \Delta c_t: \]

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

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

\[ \downarrow \text{Mussa Redux} \quad \downarrow \text{ER Disconnect} \]
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**: 
  \[
  \frac{i_t - i^*_t - \mathbb{E}_t \Delta e_{t+1}}{\omega \sigma^2_e} = \psi_t - b_{t+1}
  \]
Mussa Puzzle Redux
Resolution

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  \]

- **Changes in nominal exchange rate volatility,** \( \sigma_e^2 \equiv \text{var}_t(\Delta e_{t+1}) \), are 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:**

- **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

$\Delta q_t$

$\pi_t - \pi_t^*$

$\Delta c_t - \Delta c_t^*$

$\Delta y_t - \Delta y_t^*$

$\Delta gdp_t - \Delta gdp_t^*$

$nx_t$

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

\[ \Delta q_t \]

\[ \pi_t \]

\[ \Delta c_t \]

\[ \Delta y_t \]

\[ \Delta gdp_t \]

\[ nx_t \]

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

(a) $\Delta q_t$

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

(c) $\Delta c_t - \Delta c_t^*$

(d) $\Delta gdp_t$

(e) $\pi_t$

(f) $\Delta c_t$

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

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

(b) \((\bullet, \pi_t - \pi^*_t)\)

(c) \((\Delta q_t, \Delta c_t - \Delta c^*_t)\)

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

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

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

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

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

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

(f) $(\Delta gdp_t, \Delta gdp_{tUS})$

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 the sticky-price version of these models is relevant

- 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 inflation targeting, $\pi_t \equiv 0$
    - ‘peg’ is $\Delta e_t \equiv 0$
Model setup I

- Households:

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

s.t.  \( P_t C_t + \sum_{j \in J_t} \Theta^j_t B^j_{t+1} \leq W_t L_t + \sum_{j \in J_{t-1}} e^{-\zeta^j_t} D^j_t B^j_t + \Pi_t + T_t \)

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

- **Households:**

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

  s.t.  \[ P_t C_t + \sum_{j \in J_t} \Theta^j_t B_{t+1}^j \leq W_t L_t + \sum_{j \in J_{t-1}} e^{-\zeta^j_t} D_t^j B_t^j + \Pi_t + T_t \]

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

- **Optimality conditions:**

  \[
  C_t^\sigma L_t^\varphi = \frac{W_t}{P_t},
  \]

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

  \[
  \Theta^j_t = \beta \mathbb{E}_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}} e^{-\zeta^j_{t+1}} D_t^j \right\}
  \]
Model setup II

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

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

- Calvo price setting:
  \[ \bar{P}_{Ht}(i) = \arg \max E_t \sum_{k=0}^{\infty} (\beta \lambda)^k \left( \frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \Pi_{t+k}(i) \]

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

\[ i_t = \rho_m i_{t-1} + (1 - \rho_m) \left[ \phi_p \pi_t + \phi_e (e_t - \bar{e}) \right] + \sigma_m \varepsilon^m_t \]

- limiting case: (i) \( \phi_p \to \infty \Rightarrow \pi_t \equiv 0 \) or (ii) \( \phi_e \to \infty \Rightarrow \Delta e_t \equiv 0 \)
Model Setup III

• Fiscal authority:

\[ T_t = \sum_{j \in J_{t-1}} (1 - e^{-\zeta^j_t}) D^j_t B^j_t \]

• Monetary authority:

\[ i_t = \rho_m i_{t-1} + (1 - \rho_m) [\phi_\pi \pi_t + \phi_e (e_t - \bar{e})] + \sigma_m \varepsilon^m_t \]

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

• Market clearing in labor and product market:

\[ L_t = e^{-a_t} \int_0^1 Y_t(i) \, di \quad \text{and} \quad C_{H_t}(i) + C^*_{H_t}(i) = Y_t(i) \]

and financial market:

\[ B^j_{t+1} + B^j_{t+1} = 0 \quad \forall j \in J_t \cap J^*_t \quad \text{given price } \Theta^j_t \]
International Equilibrium

- International risk sharing:

\[ E_t \left\{ \left[ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} - \left( \frac{C_{t+1}^*}{C_t^*} \right)^{-\sigma} \right] \frac{Q_t}{Q_{t+1}} e^{\tilde{z}_t} \right\} \frac{D^j_{t+1}}{P_{t+1}/P_t} = 0 \quad \forall j \in J_t \cap J^*_t \]
International Equilibrium

- **International risk sharing:**

\[
\mathbb{E}_t \left\{ \left( \frac{C_{t+1}}{C_t} \right)^{-\sigma} - \left( \frac{C^*_t}{C^*_t} \right)^{-\sigma} \frac{Q_t}{Q_{t+1}} e^{\tilde{\xi}_{t+1}} \right\} \frac{D_{t+1}^j}{P_{t+1}/P_t} = 0 \quad \forall j \in J_t \cap J^*_t
\]

- **Country budget constraint:**

\[
B_{t+1} - R_t B_t = NX_t,
\]

where 
\[
B_{t+1} \equiv \sum_{j \in J_t} \Theta_t^j B_{t+1}^j \quad \text{and} \quad R_t \equiv \frac{\sum_{j \in J_{t-1}} D_t^j B_t^j}{\sum_{j \in J_{t-1}} \Theta_{t-1}^j B_t^j}
\]

- **and net exports are given by:**

\[
NX_t = P_{H_t} C^*_{H_t} - \mathcal{E}_t P^*_{F_t} C_{F_t} = \gamma \frac{P^\theta_t C_t}{(\mathcal{E}_t P^*_{F_t})^{\theta-1}} \left[ e^{\tilde{\xi}_t} S_t^{\theta-1} Q_t \frac{C^*_t}{C_t} - 1 \right]
\]

where terms of trade 
\[
S_t \equiv \frac{\mathcal{E}_t P^*_{F_t}}{P_{H_t}} \approx Q_t^{1-2\gamma}
\]
Cointegration Relationship

Limiting cases

- **Financial autarky:** \( NX_t \equiv 0 \) results in

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

Limiting cases

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

- **Complete markets**: \( j \in J_t \cap J^*_t \) for each state of the world

\[
\sigma(\Delta c_t - \Delta c^*_t) = \Delta q_t + \tilde{\zeta}_t
\]
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**: perfect risk sharing w/out financial market
  
  $$\sigma = \frac{1 - 2\gamma}{2(1 - \gamma)\theta - 1}$$
  
  (in particular, $\sigma = \theta = 1$)
General asset market

- Assume:
  - A foreign (US) risk-free bond $\in J_t \cap J^*_t$
  - Log-linear approximate solution
    - ‘conventional’
    - second-order (risk premia) terms are small
    - we allow for risk-sharing wedges instead
General asset market

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  ○ A foreign (US) risk-free bond $\in J_t \cap J_t^*$
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• Dynamic equilibrium system:

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

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

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

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

and we assume $\psi_t$ follows AR(1)
General asset market

• Assume:
  ○ A foreign (US) risk-free bond $\in J_t \cap J^*_t$
  ○ Log-linear approximate solution
    — ‘conventional’
    — second-order (risk premia) terms are small
    — we allow for risk-sharing wedges instead

• Dynamic equilibrium system:

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

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

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

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

and we assume $\psi_t$ follows AR(1)
Price dynamics

- Open economy Phillips curve:

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

- **Open economy Phillips curve:**

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

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

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

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 \(\Delta q_t = \Delta e_t\)
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

(a) Different values of $\sigma$  
(b) 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
- 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 $J_t \cap J^*_t = \emptyset$

  \[
  \frac{B_{t+1}}{R_t} - B_t = NX_t \quad \text{and} \quad \frac{B^*_{t+1}}{R^*_t} - B^*_t = -NX_t/E_t
  \]
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\]

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

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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} = -E_t \frac{N^*_{t+1}}{R^*_t}
  \]

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

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

  - $m$ symmetric intermediaries
  
  - $\frac{D^*_{t+1}}{R_t} = md^*_{t+1}$ 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 $J_t \cap J^*_t = \emptyset$

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

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

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

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

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

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

- **Market clearing**: $B^*_{t+1} + D^*_{t+1} + N^*_{t+1} = 0$
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 \(i_t \equiv \log R_t\) 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 \( i_t \equiv \log R_t \) 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
• **Lemma 3:** *RER follows an ARMA(2,1) process*

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

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

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

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

- **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 \( \rho \approx 1 \)

  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 $\rho \to 1$

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

- Product-market relationship between consumption and RER:
  (i) labor market clearing: \( \sigma \tilde{c}_t + \varphi \tilde{y}_t = (1 + \varphi) \tilde{a}_t - \gamma q_t \)
  (ii) goods market clearing: \( \tilde{y}_t = (1 - 2\gamma) \tilde{c}_t + 2 \theta \gamma q_t \)

- Equilibrium relationship

\[
ct - c_t^* = \frac{1+\varphi}{\sigma+(1-2\gamma)\varphi} \tilde{a}_t - \frac{2\theta(1-\gamma)\varphi+1}{\sigma+(1-2\gamma)\varphi} \frac{2\gamma}{1-2\gamma} q_t
\]

- when \( \gamma \) is small, \( \tilde{a}_t \) 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, including inflation and output
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 change corresponds to a change in this weight
• Pricing-to-market and intermediate inputs
• Capital with adjustment costs
• Shocks:
  1. Productivity or monetary shocks
  2. Taste shock
  3. Financial shock
• Standard calibration
# Results

## Table: Macroeconomic volatility

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### Correlations

- $\rho_{\Delta q_t, \Delta gdp_t}$: 30
- $\rho_{\pi_t, \Delta gdp_t}$: 32
Results

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## Results

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Models **without** financial shock $\psi_t$:

- IRBC
- NKOE-1
- NKOE-2

Models **with exogenous** financial shock:

- IRBC
- NKOE-1
- NKOE-2

Models **with endogenous** financial shock:

- IRBC
- NKOE-1
- NKOE-2

**correlations**
# Results

## Table: Variance decomposition

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Consumption:  

IRBC  | 0 | 1 | 99 | 15 | 1 | 84  
NKOE-1| 0 | 1 | 99 | 10| 0 | 90  
NKOE-2| 0 | 1 | 99 | 13| 0 | 87  

31 / 32
### 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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<td>0.04 −0.19</td>
<td>−0.06 0.00</td>
<td>−0.01 0.28</td>
</tr>
<tr>
<td><strong>Italy</strong></td>
<td>0.54 0.97</td>
<td>0.07 −0.13</td>
<td>0.02 −0.01</td>
<td>0.04 0.17</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>0.76 0.98</td>
<td>0.21 −0.00</td>
<td>0.03 0.21</td>
<td>−0.08 0.24</td>
</tr>
<tr>
<td><strong>Spain</strong></td>
<td>0.83 0.96</td>
<td>−0.09 −0.18</td>
<td>−0.06 0.16</td>
<td>0.05 0.09</td>
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<tr>
<td><strong>U.K.</strong></td>
<td>0.94 0.96</td>
<td>0.09 −0.10</td>
<td>−0.39 −0.16</td>
<td>−0.11 0.30</td>
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<tr>
<td><strong>RoW</strong></td>
<td>0.80 0.98</td>
<td>0.05 −0.19</td>
<td>−0.20 0.21</td>
<td>−0.03 0.39</td>
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</tbody>
</table>
Exchange Rate Properties
Near-random-walkness

(a) Surprise component

(b) Predictive regressions
Calibration

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
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<tbody>
<tr>
<td>$\beta$</td>
<td>discount factor</td>
<td>0.99</td>
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<tr>
<td>$\sigma$</td>
<td>inverse of the IES</td>
<td>2</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>openness of economy</td>
<td>0.035</td>
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<td>$\varphi$</td>
<td>inverse of Frisch elasticity</td>
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</tr>
<tr>
<td>$\phi$</td>
<td>intermediate share in production</td>
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<tr>
<td>$\vartheta$</td>
<td>capital share</td>
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<td>$\delta$</td>
<td>capital depreciation rate</td>
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<tr>
<td>$\theta$</td>
<td>elasticity of substitution between H and F goods</td>
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<tr>
<td>$\epsilon$</td>
<td>elasticity of substitution between different types of labor</td>
<td>4</td>
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<tr>
<td>$\lambda_w$</td>
<td>Calvo parameter for wages</td>
<td>0.85</td>
</tr>
<tr>
<td>$\lambda_p$</td>
<td>Calvo parameter for prices</td>
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<tr>
<td>$\rho$</td>
<td>autocorrelation of shocks</td>
<td>0.97</td>
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<tr>
<td>$\rho_r$</td>
<td>Taylor rule: persistence of interest rates</td>
<td>0.95</td>
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<tr>
<td>$\phi_\pi$</td>
<td>Taylor rule: reaction to inflation</td>
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## Simulations

<table>
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<tr>
<th></th>
<th>$\sigma_n$</th>
<th>$\sigma_\xi$</th>
<th>$\sigma_a$</th>
<th>$\sigma_m$</th>
<th>$\rho_{a,*}$</th>
<th>$\kappa$</th>
<th>$\phi_e$</th>
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<tbody>
<tr>
<td><strong>Models w/o financial shock:</strong></td>
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<td></td>
<td></td>
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<tr>
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<td>0.00</td>
<td>13.8</td>
<td>8.1</td>
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<td>11</td>
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<td>–</td>
<td>0.30</td>
<td>7</td>
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<td><strong>Models w/ exogenous financial shock:</strong></td>
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<td></td>
</tr>
<tr>
<td>IRBC</td>
<td>0.61</td>
<td>3.37</td>
<td>1.41</td>
<td>–</td>
<td>0.30</td>
<td>15</td>
<td>14.5</td>
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<tr>
<td>NKOE-1</td>
<td>0.59</td>
<td>2.80</td>
<td>1.01</td>
<td>–</td>
<td>0.35</td>
<td>7.5</td>
<td>3.7</td>
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<tr>
<td>NKOE-2</td>
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<td>1.23</td>
<td>–</td>
<td>0.15</td>
<td>0.42</td>
<td>20</td>
<td>3.6</td>
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<tr>
<td><strong>Models w/ endogenous financial shock:</strong></td>
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<td></td>
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</tr>
<tr>
<td>IRBC</td>
<td>0.61</td>
<td>3.37</td>
<td>1.41</td>
<td>–</td>
<td>0.30</td>
<td>15</td>
<td>0.25</td>
</tr>
<tr>
<td>NKOE-1</td>
<td>0.59</td>
<td>2.80</td>
<td>1.01</td>
<td>–</td>
<td>0.35</td>
<td>7.5</td>
<td>0.03</td>
</tr>
<tr>
<td>NKOE-2</td>
<td>0.59</td>
<td>1.23</td>
<td>–</td>
<td>0.15</td>
<td>0.42</td>
<td>20</td>
<td>0.08</td>
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</tbody>
</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 $\text{cor}(\Delta q_t, \Delta n_x t) = -0.1$ 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

<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>
</tr>
</thead>
<tbody>
<tr>
<td>peg float</td>
<td>peg float</td>
<td>peg float</td>
<td>peg float</td>
<td>peg float</td>
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<td>peg float</td>
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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>
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<tr>
<td>NKOE-1</td>
<td>0.67 0.99</td>
<td>0.28 0.70</td>
<td>-0.10 -0.49</td>
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<td>0.91 0.97</td>
<td>0.3 1.0</td>
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<tr>
<td>NKOE-2</td>
<td>0.96 0.99</td>
<td>0.49 0.99</td>
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<td>0.95 0.30</td>
<td>0.97 0.33</td>
<td>1.00 1.00</td>
<td>1.0 1.0</td>
</tr>
</tbody>
</table>

Models w/o financial shock:
- IRBC
- NKOE-1
- NKOE-2

Models w/ exogenous financial shock:
- IRBC
- NKOE-1
- NKOE-2

Models w/ endogenous financial shock:
- IRBC
- NKOE-1
- NKOE-2

$\beta_{UIP}$