Exchange Rate Disconnect in General Equilibrium

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Motivation

- Exchange Rate Disconnect (ERD) is one of the most pervasive and challenging puzzles in macroeconomics
  - exchange rates are present in all international macro models
  - yet, we do not have a satisfactory theory of exchange rates

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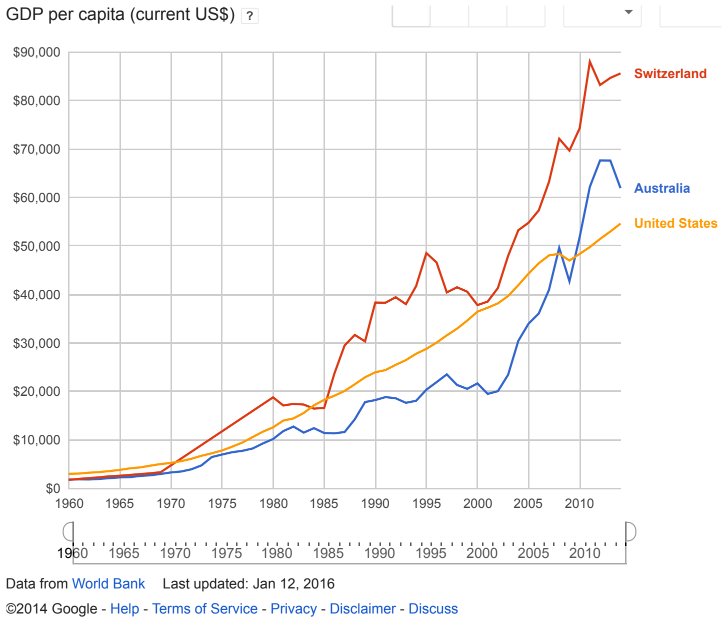
- Broader ERD combines five exchange-rate-related puzzles:
  1. Meese-Rogoff (1983) puzzle
     NER follows a volatile RW, uncorrelated with macro fundamentals
  2. PPP puzzle (Rogoff 1996)
     RER is as volatile and persistent as NER, and the two are nearly indistinguishable at most horizons (also related Mussa puzzle)
  3. LOP/Terms-of-Trade puzzle (Engel 1999, Atkeson-Burstein 2008)
     LOP violations for tradables account for nearly all RER dynamics
     ToT is three times less volatile than RER
  4. Backus-Smith (1993) puzzle
     Consumption is high when prices are high (RER appreciated)
     Consumption is five times less volatile than RER
  5. Forward-premium puzzle (Fama 1984)
     High interest rates predict nominal appreciations (UIP violations)

Motivation


GDP per capita (current US$) ?
$90,000
$80,000
$70,000
$60,000
$50,000
$40,000
$30,000
$20,000
$10,000
$0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Switzerland
Australia
United States
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010
Data from World Bank Last updated: Jan 12, 2016
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Motivation

GBP/USD (GBPUSD=X) 1.3304 -0.0047 (-0.3499%) As of 10:16 AM EDT. CCY Delayed Price. Market open.
Add Indicator
Compare
5y
Area
Settings
Reset
GBPUSD=X 1.3297
Open 1.3352
Close 1.3297
Low 1.3289
High 1.3371
Vol 0.00
% Chg -18.06%
1.7500
1.7000
1.6500
1.6000
1.5500
1.5000
1.4500
1.4000
1.3500
1.3297
1.3000
1.2500
Jan 2 '12
Jan 7 '13
Jan 6 '14
Jan 5 '15
Jan 4 '16

Our Approach

- The literature has tried to address one puzzle at a time, often at the expense of aggravating the other puzzles
- We provide a unifying theory of exchange rates, capturing simultaneously all stylized facts about their properties

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- The literature has tried to address one puzzle at a time, often at the expense of aggravating the other puzzles
- We provide a unifying theory of exchange rates, capturing simultaneously all stylized facts about their properties
- A theory of exchange rate (disconnect) must specify:
  1. The exogenous shock process driving the exchange rate
     — little empirical guidance here
     — we prove theoretically that only the financial shock is a likely candidate and then show its quantitative performance
  2. The transmission mechanism muting the response of the macro variables to exchange rate movements relies on:
     a) strategic complementarities in price setting resulting in PTM
     b) weak substitutability between home and foreign goods
     c) home bias in consumption
     d) monetary policy rule stabilizing domestic inflation
     — all admitting tight empirical discipline

     → nominal rigidities are not essential ▸ show

Contributions

- A dynamic general equilibrium model of exchange rate
  — fully analytically tractable, yet quantitative

- Four new mechanisms:
  1. Equilibrium exchange rate determination and dynamics
     (*cf*. Engel and West 2005)
  2. PPP puzzle and related puzzles
     (Rogoff '96, CKM '02, Kehoe and Midrigan '08, Monacelli '04)
  3. Backus-Smith puzzle
     (*cf*. Corsetti, Dedola and Leduc 2008)
  4. Forward premium puzzle
     (Engel 2016)

MODELING FRAMEWORK

Model setup

- Two countries: home (Europe) and foreign (US, denoted w/$*$)
- Nominal wages W_t in euros and W_t^* in dollars, the numeraires
- $\mathcal{E}_t$ is the nominal exchange rate (price of one dollar in euros)
- Baseline model:
  - representative households
  - representative firms
  - one internationally-traded foreign-bond
- We allow for all possible shocks/CKM-style wedges:

$$\boldsymbol{\Omega}_t = (w_t, \chi_t, \kappa_t, a_t, g_t, \mu_t, \eta_t, \xi_t, \psi_t)$$

and foreign counterparts

Equilibrium conditions

1. Households:
   (i) labor supply and asset demand ▸ show
   (ii) expenditure on home and foreign good ▸ show
      — γ expenditure share on foreign goods
      — θ elasticity of substitution between home and foreign goods
2. Firms:
   (i) production and profits ▸ show
   (ii) price setting ▸ show
      — α strategic complementarity elasticity in price setting
3. Government: balanced budget ▸ show
4. Foreign: symmetric ▸ show
5. GE: market clearing and country budget constraint ▸ show

DISCONNECT IN THE LIMIT

Disconnect in the Autarky Limit

- Consider an economy in **autarky** = complete ER disconnect
  - (i) NER is not determined and can take any value
  - (ii) this has no effect on domestic quantities, prices or interest rates
  - (iii) as price levels are determined independently from NER, RER moves one-to-one with NER

+ the further from autarky, the less likely the disconnect ▸ show

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- **Definition**: Exchange rate disconnect in the autarky limit

$$\lim_{\gamma\to 0}\frac{\mathrm{d}\mathbf{Z}_{t+j}}{\mathrm{d}\varepsilon_t}=\mathbf{0}\quad\forall j\qquad\text{and}\qquad\lim_{\gamma\to 0}\frac{\mathrm{d}\mathcal{E}_t}{\mathrm{d}\varepsilon_t}\neq 0.$$

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- **Proposition 1**: *The model cannot exhibit exchange rate disconnect in the limit with zero weight on:*
  - (i) *LOP deviation shocks:* η_t
  - (ii) *Foreign-good demand shocks:* ξ_t
  - (iii) *Financial (international asset demand) shocks:* ψ_t

- A pessimistic result for IRBC and NOEM models

Admissible Shocks

- Intuition: two international conditions
  - risk sharing: $\mathbb{E}_t \left\{ R^*_{t+1} \left[\Theta^*_{t+1} - \Theta_{t+1} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} e^{\psi_t} \right] \right\} = 0$
  - budget constraint: $B^*_{t+1} - R^*_t B^*_t = NX^*(\mathcal{Q}_t; \eta_t, \xi_t)$
- In the limit, shocks to these conditions have a vanishingly small effect, while other shocks still have a direct effect

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- In the limit, shocks to these conditions have a vanishingly small effect, while other shocks still have a direct effect
- **Proposition 2**: *In the autarky limit, ψ_t is the only shock that simultaneously and robustly produces:*
  - (i) *positively correlated ToT and RER (Obstfeld-Rogoff moment)*
  - (ii) *negatively correlated relative consumption growth and real exchange rate depreciations (Backus-Smith correlation)*
  - (iii) *deviations from the UIP (negative Fama coefficient).*

$\Rightarrow$ ψ_t is the prime candidate shock for a **quantitative** model of ER disconnect

BASELINE MODEL

OF EXCHANGE RATE DISCONNECT

Ingredients

1. Financial exchange rate shock ψ_t only:

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

— persistent ($\rho \lesssim 1$, e.g. $\rho = 0.97$) w/small innovations ($\sigma_\varepsilon \gtrsim 0$):

$$\psi_t = \rho \psi_{t-1} + \varepsilon_t, \qquad \beta\rho < 1$$

— important limiting case: $\beta\rho \to 1$

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2. Transmission mechanism
   (i) Strategic complementarities: $\alpha = 0.4$ (AIK 2015)
   (ii) Elasticity of substitution: $\theta = 1.5$ (FLOR 2014)
   (iii) Home bias: $\gamma = 0.07 = \frac{1}{2} \frac{\text{Imp+Exp}}{\text{GDP}} \frac{\text{GDP}}{\text{Prod-n}}$ (for US, EU, Japan)

- Monetary regime: $W_t \equiv 1$ and $W_t^* \equiv 1$
- Other parameters:

$$\beta = 0.99, \quad \sigma = 2, \quad \nu = 1, \quad \phi = 0.5, \quad \zeta = 1 - \phi$$

Microfoundations for ψ_t shock

Risk premium shock: $\psi_t = i_t - i_t^* - \mathbb{E}_t \Delta e_{t+1}$

1. International asset demand shocks (in the utility function)
   — e.g., Dekle, Jeong and Kiyotaki (2014)
2. Noise trader shocks and limits to arbitrage ▸ show
   — e.g., Jeanne and Rose (2002)
   - noise traders can be liquidity/safety traders
   - arbitrageurs with downward sloping demand
   - multiple equilibria $\longrightarrow$ Mussa puzzle
3. Heterogenous beliefs or expectation shocks
   — e.g., Bacchetta and van Wincoop (2006)
   - huge volumes of currency trades (also order flows)
   - ψ_t are disagreement or expectation shocks
4. Financial frictions (e.g., Gabaix and Maggiori 2015)
5. Risk premia models
   (rare disasters, long-run risk, habits, segmented markets)

Roadmap

1. Equilibrium exchange rate dynamics
2. Real and nominal exchange rates
3. Exchange rate and prices
4. Exchange rate and quantities
5. Exchange rate and interest rates

Exchange Rate Dynamics

1. International risk sharing (financial market):

$$\underbrace{i_t - i_t^*}_{\propto \gamma\psi_t} - \mathbb{E}_t \Delta e_{t+1} = \psi_t \quad \Rightarrow \quad \mathbb{E}_t \Delta e_{t+1} = -\frac{1}{1+\gamma\lambda_1}\psi_t$$

2. Flow budget constraint (goods market):

$$\beta b_{t+1}^* - b_t^* = nx_t, \qquad nx_t = \gamma\lambda_2 \cdot e_t$$

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- Solving forward risk sharing (*cf.* Engel and West 2005):

$$e_t = \underbrace{\lim_{T\to\infty} \mathbb{E}_t e_{t+T}}_{\equiv \mathbb{E}_t e_\infty} + \tfrac{1}{1+\gamma\lambda_1} \underbrace{\sum_{j=0}^{\infty} \mathbb{E}_t \psi_{t+j}}_{=\frac{1}{1-\rho}\psi_t}$$

- Intertemporal budget constraint:

$$b_t^* + \sum_{j=0}^{\infty} \beta^j \cdot \overbrace{\gamma\lambda_2 e_{t+j}}^{=nx_{t+j}} = 0$$

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$$\beta b_{t+1}^* - b_t^* = nx_t, \qquad nx_t = \gamma\lambda_2 \cdot e_t$$

Proposition

When $\psi_t \sim$AR(1), the equilibrium exchange rate follows ARIMA:

$$\Delta e_t = \rho \Delta e_{t-1} + \frac{1}{1+\gamma\lambda_1}\frac{\beta}{1-\beta\rho}\left(\varepsilon_t - \frac{1}{\beta}\varepsilon_{t-1}\right).$$

This process becomes arbitrary close to a random walk as $\beta\rho \to 1$.

— *This is the unique equilibrium solution, bubble solutions do not exist*

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When $\psi_t \sim$AR(1), the equilibrium exchange rate follows ARIMA:

$$(1-\rho L)\Delta e_t = \frac{1}{1+\gamma\lambda_1}\frac{\beta}{1-\beta\rho}\left(1 - \frac{1}{\beta}L\right)\varepsilon_t.$$

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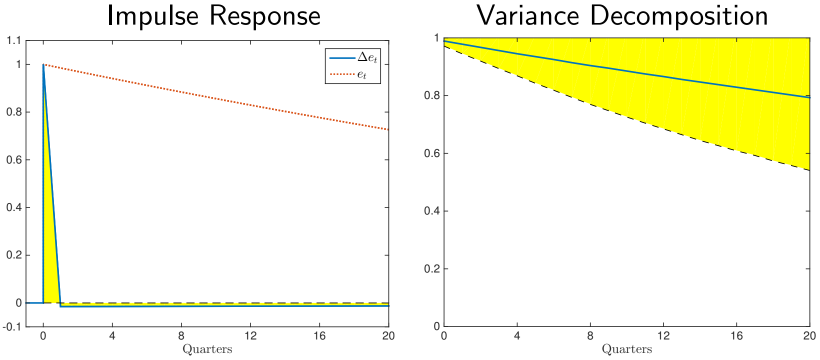
— *NFA $\Delta b_{t+1}^* \sim AR(1)$:* $\Delta b_{t+1}^* = \frac{\gamma\lambda_2}{1+\gamma\lambda_1}\frac{1}{1-\beta\rho}\psi_t$

Properties of the Exchange Rate

- Near-random-walk behavior (as $\beta\rho \to 1$):
  1. $\text{corr}(\Delta e_{t+1}, \Delta e_t) \to 0$
  2. $\frac{\text{var}(\Delta_k e_{t+k} - \mathbb{E}_t \Delta_k e_{t+k})}{\text{var}(\Delta_k e_{t+k})} \to 1$
  3. $\frac{\text{std}(\Delta e_t)}{\text{std}(\psi_t)} \to \infty$



PPP Puzzle

Proposition

RER and NER are tied together by the following relationship:

$$q_t = \frac{1}{1 + \frac{1}{1-\phi}\frac{2\gamma}{1-2\gamma}} e_t.$$

- $(q_t - e_t) \xrightarrow[\gamma \to 0]{} 0$
- Relative volatility: $\frac{\text{std}(\Delta q_t)}{\text{std}(\Delta e_t)} = \frac{1}{1+\frac{1}{1-\phi}\frac{2\gamma}{1-2\gamma}} = 0.75$
- Heterogenous firms and/or LCP sticky prices further increase volatility of RER

- Real exchange rate:

$$\mathcal{Q}_t = \frac{P_t^* \mathcal{E}_t}{P_t}$$

1. either P_t and P_t^* are very sticky (+ monetary shocks); or
2. or economies are very closed, $\gamma \approx 0$ (+ ψ_t shocks)

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1. either P_t and P_t^* are very sticky (+ monetary shocks); or
2. or economies are very closed, $\gamma \approx 0$ (+ ψ_t shocks)

- Intuition (failure of IRBC and NOEM models):

$$p_t = (w_t - a_t) + \tfrac{1}{1-\phi}\tfrac{\gamma}{1-2\gamma} q_t$$
$$p_t^* = (w_t^* - a_t^*) - \tfrac{1}{1-\phi}\tfrac{\gamma}{1-2\gamma} q_t$$

$$\Rightarrow \qquad \left[1 + \tfrac{1}{1-\phi}\tfrac{2\gamma}{1-2\gamma}\right] q_t = e_t + (w_t^* - a_t^*) - (w_t - a_t)$$

Exchange Rates and Prices

- Three closely related variables:

$$\mathcal{Q}_t = \frac{P_t^* \mathcal{E}_t}{P_t} \qquad \mathcal{Q}_t^P = \frac{P_{Ft}^* \mathcal{E}_t}{P_{Ht}} \qquad \mathcal{S}_t = \frac{P_{Ft}}{P_{Ht}^* \mathcal{E}_t}$$

- Two relationships:

$$q_t = (1-\gamma) q_t^P - \gamma s_t$$
$$s_t = q_t^P - 2\alpha q_t$$

- In the data: $q_t^P \approx q_t$, $\mathrm{std}(\Delta q_t) \gg \mathrm{std}(\Delta s_t)$, $\mathrm{corr}(\Delta s_t, \Delta q_t) > 0$

- **Proposition**:

$$q_t^P = \frac{1-2\alpha\gamma}{1-2\gamma} q_t \quad \text{and} \quad s_t = \frac{1-2\alpha(1-\gamma)}{1-2\gamma} q_t$$

  — conventional models with $\alpha = 0$ cannot do the trick

  — α needs to be positive, but not too large

Exchange Rates and Prices

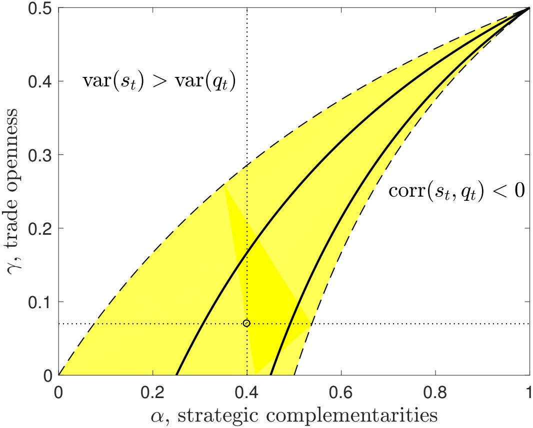

Figure: Terms of trade and Real exchange rate

Exchange Rate and Quantities

Backus-Smith puzzle

- "Dismiss" asset market (Backus-Smith) condition:

$$\sigma(c_t - c_t^*) = q_t \quad \text{vs.} \quad \mathbb{E}_t \Delta(c_{t+1} - c_{t+1}^* - q_{t+1}) = \psi_t$$

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  $\sigma(c_t - c_t^*) = q_t$ vs. $\mathbb{E}_t\Delta(c_{t+1} - c_{t+1}^* - q_{t+1}) = \psi_t$

- Static relationship between consumption and RER: ▸ show

  (i) labor market clearing: $\sigma\tilde{c}_t + \frac{1}{\nu}\tilde{y}_t = -\gamma q_t$

  (ii) goods market clearing: $\tilde{y}_t = (1-2\gamma)\tilde{c}_t + 2\theta(1-\alpha)\gamma q_t$

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- Proposition: Static expenditure switching implies: ▸ show BKK

  $$c_t - c_t^* = -\frac{2\boldsymbol{\theta}(\mathbf{1}-\boldsymbol{\alpha})(1-\gamma)+\nu}{(1-2\gamma)+\sigma\nu}\frac{2\boldsymbol{\gamma}}{1-2\gamma} q_t$$

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$$c_t - c_t^* = -\frac{2\boldsymbol{\theta(1-\alpha)}(1-\gamma)+\nu}{(1-2\gamma)+\sigma\nu}\,\frac{2\boldsymbol{\gamma}}{1-2\gamma} q_t + \kappa(a_t - a_t^*)$$

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$$\mathrm{cov}(\Delta c_t - \Delta c_t^*, \Delta q_t) = -\frac{2\boldsymbol{\theta(1-\alpha)}(1-\gamma)+\nu}{(1-2\gamma)+\sigma\nu}\frac{2\boldsymbol{\gamma}}{1-2\gamma}\mathrm{var}(\Delta q_t) + \kappa\,\mathrm{cov}(\Delta a_t - \Delta a_t^*, \Delta q_t)$$

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- Three alternatives in the literature to get BS puzzle:
  1. Super-persistent (news-like) shocks (CC 2013)
  2. Low elasticity of substitution $\theta < 1$ (CDL 2008)
  3. Non-tradable productivity shocks (BT 2008)

Exchange Rate and Quantities

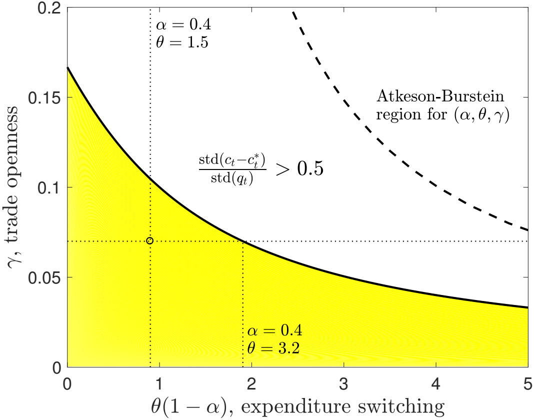


Figure: Exchange rate disconnect: relative consumption volatility

Exchange Rate and Interest rates

- Two equilibrium conditions:

$$\psi_t = (i_t - i_t^*) - \mathbb{E}_t \Delta e_{t+1} \quad \text{and} \quad i_t - i_t^* = -\gamma\lambda_1 \mathbb{E}_t \Delta e_{t+1}$$

Proposition

Fama-regression coefficient:

$$\mathbb{E}\{\Delta e_{t+1} | i_{t+1} - i_{t+1}^*\} = \beta_F (i_{t+1} - i_{t+1}^*), \qquad \beta_F \equiv -\frac{1}{\gamma\lambda_1} < 0.$$

In the limit $\beta\rho \to 1$:

(i) *Fama-regression $R^2 \to 0$*

(ii) $\mathrm{var}(i_t - i_t^*)/\mathrm{var}(\Delta e_{t+1}) \to 0$

(iii) $\rho(\Delta e_t) \to 0$, *while* $\rho(i_t - i_t^*) \to 1$

(iv) *the Sharpe ratio of the carry trade: $SR_C \to 0$*

* *carry trade return: $r_{t+1}^C = x_t \cdot (i_t - i_i^* - \Delta e_{t+1})$ with $x_t = i_t - i_i^* - \mathbb{E}_t \Delta e_{t+1}$*

EXTENSIONS

Extensions

1. Monetary model with nominal rigidities and a Taylor rule
   - different transmission mechanism
   - similar quantitative conclusions for ψ_t shock
   - Mussa puzzle

2. Multiple shocks:
   - productivity, monetary, foreign good and asset demand
   - variance decomposition: contribution of $\psi_t \approx 70\%$
   - international business cycle (BKK) moments

3. Financial model with noise traders and limits to arbitrage (De Long et al 1990, Jeanne and Rose 2002)
   - A model of upward slopping supply in asset markets with endogenous equilibrium volatility of ψ_t and Δe_{t+1}
   - Stationary model with similar small sample properties
   - Additional moments: the Engel (2016) "risk premium" puzzle

4. Robustness to parameters ▸ show

Monetary model

- Standard New Keynesian Open Economy model
- Baseline: sticky wages and LCP sticky prices
- Taylor rule: $i_t = \rho_i i_{t-1} + (1 - \rho_i)\delta_\pi \pi_t + \varepsilon_t^m$
- New transmission: i_t does not respond directly to the ψ_t shock, but instead through inflation it generates
- Results:
  1. monetary shock alone results in numerous ER puzzles
  2. financial shock ψ_t has quantitative similar properties, with two exceptions:
     + makes RER more volatile and NER closer to a random walk
     − RER is negatively correlated with ToT (see Gopinath et al)

Model comparison

		A: Single-shock models				B: Multi-shock models		
Moment	Data	Fin. shock ψ		NOEM	IRBC	NOEM	IRBC	Financial
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\rho(\Delta e)$	0.00	−0.02 (0.09)	−0.03 (0.09)	−0.05 (0.09)	0.00 (0.09)	−0.03 (0.09)	−0.02 (0.09)	−0.01 (0.09)
$\rho(q)$	0.95	0.93 (0.04)	0.91 (0.05)	0.84 (0.05)	0.93 (0.04)	0.93 (0.04)	0.93 (0.04)	0.93 (0.04)
$\sigma(\Delta q)/\sigma(\Delta e)$	0.99	0.79	0.97	0.97	1.64	0.98	0.94	0.76
$\mathrm{corr}(\Delta q, \Delta e)$	0.98	1	1	0.99	0.99	1.00	0.97	0.94
$\sigma(\Delta c - \Delta c^*)/\sigma(\Delta q)$	0.20	0.31	0.12	0.52	0.64	0.20	0.30	0.31
$\mathrm{corr}(\Delta c - \Delta c^*, \Delta q)$	−0.20	−1	−0.95	1	1	−0.20 (0.09)	−0.20 (0.09)	−0.22 (0.09)
$\sigma(\Delta nx)/\sigma(\Delta q)$	0.10	0.26	0.17	0.08	0.14	0.32	0.30	0.10
$\mathrm{corr}(\Delta nx, \Delta q)$	≈ 0	1	0.99	1	1	−0.00 (0.09)	−0.00 (0.09)	−0.02 (0.09)
$\sigma(\Delta s)/\sigma(\Delta e)$	0.35	0.23	0.80	0.82	0.49	0.80	0.28	0.23
$\mathrm{corr}(\Delta s, \Delta e)$	0.60	1	−0.93	−0.96	0.99	−0.93	0.97	0.94
Fama β	$\lesssim 0$	−2.4 (1.7)	−3.4 (2.6)	1.2 (0.7)	1.4 (0.5)	−0.6 (1.4)	−0.7 (1.3)	−2.8 (3.5)
Fama R^2	0.02	0.03 (0.02)	0.03 (0.02)	0.03 (0.03)	0.09 (0.02)	0.00 (0.01)	0.00 (0.01)	0.01 (0.02)
$\sigma(i - i^*)/\sigma(\Delta e)$	0.06	0.07 (0.02)	0.05 (0.02)	0.14 (0.02)	0.21 (0.06)	0.06 (0.02)	0.08 (0.02)	0.03 (0.01)
$\rho(i - i^*)$	0.90	0.93 (0.04)	0.98 (0.01)	0.84 (0.05)	0.93 (0.04)	0.91 (0.04)	0.93 (0.04)	0.90 (0.04)
Carry *SR*	0.20	0.21 (0.04)	0.20 (0.04)	0	0	0.17 (0.06)	0.19 (0.06)	0.12 (0.07)

Variance decomposition

		NOEM		IRBC	
Shocks		$\mathrm{var}(\Delta e_t)$	$\mathrm{var}(\Delta q_t)$	$\mathrm{var}(\Delta e_t)$	$\mathrm{var}(\Delta q_t)$
Monetary (Taylor rule)	ε_t^m	10%	10%	—	—
Productivity	a_t	—	—	3%	9%
Foreign-good demand	ξ_t	19%	20%	23%	39%
Financial	ψ_t	71%	70%	74%	52%

Mussa puzzle

Moment	Data	Model (1)	Model (2)
$\mathrm{std}(\Delta e_t)$	0.13	0.13	0.13
$\mathrm{std}(\Delta q_t)$	0.26	0.18	0.16
$\mathrm{corr}(\Delta q_t, \Delta e_t)$	0.66	0.79	0.84
$\mathrm{std}(\Delta c_t - \Delta c_t^*)$	≈ 1	2.63	1.33
$\mathrm{corr}(\Delta c_t - \Delta c_t^*, \Delta q_t)$	>0	-0.63	0.13
Fama β	>0	-0.1	1.1

International RBC (BKK) calibration

back

	Data	BKK with (a_t, a_t^*) only: Original	BKK with (a_t, a_t^*) only: Replication	Model with ψ_t: Multi-shock	Model with ψ_t: ψ_t only
Panel A: Exchange rate disconnect moments					
$\rho(\triangle e)$	0.00		−0.04 (0.09)	−0.02 (0.09)	−0.01 (0.09)
$\rho(q)$	0.95		0.97 (0.02)	0.93 (0.04)	0.93 (0.04)
$\text{corr}(\triangle e, \triangle q)$	0.98		**−0.96** (0.02)	0.99 (0.00)	1
$\sigma(\triangle c - \triangle c^*)/\sigma(\triangle q)$	0.20		**0.81** (0.01)	0.23 (0.02)	0.37
$\text{corr}(\triangle c - \triangle c^*, \triangle q)$	−0.20		**1.00** (0.00)	−0.20 (0.09)	−1
$\text{corr}(\triangle nx, \triangle q)$	≈ 0		**−0.80** (0.08)	0.03 (0.09)	1
Fama β	$\lesssim 0$		1.3 (0.6)	1.5 (3.2)	−7.7 (4.4)
Fama R^2	0.02		0.04 (0.02)	0.00 (0.01)	0.04 (0.02)
Panel B: International busyness cycle moments					
$\sigma(\triangle c)/\sigma(\triangle gdp)$	0.49	0.47	0.35 (0.01)	0.53 (0.03)	2.60
$\sigma(\triangle z)/\sigma(\triangle gdp)$	3.15	3.48	3.78 (0.03)	3.15 (0.16)	3.15
$\text{corr}(\triangle c, \triangle gdp)$	0.76	0.88	0.99 (0.00)	0.72 (0.05)	−1
$\text{corr}(\triangle z, \triangle gdp)$	0.90	0.93	0.99 (0.00)	0.83 (0.03)	−1
$\text{corr}(\triangle nx, \triangle gdp)$	−0.22	−0.64	−0.52 (0.07)	**0.26** (0.09)	1
$\text{corr}(\triangle gdp, \triangle gdp^*)$	0.70	0.02	0.31 (0.08)	0.70 (0.05)	−1
$\text{corr}(\triangle c, \triangle c^*)$	0.46	0.77	0.37 (0.08)	0.51 (0.07)	−1
$\text{corr}(\triangle z, \triangle z^*)$	0.33		0.18 (0.09)	0.55 (0.06)	−1

International RBC (BKK) calibration ◂ back

	Data	BKK with (a_t, a_t^*) only		Model with ψ_t	
		Original	Replication	Multi-shock	ψ_t only
Panel C: Variance decomposition					
Nominal exchange rate, $\mathrm{var}(\Delta e)$:					
Productivity shocks, (a_t, a_t^*)			100%	1%	—
Foreign-good demand shocks, $\tilde{\xi}_t$			—	40%	—
Financial shock, ψ_t			—	59%	100%
Consumption, $\mathrm{var}(\Delta c)$:					
Productivity shocks, (a_t, a_t^*)			100%	77%	—
Foreign-good demand shocks, $\tilde{\xi}_t$			—	7%	—
Financial shock, ψ_t			—	16%	100%

Financial model

- Symmetric countries with international bond holding intermediated by a financial sector
- Three type of agents: $B^*_{t+1} + N^*_{t+1} + D^*_{t+1} = 0$
- Noise traders: $N^*_{t+1} = n\left(e^{\psi_t} - 1\right)$
- Arbitrageurs: $\max_d \left\{ d\,\mathbb{E}_t \tilde{R}_{t+1} - \frac{\omega}{2}\mathrm{var}_t(\tilde{R}_{t+1})d^2 \right\}$, $\tilde{R}^*_{t+1} \equiv R^*_t - R_t \frac{\mathcal{E}_t}{\mathcal{E}_{t+1}}$ results in bond supply:

$$D^*_{t+1} = m \frac{\mathbb{E}_t \tilde{R}_{t+1}}{\omega\ \mathrm{var}_t(\tilde{R}_{t+1})}$$

- Generalized UIP condition:

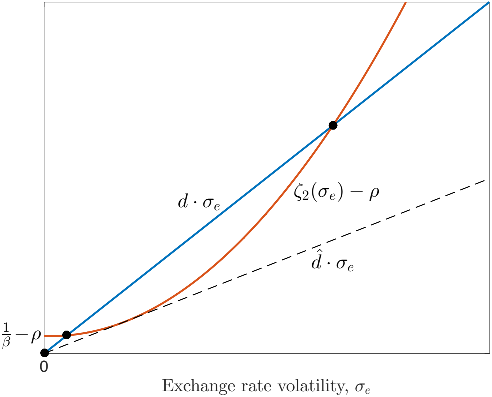
$$i_t - i^*_t - \mathbb{E}_t \Delta e_{t+1} = \chi_1 \psi_t - \chi_2 b_{t+1}, \quad \chi_1 \equiv \frac{n/\beta}{m/(\omega\sigma_e^2)}, \quad \chi_2 \equiv \frac{\bar{Y}}{m/(\omega\sigma_e^2)}$$

- Proposition: *e_t and q_t follow an ARMA(2,1), but with the same near-random-walk properties.*

back to Microfoundations

Financial model

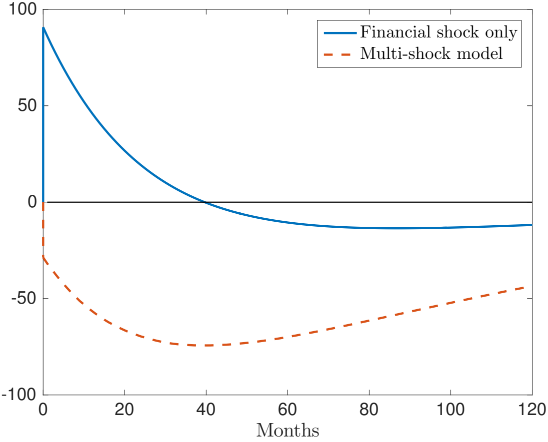
Equilibrium exchange rate volatility



- Three equilibria exist when $d = \frac{1}{\beta(1+\gamma\lambda_1)} \frac{n\omega\sigma_\varepsilon}{m} > \hat{d}$
- When $d < \hat{d}$, the only equilibrium is $\sigma_e = 0$

Engel (2016) “risk premium” puzzle

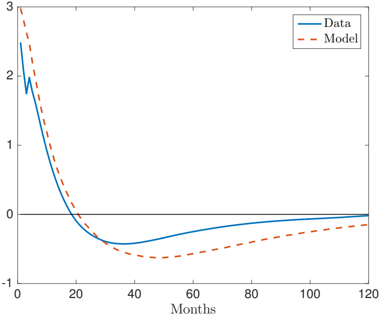
Figure: Response of e_{t+j} to innovation in $i_t - i_t^*$



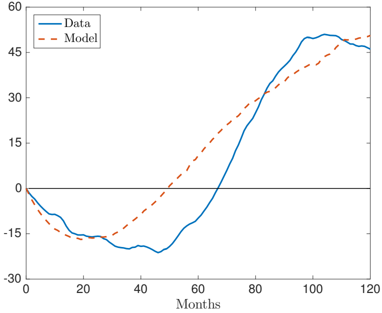
Engel (2016) "risk premium" puzzle

Figure: Projections on $i_t - i_t^*$

(a) Risk premium, $\mathbb{E}_t \rho_{t+j}$



(b) Echange rate, $e_{t+j} - e_t$



where $\rho_t = i_t - i_t^* - \Delta e_{t+1}$

Conclusion

- Exchange rates have been very puzzling for macroeconomists
- We offer a unifying quantitative GE theory of exchange rates
- Which international macro results are robust?
  - Monetary policy transmission and spillovers: likely yes
  - Welfare analysis and optimal exchange rate regimes: likely no
- Our tractable macro GE environment can be useful for both:
  1. empirical/quantitative studies of ER and transmission
  2. financial models of exchange rates

APPENDIX

Puzzle Resolution Mechanism

back to slides

Puzzle		Ingredients	
Meese-Rogoff, UIP	$\longrightarrow \{$	• persistent financial shock • conventional Taylor rule	ψ_t
PPP	$+$	• home bias	γ
Terms-of-trade	$+$	• strategic complementarities	α
Backus-Smith	$+$	• weak substitutability	θ

Puzzle Resolution Mechanism

back to slides

Puzzle		Ingredients	
Meese-Rogoff, UIP	$\longrightarrow$ {	• persistent financial shock • conventional Taylor rule	ψ_t
PPP	+	• home bias	γ
Terms-of-trade	+	• strategic complementarities	α
Backus-Smith	+	• weak substitutability	θ

- Parameter restrictions:
  1. Marshall-Lerner condition: $\theta > 1/2$
  2. Nominal UIP: $\theta > \mathit{IES}$

New Mechanisms

1. Exchange rate dynamics:
   - ⟶ near random-walk behavior emerging from the intertemporal budget constraint under incomplete markets
   - ⟶ small but persistent expected appreciations require a large unexpected devaluation on impact
2. PPP puzzle
   - ⟶ no wedge between nominal and real exchange rates, unlike IRBC and NOEM models
3. Violation of the Backus-Smith condition:
   - ⟶ we demote the dynamic risk-sharing condition from determining consumption allocation
   - ⟶ instead static market clearing determination of consumption
4. Violation of UIP and Forward premium puzzle:
   - ⟶ small persistent interest rate movements support consumption allocation, disconnected from volatile exchange rate
   - ⟶ negative Fama coefficient, yet small Sharpe ratio on carry trade

Households

back to slides

- Representative home household solves:

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

$$\text{s.t.} \quad P_t C_t + \frac{B_{t+1}}{R_t} + \frac{B_{t+1}^* \mathcal{E}_t}{e^{\psi_t} R_t^*} \leq B_t + B_t^* \mathcal{E}_t + W_t L_t + \Pi_t + T_t$$

- Household optimality (labor supply and demand for bonds):

$$e^{\kappa_t} C_t^{\sigma} L_t^{1/\nu} = \frac{W_t}{P_t},$$

$$R_t \mathbb{E}_t \{\Theta_{t+1}\} = 1,$$

$$e^{\psi_t} R_t^* \mathbb{E}_t \left\{ \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} \Theta_{t+1} \right\} = 1,$$

where the home nominal SDF is given by:

$$\Theta_{t+1} \equiv \beta e^{\Delta \chi_{t+1}} \left(\frac{C_{t+1}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+1}}$$

Demand

◂ back to slides

- Consumption expenditure on home and foreign goods:

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

arises from a homothetic consumption aggregator:

$$C_{Ht} = (1-\gamma) e^{-\gamma \xi_t} h\left(\frac{P_{Ht}}{P_t}\right) C_t,$$

$$C_{Ft} = \gamma e^{(1-\gamma)\xi_t} h\left(\frac{P_{Ft}}{P_t}\right) C_t$$

- The foreign share and the elasticity of substitution:

$$\gamma_t \equiv \left. \frac{P_{Ft} C_{Ft}}{P_t C_t} \right|_{\substack{P_{Ht}=P_{Ft}=P_t \\ \xi_t=0}} = \gamma$$

$$\theta_t \equiv - \left. \frac{\partial \log h(x_t)}{\partial \log x_t} \right|_{x_t=1} = \theta$$

Production and profits

◂ back to slides

- Production function with intermediates:

$$Y_t = e^{a_t} L_t^{1-\phi} X_t^{\phi}$$

$$MC_t = e^{-a_t} \left(\frac{W_t}{1-\phi}\right)^{1-\phi} \left(\frac{P_t}{\phi}\right)^{\phi}$$

- Profits:

$$\Pi_t = (P_{Ht} - MC_t) Y_{Ht} + (P^*_{Ht} \mathcal{E}_t - MC_t) Y^*_{Ht},$$

where $\quad Y_t = Y_{Ht} + Y^*_{Ht}$

- Labor and intermediate goods demand:

$$W_t L_t = (1-\phi) MC_t Y_t$$

$$P_t X_t = \phi MC_t Y_t$$

and fraction γ_t of $P_t X_t$ is allocated to foreign intermediates

Prices

back to slides

- We postulate the following price setting rule:

$$P_{Ht} = e^{\mu_t} MC_t^{1-\alpha} P_t^{\alpha}$$

$$P_{Ht}^* = e^{\mu_t + \eta_t} \left(MC_t / \mathcal{E}_t\right)^{1-\alpha} P_t^{*\alpha}$$

- LOP violations:

$$\mathcal{Q}_{Ht} \equiv \frac{P_{Ht}^* \mathcal{E}_t}{P_{Ht}} = e^{\eta_t} \mathcal{Q}_t^{\alpha}$$

where the real exchange rate is given by:

$$\mathcal{Q}_t \equiv \frac{P_t^* \mathcal{E}_t}{P_t}$$

Government

◂ back to slides

- Government runs a balanced budget, using lump-sum taxes to finance expenditure:

$$P_t G_t = P_t e^{g_t},$$

where fraction γ_t of $P_t G_t$ is allocated to foreign goods

- The transfers to the households are given by:

$$T_t = \left(e^{-\psi_t} - 1\right) \frac{B^*_{t+1} \mathcal{E}_t}{R^*_t} - P_t e^{g_t}$$

Foreign

◂ back to slides

- Foreign households and firms are symmetric, subject to:

$$\{\chi_t^*, \kappa_t^*, \xi_t^*, a_t^*, \mu_t^*, \eta_t^*, g_t^*\}$$

- Foreign households only differ in that they do not have access to the home bond, which is not internationally traded.

  As a result, their only Euler equation is for foreign bonds:

$$R_t^* \mathbb{E}_t \left\{\Theta_{t+1}^*\right\} = 1, \qquad \Theta_{t+1}^* \equiv \beta e^{\Delta \chi_{t+1}^*} \left(\frac{C_{t+1}^*}{C_t^*}\right)^{-\sigma} \frac{P_t^*}{P_{t+1}^*}$$

Equilibrium

back to slides

1. Labor market clearing

2. Goods market clearing, e.g.:

$$Y^*_{Ht} = \gamma e^{(1-\gamma)\xi^*_t} h\Big(\frac{P^*_{Ht}}{P^*_t}\Big)[C^*_t + X^*_t + G^*_t]$$

3. Bond market clearing:

$$B_t = 0 \quad \text{and} \quad B^*_t + B^{*F}_t = 0$$

4. Country budget constraint:

$$\frac{B^*_{t+1}\mathcal{E}_t}{R^*_t} - B^*_t\mathcal{E}_t = NX_t, \quad NX_t = P^*_{Ht}\mathcal{E}_t Y^*_{Ht} - P_{Ft}Y_{Ft},$$

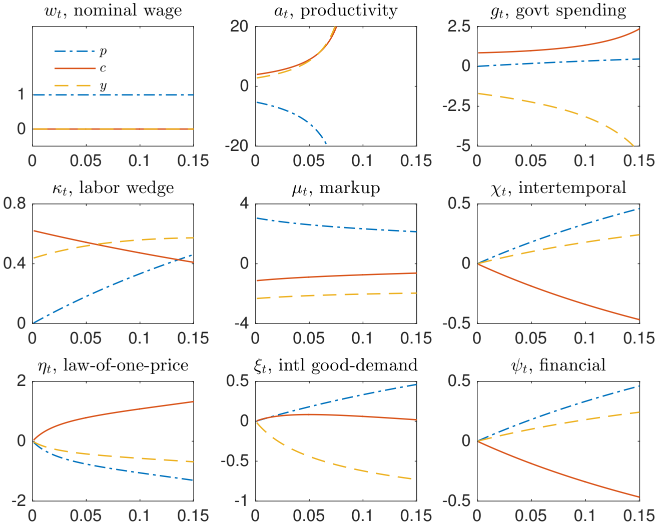
and we define the terms of trade:

$$\mathcal{S}_t \equiv \frac{P_{Ft}}{P^*_{Ht}\mathcal{E}_t}$$

Impulse responses

back

The figure plots $\frac{\partial z_t / \partial \varepsilon_t}{\partial e_t / \partial \varepsilon_t}$ for different values of γ, where $z \in \{p, c, y\}$ are different macro variables and $\varepsilon \in \Omega$ are different shocks



Properties of the Exchange Rate

back to slides

- Near-random-walk behavior (as $\beta\rho \to 1$)

$\operatorname{corr}(\Delta e_{t+1}, \Delta e_t) \to 0$ $\quad$ $\frac{\operatorname{var}(\Delta_k e_{t+k} - \mathbb{E}_t \Delta_k e_{t+k})}{\operatorname{var}(\Delta_k e_{t+k})} \to 1$ $\quad$ $\frac{\operatorname{std}(\Delta e_t)}{\operatorname{std}(\psi_t)} \to \infty$

$\rho = 0.96$ and $\beta = 0.99$ $\qquad$ $\rho = 0.99$ and $\beta = 0.995$

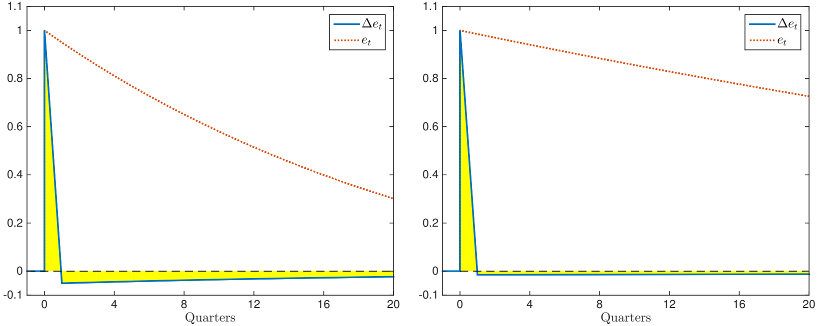


Figure: Impulse response of the exchange rate Δe_t to ψ_t

Properties of the Exchange Rate

back to slides

- Near-random-walk behavior (as $\beta\rho \to 1$)

$\mathrm{corr}(\Delta e_{t+1}, \Delta e_t) \to 0$ $\quad \frac{\mathrm{var}(\Delta_k e_{t+k} - \mathbb{E}_t \Delta_k e_{t+k})}{\mathrm{var}(\Delta_k e_{t+k})} \to 1$ $\quad \frac{\mathrm{std}(\Delta e_t)}{\mathrm{std}(\psi_t)} \to \infty$

$\rho = 0.96$ and $\beta = 0.99$ $\qquad$ $\rho = 0.99$ and $\beta = 0.995$

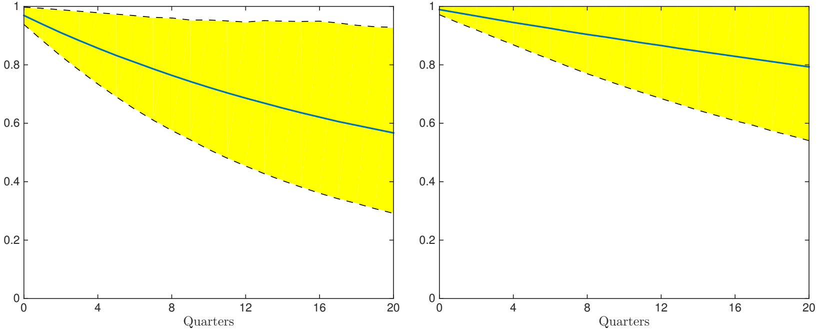


Figure: Contribution of the unexpected component (in small sample)

RER Persistence

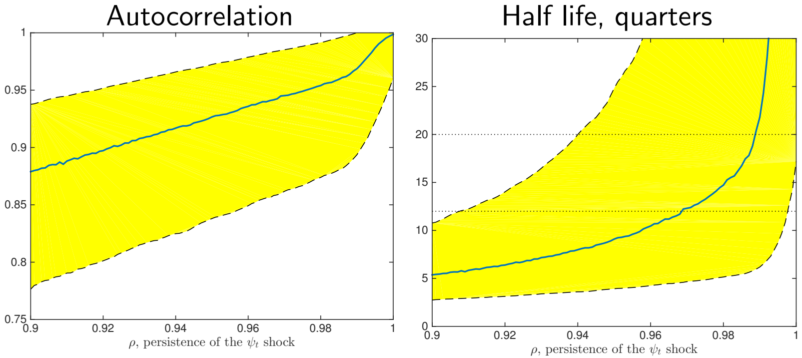
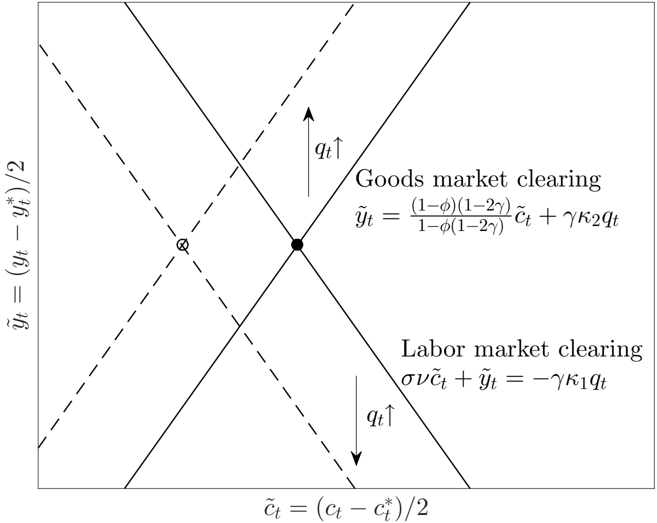


Figure: Persistence of the real exchange rate q_t in small samples

Backus-Smith illustration

back to slides



Exchange Rate and Quantities

back to slides

- Labor Supply:

$$\sigma \tilde{c}_t + \frac{1}{\nu}\tilde{\ell}_t = -\frac{1}{1-\phi}\frac{\gamma}{1-2\gamma}q_t$$

  — recall that: $p_t = w_t + \frac{1}{1-\phi}\frac{\gamma}{1-2\gamma}q_t$

- Labor Demand:

$$\tilde{\ell}_t = \tilde{y}_t + \frac{\phi}{1-\phi}\frac{\gamma}{1-2\gamma}q_t.$$

- Goods market clearing:

$$\tilde{y}_t = \frac{\zeta}{\zeta + \frac{2\gamma}{1-2\gamma}}\tilde{c}_t + \frac{2\theta(1-\alpha)\frac{1-\gamma}{1-2\gamma} - (1-\zeta)}{\zeta + \frac{2\gamma}{1-2\gamma}}\frac{\gamma}{1-2\gamma}q_t$$

Exchange Rate and Interest Rate

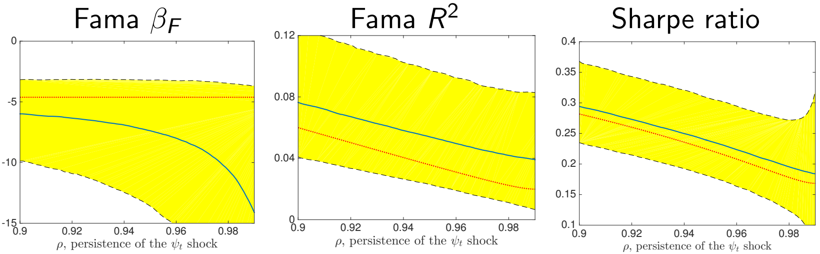


Figure: Deviations from UIP (in small samples)

ER Disconnect: Robustness

back to slides

		Data	Baseline	Robustness				
				$\theta = 2.5$	$\alpha = 0$	$\gamma = .15$	$\rho = 0.9$	$\sigma = 1$
1.	$\rho(\Delta e)$	0.00	-0.02 (0.09)				-0.05	
2.	$\rho(q)$	0.94	$0.93^{\star}$ (0.04)				0.87	
	$HL(q)$	12.0	$9.9^{\star}$ (6.4)				4.9	
	$\sigma(\Delta q)/\sigma(\Delta e)$	0.98	0.75			0.54		
3.	$\sigma(\Delta s)/\sigma(\Delta q)$	0.34	0.30		1.16	0.46		
	$\sigma(\Delta q^P)/\sigma(\Delta q)$	0.98	1.10		1.16	1.26		
4.	$\sigma(\Delta c - \Delta c^*)/\sigma(\Delta q)$	-0.25	-0.31	-0.42	-0.42	-0.81		-0.48
5.	Fama β_F	$\lesssim 0$	$-8.1^{\star}$ (4.7)					
	Fama R^2	0.02	0.04 (0.02)				0.07	
	$\sigma(i - i^*)/\sigma(\Delta e)$	0.06	0.03 (0.01)					
	Carry *SR*	0.20	0.21 (0.04)				0.29	

Note: Baseline parameters: $\gamma = 0.07$, $\alpha = 0.4$, $\theta = 1.5$, $\rho = 0.97$, $\sigma = 2$, $\nu = 1$, $\phi = 0.5$, $\mu = 0$, $\beta = 0.99$. Results are robust to changing ν, ϕ, μ and β. *Asymptotic values: $\rho(q) = 1$, $HL(q) = \infty$, $\beta_F = -4.6$.

Mechanism

1. An international asset demand shock $\varepsilon_t > 0$ results in an immediate sharp ER depreciation to balance the asset market
2. Exchange rate then gradually appreciates (as the ψ_t shock wears out) to ensure the intertemporal budget constraint
3. Nominal and real devaluations happen together, and the real wage declines
4. Devaluation is associated with a dampened deterioration of the terms of trade and the resulting expenditure switching towards home goods
5. Consumption falls to ensure equilibrium in labor and goods markets
6. Consumption fall is supported by an increase in the interest rate, which balances out the fall in demand for domestic assets