Macroeconomics of Exchange Rates

Lecture 1

Exchange Rates and International Relative Prices

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Spring 2021

Introduction

- Real exchange rate (RER) measures relative price levels across countries
  - or deviations from purchasing power parity (PPP)
- Why are we interested in RER, in particular, in its dynamics?
  - an artificial construct, not an actual relative price in any market
  - yet, it is a crucial diagnostic variable for our models — in both goods and assets
- RER is also one of the most starkly-behaved variables:
  - co-moves tightly with the nominal exchange rate
  - and is virtually uncorrelated with most other macroeconomic fundamentals, real or nominal
- This offers sharp testable implications for models, which has resulted in a number of puzzles: PPP, Backus-Smith, Mussa
- RER is also inherently a general-equilibrium object

DEFINITIONS AND FACTS

Nominal Exchange Rate (NER)

- Nominal ER is the relative price of currencies
  - $\mathcal{E}_t =$ units of home currency for one unit of foreign currency
  - $\mathcal{E}_t \uparrow (\downarrow)$ is home depreciation (appreciation)
  - $e_t \equiv \log \mathcal{E}_t$ is the log of NER
  - $\Delta e_t \equiv e_t - e_{t-1}$ is nominal depreciation in log points
  - bilateral vs (trade) weighted exchange rates

- Under floating, e_t follows a process close to a *random walk*
  - ER depreciations are nearly unpredictable, $\mathbb{E}_t \Delta e_{t+1} \approx 0$, and the current level offers the best forecast, $\mathbb{E}_t e_{t+h} \approx e_t$ for $h > 0$
    - — a number of departures from pure random walk
  - ER changes Δe_t exhibit *no* robust contemporaneous correlation with macro aggregates (Meese and Rogoff puzzle)

- Macroeconomists view ER as "excessively" volatile, while finance economists — as "insufficiently" volatile
  - an order of magnitude more volatile than macro aggregates
  - two thirds as volatile as the stock market

Real Exchange Rate

- Real ER is the relative price of consumption baskets

$$\mathcal{Q}_t \equiv \frac{\mathcal{E}_t P_t^*}{P_t}, \qquad \text{or in logs} \quad q_t \equiv e_t + p_t^* - p_t$$

  - P_t and P_t^* are consumer price levels at home and abroad
  - $\mathcal{Q}_t \uparrow$ is *real depreciation*, a decline in the *relative* purchasing power of one unit of currency abroad
  - consumer vs producer vs cost-based RER

- We focus on the dynamics of RER:

$$\Delta q_t = \Delta e_t + \pi_t^* - \pi_t,$$

  - $\pi_t = \log P_t - \log P_{t-1}$ is home CPI inflation
  - monetarist view: $\Delta e_t \sim \pi_t - \pi_t^*$, and thus q_t stationary

Main empirical facts about RER

(unconditional moments)

1. RER is nearly indistinguishable from NER at most horizons, that is follows a volatile near-random-walk process
   — very long half-lives (PPP Puzzle), no mean reversion?

2. all RERs (CPI, PPI, wage-based, tradable) comove closely, with similar volatility and persistence

3. RER is almost an order of magnitude more volatile than macro aggregates, includion inflation, consumption and output
   — weakly negatively correlated w/consumption (BS puzzle)
   — o/w, like NER, nearly uncorrelated with macro fundamentals

4. RER comoves closely with NER not only under a float, but changes its properties with a switch to peg (Mussa puzzle)

Terms of Trade

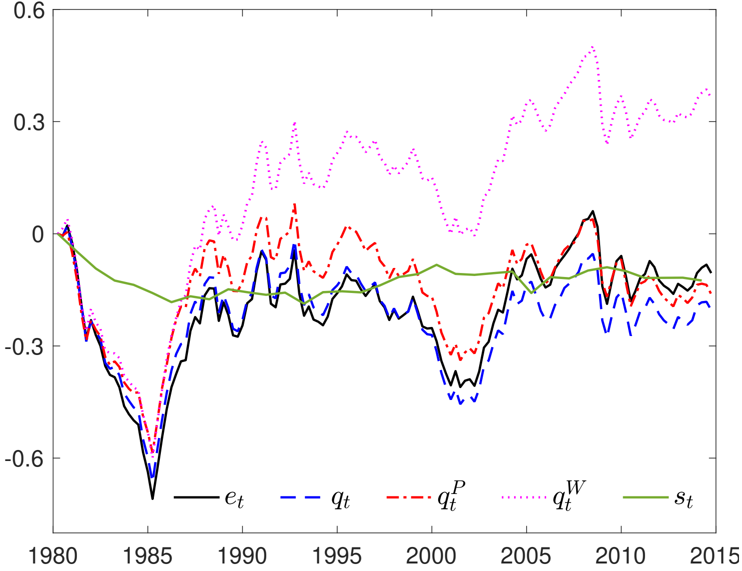
- ToT measure the relative price of imports and exports:

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

  - P_{Ft} (P^*_{Ht}) is home (foreign) import price index in local currency
  - $\mathcal{S}_t$ is the relative price of imports in units of exports
  - $\mathcal{S}_t \uparrow$ is ToT *deterioration* (more exports for one unit of imports)

- ToT and RER (in particular, ToT deterioration and real depreciation) are often confused
  - in many models the two variables are closely linked
  - this is not, however, the case in the data: RER depreciations are not always accompanied by significant ToT deteriorations
  - ToT is about 2-3 times less volatile than RER and the two are only weakly positively correlated
  - ToT is an actual relative price, while RER is not quite

Empirical illustrations



Empirical illustrations

Rogoff: The Purchasing Power Parity Puzzle 655

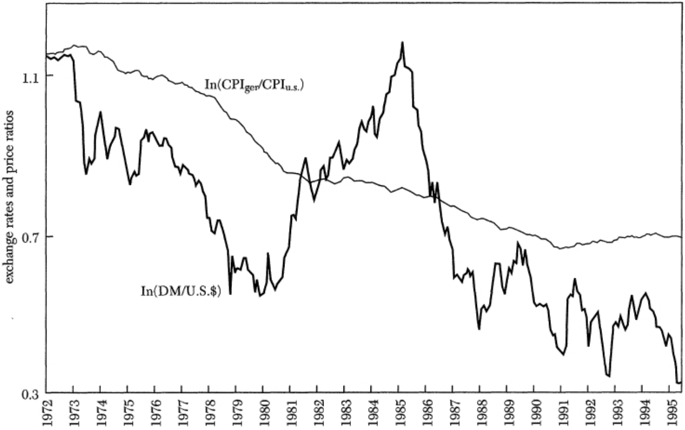


Figure 2. DM/U.S.$ exchange rate and ratio of German to U.S. CPIs, Jan. 1972–May 1995

Source: International Financial Statistics

Empirical illustrations

536 REVIEW OF ECONOMIC STUDIES

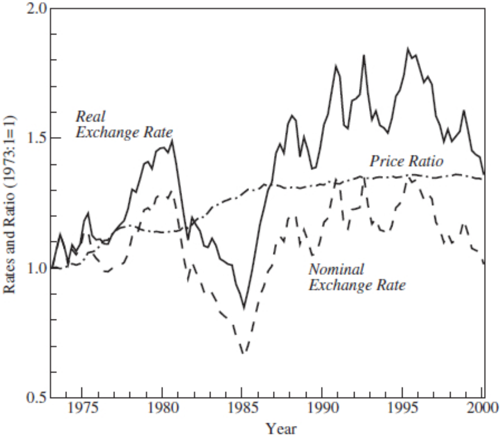


FIGURE 1

Exchange rates and the price ratio between the U.S. and Europe.

Note: the real exchange rate is eP^*/P, where the nominal exchange rate e is the U.S. dollar price of a basket of European currencies, P^* is an aggregate of European CPIs, and P is the U.S. CPI. The price ratio is P^*/P

RER AND INTERNATIONAL RELATIVE PRICES

PPP HYPOTHESIS

PPP Hypothesis

- PPP hypothesis: prices of consumption baskets equalized in space; one dollar buys the same quantity of goods everywhere

- Three forms of the PPP hypothesis

  1. *Absolute PPP*: equality of the price levels, $P_t = P_t^* \mathcal{E}_t$, which implies $\mathcal{Q}_t \equiv 1$, or in logs $q_t \equiv 0$.

     — in general, RER equals PPP deviations

  2. *Relative PPP*: nominal depreciation equals relative inflation, $\Delta e_t = \pi_t - \pi_t^*$, that is RER is constant over time, $\Delta q_t \equiv 0$.

  3. *Weak relative PPP*: mean reversion in relative price levels, or equivalently (mean) stationarity of q_t

     - $\Delta e_t = \pi_t - \pi_t^*$ holds over long time intervals

Relative PPP

- Express inflation rate as: $\pi_t = \Delta p_t = \sum_{i \in \Omega_t} \omega_{it} \Delta p_{it}$
- Then real exchange rate can be written as:

$$\Delta q_t = \Delta e_t + \sum_{i \in \Omega_t^*} \omega_{it}^* \Delta p_{it}^* \; - \; \sum_{i \in \Omega_t} \omega_{it} \Delta p_{it}$$

- **Lemma 1** The relative PPP holds if the following three conditions are simultaneously satisfied:
  (i) all goods are traded, $\Omega_t = \Omega_t^*$;
  (ii) there is no home bias, $\omega_{it} = \omega_{it}^*$ for all $i \in \Omega_t = \Omega_t^*$;
  (iii) the law of one price (LOP) holds, at least in changes

$$\Delta p_{it} = \Delta p_{it}^* + \Delta e_t \quad \text{for all } i \in \Omega_t = \Omega_t^*$$

- Two types of LOP deviations:
  1. "Long-run" due to variable markups
  2. "Short-run" due to sticky prices

Three remarks

1. Lemma is a set of sufficient requirements for $\Delta q_t = 0$; or alternative necessary conditions for PPP violations, $\Delta q_t \neq 0$

   — guidance for both theory and empirics

2. The macroeconomic concept of PPP is often motivated with a microeconomic concept of LOP
   - LOP is one of the conditions in the Lemma
   - however, LOP neither ensures PPP, nor is strictly necessary!
   - the main source of PPP violations is not LOP violations (see below)

3. Lemma illustrates why PPP hypothesis is a very tall order
   - why then PPP hypothesis plays such a prominent role?
   - why the idea of a stationary RER is so profoundly rooted in the literature?
   - deep assumption of monetary-driven RER

NON-TRADABLES

Non-Tradables

- Price index with tradables and non-tradables:

$$p_t = (1-\omega)p_{Tt} + \omega p_{Nt}$$

  - in log deviations from steady state (special case of π_t above)

- Engel (1999) decomposition:

$$q_t = \underbrace{(p^*_{Tt} + e_t - p_{Tt})}_{\equiv q_t^T \text{ (tradable RER)}} + \underbrace{\omega[(p^*_{Nt} - p^*_{Tt}) - (p_{Nt} - p_{Tt})]}_{\equiv v_t^N \text{ (relative price of N)}}$$

  - general decomposition where v_t^N is the non-tradable "residual"
  - v_t^N is double-difference (N relative to T, relative to foreign)

- If LOP holds for tradables, $p^*_{Tt} + e_t = p_{Tt}$, then:

$$q_t^T \equiv 0 \quad \text{and} \quad q_t = v_t^N$$

Balassa-Samuelson Hypothesis

- Assumptions:
  1. Marginal-cost pricing under linear technology:

$$
\begin{aligned}
p_{it} &= w_t - a_{it} \quad \text{for } i \in \Omega = \{T, N\}, \\
p^*_{jt} &= w^*_t - a^*_{jt} \quad \text{for } j \in \Omega^* = \{T, N^*\}
\end{aligned}
$$

  2. LOP for tradables: $p_{Tt} = p^*_{Tt} + e_t$

- Relative wage rates are determined in the tradable sector:

$$q^W_t = w^*_t + e_t - w_t = a^*_{Tt} - a_{Tt}$$

- The relative price of non-tradables is then:

$$p_{Nt} - p_{Tt} = a_{Tt} - a_{Nt}$$

- And, therefore, RER is given by:

$$q_t = v^N_t = \omega \nu^N_t, \quad \text{where} \quad \nu^N_t \equiv (a^*_{Tt} - a^*_{Nt}) - (a_{Tt} - a_{Nt})$$

Empirical Test and Implications

- Variance decomposition of $q_t = q_t^T + v_t^N$ shows that q_t^T accounts for the bulk of the variance in q_t, even 10 years out
  - intuitively, q_t^T contains e_t, while v_t^N is based on $p_{Nt} - p_{Tt}$ (i.e., relative price in the same geography which tends to be smooth)

- This puts emphasis on the tradable LOP deviation term $q_t^T = p_{Tt}^* + e_t - p_{Tt}$ for understanding RER

- Nonetheless, the non-tradable theory of RER works well in three special case:
  1. between very rich and very poor countries (large cross section)
  2. over "growth miracles" (after-war Japan; long time series)
  3. in currency unions/under pegs (when e_t is switched off)
  - also may apply in policy counterfactuals (how $c_t\downarrow \Rightarrow q_t\uparrow$)

Empirical illustrations

(Rogoff 1996)

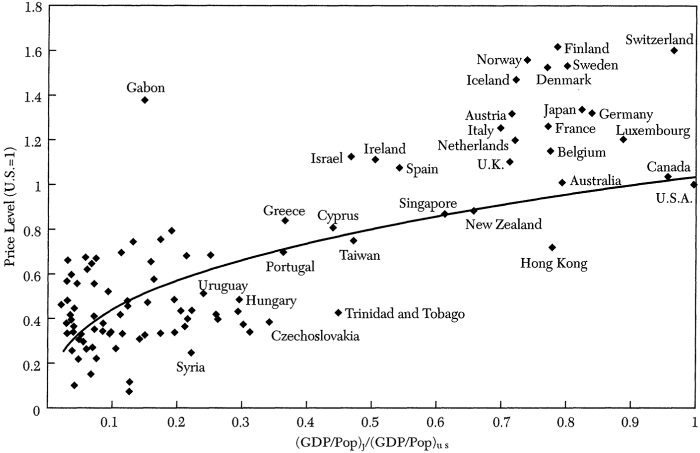


Figure 3. Price Level versus GDP per capita (U.S. = 1) 1990 $\log(P_j/P_{u.s.}) = \underset{(0.090)}{0.035} + \underset{(0.042)}{0.366} \log(Y_j/Y_{u.s.})$

Source: The Penn World Table, Aug. 1994

Empirical illustrations

(Rogoff 1996)

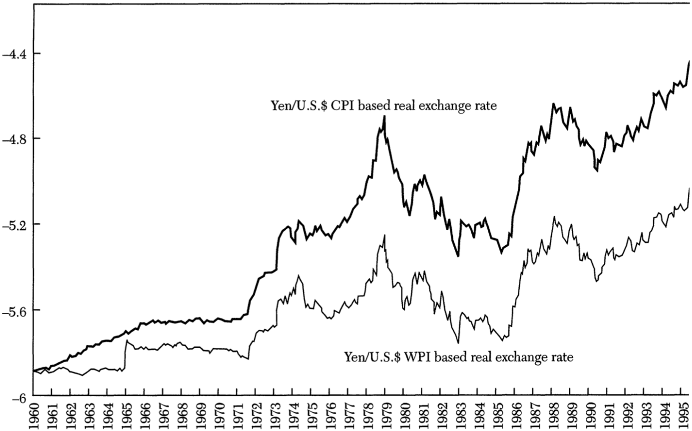


Figure 4. Yen/U.S.$ CPI and WPI based real exchange rates: Jan. 1960–Apr. 1995

Source: International Financial Statistics

HOME BIAS IN TRADABLES

Home Bias in Tradables

- Generalize previous setup with home bias in tradables:

$$p_{Tt} = (1-\tilde{\gamma})p_{Ht} + \tilde{\gamma}p_{Ft},$$
$$p^*_{Tt} = (1-\tilde{\gamma})p^*_{Ft} + \tilde{\gamma}p^*_{Ht}$$

  - sets of goods now $\Omega = \{H, F, N\}$ and $\Omega^* = \{F, H, N^*\}$, so that $\Omega \neq \Omega^*$ and $\omega_H = (1-\tilde{\gamma})(1-\omega) \neq \tilde{\gamma}(1-\omega) = \omega^*_H$

- Still assuming LOP and MC-pricing:

$$q^T_t \equiv p^*_{Tt} + e_t - p_{Tt} = (1-2\tilde{\gamma})q^P_t,$$

$$q^P_t \equiv p^*_{Ft} + e_t - p_{Ht} = q^W_t - (a^*_{Tt} - a_{Tt}),$$

$$v^N_t = \nu^N_t + 2\tilde{\gamma}q^P_t$$

  - note that under LOP, $q^P_t = s_t$ (i.e., PPI-RER equals ToT)

Real Exchange Rate

- RER is still given by $q_t = q_t^T + \omega v_t^N$, therefore we have:

- **Proposition 1** *With competitive pricing, in the presence of home bias $\tilde{\gamma} \leq 1/2$ and non-tradables $\omega \geq 0$, RER is given by:*

$$q_t = (1 - 2\gamma)\big[q_t^W - (a_{Tt}^* - a_{Tt})\big] + \omega \nu_t^N,$$

where $\gamma \equiv \tilde{\gamma}(1 - \omega)$ is aggregate foreign share and ν_t^N is the relative non-tradable productivity.

- Aggregate home bias $\gamma < 1/2$ is essential. Sources:
  - trade costs, distribution costs, intermediate inputs
  - heterogeneous $\tilde{\gamma}_i$

- Tradable q_t^T may comove closely with e_t, q_t, q_t^W
  - even without any micro-level LOP deviations
  - essentials: home bias in tradables $\tilde{\gamma}$ and volatile q_t^W

VARIABLE MARKUPS AND PRICING TO MARKET

PTM and LOP deviations

- Markup identities:

$$p_{Ht}(i) = \mu_{it} + mc_{it},$$
$$p^*_{Ht}(i) = \mu^*_{it} + mc_{it} - e_t + \tau_i.$$

- LOP deviation:

$$\Delta q_{Ht}(i) \equiv \Delta p^*_{Ht}(i) + \Delta e_t - \Delta p_{Ht}(i)$$
$$= \Delta \mu^*_{it} - \Delta \mu_{it}.$$

- Empirical test:
  - project $\Delta q_{Ht}(i)$ on Δe_t
  - Fitzgerald and Haller (2013) find close comovement (even conditional on price adjustment)

Pricing to Market

- A model of the markup:

$$\mu_{it} = \mathcal{M}(p_{Ht}(i) - p_t), \quad \text{with} \quad \mathcal{M}'(\cdot) < 0$$

- Then pricing equations:

$$p_{Ht}(i) = (1-\alpha)mc_{it} + \alpha p_t,$$
$$p^*_{Ht}(i) = (1-\alpha)(mc_{it} - e_t) + \alpha p^*_t,$$

  - $\alpha \equiv \frac{-\mathcal{M}'(p_{Ht}(i)-p_t)}{1-\mathcal{M}'(p_{Ht}(i)-p_t)} \in [0,1)$ is *strategic complementarity*
  - $(1-\alpha)$ is the cost *pass-through* elasticity

- LOP deviations are common across products i (common α):

$$q_{Ht} = p^*_{Ht}(i) + e_t - p_{Ht}(i) = \alpha q_t,$$
$$q_{Ft} = p^*_{Ft}(i) + e_t - p_{Ft}(i) = \alpha q_t$$

RER and ToT

(with home bias, $\gamma = \tilde{\gamma} < 1/2$)

- Using defintions:

$$q_t^P \equiv p_{Ft}^* + e_t - p_{Ht} \quad \text{and} \quad s_t \equiv p_{Ft} - p_{Ht}^* - e_t$$

- Two relationships between relative prices are:

$$q_t^P = s_t + (q_{Ht} + q_{Ft}) = s_t + 2\alpha q_t,$$

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

- **Proposition 2** *The relationship between RERs and ToT:*

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

    - Without PTM ($\alpha = 0$): $s_t = q_t^P = \frac{1}{1-2\gamma} q_t$
    - PTM and LOP deviations help explain (q_t^P, s_t) relative to q_t
    - relative volatility vs correlation!

Aggregate Irrelevance of PTM

- Assume $mc_t = w_t - a_t$ and $mc_t^* = w_t^* - a_t^*$
- Solve for price levels (in the presence of PTM):

$$p_t = (1-\gamma)(w_t - a_t) + \gamma(w_t^* + e_t - a_t^*),$$
$$p_t^* = (1-\gamma)(w_t^* - a_t^*) + \gamma(w_t - e_t - a_t)$$

- Therefore, RER is still (special case of Prop. 1):

$$q_t = (1-2\gamma)\big[q_t^W - (a_t^* - a_t)\big]$$

  - no extra comovement in q_t relative to e_t beyond q_t^W
  - note that we can solve for: $p_t = w_t - a_t + \frac{\gamma}{1-2\gamma} q_t$

- How can this be?!
  - correlated heterogeneity in α_i and ϕ_i

FOREIGN-CURRENCY PRICE STICKINESS

Monetary Model

- Simple general equilibrium model:
  1. cash-in-advance, $P_t C_t = M_t$ (instead of dynamic money demand)
  2. log-linear utility, $u_t = \log C_t - L_t$ ("real neutrality"), which impies perfectly elastic labor supply at a wage rate $W_t/P_t = C_t$
  3. complete asset markets: Backus-Smith condition, $C_t/C_t^* = \mathcal{Q}_t$

- Immediate solution for wages and exchange rate:

$$w_t = m_t, \qquad w_t^* = m_t^*, \qquad \text{and} \qquad e_t = m_t - m_t^*$$

  - m_t and m_t^* follow exogenous processes (random walk)
  - in particular: $q_t^W = w_t^* + e_t - w_t = 0$ (assuming $a_t = a_t^* = 0$)

- Sticky prices: λ is Calvo probability of non-adjustment
  - desired prices $\tilde{p}_{Ht} = w_t = m_t$ and $\tilde{p}_{Ht}^* = w_t - e_t = m_t^* = \tilde{p}_{Ft}^*$
  - reset prices $\bar{p}_t = w_t = m_t$ and $\bar{p}_t^* = w_t - e_t = m_t^*$
  - price dynamics: $p_t = \lambda p_{t-1} + (1-\lambda)\bar{p}_t$

Real Exchange Rate

- Solving for RER: $q_t = \lambda q_{t-1} + \lambda \Delta e_t + (1-\lambda)\bar{q}_t$
    - however, reset RER: $\bar{q}_t = \bar{p}_t^* + e_t - \bar{p}_t = 0 \quad (q_t^W = 0)$
- **Proposition 3** *Under LCP, RER follows an AR(1) process:*

$$q_t = \lambda q_{t-1} + \lambda \Delta e_t,$$

with iid innovation $\lambda \Delta e_t$ and persistence λ.

- falsification in the time series: CKM (2002), Blanco & Cravino
    - implied half-life is 3 quarters vs 4 years in the data
    - half-life: $\lambda^h = 0.5$ with $\lambda = 0.75$ quarterly
- in the cross-section: Kehoe & Midrigan, Carvalho & Necchio
    - little heterogeneity in $q_{z,t}$ across sectors with differential λ_z
    - heterogeneous λ_z increase overall persistence of $q_t \sim ARMA$
- other implied puzzles: Itskhoki & Mukhin (2018, 2021)
    - Meese-Rogoff disconnect, Backus-Smith, Mussa
    - as a result of $\mathcal{E} = M/M^* = PC/P^*C^*$

Generalizations

1. Menu costs (vs Calvo): selection effects
2. Input-output linkages and strategic complementarities
3. Interest rate rule (vs money supply)
   - adjustment in q_t via jumps in e_t vs p_t dynamics (Engel 2019)
4. PCP (vs LCP): LOP holds and $q_t = \lambda q_{t-1} + \lambda(1 - 2\gamma)\Delta e_t$
5. Sticky wages:
   - $q_t^W = \lambda_w q_{t-1}^W + \lambda_w \Delta e_t$ and $\bar{q}_t = (1 - 2\gamma)\frac{1-\beta\lambda}{1-\beta\lambda\lambda_w} q_t^W$
   - $q_t = \lambda q_{t-1} + \lambda \Delta e_t + (1 - \lambda)\bar{q}_t \sim ARMA(2, 1)$
   - $\lambda_w \to 1$ improves the fit of the model independently of λ

- Why does the monetary sticky price model fail?
  - issue is not the structure of the model or nominal rigidities
  - it is the premise that monetary shocks are key drivers of (e_t, q_t)

Conclusion

- Mechanisms of LOP deviations do not change the qualitative relationship between e_t and q_t
  - nonetheless, LOP deviations are important for individual prices
  - PTM and DCP essential for ToT (Proposition 2)

- Proposition 1 is still a good benchmark for RER:

$$q_t = (1 - 2\gamma)[q_t^W - (a_t^* - a_t)]$$

  - two key ingredients: small γ and volatile and persistent q_t^W
  - variable markups, imported intermediates, firm heterogeneity, DCP/LCP further mute ERPT (reinforcing small γ)

- The key outstanding issue is GE determination of (e_t, q_t^W, q_t)
  - limited role of specific type of PPP deviation (Lemma 1)