Accounting for persistence and volatility of good-level real exchange rates:

the role of sticky information

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Motivation: Law-of-One-Price (LOP) deviation

- Like PPP, the speed of adjustment toward a long-run LOP level is measured by estimating α_j of

$$q_t^j = \alpha_j q_{t-1}^j + \nu_t^j.$$

q_t^j: (log) real exchange rate for good j

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KM's findings on persistence and volatility

- Using recent micro studies, λ_j is observable.
  KM find the following two puzzles:

1. If the model is correct, $\alpha_j = \lambda_j$. However,

$$\hat{\alpha}_j \gg \lambda_j \text{ (\textbf{\textit{Persistence puzzle}})}$$

2. If the model is correct, it will fully explain volatility. However,

$$\hat{std}(q_t^{j,data}) \gg std(q_t^{j,model}) \text{ (\textbf{\textit{Volatility puzzle}})}$$

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Contributions of this paper

1. Confirm KM's findings with highly disaggregated panel data
   - Crucini and Shintani's (2007) data
   - Highly disaggregated data with 165 goods. (KM: 66 goods)
   - Panel data of good-level RER between cities in US and Canada. (KM: time series)
2. Propose a model to solve the two puzzles.
   - Integrate sticky information with the standard Calvo sticky price model
   - Add sticky information by Mankiw and Reis (2002)
   - We call the model 'dual stickiness' model.

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Intuition: Why can dual stickiness model solve the puzzles?

1. Persistence Puzzle
   - Even if price adjustment is very fast, good-price adjustment can be slow due to information stickiness ($\omega_j \uparrow$).
   - Persistence $\uparrow$.
2. Volatility Puzzle
   - Even if price adjustment is very fast, good-prices can be almost unaltered due to information stickiness ($\omega_j \uparrow$).
   - RER keeps track of volatile nominal exchange rate.
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Overview of the model: Two-country general equilibrium model

- **Households**
  - $U(c_t, n_t) = \log c_t - \chi n_t$ with cash-in-advance constraint.
- **Firms producing good j**
  - sell goods in monopolistically competitive domestic and foreign local markets.
  - set price for good j in each local market (local currency pricing)
  - face two constraints:

1. cannot change price with prob. λ_j.
2. cannot update info. with prob. ω_j.

- **Governments**
  - control money growth rates. AR(1)

Sketch of dual stickiness model (Calvo model with info. delay)

- Dual stickiness model has two nominal rigidities. (price & information)
- Under sticky prices, the domestic optimal price is

$$\hat{P}^j_{H,t} = (1 - \beta\lambda_j) \sum_{h=0}^{\infty} (\beta\lambda_j)^h \mathbb{E}_t(\hat{W}_{t+h})$$

$$\hat{P}^j_{F,t} = (1 - \beta\lambda_j) \sum_{h=0}^{\infty} (\beta\lambda_j)^h \mathbb{E}_t(\hat{S}_{t+h} + \hat{W}^*_{t+h})$$

$\hat{W}_t(\hat{W}^*_t)$: nominal wages in the home (foreign) country. S_t: nominal exchange rate.

Sketch of dual stickiness model (2)

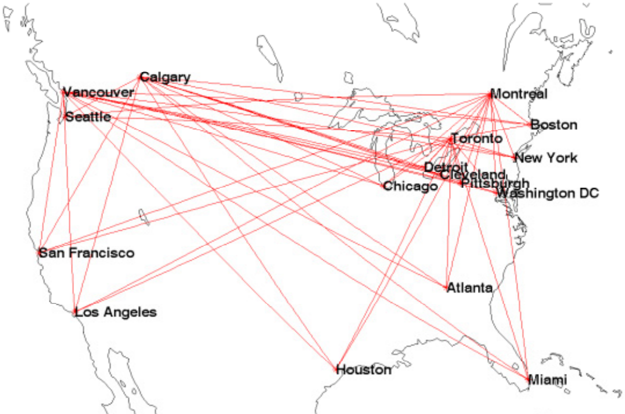
- Sticky information: a fraction of firms cannot have the newest information
  - Prob. ω_j: use info. set they last updated $\Rightarrow \mathbb{E}_{t-k}\hat{P}^j_{H,t}$, $\mathbb{E}_{t-k}\hat{P}^j_{F,t}$
  - Prob. $1-\omega_j$: use the newest info. set $\Rightarrow \hat{P}^j_{H,t}$, $\hat{P}^j_{F,t}$
  - The index for newly set prices $\hat{X}^j_t$ collects these prices.
- Due to Calvo assumption,

$$\hat{P}^j_t = \lambda_j \hat{P}^j_{t-1} + (1-\lambda_j)\hat{X}^j_t$$

- Good-level RER is given by $q^j_t = \hat{S}_t + \hat{P}^{j*}_t - \hat{P}^j_t$.

Overview of Data: *Worldwide Cost of Living Survey*

- Prices from 13 US $\times$ 4 CAN cities:
- Total of 52 cross-border city pairs
- # of goods = 165. Annual data over 1990-2005.



Persistence Puzzle

1. KM's benchmark case ($\omega_j = 0$)
   - Calvo model without info. delay

2. Our dual stickiness model ($\omega_j \geq 0$)
   - Calvo model with info. delay

Calvo model's predictions (No information delay)

- We estimate the model with the annual data.
- We have λ_j: **monthly** infrequency of price change from micro studies.
- Panel version of KM's benchmark case (i.i.d. money growth)

$$\textbf{AR(1)} \qquad q^j_{i,t} = \lambda_j^{12} q^j_{i,t-1} + u'\tilde{D}_t + \zeta^j_i + \nu^j_{i,t}$$

- i: cross-border city pair (e.g., NY and Tronto)
- If the Calvo model is correct,
- our estimate of AR(1) coef. $\hat{\alpha}_j = \lambda_j^{12}$ **with annual data**

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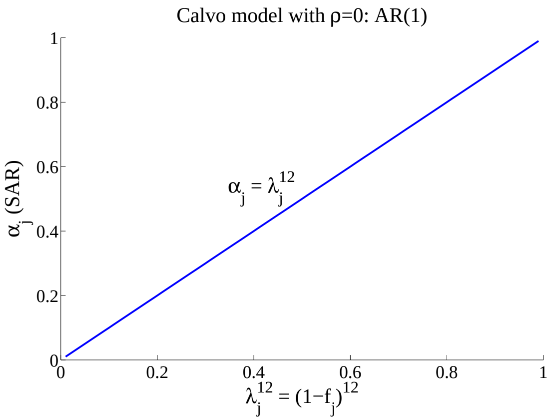
Persistence Puzzle: KM's benchmark case



Blue line: Calvo model's prediction

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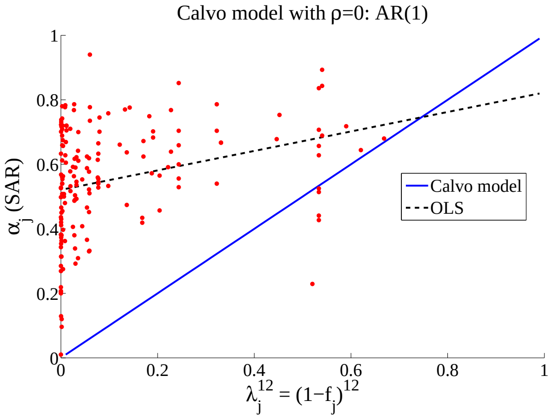

Black dashed line: OLS line from red points.

Dual stickiness model's prediction ($\omega_j > 0$)

- Panel version of good-level RER under dual stickiness model

$$\textbf{AR(4)} \qquad q^j_{i,t} = \sum_{r=1}^{4} \Psi_r q_{i,t-r} + u'\tilde{D}_t + \zeta^j_i + \nu^j_{i,t}$$

- In a general AR(p) model, a persistence measure is the sum of autoregressive coefficients (SAR).
- If dual stickiness model is correct, $\alpha_j = \sum_{r=1}^{4} \Psi_r$ must be

$$\hat{\alpha}_j = 1 - (1 - \lambda_j^{12})(1 - \rho^{12})(1 - \omega_j^{12})(1 - \omega_j^{12}\rho^{12}).$$

So, $\omega_j \uparrow \Rightarrow$ persistence $\uparrow$!!

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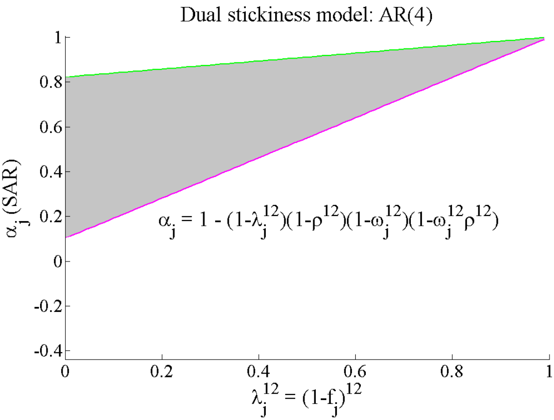
Persistence Puzzle: dual stickiness model



Purple line: No info. delay, Green line: 50 month info. delay

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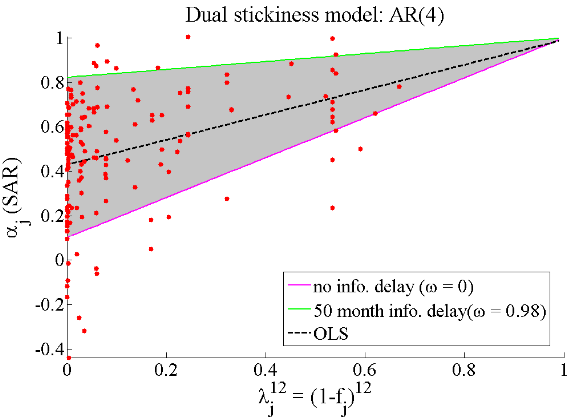

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How much should be information stickiness needed to explain persistence?

	$median(\alpha_j^{theory} / \alpha_j^{data})$				
ω	0	0.5	0.9	0.95	0.98
Bils and Klenow's data	0.31	0.32	0.79	1.21	1.53

- Our model can explain 100% of the median of persistence if
- $\omega = 0.93$ with Bils and Klenow's data
- ($\omega = 0.89$ with Nakamura and Steinsson's data)
- **Avg. duration btwn info. updates is 14 and 9.5 months, resp.**

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Calvo model's predictions (No information delay)

We compute std ratio of the theory to the data in terms of a time varying component.

$$median\left[\frac{std(q_{i,t}^{j,theory})}{std(q_{i,t}^{j,data})}\right] = 0.13 \qquad \text{from Bils \& Klenow}$$

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Conclusion

1. The Kehoe and Midrigan's findings are robust to the use of highly disaggregate panel data.
   - Calvo model fails to explain perisistence and volatility of good-level RER.
2. One possible explanation is the dual stickiness model.
   - The dual stickiness model solves persistence and volatility puzzles.
   - Implied durations between info. updates are comparable to estimates of previous studies.

Reconciling monthly models with annual data

- e.g., the monthly Calvo model with iid money growth:

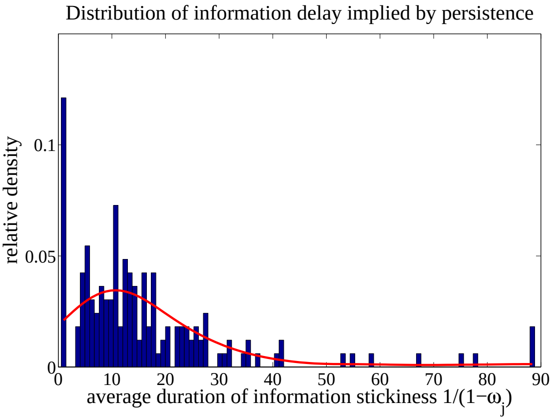
$$q_{it}^j = \lambda_j q_{it-1}^j + \lambda_j \eta_t + \tilde{\zeta}_i^j.$$

where η_t: difference between money growth rates of two countries.

- Annual transformation

$$\begin{aligned} q_{it}^j &= \lambda_j q_{it-1}^j + \lambda_j \eta_t + \tilde{\zeta}_i^j \\ &= \lambda_j^2 q_{it-2}^j + \lambda_j \eta_t + \lambda_j^2 \eta_{t-1} + (1+\lambda_j)\tilde{\zeta}_i^j \\ &\dots \\ &= \lambda_j^{12} q_{it-12}^j + \underbrace{\lambda_j \sum_{r=0}^{11} \lambda^j \eta_{t-r}}_{u'\tilde{D}_t} + \underbrace{\sum_{r=0}^{11} \lambda^j \tilde{\zeta}_i^j}_{\zeta_i^j} \end{aligned}$$

How much should be information stickiness needed to explain persistence?Good-specific ω_j rather than ω



median = 12.9 months (Bils and Klenow), 8.9 months (Nakamura and Steinsson)

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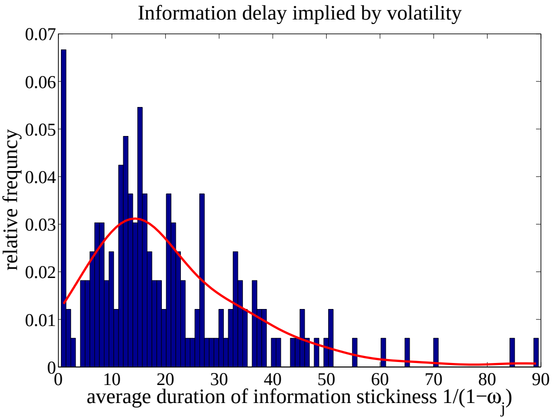

median = 16.6 months (Bils and Klenow), 11.9 months (Nakamura and Steinsson)

KM find pricing complementarities do not help for solving puzzles

- KM also consider pricing complementarities.
- Production function of firms

$$y = m^a n^{1-a}, \quad m = \left(\int m_j^{\frac{\theta-1}{\theta}} dj \right)^{\frac{\theta}{\theta-1}}, \quad m_j = \left(\int m_{j,z}^{\frac{\theta-1}{\theta}} dz \right)^{\frac{\theta}{\theta-1}}$$

- Input costs of firms in all good j move together.
- They set an extreme value of $a = 0.99$. They find....
- The persistence can be explained somewhat better than otherwise.
- The volatility cannot be explained by pricing complementarities.