Currency Choice and Exchange Rate Pass-through

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Motivation

- Most NOEM papers assume exogenous currency choice:
  - PCP as originally in Obstfeld and Rogoff (1995)
  - LCP as in Betts and Devereux (2000)
  - both LCP and PCP as in Devereux and Engel (2003)
- This has immediate implications for short-run and long-run pass-through, as well as for optimal policy

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- This has immediate implications for short-run and long-run pass-through, as well as for optimal policy
- When currency of pricing is chosen endogenously, pass-through and currency choice are tightly interrelated
- We study both empirically and theoretically this link between exchange rate pass-through and optimal currency choice

Main Findings

- Pass-through is very different for LCP and PCP firms:
  - at a 2 year horizons at the aggregate: 0.15 vs. 0.95
  - conditional on price adjustment: 0.25 vs. 0.95
  - conditional on multiple price adjustments: 0.50 vs. 0.95
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  - Sufficient statistic: Medium-run Pass-through
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- We extend Engel's (2006) equivalence result to a dynamic sticky price environment:
  - Sufficient statistic: Medium-run Pass-through
  - MRPT can be estimated empirically from observed prices
- The data strongly support endogenous currency choice theory

Outline

1. Data
2. Empirical Facts
   - Aggregate Evidence
   - Micro-level Evidence
   - Additional Facts
   - Life-long Pass-through
3. Currency and Prices: Model
   - Analytical Model
   - Structural Model
   - Estimation of MRPT
   - Numerical Simulation
4. Discussion

Dataset

- Unpublished BLS micro data on prices at the dock of imports and exports for the U.S. (Gopinath and Rigobon, 2008)
- Monthly transaction prices for 55k imported items, period 1994-2004
- Currency Information:
  - Firms report the price and the currency of pricing
  - Prices are sticky in the reported currency (11 months)
  - Over 90% of import items priced in dollars with large variation across countries

Our Sample

- Market transactions only
- 12 countries with $>$10 and $>$5% of non-dollar items

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Country	% Non-$	N
Germany	0.40	1,156
Switzerland	0.38	220
Italy	0.22	1,112
Japan	0.21	2,553
UK	0.19	719
Belgium	0.17	122
France	0.13	582
Sweden	0.12	181
Spain	0.11	261
Netherlands	0.10	148
Austria	0.10	93
Canada	0.04	1,906

Aggregate Evidence

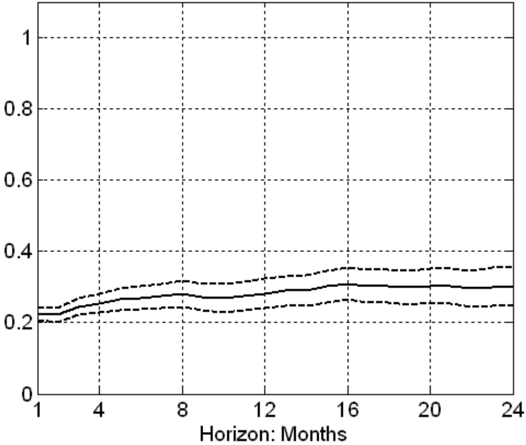


Figure: Conventional Measure of ERPT at different horizons T:

$$\Delta p_t = a + \sum_{\tau=0}^{T} b_\tau \Delta e_{t-\tau} + z_t'\gamma + \varepsilon_t \quad \longrightarrow \quad \beta_T \equiv \sum_{\tau=0}^{T} b_\tau$$

Aggregate ERPT: splitting by Currency

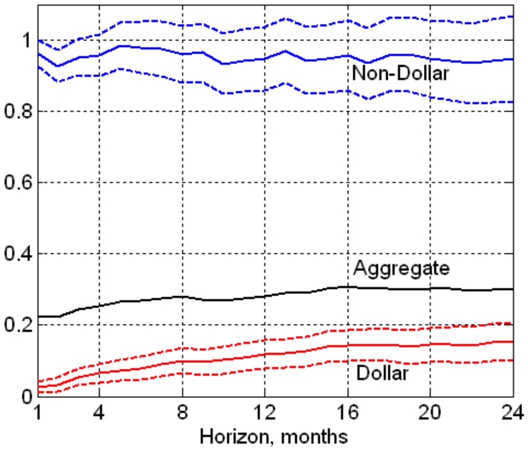


Figure: ERPT at different horizons by currency of pricing:

$$\Delta p_t^c = a^c + \sum_{\tau=0}^{T} b_\tau^c \Delta e_{t-\tau} + z_t' \gamma^c + \varepsilon_t, \quad c \in \{\$, €\}$$

By country

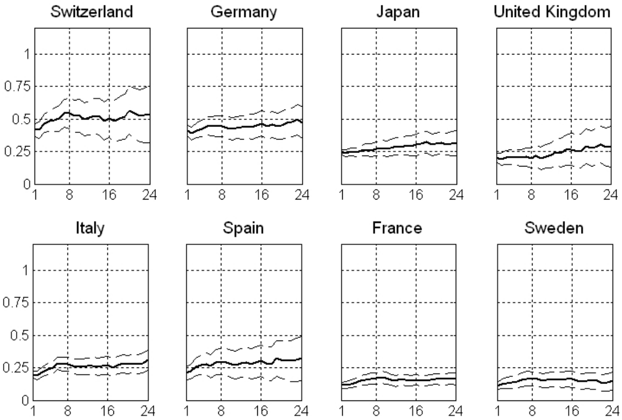
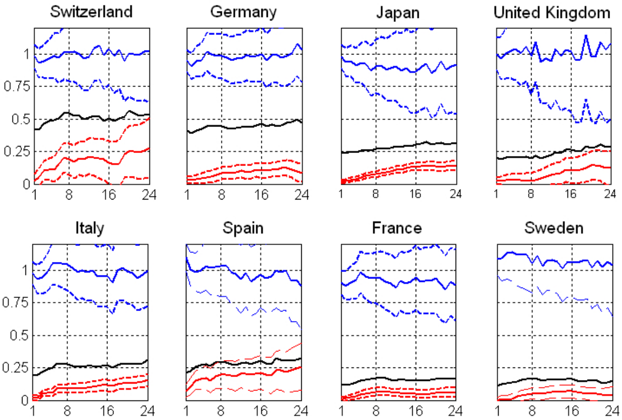


Figure: ERPT at different horizons by country and currency:

$$\Delta p^c_{i,t} = a^c_i + \sum_{\tau=0}^{T} b^c_{i,\tau} \Delta e_{i,t-\tau} + z'_{it}\delta^c_i + \varepsilon^c_{it}$$

More countries

By country



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More countries

Micro-level Evidence

- Pass-through Conditional on Price Adjustment

$$\Delta \bar{p}_{i,t} = \left[\beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i)\right] \cdot \Delta_c e_{i,t} + Z'_{i,t}\gamma + \epsilon_{i,t}$$

Pass-through Cond'l on Price Adjustment

Differentiated Goods

All goods

	Dollar		Non-Dollar		Difference		N_g	R^2
	β_D	s.e.(β_D)	β_{ND}	s.e.(β_{ND})	$\beta_{ND} - \beta_D$	t-stat		
All Countries	0.24	0.04	0.96	0.06	0.72	10.20	3,191	0.15
Germany	0.44	0.10	0.92	0.12	0.48	3.09	489	0.24
Switzerland	0.10	0.15	0.99	0.31	0.89	2.77	78	0.38
Italy	0.23	0.08	0.81	0.10	0.58	4.81	409	0.18
Japan	0.19	0.04	0.98	0.10	0.81	7.31	838	0.16
UK	0.32	0.19	0.89	0.16	0.56	2.14	277	0.16
Belgium	0.01	0.07	0.98	0.14	0.98	6.05	97	0.41
France	0.29	0.12	1.17	0.14	0.88	4.89	178	0.23
Sweden	0.44	0.15	1.43	0.11	0.99	6.01	95	0.33
Spain	0.53	0.11	0.73	0.15	0.20	0.92	97	0.17
Netherlands	0.17	0.22	1.19	0.03	1.01	4.33	36	0.07
Canada	-0.06	0.12	0.51	1.16	0.57	0.50	619	0.06

$$\Delta \bar{p}_{i,t} = \left[\beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i)\right] \cdot \Delta_c e_{i,t} + Z'_{i,t}\gamma + \epsilon_{i,t}$$

Sectoral Evidence

Pass-through Conditional on Price Adjustment

Category	Harm. Code	Dollar		Non-Dollar		Difference		N_{obs}	N_g	N_g^{ND}/N_g	R^2
		β_D	s.e.(β_D)	β_{ND}	s.e.(β_{ND})	$\beta_{ND}-\beta_D$	t-stat				
Live Animals; Animal Products	01-05	0.18	0.16	-0.11	0.53	-0.28	-0.53	1,841	170	0.06	0.12
Vegetable Products	06-14	0.04	0.27	1.10	0.10	1.06	4.00	746	87	0.07	0.07
Animal/Vegetable Fats, Oils	15	0.65	0.32	—	—	—	—	145	18	0.00	0.12
Prepared Foodstuffs	16-24	0.24	0.06	0.83	0.25	0.59	2.27	1,668	426	0.07	0.12
Mineral Products	25-27	0.96	0.19	1.14	0.35	0.18	0.50	4,588	310	0.05	0.03
Products of chemical and allied industries	28-38	0.27	0.08	0.64	0.25	0.37	1.38	2,291	456	0.08	0.27
Plastics/Rubber articles	39-40	0.21	0.07	0.53	0.11	0.32	2.57	896	219	0.15	0.22
Raw Hides/leather articles, furs	41-43	-0.15	0.14	0.91	0.03	1.06	7.40	158	54	0.30	0.71
Wood and articles of wood	44-46	-0.08	0.17	0.85	0.00	0.94	5.39	4,850	307	0.01	0.03
Pulp of wood/other fibrous cellulosic material	47-49	0.26	0.11	1.02	0.20	0.76	2.85	482	293	0.05	0.57
Textile and textile articles	50-63	0.41	0.14	0.94	0.12	0.54	2.85	482	175	0.18	0.57
Footwear, headgear etc.	64-67	0.45	0.16	0.97	0.07	0.52	4.61	161	72	0.58	0.56
Misc. manufactured articles	68-70	0.19	0.17	1.06	0.24	0.87	2.83	460	214	0.19	0.32
Precious or semi-prec. stones	71	0.24	0.13	2.03	0.74	1.79	2.48	1,882	171	0.05	0.09
Base metals and articles of base metals	72-83	0.21	0.04	1.35	0.36	1.15	3.19	3,693	614	0.13	0.27
Machinery and mechanical appliances etc.	84-85	0.22	0.05	0.90	0.06	0.67	9.51	5,943	1775	0.20	0.26
Vehicles, aircraft etc.	86-89	0.17	0.07	0.93	0.10	0.76	6.31	2,337	662	0.13	0.13
Optical, photographic etc.	90-92	0.22	0.07	1.09	0.20	0.88	4.18	928	317	0.27	0.37
Arms and ammunition	93	0.08	0.16	1.03	0.09	0.95	5.00	109	47	0.15	0.31
Articles of stone, plaster etc.	94-96	0.54	0.09	0.76	0.12	0.23	1.53	394	148	0.15	0.29

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- 125 goods that changed currency of invoicing:
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- Exports: Dollar (PCP, 97%) and Non-Dollar (LCP, 3%)
  - 0.84 versus 0.25
- Frequency: Dollar versus Non-Dollar
  - All: 0.10 versus 0.07
  - 6-digit: 0.14 versus 0.08

Life-long Pass-through

$$\Delta_L \bar{p}_{i,T} = \left[\beta_D^L \cdot D_i + \beta_{ND}^L \cdot (1 - D_i)\right] \cdot \Delta_L e_{i,T} + Z'_{i,T}\gamma + \epsilon_{i,t}$$

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	Dollar		Non-Dollar		Difference		N_g	R^2
	β_D^L	s.e.(β_D^L)	β_{ND}^L	s.e.(β_{ND}^L)	$\beta_{ND}^L - \beta_D^L$	t-stat		
Manufactured Goods	0.49	0.06	0.98	0.06	0.49	5.84	6,643	0.37
Euro Area	0.42	0.09	0.95	0.08	0.53	4.54	2,374	0.49
Non-Euro Area	0.56	0.09	0.96	0.12	0.40	2.88	4,269	0.32
Differentiated Goods	0.52	0.10	1.07	0.08	0.55	4.45	3,193	0.38
Euro Area	0.50	0.11	0.99	0.10	0.48	2.99	1,264	0.48
Non-Euro Area	0.54	0.15	1.12	0.20	0.58	2.34	1,928	0.32

Currency and Prices

in a Dynamic Sticky Price Model

- Multi-period sticky price model
- A firm chooses currency of pricing when it adjusts its price
- Exogenous frequency of price adjustment (Calvo)
- Partial equilibrium: single firm's problem
  - exchange rate process is exogenous
  - price level dynamics is exogenous
- General result linking currency choice with pass-through independently of their primitive determinants

Currency and Prices

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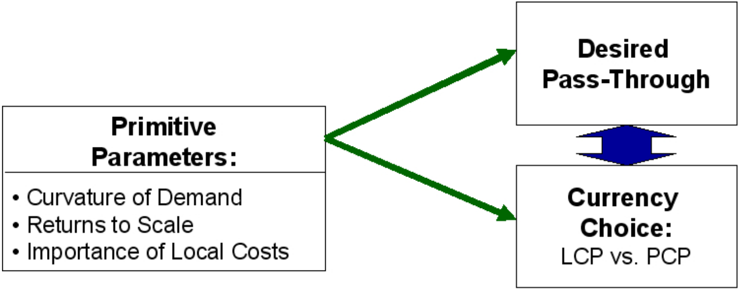

Price Setting

- Desired Price:

$$\tilde{p}(s_t) = \arg\max_{p} \Pi(p|s_t), \qquad \tilde{p}^*_t = \tilde{p}_t - e_t$$

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$$V_L(p|s^t) = \Pi(p|s_t) + \delta\theta\mathbb{E}_t V_L(p|s^{t+1}) + \delta(1-\theta)\mathbb{E}_t V(s^{t+1})$$
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- Producer Currency Pricing:

$$V_P(p^*|s^t) = \Pi(p^* + e_t|s_t) + \delta\theta\mathbb{E}_t V_P(p^*|s^{t+1}) + \delta(1-\theta)\mathbb{E}_t V(s^{t+1})$$
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$$\bar{p}_P^*(s^t) = \arg\max_p V_P(p^*|s^t)$$

- Currency Choice:

$$V(s^t) = \max\left\{ V_L\big(\bar{p}_L(s^t)|s^t\big), V_P\big(\bar{p}_P^*(s^t)|s^t\big) \right\}$$

Optimal Price Setting

Equivalence Result

Proposition

The first order approximation to optimal price setting in local and producer currency is given respectively by:

$$\bar{p}_L(s^t) = (1-\delta\theta)\sum_{\ell=0}^{\infty}(\delta\theta)^{\ell}\mathbb{E}_t\tilde{p}(s_{t+\ell}),$$
$$\bar{p}_P^*(s^t) = (1-\delta\theta)\sum_{\ell=0}^{\infty}(\delta\theta)^{\ell}\mathbb{E}_t\{\tilde{p}(s_{t+\ell}) - e_{t+\ell}\},$$

which implies the following equivalence between optimal prices in the local and producer currency:

$$\bar{p}_L(s^t) = \bar{p}_P^*(s^t) + e_t.$$

$\Rightarrow$ Pass-through is the same conditional on price adjustment

Currency Choice

- Value Differential between LCP and PCP:

$$\begin{aligned}\mathcal{L}(s^t) =& V_L\big(\bar{p}_L(s^t)|s^t\big) - V_P\big(\bar{p}^*_P(s^t)|s^t\big)\\ =& \textstyle\sum_{\ell=0}^{\infty}(\delta\theta)^{\ell}\mathbb{E}_t\left\{\Pi\big(\bar{p}_L(s^t)|s_{t+\ell}\big) - \Pi\big(\bar{p}^*_P(s^t)+e_{t+\ell}|s_{t+\ell}\big)\right\}\end{aligned}$$

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$$= \sum_{\ell=0}^{\infty}(\delta\theta)^{\ell}\mathbb{E}_t\left\{\Pi\big(\bar{p}_L(s^t)|s_{t+\ell}\big) - \Pi\big(\bar{p}_P^*(s^t)+e_{t+\ell}|s_{t+\ell}\big)\right\}$$

Proposition

The second order approximation to $\mathcal{L}(s^t)$:

$$\mathcal{L}(s^t) = K(s^t)\sum_{\ell=0}^{\infty}(\delta\theta)^{\ell}\mathrm{var}_t(e_{t+\ell})\left[\frac{1}{2} - \frac{\mathrm{cov}_t\big(\tilde{p}(s_{t+\ell}),e_{t+\ell}\big)}{\mathrm{var}_t(e_{t+\ell})}\right],$$

Therefore, the firm chooses LCP when

$$\bar{\Psi} \equiv (1-\delta\theta)^2\sum_{\ell=1}^{\infty}(\delta\theta)^{\ell-1}\ell\frac{\mathrm{cov}_t\big(\tilde{p}(s_{t+\ell}),e_{t+\ell}\big)}{\mathrm{var}_t(e_{t+\ell})} < \frac{1}{2}$$

and PCP otherwise.

Medium-run Pass-through

- General Expression:

$$\bar{\Psi} = (1-\delta\theta)\sum_{j=0}^{\infty}(\delta\theta)^j\left[(1-\delta\theta)\sum_{\ell=1}^{\infty}(\delta\theta)^{\ell-1}\tilde{\Psi}_{\ell,\ell+j}(s^t)\right],$$

where

$$\tilde{\Psi}_{j,\ell}(s^t) \equiv \frac{\mathrm{cov}_t\left(\tilde{p}(s_{t+\ell}), \Delta e_{t+j}\right)}{\mathrm{var}_t(\Delta e_{t+j})}$$

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- Special Case: $\tilde{\Psi}_{\ell,\ell+j}(s^t) = \tilde{\Psi}_j$

$$\bar{\Psi} = (1-\delta\theta)\sum_{j=0}^{\infty}(\delta\theta)^j\tilde{\Psi}_j$$

Structure Model

of Incomplete Pass-through

- Desired Price:

$$\tilde{p}_t \equiv \tilde{p}(e_t, P_t|z_t) = \mu(\tilde{p}_t - P_t|z_t) + mc^*(e_t|z_t) + e_t$$

- Denote:

$$\phi_t \equiv \frac{\partial[mc_t^* + e_t]}{\partial e_t} \qquad \text{and} \qquad \Gamma_t \equiv -\frac{\partial \mu_t}{\partial(p_t - P_t)}$$

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Proposition

Let ϕ and Γ be constant. Then

$$\tilde{\Psi}_{\ell,\ell+j}(s^t) = \tilde{\Psi}_j = \frac{\phi}{1+\Gamma} + \frac{\Gamma}{1+\Gamma} \cdot \frac{\mathrm{cov}(P_{t+j}, \Delta e_t)}{\mathrm{var}(\Delta e_t)}.$$

Estimation of MRPT

- Define price change:

$$\Delta \bar{p}_t \equiv \begin{cases} \bar{p}_{L,t} - \bar{p}_{L,t-\tau}, & \text{for LCP,} \\ \bar{p}^*_{P,t} + e_t - \bar{p}^*_{P,t-\tau} - e_{t-\tau}, & \text{for PCP.} \end{cases}$$

- Run regression:

$$\Delta \bar{p}_t = \alpha + \beta_{MR} \Delta e_t + \epsilon_t$$

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$$\Delta \bar{p}_t = \alpha + \beta_{MR} \Delta e_t + \epsilon_t$$

Proposition

β_{MR} equals MRPT:

$$\beta_{MR} \equiv \frac{\mathrm{cov}\big(\Delta \bar{p}_t, \Delta e_t\big)}{\mathrm{var}(\Delta e_t)} = (1 - \delta\theta) \sum_{\ell=0}^{\infty} (\delta\theta)^{\ell} \tilde{\Psi}_{\ell} = \bar{\Psi}.$$

Numerical Simulation

Twofold purpose of the exercise:

1. Relate currency choice and pass-through to primitives

2. Relax the assumptions of the analytical model
   - Menu Cost price setting
   - Mean reversion in the exchange rate
   - Non-constant Γ
   - Empirical measures of MRPT

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- Source of incomplete pass-through:
   - Demand driven variable markups (Kimball demand)
   - Proxy for strategic complementarity (as in Atkeson and Burstein, 2008)

Demand and Costs

- Klenow and Willis (2006) specification of Kimball (1995) demand:

$$q = q(p, P) = \left[1 - \varepsilon(p - P)\right]^{\sigma/\varepsilon}, \qquad \sigma > 1, \varepsilon \geq 0$$

- Markup variability:

$$\tilde{\Gamma} = -\frac{\partial \mu}{\partial p} = \frac{\varepsilon}{\sigma - 1 + \varepsilon(p - P)}$$

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- Price level dynamics:

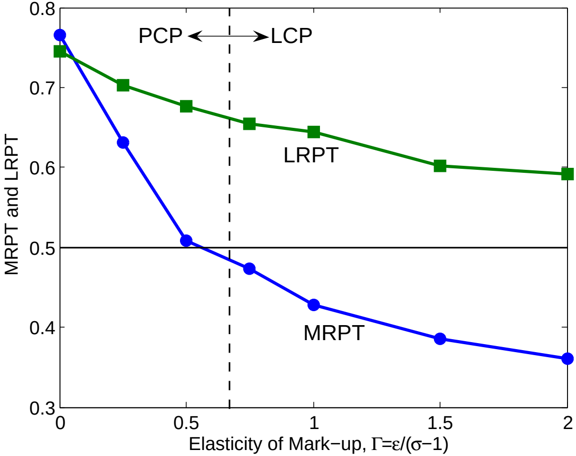
$$(P_t - \bar{P}) = \alpha(P_{t-1} - \bar{P}) + (1 - \alpha)\bar{\phi} e_t$$

Calibration

Parameter	Symbol	Value	Source\Moment
Discount Factor	δ	$0.96^{1/12}$	Monthly data
St.dev. of e_t	σ_e	0.025	Data
Persistence of e_t	ρ_e	0.986	Data
St.dev. of a_t	σ_a	0.08	Abs. Size of Price Adj.
Persistence of a_t	ρ_a	0.95	Persistence of new prices
Inertia in P_t	α	0.95	
Long-run response of P_t	$\bar{\phi}$	0.50	
Cost sensitivity	ϕ	0.75	Input-Output Tables
Calvo parameter	θ	0.89	Price Durations
Menu Cost	κ	0.05	Price Durations
Demand elasticity	σ	5	Steady State Mark-up
Demand super-elasticity	ε	3	

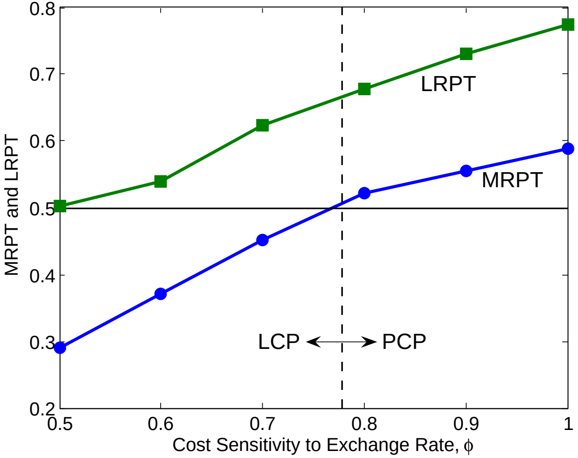
Currency Choice, MRPT and LRPT

Variation in Γ



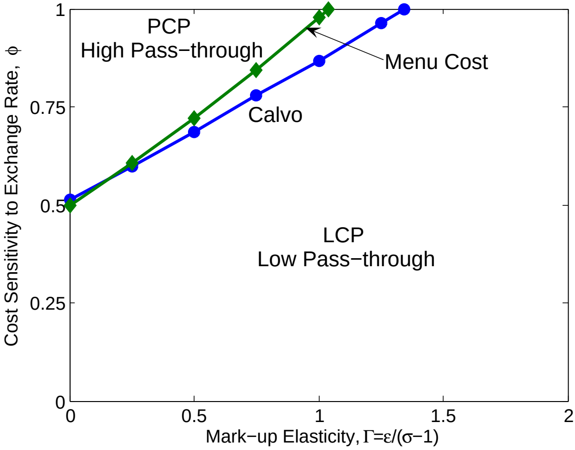
Currency Choice, MRPT and LRPT

Variation in ϕ

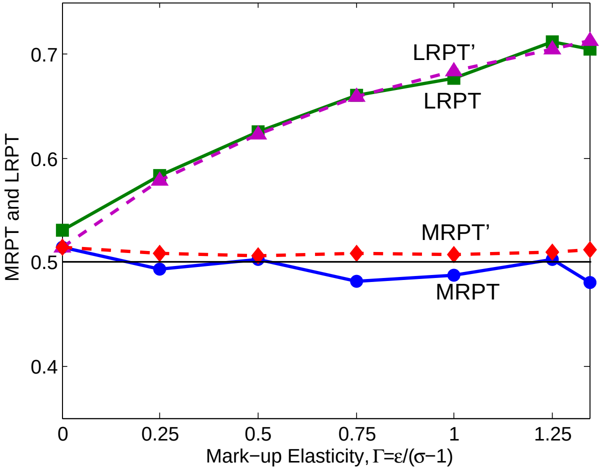


Currency Choice

In the Space of Primitives

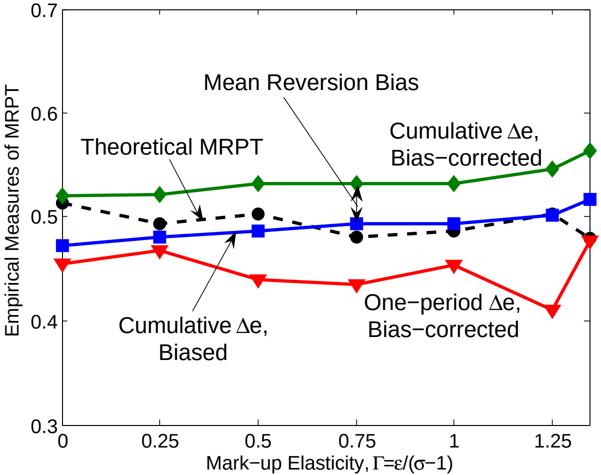


MRPT vs LRPT



LRPT'
LRPT
MRPT'
MRPT
0.7
0.6
0.5
0.4
MRPT and LRPT
0
0.25
0.5
0.75
1
1.25
Mark−up Elasticity, Γ=ε/(σ−1)

Empirical Measures of MRPT



Linking Theory and Evidence

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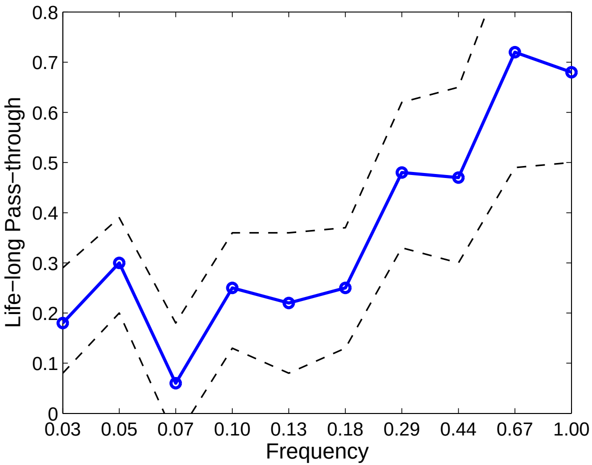
  - — variables affecting markup variability (Γ)

Frequency and Pass-through

Gopinath and Itskhoki (2009)



- Long-run Pass-through:

$$\Psi = \frac{\phi}{1+\Gamma}$$

- Approximation to the profit loss function:

$$\mathbb{L}(X) \approx \frac{1}{2}(\sigma - 1)\Psi\Sigma \cdot X^2 \quad \gtrless \quad \kappa,$$

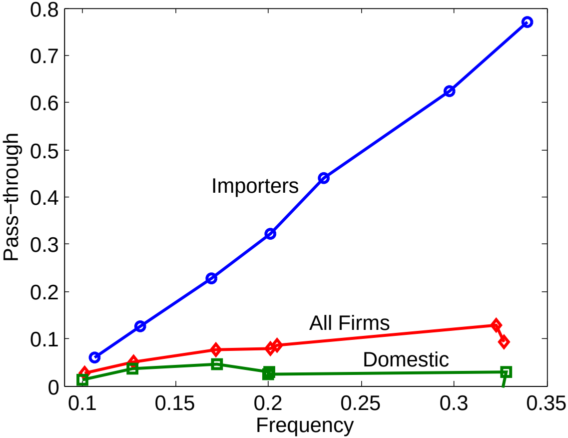
$$X \equiv \frac{-a + \phi e}{\sqrt{\Sigma}}, \qquad \Sigma \equiv \sigma_a^2 + \phi^2\sigma_e^2$$

- Frequency:

$$\Phi \approx \Pr\left\{ |X| > \sqrt{\frac{2\kappa}{(\sigma - 1)\Psi\Sigma}} \right\}$$

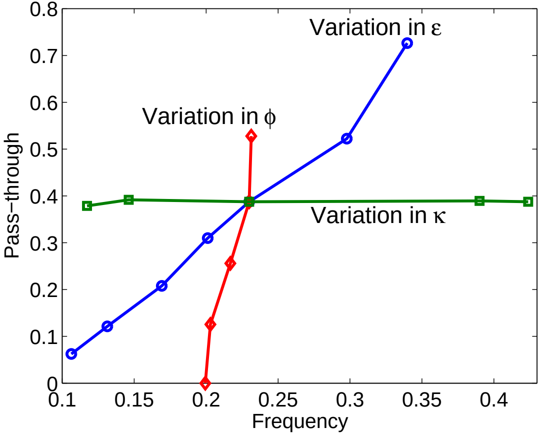
Frequency and Pass-through

Simulation



Frequency and Pass-through

Simulation



Frequency and Pass-through

Simulation

	Data	Variation in		
		ε	κ	ε and κ
Slope(Freq., LRPT)	0.56	1.86	0.03	0.55
Min LRPT	0.06	0.13	0.44	0.22
Max LRPT	0.72	0.76	0.46	0.57
Slope(Freq., size)	-0.01	0.23	-0.15	-0.05
Min size	5.4%	3.8%	4.8%	5.8%
Max size	7.4%	11.8%	12.2%	8.2%
Std. dev. of Freq.	0.30	0.11	0.17	0.18
Min freq.	0.03	0.07	0.06	0.05
Max freq.	1.00	0.44	0.59	0.61

Aggregate Evidence

More Countries

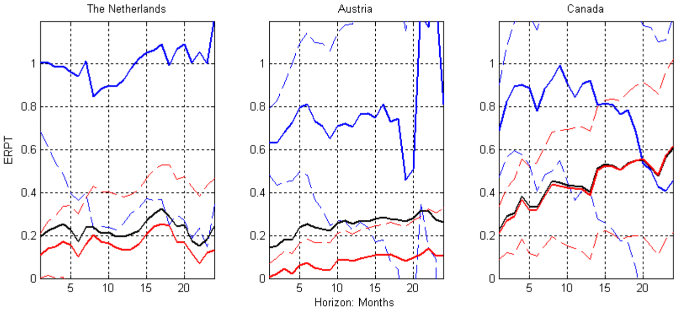


Figure: ERPT at different horizons by country and currency:

$$\Delta p_{i,t}^{c} = a_i^c + \sum_{\tau=0}^{T} b_{i,\tau}^{c} \Delta e_{i,t-\tau} + z_{it}' \delta_i^c + \varepsilon_{it}^c$$

Back to Aggregate Evidence

Pass-through Cond'l on Price Adjustment

All Goods

	Dollar		Non-Dollar		Difference		N_g	R^2
	β_D	s.e.(β_D)	β_{ND}	s.e.(β_{ND})	$\beta_{ND} - \beta_D$	t-stat		
All Countries	0.24	0.03	0.92	0.04	0.68	13.89	6,637	0.11
Germany	0.31	0.07	0.87	0.10	0.56	4.71	801	0.22
Switzerland	0.24	0.11	0.96	0.18	0.72	3.36	130	0.36
Italy	0.21	0.06	0.84	0.13	0.63	4.31	744	0.18
Japan	0.23	0.04	0.96	0.06	0.73	10.77	1,733	0.14
UK	0.19	0.11	0.74	0.17	0.55	2.92	541	0.17
Belgium	0.01	0.07	0.98	0.14	0.98	6.05	97	0.41
France	0.26	0.07	1.03	0.10	0.77	6.11	425	0.21
Sweden	0.28	0.14	0.94	0.21	0.66	2.73	160	0.25
Spain	0.46	0.14	0.83	0.27	0.37	1.19	164	0.20
Netherlands	0.21	0.09	0.89	0.35	0.67	1.85	126	0.08
Canada	0.22	0.13	0.66	0.45	0.44	1.00	1,654	0.03

$$\Delta \bar{p}_{i,t} = \left[\beta_D \cdot D_i + \beta_{ND} \cdot (1 - D_i)\right] \cdot \Delta_c e_{i,t} + Z'_{i,t}\gamma + \epsilon_{i,t}$$

Back to Evidence