Frequency of Price Adjustment and Pass-through

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March 11, 2009

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  - Menu Costs
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- Study the link between frequency and pass-through to:
  1. Sources of variation in frequency / transmission of shocks
  2. Evidence of real rigidities
  3. Test theories of price setting

What we do

- Document a positive relation between frequency and "long-run" pass-through (LRPT)

$$LRPT^{HighFreq} \approx 2 * LRPT^{LowFreq}$$

  — LRPT increases from 15% to 75% from first to tenth frequency deciles

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- Calibrate and simulate a dynamic menu cost model to show:
  – Variable mark-ups generate quantitatively large effects: 37% of the variation in frequency

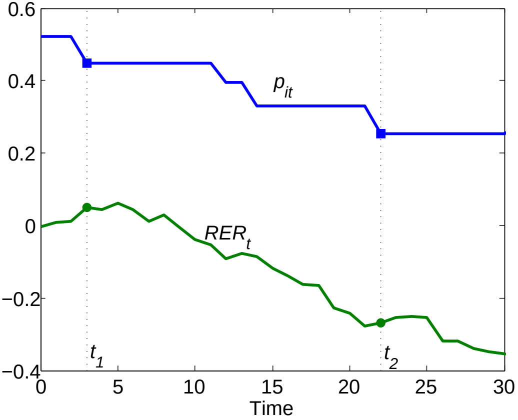
Empirical Findings: Dataset

- BLS micro data on import prices at the dock for the U.S. (Gopinath and Rigobon, 2007)
- Monthly reported transaction prices for 55k imported items, period 1994-2004
- Data Sub-sample
  - Dollar priced goods (90% of all goods)
  - Manufactured Goods
  - Market Transactions
  - Crop Outliers

Long-Run Pass-through Estimates

- Life-long Micro-Regressions:

$$\Delta p_{LR}^{i,c} = \alpha_c + \beta_{LR} \Delta RER_{LR}^{i,c} + \epsilon^{i,c} \quad (1)$$



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- Aggregate Pass-through Regressions:

$$\Delta P_{c,t} = \alpha_c + \sum_{j=0}^{n} \beta_{1,j} \Delta RER_{c,t-j} + \epsilon^{c,t} \tag{2}$$

— Includes country fixed effect, SE clustered by country and 4 digit sector code.

Life-Long Micro-Regressions

All Countries

	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
Manufacturing				
– Low Frequency	0.07	0.20	0.03	5111
– High Frequency	0.39	0.40	0.05	5078
Differentiated				
– Low Frequency	0.07	0.19	0.04	2655
– High Frequency	0.29	0.40	0.06	2573

Life-Long Micro-Regressions

High-Income OECD Subsample

	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
Manufacturing				
– Low Frequency	0.07	0.27	0.04	3000
– High Frequency	0.40	0.58	0.07	2867
Differentiated				
– Low Frequency	0.07	0.26	0.07	1503
– High Frequency	0.33	0.58	0.08	1461

Life-Long Micro-Regressions

Regions

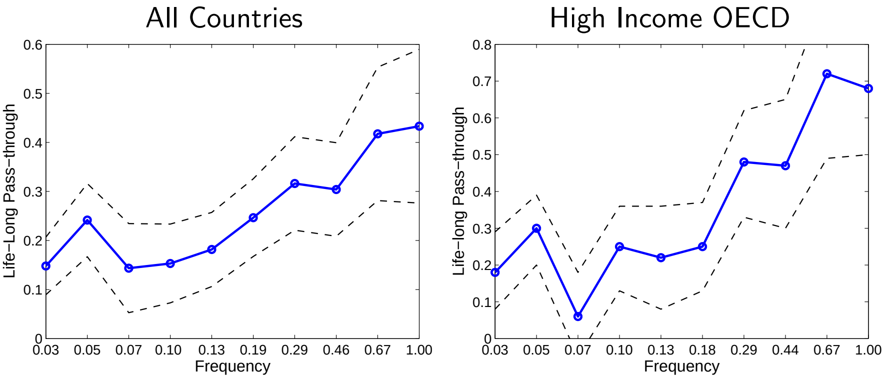
	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
Japan				
– Low Frequency	0.07	0.31	0.07	714
– High Frequency	0.27	0.62	0.15	704
Euro Area				
– Low Frequency	0.07	0.28	0.09	972
– High Frequency	0.33	0.49	0.09	980
Canada				
– Low Frequency	0.10	0.36	0.12	621
– High Frequency	0.87	0.74	0.23	529
Non HIOECD				
– Low Frequency	0.07	0.12	0.04	2031
– High Frequency	0.36	0.26	0.06	2291

Table: Life-long pass-through, 3 and more price changes

	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
		All Countries		
Manufacturing				
– Low Frequency	0.13	0.22	0.04	2281
– High Frequency	0.58	0.44	0.07	2299
Differentiated				
– Low Frequency	0.11	0.15	0.07	1035
– High Frequency	0.42	0.51	0.09	1095
		High-Income OECD		
Manufacturing				
– Low Frequency	0.12	0.30	0.07	1436
– High Frequency	0.60	0.73	0.08	1323
Differentiated				
– Low Frequency	0.11	0.23	0.12	657
– High Frequency	0.50	0.77	0.09	646

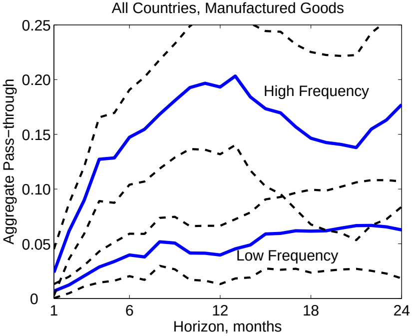
Life-long Pass-through

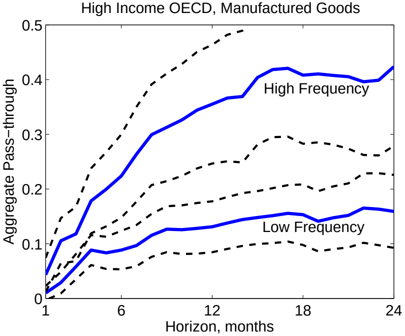
Frequency Deciles, Manufactured Goods



Aggregate Pass-through Regressions

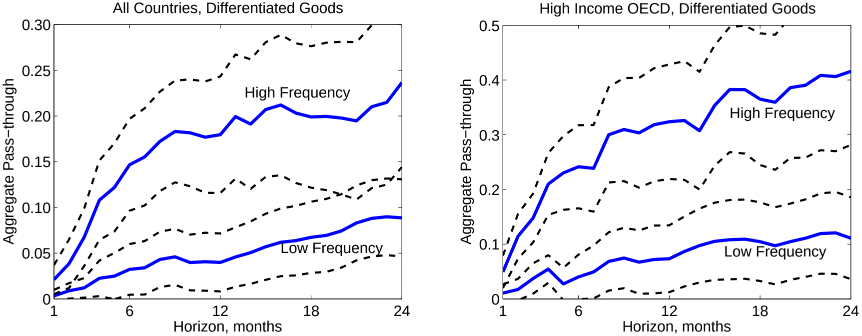
Manufactured Goods





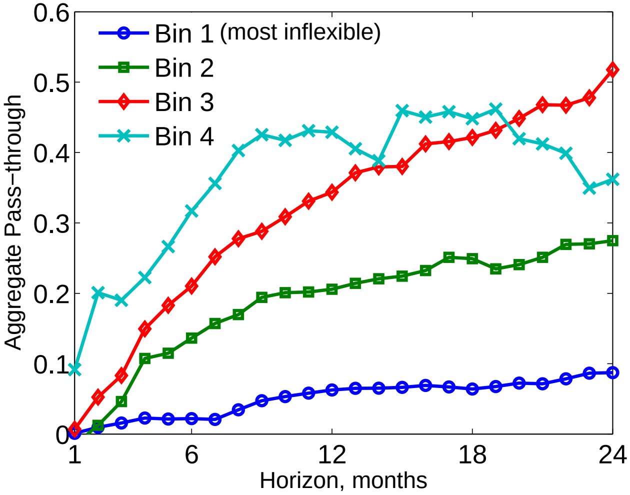
Aggregate Pass-through Regressions

Differentiated Goods



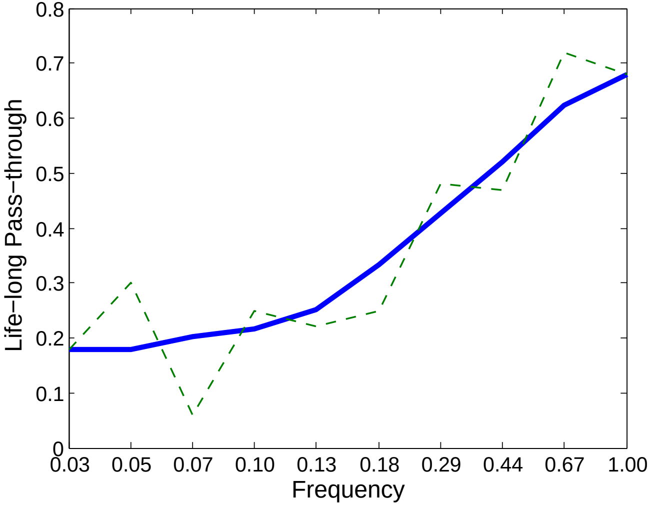
Aggregate Pass-through Regressions

High-Income OECD Subsample, Differentiated Goods

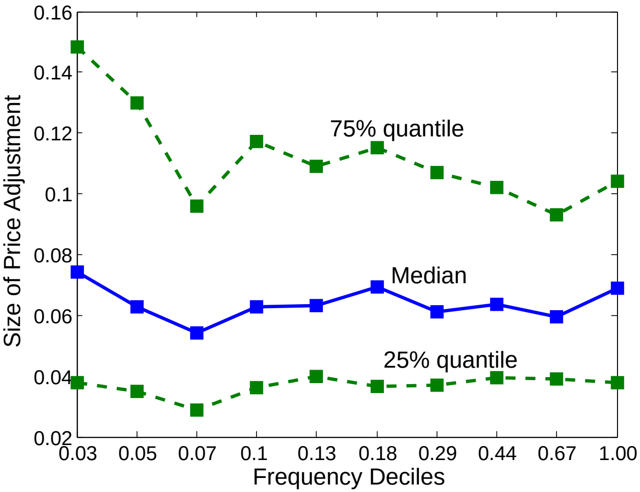


Summary Slide

Relation between Frequency and Pass-through



Frequency and Size



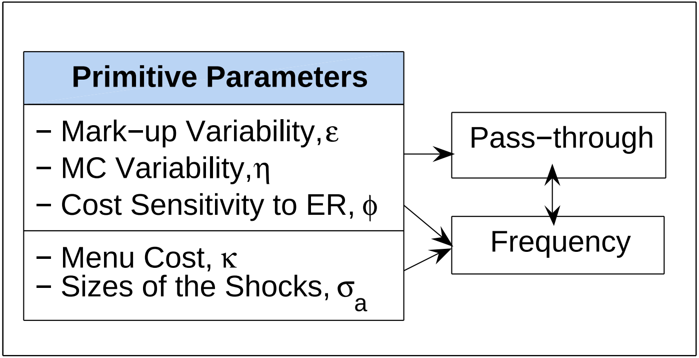
- No correlation between frequency and size

Substitutions

Table: Substitutions

Decile	Freq	Life 1	Life 2	Freq sub 1	Freq sub 2
1	0.03	59	42	0.05	0.05
2	0.05	50	34	0.07	0.08
3	0.07	52	32	0.09	0.10
4	0.10	55	36	0.12	0.13
5	0.13	52	33	0.15	0.16
6	0.18	49	32	0.20	0.21
7	0.29	50	26	0.30	0.31
8	0.44	51	34	0.46	0.46
9	0.67	52	33	0.67	0.68
10	1.00	43	30	1.00	1.00

Frequency and Pass-through



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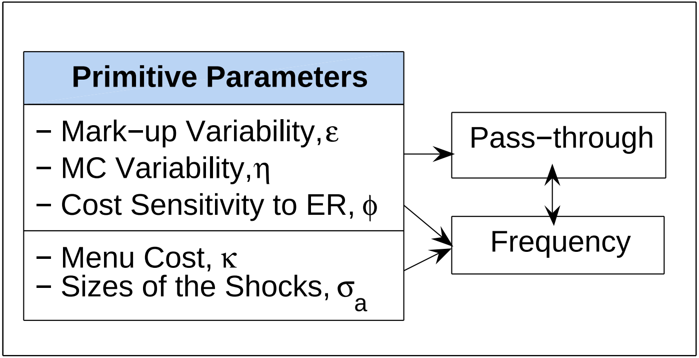

- Sources of variable mark-ups:
  - Curvature of demand (e.g., Kimball demand)
  - Strategic Complementarities (Atkeson and Burstein, 2005)

Analytical Model

- Static (or two period) menu cost model
- Problem of the firm
- Variable elasticity of demand
  - Extensions: (i) variable marginal costs; (ii) demand shocks

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  - Extensions: (i) variable marginal costs; (ii) demand shocks
- Previous Literature:
  - Barro (1972)
  - Rotemberg and Saloner (1987)
  - Romer (1989)
  - Ball and Mankiw (1994)

Demand

- Demand schedule:

$$q = \varphi(p|\sigma, \varepsilon), \qquad \sigma > 1 \quad \text{and} \quad \varepsilon \geq 0$$

- Price elasticity of demand:

$$\tilde{\sigma} \equiv \tilde{\sigma}(p|\sigma, \varepsilon) = -\frac{\partial \ln \varphi(p|\sigma, \varepsilon)}{\partial \ln p}$$

- Super-Elasticity of demand:

$$\tilde{\varepsilon} \equiv \tilde{\varepsilon}(p|\sigma, \varepsilon) = \frac{\partial \ln \tilde{\sigma}(p|\sigma, \varepsilon)}{\partial \ln p}.$$

- Normalization: $\tilde{\sigma}(1) = \sigma$, $\tilde{\varepsilon}(1) = \varepsilon$, $\varphi(1) = 1$
- Example (Klenow-Willis):

$$\varphi(p) = A\big[1 - \varepsilon \ln p\big]^{\sigma/\varepsilon}$$

Costs and Profits

- Cost Function:

$$C(q|a, e; \phi) = (1 - a)(1 + \phi e)cq,$$

  - a is idiosyncratic productivity shock
  - e is a real exchange rate shock
  - $\phi \in [0, 1]$ is sensitivity to exchange rate shock ("local costs")
  - a and e are independent with $\mathbb{E}a = \mathbb{E}e = 0$ and standard deviations σ_a and σ_e.

- Normalization: $c = (\sigma - 1)/\sigma$

Price Setting

- Firm sets price before observing shocks, $\bar{p}_0$
- After shock, can choose to adjust price to

$$p(a,e) = \arg\max_p \Pi(p|a,e), \qquad \Pi(a,e) \equiv \Pi\big(p(a,e)|a,e\big)$$

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- Will adjust if

$$\mathrm{L}(a,e) \equiv \Pi(a,e) - \Pi(\bar{p}_0|a,e) > \kappa$$

- Region of Non-Adjustment

$$\Delta \equiv \Delta_\kappa = \Big\{(a,e) : \ \mathrm{L}(a,e) \leq \kappa\Big\}$$

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- Initial Price:

$$\bar{p}_0 = \arg\max_p \mathbb{E}_\Delta \Pi(p|a,e) \approx p(0,0) = 1$$

Exchange Rate Pass-through

- Log Desired price:

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$$\frac{p(a,e) - \bar{p}_0}{\bar{p}_0} \approx \Psi \cdot (-a + \phi e), \qquad \Psi \equiv \frac{1}{1 - \frac{\partial \tilde{\mu}(1)}{\partial p}} = \frac{1}{1 + \frac{\varepsilon}{\sigma - 1}}$$

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- Exchange rate pass-through:

$$\Psi_e \equiv \frac{\partial \ln p(a, e)}{\partial e}\bigg|_{a=e=0} \approx \phi\Psi = \frac{\phi}{1 + \frac{\varepsilon}{\sigma - 1}}$$

  - Pass-through decreases in ε and increases in ϕ
  - Pass-through depends uniquely on $\{\varepsilon, \phi, \sigma\}$

Frequency of Price Adjustment

- Definition: probability of price adjustment

$$\Phi = \Pr\left\{(a, e) : \mathrm{L}(a, e) > \kappa\right\}$$

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$$= \tfrac{1}{2}(\sigma-1)\Psi\big(-a+\phi e\big)^2,$$

  - Recall that $\Psi = 1/\big[1+\frac{\varepsilon}{\sigma-1}\big]$
  - An increase in ε flattens out profit function
  - Two effects: curvature vs. pass-through

Summary: Frequency and Pass-through

- Exchange Rate Pass-through:

$$\Psi_e = \phi\Psi = \frac{\phi}{1 + \frac{\varepsilon}{\sigma - 1}}$$

- Frequency:

$$\Phi \approx \Pr\left\{ |X| > \sqrt{\frac{2}{(\sigma-1)\Psi}\frac{\kappa}{\Sigma}} \right\}, \qquad \Sigma \equiv \sigma_a^2 + \phi^2\sigma_e^2,$$

  — $X \equiv (-a + \phi e)/\sqrt{\Sigma}$ is a normalized RV, e.g. $\mathcal{N}(0,1)$

  — Frequency increases in Ψ, Σ, σ and decreases in κ

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- Positive relationship between Ψ_e and Φ can be induced by:
  - Variation in ε
  - Variation in σ if $\varepsilon > 0$
  - Variation in ϕ: limited by σ_e^2/σ_a^2

Dynamic Model

- Dynamic menu cost model with domestic and foreign firms
- Two sources of shocks:
  - idiosyncratic productivity shocks
  - exchange rate shocks (semi-aggregate)
- Wage-based real exchange rate: $E = W^*/W$
- Partial equilibrium: wage rate is given exogenously

Firms: Demand and Cost Function

- Demand: Kimball consumption aggregator in each sector

$$\frac{1}{|\Omega|}\int_{\Omega}\Psi\left(\frac{|\Omega|C_{js}}{C_s}\right)dj = 1, \qquad |\Omega| = 1+\omega$$

- Marginal cost:

$$MC_{jt} = \frac{W_t^{(1-\phi)}W_t^{*\phi}}{A_{jt}},$$

A_{jt} is the idiosyncratic productivity shock:

$$a_{jt} = \rho_a a_{j,t-1} + \sigma_a u_{jt}, \qquad u_{jt} \sim iid\ \mathcal{N}(0,1)$$

- $j \in \Omega$, $|\Omega| = 1+\omega$ firms:
  - $[0,1]$ domestic firms with $\phi = 0$
  - $[1, 1+\omega]$ foreign firms with $\phi \in (0,1]$

Dynamic Price Setting

- State vector for firm j:

$$\mathbb{S}_{jt} = (P_{j,t-1}, A_{jt}; P_t, W_t, W_t^*)$$

- Bellman Equations for the Value of the Firm:

$$\begin{aligned} V_j^N(\mathbb{S}_t) &= \Pi_{jt}(P_{j,t-1}) + \mathbb{E}_{\mathbb{S}_{t+1}|\mathbb{S}_t} Q(\mathbb{S}_{t+1}) V_j(\mathbb{S}_{t+1}) \\ V_j^A(\mathbb{S}_t) &= \max_P \left\{ \Pi_{jt}(P) + \mathbb{E}_{\mathbb{S}_{t+1}|\mathbb{S}_t} Q(\mathbb{S}_{t+1}) V_j(\mathbb{S}_{t+1}) \right\}, \\ V_j(\mathbb{S}_t) &= \max \left\{ V_j^N(\mathbb{S}_t), V_j^A(\mathbb{S}_t) - \kappa_{jt} \right\} \end{aligned}$$

- Policy Function:

$$\bar{P}_j(\mathbb{S}_t) = \arg\max_P \left\{ \Pi_{jt}(P_{jt}) + \mathbb{E}_{\mathbb{S}_{t+1}|\mathbb{S}_t} Q(\mathbb{S}_{t+1}) V_j(\mathbb{S}_t) \right\}$$

$$P_{jt} = \begin{cases} P_{j,t-1}, & V_{jt}^N > V_{jt}^A - \kappa_{jt}, \\ \bar{P}_{jt}, & \text{otherwise.} \end{cases}$$

Simulation Procedure

- Bellman Operator Iteration on a Grid:
  - Grids for P_j, P, E, A

- Simulation of Prices for $N = 12,000$ domestic and foreign firms for $T = 120$ months repeated 100 times
  - Firms have random lives in the sample with an average number of price adjustments equal to 3.5

- Two fixed point problems:
  - Price level:

$$\ln P_t(E_t) = \int_{j=0}^{N} \ln P_{jt}(P_t, A_{jt}, E_t) dj$$

  - Forecasting Rule:

$$\mathbb{E}_t \ln P_{t+1} = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \mathbb{E}_t \ln E_{t+1}$$

Baseline Calibration

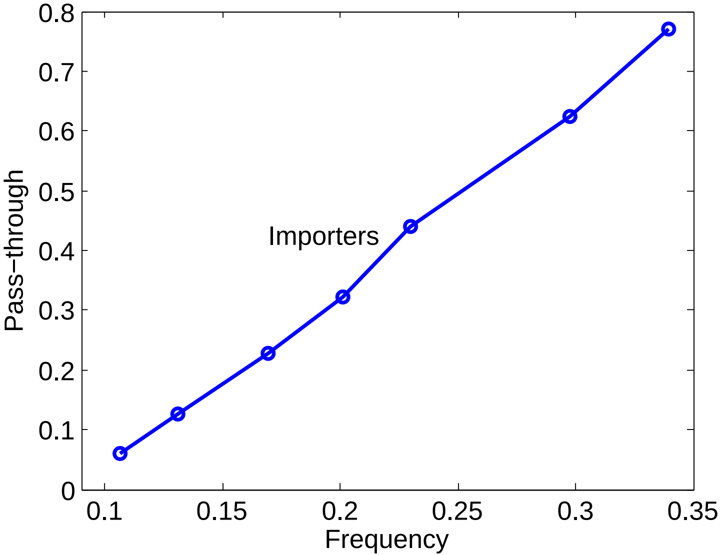
Klenow and Willis (2006) specification:

$$\psi(x) \equiv \Psi'^{-1}(x) = \left[1 - \varepsilon \ln x\right]^{\sigma/\varepsilon}, \qquad x \equiv P_{jt}/P_t$$

Parameter	Symbol	Values
Discount factor	δ	$0.96^{1/12}$
Menu Cost	κ	2.5%
Exchange Rate Shock	Δe	2.5%
Idiosyncratic Shock	σ_a	8.5%
	ρ_a	0.95
Fraction of Imports	$\omega/(1+\omega)$	16.7%
Cost Sensitivity to W^*	ϕ	0.75

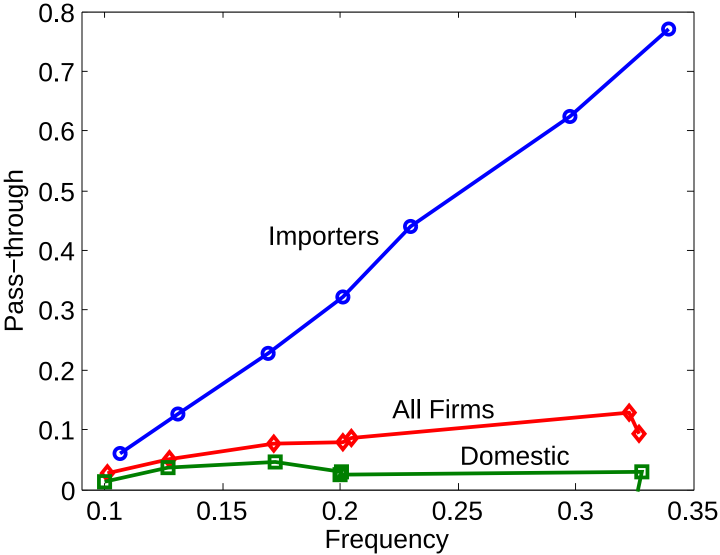
Frequency and Pass-through

Variation in $\varepsilon \in [0, 40]$



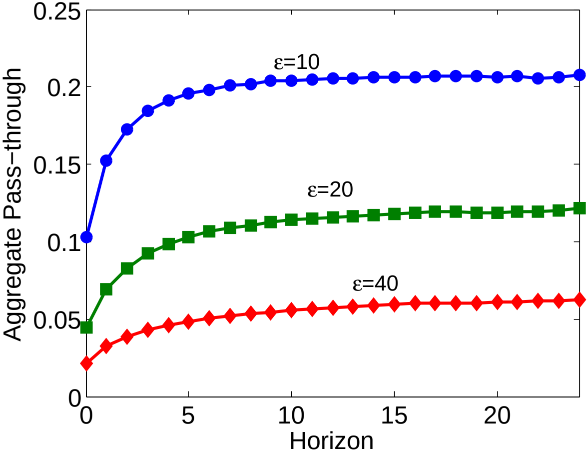
Frequency and Pass-through

Import Prices vs. Consumer Prices



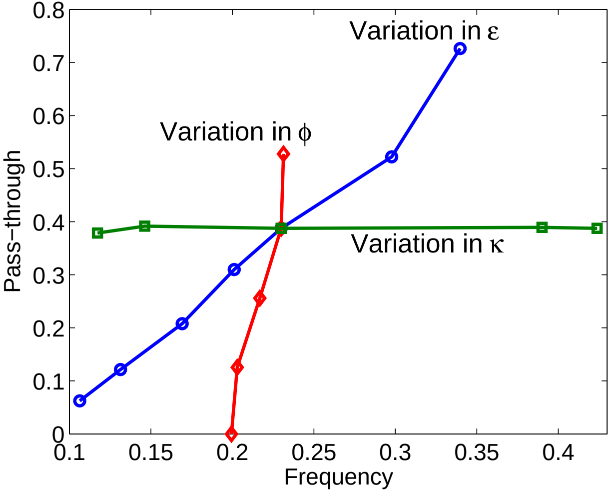
Aggregate Pass-through Regressions

Varying ε



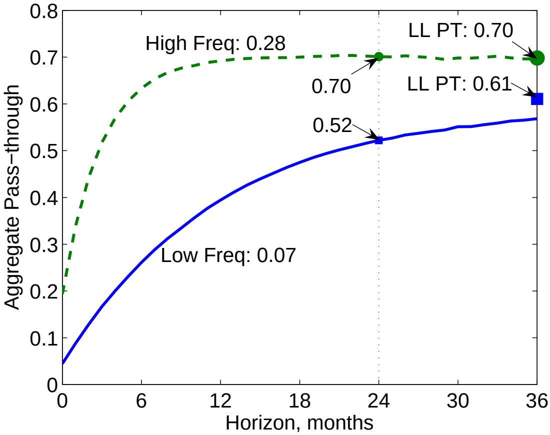
Frequency and Pass-through

Effect of $\phi \in [0, 1]$ and $\kappa \in [0.5\%, 7.5\%]$, $\varepsilon = 4$



Calvo

$\sigma = 5$, $\varepsilon = 0$



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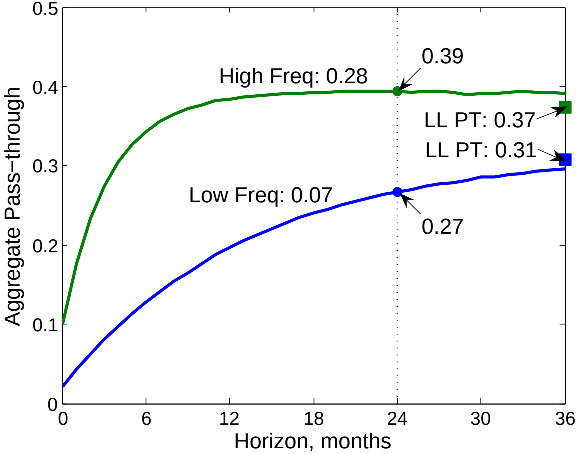
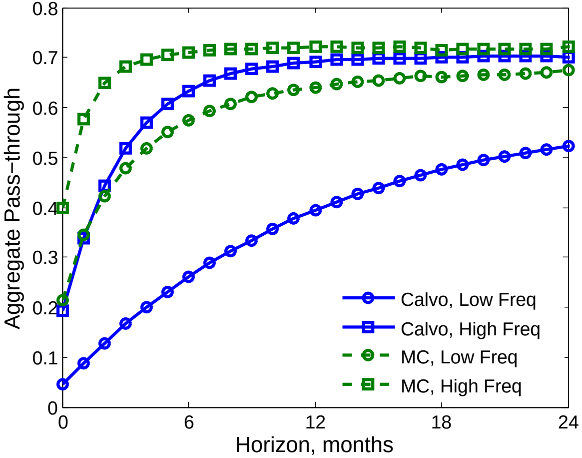
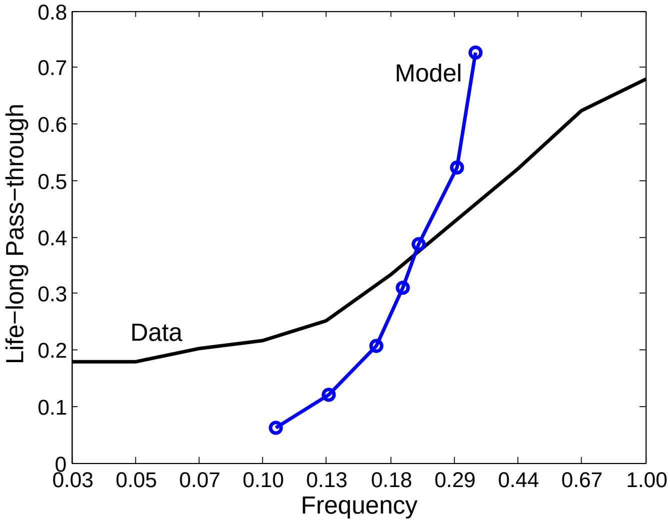


Calvo vs Menu Cost



Model vs Data

Frequency and Pass-through



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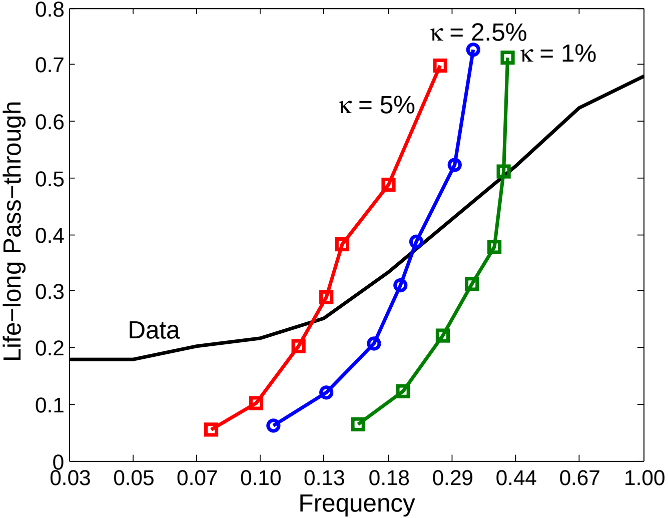

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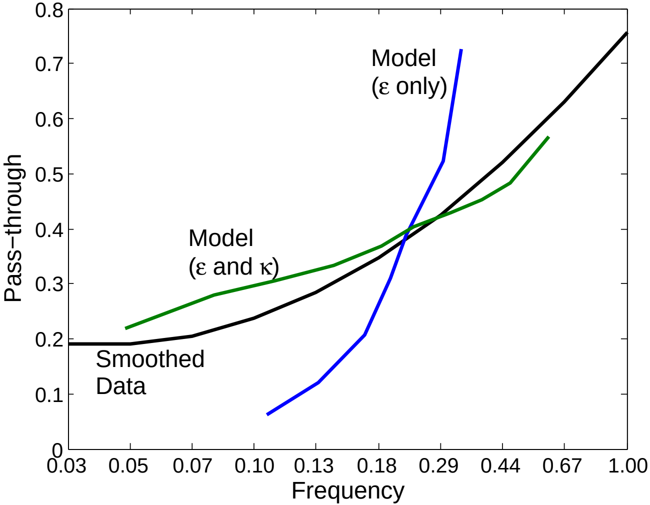
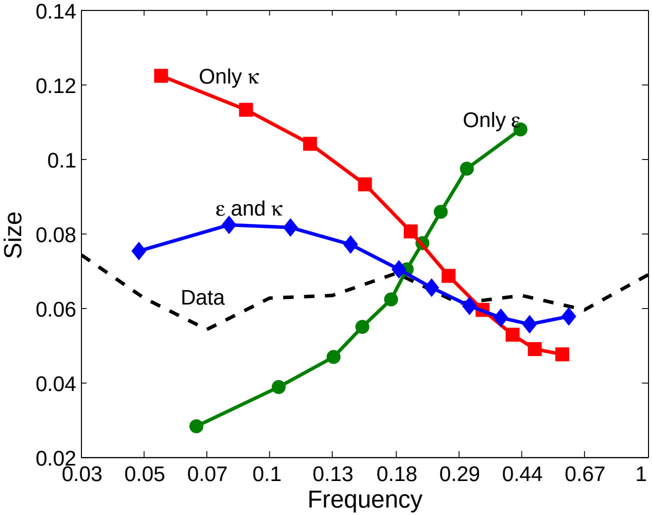


Model vs Data

Frequency and Size



Model vs Data

Summary

	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

Conclusion

- Exploit the open economy context to understand frequency and dynamic response to cost shocks

- Document a positive relationship between LRPT and frequency:
  - As frequency increases from 0.03 to 1, pass-through increases from 0.15 to 0.75

- Models with incomplete pass-through and endogenous frequency choice are consistent with this pattern, while standard CES-Calvo framework is not

- Variable mark-ups generate quantitatively large variation in frequency

Pass-through and Currency Choice