Frequency of Price Adjustment and Pass-through

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Introduction

- Recent surge in the micro-level studies of the frequency of price adjustment
  - Significant heterogeneity in frequency even for similar goods
- Primitive determinants of frequency are difficult to measure
  - Menu Costs
  - Volatility of Shocks
  - Curvature of the Profit Function

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  - International data is particularly useful as it provides an observable cost shock and allows to measure pass-though
  - Pass-through vs Size of price adjustment

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- We exploit the fact that pass-through of the cost shocks is shaped by the same primitives
  - International data is particularly useful as it provides an observable cost shock and allows to measure pass-though
  - Pass-through vs Size of price adjustment
- By studying the link between frequency and pass-through we:
  1. Explain variation in frequency and pass-through
  2. Test theories of price setting
  3. Shed light on a new selection effect

Main Findings

- New empirical fact: Robust positive relation between frequency and "long-run" pass-through
  - Exchange rate pass-through increases from 15% to 70% from first to tenth frequency deciles
- Selection Effect: High frequency adjusters have long-run pass-through that is twice as high as low frequency adjusters
  - Implications for the amount of nominal rigidity
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  - Implications for the amount of nominal rigidity
  - Different from the Caplin-Spulber selection effect
- We show analytically that variable mark-ups generate a positive relation between frequency and pass-through
- We then calibrate and simulate a dynamic menu cost model to show:
  - Variable mark-ups generate quantitatively large effects and can explain a significant share of variation in frequency
  - To match the facts need a model with endogenous frequency and variable mark-ups

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
- Our sample:
  - Dollar priced goods (90% of all goods)
  - Manufactured Goods
  - Market Transactions
  - Crop Outliers (0.5%)

Long-Run Pass-through Estimates

- Life-long Micro-Regressions:

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

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  - We need to avoid a potential mechanical link between frequency and pass-through
  - Later we run the same regressions on model-generated data

Life-Long Micro-Regressions

All Countries

	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
Manufacturing				
– Low Frequency	0.07	0.17	0.02	5111
– High Frequency	0.39	0.33	0.03	5078
Differentiated				
– Low Frequency	0.07	0.16	0.03	2655
– High Frequency	0.29	0.35	0.03	2573

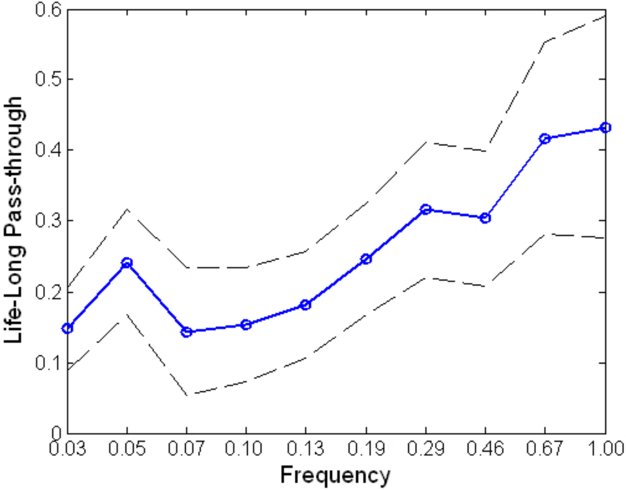
Life-Long Micro-Regressions

High-Income OECD Subsample

	Median Freq.	β_{LR}	$\sigma(\beta_{LR})$	N
Manufacturing				
– Low Frequency	0.07	0.21	0.03	3000
– High Frequency	0.40	0.50	0.05	2867
Differentiated				
– Low Frequency	0.07	0.20	0.04	1503
– High Frequency	0.33	0.51	0.05	1461

Life-long Pass-through

Frequency Deciles, All Countries



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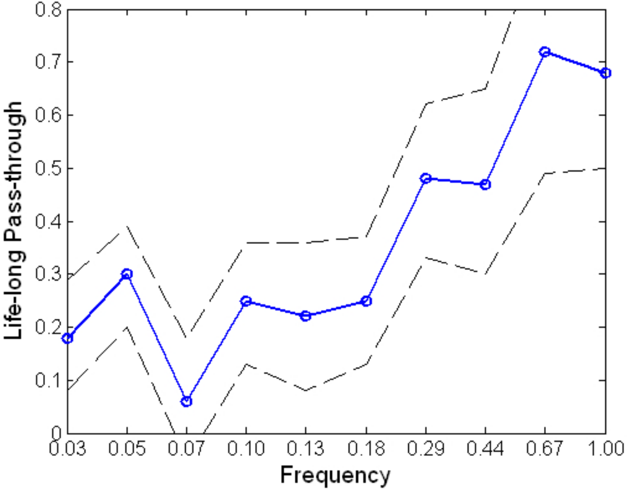
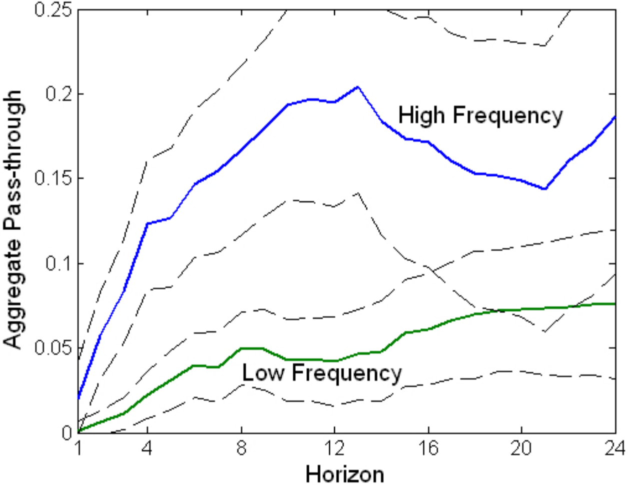


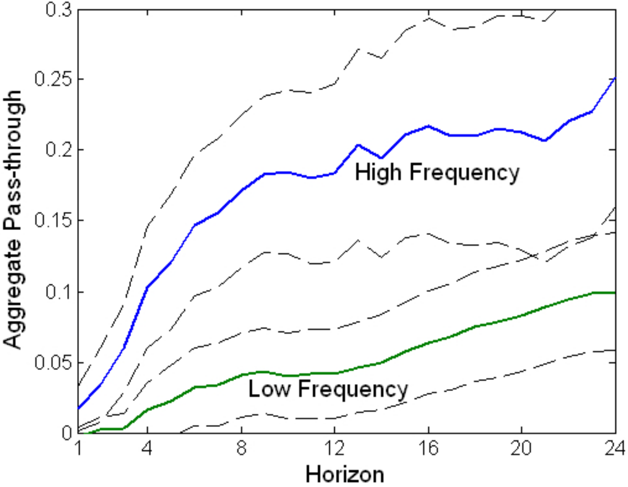
Aggregate Pass-through Regressions

All Countries , Manufactured Goods



Aggregate Pass-through Regressions

All Countries , Differentiated Goods



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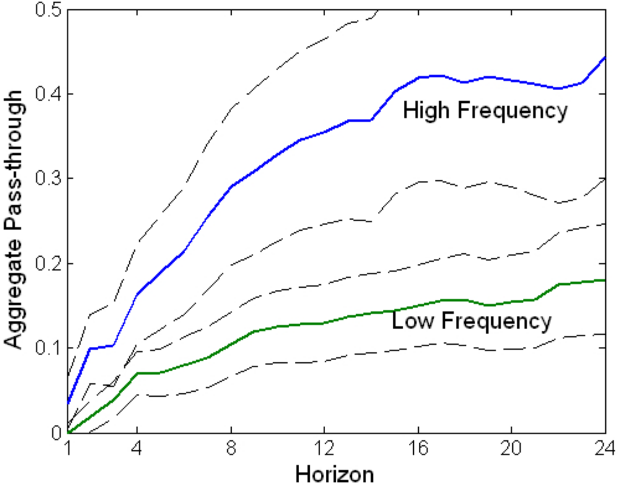
High-Income OECD Subsample, Manufactured Goods



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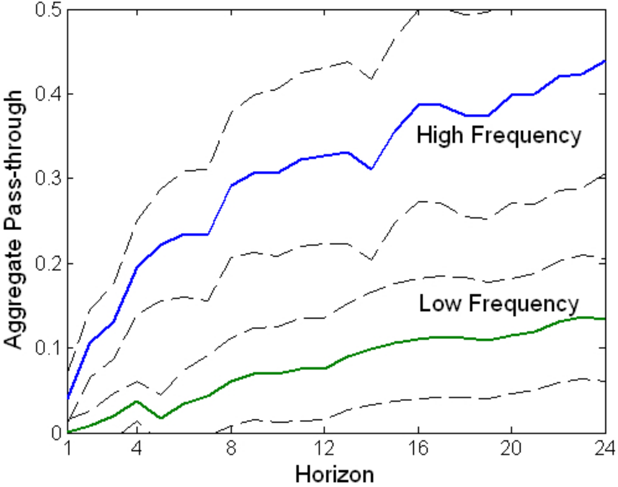

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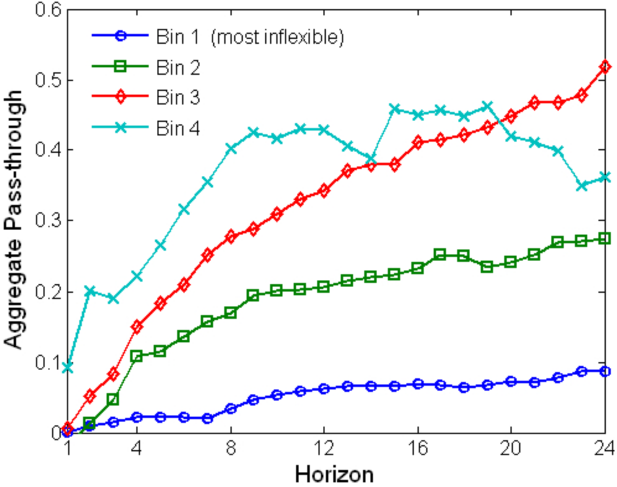
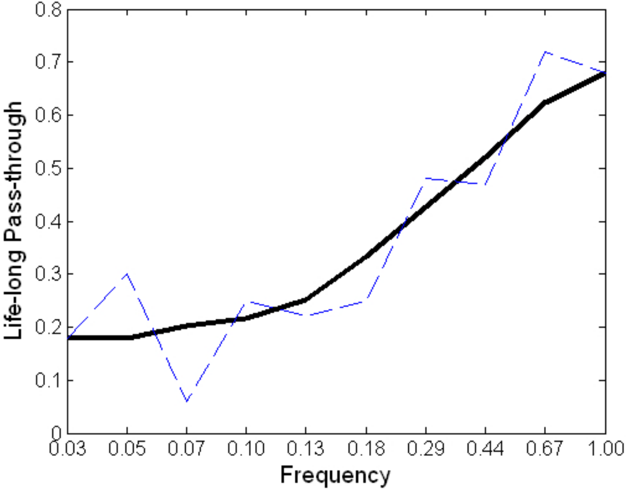


Summary Slide

Relation between Frequency and Pass-through

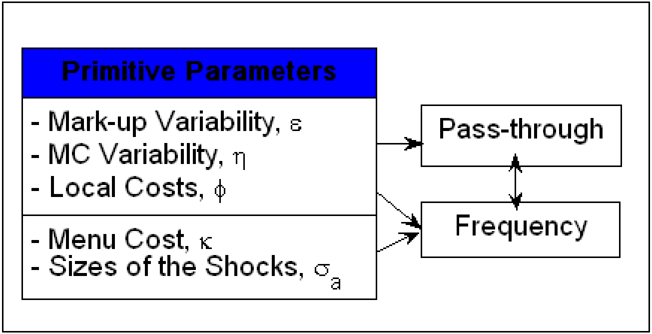


Substitutions/Product Replacement

Percentiles	Freq	Freq plus subs1	Freq plus subs2
1	0.03	0.05	0.05
2	0.05	0.07	0.08
3	0.08	0.09	0.10
4	0.10	0.12	0.13
5	0.13	0.15	0.16
6	0.19	0.21	0.22
7	0.29	0.30	0.31
8	0.46	0.47	0.48
9	0.67	0.67	0.68
10	1.00	1.00	1.00

Table: Frequency including Substitutions

Frequency and Pass-through



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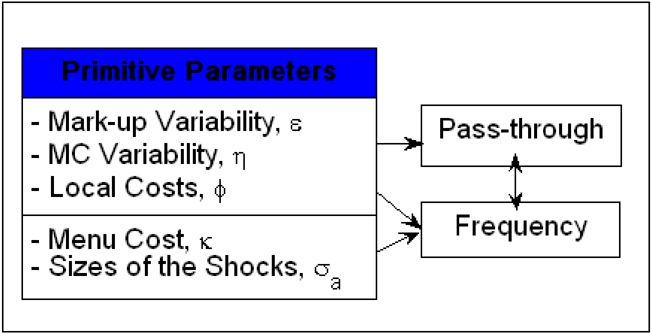

- Sources of variable mark-ups:
  - Curvature of demand (e.g., Kimball demand)
  - Strategic Complementarities (Atkeson and Burnstein, 2005)

Analytical Model

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

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- 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: $\tilde{\sigma}(1) = \sigma$, $\tilde{\varepsilon}(1) = \varepsilon$, $\varphi(1) = 1$

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.

- Profit Function:

$$\Pi(p|a,e) = p\varphi(p) - C\big(\varphi(p)|a,e\big)$$

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:

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

Exchange Rate Pass-through

- Definition:

$$\Psi_e \equiv \frac{\partial \ln p(a,e)}{\partial \ln(1+e)}\Big|_{a=0} = \lim_{\substack{e\to 0\\ a=0}} \frac{\ln p(a,e) - \ln \bar{p}_0}{e},$$

- Result:

$$\Psi_e = \phi \cdot \Psi, \qquad \Psi \equiv \frac{1}{1+\frac{\varepsilon}{\sigma-1}},$$

- Response to cost shock decomposition:
  - Reduction in mark-up: $\frac{\varepsilon}{\sigma-1}$ is mark-up elasticity
  - Reduction in marginal-cost: absent here
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Proposition

Exchange rate pass-through, Ψ_e, depends uniquely on $\{\sigma, \varepsilon, \phi\}$. It is increasing in ϕ and decreasing in ε. It increases in σ if $\varepsilon > 0$ and is constant otherwise.

Frequency of Price Adjustment

- Definition: probability of price adjustment

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$$= \tfrac{1}{2}(\sigma-1)\Psi\big(-a+\phi e\big)^2 + h.o.t.$$

$$\Phi \approx \Pr\left\{|-a+\phi e| > \sqrt{2\kappa/[(\sigma-1)\Psi]}\right\}, \qquad \Psi = \frac{1}{1+\frac{\varepsilon}{\sigma-1}}$$

Proposition

Frequency of price adjustment decreases with ε and increases with ϕ and σ. Additionally, it decreases with κ and increases with σ_a and σ_e.

Example: Klenow-Willis Demand Specification

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

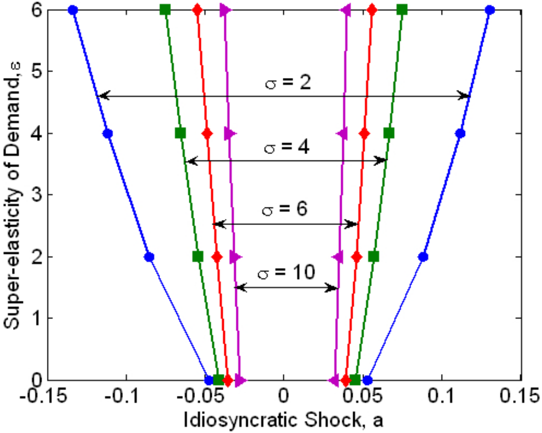

Figure: No Adjustment Region

Summary: Frequency and Pass-through

- Pass-through:

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

- Frequency:

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

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- Positive relationship between Ψ_e and Φ can be induced by:
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  - Variation in σ if $\varepsilon > 0$
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- Size of price adjustment:
  - Increases in Ψ (and ϕ)
  - Increases in Σ
  - Increases in κ

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- We use Klenow and Willis (2006) specification:

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

Firms: Cost Function and Profits

- Marginal cost of the firm:

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

where A_{jt} is the idiosyncratic productivity shock:

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

- Profit function of the firm:

$$\Pi_{jt}(P_{jt}) = \left[P_{jt} - MC_{jt}\right] \cdot \psi\left(\frac{P_{jt}}{P_t}\right) \frac{C_t}{|\Omega|}$$

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

- Wage-based real exchange rate: $E = W^*/W$

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:

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

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

Calibration

Parameter	Symbol	Values
Discount factor	δ	$0.94^{1/12}$
Menu Cost	κ	$\{1\%, 2.5\%, 5\%\}$
Idiosyncratic Shock	σ_a	8.5%
	ρ_a	0.95
Exchange Rate Shock	Δe	2.5%
Fraction of Exporters	ω	20%
Local Cost Parameter	ϕ	0.75
Demand Parameters	σ	$\{1.5, 3, 5, 10\}$
	ε	$\{0, 2, 4, 6, 10, 20, 40\}$

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
  - Firms have random live in the sample of 3.5 years on average

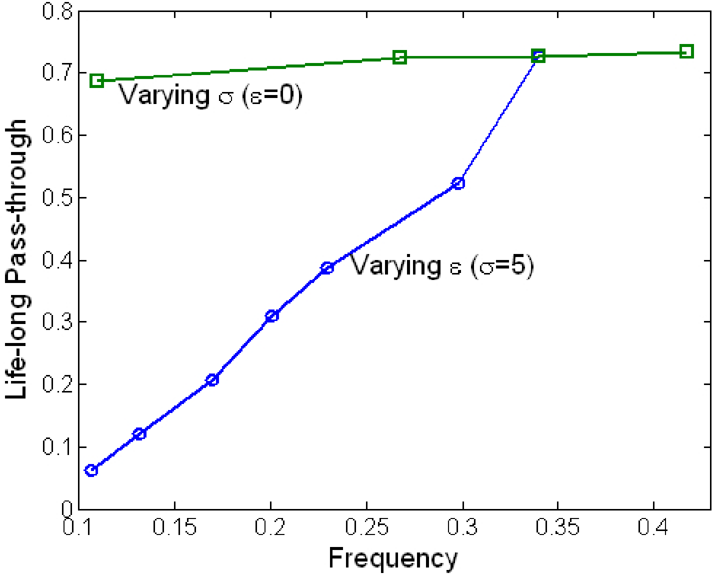
- Two fixed point problems:
  - Price level:

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

  - Forecasting Rule:

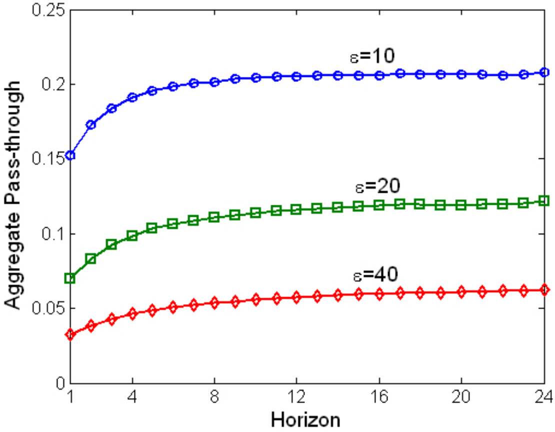
$$\mathbb{E}_t \ln P_{t+1} = \gamma_0 + \gamma_1 \ln P_t + \gamma_2 \mathbb{E}_t \ln E_{t+1}$$

Model: Frequency and Pass-through



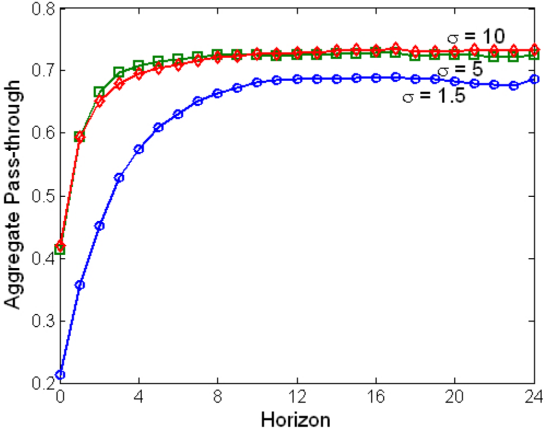
Model: Aggregate Pass-through Regressions

Varying ε



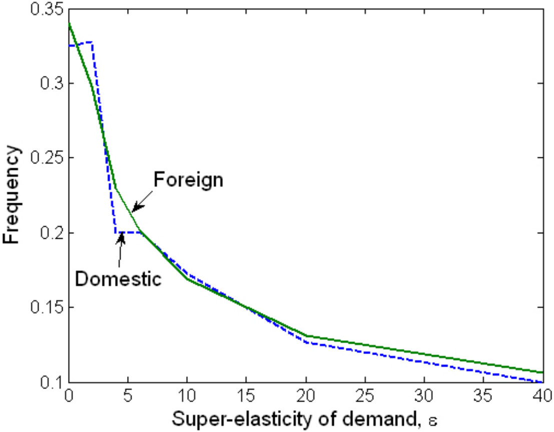
Model: Aggregate Pass-through Regressions

Varying σ



Model: Frequency

Domestic Versus Foreign Firms



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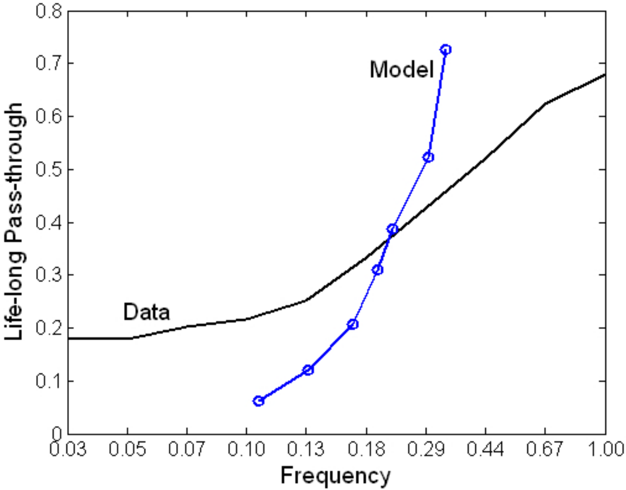

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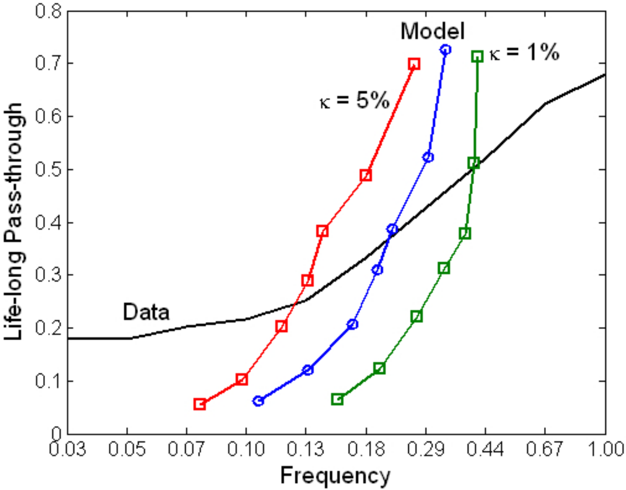

Conclusion

- Use the open economy context to study the determinants of the frequency of price adjustment
- Document a positive relationship between LR pass-through and frequency:
  - As frequency increases from 0.03 to 1, pass-through increases from 0.15 to 0.7
- Test which theories help best fit the data:
  - Models with CES and Calvo pricing do not work
  - Need combination of endogenous frequency and variable mark-ups
- Things to do:
  - Provide a decomposition for the role of the various factors affecting frequency (ε versus κ)
  - Access the importance of the documented selection effect