International Menu Costs and Price Dynamics

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Outline

- **Motivation**
- **Empirics**
  - New Evidence on Price Dynamics
  - Robustness Checks
- **Model**
  - Estimation
  - Results
- **Conclusion**

Motivation

Research Question:

How do firms set prices for the same products in the domestic and the export markets?

(Part of bigger agenda on how firms set prices.)

Motivation

Why do we care?

Particular Motivation:

- One new stylized fact: domestic prices change twice as often as export prices
- Benigno (2004): can explain PPP puzzle if domestic and export prices adjust at different frequencies
- New fact directly speaks to this way of explaining PPP puzzle

Motivation

Why do we care?

General Motivation:

- Provide guidance how to model pricing behavior of firms
- Small changes in assumptions can have large implications
  - Explanation for PPP puzzle: Benigno (2004)
  - Inter-country heterogeneity generates real output effects like intra-country heterogeneity: Carvalho (2006), Nakamura and Steinsson (2008)
  - Welfare implication - optimal monetary policy in open economies targets inflation according to stickiness of prices: Aoki (2001), P. Benigno (2004)

Why do we care?

General Motivation:

- Reconsider standard assumptions:
  - Identical domestic and export Calvo parameters?
  - Complementarity in menu cost technology?
  - Simultaneous adjustment across markets?
- Some evidence for state-dependent pricing

Related Literature

- Gopinath and Rigobon (2008), Neiman (2009), Nakamura and Steinsson (2008)
- European Inflation Network: Vermeulen et al. (2007)
- Barsky and Miron (1989), Olivei and Tenreyro (2007)
- Blinder et al. (1998), Zbaracki (2004)
- Gopinath et al. (2008), Gopinath and Itskhoki (2010), Fitzgerald and Haller (2008)

Empirical Analysis

1. **How are domestic and export pricing behavior different?**
   - **Illustrative evidence from The Economist**
   - Evidence from BLS micro-data

Empirical Analysis: The Economist

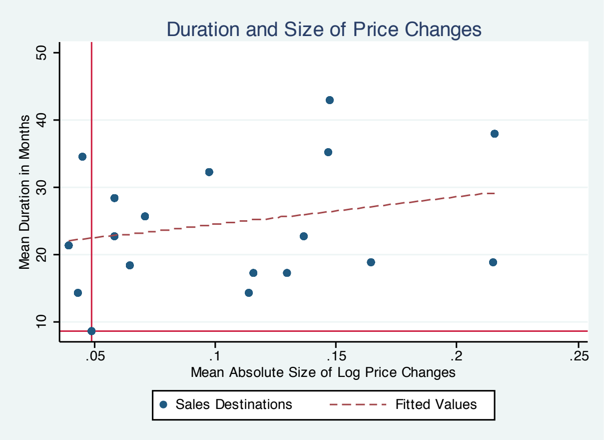


Figure: Duration and Size of Price Changes, The Economist

Empirical Analysis: The Economist

Table: Frequency and Size of Price Changes, The Economist

	Domestic	Exports
Frequency	11.67%	4.49%
	(-)	(0.16%)
Duration	8.57	22.22
	(1.83)	(1.95)
$\|\Delta p\|$	4.92%	10.32%
	(0.75%)	(1.08%)
r_f	2.65	
	(0.38)	
$r_{\Delta p}$	2.31	
	(0.49)	
Spells	15	83

Empirical Analysis

1. **How do domestic and export pricing behavior differ?**
    - Illustrative evidence from the Economist
    - **Evidence from BLS micro-data**

Empirical Analysis: BLS Micro Data

BLS micro price data:

- Data underlying U.S. PPI and U.S. IPP (export index)
- Producer prices - no consumer prices
- Monthly transaction prices - Stigler and Kindahl (1970)
- Prices exclude intra-firm prices ("transfer pricing")
- Prices exclude 'lumpy trade' prices
- USD-denominated exports (98.5%)
- Individual "items" such as "Rug; 100% New Zealand wool; hand-tufted; hand-hooked; style name: XXX"
- Time frame: 1998-2005

Empirical Analysis: BLS Micro Data

How do I compare domestic and export prices?

Goal - compare pricing behavior along these dimensions:

- Frequency of price change
- Size of price change
- Probability of synchronization
- Seasonality (monthly)

Strategy:

- Compute statistics for each item
- Aggregate up to common categories:
  - six-digit product level
  - product-firms
- Compute ratio and difference of domestic and export statistic

Example: Frequency Comparison

Hypothetical price series:

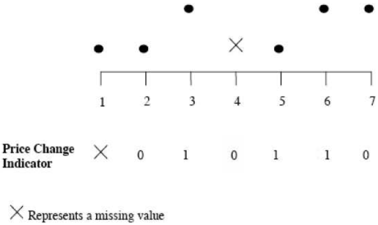


Figure I
A Hypothetical Price Series for a good

Empirical Analysis: BLS Micro Data

Example: Frequency Comparison

- Compute frequency for each item
- Take median across items in next higher classification
- Take median within product/firm/destination category
- Compute ratio $r^f = \frac{f^X}{f^D}$
- Report (un)weighted median

Use two methods robust to missing values:

- Method II: Fraction of price changes, Aucremanne and Dhyne (2004)
- Method III: Hazard model, Neiman (2008)

Explaining Differential Export Pricing

1. **Export pricing is systematically different**
2. What explains differential export pricing behavior?

Empirical Analysis: BLS Micro Data

Surprising, large differences in export pricing behavior:

- Domestic sales prices change twice as often as export prices
- Upwards (downwards) synchronization probability is 0.21 (0.14)
- New seasonality effect: year-end synchronization
- Export price changes are substantially larger

Empirical Analysis: BLS Micro Data

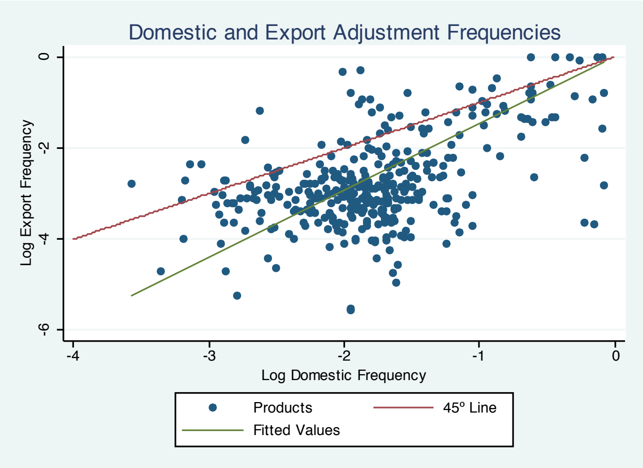


Figure: Frequency of Price Adjustment

Table: Frequency and Implied Duration, Domestic and Export Sales

		Domestic	Export I	Export II
Unweighted				
Frequency	Mean	20.9%	11.5%	11.6%
	Median	16.3%	5.5%	6.0%
	Std. Error	0.9%	0.9%	0.3%
Implied Duration	Mean	6.64	20.53	20.49
	Median	5.60	17.84	16.23
	Std. Error	0.25	0.83	0.32
Weighted				
Frequency	Mean	28.9%	13.3%	12.7%
	Median	18.5%	6.4%	6.9%
	Std. Error	1.3%	1%	0.3%
Implied Duration	Mean	5.55	18.16	18.52
	Median	4.88	15.12	13.99
	Std. Error	0.24	0.79	0.34
	N	354	354	2731

Table: Frequency and Duration, Direct Comparison

			Mean	Median	Std. Error	N
Exports I	Method I	r^f	0.5448	0.3796	0.0327	354
		Δd	14.01	10.89	0.81	354
	Method II	r^f	0.7277	0.4721	0.0430	354
		Δd	12.66	7.39	1.16	354
	Method III	r^f	0.7798	0.5915	0.0305	354
		Δd	5.89	4.56	0.71	354
Exports II	Method I	r^f	0.5673	0.4102	0.0284	2731
		Δd	11.20	9.33	0.58	2731
	Method II	r^f	0.6456	0.4155	0.0378	2715
		Δd	9.74	6.77	0.74	2715
	Method III	r^f	0.7359	0.5576	0.0292	2715
		Δd	5.06	4.95	0.36	2715

Are price changes synchronized across markets?

Table: Export-Domestic Synchronization Probabilities

	$Prob_{Up\|Up}$	$Prob_{Down\|Down}$
Product	20.81%	14.14%
	(2.16)	(2.17)
Product-Destination	20.37%	13.76%
	(2.19)	(2.24)
Benchmark	47.48%	50.31%
	(2.93)	(2.42)
N	768	67

Empirical Analysis: BLS Micro Data

Are price changes synchronized across markets?

Alternative to conditional adjustment probabilities.

Estimate synchronization equations:

$$I(\Delta p^{X}_{i,j,t} \geq 0) = \beta_0 + \beta_1^{X+} f^{D+}_{i,t} + \epsilon_{i,j,t}$$
$$I(\Delta p^{D}_{i,j,t} \geq 0) = \beta_0 + \beta_1^{D+} f^{D+}_{i,t} + \epsilon_{i,j,t}$$

Similarly for downwards adjustments.

Empirical Analysis: BLS Micro Data

Are price changes synchronized across markets?

Table: Strength of Synchronization from Sychronization Regressions

	β_1^{D+}	β_1^{X+}	β_1^{D-}	β_1^{X-}
Product	0.71337	0.10137	0.70622	0.05407
	(0.01493)	(0.01609)	(0.01602)	(0.01417)
Product-Destination	0.71337	0.15174	0.70622	0.04437
	(0.01493)	(0.04869)	(0.01602)	(0.02192)

Empirical Analysis: BLS Micro Data

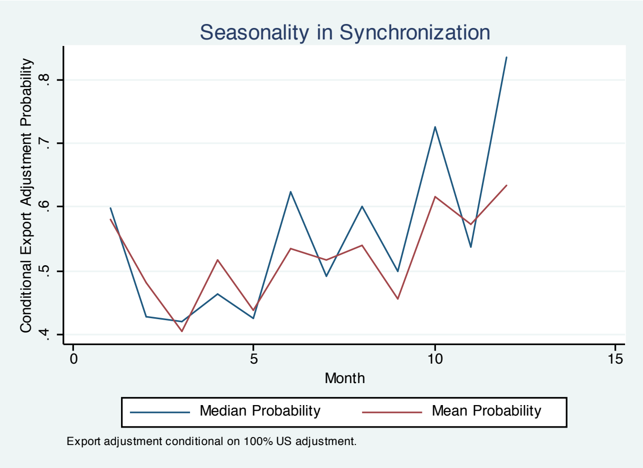


Figure: Seasonality in Synchronization

Empirical Analysis: BLS Micro Data

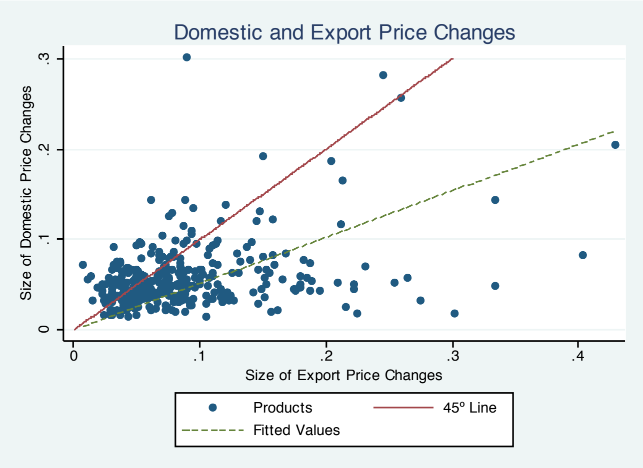


Figure: Size of Domestic and Export Price Changes, by Products

Empirical Analysis: Robustness

Fuzzy matching

- Matching exporting firm names to domestic
  - String manipulations and matching
  - Additional bigram string similarity comparisons
  - No city-state requirements
  - Manual quality verification
- Matching rate of 10%

Empirical Analysis: Robustness

Table: Firm-Level Comparison

	Frequency		Duration		$\lvert\Delta p\rvert$	
	Domestic	Exports	Domestic	Exports	Domestic	Exports
Median	15.91%	6.27%	5.77	15.46	4.60%	9.57%
	(0.64%)	(0.06%)	(0.26)	(0.16)	(0.45%)	(0.66%)
Ratio	0.4840		0.4520		2.48	
	(0.0356)		(0.0354)		(0.43)	
Difference	0.0675		7.38		3.10%	
	(0.0085)		(0.80)		(0.38%)	
N	381	381	381	381	381	381

Empirical Analysis: Robustness

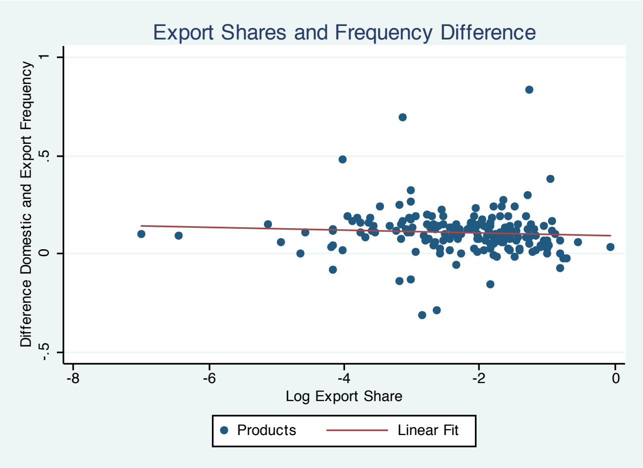


Figure: Frequency Differential and Export Share

Empirical Analysis: Robustness

Table: Firm-Level Comparison, Largest Sales-Item

	Frequency		Duration		$\lvert\Delta p\rvert$	
	Domestic	Exports	Domestic	Exports	Domestic	Exports
Median	15.15%	6.27%	6.09	15.46	4.89%	9.57%
	(0.54%)	(0.06%)	(0.23)	(0.15)	(0.35%)	(0.66%)
Ratio	0.48		0.47		2.33	
	(0.05)		(0.48)		(0.17)	
Difference	5.94%		7.26		2.34%	
	(0.99%)		(1.12)		(0.68%)	
N	381	381	381	381	381	381

Surprising, large differences in export pricing behavior:

- Domestic sales prices change twice times as often as export prices
- Synchronization probability is low
- New seasonality effect: year-end synchronization
- Export price changes are substantially larger
- Robustness to selection bias

Explaining Differential Export Pricing

1. Export pricing is systematically different
2. **What explains differential export pricing behavior?**

Explaining Differential Export Pricing

Strategy:

- Use dynamic menu cost model to relate pricing decisions to fundamentals
- Attribute differences in domestic and export pricing behavior to differences in menu costs
- Back out menu costs in estimation exercise, taking moments from data and controlling for characteristics of fundamentals

Model

- Firm selling in two segmented markets, Home H and Foreign F
- Linear production technology:

$$Y_t = A_t L_t \tag{1}$$

$$\ln A_t = \rho_A \ln A_{t-1} + \epsilon_{A,t} \tag{2}$$

with $\epsilon_{A,t}$ i.i.d. normal, $E[\epsilon_{A,t}] = 0$ and $var(A_t) = {\sigma_A}^2 > 0$

- Real wage normalized to $\frac{\theta-1}{\theta}$
- Domestic demand:

$$c_t^H = C^H \left(\frac{p_t^H}{P_t^H} \right)^{-\theta} \tag{3}$$

- Foreign demand:

$$c_t^F = C^F \left(\frac{p_t^F E_t}{P_t^F} \right)^{-\theta} = C^F \left(\frac{p_t^F}{P_t^H} \frac{P_t^H E_t}{P_t^F} \right)^{-\theta} = C^F \left(\frac{p_t^F}{P_t^H} Q_t \right)^{-\theta} \tag{4}$$

Model

- Home price level:

$$\ln P_t^H = \mu^H + \ln P_{t-1}^H + \eta_{P,t}^H \tag{5}$$

with i.i.d. normal shocks, $E[\eta_{P,t}^i] = 0$ and $var(\eta_{P,t}^H) = \sigma_{P,H}^2 > 0$

- Real exchange rate:

$$\ln Q_t = \rho_Q \ln Q_{t-1} + \epsilon_{Q,t} \tag{6}$$

with i.i.d. normal shocks $\epsilon_{Q,t}$, $E[\epsilon_{Q,t}] = 0$ and $var(Q_t) = \sigma_Q^2 > 0$

Model

- Home period profit functions

$$\pi_t^H = \left(\frac{p_t^H}{P_t^H} - \frac{1}{A_t} \right) C^H \left(\frac{p_t^H}{P_t^H} \right)^{-\theta} \tag{7}$$

- Foreign period profit functions

$$\pi_t^F = \left(\frac{p_t^F}{P_t^H} - \frac{1}{A_t} \right) C^F \left(\frac{p_t^F}{P_t^H} Q_t \right)^{-\theta} \tag{8}$$

- Firm's dynamic problem:
  - when to adjust
  - by how much to adjust

Model

- Recursive formulation of the problem:

$$V_i^{adj}(S_t^i) = \max_{p_t^i}\{\pi_t^i(p_t^i) - K^i + \beta E[V_i(S_{t+1}^i)]\} \tag{9}$$

$$V_i^{noadj}(S_t^i) = \pi_t^i(p_{t-1}^i) + \beta E[V_i(S_{t+1}^i)] \tag{10}$$

where

$$V_i(S_t^i) = \max\{V_i^{adj}(S_t^i), V_i^{noadj}(S_t^i)\} \tag{11}$$

- States $S_t^H = (p_{t-1}^H, P_t^H, A_t)$, $S_t^F = (p_{t-1}^F, P_t^F, A_t, P_t^H, E_t)$
- K^i is menu cost in $i \in \{H, F\}$, fraction of steady state revenues
- Numerical solution using projection methods: policy function $p(S_t^i)$

Model Estimation

Two steps

- Calibrate model with parameter values Ω_c from the data:
  - Productivity: NBER productivity database
  - Inflation: OECD MEI
  - Exchange rate: Oanda.com
  - Elasticity
- Use simulation-based maximum likelihood to estimate domestic and export market menu cost, given f and $\overline{|\Delta p|}$ in data

Model Estimation

Parameters in calibration

- U.S. productivity: $\rho_A = 0.96$, $\sigma_A = 2.1\%$
- U.S. inflation: $\mu_P = 0.21\%$, $\sigma_P = 0.37\%$ as in Nakamura and Steinsson (2008)
- Export real exchange rates: very persistent, large shocks. 23 countries, for example $\rho_{Q,UK} = 0.9763$, $\sigma_{Q,UK} = 1.83\%$
- Constant consumption levels
- $\beta = 0.96^{1/12}$
- Symmetric elasticity of $\theta = 4$
  Broda and Weinstein (2006): 3.2-3.7
- Constant real wages $\frac{W_t^H}{P_t^H} = \frac{\theta - 1}{\theta}$

Model Estimation

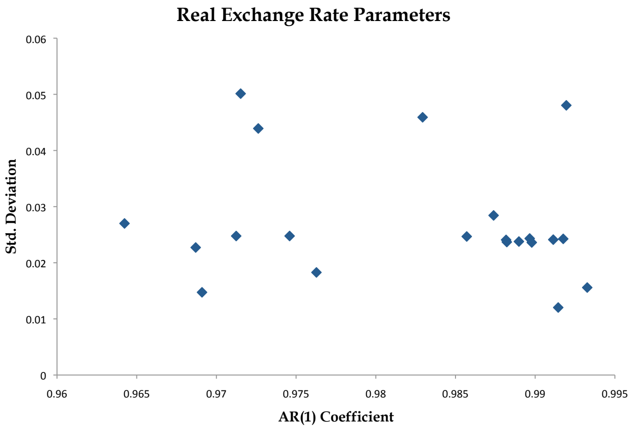


Figure: Real Exchange Rate Parameters

Model Estimation

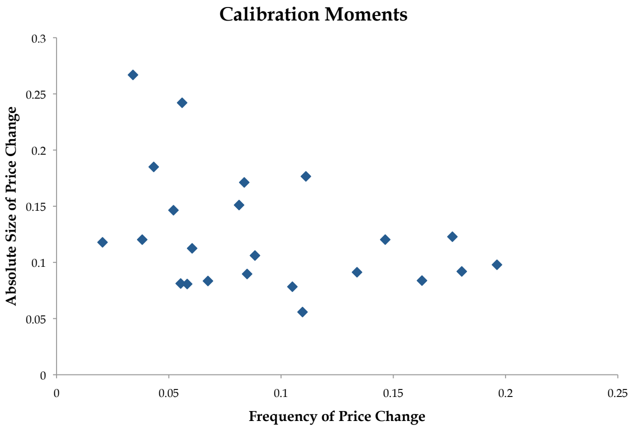


Figure: Calibration Moments

Model Estimation

Simulation-based maximum likelihood estimation:

- Pick a grid of menu costs $\{K_i\}$
- For each K_i, simulate many time series given parameters Ω_c
- For each time series, compute frequency and mean absolute size of price changes
- Find likelihood of K_i given data on frequency, mean absolute size of price change, or both: $L(K_i|\Omega_c, X_c)$
- Four maximum likelihood estimates of menu costs:
  - Country-specific:
    $K^*_{c,X} = argmax_{K_i} L(K_i|\Omega_c, X_c)$
  - Uniform across countries ($K^*_c = K^*$):
    $K^* = argmax_{K_i} \sum_c L(K_i|\Omega_c, X_c)$

Model Estimation

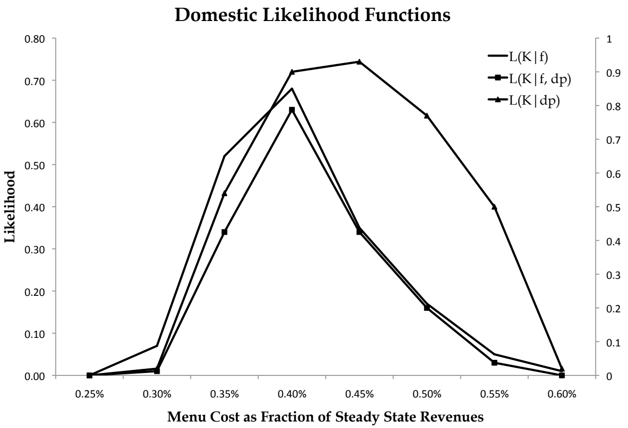


Figure: Likelihood of US Domestic Menu Costs

Model Estimation

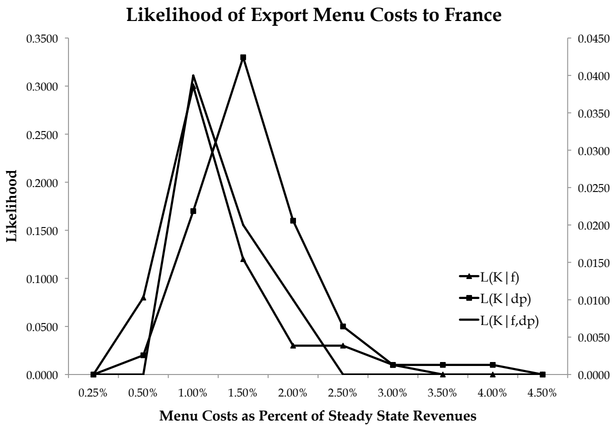


Figure: Likelihood of France Export Menu Costs

Model Estimation

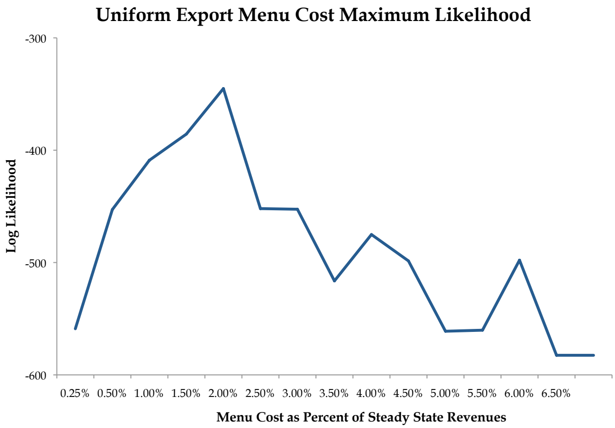


Figure: Log Likelihood of Uniform Export Menu Costs

Model Estimation

Table: Export Menu Cost Maximum Likelihood Estimates

	f	Δp	f, Δp	f, Δp, All Countries
Mean	1.97%	1.50%	1.85%	2%
Median	1.5%	1.5%	1.75%	2%
Std. Error	0.34%	0.16%	0.34%	-
Maximum	6.00%	3.00%	5.50%	
Minimum	0.25%	0.25%	0.50%	
N	23	23	17	17

Domestic menu cost estimate: 0.4%.

How well do the moments fit for ML menu costs?

Table: Fit of Moments under ML Menu Costs

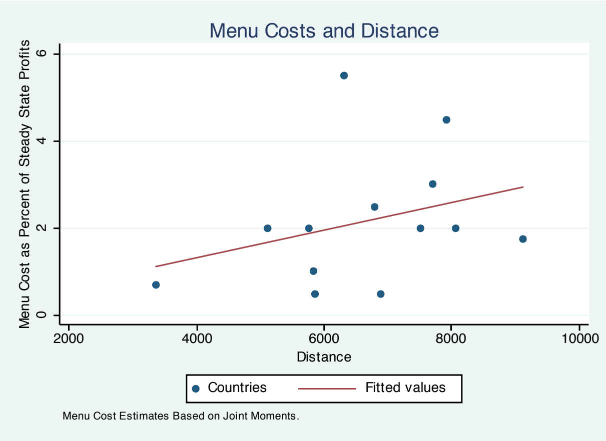
	Frequency	$\lvert\Delta p\rvert$
$\bar{x}$	0.0712	0.12616
$\hat{\bar{x}}$	0.0705	0.13241
σ	0.0262	0.05028
$\hat{\sigma}$	0.0274	0.06631

Interpretation

How to interpret menu costs?

- Cost of price adjustment, conditional on adjustment. Broadly understood, Blinder (1998)
- Higher managerial and customer communication costs for export price changes, Zbaracki (2004)
- Similar percentage range to 1.22%
- Test interpretation using distance and common language

How to interpret menu costs?



How to interpret menu costs?

Table: Menu Costs and Common Language

	$K^*_{c,3}$	$K^*_{c,2}$	$K^*_{c,1}$
Common Language			
No	2.02%	1.60%	2.15%
	(0.47%)	(0.20%)	(0.44%)
Yes	1.875%	1.25%	1.67%
	(0.125%)	(0.52%)	(0.44%)

Conclusion

Summary

- Surprising, large differences in export pricing behavior
  - Domestic prices change twice as often
  - Probability of synchronized adjustments is low
  - Synchronization is highly seasonal
  - Size of export price changes is substantially larger
- New facts link directly to macro puzzles, give modeling guidance
- Simulation exercise: export menu costs larger than domestic menu costs, 1.5% vs. 0.4%
- Interpretation in terms of economic geography

Future research

- Shocks travel at different times - explore implications for
  - Real exchange rate dynamics
  - Business cycle synchronization
  - Pass-through of productivity shocks
- What drives seasonality in the data?
- Use model to learn about export market structure