In Search of Real Rigidities

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NBER Macroannual
April 9–10, 2010

Motivation

- Long-lasting real effects of money (over 2 years)
- Frequent price adjustments (every 4-12 months)
- Need for real rigidities
  - aggregate (industry-level)
  - micro (firm-level)

- Question: Are (important) real rigidities present in the data?
- Obstacle: Hard to measure real rigidities directly

- Two parallel literatures:
  - *indirect tests* in the closed-economy literature
  - open-economy literature on *exchange rate pass-through* and *pricing to market*

Main Results

1. Consistent patterns across studies:
   - retail (final-good) prices vs. wholesale (intermediate) prices

2. New evidence consistent with significant real rigidities:
   - persistent price changes in response to exchange rate shocks
   - firm price changes sensitive to competitor pricing

3. A sticky price model with a wholesale sector:
   - Generates differential inflation persistence
   - Cannot capture very sluggish micro-level dynamics
   - Calibrated variable markups and non-neutrality

4. A bargaining model of price setting

Literature Review

- Closed-economy indirect tests for real rigidities:
  - Klenow and Willis (2006), Burstein and Hellwig (2007), Klenow and Willis (2007)
  - Bils, Klenow and Malin (2009)
  - Eichenbaum, Jaimovich and Rebelo (2007)
- Open-economy pricing-to-market literature:
  - Goldberg and Knetter (1997), Fitzgerald and Haller (2008)
  - Goldberg and Hellerstein (2006), Nakamura and Zerom (2008), Burstein and Jaimovich (2008)
  - Gopinath et al. (2009), Berger, Faust and Rogers (2009)
  - Gopinath, Itskhoki and Rigobon (2008), Gopinath and Itskhoki (2009), Neiman (2007)

Literature Review

A descriptive framework

- Intermediate good *desired price*:

$$\tilde{s}_{jt} = \frac{1}{1+\Gamma}\left[w_t + \phi_j e_t - a_{jt}\right] + \frac{\Gamma}{1+\Gamma} s_t$$

- Final good *desired price*:

$$\tilde{p}_{it} = \frac{1}{1+\Gamma_R}\left[\alpha s_t + (1-\alpha) w_t - z_{it}\right] + \frac{\Gamma_R}{1+\Gamma_R} p_t$$

Empirical evidence is consistent with:

$$\Gamma_R \approx 0 \qquad \text{and} \qquad \Gamma > 0$$

— sluggishness in the wholesale prices and $\alpha > 0$

— relatively large and transitory sectoral shocks, a_{jt} and z_{it}

New Empirical Evidence

1. Evidence on reset-price inflation
2. Micro-level response of prices to exchange rate
3. Response of prices to competitor pricing
4. Industry competition and price adjustment

Empirical Evidence

Data

- BLS micro data on import prices at the dock for the U.S. (Gopinath and Rigobon, 2008)
- 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

Empirical Evidence

Reset-price inflation

- Reset-price inflation (as in Bils, Klenow and Malin, 2009):

$$\begin{aligned} p^*_{it} &= p_{i,t}, && \text{if} \quad p_{i,t} \neq p_{i,t-1}, \\ p^*_{it} &= p^*_{i,t-1} + \pi^*(t), && \text{if} \quad p_{i,t} = p_{i,t-1}. \end{aligned}$$

— less persistent than regular inflation

— filters out the effect of nominal stickiness

— benchmark with Calvo pricing and no real rigidities

- Caveats:
  - Sectoral shocks and selection
  - Aggregation across various shocks

Empirical Evidence

Reset-price inflation

Table: Persistence of regular and reset-price inflation

	Unconditional	Conditional on ER
Regular-price inflation		
Consumer prices	−0.05	—
Import prices	**0.56**	**0.79**
Reset-price inflation		
Consumer prices	−0.41	—
Import prices	**−0.04**	**0.33**

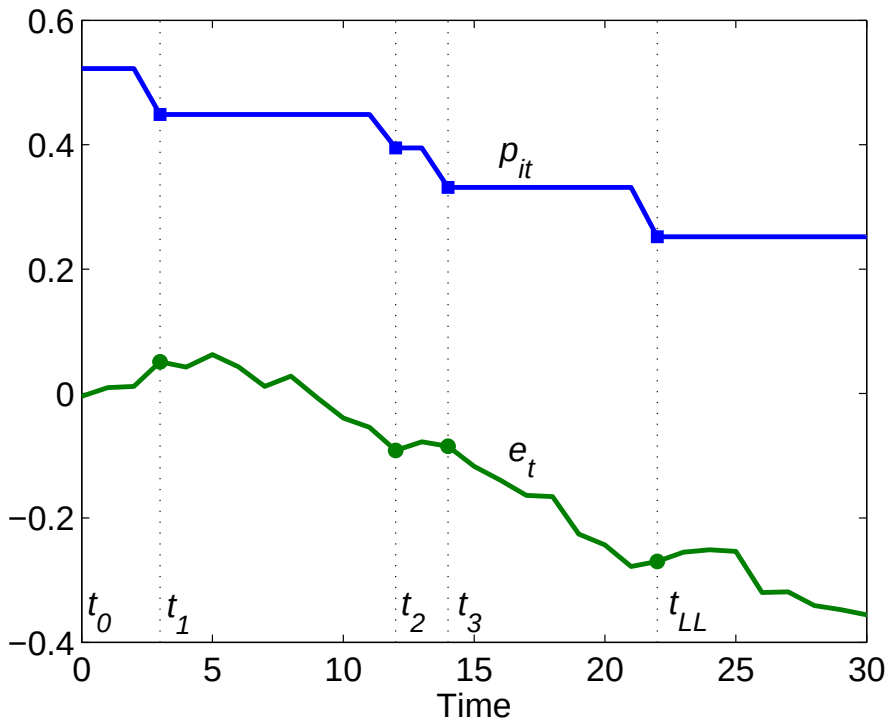
▸ Additional results

— Consistent with $\Gamma > \Gamma_R = 0$ and presence of a_{jt}

Empirical Evidence

Micro-dynamics of price adjustment

$$\Delta \bar{p}_{i,t} = \beta_1 \Delta_{\tau_1} e_{i,t} + \beta_2 \Delta_{\tau_2} e_{i,t-\tau_1} + Z'_{i,t}\gamma + \epsilon_{it}, \qquad (1)$$



Empirical Evidence

Micro-dynamics of price adjustment

	β_1	$s.e.(\beta_1)$	β_2	$s.e.(\beta_2)$
All countries	0.11	(0.02)	0.08	(0.01)
Non-OECD	0.06	(0.02)	0.04	(0.01)
High-income OECD	**0.23**	(0.02)	**0.18**	(0.02)
Differentiated goods	0.14	(0.02)	0.10	(0.02)

▸ Additional results ▸ By End Use

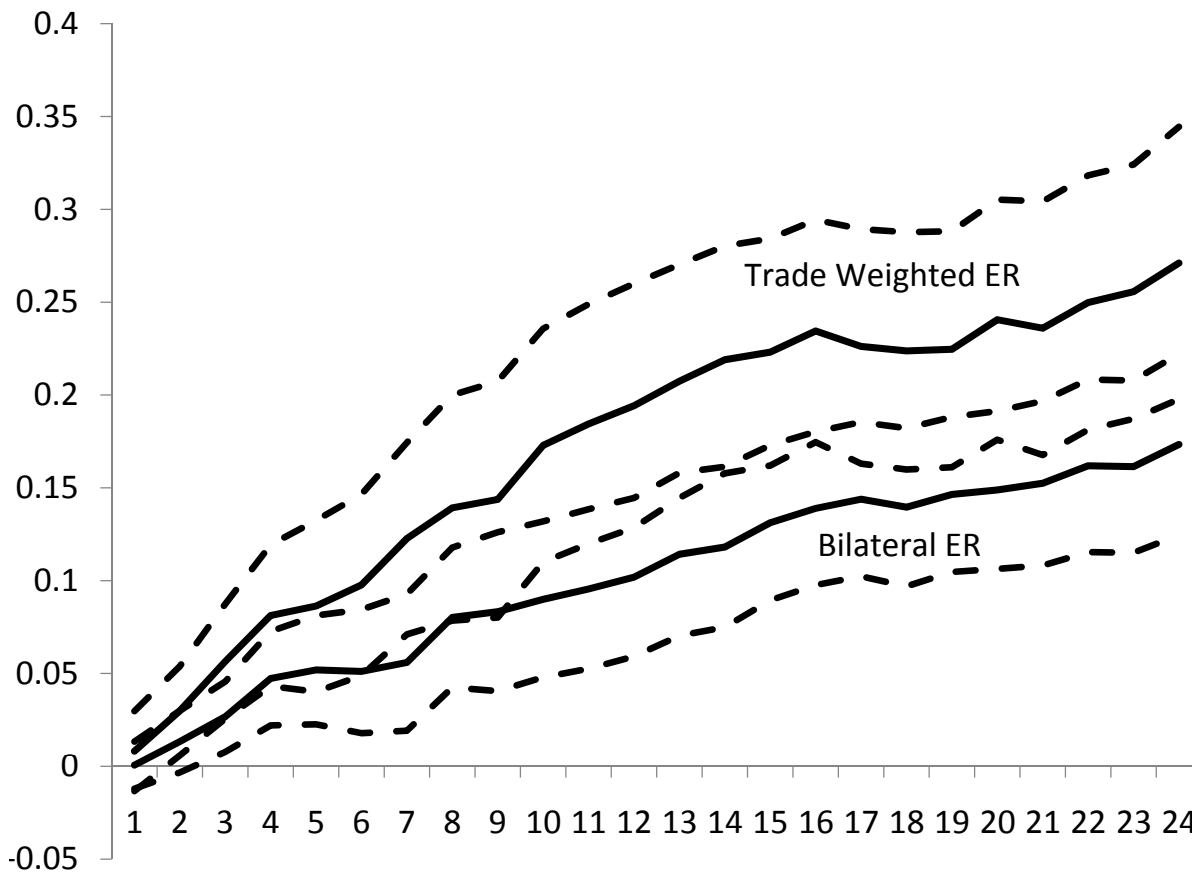
— Consistent with $\Gamma > 0$

— Very large delayed effects!

Empirical Evidence

Competition and Pass-through

$$\Delta p_{k,t} = \alpha_i + \sum_{j=0}^{n} \beta_j \Delta e_{k,t-j} + \sum_{j=0}^{n} \gamma_j \pi_{k,t-j} + \epsilon_{k,t}, \qquad (2)$$



Empirical Evidence

Competition and Pass-through

Table: Micro-level response to trade-weighted exchange rate

	Bilateral ER		T-W ER	
All countries	0.11	(0.01)	0.19	(0.02)
Non-OECD	0.07	(0.02)	0.18	(0.02)
High-income OECD	**0.22**	(0.02)	**0.17**	(0.05)
Differentiated	0.12	(0.01)	0.17	(0.03)

▸ Additional results

— Consistent with $\Gamma > 0$

— Also consistent with imported inputs from other countries

Empirical Evidence

Competitor Prices

$$\Delta \bar{p}_{i,k,t} = \beta_e \Delta_{\tau_1} e_{i,k,t} + \beta_I \Delta_{\tau_1} P^I_{k,t} + \gamma Z_{i,t} + \epsilon_{i,t}, \qquad (3)$$

	β_e	$s.e.(\beta_e)$	β_I	$s.e.(\beta_I)$
Pass-through conditional on first price change				
No $\Delta_{\tau_1} P^I_{k,t}$	0.13	(0.01)	—	—
$\Delta_{\tau_1} P^I_{k,t}$	0.07	(0.01)	0.61	(0.02)
Long-run pass-through				
No $\Delta_{\tau_1} P^I_{k,t}$	0.31	(0.03)	—	—
$\Delta_{\tau_1} P^I_{k,t}$	0.13	(0.02)	0.66	(0.03)

▸ Additional results ▸ Concentration Measures

- $\beta_I = \Gamma/(1+\Gamma) \approx 0.6 \quad \Rightarrow \quad \Gamma \approx 1.5$
- Additional sources of real rigidity beyond $\Gamma > 0$

Empirical Evidence

Summary

- We document:
  - sluggish response of prices to exchange rate shocks
  - sensitivity of firm price to competitor prices

- Evidence consistent with variable markups ($\Gamma > 0$), but possibly admits other interpretations

- Also consistent with large literature documenting incomplete exchange rate pass-through and pricing to market

Model

- Reduced-form sticky price model (Calvo and menu cost) with retail and wholesale sectors
- Variable markups at the wholesale level, constant markup at the retail
- Evaluate price dynamics and monetary non-neutrality

Model

Setup

- Retail sector with constant markups:

$$\tilde{p}_{it} = \bar{\mu}^R + \alpha s_t + (1-\alpha) w_t - \bar{z}_t - \tilde{z}_{it}$$

- Wholesale sector with variable markups:

$$\tilde{s}_{jt} = \bar{\mu} - \Gamma\left(\tilde{s}_{jt} - s_t\right) + w_t + \phi_j e_t - \bar{a}_t - \tilde{a}_{jt}$$

- Aggregate wage:

$$w_t = \gamma m_t + (1-\gamma) p_t$$

- Real output:

$$y_t = m_t - p_t$$

- Calvo price setting with parameters θ and θ_R ▸ Details

▸ Details of Calibration

Model Results

Persistence of regular and reset-price inflation

	Unconditional				Conditional on ER	
	Δp_t	Δp_t^*	Δs_t	Δs_t^*	$\widehat{\Delta s_t}$	$\widehat{\Delta s_t^*}$
$\Gamma = 0$	0.41	−0.25	0.64	−0.23	0.85	−0.03
$\Gamma = 1.5$	**0.32**	**−0.25**	**0.82**	**−0.14**	**0.92**	**0.10**
$\Gamma = 4$	0.37	−0.28	0.87	−0.01	0.91	0.18
$\rho_m = 0$	0.39	−0.23	0.76	−0.19	0.91	0.17
$\rho_m = 0.8$	0.48	−0.14	0.79	−0.07	0.86	0.16
$\gamma = 1.5$	0.37	−0.27	0.76	−0.09	0.87	0.07
Menu Cost	—	—	0.29	−0.89	0.38	−0.66

- Calvo model fits the broad patterns in the data
- Menu cost model does not generate persistent reset-price inflation even conditional on exchange rate shock

Model Results

Micro-dynamics of price adjustment

	$\Gamma = 0$	$\mathbf{\Gamma = 1.5}$	$\Gamma = 4$	Menu Cost
First adjustment	61%	**44%**	35%	55%
Second adjustment	−5%	**4%**	7%	−8%

— Even Calvo model with very large Γ does not match the slow micro dynamics

Model Results

Monetary non-neutrality: half-life of output (months)

	$\rho_m = 0$	$\rho_m = 0.5$	$\rho_m = 0.8$
Panel A: $\gamma = 0.75$			
$\Gamma = 0$	5.3	17.2	56.1
$\Gamma = 1.5$	7.0	23.7	83.0
$\Gamma = 4$	8.9	31.3	114.8
Panel B: $\gamma = 1.5$			
$\Gamma = 0$	3.6	11.8	40.0
$\Gamma = 1.5$	4.4	15.5	58.1
$\Gamma = 4$	5.4	19.8	80.0

- Benchmark menu cost model: 15.1 months
- Γ increases contract multiplier
- Effect of Γ is moderate without exogenous persistence, $\rho_m > 0$

Bargaining Model of Price Setting

- What explains why we have variable markups at the wholesale and not at the retail
- Competitive environment
- Retail: large number of buyers and sellers, monopolistic competition
- Wholesale: bilateral bargaining environment
- Wholesale markup depends on the market share of wholesale producers, bargaining power ...

Conclusion

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- Very sluggish micro-dynamics of prices
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- Reduced form model:
  - markup channel: $\Gamma \approx 1.5$
  - captures patterns of aggregate price dynamics, but not enough micro sluggishness
  - real effects of variable markups alone are moderate

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- Bargaining model of price setting

Empirical Evidence

Reset-price inflation

	Unconditional AR(1)	Unconditional St.D.	Conditional on ER AR(1)	Conditional on ER St.D.
		Regular-price inflation		
Consumer prices (from BKM)	−0.05	0.14%	—	—
Import prices	0.51	0.33%	0.55	0.25%
– Dollar-priced goods	0.56	0.27%	0.79	0.18%
– Market transactions	0.43	0.30%	0.70	0.20%
		Reset-price inflation		
Consumer prices (from BKM)	−0.41	0.95%	—	—
Import prices	0.02	1.60%	0.31	0.82%
– Dollar-priced goods	−0.04	1.20%	0.33	0.75%
– Market transactions	−0.03	1.70%	0.17	0.91%

▸ Back to Empirical Evidence

Empirical Evidence

Micro-dynamics of price adjustment

	β_1	$s.e.(\beta_1)$	β_2	$s.e.(\beta_2)$	N_{obs}	R^2
All countries	0.11	(0.02)	0.08	(0.01)	69,917	0.01
Non-OECD	0.06	(0.02)	0.04	(0.01)	37,108	0.01
High-income OECD	0.23	(0.02)	0.18	(0.02)	32,809	0.02
Euro area	0.22	(0.04)	0.14	(0.03)	5,933	0.02
Japan	0.26	(0.04)	0.24	(0.03)	4,249	0.06
Canada	0.28	(0.16)	0.34	(0.05)	14,620	0.01
Differentiated goods	0.14	(0.02)	0.10	(0.02)	21,360	0.02
No missing prices						
All countries	0.10	(0.02)	0.08	(0.01)	45,765	0.01
High-income OECD	0.19	(0.03)	0.13	(0.02)	22,436	0.01

▸ Back to Empirical Evidence

Empirical Evidence

Micro-dynamics of price adjustment

	β_1	$s.e.(\beta_1)$	β_2	$s.e.(\beta_2)$	N_{obs}	R^2
Panel A: All countries						
Food, feed and beverages	0.05	(0.04)	0.03	(0.02)	17,731	0.01
Industrial supplies and materials	0.13	(0.03)	0.11	(0.02)	22,396	0.02
Capital goods, except automotive	0.16	(0.03)	0.17	(0.03)	4,220	0.05
Consumer goods (non-food)	0.05	(0.04)	0.03	(0.02)	8,222	0.01
Panel B: High-income OECD						
Food, feed and beverages	0.16	(0.04)	0.15	(0.03)	5,207	0.03
Industrial supplies and materials	0.21	(0.05)	0.25	(0.03)	13,089	0.01
Capital goods, except automotive	0.21	(0.04)	0.22	(0.03)	2,587	0.05
Consumer goods (non-food)	0.17	(0.06)	0.03	(0.04)	2,915	0.02

▸ Back to Empirical Evidence

Empirical Evidence

Competition and Pass-through

	Bilateral ER		T-W ER		N_{obs}	R^2
All countries	0.11	(0.01)	0.19	(0.02)	83,064	0.01
Non-OECD	0.07	(0.02)	0.18	(0.02)	46,420	0.01
High-income OECD	0.22	(0.02)	0.17	(0.05)	32,809	0.02
Euro area	0.27	(0.03)	0.31	(0.07)	7,856	0.03
Japan	0.21	(0.04)	0.17	(0.06)	5,733	0.02
Canada	0.23	(0.12)	0.12	(0.10)	16,221	0.01
Differentiated	0.12	(0.01)	0.17	(0.03)	21,360	0.02

▸ Back to Empirical Evidence

Empirical Evidence

Competitor Pricing

	β_e	$s.e.(\beta_e)$	β_I	$s.e.(\beta_I)$	N_{obs}	R^2
Panel A: Pass-through conditional on first price change						
No $\Delta_{\tau_1} P^I_{k,t}$	0.13	(0.01)	—	—	83,056	0.01
$\Delta_{\tau_1} P^I_{k,t}$ (Primary strata)	0.07	(0.01)	0.61	(0.02)	78,942	0.13
$\Delta_{\tau_1} P^I_{k,t}$ (10-digit HTS)	0.04	(0.01)	0.61	(0.02)	59,972	0.25
Panel B: Long-run pass-through						
No $\Delta_{\tau_1} P^I_{k,t}$	0.31	(0.03)	—	—	16,145	0.06
$\Delta_{\tau_1} P^I_{k,t}$ (Primary strata)	0.13	(0.02)	0.66	(0.03)	15,273	0.24
$\Delta_{\tau_1} P^I_{k,t}$ (10 digit HTS)	0.16	(0.01)	0.62	(0.03)	11,379	0.34

▸ Back to Empirical Evidence

Empirical Evidence

Importer Concentration Measures

	β	$s.e.(\beta)$	ψ	$s.e.(\psi)$	N_{obs}	R^2
Herfindahl index	0.30	(0.03)	-0.02	(0.02)	12,432	0.06
No. importers in top 50%	0.23	(0.02)	0.02	(0.02)	12,435	0.06

▸ Back to Empirical Evidence

- Calvo price setting:

$$\bar{s}_{jt} = (1-\beta\theta)\sum_{\ell=0}^{\infty}(\beta\theta)^{\ell}\mathbb{E}_t\tilde{s}_{j,t+\ell}$$

- Dynamic inflation equations (Phillips curves):

$$s_t = \theta s_{t-1} + (1-\theta)\mathbb{E}_j\bar{s}_{jt}$$

$$\Delta s_t = \beta\mathbb{E}_t\Delta s_{t+1} + \frac{\lambda}{1+\Gamma}\left[w_t - s_t + \bar{\phi}e_t\right]$$

- Exogenous shock processes:

$$\Delta m_t = \rho_m\Delta m_{t-1} + \sigma_m\epsilon_t^m$$

RW for exchange rate
AR(1) for sectoral and idiosyncratic shocks

Model

Calibration

▸ Back to Model

Parameter	Symbol	Value	Source
Discount factor	β	$0.96^{1/12}$	Monthly data
Money growth process, Δm_t			BEA data on M2
volatility	σ_m	0.25%	
persistence	ρ_m	0, 0.5, 0.8	
Exchange rate process, Δe_t			OECD exchange rates
volatility	σ_e	2%	
persistence	ρ_e	0.995	
Retail idiosyncratic shocks, $\tilde{z}_{it}$			BLS CPI data
volatility	$\tilde{\sigma}_z$	8%	Size of price adjustment of 8.5%
persistence	$\tilde{\rho}_z$	0.90	
Whole-sale idiosyncratic shocks, $\tilde{a}_{jt}$			BLS IPP and PPI data
volatility	$\tilde{\sigma}_a$	10%	Size of price adjustment of 7.5%
persistence	$\tilde{\rho}_a$	0.95	Persistence of new prices of 0.77
Retail aggregate shocks, $\bar{z}_t$			Volatility and persistence of CPI
volatility	$\bar{\sigma}_z$	5%	regular and reset-price inflation
persistence	$\bar{\rho}_z$	0.50	from BKM
Whole-sale aggregate shocks, $\bar{a}_t$			Volatility and persistence of IPP
volatility	$\bar{\sigma}_a$	4%	regular and reset-price inflation
persistence	$\bar{\rho}_a$	0.75	
Calvo parameters			
Retail	θ_R	0.75	Duration of 4 months, CPI data
Wholesale	θ	0.90	Duration of 10 months, IPP data
Share of intermediate inputs	α	0.5	Nakamura and Steinsson (2009)
Wholesale markup elasticity	Γ	0, 1.5, 4	Evidence on pass-through
Aggregate real rigidities	γ	0.75 and 1.5	
Sensitivity to the ER shock	$\bar{\phi}$	0.225	Gopinath and Itskhoki (2008)