XII Annual Inflation Targeting Seminar

Central Bank of Brazil, Rio de Janeiro

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Macro models of nominal rigidities

- Can monetary shocks generate large real effects?

- New Keynesian Philips Curve

$$\pi_t = \varphi(f)(1-k)\log(M_t/P_t) + \beta E_t(\pi_{t+1})$$

  - f : price adjustment frequency – degree of nominal rigidities
  - k: strategic complementarities

- Monetary propagation mechanism shaped by interaction between price rigidities and strategic complementarities between firms

- Need theory and data to guide choice of key parameters, f, k

Macro models of nominal rigidities

- Optimal design of monetary policy

$$\min E_t \sum_{t=0}^{\infty} \beta^t \left[\left(\log Y_t / \bar{Y}_t \right)^2 + \chi \pi_t^2 \right]$$

  subject to

$$\pi_t = \varphi(f)(1-k) \log Y_t / \bar{Y} + \beta E_t (\pi_{t+1})$$

- Costs of inflation capture relative price distortions arising from nominal rigidities

- Need theory and data to guide choice of key parameters f, k, and χ

Simple model to illustrate identification

- **Demand:** Continuum $[0,1]$ of varieties with demand $Y_{it} = Y_t \left(\frac{P_{it}}{P_t}\right)^{-\theta}$

- **Firms:** monopolistic competition, labor as single input: $Y_{it} = Z_{it} L_{it}^{\omega}$

- **Idiosyncratic cost shock:** $Z_{it} \sim G\left(Z_{it-1}\right)$

- **Menu cost:** Cost of price change (in labor units): F
  - Adjust price if $\log\left(P_{it}^{*}/P_{it}\right) \notin [-s, S]$, do not adjust otherwise

- **General Equilibrium:** summarized by $$\begin{aligned} M_t &= Y_t P_t \\ W_t &= M_t^{1-\gamma} P_t^{\gamma} \end{aligned}$$
  - Micro-foundation of γ: share of intermediate goods in production, or $U = C^{\gamma} + \psi_t (1 - L)$

Simple model to illustrate identification

- **Static optimal price:** $F = 0$

$$p_{it}^* = \Gamma + (1-k)\,m_t + kp_t - \frac{1}{\omega + \theta(1-\omega)} z_{it}$$

$$\text{Strategic complementarities: } k = 1 - \frac{1-\omega\gamma}{\omega + \theta(1-\omega)}$$

- Strategic complementarities:
  - Increasing in γ
  - Decreasing in ω, increasing in θ

- ω and θ also determine response of price to idiosyncratic shock
  - But γ does not affect response to idiosyncratic shocks.

Macro identification

- With Calvo pricing

$$\pi_t = \varphi(f)(1-k)\log(M_t/P_t) + \beta E_t(\pi_{t+1})$$

- Use VAR to estimate $\varphi(f)(1-k)$
- Set f to match micro studies on frequency of price adjustment
- Identify γ from aggregate data (VAR impulse response of interest rates or wages)
- Set 'residual parameters' ω and θ to match required value of k.

Macro identification

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- Identify γ from aggregate data (VAR impulse response of interest rates or wages)
- Set 'residual parameters' ω and θ to match required value of k.
- Problem: are estimated values of γ, ω, and θ consistent with important features of micro-data?
- Use theory and micro data to guide parameter choice.

Burstein and Hellwig - 2007

- Optimal price: $p_{it}^{*} = \Gamma + (1-k)\, m_t + k p_t - \frac{1}{\omega + \theta(1-\omega)} z_{it}$

- U.S. 90's, 00's: Movements in P and M relatively small
  - Assume steady-state growth in M and P

- ω and θ affect response of prices to idiosyncractic shocks $\Longrightarrow$ implications for cross-sectional, micro moments of prices and quantities

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- Classic inference problem: variability and comovement of prices and quantities not sufficient to separately identify ω and θ

- Bring in additional model restrictions to identify ω and θ

- Micro-data not helpful to identify γ

Correa, Bonomo, and Medeiros – 2010

- Optimal price: $p_{it}^{*} = \Gamma + (1-k)\, m_t + k p_t - \frac{1}{\omega + \theta(1-\omega)} z_{it}$

- Brazil: Movements in M and P relatively more important
  - Use observed movements of P and M to estimate k

- Problem: do not observe p_{it}^{*} every period, only after price change

Correa, Bonomo, and Medeiros – 2010

- Solution: If firm changes price at time τ and t

$$p_{it}^* - p_{i\tau}^* = (1-k)(m_t - m_\tau) + k(p_t - p_\tau) + z_{it} - z_{i\tau}$$

- Adjust iff

$$(1-k)(m_t - m_\tau) + k(p_t - p_\tau) + z_{it} - z_{i\tau} \notin [-s, S]$$

- Estimate probit on probability of price adjustment, assuming that $z_{it} - z_{i\tau}$ is **Normally** distributed

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- Estimate probit on probability of price adjustment, assuming that $z_{it} - z_{i\tau}$ is **Normally** distributed

- But, conditional on prices **not** having adjusted between τ and t, $z_{it} - z_{i\tau}$ is **not Normally** distributed and is correlated over time

- Feasible to estimate, but likelihood function more complicated

Kryvtsov and Midrigan – 2009

- Focus on aggregate marginal cost parameter γ:
  $W_t / P_t = (M_t / P_t)^{1-\gamma}$

- High γ: W_t / P_t does not move much over business cycle

Kryvtsov and Midrigan – 2009

- Focus on aggregate marginal cost parameter γ:
  $W_t / P_t = (M_t / P_t)^{1-\gamma}$
- High γ: W_t / P_t does not move much over business cycle
- Movements in W_t / P_t, strong implications on firms' inventories
- Shadow valuation of inventory:

$$\frac{(1-\delta)\, W_{t+1} / P_{t+1}}{1 + R_t}$$

- Value functions close to linear in stock of inventories
- Reduction in shadow valuation of inventory, large increase in inventories
  - To avoid counterfactually large movements in inventories, need smooth $(W / P) \,/\, (1 + R)$

Kryvtsov and Midrigan – 2009

- To avoid counterfactually large movements in inventories, need smooth $\left(W/P\right)/\left(1+R\right)$

- General equilibrium determination of $1+R$: $U_{ct} = \beta U_{ct+1}\left(1+R_t\right)$

- Need $\frac{W}{P} \sim \frac{U_c}{U_c'}$

- But, $U\left(C\right)$ is far less than linear, implies W/P cannot be too sticky

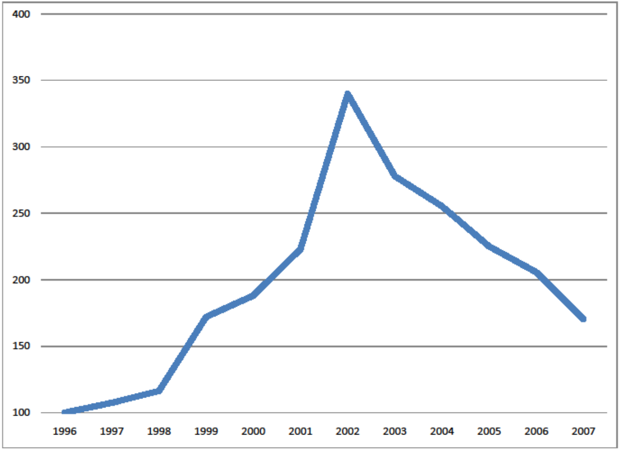
- But: Inference relies again on aggregate structure of model... which cannot be directly inferred from micro data

- Can model account for aggregate inventory behaviour in presence of other aggregate shocks such as productivity shocks?

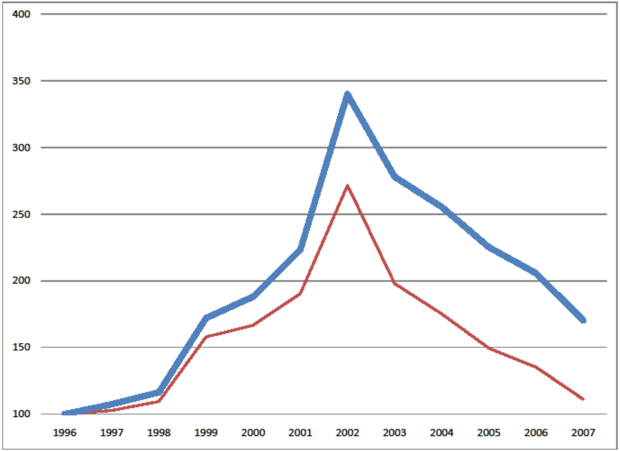
Use response of prices to exchange rates to measure complementarities

- Brazil 1996-2007
- Large exchange rate movements
- At-the-dock dollar prices of imported manufactured goods (in local currency) vary a lot with exchange rate
- Consumer price of tradeable goods do not vary a lot with exchange rate
- Why does retail price of imported goods increase by small magnitude when Real depreciates?
- Why does retail price of local substitute increase by small magnitude?
  - Non-tradeable retail component cannot be the whole story
- Good place to look for strategic complementarities

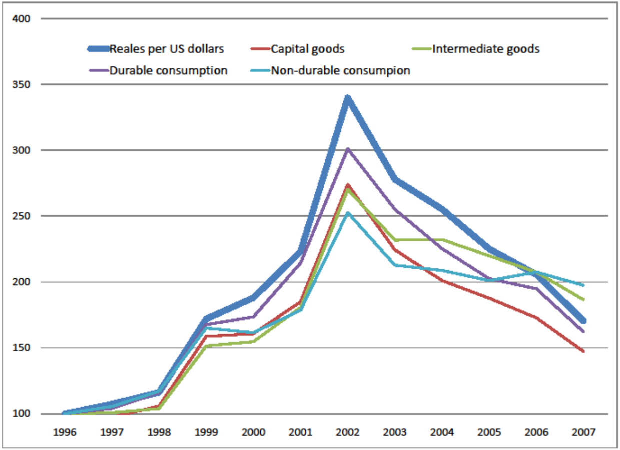
Nominal Exchange Rate, Brazil



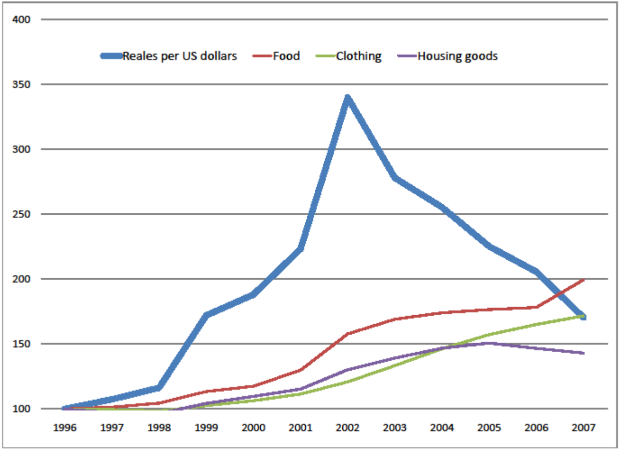
Nominal and RER, Brazil



Import Prices (in local currency), Brazil



CPI for tradeable goods, Brazil



How important are relative price distortions for welfare costs of inflation?

- Utility function:

$$
\begin{aligned}
u\left(C, \frac{M}{P}\right) &= \frac{1}{1-\omega}\left(bC^{\frac{\eta-1}{\eta}} + (1-b)\left(\frac{M}{P}\right)\right)^{\frac{\eta-1}{\eta}(1-\omega)} \\
v\left(N_t\right) &= \frac{1}{1+\psi} N_t^{1+\psi}
\end{aligned}
$$

- $\eta \longrightarrow -\infty$: constant velocity (CV), no opportunity costs of real balances.

Calculating welfare costs of inflation

- **The experiment:** *Increase annual inflation from* 2.2% *to* 12.2%
- Compute welfare in consumption-equivalent units
- Report results for benchmark calibration, alternative versions with near constant returns ($\omega = 0.99$, $\theta = 1.55$, $f = 0.22$), high demand elasticity/low frequency ($\omega = 0.65$, $\theta = 8$, $f = 0.08$)
- Report results for 'CV economy' (constant velocity) and 'MUF economy' ($b = 0.74$, $\eta = 0.39$).
- Report results with menu costs, flexible prices, Calvo (f) and Taylor (choose duration T to match average age under Calvo, $T = (2 - f)/f$).

Menu cost model

Welfare Costs of 10% Increase in Inflation (in percent)			
(negative numbers indicate losses)			
	$\omega = 0.55$	$\omega = 0.99$	$\omega = 0.65$
	$\theta = 4.4$	$\theta = 1.55$	$\theta = 8,\ f = 0.08$
CV economy, menu costs	-0.03	0.02	-0.48

Relative price distortions vs opportunity cost of money

Welfare Costs of 10% Increase in Inflation (in percent)			
(negative numbers indicate losses)			
	$\omega = 0.55$ $\theta = 4.4$	$\omega = 0.99$ $\theta = 1.55$	$\omega = 0.65$ $\theta = 8$, $f = 0.08$
CV economy, menu costs	-0.03	0.02	-0.48
MUF economy, flexible prices	-1.33	-1.93	-1.28
MUF economy, menu costs	-1.36	-1.92	-1.73

Menu costs vs Calvo/Taylor

Welfare Costs of 10% Increase in Inflation (in percent)			
(negative numbers indicate losses)			
	$\omega = 0.55$ $\theta = 4.4$	$\omega = 0.99$ $\theta = 1.55$	$\omega = 0.65$ $\theta = 8,\ f = 0.08$
CV economy, menu costs	-0.03	0.02	-0.48
CV economy, Calvo	-2.13	-0.08	-37.93
CV economy, Taylor	-0.54	-0.03	-8.00

Higher inflation

Welfare Costs Increase in Inflation (in percent)			
(negative numbers indicate losses)			
$\omega = 0.55$, $\theta = 4.4$, CV economy			
	Menu costs	Calvo	Taylor 8
10% inflation	-0.03	-2.12	-0.54
20% inflation	-0.05	-8.53	-1.56
30% inflation	-0.12	-22.27	-2.92
40% inflation	-0.22	-47.15	-4.50
50% inflation	-0.35		-6.24
100% inflation	-0.96		-15.60

Findings

- With menu costs: Nominal rigidities have negligible effect on welfare costs of inflation, relative to the opportunity cost of real money balances.
- With Calvo and Taylor-style price staggering: Nominal rigidities have much larger effects for the welfare costs of inflation.
- θ and ω are important in determining the welfare costs of inflation.
- With large idiosyncratic price changes: Welfare less sensitive to inflation than without idiosyncratic shocks.
  - Inflation is a small factor relative to other sources of product-level fluctuations
  - Change in inflation has small impact on firm's pricing practices