Behavior of sectoral prices

- After so much price micro data, some evidence from sectoral price data

- Seminal contribution: Boivin, Giannoni and Mihov (2009, AER)
  - Statistical factor (FAVAR) model to isolate response of sectoral prices to common ("aggregate") and series-specific ("sectoral") shocks
  - Main finding: sectoral prices respond faster to sectoral than to common shocks
  - Other interesting cross-sectional results

- Similar results: Maćkowiak, Moench, and Wiederholt (2009, JME)
Empirical facts

Figures 1-2: Empirical IRFs - FAVAR

- Responses of 154 subcomponents of PCE price index to shocks to common and sector-specific components in BGM’s FAVAR
First pass on existing sticky-price models

- First-pass intuition: existing sticky-price models cannot match sectoral price facts

- Calvo (1983) model:
  - Frequency of price changes is exogenous, and same for all types of shocks

- Menu-cost models:
  - Paying cost allows firm to choose whichever price it desires; it should take the opportunity to respond to all relevant shocks
This paper - 1

- Sectoral price facts in sticky-price DSGE model, with Calvo (1983) pricing
  - “Stack the odds against us”

- Why?
  - Useful benchmark model for thinking about inflation dynamics
  - Workhorse of most recent models that have been brought to bear on monetary policy questions
  - Is first-pass intuition correct?
  - Discipline analysis of existing models / search for alternative models

- Closest paper: Shamloo (2010)
This paper - 2

- Four departures from standard new Keynesian model
  - Intermediate inputs as in Basu (1995)
  - Sectoral labor markets
  - Sectoral demand and productivity shocks as in Lee (2007)
  - Sectoral heterogeneity in price stickiness as in Carvalho (2006)
Findings

- Model can *endogenously* deliver differential response of sectoral prices to aggregate and sectoral shocks

- Mechanisms:
  - Intermediate inputs
  - Labor market segmentation at sectoral level
  - Monetary policy that responds to endogenous variables

- Differences in dynamics of shocks also matter

- Quantitative results
  - Model can generate faster response to sectoral shocks
  - Match various sectoral price facts
**Mechanism**

- First-pass intuition:

\[
p^*_k(t) = p^*_k(t) \propto E_t \sum_{s=0}^{\infty} \beta^s \alpha_k^s (\text{nominal } MgCost_{k,t+s})
\]

\[
p_k,t = (1 - \alpha_k) p^*_k,t + \alpha_k p_{k,t-1},
\]

with sectoral and aggregate shocks driving nominal \( MgCost_{k,t+s} \)

- In general:

\[
\text{nominal } MgCost_{k,t} = \underbrace{\text{exogenous processes}}_{\{\text{aggregate} \ \text{sectoral}\}} + \underbrace{\text{endogenous variables}}_{\{\text{aggregate} \ \text{sectoral}\}}
\]

- To the extent that different shocks have differential effect on endogenous variables, may have differential effect on sectoral prices
Preview of results

Figures 17-18: Model-FAVAR IRFs - 15 sectors

FAVAR: response of sectoral prices to common component

FAVAR: response of sectoral prices to sector-specific components
Outline

- Overview of the model
- Mechanisms and nature of pricing interactions
- Review of empirical facts
- Quantitative performance of the estimated model
- Conclusion
• Continuum of monopolistically competitive firms indexed in \([0, 1]\)
  
  – Each firm produces unique variety of consumption good
  
  – Firms divided into \(K\) sectors that differ in the frequency of price changes, Calvo pricing; \(I_k\) denotes indices of firms in sector \(k\)
  
  – Size of sector = mass of firms: \((n_1, \ldots, n_K)\) with \(n_k > 0, \sum_{k=1}^{K} n_k = 1\)
  
  – Firms use sectoral labor and (intermediate) composite of all varieties to produce
  
  – Technology subject to sectoral and aggregate shocks
  
  – Sectors subject to demand shifts
Model - representative household

\[
\text{Max } E_0 \sum_{t=0}^{\infty} \beta^t \Gamma_t \left( \log(C_t) - \sum_{k=1}^{K} \omega_k \frac{H_{k,t}^{1+\varphi}}{1+\varphi} \right) \\
\text{s.t. } P_t C_t + E_t \left[ Q_{t,t+1} B_{t+1} \right] = B_t + \sum_{k=1}^{K} W_{k,t} H_{k,t} + \sum_{k=1}^{K} \int_{\mathcal{I}_k} \Pi_{k,t}(i) di \\
C_t = \left( \sum_{k=1}^{K} \left( n_k D_{k,t} \right)^{1/\eta} C_{k,t} \frac{(\eta-1)/\eta}{\eta/(\eta-1)} \right)^{\eta/(\eta-1)} \\
C_{k,t} = \left( \left( \frac{1}{n_k} \right)^{1/\theta} \int_{\mathcal{I}_k} C_{k,t}(i) \frac{(\theta-1)/\theta}{\theta/(\theta-1)} di \right)^{\theta/(\theta-1)}
\]
Model - representative household cont’d

\[ C_{k,t} = n_k D_{k,t} \left( \frac{P_{k,t}}{P_t} \right)^{-\eta} C_t \]

\[ C_{k,t}(i) = \frac{1}{n_k} \left( \frac{P_{k,t}(i)}{P_{k,t}} \right)^{-\theta} C_{k,t} \]

\[ P_t = \left( \sum_{k=1}^{K} \left( n_k D_{k,t} P_{k,t}^{1-\eta} \right) \right)^{1/(1-\eta)} \]

\[ P_{k,t} = \left( \frac{1}{n_k} \int_{\mathcal{I}_k} P_{k,t}(i)^{1-\theta} di \right)^{1/(1-\theta)} \]

\[ Q_{t,t+1} = \beta \left( \frac{\Gamma_t}{\Gamma_{t+1}} \right) \left( \frac{C_t}{C_{t+1}} \right)^{-1} \left( \frac{P_t}{P_{t+1}} \right) \]

\[ \frac{W_{k,t}}{P_t} = \omega_k H_{k,t}^\varphi C_t \]
Model - firms

$$\max E_t \sum_{s=0}^{\infty} \alpha_k^s Q_{t,s} \left[ P_{k,t}(i) Y_{k,t+s}(i) - W_{k,t+s} H_{k,t+s}(i) - P_{t+s} Z_{k,t+s}(i) \right]$$

s.t.  
$$Y_{k,t}(i) = A_t A_{k,t} H_{k,t}(i)^{1-\delta} Z_{k,t}(i)^\delta$$

$$Z_{k,t}(i) = \left( \sum_{k'=1}^{K} \left( n_{k',D_{k',t}} \right)^{1/\eta} Z_{k,k',t}(i)^{(\eta-1)/\eta} \right)^{\eta/(\eta-1)}$$

$$Z_{k,k',t}(i) = \left( \left( \frac{1}{n_{k'}} \right)^{1/\theta} \int_{\mathcal{I}_{k'}} Z_{k,k',t}(i,i')^{(\theta-1)/\theta} d_{i'} \right)^{\theta/(\theta-1)}$$

$$+ \text{demand}$$
\[ Z_{k,t}(i) = \frac{\delta}{1 - \delta} \frac{W_{k,t}}{P_t} H_{k,t}(i) \]

\[ Z_{k,k',t}(i) = n_{k'} D_{k',t} \left( \frac{P_{k',t}}{P_t} \right)^{-\eta} Z_{k,t}(i) \]

\[ Z_{k,k',t}(i, i') = \frac{1}{n_{k'}} \left( \frac{P_{k',t}(i')}{P_{k',t}} \right)^{-\theta} Z_{k,k',t}(i) \]
Model - sectoral prices

\[ E_t \sum_{s=0}^{\infty} \alpha_k^s Q_{t,t+s}^{\text{real}} \left( \frac{P_{k,t}}{P_{k,t+s}} \right)^{-\theta} \left( \frac{P_{k,t+s}}{P_{t+s}} \right)^{-\eta} Y_{t+s} \frac{P_{k,t}}{P_{t+s}} \]

\[ = E_t \sum_{s=0}^{\infty} \alpha_k^s Q_{t,t+s}^{\text{real}} \left( \frac{P_{k,t}}{P_{k,t+s}} \right)^{-\theta} \left( \frac{P_{k,t+s}}{P_{t+s}} \right)^{-\eta} Y_{t+s} \frac{\theta}{\theta - 1} MC_{k,t+s} \]

\[ MC_{k,t+s} = A_{t+s}^{-1} A_{k,t+s}^{-1} \frac{1}{1 - \delta} \left( \frac{\delta}{1 - \delta} \right)^{-\delta} \left( \frac{W_{k,t+s}}{P_{t+s}} \right)^{1-\delta} \]

\[ P_{k,t} = \left[ \frac{1}{n_k} \int_{\mathcal{I}_k}^{\mathcal{I}^*_k} P_{k,t} 1^{-\theta} di + \frac{1}{n_k} \int_{\mathcal{I}_k - \mathcal{I}^*_k} P_{k,t-1(i)} 1^{-\theta} di \right]^{1-\theta} \]
Model - policy and equilibrium

- Monetary policy that ensures existence and (local) uniqueness of equilibrium:

  $P_t C_t = M_t = \text{exogenous}$

  - or Taylor rule: $I_t = \beta^{-1} I_{t-1} \left[ \left( \frac{P_t}{P_{t-1}} \right)^{\phi_i} \left( \frac{C_t}{C} \right)^{\phi_y} \right]^{(1-\rho_i)} \exp(\mu_t)$

- Equilibrium: optimality +

  $B_t = 0,$

  $H_{k,t} = \int_{I_k} H_{k,t}(i) di \quad \forall k,$

  $Y_{k,t}(i) = C_{k,t}(i) + \sum_{k'=1}^{K} \int_{I_{k'}} Z_{k',k,t}(i',i) di' \quad \forall i, k.$

- Solution by loglinearizing around zero-inflation steady state
Mechanisms - nature of pricing interactions

\[ p^*_k,t \propto E_t \sum_{s=0}^{\infty} \beta^s \alpha^s_k \left( p_{t+s} + mc_{k,t+s} \right) \]

\[ p_t + mc_{k,t} = \frac{(1 - \delta) \left( 1 + \varphi - \delta \theta^{-1} \varphi \right)}{1 + \delta \varphi} \eta p_{k,t} \]

\[ + \frac{(1 - \delta) \varphi}{1 + \delta \varphi} \left( 1 + \delta \varphi - (1 - \delta) \left( 1 + \varphi - \delta \theta^{-1} \varphi - \varphi \eta \right) \right) p_t \]

\[ + \frac{(1 - \delta) \theta^{-1} \varphi}{1 + \delta \varphi} z_t \]

\[ + \frac{(1 - \delta) \varphi}{1 + \delta \varphi} d_{k,t} - \frac{1 + \varphi}{1 + \delta \varphi} \left( a_t + a_{k,t} \right). \]
Special case 1

- Strategic neutrality in price-setting: $\delta = 0, \varphi = 0$:

$$p_t + mc_{k,t} = m_t - a_t - a_{k,t}$$

$m_t$ exogenous $\implies$ nominal marginal costs are combinations of exogenous processes

shocks have same dynamics $\implies$ first-pass intuition works: identical responses

$\implies$ first potential source of differential responses: exogenous dynamics
Special case 2

- Intermediate inputs ($\delta > 0$); labor segmentation irrelevant ($\varphi = 0$)

$$pt + mc_{k,t} = (1 - \delta) mt + \delta pt - at - ak,t$$

$\delta pt \rightarrow$ “uniform pricing complementarities”. Slower response to aggregate shocks:

Sectoral shocks have negligible effect on $pt$; response similar to previous case

Aggregate shocks: uniform complementarities make adjustment more sluggish than previous case
Special case 3

- No intermediate inputs ($\delta = 0$), segmentation relevant ($\varphi > 0$), $m_t$ exogenous

\[
p_t + mc_{k,t} = (1 + \varphi) m_t - \varphi p_t \\
+ \varphi \eta p_t - \varphi \eta p_{k,t} \\
+ \varphi d_{k,t} - (1 + \varphi) (a_t + a_{k,t})
\]

\[\implies (1 + \varphi) m_t - \varphi p_t: \text{ standard economy-wide labor terms - strategic substitutability in price setting}\]

\[\implies \varphi \eta p_t - \varphi \eta p_{k,t}: \text{ across-sector strategic complementarity, within-sector strategic substitutability}\]
Intuition

- Take positive sectoral productivity shock, start with economy-wide labor markets
  - Conditional on price change, firms adjust downwards; others still have high relative price
  - No effect on marginal costs besides direct effect of productivity shock
Intuition

• Take positive sectoral productivity shock, start with economy-wide labor markets
  
  – Conditional on price change, firms adjust downwards; others still have high relative price
  
  – No effect on marginal costs besides direct effect of productivity shock

• With sectoral labor (input) markets
  
  – Lower employment by firms that haven’t yet adjusted: $w_{k,t}$
  
  – Firms that adjust cut prices even more than they would otherwise

  – For observer with economy-wide labor in mind, “looks like” a selection effect: price changers cut prices even more, for a given shock. Looks like they were hit with larger shocks
General case

- Intermediate inputs + sectoral labor markets $\implies$ possibility of within-sector strategic substitutability and across-sector strategic complementarity in price setting
  - Impossible in version of the model with economy-wide labor market
  - Requires $\eta > \theta$ in version of the model with firm-specific labor

- Role of policy
  - Under Taylor rule, “$m_t$ is endogenous”
  - Essentially doesn’t matter for sectoral shocks; matters for aggregate shocks
  - Potential for differential responses even under strategic neutrality in price setting

- Differences in dynamics of shocks
Empirical facts - BGM’s FAVAR model

Figures 1-2: Empirical IRFs - FAVAR
Empirical facts - 2

- Define

\[
\text{speed of response} = \frac{\sum_{t=0}^{5} |IRF_t|}{\sum_{t=19}^{24} |IRF_t|}
\]

Figures 3-4: Cross-sectional distribution of speed of responses
More empirical facts

Figures 5-6: Cross-section of correlations between components of prices and quantities
Estimation

- All shocks follow AR(1); \( \beta = 0.9967, \theta = 6, \varphi = 2, \eta = 2, \delta = 0.7 \)

- 15 sectors - 1\(^{st}\) level disaggregation of PCE data

- \( \alpha_k, n_k \)'s: mapping from Nakamura and Steinsson's (2008) statistics

- Estimate
  - Policy parameters \( \phi_\pi \) and \( \phi_c \)
  - All shock parameters

- Observables: \( \{i_t, h_t\} \) and \( \{c_{k,t}, \pi_{k,t}\}_{k=1}^K \), monthly 1983:01 to 2008:12

- Bayesian methods
Figures 17-18: Model-FAVAR IRFs - 15 sectors
### Speed of response

<table>
<thead>
<tr>
<th></th>
<th>to common component</th>
<th>to specific components</th>
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<tbody>
<tr>
<td><strong>Average</strong></td>
<td>0.274</td>
<td>1.010</td>
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<td><strong>Median</strong></td>
<td>0.261</td>
<td>1.001</td>
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<tr>
<td><strong>Std. deviation</strong></td>
<td>0.066</td>
<td>0.281</td>
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<td><strong>Coeff. of variation</strong></td>
<td>0.239</td>
<td>0.278</td>
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<tr>
<td><strong>Corr. with $1 - \alpha_k$</strong></td>
<td>0.422</td>
<td>0.188</td>
</tr>
<tr>
<td><strong>Correlation</strong></td>
<td>—</td>
<td>0.306</td>
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### Speed of response

<table>
<thead>
<tr>
<th></th>
<th>to common component</th>
<th>to specific components</th>
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<tbody>
<tr>
<td><strong>Average</strong></td>
<td>0.258</td>
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<tr>
<td><strong>Median</strong></td>
<td>0.248</td>
<td>1.080</td>
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<tr>
<td><strong>Std. deviation</strong></td>
<td>0.041</td>
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<tr>
<td><strong>Coeff. of variation</strong></td>
<td>0.158</td>
<td>0.177</td>
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<td><strong>Corr. with $1 - \alpha_k$</strong></td>
<td>0.682</td>
<td>0.383</td>
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<tr>
<td><strong>Correlation</strong></td>
<td>—</td>
<td>0.151</td>
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<tr>
<td></td>
<td>Common component</td>
<td>Specific components</td>
</tr>
<tr>
<td>----------------------</td>
<td>------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td><strong>Correlation between inflation and growth of quantities</strong></td>
<td></td>
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<tr>
<td>Data</td>
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<td></td>
</tr>
<tr>
<td>Average</td>
<td>-0.229</td>
<td>-0.296</td>
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<td>Median</td>
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<td>-0.239</td>
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<td>Max.</td>
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<td>Min.</td>
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<td>Estimation</td>
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<td>Average</td>
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<td>Min.</td>
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<td>-0.690</td>
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Conclusion

- Model that can break “uniformity” of pricing interactions in useful direction

- Enhances ability to produce differential (faster) responses of sectoral prices to sectoral shocks relative to aggregate shocks

- Match various facts of the recent empirical literature on sectoral prices

- Mechanism seems promising to reconcile other (microeconomic) facts about price setting with dynamics of aggregate price level

- First-pass intuition only applies in very special (and empirically unimportant) case