Reconciling Micro-Data and Macro Estimates of Price Setting

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Estimates of Average Duration Between Price Resetting

$$\begin{array}{ll}
\text{Micro} & \text{Macro} \\
\text{US} & 4.3 \text{ months} \approx 6 \text{ quarters} \\
\end{array}$$

Importance

- The extent of nominal rigidities considerably influences the real impact of monetary policy.
- The Calvo framework is extensively used in central bank models. Resolving this puzzle gives us greater understanding of these models.
Summary

AIM: Reconcile the micro data on price setting with estimates from a macro model.

METHOD:

▶ Introduce into a standard model:
  ▶ heterogeneity across firms, and,
  ▶ a richer production structure, incorporating intermediate goods.

▶ Calibrate the model using the micro data, and simulate macro aggregates.

▶ Estimate the aggregate Phillips curve using the simulated macro data.

▶ Compare these macro estimates to the calibrated true values.
Results

- The aggregate Phillips curve *appears* to overstate price stickiness
- Ignoring heterogeneity has consequences
- The slope of the NKPC in calibrated models is too flat
Heterogeneity

- Most models capture heterogeneity via Calvo pricing
  - The Calvo parameter, $\theta$, is the probability that a firm cannot change its price
- Heterogeneity affects aggregate dynamics (Carvalho, 2006)
- Our model assumes heterogeneity in pricing and technology
Heterogeneity in Micro Data

- Micro Data studies report the average duration prices remain fixed for each sector

\[ D(\theta_j) = \frac{1}{1 - \theta_j}, \]

- The Calvo probability is typically calculated from the average duration across sectors

- Since \( D(\theta_j) \) is convex and increasing in \( \theta \), we can apply Jensen’s inequality

\[
D(\hat{\theta}^{MICRO}) = \mathbb{E}(D(\theta_j)) > D(\mathbb{E}(\theta_j)) \\
\Rightarrow \hat{\theta}^{MICRO} > \mathbb{E}(\theta_j). \quad (1)
\]
Heterogeneity in Macro Data

- Estimates of the Calvo parameter are extracted from the NKPC
  \[ \pi_t = \frac{(1 - \beta\theta)(1 - \theta)}{\theta} mc_t + \beta E_t \pi_{t+1} \]

- Suppose we can write the NKPC as the sum of sectoral NKPCs
  \[ \pi_t = \sum_{j=1}^{N} w_j \left( \frac{(1 - \theta_j)(1 - \beta\theta_j)}{\theta_j} mc_{j,t} + \beta E_{t} \pi_{j,t+1} \right) \]
  and the slope coefficient can be decomposed as follows
  \[ \lambda(\theta_j, \beta) = \frac{(1 - \beta \theta_j)(1 - \theta_j)}{\theta_j} = \bar{\lambda} + e_{\lambda,j} \]

  We can write
  \[ \pi_t = \bar{\lambda} mc_t + \beta E_t \pi_{t+1} + \sum_j w_j e_{\lambda,j} mc_{j,t}, \]
If we get a “good” estimate of $\bar{\lambda}$, we can compute the corresponding Calvo probability, $\theta^{MACRO}$.

Since $\lambda(\theta_j)$ is convex and decreasing in $\theta$, we can apply Jensen’s inequality

$$\lambda(\hat{\theta}^{MACRO}) = \mathbb{E}(\lambda(\theta_j)) \geq \lambda(\mathbb{E}(\theta_j))$$

$$\Rightarrow \hat{\theta}^{MACRO} \leq \mathbb{E}(\theta_j). \quad (2)$$
Puzzle

\[ \theta^{MACRO} \leq E(\theta) \leq \theta^{MICRO} \]

- Avg Duration from NKPCs \( \approx 6 \) quarters
- Avg Duration from Micro Data \( \approx 1-2 \) quarters
Implications for Calibration/Bayesian Estimation

- The Calvo used in most calibrated models is likely to be too high
- The slope of the NKPC is too flat
Roadmap

- Look at effects of including heterogeneity and roundabout production
- Assess econometric properties of estimates of the NKPC
The model contains standard New-Keynesian features with

- Heterogeneity across sectors
- Roundabout production

A sector, say sector $j$, is a subset with measure $\gamma_j$ of the firms indexed over the continuum $[0, 1]$. 

![Diagram showing sectors](image-url)
Roundabout Production

- Production in a modern economy is not well represented by a tiered production process.
- Firms produce output that can be consumed or used as a factor in production.
- Roundabout production introduces strategic complementarities in pricing.
Model Diagram

Households

Intermediate Goods Firms

Labour: $l_t$

Final Good: $c_{j,t}$

Intermediate Goods Firms

Intermediate Good used in consumption: $c_t(i)$

Final Goods Firms

Intermediate Good used in production: $m_{k,t}(i)$
Intermediate-Goods Firms’ Pricing

Following the Calvo set up, sectoral inflation is described by

\[
\pi_{j,t} = \frac{(1 - \beta \theta_j)(1 - \theta_j)}{\theta_j} \left( mc_{j,t} \right) + \beta E_t \pi_{j,t+1}. \tag{3}
\]

Aggregating these sectoral NKPCs leads to an aggregate NKPC

\[
\pi_t = \sum_{j=1}^{N} \gamma_j \left( \frac{\hat{P}_j}{P} \right)^{1-\epsilon} \left[ \frac{(1 - \beta \theta_j)(1 - \theta_j)}{\theta_j} \left( mc_{j,t} \right) + \beta E_t \pi_{j,t+1} \right]. \tag{4}
\]
## Calibration and Estimation

<table>
<thead>
<tr>
<th>Sector</th>
<th>Avg. Duration (Q)</th>
<th>Calvo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Construction</td>
<td>1.33</td>
<td>0.25</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>2</td>
<td>0.50</td>
</tr>
<tr>
<td>Mining</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Utilities</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Wholesale and Retail Trade</td>
<td>1</td>
<td>&lt;0.25</td>
</tr>
<tr>
<td>Transport and Storage</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Business Services</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Household Services</td>
<td>4</td>
<td>0.75</td>
</tr>
<tr>
<td>Tourism</td>
<td>4</td>
<td>0.75</td>
</tr>
</tbody>
</table>

**Table:** Calvo probabilities for each sector

**Source:** RIA/RBA Pricing Survey (D’Arcy, Rayner and Park, Forthcoming)
Simulated data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual</th>
<th>Simulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Var(g_t)$</td>
<td>0.333</td>
<td>0.378</td>
</tr>
<tr>
<td>$Var(\pi_t)$</td>
<td>0.052</td>
<td>0.062</td>
</tr>
<tr>
<td>$Var(r_t)$</td>
<td>0.047</td>
<td>0.029</td>
</tr>
<tr>
<td>$Corr(g_t, \pi_t)$</td>
<td>-0.005</td>
<td>-0.077</td>
</tr>
<tr>
<td>$Corr(g_t, r_t)$</td>
<td>-0.121</td>
<td>-0.009</td>
</tr>
<tr>
<td>$Corr(r_t, \pi_t)$</td>
<td>0.273</td>
<td>0.241</td>
</tr>
<tr>
<td>$Corr(g_t, g_{t-1})$</td>
<td>-0.044</td>
<td>-0.023</td>
</tr>
<tr>
<td>$Corr(r_t, r_{t-1})$</td>
<td>0.926</td>
<td>0.859</td>
</tr>
<tr>
<td>$Corr(\pi_t, \pi_{t-1})$</td>
<td>0.422</td>
<td>0.372</td>
</tr>
</tbody>
</table>

Table: Moments of observed and simulated series (1993Q1 to 2007Q4)
Results

Compare 4 models

- Baseline, single sector and no roundabout production
- Roundabout, roundabout production and no heterogeneity
- Heterogeneous, multiple sectors but no roundabout production
- Full model
Impulse Response Functions

Policy Shock on Value Added

Policy Shock on Inflation

Baseline  Roundabout  Heterogeneous  Full
Roadmap

- Look at effects of including heterogeneity and roundabout production
- Assess econometric properties of estimates of the NKPC
Monte Carlo Exercise

- For each of the four models
  - Simulate model over $T$ periods
  - Estimate hybrid aggregate NKPC using simulated data

\[
\pi_t = \frac{(1 - \omega)(1 - \beta \theta)(1 - \theta)}{\phi} m c_t + \frac{\beta \theta}{\phi} E_t \pi_{t+1} + \frac{\omega}{\phi} \pi_{t-1}
\]

\[
\phi = \theta + \omega [1 - \theta (1 - \beta)]
\]

- Save parameter estimates
- Repeat $N$ times
Estimates of the Aggregate NKPC

Table: GMM estimates of the aggregate NKPC from various models

<table>
<thead>
<tr>
<th>Parameter</th>
<th>True</th>
<th>Full</th>
<th>Heterogeneous</th>
<th>Baseline</th>
<th>Roundabout</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>0.87 (0.12)</td>
<td>0.57 (0.20)</td>
<td>0.72 (0.13)</td>
<td>0.82 (0.11)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.30</td>
<td>0.82 (0.12)</td>
<td>0.85 (0.07)</td>
<td>0.31 (0.15)</td>
<td>0.33 (0.18)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.00</td>
<td>0.17 (0.07)</td>
<td>0.04 (0.04)</td>
<td>0.00 (0.02)</td>
<td>0.03 (0.08)</td>
</tr>
</tbody>
</table>

Median and standard deviation in brackets.

Monte Carlo Results

Figure: Estimates of $\theta$
Figure: Estimates of $\omega$
Why does Heterogeneity affect estimates of the NKPC?

There are 3 possible explanations

- Misweighting of marginal costs
- Weak instruments
- Lack of instrument exogeneity
Misspecification

- Aggregate marginal costs is not the aggregate labour share
- Instead, aggregate marginal costs are gross revenue weighted labour shares for each sector

Table: GMM estimates of the full model using aggregate marginal costs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Actual</th>
<th>Full</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>0.83 (0.10)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.3</td>
<td>0.73 (0.05)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.00</td>
<td>0.06 (0.05)</td>
</tr>
</tbody>
</table>
Weak Instruments

- The NKPC is plagued by weak instrument problems (Mavroeidis, 2005 JMCB)
- Sectoral NKPCs do not have heterogeneity problems but weak instrument problems remain
- Weak instruments only pose modest problems when heterogeneity is existent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Construction Actual</th>
<th>Estimated</th>
<th>Manufacturing Actual</th>
<th>Estimated</th>
<th>Business Services Actual</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>0.67 (0.15)</td>
<td>0.99</td>
<td>0.82 (0.10)</td>
<td>0.99</td>
<td>0.87 (0.12)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.25</td>
<td>0.27 (0.06)</td>
<td>0.5</td>
<td>0.55 (0.07)</td>
<td>0.75</td>
<td>0.80 (0.21)</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.00</td>
<td>0.00 (0.01)</td>
<td>0.00</td>
<td>0.05 (0.06)</td>
<td>0.00</td>
<td>0.36 (0.17)</td>
</tr>
</tbody>
</table>

Table: GMM estimates of sectoral NKPCs
Instrument Exogeneity

In our model we can write

$$\pi_t = \bar{\lambda}mc_t + \beta\pi_{t+1} + \nu_{t+1} + \sum_j w_j e_{\lambda,j}mc_{jt}$$

Using GMM to estimate the NKPC requires the moment condition

$$E(\nu_{t+1} + \sum_j w_j e_{j}mc_{jt} | z_{it}) = 0 \forall i$$

which is hard to satisfy for any relevant instruments when instrumenting for marginal cost.
Macroeconomic Implications

GMM estimates of the NKPC are useful

GMM Estimate

<table>
<thead>
<tr>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Technology Shock on Value Added</td>
<td>Technology Shock on Growth</td>
<td>Technology Shock on Inflation</td>
<td>Technology Shock on Policy Rate</td>
</tr>
</tbody>
</table>

GMM Estimate Full
Conclusion

- Heterogeneity and roundabout production affect dynamics in a non-trivial manner.
- Estimates of the aggregate Calvo from Gali and Gertler (1999) suggest that:
  - the economy is populated by homogeneous firms resetting every 6.5 quarters on average; OR
  - the average duration of price changes across heterogeneous sectors is 2 quarters on average.
- The latter is more plausible and resolves the discrepancy between the micro and macro-data.