Reconciling Micro-Data and Macro Estimates of Price Setting

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Puzzle

Estimates of Average Duration Between Price Resetting

Micro     Macro
US  4.3 months  \approx 6 quarters

IMPORTANCE

- The Calvo framework is extensively used in many DSGE models. Resolving this puzzle gives us greater understanding of these models.
- The extent of nominal rigidities considerably influences the real impact of monetary policy.
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 \( \theta_j \), we can apply Jensen’s inequality

\[ D(\hat{\theta}^{MICRO}) = \mathbb{E}(D(\theta_j)) > D(\mathbb{E}(\theta_j)) \]

\[ \Rightarrow \hat{\theta}^{MICRO} > \mathbb{E}(\theta_j). \]
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

\[ \pi_t = \bar{\lambda} mc_t + \beta E_t \pi_{t+1} + \sum_{j} w_j e_{\lambda,j} mc_{j,t}, \]
Heterogeneity in Macro Data

- 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

\[
\lambda(\hat{\theta}^{MACRO}) = \mathbb{E}(\lambda(\theta_j)) \geq \lambda(\mathbb{E}(\theta_j)) \Rightarrow \hat{\theta}^{MACRO} \leq \mathbb{E}(\theta_j). \tag{2}
\]
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 probability 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

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 $[0, 1]$. 

\[ \begin{array}{c|c|c}
\text{Sector 1} & \text{Sector 2} \\
\hline
0 & 0.33 & 1 \\
\end{array} \]
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 more interdependence of prices between intermediate goods producers.
Intermediate Good used in production: $m_{k,t}(i)$

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

Labour: $l_t$

Final Good: $c_{j,t}$
Intermediate-Goods Firms

Each period, firm $k$ in sector $j$ faces the cost minimisation problem below

$$\min_{l_{k,t}, m_{k,t}^d(i)} W_t l_{k,t}^d + \int_0^1 P_t(i) m_{k,t}^d(i) di$$

s.t. \[ y_t^s(k) = \left( z_{j,t} z_{t,l_{k,t}} \right)^{\alpha_j} m_{k,t}^{1 - \alpha_j} \] \hspace{1cm} (3)

\[ m_{k,t} \equiv \left( \int_0^1 m_{k,t}^d(i) \frac{\epsilon - 1}{\epsilon} di \right) \frac{\epsilon}{\epsilon - 1} \] \hspace{1cm} (4)

Market Clearing:

$$y_t^s(k) = \int_0^1 m_{i,t}^d(k) di + c_t^d(k)$$
Intermediate-Goods Firms' Pricing

Following the Calvo set up, sectoral inflation is described by

$$\pi_{j,t} = \frac{(1 - \beta \theta_j)(1 - \theta_j)}{\theta_j} (mc_{j,t}) + \beta E_t \pi_{j,t+1}. \quad (5)$$

Aggregating these sectoral NKPCs leads to an aggregate NKPC

$$\pi_t = \sum_{j=1}^{N} \gamma_j \left( \frac{\hat{P}_j}{P} \right)^{1-\epsilon} \left[ \frac{(1 - \beta \theta_j)(1 - \theta_j)}{\theta_j} (mc_{j,t}) + \beta E_t \pi_{j,t+1} \right] \quad (6)$$
### 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
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>$\theta_{macro}$</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 $\theta$
**Monte Carlo Results**

**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>$\theta^{macro}$</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 with heterogeneity

Table: GMM estimates of sectoral NKPCs

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Construction</th>
<th>Manufacturing</th>
<th>Business Services</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Estimated (std)</td>
<td>Actual</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.99</td>
<td>0.67 (0.15)</td>
<td>0.99</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.25</td>
<td>0.27 (0.06)</td>
<td>0.5</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.00</td>
<td>0.00 (0.01)</td>
<td>0.00</td>
</tr>
</tbody>
</table>
**Instrument Exogeneity**

- In our model we can write

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

- Using GMM to estimate the NKPC requires the moment condition

\[ E(\nu_{t+1} + \sum_j w_j e_{\lambda,j}mc_{j,t} | z_{it}) = 0 \quad \forall i \]

which is hard to satisfy for any relevant instruments when instrumenting for marginal cost
Conclusion

- Heterogeneity and roundabout production have a non-trivial effect on model dynamics
- 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 helps resolve some of the discrepancy between the micro and macro-data