Price Selection

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The views expressed here are ours, and they do not necessarily reflect the views of Central Bank of Brazil or Bank of Canada
Inflation and micro price adjustments

- Challenge: reconciling price behavior at micro and macro levels
  - Macro: inflation is stable, persistent, little sensitive to shocks
  - Micro: product-level prices change frequently, volatile, transient

- Need large “contract multiplier”
  - Real rigidities and/or information
  - Micro price changes do not fully adjust to nominal shocks

- This paper: price selection
  - *which* prices adjust/do not adjust to shocks?
Price selection

- Prices that change are not representative of population
  - Theory: price selection makes inflation more sensitive to shocks
    - E.g., increases in inflation can be amplified because adjusting prices tend to originate from below-average levels
  - Heuristic example
Price selection in Golosov-Lucas (2007)

- \( p \) - firm's log price
- \( p^* \) - desired log price

Probability of adjustment \( \Lambda(p-p^*) \)

Probability of a price change increases with \( |p-p^*| \)
Price selection in Golosov-Lucas (2007)

Conditional on common nominal shock, probability higher for low prices, and lower for high prices

$p$ - firm's log price
$p^*$ - desired log price
$\Lambda(p-p^*)$ - Prob of adjustment

$+\Delta\%$ nominal shock

Carvalho-Kryvtsov
Zero price selection in Calvo (1983)

\[ \text{Prob of adjustment } \Lambda(p-p^*) \]

- \( p \) - firm's log price
- \( p^* \) - desired log price

Probability of \( p \)-adjustment does not depend on \( |p-p^*| \)
Zero price selection in Calvo (1983)

$p$ - firm's log price
$p^*$ - desired log price

Conditional on common nominal shock, adjusting prices are representative of population

$\Lambda(p-p^*)$

Prob of adjustment

$p^*$ $p^*+1\%$

Conditional on common nominal shock, adjusting prices are representative of population
This paper

- Study if up (down) movements in inflation in $t$ tend to be associated with price changes that come from below (above) average in $t-1$
  - Model-free way to measure price selection (inflation decomposition)
  - Apply to micro data for the U.K., U.S. and Canada:
    - @Product: 28–36% of inflation variance over time
    - Price selection stronger with price durations and avg size of p-changes
    - @Aggregate: weaker than product price selection (except if price discounts are included)
  - Multi-sector models with selection qualitatively consistent with facts
    - Fit well sector-level selection, generate weaker aggregation selection
    - Predict tight relationship bw price selection and monetary non-neutrality
Existing work

1 **Models:** wide range of "estimates"

2 **Empirical studies of \( p^* \)-shocks:** hard to measure \( p^* \)

3 **Theoretical decompositions:** assumptions on \( p^* \)
Existing work

1 **Models:** wide range of "estimates"

2 **Empirical studies of \( p^* \)-shocks:** hard to measure \( p^* \)

3 **Theoretical decompositions:** assumptions on \( p^* \)
Existing work

1. **Models:** wide range of "estimates"

2. **Empirical studies of $p^*$-shocks:** hard to measure $p^$

3. **Theoretical decompositions:** assumptions on $p^*$
## Price micro data

<table>
<thead>
<tr>
<th>Statistic</th>
<th>U.K.</th>
<th>Canada</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumption coverage</td>
<td>Non-shelter goods and services</td>
<td>Non-shelter goods and services</td>
<td>Grocery products</td>
</tr>
<tr>
<td># of months</td>
<td>236</td>
<td>143</td>
<td>132</td>
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<tr>
<td># of obs/month</td>
<td>102,801</td>
<td>58,670</td>
<td>274,369</td>
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<tr>
<td># of categories</td>
<td>1152</td>
<td>705</td>
<td>31</td>
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<tr>
<td># of strata/category</td>
<td>22</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>Fraction of sales</td>
<td>5.6</td>
<td>9.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Fraction of subs</td>
<td>4.6</td>
<td>3.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.121</td>
<td>0.182</td>
<td>0.291</td>
</tr>
<tr>
<td>Freq of p-changes</td>
<td>0.127</td>
<td>0.217</td>
<td>0.223</td>
</tr>
<tr>
<td>Mean of p-spells</td>
<td>5.62</td>
<td>6.94</td>
<td>3.56</td>
</tr>
<tr>
<td>Std of p-spells</td>
<td>5.33</td>
<td>6.28</td>
<td>4.11</td>
</tr>
<tr>
<td>Abs. size of p-changes</td>
<td>12.22</td>
<td>8.25</td>
<td>8.43</td>
</tr>
</tbody>
</table>
Inflation decomposition using micro price data

\[ \pi_{st} \equiv \frac{\sum_i (p_{is,t} - p_{is,t-1})}{N_{st}} \]

\[ p_{is,t} \text{ log price of product } i \text{ in category-stratum } s \text{ in month } t \]
Inflation decomposition using micro price data

\[ \pi_{st} \equiv \sum_i \frac{(p_{is,t} - p_{is,t-1})}{N_{st}} \]

\[ \equiv \sum_i I_{is,t} \times \left\{ \frac{N_{st}}{N_{st}} \times Fr_{st} \right\} \]

\( I_{is,t} \) p-change indicator: \( I_{ist} = 1 \) if \( p_{is,t} - p_{is,t-1} \neq 0 \), and 0 otherwise

\( Fr_{st} \) fraction of price changes in category-stratum \( s \) in month \( t \)
Inflation decomposition using micro price data

\[
\pi_{st} \equiv \frac{\sum_i (p_{is,t} - p_{is,t-1})}{N_{st}}
\]

\[
\equiv \frac{\sum_i l_{is,t}}{N_{st}} \times \left[ \frac{\sum_i l_{is,t} (p_{is,t} - P_{st-1})}{\sum_i l_{is,t}} - \frac{\sum_i l_{is,t} (p_{is,t-1} - P_{st-1})}{\sum_i l_{is,t}} \right]
\]

\(DP_{st}\) avg size of price changes in month \(t\), \(DP_{st} \equiv P_{st}^{res} - P_{st}^{pre}\)
\(P_{st}^{res}\) avg ending level of price changes
\(P_{st}^{pre}\) avg starting level of price changes
\(P_{st-1}\) category-stratum \(s\) mean log price level in month \(t\)
How much $P_{st}^{pre}$ contributes to $DP_{st}$ fluctuations?

- Price selection, category-stratum time series

$$\pi_{st} \equiv Fr_{st} \cdot \left[ P_{st}^{res} - P_{st}^{pre} \right]$$

- Estimate weighted panel regression
  - $\delta_s$ – category-stratum fixed effects, $\delta_{cal}$ – calendar-month fixed effects
  
  $$P_{st}^{pre} = \beta DP_{st} + \delta_{cal} + \delta_s + error$$

- Estimated $\beta$ is the measure of price selection
  - $|\beta|$ is the fraction of $DP_{st}$ variance accounted for by $P_{st}^{pre}$
$P_{st}^{pre}$ and $DP_{st}$ for selected categories in the U.K.
## Price selection, category-stratum time series

### United Kingdom

<table>
<thead>
<tr>
<th></th>
<th>Regular prices, excluding subs</th>
<th>Unweighted</th>
<th>All prices</th>
<th>Incl. subs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
<td>(3)</td>
<td>(4)</td>
</tr>
<tr>
<td>Price selection</td>
<td>-0.371*** (0.002)</td>
<td>-0.371*** (0.002)</td>
<td>-0.369*** (0.002)</td>
<td>-0.357*** (0.002)</td>
</tr>
<tr>
<td>Calendar-month effects</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Stratum linear trend</td>
<td>N</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Number of observations</td>
<td>1,073,089</td>
<td>1,073,089</td>
<td>1,073,089</td>
<td>1,073,089</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.032</td>
<td>0.032</td>
<td>0.032</td>
<td>0.046</td>
</tr>
</tbody>
</table>

### Significant price selection

- Robust across datasets, treatments of sales, subs, seasonal effects, category-level linear and business-cycle (Baxter-King) trends
Price selection, category-stratum time series

*Regular prices, excluding subs*

<table>
<thead>
<tr>
<th></th>
<th>U.K.</th>
<th>Canada</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price selection</td>
<td>-0.371***</td>
<td>-0.285***</td>
<td>-0.360***</td>
</tr>
<tr>
<td></td>
<td>(0.002)</td>
<td>(0.003)</td>
<td>(0.000)</td>
</tr>
<tr>
<td>Calendar-month effects</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Stratum linear trend</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Number of observations</td>
<td>1,073,089</td>
<td>568,264</td>
<td>18,402,238</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.032</td>
<td>0.022</td>
<td>0.198</td>
</tr>
</tbody>
</table>

- Results consistent across country datasets
  - Weaker selection in Canada (coarser strata)
$P_{st}^{pre}$ and $DP_{st}$ for selected months in the U.K.
Price selection across product categories, U.K.

- Mean = –0.392 (all), –0.396 (non-zero); 91% weight bw 0 and –1
Price selection and price adjustment

- Modify the weighted panel regression

\[ P_{st}^{pre} = \beta_1 D\!P_{st} + \beta_2 D\!P_{st} \times \Gamma_{st} + \delta_t + \text{error} \]

- Study how price selection varies with price adjustment moments

\[ \beta = \beta_1 + \beta_2 \Gamma_{st} \]

- Price adjustment moments, \( \Gamma_{st} \):
  - Frequency and average size of price changes
  - Absolute size of individual price changes
  - Kurtosis of non-zero price changes
  - Standard deviation of price spell durations

- Focus on cross-section: \( \delta_t \) – time fixed effects
## Price selection and price adjustment, U.K.

| Independent variables | U.K. | | | Canada | | |
|-----------------------|-----|-----|-----|--------|-----|
|                       | Baseline | Baseline | All prices | Incl. subs | Baseline | Baseline |
|                       | With interaction terms | With interaction terms |
| $DP_{st}$             | -0.367*** (0.002) | -0.370*** (0.010) | -0.368*** (0.009) | -0.437*** (0.008) | -0.560*** (0.013) | -0.546*** (0.000) |
| Interaction terms     |       |       |       |        |       |       |
| $DP_{st} \times Fr_{st}$ | 0.220*** (0.012) | 0.193*** (0.010) | 0.396*** (0.011) |        | 0.566*** (0.011) | 0.668*** (0.001) |
| $DP_{st} \times DP_{st}$ | -0.003*** (0.000) | -0.003*** (0.000) | -0.001*** (0.000) |        | -0.005*** (0.000) | -0.003*** (0.000) |
| $DP_{st} \times ADP_{st}$ | 0.001** (0.000) | 0.001*** (0.000) | -0.001*** (0.000) |        | 0.003*** (0.000) | -0.001*** (0.000) |
| $DP_{st} \times Kurt$ | -0.006*** (0.001) | -0.005*** (0.001) | -0.004*** (0.000) |        | 0.004** (0.002) | 0.001*** (0.000) |
| p-chgs$_s$            |       |       |       |        |       |       |
| $DP_{st} \times Std$ | -0.005*** (0.001) | -0.012*** (0.001) | -0.001 (0.001) |        | 0.005*** (0.001) | 0.003*** (0.000) |
| p-spells$_s$          |       |       |       |        |       |       |

Number of obs 1,073,089 1,072,899 1,075,029 1,077,315 56 7,573 18,393,701

$R^2$ 0.033 0.036 0.049 0.059 0.033 0.224

- Selection increases with price stickiness and size of price changes

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Carvalho-Kryvtsov

Price Selection

Cleveland Fed May 2019 17/28
## Price selection and price adjustment, U.K.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>U.K.</th>
<th></th>
<th></th>
<th></th>
<th>Canada</th>
<th>U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Baseline</td>
<td>All prices</td>
<td>Incl. subs</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td></td>
<td>With interaction terms</td>
<td>With interaction terms</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{DP}_{st}$</td>
<td>-0.367*** (0.002)</td>
<td>-0.370*** (0.010)</td>
<td>-0.368*** (0.009)</td>
<td>-0.437*** (0.008)</td>
<td>-0.560*** (0.013)</td>
<td>-0.546*** (0.000)</td>
</tr>
<tr>
<td><strong>Interaction terms</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{DP}<em>{st} \times \text{Fr}</em>{st}$</td>
<td>0.220*** (0.012)</td>
<td>0.193*** (0.010)</td>
<td>0.396*** (0.011)</td>
<td>0.566*** (0.011)</td>
<td>0.668*** (0.001)</td>
<td></td>
</tr>
<tr>
<td>$\text{DP}<em>{st} \times \text{DP}</em>{st}$</td>
<td>-0.003*** (0.000)</td>
<td>-0.003*** (0.000)</td>
<td>-0.001*** (0.000)</td>
<td>-0.005*** (0.000)</td>
<td>-0.003*** (0.000)</td>
<td></td>
</tr>
<tr>
<td>$\text{DP}<em>{st} \times \text{ADP}</em>{st}$</td>
<td>0.001** (0.000)</td>
<td>0.001*** (0.000)</td>
<td>-0.001*** (0.000)</td>
<td>0.003*** (0.000)</td>
<td>-0.001*** (0.000)</td>
<td></td>
</tr>
<tr>
<td>$\text{DP}<em>{st} \times \text{Kurt p-chgs}</em>{s}$</td>
<td>-0.006*** (0.001)</td>
<td>-0.005*** (0.001)</td>
<td>-0.004*** (0.000)</td>
<td>0.004** (0.002)</td>
<td>0.001*** (0.000)</td>
<td></td>
</tr>
<tr>
<td>$\text{DP}<em>{st} \times \text{Std p-spells}</em>{s}$</td>
<td>-0.005*** (0.001)</td>
<td>-0.012*** (0.001)</td>
<td>-0.001 (0.001)</td>
<td>0.005*** (0.001)</td>
<td>0.003*** (0.000)</td>
<td></td>
</tr>
<tr>
<td>Number of obs</td>
<td>1,073,089</td>
<td>1,072,899</td>
<td>1,075,029</td>
<td>1,077,315</td>
<td>567,573</td>
<td>18,393,701</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.033</td>
<td>0.036</td>
<td>0.049</td>
<td>0.059</td>
<td>0.033</td>
<td>0.224</td>
</tr>
</tbody>
</table>

- Selection increases with price stickiness and size of price changes.
Aggregate price selection

- Aggregate time series:
  - $F_{rt} = \sum_s \omega_s F_{rst}$
  - $P_{t}^{res} = \sum_s \omega_s \frac{F_{rst}}{F_{rt}} P_{st}^{res}$, $P_{t}^{pre} = \sum_s \omega_s \frac{F_{rst}}{F_{rt}} P_{st}^{pre}$
    (frequency-weighted to account for heterogeneity across strata)

- Obtain same decomposition as before:
  \[
  \pi_t \equiv F_{rt} \cdot \left[ P_{t}^{res} - P_{t}^{pre} \right]_{DP_{t}}
  \]

- Estimate time series OLS regression
  \[
P_{t}^{pre} = \beta DP_{t} + \delta_{cal} + error
  \]
Price selection, aggregate time series

<table>
<thead>
<tr>
<th>Level of aggregation</th>
<th>Number of groups</th>
<th>Regular prices, excluding subs</th>
<th>Incl. subs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. U.K.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum</td>
<td>8941</td>
<td>-0.371***</td>
<td>-0.415***</td>
</tr>
<tr>
<td>Aggregate</td>
<td>1</td>
<td>-0.197*** (0.072)</td>
<td>-0.188*** (0.069)</td>
</tr>
<tr>
<td><strong>B. Canada</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum</td>
<td>9165</td>
<td>-0.285***</td>
<td>-0.268***</td>
</tr>
<tr>
<td>Aggregate</td>
<td>1</td>
<td>-0.003 (0.021)</td>
<td>0.013 (0.020)</td>
</tr>
<tr>
<td><strong>C. U.S.</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum</td>
<td>1550</td>
<td>-0.360***</td>
<td>N/A</td>
</tr>
<tr>
<td>Aggregate</td>
<td>1</td>
<td>0.061* (0.035)</td>
<td></td>
</tr>
</tbody>
</table>

- Price selection weakens with aggregation of the data
Price selection weakens with aggregation of the data

- Sales tend to strengthen aggregate price selection (consistent with cyclical sales behavior - Kryvtsov and Vincent, 2017)
### Aggregate price selection, U.K.

<table>
<thead>
<tr>
<th>Level of aggregation</th>
<th>Number of groups</th>
<th>Regular prices, excluding subs</th>
<th>All prices</th>
<th>Incl. subs</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. U.K.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum</td>
<td>8941</td>
<td>-0.371***</td>
<td>-0.333***</td>
<td>-0.415***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.002)</td>
<td>(0.002)</td>
<td>(0.002)</td>
</tr>
<tr>
<td>Category</td>
<td>1037</td>
<td>-0.385***</td>
<td>-0.359***</td>
<td>-0.404***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.005)</td>
</tr>
<tr>
<td>Basic class</td>
<td>66</td>
<td>-0.361***</td>
<td>-0.357***</td>
<td>-0.330***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.016)</td>
<td>(0.013)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>Aggregate</td>
<td>1</td>
<td>-0.197***</td>
<td>-0.394***</td>
<td>-0.188***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.072)</td>
<td>(0.065)</td>
<td>(0.069)</td>
</tr>
</tbody>
</table>

- Aggregation across broad consumption sectors contributes the most
Price selection in multi-sector sticky-price models

  - Monopolistically competitive firms pay menu cost to adjust prices
    - Firms-specific AR(1) cost shocks, i.i.d. money growth shock
  - $N$ consumption sectors differ by frequency of p-changes
    - U.K. data for 66 consumption sectors
    - Pick menu cost for each sector to match freq of p-changes in the data
    - Parameters for AR(1) shocks common across sectors
    - Strategic neutrality for p-changes across firms
Model results: sector-level price selection

Freq of p-changes accounts for around 20% of selection across sectors
Model results: sector-level price selection

- GL model fits fairly well sector-level selection
Monetary non-neutrality in nested Calvo-GL model

- Nested GL and Calvo model: weight $\phi$ on Calvo price adjustment
  - Tight relationship between price selection and monetary non-neutrality
Conditional selection: two aggregate shocks

- Selection: Unconditional in the data x conditional in the model
- Calvo-GL model with monetary and productivity shocks

Table 5. Calibration strategy: GL-Calvo 2 shocks model

<table>
<thead>
<tr>
<th>Calibration targets</th>
<th>Data</th>
<th>No Correlation</th>
<th>Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fraction of pch (%)</td>
<td>0.13</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>Abs size of pch (%)</td>
<td>12.22</td>
<td>12.23</td>
<td>12.22</td>
</tr>
<tr>
<td>Ser. corr of reset prices</td>
<td>-0.03</td>
<td>-0.02</td>
<td>0.01</td>
</tr>
<tr>
<td>Inflation stdev (%)</td>
<td>0.002</td>
<td>0.003</td>
<td>0.002</td>
</tr>
<tr>
<td>Consumption ser. corr</td>
<td>0.85</td>
<td>0.83</td>
<td>0.83</td>
</tr>
<tr>
<td>Inflation mean (%)</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Consumption stdev (%)</td>
<td>0.89</td>
<td>0.88</td>
<td>0.92</td>
</tr>
</tbody>
</table>

Price Selection: -0.20 -0.23 -0.22

Table 6. Price Selection

<table>
<thead>
<tr>
<th></th>
<th>All shocks</th>
<th>Monetary Shocks Only</th>
<th>Productivity Shocks Only</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Correlation</td>
<td>-0.23</td>
<td>-0.29</td>
<td>-0.29</td>
</tr>
<tr>
<td>Correlation</td>
<td>-0.22</td>
<td>-0.27</td>
<td>-0.28</td>
</tr>
</tbody>
</table>

Why not estimate conditional selection in the data?
Conclusions

- Multi-sector models with selection qualitatively consistent with facts
  - Generate sector-level selection, weaker aggregate selection
    - Still need: broader range of selection, weaker agg selection (e.g., information frictions, other features)
  - Measuring price selection allows more accurately identify determinants of monetary non-neutrality
    - “Model-free” measure, straightforward to apply to models/data
    - Models: tight relationship between price selection and non-neutrality
    - Can assess importance “real rigidities”, sufficient statistics, etc.
Price selection and real rigidities

Strategic complements, $\zeta=0.15$

Strategic neutrals, $\zeta=1$

Strategic substitutes, $\zeta=7$

Calvo

Nested

GL
Price selection and real rigiditites

![Graphs showing price selection and real rigidities](image-url)

### Strategic complements, $\zeta=0.15$

- M
- Calvo
- Nested
- GL

### Strategic neutrals, $\zeta=1$

- M
- Calvo
- Nested
- GL

### Strategic substitutes, $\zeta=7$

- M
- Calvo
- Nested
- GL

![Graphs showing Calvo, Nested, and GL](image-url)
Price selection and size of aggregate shocks

![Graph showing price selection and standard deviation of log money growth](image)

- **Golosov-Lucas**
- **Taylor**

**Figure:** Graphs illustrating the relationship between price selection and the standard deviation of log money growth, as estimated by Golosov-Lucas and Taylor models. The graph shows the impact of price selection on the variability of log money growth across different levels of standard deviation.