Price Selection
– Supplementary Material

For online publication

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Contents

A Additional tables and figures 3

B Sticky-price models 19
  B.1 Representative household 19
  B.2 Firms in Golosov and Lucas (GL) model 20
  B.3 Firms in Calvo model 21
  B.4 Firms in Taylor model 22

C Formal derivations of price selection in sticky-price models 22
  C.1 Equilibrium in a sticky-price model 22
  C.2 Calvo (1983) model 24
  C.3 Taylor (1980) model 25
  C.4 Aggregation and price selection in two-sector Taylor model 26
  C.5 N-sector nested Taylor-Calvo model 27
  C.6 Caplin and Spulber (1987) model 29
  C.7 Head-Liu-Menzio-Wright model 30

D Selection effects and price selection 33

E Price selection across different models 34

F Price selection, real rigidities and monetary non-neutrality 35
A Additional tables and figures

Tables A.1–A.3 provide summary statistics for different treatments of price discounts and product substitutions for the U.K., U.S. and Canada.

Table A.4 provides comparisons with alternative standard errors: Driscoll and Kraay (1998), clustered by strata, and clustered by month.

Tables A.7 and A.8 provide simulations for sticky-price models: Calvo, Taylor, and Golosov-Lucas models, and their generalized versions (Taylor+ and Golosov-Lucas+), with strategic complementarity in pricing decisions (ζ = 0.15), strategic substitutability (ζ = 7), and strategic neutrality (ζ = 1). Figures A.5 and A.6 compare models’ consumption responses to +1% impulse to money supply.

Figure A.1 Panel A provides monthly time aggregate series for $DP_t$ and $P_{t}^{pre}$ for the case of regular prices and no substitutions in the U.K.). The series display similar volatility, and are significantly negatively correlated. These correlations indicate that price selection contributes to fluctuations in the size of price changes, since lower preset price pushes up the average size of price changes. Panel B shows bandpass-filtered series for $DP_t$ and $P_{t}^{pre}$. The two series lose more than half of volatility, but the negative correlation remains significant. Therefore, preset prices contribute to the dynamics of the average size of price changes, even when high-frequency fluctuations are excluded.

Figure A.7 provides scatter plots for average duration and standard deviation of price spells across 66 basic classes in the U.K. CPI data, and predicted values in 66-sector Golosov-Lucas and Taylor models. See Section 5.3 in the main text.
Table A.1: Summary statistics for the U.K. CPI Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Regular prices, excl. substitutions</th>
<th>Regular prices, incl. substitutions</th>
<th>Posted prices, excl. substitutions</th>
<th>Posted prices, incl. substitutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) $\pi$</td>
<td>0.121</td>
<td>0.220</td>
<td>-0.161</td>
<td>0.115</td>
</tr>
<tr>
<td>(2) $Fr$</td>
<td>0.127</td>
<td>0.158</td>
<td>0.162</td>
<td>0.191</td>
</tr>
<tr>
<td>(3) $DP = \frac{\pi}{Fr}$</td>
<td>0.955</td>
<td>1.273</td>
<td>-0.649</td>
<td>0.922</td>
</tr>
<tr>
<td>(4) $p^{pre}$</td>
<td>1.116</td>
<td>1.974</td>
<td>0.932</td>
<td>2.018</td>
</tr>
<tr>
<td>(5) $p^{pre}$</td>
<td>0.761</td>
<td>0.701</td>
<td>1.581</td>
<td>1.096</td>
</tr>
<tr>
<td>(6) $adp$</td>
<td>12.22</td>
<td>14.11</td>
<td>14.68</td>
<td>15.92</td>
</tr>
<tr>
<td>(7) $corr$</td>
<td>-0.032</td>
<td>-0.012</td>
<td>-0.072</td>
<td>-0.049</td>
</tr>
<tr>
<td>(8) $sd_{\text{delta}}$</td>
<td>15.74</td>
<td>18.88</td>
<td>18.11</td>
<td>20.74</td>
</tr>
<tr>
<td>(9) $kurt$</td>
<td>5.73</td>
<td>6.12</td>
<td>5.35</td>
<td>5.64</td>
</tr>
<tr>
<td>(10) $meandur$</td>
<td>5.62</td>
<td>5.98</td>
<td>5.08</td>
<td>5.40</td>
</tr>
<tr>
<td>complete</td>
<td>6.24</td>
<td>6.55</td>
<td>5.73</td>
<td>5.96</td>
</tr>
<tr>
<td>incomplete</td>
<td>5.33</td>
<td>5.75</td>
<td>4.85</td>
<td>5.27</td>
</tr>
<tr>
<td>(11) $sd_{\text{dur}}$</td>
<td>6.48</td>
<td>6.88</td>
<td>6.07</td>
<td>6.39</td>
</tr>
</tbody>
</table>


The entries are weighted means of stratum-level monthly variables. Observations across strata are based on consumption expenditure weights, observations across months are weighted equally. $\pi$ - inflation, in %; $Fr$ - the fraction of items with changing prices; $DP$ - the size of price changes, in %; $p^{pre}$ (Pres) - preset (reset) price level defined as the unweighted means of starting (ending) log price levels for all products in the stratum in each month, expressed as % deviations from the average for all log prices in the stratum; $adp$ - the average absolute size of price changes, in %; $corr$ - serial correlation of newly set prices for an individual product; $sd_{\text{delta}}$ - standard deviation of non-zero price changes for a given stratum, in %; $kurt$ - kurtosis of non-zero price changes for a given stratum; $meandur$ - mean price spell duration (for complete spells), in months; $sd_{\text{dur}}$ - standard deviation of price spell durations for a given stratum (for complete spells), in months.
Table A.2: Summary statistics for the Statistics Canada CPI Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Regular prices, excl. substitutions</th>
<th>Regular prices, incl. substitutions</th>
<th>Posted prices, excl. substitutions</th>
<th>Posted prices, incl. substitutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) $\pi$</td>
<td>0.182</td>
<td>0.210</td>
<td>0.168</td>
<td>0.185</td>
</tr>
<tr>
<td>(2) $Fr$</td>
<td>0.217</td>
<td>0.223</td>
<td>0.280</td>
<td>0.290</td>
</tr>
<tr>
<td>(3) $DP = \pi/Fr$</td>
<td>0.842</td>
<td>0.943</td>
<td>0.598</td>
<td>0.638</td>
</tr>
<tr>
<td>(4) $p^\text{pre}$</td>
<td>-0.198</td>
<td>0.037</td>
<td>-1.041</td>
<td>-0.938</td>
</tr>
<tr>
<td>(5) $p^\text{pre}$</td>
<td>-0.718</td>
<td>-0.521</td>
<td>-1.508</td>
<td>-1.422</td>
</tr>
<tr>
<td>(6) adp</td>
<td>8.25</td>
<td>8.48</td>
<td>12.90</td>
<td>12.82</td>
</tr>
<tr>
<td>(7) corr</td>
<td>0.164</td>
<td>0.164</td>
<td>0.110</td>
<td>0.123</td>
</tr>
<tr>
<td>(8) sd_delta</td>
<td>10.00</td>
<td>10.37</td>
<td>15.53</td>
<td>15.56</td>
</tr>
<tr>
<td>(9) kurt</td>
<td>4.70</td>
<td>4.81</td>
<td>4.17</td>
<td>4.25</td>
</tr>
<tr>
<td>(10) meandur</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete</td>
<td>6.78</td>
<td>6.94</td>
<td>5.16</td>
<td>5.24</td>
</tr>
<tr>
<td>incomplete</td>
<td>7.46</td>
<td>7.68</td>
<td>5.65</td>
<td>5.78</td>
</tr>
<tr>
<td>(11) sd_dur</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>complete</td>
<td>6.14</td>
<td>6.28</td>
<td>4.69</td>
<td>4.79</td>
</tr>
<tr>
<td>incomplete</td>
<td>7.24</td>
<td>7.29</td>
<td>5.64</td>
<td>5.68</td>
</tr>
</tbody>
</table>

Notes: Data are from the Statistics Canada's Consumer Price Research Database. Sample period: from February 1998 to December 2009.

The entries are weighted means of stratum-level monthly variables. Observations across strata are based on consumption expenditure weights, observations across months are weighted equally. $\pi$ - inflation, in %; $Fr$ - the fraction of items with changing prices; $DP$ - the size of price changes, in %; $P^\text{pre}$ ($P^\text{Res}$) - preset (reset) price level defined as the unweighted means of starting (ending) log price levels for all products in the stratum in each month, expressed as % deviations from the average for all log prices in the stratum; adp - the average absolute size of price changes, in %; corr - serial correlation of newly set prices for an individual product; sd_delta - standard deviation of non-zero price changes for a given stratum, in %; kurt - kurtosis of non-zero price changes for a given stratum; meandur - mean price spell duration (for complete spells), in months; sd_dur - standard deviation of price spell durations for a given stratum (for complete spells), in months.
Table A.3: Summary statistics for the Symphony IRI Inc. Data

<table>
<thead>
<tr>
<th>Sample</th>
<th>Regular prices, excl. substitutions</th>
<th>Posted prices, excl. substitutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) $\pi$</td>
<td>0.291</td>
<td>0.021</td>
</tr>
<tr>
<td>(2) $Fr$</td>
<td>0.223</td>
<td>0.323</td>
</tr>
<tr>
<td>(3) $DP = \pi/Fr$</td>
<td>1.306</td>
<td>0.066</td>
</tr>
<tr>
<td>(4) $p^{pre}$</td>
<td>-2.191</td>
<td>-3.642</td>
</tr>
<tr>
<td>(5) $p^{rev}$</td>
<td>-2.904</td>
<td>-3.518</td>
</tr>
<tr>
<td>(6) $adp$</td>
<td>8.43</td>
<td>13.98</td>
</tr>
<tr>
<td>(7) $corr$</td>
<td>-0.027</td>
<td>-0.136</td>
</tr>
<tr>
<td>(8) $sd_{delta}$</td>
<td>11.21</td>
<td>18.49</td>
</tr>
<tr>
<td>(9) $kurt$</td>
<td>5.11</td>
<td>4.37</td>
</tr>
<tr>
<td>(10) $meandur$</td>
<td>3.56</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>complete</td>
<td>5.75</td>
</tr>
<tr>
<td>(11) $sd_{dur}$</td>
<td>4.11</td>
<td>3.29</td>
</tr>
<tr>
<td></td>
<td>complete</td>
<td>5.63</td>
</tr>
</tbody>
</table>

Notes: Data are from the Symphony IRI Inc. Sample period: from January 2001 to December 2011.

The entries are weighted means of stratum-level monthly variables. Observations across strata are based on consumption expenditure weights, observations across months are weighted equally. $p$ - inflation, in %; $Fr$ - the fraction of items with changing prices; $DP$ - the size of price changes, in %; $P^{pre}$ ($P^{res}$) - preset (reset) price level defined as the unweighted means of starting (ending) log price levels for all products in the stratum in each month, expressed as % deviations from the average for all log prices in the stratum; $adp$ - the average absolute size of price changes, in %; $corr$ - serial correlation of newly set prices for an individual product; $sd_{delta}$ - standard deviation of non-zero price changes for a given stratum, in %; $kurt$ - kurtosis of non-zero price changes for a given stratum; $meandur$ - mean price spell duration (for complete spells), in months; $sd_{dur}$ - standard deviation of price spell durations for a given stratum (for complete spells), in months.
Table A.4: Alternative standard errors, U.K. CPI data

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Point estimate</th>
<th>Standard errors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(1)</td>
<td>(2)</td>
</tr>
<tr>
<td>Price selection</td>
<td>-0.373</td>
<td>0.002***</td>
</tr>
</tbody>
</table>

Notes: Data are from the U.K. Office for National Statistics CPI database, available at [http://www.ons.gov.uk/ons/datasets-and-tables/index.html](http://www.ons.gov.uk/ons/datasets-and-tables/index.html). Sample period is from February 1996 through September 2015. Point estimate in Column (1) is the estimated coefficient \( \gamma \) in the following empirical specification: \( P_{pre}^{ct} = \gamma DP_{ct} + \delta_t + \delta_c + \text{error} \), where \( \delta_t \) and \( \delta_c \) are month and category fixed effects. The number of observations is 1,073,089. Column (1) presents the estimates, Column (2) provides baseline standard errors (pooled WLS), Column (3) provides Driscoll-Kraay standard errors, Column (4) clusters standard errors by strata (8,941 clusters) which allows for arbitrary correlation of errors across time, and Column (5) clusters standard errors by month (235 clusters) which allow for arbitrary cross-sectional correlation of errors. *** – denotes statistical significance at 1% confidence level.
Table A.5: 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>All prices</th>
<th>Incl. subs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>weighted freq-weighted</td>
<td>weighted freq-weighted</td>
<td>weighted freq-weighted</td>
</tr>
<tr>
<td><strong>A. U.K.</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stratum</td>
<td>8941</td>
<td>-0.371*** (0.002)</td>
<td>-0.333*** (0.002)</td>
<td>-0.415*** (0.002)</td>
</tr>
<tr>
<td>Category</td>
<td>1037</td>
<td>-0.355*** (0.006) -0.385*** (0.006)</td>
<td>-0.342*** (0.005) -0.359*** (0.005)</td>
<td>-0.402*** (0.005) -0.404*** (0.005)</td>
</tr>
<tr>
<td>Basic class</td>
<td>66</td>
<td>-0.294*** (0.017) -0.361*** (0.016)</td>
<td>-0.363*** (0.013) -0.357*** (0.013)</td>
<td>-0.349*** (0.014) -0.330*** (0.014)</td>
</tr>
<tr>
<td>Aggregate</td>
<td>1</td>
<td>-0.209** (0.094) -0.197*** (0.072)</td>
<td>-0.386*** (0.087) -0.394*** (0.065)</td>
<td>-0.217** (0.094) -0.188*** (0.069)</td>
</tr>
</tbody>
</table>

| **B. Canada**        |                  |                                |            |           |
| Stratum              | 9165             | -0.285*** (0.003)              | -0.327*** (0.001) | -0.268*** (0.003) |
| Aggregate            | 1                | -0.114 (0.062)                | -0.116** (0.054) | -0.108 (0.058) |

| **C. U.S.**          |                  |                                |            |           |
| Stratum              | 1550             | -0.360*** (0.000)              | -0.303*** (0.000) | N/A       |
| Aggregate            | 1                | -0.068 (0.044) 0.061* (0.035)  | -0.211*** (0.024) -0.140*** (0.021) |           |

Notes: Data sources are described in notes for Table 1. For row "Stratum" the entries are price selection coefficients at a stratum level replicated from Table 2. Other rows provide price selection for aggregated groups (category, basic class, and aggregate). For the U.K. basic class corresponds to Classification of Individual Consumption by Purpose (COICOP). For "Aggregate" rows the estimated values of the coefficient in the time-series regression of aggregate preset price level on the aggregate size of price changes, with calendar-month fixed effects. Aggregate variables are frequency-weighted means (regression 10), or by weighted means. Standard errors are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Table A.6: Price selection in sticky-price models

<table>
<thead>
<tr>
<th>Moments</th>
<th>Data</th>
<th>Identical sectors</th>
<th>Heterogeneous sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Calvo</td>
<td>Taylor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2)</td>
<td>(3)</td>
</tr>
<tr>
<td><strong>Fraction of p-changes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>weighted mean</td>
<td>0.121</td>
<td>0.124</td>
<td>0.125</td>
</tr>
<tr>
<td>min</td>
<td>0.033</td>
<td>0.124</td>
<td>0.125</td>
</tr>
<tr>
<td>max</td>
<td>0.404</td>
<td>0.124</td>
<td>0.125</td>
</tr>
<tr>
<td><strong>Sector-level selection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>weighted mean</td>
<td>-0.395</td>
<td>0.000</td>
<td>-0.438</td>
</tr>
<tr>
<td>min</td>
<td>-0.482</td>
<td>0.000</td>
<td>-0.438</td>
</tr>
<tr>
<td>max</td>
<td>-0.198</td>
<td>0.000</td>
<td>-0.438</td>
</tr>
<tr>
<td><strong>Aggregate selection</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.197</td>
<td>0.000</td>
<td>-0.438</td>
</tr>
<tr>
<td><strong>Aggregation effect</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>due to freq dispersion</td>
<td>0.198</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>due to other factors</td>
<td>21%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>79%</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Half-life of C impulse</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>response, months</td>
<td>5.26</td>
<td>3.11</td>
<td>1.07</td>
</tr>
</tbody>
</table>

Notes: Data entries correspond to statistics from the 66 basic classes in the U.K. data. Price selection entries in the Column (1) correspond to predicted values based on weighted linear regression of sector-level price selection on a constant and sector-level monthly mean fraction of price change as regressors, for the case with regular prices and no substitutions, not controlling for calendar-month effects. Aggregation effect is the difference between aggregate and sector-level selection. The remaining columns provide the results from 66-sector models. Columns (2)–(4) Calvo, Taylor, Golosov-Lucas models with identical sectors; Columns (5)–(7): Calvo, Taylor and Golosov-Lucas models with heterogeneous sectors. Shaded moments are matched by calibration of adjustment and nesting parameters corresponding empirical moments in Column 1. Calvo and Taylor models are solved analytically. For Golosov-Lucas model, we simulate equilibrium dynamics in each model over 235 months for a given draw of a money growth shocks and 10000 draws of idiosyncratic productivity shock. For each simulation we compute the time series for each of the variables. We repeat this simulation 100 times and report the means of model moments over these simulations.
Table A.7: Price selection, real rigidities and monetary non-neutrality in Calvo, Golosov-Lucas and Golosov-Lucas+ models

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Calvo</th>
<th>GL</th>
<th>Calvo-GL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strategic complementarity</td>
<td></td>
<td>$\zeta=0.15$</td>
<td>$\zeta=1$</td>
<td>$\zeta=7$</td>
</tr>
<tr>
<td>Weight on GL in nested model</td>
<td></td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
</tr>
<tr>
<td>A. Calibration targets</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fraction of pch, %</td>
<td>0.16</td>
<td>16.01</td>
<td>16.01</td>
<td>16.01</td>
</tr>
<tr>
<td>Abs size of pch, %</td>
<td>14.7</td>
<td>14.72</td>
<td>14.72</td>
<td>14.72</td>
</tr>
<tr>
<td>Serr corr of reset prices</td>
<td>0.13</td>
<td>0.12</td>
<td>0.12</td>
<td>0.12</td>
</tr>
<tr>
<td>Inflation mean, %</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>Inflation stdev, %</td>
<td>0.29</td>
<td>0.28</td>
<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
<td>B. Sensitivity to $DP_t$</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$P_t^{res}$</td>
<td>0.86</td>
<td>0.94</td>
<td>0.94</td>
<td>0.64</td>
</tr>
<tr>
<td>$P_t^{pre}$</td>
<td>-0.14</td>
<td>-0.06</td>
<td>-0.06</td>
<td>-0.36</td>
</tr>
<tr>
<td>C. Predicted moments</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumption stdev, %</td>
<td>3.39</td>
<td>1.43</td>
<td>0.54</td>
<td>1.06</td>
</tr>
<tr>
<td>Consumption ser. corr</td>
<td>0.91</td>
<td>0.81</td>
<td>0.65</td>
<td>0.81</td>
</tr>
<tr>
<td>Half-life of C, months</td>
<td>7.77</td>
<td>3.34</td>
<td>1.59</td>
<td>3.38</td>
</tr>
<tr>
<td>Std of price spells</td>
<td>5.70</td>
<td>5.70</td>
<td>5.70</td>
<td>5.70</td>
</tr>
<tr>
<td>Kurtosis of p-changes, %</td>
<td>3.93</td>
<td>4.02</td>
<td>2.85</td>
<td>1.3</td>
</tr>
</tbody>
</table>

Notes: We simulate equilibrium dynamics in each model over 217 months for a given draw of a money growth shocks and 10000 draws of idiosyncratic productivity shock. For each simulation we compute the time series for each of the variables. We repeat this simulation 1000 times and report the means and standard deviations of model moments over these simulations.
Table A.8: Price selection, real rigidities and monetary non-neutrality in Calvo, Taylor and Taylor+ models

<table>
<thead>
<tr>
<th></th>
<th>Data</th>
<th>Calvo*</th>
<th>Taylor</th>
<th>Calvo-Taylor</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ζ=0.15</td>
<td>ζ=1</td>
<td>ζ=7</td>
</tr>
<tr>
<td>Strategic complementarity</td>
<td>0.15</td>
<td>2</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Nesting parameter</td>
<td>1</td>
<td>2</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>

**A. Calibration targets**

<table>
<thead>
<tr>
<th></th>
<th>Fraction of pch, %</th>
<th>Abs size of pch, %</th>
<th>Serr corr of reset prices</th>
<th>Inflation mean, %</th>
<th>Inflation stdev, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>0.16</td>
<td>14.7</td>
<td>0.13</td>
<td>0.25</td>
<td>0.29</td>
</tr>
<tr>
<td>Calvo*</td>
<td>16.67</td>
<td>14.70</td>
<td>0.13</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>Taylor</td>
<td>16.67</td>
<td>14.71</td>
<td>0.13</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>Calvo-Taylor</td>
<td>16.67</td>
<td>14.70</td>
<td>0.13</td>
<td>0.26</td>
<td>0.29</td>
</tr>
</tbody>
</table>

**B. Sensitivity to DP\_t**

<table>
<thead>
<tr>
<th></th>
<th>(p_{t}^{\text{res}})</th>
<th>(p_{t}^{\text{pre}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>0.86</td>
<td>-0.14</td>
</tr>
<tr>
<td>Calvo*</td>
<td>0.99</td>
<td>-0.01</td>
</tr>
<tr>
<td>Taylor</td>
<td>0.99</td>
<td>-0.01</td>
</tr>
<tr>
<td>Calvo-Taylor</td>
<td>0.86</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

**C. Predicted moments**

<table>
<thead>
<tr>
<th></th>
<th>Consumption stdev, %</th>
<th>Consumption ser. corr</th>
<th>Half-life of C, months</th>
<th>Std of price spells</th>
<th>Kurtosis of p-changes, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data</td>
<td>4.00</td>
<td>0.92</td>
<td>8.25</td>
<td>5.33</td>
<td>3.05</td>
</tr>
<tr>
<td>Calvo*</td>
<td>1.44</td>
<td>0.82</td>
<td>3.57</td>
<td>5.33</td>
<td>3.12</td>
</tr>
<tr>
<td>Taylor</td>
<td>0.47</td>
<td>0.61</td>
<td>1.41</td>
<td>5.33</td>
<td>3.16</td>
</tr>
<tr>
<td>Calvo-Taylor</td>
<td>1.75</td>
<td>0.84</td>
<td>4.03</td>
<td>0.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>0.89</td>
<td>0.72</td>
<td>2.13</td>
<td>0.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>0.43</td>
<td>0.56</td>
<td>1.19</td>
<td>0.00</td>
<td>3.00</td>
</tr>
<tr>
<td></td>
<td>3.08</td>
<td>0.90</td>
<td>6.71</td>
<td>4.15</td>
<td>3.08</td>
</tr>
<tr>
<td></td>
<td>1.24</td>
<td>0.79</td>
<td>2.91</td>
<td>3.70</td>
<td>3.15</td>
</tr>
<tr>
<td></td>
<td>0.49</td>
<td>0.60</td>
<td>1.34</td>
<td>3.04</td>
<td>3.20</td>
</tr>
</tbody>
</table>

Notes: Calvo* model is solved by a linear approximation, so simulated moments may differ from Calvo predictions in Table 2. We simulate equilibrium dynamics in each model over 217 months for a given draw of a money growth shocks and 10000 draws of idiosyncratic productivity shock. For each simulation we compute the time series for each of the variables. We repeat this simulation 1000 times and report the means and standard deviations of model moments over these simulations.
Figure A.1: Preset price level and average size of price changes in the United Kingdom, aggregate time series, regular prices and no substitutions.
Conditional on common nominal shock, probability is higher for low prices and lower for high prices

\[ p \] - firm's log price
\[ p^* \] - desired log price

B. Zero price selection in Calvo (1983)
Conditional on common nominal shock, probability of adjustment is the same for all prices
Figure A.3: Sector-level price selection in sticky-price models

Notes: Scatter plot contains estimated price selection for 66 basic classes in the U.K. CPI data ("Data") and their predicted values based on weighted linear regression with a constant and basic-class-level monthly mean fraction of price changes as regressors, for the case with regular prices and no substitutions, not controlling for calendar-month effects ("Data (fitted)"). The remaining scatter points provide sector-level price selection in the 66-sector Taylor and Golosov and Lucas models. In each model, we parameterize price adjustment parameters to match the frequency of price changes for each class.
Figure A.4: Impulse responses in 66-sector sticky-price models

Notes: Figure provides responses to a +1% impulse to money supply growth in the 66-sector Calvo model, Taylor model, and Golosov-Lucas model. Left panels correspond to responses in Calvo, Taylor, Golosov-Lucas models with identical sectors. Right panels: Calvo, Taylor and Golosov-Lucas models with heterogeneous sectors. Top panels provide responses for money supply ($M_t$—solid blue line) and aggregate price ($P_t$); bottom panels provide responses for the preset price level ($P_{t}^{pre}$).
Figure A.5: Price selection and real rigidities in Calvo, Golosov-Lucas and Golosov-Lucas+ models

Notes: Figure provides consumption responses to a +1% impulse to money supply in Calvo, Golosov-Lucas and nested (Golosov-Lucas+) models with strategic complementarity in pricing decisions ($\zeta = 0.15$), strategic substitutability ($\zeta = 7$), and strategic neutrality ($\zeta = 1$). Solid blue line indicates the money supply.
Figure A.6: Price selection and real rigidities in Calvo, Taylor and Taylor+ models

Notes: Figure provides consumption responses to a +1% impulse to money supply in Calvo, Taylor and nested (Taylor+) models with strategic complementarity in pricing decisions ($\zeta = 0.15$), strategic substitutability ($\zeta = 7$), and strategic neutrality ($\zeta = 1$). Solid blue line indicates the money supply.
Figure A.7: Average price spell duration and standard deviation of spells across sectors

Notes: Scatter plots for average duration and standard deviation of price spells. Data are for 66 basic classes in the U.K. CPI data, regular prices and no product substitutions (blue circles). Regression (black dashed line) fits the data. Red circles are predicted values in 66-sector Golosov-Lucas model. Green x-s are predicted values in 66-sector Taylor model. See Section 5.3 in the main text.
B Sticky-price models

We study price dynamics in one-sector Taylor (1980), Calvo (1983), and Golosov and Lucas (2007) models. Each model represents an economy populated by a large number of infinitely lived households and monopolistically competitive producers of intermediate goods. The shocks in this economy are aggregate shocks to the money supply and idiosyncratic productivity shocks. We describe the idiosyncratic shocks below. We assume that money supply, \( M_t \), follows random walk with drift

\[
\log M_t = \log \mu + \log M_{t-1} + \varepsilon_{mt}, \tag{B.1}
\]

where \( \mu \) is mean growth rate of money supply, and \( \varepsilon_{mt} \) is a normally distributed i.i.d. random variable with mean 0 and standard deviation \( \sigma_m \).

B.1 Representative household

The problem of representative household is identical for all models. Households buy a continuum of consumption varieties, indexed by \( i \), trade money and state-contingent nominal bonds, and work in competitive labour market. The problem of a representative household is to choose sequences of money holdings, \( \{M^d_t\} \), consumption varieties, \( \{c_t(i)\} \), state-contingent bonds, \( \{B_{t+1}\} \), with and hours worked \( \{h_t\} \) to maximize utility:

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln c_t - \psi h_t \right],
\]

subject to aggregate consumption aggregator

\[
1 = \int_0^1 \Gamma \left( \frac{c_t(i)}{c_t} \right) \, di, \tag{B.2}
\]

the budget constraint

\[
M^d_t + E_t \left[ Q_{t+1|t} \cdot B_{t+1} \right] \leq M^d_{t-1} - \int_0^1 p_{t-1}(i) c_{t-1}(i) \, di + W_t h_t + B_t + \int_0^1 \Pi_t(i) \, di + T_t, \tag{B.3}
\]

and a cash-in-advance constraint,

\[
\sum_{j=0}^{\infty} p_t(i) c_t(i) \leq M^d_t. \tag{B.4}
\]

Here \( c_t \) is aggregate consumption given by a homothetic function \( \Gamma \), and where the curvature of function \( \Gamma \) will determine the degree of real rigidities; \( M^d_t \) are money holdings,
$B_{t+1}$ is a vector of state-contingent bonds, $B_{t+1}$, where one unit of each bond pays one dollar in date $t + 1$ if a particular state is realized, and it pays zero otherwise; $Q_{t+1|t}$ is a vector of bond prices, $Q_{t+1|t}$, in each state in date $t$. $p_t(i)$ is the price of consumption good $j$, $\Pi_t(i)$ are firms’ dividends, and $T_t$ are lump-sum transfers from the government. The budget constraint (B.3) says that the household’s beginning-of-period balances combine unspent money from the previous period, $M_{y_{t-1}} - \int_0^1 p_{t-1}(i)c_{t-1}(i)di$, labor income, returns from bond holdings, dividends, and government transfers. The household divides these balances into money holdings and purchases of state-contingent bonds. Money is used to buy consumption subject to cash-in-advance constraint (B.4). Household starts period 0 with initial money and bond holdings $M_{y_0}$ and $B_1$.

First-order conditions for household’s problem yield a standard expression for household’s stochastic discount factor, the demand for consumption of variety $i$:

$$c_t(i) = c_t(\Gamma')^{-1}\left(\frac{P_t(i)}{P_t}\right),$$

where $P_t$ is the price of aggregate consumption

$$1 = \int_0^1 \Gamma\left(\Gamma'\right)^{-1}\left(\frac{P(i)}{P_t}\right)di,$$

and a condition for the optimal allocation of working hours:

$$\psi P_t c_t = W_t.$$

**B.2 Firms in Golosov and Lucas (GL) model**

A monopolistically competitive firm producing variety $i$ is endowed with a constant returns to scale technology that converts $l(i)$ unit of labor input into $a(i)l(i)$ units of output in each period, where $a(i)$ represents a firm’s productivity level in that period. We assume $\ln a(i)$ follows an AR(1) process:

$$\ln a(i) = \rho a \ln a_{-1}(i) + \varepsilon_a,$$

where $a_{-1}(i)$ is the previous period’s productivity level, $\varepsilon_a$ is a mean zero, normally i.i.d. error with standard deviation $\sigma_a$. Due to symmetry of the firm’s problem across varieties, we can omit index $i$.

Let $\kappa$ denote a fixed cost of changing a price ("menu cost") expressed in units of labor. The firm begins the current period with price $p_{-1}$, inherited from the previous period. After realizing its current productivity level $a$, the firm chooses whether to adjust its price. If it
changes its price, the firm pays the fixed labor cost at wage $W$, and chooses the new relative price $p$. Otherwise, the firm keeps its previous price. Since at price $p$ the demand for firm’s output is given by (B.5), the firm will produce $c(\Gamma')^{-1}\left(\frac{p}{P}\right)$ units of consumption good of its variety. The problem of the firm therefore can be written as follows:

$$V^a(p_{-1}, a; f) = \max_{p \geq 0} \frac{1}{Pc} \left[ \left( p - \frac{W}{a} \right) c(\Gamma')^{-1}\left(\frac{p}{P}\right) - W\kappa \right]$$

$$+ \beta \int V(p'_{-1}, a'; f') F \left( da'|a \right), \quad (B.6)$$

$$V^n(p_{-1}, a; f) = \frac{1}{Pc} \left[ \left( p_{-1} - \frac{W}{a} \right) c(\Gamma')^{-1}\left(\frac{p}{P}\right) \right]$$

$$+ \beta \int V(p'_{-1}, a'; f') F \left( da'|a \right), \quad (B.7)$$

$$V = \max \{V^a, V^n\}, \quad (B.8)$$

where function $V^a$ is the value of adjusting firm’s price, $V^n$ is the value of not adjusting firm’s price, and $V$ is the value before the adjustment decision. Firm’s state before price adjustment consists of firm price $p_{-1}$, realized productivity $a$, and aggregate state variable $f$, a measure of firms over $(p_{-1}, a)$. Function $F$ denotes the c.d.f. of future productivity shocks $a'$ conditional on the current realization $a$.

The firm’s problem is completed by specifying the laws of motion for the firm’s endogenous state variables $p'_{-1}$ and $f'$. Its price level is set to its optimal level in case of price adjustment, and it remains at $p_{-1}$ otherwise. Price and productivity realizations for all firms determine the new measure $f'$.

**B.3 Firms in Calvo model**

The only difference from firm’s problem in GL model is the price adjustment decision. In GL model the firm chooses optimally whether or not to adjust its price in each period. In Calvo model that decision is exogenous: with probability $\lambda$, $0 < \lambda < 1$, the firm does not adjust its price, and with probability $1 - \lambda$ it sets its price optimally. Formally, in the firm’s problem, equations (B.6) and (B.7) will stay the same, and equation (B.8) is replaced with

$$V = \begin{cases} 
V^a, \text{ w/prob } 1 - \lambda \\
V^n, \text{ w/prob } \lambda 
\end{cases}$$

An equilibrium consists of prices and allocations $p_t(i)$, $P_t$, $W_t$, $c_t(i)$, $c_t$ and $l_t$ that, given prices, solve households’ and firms’ decision problems, and markets for consumption goods, labour, money and bonds clear. The model is solved by a non-linear projection method.

B.4 Firms in Taylor model

In Taylor model, the firm adjusts its price according to a fixed schedule, after $T$ periods. The firm’s problem has an additional state variable $t$, which keeps track of the time since the last time the price was adjusted.

The price-setting equations (B.6), (B.7), (B.8) are replaced with:

$$V^a(p_{-1}, a, t; f) = \max_{p \geq 0} \frac{1}{Pc} \left[ \left( p - \frac{W}{a} \right) \left( \frac{p}{P} \right)^{-\theta} c \right]$$

$$+ \beta \int V(p'_{-1}, a', 0; f')F(da'|a),$$

$$V^n(p_{-1}, a, t; f) = \frac{1}{Pc} \left[ \left( p_{-1} - \frac{W}{a} \right) \left( \frac{p_{-1}}{P} \right)^{-\theta} c \right]$$

$$+ \beta \int V(p'_{-1}, a', t + 1; f')F(da'|a),$$

$$V(p_{-1}, a, t; f) = V^a(p_{-1}, a, t; f)I(t = T) + V^n(p_{-1}, a, t; f)I(t < T),$$

where function $I$ is an indicator function. The model is solved by a log-linear approximation around the deterministic steady state.

C Formal derivations of price selection in sticky-price models

C.1 Equilibrium in a sticky-price model

Let $\Gamma (S)$ be the numeraire for nominal variables: it could be the money supply or the aggregate price level. All nominal variable will be normalized to one-period lag of the numeraire, $\Gamma (S_{-1})$. Denote by $\gamma (S)$ the growth rate of the numeraire, $\gamma (S) = \Gamma (S) / \Gamma (S_{-1})$.

A monopolistically competitive firm is endowed with production technology that implies cost function $W(s, S)$, where $s$ denotes firm-specific exogenous state variables and $S$ denotes aggregate state in the economy. The firm uses this technology to produce its own variety of differentiated good that is used for consumption. The firm also faces fixed (menu) cost of changing its price, $\kappa (S)$. A firm that decides to change its price $p$ faces the following problem,
written in recursive form,

\[
V^a (p_{-1}, s; S) = \max_p \left[ \frac{U_c (S)}{P (S)} \left( p - W' (s, S) \right) \left( \frac{p}{P (S)} \right)^{-\theta} C (S) - \kappa (S) \right] \\
+ \beta \int V \left( p, s'; S' \right) F_s (ds' | s) F_S (dS' | S)
\]

where \( V^a (p_{-1}, s; S) \) is the value of adjusting price, \( P (S), C(S), U_c (S) \) are aggregate price, consumption, marginal utility, and \( F_s (s'|s, S), F_S (S'|S) \) are the laws of motion of individual and aggregate state. The notational convention for \( V^a (p_{-1}, s; S) \) is that \( p_{-1} \) is the price normalized by \( \Gamma (S_{-1}) \).

The value function of the firm that does not change its price is

\[
V^n (p_{-1}, s; S) = \frac{U_c (S)}{P (S)} \left[ (p_{-1} \gamma (S) - 1 - W' (s, S)) \left( \frac{p_{-1} \gamma (S) - 1}{P (S)} \right)^{-\theta} C (S) - \kappa W \right] \\
+ \beta \int V \left( p_{-1} \gamma (S) - 1, s'; S' \right) F_s (ds' | s) F_S (dS' | S)
\]

Finally, continuation value is

\[
V \left( p, s'; S' \right) = \lambda (p, s'; S') V^a \left( p, s'; S' \right) + (1 - \lambda (p, s'; S')) V^n \left( p, s'; S' \right)
\]

where function \( \lambda (p_{-1}, s'; S') \) is the probability of adjustment. For example, in the standard menu cost model

\[
\lambda \left( p_{-1}, s'; S' \right) = \begin{cases} 
1, & \text{if } V^a \geq V^n \\
0, & \text{if otherwise}
\end{cases}
\]

and in Calvo model

\[
\lambda \left( p_{-1}, s'; S' \right) = \lambda
\]

The new price

\[
p \left( p_{-1}, s; S \right) = \begin{cases} 
p^* \left( p_{-1}, s; S \right), & \text{if adjust} \\
p_{-1} \gamma (S)^{-1}, & \text{if not adjust}
\end{cases}
\]

and accordingly the conditional distribution of new prices

\[
h \left( p \mid p_{-1}, s; S \right)
\]

Firm’s decision functions can be aggregated to give the functions \( P (S), C (S), U_c (S), W (S) \), and the laws of motion for \( F \left( p_{-1}, s \mid S \right) \) and \( F_S \left( S' \mid S \right) \). First, assuming "cash-in-advance" aggregate demand gives

\[
P (S) C (S) = 1
\]
Next, log-linear utility gives
\[ W(S) = \frac{\theta - 1}{\theta} \]
where wage is normalized such that the average price level is unity.

The end-of-period distribution of price-state pairs is
\[ G(p, s | S) = \int_{p-1} h(p | p-1, s; S) F(dp_{-1}, s | S) \]

Note again the notation convention: in \( G(p, s | S) \) prices \( p \) are normalized by \( \Gamma(S) \), whereas in \( F(p_{-1}, s | S) \) prices \( p_{-1} \) are normalized by \( \Gamma(S_{-1}) \).

The end-of-period distribution of prices is
\[ G(p | S) = \int_s G(p, ds | S) \]
so the aggregate price is
\[ P(S) = \int_p p dG(p | S) \]

The law of motion for the distribution of price-state pairs is
\[ F'(p, s' | S') = G(p, s | S) F_s(s' | s) F_S(S' | S) \]
\[ = \left\{ \int_{p-1} h(p | p-1, s; S) F(dp_{-1}, s | S) \right\} \cdot F_s(s' | s) F_S(S' | S) \]

Finally, the law of motion for \( F_S(S' | S) \) is such that
\[ P(S') = \int_p p dG'(p | S') \]
\[ G'(p | S') = \int_s G'(p, ds | S') \]
\[ G'(p, s | S') = \int_{p-1} h(p | p-1, s; S') F'(dp_{-1}, s | S') \]

C.2 Calvo (1983) model

Firms change their price with probability that is independent of the state:
\[ \lambda(p_{-1}, s; S) = \lambda \]

Conditional on changing price in period \( t \), firms set price as a markup over the average (discounted) marginal cost the firm expects to face over the duration of time the price remains
in effect. The natural log of this price (up to a constant) is (assuming no inflation trend)

\[ P_{res}^t(i) = (1 - (1 - \lambda)\beta)^{-1} \sum_{\tau=0}^{\infty} (1 - \lambda)^\tau \beta^\tau E_t [W_{t+\tau}^t(i)] \]

where \( W_t^t(i) \) is the log of firm \( i \)'s nominal marginal cost. Consider a special case with log linear preferences, cash-in-advance constraint and labor-only constant returns technology. In this case, firm's nominal marginal cost is

\[ W_t^t(i) = M_t - a_t(i) \]

where \( M_t \) is the log of money stock and \( a_t(i) \) is the log of firm-level productivity. Assume for simplicity that both \( M_t \) and \( a_t(i) \) follow a random walk. Then firm \( i \)'s log reset price is

\[ P_{res}^t(i) = M_t - a_t(i) \]

and the average reset price is

\[ P_{res} = M_t \]

and the average preset price is

\[ P_{pre}(S) = \Lambda(S)^{-1} \int p \Lambda(p;S) dG(p \mid S_{-1}) = P(S_{-1}) \]

which implies that the decomposition is

\[ P_t - P_{t-1} = \lambda [M_t - P_{t-1}] . \]

That is, all of the inflation variance is explained by the reset price and price selection is zero.

C.3 Taylor (1980) model

Assume for concreteness that prices in Taylor price contracts are fixed for \( T = 4 \) periods. Log money supply follows a random walk:

\[ M_t = M_{t-1} + \varepsilon_t \]

In the simplest case with no strategic complementaries and no front-loading effects, firms that can adjust their price will set it to the desired price level, which is equal to the level of the
money supply. The reset price level, expressed as deviation from population average $P_{t-1}$, is

$$P_{t}^{\text{res}} = M_t - P_{t-1}$$

which in turn implies that preset price level is equal to the money supply $T$ period ago:

$$P_{t}^{\text{pre}} = M_t - 4 - P_{t-1}$$

while the remaining prices in the cross-section are

$$P_{jt} = M_t - j, \ j = 1 \ldots 3 .$$

We can then write the aggregate price index as

$$P_t = M_t - 4 - P_{t-1} = \frac{M_t - M_{t-4}}{4} ,$$

and reset and preset price levels

$$P_{t}^{\text{res}} = \frac{4 \varepsilon_t + 3 \varepsilon_{t-1} + 2 \varepsilon_{t-2} + \varepsilon_{t-3}}{4}$$

$$P_{t}^{\text{pre}} = -\frac{\varepsilon_{t-1} + 2 \varepsilon_{t-2} + 3 \varepsilon_{t-3}}{4}$$

Price selection is given by the regression of preset price on the difference of reset and preset prices:

$$\gamma = -\frac{\text{cov}(P_{t}^{\text{pre}}, P_{t}^{\text{res}} - P_{t}^{\text{pre}})}{\text{var}(P_{t}^{\text{res}} - P_{t}^{\text{pre}})} = -\frac{\sigma_{\varepsilon}^2}{4} \left(1 + 2 + 3 \right) = -\frac{6}{16}$$

The main text presents the derivation of price selection for any price stickiness $T$:

$$\gamma = -\frac{T - 1}{2T} . \quad (C.1)$$

Hence price selection is stronger with price stickiness.

### C.4 Aggregation and price selection in two-sector Taylor model

Suppose now that the Taylor model has two equally weighted sectors with different degree of price flexibility: $T_1 = 2$ and $T_2 = 4$ . Using the formula for price selection (C.1) gives us price selection in each sector: $\gamma_1 = -\frac{1}{4}$, $\gamma_2 = -\frac{3}{8}$. The average selection is $\frac{\gamma_1 + \gamma_2}{2} = -\frac{5}{16}$.

The aggregate price index as $P_t = \frac{1}{2} \left( \frac{M_t + M_{t-1} + M_{t-2} + M_{t-3}}{4} \right)$, and the inflation identity can be written as $P_t - P_{t-1} = \frac{3}{8} \left( \frac{2M_t + M_{t-1} - 2M_{t-2} + M_{t-3}}{3} \right)$, where in the last equation $\frac{3}{8}$ is the average frequency of price adjustment, and the term in
the vector of sector $j$ during the duration $\tau$. The weighted mean size of price changes is $DP_t^w = \varepsilon_t + \varepsilon_{t-1} + \frac{\varepsilon_{t-2} + \varepsilon_{t-3}}{2}$.

The frequency-weighted preset price level is

$$DP_t^{pre,fr} = \frac{2M_{t-2} + M_{t-4}}{3} - \frac{2M_{t-1} + M_{t-2}}{2} - \frac{1M_{t-1} + M_{t-2} + M_{t-3} + M_{t-4}}{4}$$

and the weighted preset price level is $DP_t^{pre,w} = \frac{3\varepsilon_{t-1} + 2\varepsilon_{t-2} + 3\varepsilon_{t-3}}{8}$.

Price selection is given by the regression of preset price on the difference of reset and preset prices:

$$\gamma_{fr} = \frac{\text{cov}(P_t^{pre,fr}, DP_t^{fr})}{\text{var}(DP_t^{fr})} = \frac{5/12 + 2/36 + 3/36}{1 + 1/9 + 1/9} = \frac{1}{4},$$

$$\gamma_{w} = \frac{\text{cov}(P_t^{pre,w}, DP_t^{w})}{\text{var}(DP_t^{w})} = \frac{3/8 + 1/8 + 3/16}{1 + 1/4 + 1/4} = \frac{11}{40}.$$  

Note that aggregate selection is weaker than the average of sector-level price selections, and frequency-weighted selection is weaker than weighted selection:

$$|\gamma_{fr}| < |\gamma_{w}| < \left| \frac{\gamma_1 + \gamma_2}{2} \right|.$$  

Hence price selection is weaker with aggregation.

**C.5 N-sector nested Taylor-Calvo model**

Consider $N$ sectors in a truncated Calvo price setting, where sectors are indexed by $j$. Let $T_j$ denote the total price cohorts (ages) in sector $j$. Let $T = \max \{T_j\}$. Then any price at age $\tau < T_j$ adjusts with probability $\lambda_j$, and prices adjust for sure after $T_j$ periods. The fraction of prices with duration $\tau = 1$ in sector $j$ is $\lambda_j(1 - (1 - \lambda_j)^{T_j})^{-1}$.

Define auxiliary vectors: let $A$ be a $N$–vector with $j$’s entry $\lambda_j(1 - (1 - \lambda_j)^{T_j})^{-1}$, $A$ be a $N$–vector with $j$’s entry $\lambda_j$, $\Gamma$ be a $(N \times T)$ –matrix with $j$’s row corresponding to the vector of sector $j$ pricing cohorts equal to $A_j(1 - \lambda_j)^{\tau-1}$ for $\tau = 1, \ldots, T_j$, and zero for $\tau = T - T_j + 1, \ldots, T$. And let $\omega_j$ the vector with weights $\omega_j$ denoting consumption weight of sector $j$. The frequency of price changes in sector $j$ is $Fr_j = \frac{\lambda_j}{1 - (1 - \lambda_j)^{T_j}} = A_j$.

Denote the following vectors:

$$M_{t,t-(T-1)} = [M_t, M_{t-1}, \ldots M_{t-(T-1)}]' \quad (T \times 1),$$

$$\varepsilon_{t-1,t-T} = [\varepsilon_t, \varepsilon_{t-1}, \ldots \varepsilon_{t-(T-1)}]' \quad (T \times 1).$$

27
The vector of price indexes $\mathbf{\Gamma} \cdot \mathbf{M}_{t,t-(T-1)}$, and so the aggregate price index is

$$P_t = \omega' \mathbf{\Gamma} \mathbf{M}_{t,t-(T-1)}.$$ 

The reset and preset price levels

$$P_{t}^{\text{pre}} = \delta' \left[ \varepsilon_t \mathbf{I}_{N \times 1} + (\mathbf{I}_{N \times T} - \mathbf{\Gamma} \mathbf{L}) \varepsilon_{t-1,t-T} \right]$$

$$P_{t}^{\text{pre}} = \delta' (\kappa - \mathbf{I}_N) (\mathbf{\Gamma} \mathbf{L}' - \mathbf{I}_{N \times T}^0) \varepsilon_{t-1,t-T}$$

$$P_{t}^{\text{res}} - P_{t}^{\text{pre}} = \delta' \left[ \varepsilon_t \mathbf{I}_{N \times 1} + (\mathbf{I}_{N \times T} - \mathbf{\Gamma} \mathbf{L}) \varepsilon_{t-1,t-T} - (\kappa - \mathbf{I}_N) (\mathbf{\Gamma} \mathbf{L}' - \mathbf{I}_{N \times T}^0) \varepsilon_{t-1,t-T} \right],$$

where $\delta$ is the $(N \times 1)$ vector with entries $\frac{\omega_j A_j}{\omega \mathbf{X}}$ (or $\omega_j$) for the frequency-weighted (weighted) aggregation, and $\kappa$ is a $(N \times N)$ diagonal matrix with diagonal element in row $j$ equalling $\lambda_j/A_j$, $\mathbf{L}$ is lower triangular $(T \times T)$ matrix, $\mathbf{I}_N$ is the diagonal $(N \times N)$ matrix, $\mathbf{I}_{T \times N}$ is the $(T \times N)$ matrix of 1’s, and $\mathbf{I}_{N \times T}^0$ is an $(N \times T)$ matrix in which the entries of row $j$ are 0’s for $\tau = 1, ..., T_j$, and 1’s for $\tau = T - T_j + 1, ..., T$.

Price selection is given by the regression of preset price on the difference of reset and preset prices:

$$\gamma = \frac{\text{cov} (P_{t}^{\text{pre}}, P_{t}^{\text{res}} - P_{t}^{\text{pre}})}{\text{var} (P_{t}^{\text{res}} - P_{t}^{\text{pre}})}$$

$$= \frac{\delta' (\kappa - \mathbf{I}_N) (\mathbf{\Gamma} \mathbf{L}' - \mathbf{I}_{N \times T}^0) \left[ \mathbf{I}_{N \times T} - \mathbf{\Gamma} \mathbf{L}' - (\kappa - \mathbf{I}_N) (\mathbf{\Gamma} \mathbf{L}' - \mathbf{I}_{N \times T}^0) \right]' \delta}{1 + \delta' \left[ \mathbf{I}_{N \times T} - \mathbf{\Gamma} \mathbf{L}' - (\kappa - \mathbf{I}_N) (\mathbf{\Gamma} \mathbf{L}' - \mathbf{I}_{N \times T}^0) \right]' \delta.}$$

We can check that selection goes to zero as $T \to \infty$ (Calvo model). And it goes to $-\frac{T-1}{2T}$ as $\lambda \to 0$ (Taylor mode).

Consumption response is

$$C_t = M_t - P_t = \omega' (\mathbf{I}_{T \times N} - \mathbf{L} \mathbf{\Gamma}') \varepsilon_{t,t-(T-1)},$$

and serial correlation of consumption is

$$\rho_C = \frac{\text{cov}(C_t, C_{t-1})}{\text{var}(C_t)} = \frac{\omega' (\mathbf{I}_{T \times N} - \mathbf{L} \mathbf{\Gamma}')' \mathbf{U}_1 (\mathbf{I}_{T \times N} - \mathbf{L} \mathbf{\Gamma}') \omega}{\omega' (\mathbf{I}_{T \times N} - \mathbf{L} \mathbf{\Gamma}')' (\mathbf{I}_{T \times N} - \mathbf{L} \mathbf{\Gamma}') \omega},$$

where $\mathbf{U}_1$ is the $(T \times T)$ matrix that gives the lag of vector $\varepsilon_{t,t-(T-1)}$: $\varepsilon_{t-1,t-T} = \mathbf{U}_1 \varepsilon_{t,t-(T-1)}$.

Monetary non-neutrality is defined as the half-life of consumption response: $\Psi = \frac{\ln(0.5)}{\ln \rho_C}$. 

28
C.6 Caplin and Spulber (1987) model

In a monetary equilibrium log prices are uniformly distributed on \([b, B]\) with distribution

\[
G(p \mid S) = \begin{cases} 
1 & \text{if } p \in (B, \infty) \\
\frac{p - b}{B - b} & \text{if } p \in [b, B] \\
0 & \text{if } p \in (-\infty, b) 
\end{cases}
\]

Recalling that money supply follows a one-sided process, the hazard function is:

\[
\Lambda(p - 1; S) = \begin{cases} 
1 & \text{if } p - 1 \in (-\infty, b + \omega) \\
0 & \text{if } p - 1 \in [b + \omega, \infty) 
\end{cases}
\]

which gives the average fraction of adjusting prices

\[
\overline{\Lambda}(S) = G(b + \omega \mid S - 1) = \frac{\omega}{B - b}
\]

To find distribution of reset prices, write the law of motion

\[
G(p \mid S) = G(p + \omega \mid S - 1) - G(b + \omega \mid S - 1) + H(p \mid S)G(b + \omega \mid S - 1)
\]

so that

\[
H(p \mid S) = \frac{G(p \mid S) - G(p + \omega \mid S - 1) + \overline{\Lambda}(S)}{\overline{\Lambda}(S)}
\]

The reset price is

\[
P_{\text{res}}(S) = \int_p p \, dH(p \mid S)
\]

\[
= \int_{[b, B]} p \, dH(p \mid S) + \int_{[b + \omega, B]} p \, dH(p \mid S) - \int_{[b, b + \omega]} p \, dH(p + \omega \mid S - 1) + \int_{[b + \omega, B]} p \, dH(p + \omega - b \mid S - 1)
\]

\[
= \overline{\Lambda}(S)^{-1} \left( \int_{[b, B]} p \, dG(p \mid S) - \int_{[b, B]} p \, dG(p + \omega \mid S - 1) + \int_{[b + \omega, B]} p \, dG(p + \omega - b \mid S - 1) \right)
\]

\[
= \overline{\Lambda}(S)^{-1} \left( \int_{[b, B]} p \, dG(p \mid S) - \int_{[b, B]} p \, dG(p + \omega - b \mid B - b) \right)
\]

\[
= \frac{1}{2\omega} \left( B^2 - b^2 - (B - \omega)^2 - b^2 \right) = B - \omega/2
\]
So

\[
\pi^{res}(S) = \pi^{res}(S) - P(S_{-1}) + \omega \\
= B - \omega/2 - \int_{[b,B]} pd \frac{p-b}{B-b} + \omega \\
= B - \omega/2 - \frac{B+b}{2} + \omega \\
= \frac{B-b + \omega}{2}
\]

The preset price is

\[
P^{pre}(S) = \mathcal{K}(S)^{-1} \int_{p} p \Lambda(p;S) dG(p \mid S-1) \\
= \frac{B-b}{\omega} \int_{b}^{b+\omega} pd \left( \frac{p-b}{B-b} \right) = b + \omega/2
\]

so

\[
\pi^{pre}(S) = P(S_{-1}) - P^{pre}(S) = \frac{B+b}{2} - b - \omega/2 = \frac{B-b - \omega}{2}
\]

Overall, this gives us the following decomposition

\[
P(S) - P(S_{-1}) + \omega = \left[ \frac{B-b + \omega}{2} + \frac{B-b - \omega}{2} \right] \frac{\omega}{B-b} = \omega
\]

So inflation is equal to the rate of money growth, i.e., there is full monetary neutrality. Price selection is ill-defined, since preset price level relative to the aggregate price is moving with money supply, \( \omega - (B-b) \), but the average size of price changes is constant, \( B-b \).

C.7 Head-Liu-Menzio-Wright model

Head et al. (2012) (HLMW) study a model in which price dispersion arises due to decentralized trade and search frictions in the goods market. An equilibrium pins down a unique relative price distribution \( G(p_{-1} \mid S-1) \) but does not pin down price changes. This distribution is invariant to monetary shocks. Hence there is full monetary neutrality despite arbitrary price stickiness for a nontrivial measure of goods at a micro level.

Hazard function in HLMW model:

\[
\Lambda(p_{-1};S) = \begin{cases} 
1 & \text{if } p_{-1} \in (-\infty, b + \omega) \cap (B + \omega, \infty) \\
1 - \rho & \text{if } p_{-1} \in [b + \omega, B + \omega]
\end{cases}
\]
which gives the average fraction of adjusting prices

\[ \bar{\Lambda} (S) = \int_{p_{-1}} \Lambda (p_{-1}; S) dG (p_{-1} | S_{-1}) \]

\[ = G (b + \omega | S_{-1}) + (1 - \rho) [1 - G (b + \omega | S_{-1})] \]

\[ = 1 - \rho + \rho G (b + \omega | S_{-1}) \]

To find \( H \) write the law of motion for \( G \):

\[ G (p | S) = \rho [G(p + \omega | S_{-1}) - G(b + \omega | S_{-1})] + H (p | p_{-1}; S) [1 - \rho + \rho G (b + \omega | S_{-1})] \]

HLMW show that there exists a monetary equilibrium in which this distribution is invariant to changes in the money supply, i.e., there is monetary neutrality. In this case, \( G (p | S) = G (p | S_{-1}) = G (p) \), and so

\[ H(p | S) = \begin{cases} 
\frac{G(p) - \rho [G(p + \omega) - G(b + \omega)]}{1 - \rho + \rho G(b + \omega)} & \text{if } p \in [b, B - \omega] \\
\frac{G(p) - \rho [1 - G(b + \omega)]}{1 - \rho + \rho G(b + \omega)} & \text{if } p \in [B - \omega, B]
\end{cases} \]

Check that \( H \) is indeed a distribution function:

\[ \int dH (p | p_{-1}; S) = \int_{[b, B - \omega]} dG(p) - \rho \int_{[b, B - \omega]} G(p) \frac{G(p + \omega) - G(b + \omega)}{1 - \rho + \rho G(b + \omega)} + \int_{[B - \omega, B]} dG(p) - \rho \int_{[B - \omega, B]} [1 - G(b + \omega)] \frac{1}{1 - \rho + \rho G(b + \omega)} = 1 \]

The reset price is

\[ P_{\text{res}} (S) = \int_p p dH (p | S) \]

\[ = \int_{[b, B - \omega]} p dG(p) - \rho \int_{[b, B - \omega]} p dG(p + \omega) + \int_{[B - \omega, B]} p dG(p) - \rho \int_{[B - \omega, B]} [1 - G(b + \omega)] \frac{1}{1 - \rho + \rho G(b + \omega)} + \rho \omega \frac{1}{1 - \rho + \rho G(b + \omega)} \]

\[ = \bar{\Lambda} (S)^{-1} \left[ \int_{[b, B]} p dG(p) - \rho \int_{[b, B - \omega]} p dG(p + \omega) \right] \]

\[ = \bar{\Lambda} (S)^{-1} \left[ \int_{[b, B]} p dG(p) - \rho \int_{B - \omega, B]} p dG(p) + \rho \omega (1 - G(b + \omega)) \right] \]
So

\[
\pi_{res} (S) = P_{res} (S) - P (S_{-1}) + \omega
\]

\[
= \overline{\Lambda} (S)^{-1} \left[ \int_{[b, B]} p \, dG(p) - \rho \int_{[b + \omega, B]} p \, dG(p) + \rho \omega \left( 1 - G(b + \omega) \right) \right] - \int_{[b, B]} p \, dG(p) + \omega
\]

\[
= \overline{\Lambda} (S)^{-1} \left[ (1 - \overline{\Lambda} (S)) \int_{[b, B]} p \, dG(p) - \rho \int_{[b + \omega, B]} p \, dG(p) + \omega \right]
\]

The preset price is

\[
P_{pre} (S) = \overline{\Lambda} (S)^{-1} \int_p \Lambda (p; S) \, dG(p)
\]

\[
= \overline{\Lambda} (S)^{-1} \left[ \int_{[b, b + \omega]} p \, dG(p) + (1 - \rho) \int_{[b + \omega, B]} p \, dG(p) \right]
\]

\[
= \overline{\Lambda} (S)^{-1} \left[ \int_{[b, B]} p \, dG(p) - \rho \int_{[b + \omega, B]} p \, dG(p) \right]
\]

so that

\[
\pi_{pre} (S) = P (S_{-1}) - P_{pre} (S)
\]

\[
= \overline{\Lambda} (S)^{-1} \left[ - (1 - \overline{\Lambda} (S)) \int_{[b, B]} p \, dG(p) + \rho \int_{[b + \omega, B]} p \, dG(p) \right]
\]

Finally,

\[
P (S) - P (S_{-1}) + \omega = \left\{ \overline{\Lambda} (S)^{-1} \left[ (1 - \overline{\Lambda} (S)) \int_{[b, B]} p \, dG(p) - \rho \int_{[b + \omega, B]} p \, dG(p) + \omega \right] + \overline{\Lambda} (S)^{-1} \left[ - (1 - \overline{\Lambda} (S)) \int_{[b, B]} p \, dG(p) + \rho \int_{[b + \omega, B]} p \, dG(p) \right] \right\} \overline{\Lambda} (S)
\]

\[
= \omega
\]

Note that this model nests Caplin-Spulber’s case for \( \rho = 1 \) and \( G(p) \) as in their case. As in Caplin-Spulber’s case, reset-price inflation and selection effect co-move in offsetting fashion. Unlike Caplin-Spulber’s case, for \( \rho > 0 \), the sum of the two effects does move around, so that some of the inflation variance is due to intensive margin.

HLMW solve for \( G \):

\[
G (p, n^*) = \begin{cases} 
1 - \frac{\alpha_1}{2\alpha_2} \left\{ \frac{p(n^*) - \hat{p}}{p - \hat{p}} \left[ p(n^*) - c \right] - 1 \right\}, & \text{if } p \in \left[ \hat{p} (n^*), p(n^*) \right] \\
1 - \frac{\alpha_1}{2\alpha_2} \left\{ \frac{p(n^*) - \hat{p}}{p - n^* (p - c)} \left[ p(n^*) - c \right] - 1 \right\}, & \text{if } p \in \left[ p(n^*), \hat{p} (n^*) \right]
\end{cases}
\]

32
where $n^*$ is the equilibrium real balances and $p$ is the real price, and

$$
\hat{p}(n^*) = (n^*)^{\sigma-1} \\
\overline{p}(n^*) = \max \left\{ \frac{c}{1-\sigma}, (n^*)^{\sigma-1} \right\} \\
\underline{p}(n^*) = \frac{c\overline{p}(n^*) (\alpha_1 + 2\alpha_2)}{\alpha_1 c + 2\alpha_2 \overline{p}(n^*)}
$$

with

$$
\lambda = 0.401 \\
\sigma = 0.45 \\
\rho = 0.937 \\
\alpha_1 = 2 (1 - \lambda) \lambda \\
\alpha_2 = \lambda^2
$$

We recalibrate $\rho$ to 0.792 so that the model matches the frequency of 0.22, a typical value in the CPI data. Numerical simulations show that in HLMW model reset price inflation accounts for about two thirds of inflation variance and the selection effect is responsible for almost one third. Increasing $\rho$ to 1, so that the frequency of price changes not triggered by the monetary shock is zero, brings model’s predictions close to those in the Caplin-Spulber’s model with fraction of price changes accounting for all inflation fluctuations.

## D Selection effects and price selection

In this section we use the Calvo and Golosov-Lucas models to provide intuition on selection effects in sticky-price models, and to illustrate how they relate to our model-free measure of price selection. The two panels in Figure A.2 provide a stylized representation of the probability of adjustment at a point of time for a log price, $p_i$, from a distribution of prices in the population. Let $p^*$ denote the common component of the desired log price level at that point in time (each firm’s desired price also depends on idiosyncratic components that we omit for clarity of exposition). The dispersion of prices at that point in time is the outcome of infrequent price changes; otherwise, all prices would be equal to $p^*$. The two models considered here differ in the shape of the function that gives the probability of adjustment as a function of the firm’s “price gap”, $|p_i - p^*|$. In the Calvo model (Panel B), that probability is a flat function of the price gap $|p_i - p^*|$. In the GL model (Panel A), firms face a fixed cost every time they adjust their prices. Since a firm’s profit function is concave with respect to the price gap $|p_i - p^*|$, they are more likely to adjust their price the bigger that distance.
Hence, the probability of adjustment \( \Lambda \) is a convex function with respect to \( |p_i - p^*| \), reaching the maximum of 1 when that distance becomes big enough that the benefits of adjusting outweigh the fixed cost.

Now consider the change in the probability of adjustment in response to a common shock that increases the desired level \( p^* \), say, by 1%. Since the shock increases the distance \( |p_i - p^*| \) for low prices and decreases it for high prices, it affects the probability of their adjustments. Graphically, this is captured by the shift of the probability function to the right by 1%. The distance between the the pre-shock probability function (blue line) and the after-shock function (red line) gives the change in the probability of adjustment for any price in the domain.

Since the probability function is flat in the Calvo model, there is no change in how likely a given price \( p_i \) will adjust in response to the shock. Hence, prices that adjust in response to that shock are representative of the whole population of adjusting prices and there is no price selection. In the GL model, lower prices are more likely to adjust, and higher prices are less likely to change. Hence, in response to a positive nominal shock, the average level of prices that adjust is lower than the average over the population of all prices. This is an example of price selection that amplifies the response of aggregate inflation to the shock.

\( \text{Golosov and Lucas} (2007) \) give an informal explanation of the selection effect along these lines. \( \text{Caballero and Engel} (2007) \) provide a formal treatment. They clarify that although the probability of price adjustment monotonically increases with the price gap \( |p_i - p^*| \) in some sticky-price models, the marginal contribution to the aggregate price response after a monetary shock does not always monotonically increase with the price gap. Note that in our example, the extensive margin complements price selection to amplify fluctuations of the average price level in response to common nominal shocks: both price increases (more frequent) and price decreases (less frequent) push the average price level up.

### E Price selection across different models

Figure [A.4] shows the responses to a +1% impulse to money supply in the Calvo, Taylor, and Golosov-Lucas models. The left bottom panel shows the responses of aggregate preset price levels \( P_{t}^{\text{pre}} \). In the Calvo model, preset price does not move after the shock and the aggregate price response is due to the increase in the reset price level. In the Golosov-Lucas model, the shock triggers more adjustments of prices below population average and prevents adjustments of prices above it, leading to a decrease of the preset price level on impact, by 1.2 percentage points. This decrease amplifies the response of the aggregate price level on impact, to around 0.46% versus 0.12% in the Calvo model. As a result of quicker aggregate price response, monetary non-neutrality in the Golosov-Lucas model, measured by the response of aggregate consumption, is smaller than in the Calvo model: consumption responds by 0.54% on impact.
(0.88% in Calvo) with a half-life of the response of 1.07 months (5.26 months in Calvo), Columns 2–4 in Table A.6).

Stronger price selection in the Taylor model relative to the Golosov-Lucas model, however, does not imply smaller monetary non-neutrality as consumption responds as much as in the Calvo model and lasts longer than in the Golosov-Lucas model. The key difference is that, unlike in the Golosov-Lucas model, negative comovement between the preset price and the intensive margin of inflation fluctuations in the Taylor model materializes only gradually after the shock, with most of its impact at the end of the response. The left bottom panel shows that the response of preset price gradually builds from zero on impact to -0.86 percentage points on month 6 after the shock, returning to zero on month 7 as all prices respond to the shock. Since most of the reset-price response occurs only late after the impulse, its impact on aggregate price response is reduced relative to the Golosov-Lucas model. Note that these results are not influenced by the response of the fraction of price changes in the Golosov-Lucas model, which moves very little, increasing by only 0.2 percentage points after the shock.

This example is useful for relating back to the analytical results derived for the Taylor model (see Section 5.1 in the paper). In the Taylor model, the subset of price adjusters does not change at the time of the shock $\varepsilon_t$, and so the preset price-relative does not immediately respond to the change in money supply $M_t$. By contrast, in menu cost models, the shock triggers (and also prevents) the adjustments of those prices that are affected by the shock as we illustrated in Section D and Figure A.2. Second, prices become increasingly more misaligned after a shock with the largest price gap for prices at the end of the price spell; i.e., the impact of price selection is backloaded over the duration of the response. This is unlike menu cost models, where the preset price level responds the most shortly after the shock. These differences lead to a bigger impact of price selection on the response of the aggregate price in menu cost models, as seen in the impulse response functions.

**F Price selection, real rigidities and monetary non-neutrality**

Here we analyze whether price selection and real rigidities interact in generating monetary non-neutrality. We change assumptions on preferences and technologies in the baseline models and parametrize them to obtain different degrees of real rigidity as measured by the Ball and Romer (1990) index of real rigidities ($\zeta$). In addition to the baseline parametrization, which yields strategic neutrality in price setting ($\zeta = 1$), we also study parametrizations that yield strong strategic complementarity ($\zeta = 0.15$) or substitutability ($\zeta = 7$) in pricing decisions. Moreover, we also study this interaction in generalized versions of the Golosov-Lucas and Taylor models, which introduce the possibility of some random price changes as in the Calvo model. Results are presented in Tables A.7 and A.8. Results show that real rigidities have an independent effect on monetary non-neutrality. This holds in different models with different
levels of price selection. Figures A.5 and A.6 show the underlying impulse response functions.

References


