Five Facts About Prices: 
A Reevaluation of Menu Cost Models

Emi Nakamura and Jón Steinsson
Harvard University

May 2008
Nominal price rigidities are a key assumption in a large body of macroeconomic models that seek to:

- Understand the effects of monetary policy
- Explain the behavior of the real exchange rate
- Understand business cycles

How much price rigidity actually exists in the economy?
Literature Review: Frequency of Price Change

- Case studies of particular industries:

- Surveys
  - Blinder et al. (1998)

- CPI Data
  - Inflation Persistence Network
    - Alvarez et al., 2005, Dhyne et al., 2006
New empirical evidence on consumer and producer prices

Key questions:

- How often and how much do prices change?
- Are the predictions of macroeconomic models of price-setting consistent with the data?
  - Time series variation in size & frequency of price adjustments
  - Seasonality of price change
  - Hazard function of price change
The Data: CPI Research Database

- Approx. 70% of consumer expenditures
- Sample Period: 1988-2005
- # obs. approx. 9 million
  - Provides average frequency of price changes, product substitutions and missing imputed prices
The Data: PPI

- New dataset on producer prices created from raw production files for the PPI
- We focus on Finished goods
- Sample Period: 1980-2005 (unbalanced panel)
- # obs. approx. 10 million
- Transaction prices: Hold fixed all “price determining” variables
CPI Data: Different Events

- Several different events lead price spells to end
  - Regular price changes
  - Sales
  - Stockouts
  - Product exit, seasonal products
Table 1: Frequency of Price Change in the CPI

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Regular</td>
<td>Price</td>
<td>Regular</td>
<td>Price</td>
</tr>
<tr>
<td>Median Freq. of Change</td>
<td>11.1</td>
<td>20.3</td>
<td>8.7</td>
<td>19.4</td>
</tr>
<tr>
<td>Median Implied Duration</td>
<td>8.5</td>
<td>4.4</td>
<td>11.0</td>
<td>4.6</td>
</tr>
<tr>
<td>Median Freq. of Change Incl. Subs.</td>
<td>12.7</td>
<td>21.7</td>
<td>10.9</td>
<td>20.5</td>
</tr>
<tr>
<td>Mean Freq. of Change</td>
<td>18.7</td>
<td>23.9</td>
<td>21.1</td>
<td>26.5</td>
</tr>
<tr>
<td>Mean Implied Duration</td>
<td>11.6</td>
<td>8.3</td>
<td>13.0</td>
<td>9.0</td>
</tr>
</tbody>
</table>
Empirical Features of Sales

Sales are not simply short price spells

– Price usually returns to old regular price after a sale
– Sales price changes are more than twice the as large as other price changes on average
– Different relationship to aggregate variables
– Hazard function of price change including sales is very different from that excluding sales
<table>
<thead>
<tr>
<th></th>
<th>Freq. Reg. Price Ch.</th>
<th>Freq. Price Ch. During One Period Sales</th>
<th>Frac. Return After One Period Sales</th>
<th>Frac. of Sales that Last One Period</th>
<th>Freq. Price Ch. During One Period Sales/Missing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Processed Food</td>
<td>10.5</td>
<td>11.4</td>
<td>78.5</td>
<td>64.7</td>
<td>11.1</td>
</tr>
<tr>
<td>Unprocessed Food</td>
<td>25.0</td>
<td>22.5</td>
<td>60.0</td>
<td>63.2</td>
<td>22.1</td>
</tr>
<tr>
<td>Househ. Furnish.</td>
<td>6.0</td>
<td>11.6</td>
<td>78.2</td>
<td>43.3</td>
<td>9.4</td>
</tr>
<tr>
<td>Apparel</td>
<td>3.6</td>
<td>7.1</td>
<td>86.3</td>
<td>35.8</td>
<td>5.9</td>
</tr>
</tbody>
</table>
Comparison to IPN

- Median frequency of price change comparable to US excluding sales
- Treatment of sales appear to make a much larger difference in US data
- Treatment of substitutions also makes a larger difference in US data
### Table: Frequency of Price Change: Comparison of CPI and PPI Categories

<table>
<thead>
<tr>
<th>Category</th>
<th>Num. of Matches</th>
<th>CPI Prices</th>
<th></th>
<th>CPI Regular Prices</th>
<th></th>
<th>PPI Prices</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Processed Food</td>
<td>32</td>
<td>26.1</td>
<td>3.3</td>
<td>10.5</td>
<td>9.0</td>
<td>7.2</td>
<td>13.4</td>
</tr>
<tr>
<td>Unprocessed Food</td>
<td>24</td>
<td>37.3</td>
<td>2.1</td>
<td>25.9</td>
<td>3.3</td>
<td>67.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Household Furnishings</td>
<td>27</td>
<td>23.0</td>
<td>3.8</td>
<td>6.5</td>
<td>14.9</td>
<td>5.6</td>
<td>17.3</td>
</tr>
<tr>
<td>Apparel</td>
<td>32</td>
<td>31.0</td>
<td>2.7</td>
<td>3.6</td>
<td>27.3</td>
<td>2.7</td>
<td>36.3</td>
</tr>
<tr>
<td>Recreation Goods</td>
<td>16</td>
<td>14.5</td>
<td>6.4</td>
<td>6.8</td>
<td>14.2</td>
<td>6.1</td>
<td>15.9</td>
</tr>
<tr>
<td>Other Goods</td>
<td>13</td>
<td>33.6</td>
<td>2.4</td>
<td>23.2</td>
<td>3.8</td>
<td>17.1</td>
<td>5.3</td>
</tr>
</tbody>
</table>
Fact 2: One-third of regular price changes are price decreases
Fact 3: The frequency of price increases responds strongly to inflation while the frequency of price decreases and the size of price increases and price decreases do not.
Figure 4: Inflation and the Frequency Price Changes for Consumer Prices
Figure 5: Inflation and the Size of Price Changes for Consumer Prices

Log Change

Year


Inflation

Reg Price Increases

Reg Price Decreases

Inflation
Figure 8: Evolution of the Frequency of Sales

- Processed Food
- Unprocessed Food
- Household Furnishings
- Apparel
Figure 9: Evolution of the Size of Sales
Fact 4: The frequency of price change is highly seasonal
Figure 10: Frequency of Price Change by Quarter for Consumer Prices
Figure 12: Frequency of Price Increases and Decreases by Month for Consumer Prices
Macroeconomic Implications:

- Seasonality in pricing is basic evidence of coordination
- Could reflect either coordinated changes in costs or pricing decisions
- Olivei and Tenreyro (2005) find that monetary non-neutrality is larger in response to monetary policy shocks that occur in certain quarters.
Figure 15: Seasonality of the Frequency of Sales
Hazard Function of Price Changes

- Key feature of interest:
  - Duration dependence (slope of the hazard function)

- Upward sloping hazard function: Older prices more likely to change.

- Traditional macroeconomic models: Flat or upward sloping hazard functions
Controlling for Unobserved Heterogeneity: CPI

1. Divide data into groups
   - Major Groups (11)
   - Entry-Level Item (ELI) Groups (270-360)

2. Product specific unobserved heterogeneity model
   - Meyer (1990):
     \[
     \lambda_{i,j}(t|\nu_i) = \nu_i \lambda_0(t) \exp(x_{i,j}\beta)
     \]
   - \(i\) indexes goods
   - \(j\) indexes price spells for a particular good
   - \(\nu_i\) is a product specific unobserved “frailty” factor (e.g. 2 liter bottle of Diet Coke in a particular supermarket in Chicago)
   - \(x_{i,j}\) is a vector of covariates
   - This model is estimated separately for each “group” (Major Group or ELI)
Main results:

- No evidence of upward sloping hazard functions
- Large difference between raw price and regular price
- Typical shape:
  - A bit downward sloping at first
  - Then mostly flat
  - For some categories: A large spike at 12 months
- Similar for PPI
Panel A: Processed Food

Hazard

<table>
<thead>
<tr>
<th>Months</th>
<th>Regular Price 88-97</th>
<th>Price 88-97</th>
<th>Regular Price 98-05</th>
<th>Price 98-05</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>2</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>3</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>4</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>5</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>6</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>7</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>8</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>9</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>10</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>11</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>12</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>13</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>14</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>15</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>16</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>17</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
<tr>
<td>18</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
<td>(values shown)</td>
</tr>
</tbody>
</table>
Comparison to IPN

- A great deal of work on this subject in IPN

- Baumgartner et al. (2005), Alvarez et al. (2005), Jenker et al. (2004), Dias et al. (2005), Fougere et al. (2005)

- Somewhat different methodologies

- Some papers conclude that it is not possible to reject a flat hazard
Conclusions

1. Temporary sales play a major role in US price flexibility
2. One-third of price changes are price decreases.
3. The frequency of price increases responds strongly to inflation while the frequency of price decreases and the size of price increases and price decreases do not.
4. The frequency of price change is highly seasonal.
5. The hazard function of price changes for individual consumer and producer goods is downward sloping for the first few months and then flat, with a spike at 12 months.