Reference Prices and Nominal Rigidities

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October 2007
The empirical plausibility of monetary business cycle models depends critically on the nature of nominal rigidities in goods markets.

Macroeconomists are increasingly using micro data sets to measure how frequently prices change.

The seminal article by Bils and Klenow (2004) argues that prices are quite flexible.

- Using monthly CPI data, they find that median duration of prices is 4.3 months.
The Bils and Klenow challenge

- The Bils and Klenow price duration estimate has became a litmus test for the plausibility of macro models.

  - Can a model account for the observed inertial behavior of inflation while being consistent with the Bils and Klenow evidence?
Bils and Klenow challenged

- Bils and Klenow focus on raw price changes.
  - They conclude prices are *not* very inertial.

- Nakamura and Steinsson focus on non-sale prices.
  - They argue that prices *are* quite inertial.
  - When sales are excluded, prices change on average every 8 to 11 months.
Which prices?

- Kehoe and Midrigan (2007) examine the impact of sales on price inertia using weekly supermarket scanner data.

- They apply their own algorithm to define sales.
  
  - They find that over 83 percent of price changes occur during a sales period.

- When sales observations are excluded, prices change once every 4.5 months.

- When sales are included, prices change every 3 weeks.
The impact of sales on inference

- Excluding ‘sales prices’ from the data has a major impact on inference about price inertia.

- What exactly is a sale?

- Should we treat ‘regular’ and ‘sales’ prices asymmetrically?
  - Are both inertial?
  - Are regular prices sticky?

- How you actually define sales in the data can have a major impact of inference.
Motivating our analysis

- There are high frequency movements in many prices.

- Some authors want to abstract from a subset of these movements that they regard as ‘sales’, others don’t.

- We organize our analysis around the ‘reference price’,
  - The price most often quoted within a given quarter.
Reference prices

Examples

Newman’s own balsamic vinagrette salad dressing

Weeks

Price

20 40 60 80 100 120 140

Price

Tims Jalapeno potato chips

Weeks

Price

20 40 60 80 100 120 140

Price

Basic red ice cream neapolitan

Weeks

Price

20 40 60 80 100 120 140

Price

Motts clamato juice

Weeks

Price

20 40 60 80 100 120 140

Price

Skinner long spaghetti

Weeks

Price

20 40 60 80 100 120 140

Price

Alpo pet care chicken strips

Weeks

Price

20 40 60 80 100 120 140

Price
Reference prices

- Some non-reference prices can be thought of as ‘sales prices’ because they are lower than the reference price.

- Other non-reference prices can’t be interpreted as ‘sales prices’ because they are higher than the reference price (26 percent in our data).

- We don’t want to take a stand on what sales are or on whether they are special events that should be disregarded by macroeconomists.
Key findings

- Reference prices are ‘important’.
- Reference prices are much more inertial than weekly prices.
- Reference prices are systematically but imperfectly related to costs.
- Demand shocks are important.
- It is very hard to reconcile existing models (flexible prices, menu costs, Calvo pricing) with our evidence.
- We describe a simple pricing rule that is consistent with the evidence.
  - This rule is consistent with the importance of nominal rigidities even though it implies that prices change frequently.
Data

- **Safeway Corp.**: a large food and drug retailer that operates roughly 1,800 stores in different U.S. states.
  - Weekly prices and sales revenue for 60,000 items.
  - High-quality weekly cost measures.

- **Dominicks**: a chain of grocery stores in the Midwest with one hundred outlets.
  - Weekly observations on price and sales revenue for 3,500 items.
  - Cost measure are available but problematic because it’s an average over time.
Scanner data versus CPI data

- **Disadvantage of scanner data.**
  - Scanner data are less comprehensive than CPI price data.

- **Advantage of scanner data.**
  - Scanner data are available at a weekly frequency and include information about prices, quantities, and cost.

- **Our data is concentrated in the processed and unprocessed food, household furnishings, and other goods categories.**
  - These categories have duration of prices roughly equal to the median duration of prices in the CPI basket.
  - Prices change more frequently in categories like vehicle fuel and less frequently in categories like services.
Safeway cost measure

- We observe Adjusted gross profit and Sales.

\[
\text{Net cost of goods} = \text{Cost of goods} - \text{Retail allowances},
\]
\[
\phantom{=} = \text{Adjusted gross profit} - \text{Sales}.
\]

- Retail Allowances are a rebate from the manufacturer or wholesaler.
- Cost of Goods = vendor cost, buying allowances, freight allowances, other allowances, unauthorized prc, overseas freight and distress.
Marginal cost

- Which costs are marginal depends on the time horizon.
  - At the weekly level it seems reasonable to assume that rent, capital and labor are all fixed, so net cost of goods = marginal cost.
    - Under this assumption the average markup in our data is 78 percent.
  - At lower frequencies the net cost of goods is a lower bound for both the level and variability of marginal cost.
- For the remainder of paper we refer to net cost of goods as marginal cost.
Volatility of prices, marginal cost, markups, and quantities

- Weekly prices are more volatile than weekly marginal costs.
  - Median standard deviation of log(marginal cost) is 0.11.
  - Median standard deviation of log(price) is 0.14.

- The realized markup is very volatile.
  - Median standard deviation of log(markup) is 0.12.

- Weekly quantities are much more volatile than weekly prices.
  - Median standard deviation of log(quantities) is 0.66.
Computing reference prices

- We compute reference prices at a quarterly frequency.
- Define a product as a UPC-store pair.
- For each product we observe weekly prices.
- We compute the reference price as the most common price for a given good in a given quarter.
Computing reference cost

- We follow a procedure similar to the one used for prices to identify reference cost.

- For convenience we refer to this cost as the reference cost.
Reference prices are important in our data set

- A high percentage of price observations correspond to reference prices (62 percent).
- Most quantities are sold at reference prices (54 percent).
- One third of all price changes involve movements from a non-reference price to a reference price.
- The probability of going back to a reference price conditional on being at a non-reference price is high (47 percent).
- The variance of quantities sold at reference prices is the same as the variance of quantities sold at non-reference prices.
Distribution of time spent and quantity sold at reference price

Distribution of time spent at reference price

Distribution of quantity sold at reference price

Grapes, bananas, pears, and stone fruit
Selected beef and fresh salmon
Magazines

Median (62%)

Bananas and pears
Fresh salmon
Magazines

Median (54%)
Reference prices are much more inertial than raw prices.

**Implied duration of prices (quarters)**

- **Safeway**
  - Reference prices: 2.8 quarters
  - Raw prices: 0.19 quarters

- **Dominicks**
  - Reference prices: 2.9 quarters
  - Raw prices: 0.31 quarters
Distribution of implied duration for reference prices and weekly prices

![Distribution of duration of the most common price (Safeway)](image1)

- Median (36 weeks)

![Distribution of duration of raw prices (Safeway)](image2)

- Median (2.5 weeks)
Reference costs are much more inertial than raw costs.
Reference prices are systematically but imperfectly related to costs

- Probability of reference prices changing when there is no change in reference cost is low (3 percent).
  - Probability of weekly prices changing when there is no change in weekly cost is also low (10 percent).

- But, reference prices don’t always change when reference costs change.
  - The probability of the reference price changing conditional on a change in marginal costs is only 50 percent.
  - There’s substantial variation in markup associated with a given reference price.
Distribution of markups for a given reference price
Determinants of the probability of a reference price change

- Define the reference markup in a quarter as the ratio of the reference price to the reference cost in that quarter.
- Suppose that the reference cost in quarter $t$ changes.
  - Other things equal this change induces a change in the value of the time $t$ reference markup.
  - For convenience we refer to this value as the ‘hypothetical reference markup’.
    - It’s the reference markup that would obtain if the firm didn’t change its reference price after a change in reference cost.
- We find that the probability of a change in the reference price is increasing in the deviation of the markup from its average level.
Median probability of reference price change

Percentage deviation of hypothetical reference markup from mean markup
Determinants of reference price changes

Once the firms decide to change the reference price they do so in a way that re-establishes the unconditional mean markup for the good.
Realized markup as percentage deviation from mean markup conditional on reference price changing

Percentage deviation of hypothetical reference markup from mean markup
Weekly prices and marginal cost

- The contemporaneous probability of a change in the weekly price increases with the percentage deviation of the markup from its unconditional mean.

- When there is a price change the new markup is between 66 and 100 percent of the unconditional markup.
  - When costs fall the firm passes almost all of the benefits to the consumer.
  - When costs rise the firm passes only a fraction of the rise to the consumer.
Median probability of weekly price change
Realized weekly markup as percentage deviation from mean markup conditional on weekly price changing

Percentage deviation of hypothetical markup from mean weekly markup
Which product categories have short price duration?

- Categories with a high probability of a reference cost change have a high probability of a reference price change.

- Categories with a high probability of weekly price change have a high probability of a weekly cost change.
Probability (p) of a change in the reference price
Cross-sectional evidence

\[ p = 0.82c - 0.04 \]

\[ R^2 = 0.62 \]
Probability (p) of a change in the weekly price
Cross-sectional evidence

\[ p = 0.91c - 0.02 \]
\[ R^2 = 0.81 \]
Determinants of reference price duration

The duration of reference prices seems to be chosen to keep the reference markup within plus or minus 10 percent of the mean markup.

- The distribution of realized markups is very similar for goods with different reference price duration.
Distribution of weekly markups for the life of a reference prices, by duration

Percentage deviation from average markup
Demand shocks are important

- Conditional on the price being constant the standard deviation of quantities sold is roughly 52 percent.
Small price changes

- There is substantial heterogeneity across categories with respect to the prevalence of small price changes.

- Many reference price changes are small.
  - Fraction of categories where 10 percent of more of the price changes are less than 1% is equal to 27 percent.

- Many weekly price changes are also small.
  - Fraction of categories where 10 percent of more of the price changes are less than 1% is equal to 13 percent.
Small price changes
Reference prices

Fraction of reference price changes smaller than one percent, by category
Small price changes
Weekly prices
Calender-time dependence in reference prices and/or marginal cost

• Suppose there was no calendertime dependence in reference prices/marginal cost.

• Each week of year $t$, firms flip a 4 sided coin with no memory to decide which state to be in.

• Assume that the probability of each state is equal to the corresponding fraction of type1, type2, type3 or ‘other’ prices in our data set.

→ Compute the probability of being in state $j$ in week $i$ of year $t$ and state $k$ in week $i$ of year $t + 1$.

• Compare resulting transition probabilities to our non-parametric estimates.
What’s the probability that you are in the same state in week \( i \) of year \( t \) and year \( t + 1 \)?

Suppose there’s perfect calendar-time dependence.

- Then the agreement fraction is one.

Other extreme: firms randomize in the manner just described.

- Then the calendar-time independent agreement fraction would be the sum of the transition probabilities calculated under the null of no calendar-time dependence.
The estimated agreement fraction

Actual agreement fraction = 0.42

Calendar-time independent agreement fraction = 0.40

We conclude there is very little evidence of time dependence in agreement fractions
Macro conditions, reference, and marginal cost

- Macro variables (quarterly frequency)
  - Fed funds rate, unemployment rate, growth rates of: nominal and real GDP, and MZM.

- Basic regression:
  \[ y_t = b_0 + b_1 x_t + b_2 x_{t-1} + \varepsilon_t \]

- \( y_t \) = growth rate of reference price, cost, or quantity.
- \( x_t \) = macro variable.

- The fraction of the slope coefficients (\( b_1 \) and \( b_2 \)) that is statistically significant is always less than 3 percent.

- This result suggests that idiosyncratic demand and cost shocks are important.

- We are currently studying the correlation of aggregate sales measures with macro variables.
Reconciling different pricing models with our findings

Flexible price models

- Flexible price models based on Dixit-Stiglitz specifications are inconsistent with the data.
  - Roughly 50% of the variance in prices is due to the variance in markups.

- Reconciling more general flexible price models with the data, requires an incredible configuration of cost and demand shocks.
Flexible price models

Example

- Linear demand:
  \[ P_t = a_t - b_t Q_t. \]

- Profits:
  \[ \pi = P_t Q_t - C_t Q. \]

- \( C_t \) = marginal cost.

- Optimal price and quantity:
  \[ P_t^* = \frac{a_t + C_t}{2}, \]
  \[ Q_t^* = \frac{a_t - C_t}{2b_t}. \]
Flexible price models

Example

\[ P_t^* = \frac{a_t + C_t}{2}, \]

\[ Q_t^* = \frac{a_t - C_t}{2b_t}. \]

- For every UPC we deduce the time series for \( a_t \) and \( b_t \) such that \( P_t^* \) and \( Q_t^* \) match the data exactly.

- Data:
  - Median standard deviation of \( \log(\text{cost}) \) = 0.11.
  - Median standard deviation of \( \log(\text{price}) \) = 0.14.
  - Median standard deviation of \( \log(\text{quantities}) \) = 0.66.

- To match the data demand shocks must be very volatile.
  - Median standard deviation of \( \log(a) \) = 0.16.
  - Median standard deviation of \( \log(b) \) = 0.82.
Flexible price models

Example

\[ P_t^* = \frac{a_t + C_t}{2}, \]

\[ Q_t^* = \frac{a_t - C_t}{2b_t}. \]

- 25 percent of the observations involve changes in cost but no changes in price.
  - To match these observations the change in \( a_t \) has to exactly offset the change in \( C_t \).
  - We find this configuration of shocks to be incredible.

- A similar argument goes through for Dixit-Stiglitz demand with stochastic coefficients.
Standard menu cost models

- Standard menu cost models are inconsistent with the data.

- Prices are more volatile than marginal cost.
  - Median of the standard deviation of log(price)/standard deviation of log(cost) = 1.25.

- Many price changes are small.

- We also need an incredible configuration of cost and demand shocks to explain why firms return often to an old (reference) price.
Non-standard menu cost models

- You can account for the return to reference prices by assuming that there are different menu costs for different changes in different types of prices (Kehoe and Midrigan (2007)).

- Problem 1: many reference and non-reference price changes are ‘small’.

  - So you need to assume that:
    - Once the firm pays menu cost to change one reference price, it can change some other reference price for free.
    - Once the firm pays menu cost to change one non-reference price, it can change some other non-reference price for free. (Midrigan\(^2\)).

- Problem 2: the standard deviation of reference prices is roughly 50 percent higher than the standard deviation of reference cost.
Calvo models

- Inconsistent with our finding the probability of a reference price change is increasing in the deviation of the realized markup from its unconditional mean.
Simple pricing rule

- Our findings can be reconciled with a relatively simple pricing rule.

- For any given good, firms set prices so that, on average, the nominal reference price is a particular markup over nominal reference cost.
  - Firms set the frequency with which they reset the reference price so as to keep the actual markup within plus/minus 10 percent of the desired markup over reference cost.

- This rule implies that the unconditional markup and the duration of the reference price is good specific.
Simple pricing rule

- Firms are more likely to change reference and non-reference prices when not doing so would imply a larger deviation between the realized markup and the unconditional markup.

- When firms change the reference price they re-establish the unconditional markup.

- When they change non-reference prices they buffer consumers from rises in marginal cost.
Implications of the pricing rule

- The simple pricing rule implies that observed prices change frequently.
- But this rule doesn’t coincide with a flexible price rule and is consistent with the importance of significant nominal rigidities.
Rationalizing the pricing rule

- The simple pricing rule is consistent with our empirical findings but we didn’t derive it from first principles.

- Doing so and understanding the implications for nominal shocks in a general equilibrium setting is a task we leave for future research.
Conclusion

- Reference prices are important and persistent.

- In the presence of reference prices, nominal rigidities can be important, even when prices change very frequently.

- Existing macro models cannot be easily reconciled with our empirical results.