Producers rational inattention and price stickiness: an inflated ordered probit approach

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Introduction and Background

- There are many papers (IPN and US) across many countries (US, Mexico, Hungary, etc., etc.) looking at the presence of price inertia, or “stickiness” →

- Even with a changing economic environment, firms are reluctant to change prices → Banque de France Survey Responses

![Bar chart showing price changes](chart.png)
The usual explanations for this inertia are menu costs and/or time-dependent behaviour.

2. However, this does not account for the information we find in much survey data (see Fabiani et al., 2006), which suggests that most (manufacturing) firms in the Euro area only review their prices very infrequently.

- Fabiani et al., (2006) - for the Euro area show that:
  - on average, only about 25% of firms review their prices at least monthly
  - this ranged from 10% (Italy, France, Austria, the Netherlands and Germany) to 30% (Belgium, Spain and Portugal)
  - however; nearly 60% of firms review their prices at most 3 times per year
  - ranged from 50% - 80%
In the UK, Hall et al., (1997): while only 30% of them declare a similar frequency for their price changes:
- about 70% of UK firms review their prices at least quarterly

3. The majority of price reviews $\rightarrow$ price changes

- For the Euro area, only one price review in three $\rightarrow$ price change:
  - two thirds of firms only change prices once a year at most
- For the UK, only 30% of firms change their prices at least quarterly
- So, in summary, we have:
  - infrequent price reviews, plus
  - a small conversion rate of these to price change, equals
  - sticky prices!
The approach we suggest here, is to model price reviews and price changes simultaneously, and hence explain the high proportion of price inertia.
So, why do firms only periodically review their prices?
Most obvious answer is cost!! (Sims, 1998, 2003)
That is, there are significant costs in firms undertaking price reviews in order to determine their optimal prices →
Zbaracki et al., (2004) estimate these costs (net of consumer reactions and/or physical menu costs associated with the price change) for US manufacturing firm (with 8,000 products):
- 30 man/months ($250,000US at the time of the study!)
- comprised of costs of gathering and processing the information needed for reviewing prices (around 11 man/months of labor: about $100,000US);
- and those of the decision making process itself (computation of new prices, simulation of alternative price strategies, and so on): 18 man/months: about $150,000US
These are big numbers, and represent a high proportion (1/4) of total costs incurred by a price change
Price Reviews

- So, likelihood of a price review will be a function of perceived costs relative to benefits (of the review, not necessarily a price change)
- However, these costs and expected benefits (of a price review) are unobserved
- Characteristics of the firm’s environment should be good proxies here though:
  - a volatile environment → ↑ incentive for a review(s)
- However, even in a “stable” environment, there will also be factors that are likely to trigger a review
  - seasonality - many changes occur in January (↓ coordination problems due to the higher synchronization of price changes across firms and seasons: Konieczny and Rumler, 2005)
  - duration dependence - prices that do not change frequently appear to do so on a (broadly) yearly basis (may reflect the explicit/implicit contracts between firms and customers)
We split the sources of potential volatility into the main three drivers of a firm's prices: production costs; product demand; and competitors’ prices.

“significant” movements in any of these are likely to trigger a review.

We also distinguish between two types of changes in the firm environment:

- long run ("permanent shocks") variations in price determinants; and
- short-term ("transitory shocks") variations.
Here, we base our approach on a standard state-dependent pricing model.

So, given that a price review has been undertaken, what are the likely factors that will trigger a subsequent change (or not)?

Essentially, divergences of prevailing current price $P_{it-1}$ from the optimal one $P^*_{it}$ are likely to cause price changes (note, we have $i = 1, \ldots, N$ firms observed over $t = 1, \ldots, T_i$ periods).

Assume monopolistic competition and a constant price elasticity of demand, given by $a$ ($a < -1$), profit maximization leads to the usual equality:

$$P^*_{it} = \frac{a}{1 + a} MC_{it},$$

where $MC$ represents marginal cost.
Price Changes

- Assuming a simple static Cobb-Douglas cost function:

\[ C_{it} = A_{ijt} Q_{it}^{\alpha} w_{it}^{\beta} \pi_{it}^{\gamma} \]

- \( Q_{it} \) = firm production level
- \( w_{it} \) = represents the wage rate
- \( \pi_{it} \) = the price of intermediate inputs
- \( A_{ijt} \) = unobserved variables affecting costs, varying by sector \( j \)

Then the 1st-order condition for output gives us an expression for \( MC \) which is substituted into the \( P_{it}^* \) equation giving:

\[
P_{it}^* = \alpha \frac{a}{(a+1)} A_{ijt} Q_{it}^{\alpha-1} w_{it}^{\beta} \pi_{it}^{\gamma}, \text{ or in logs}
\]

\[
p_{it}^* = \ln \left[ \alpha \frac{a}{(a+1)} \right] + \ln(A_{ijt}) + \ldots + \gamma \ln(\pi_{it})
\]
We assume that $A_{ijt}$ can be decomposed into three (multiplicative components):

- a firm specific effect $A_i$;
- a sector-specific effect, $B_j$; and
- a third term representing a sectoral (common) time-varying component of prices $C_{jt}$.

Due to the relative dimensions of $T$ and $J$, we proxy $C_{jt}$ by sectoral production price indices at the NACE2 level:

$$\left( PPI_{jt}; C_{jt} = PPI_{jt}^\delta \right)$$
Thus we have proxies for $p_{it}^*$ but the difference $(p_{it}^* - p_{it-1})$ is still unobserved! How to proceed...

For a *price spell* (starting at $t_0$), where price hasn’t changed, we have

$$p_{it}^* - p_{it-1} = p_{it}^* - p_{it_0}$$

Where the difference on the LHS $(p_{it}^* - p_{it-1})$ is exactly what we’re interested in *i.e.*, the desired price change $(\Delta p_{it}^d)$!

Assuming that (as usual in state-dependent pricing models) firms fully adjust to the optimal price level (when indeed, they change prices), then we have, at the start of the spell that prices were optimal:

$p_{it_0} = p_{it_0}^*$

So, the desired price change $(\Delta p_{it}^d)$ can be written as

$$\Delta p_{it}^d = p_{it}^* - p_{it-1} = p_{it}^* - p_{it_0}^*$$
From above, we have expressions for $p_{it}^*$ so all we have to do is difference the RHS of this equation, giving

$$\Delta p_{it}^d = p_{it}^* - p_{it0} = \Delta_s \ln(A_{ijt}) + (\alpha - 1) \Delta_s \ln Q_{it} + \beta \Delta_s \ln w_{it} + \gamma \Delta_s \ln \pi_{it} + u_{it}$$

Where $\Delta_s x$ represents the variation of $x$ over the course of the spell.

However, following Loupias and Sevestre (2007), we consider a more flexible form than simply the cumulative change in the $x$’s and let the effect of these vary over a given price spell.
Thus our final estimated equation is based on

\[ \Delta p_{it}^d = \delta \Delta_s \ln(PPI_{jt}) + (\alpha - 1) \Delta_s \ln Q_{it} + \beta \Delta_s \ln w_{it} + \gamma \Delta_s \ln \pi_{it} + u_{it} \]

Our “general” version of this replaces \( \Delta_s x \) with the individual distributed lag function of \( \Delta x \)

The desired price change, depends on:

1. Firm specific variables: current and lagged changes in wages and prices of intermediate goods; current and lagged changes in the demand being addressed to the firm and

2. Sector-specific and macro variables: e.g., variation in the sectoral inflation (common industry price shocks); note we also include here macro variables such as dummies for the VAT change (April 2000) and the Euro cash change-over (2002)
The so-called \((s, S)\) rule states when the foregone benefits of \(P_{it} - P^*_it\) exceeds the costs, price is changed.

That is, when \(\Delta p^d_{it}\) is in excess of certain threshold values \((\mu)\), observed prices will change.

Specifically, with \(j = -2, \ldots, 2\) outcomes observed in our data ("big" decreases to "big" increases: \(J = 5\)), we have:

\[
\Delta p_{it} = \begin{cases} 
-2 & \text{if } \Delta p^d_{it} \leq \mu_j, \\
\mu_{j-1} < \Delta p^d_{it} \leq \mu_j, & \text{if } j = -1, 0, 1 \\
2 & \text{if } \mu_{j-1} \leq \Delta p^d_{it}
\end{cases}
\]

with \(\mu_0\) normalised to 0.
Thus our dependent variable, is an ordered discrete one might suggest an ordered probit approach; but let’s have a look at the raw data again...
And, we believe that the price-setting process can be decomposed into two sequential decisions →

But we don’t observe all price reviews
Econometric Model

- So, we want our model to explicitly allow for *jointly* the price review process and the price-rule/change process →
- Let’s start with a underlying latent variable, $r_{it}^*$, which is a firm’s price review equation

$$r_{it}^* = x_{it}' \beta + u_{it}$$

- $x$ are our proxies for stability of the firm’s environment *etc.*
- $r_{it}^* > 0 \rightarrow$ price review
- Under normality, the probability of this is, where $\Phi(\cdot)$ is the standard normal c.d.f.:

$$\Pr(r_{it} = 1|x_{it}) = \Pr(r_{it}^* > 0|x_{it}) = \Phi(x_{it}' \beta)$$
Econometric Model

- However, this needs to be combined with the price change process →
- Need to allow for price review firms to make a price decision, which may still be no change →
- Conditional on being in the price review regime, the price change process, $\Delta p^d_{it}$, kicks in...

$$\Delta p^d_{it} = z'_{it} \gamma + \epsilon_{it}$$

- Where $z$ are the firms costs, demand etc., variables: denote this our price change equation
Econometric Model

- Conditional on $r_{it} = 1$, probability of each “observed” $\Delta p_{it}$ outcome (under normality) are

$$
\Pr(\Delta p_{it}) = \begin{cases} 
\Pr(\Delta p_{it} = -1 \mid r_{it} = 1) = \Phi(\mu_1 - z'_{it} \gamma) \\
\Pr(\Delta p_{it} = 0 \mid r_{it} = 1) = \Phi(\mu_{j-1} - z'_{it} \gamma) - \Phi(\mu_{j-2} - z'_{it} \gamma) \\
\Pr(\Delta p_{it} = 1 \mid r_{it} = 1) = 1 - \Phi(\mu_{j-2} - z'_{it} \gamma) 
\end{cases}
$$
Econometric Model

- Under independence of $\varepsilon$ and $u$ the full probabilities for $\Delta p_{it}$, *unconditional on regime*, are (for $j = -1, 0, 1$)

\[ \Pr(\Delta p_{it}) = \begin{cases} 
\Pr(\Delta p_{it} = -1) = \Phi(x'_{it}\beta) \Phi(\mu_0 - z'_{it}\gamma) \\
\Pr(\Delta p_{it} = 0) = [1 - \Phi(x'_{it}\beta)] + \\
\Phi(x'_{it}\beta) [\Phi(\mu_0 - z'_{it}\gamma) - \Phi(\mu_1 - z'_{it}\gamma)] \\
\Pr(\Delta p_{it} = 1) = \Phi(x'_{it}\beta) [1 - \Phi(\mu_1 - z'_{it}\gamma)] 
\end{cases} \]

- In this way, (along ZIP and ZIOP lines), the probability of a no-change outcome has been ‘inflated’
Empirical Approach

- To observe a $\Delta p_{it} = 0$ (no-change) outcome we require either that:
  - $r_{it} = 0$ (the price review equation for no review dominates);
  - or jointly that $r_{it} = 1$ (review equation for review dominates) and that $0 < \Delta p_{it}^d \leq \mu$ (prevailing price not “far enough away” from optimal)
  - note observationally equivalent observations arise from two distinct sources!
- Can allow for a correlation between $\varepsilon$ and $u$ (equations relate to the same individual)
- Probabilities are now functions of the standardized bivariate normal c.d.f. with correlation coefficient $\rho_{\varepsilon u}$, $\Phi_2(a, b; \rho)$;
- $\Pr(\Delta p_{it}) =$

\[
\begin{align*}
\Pr (\Delta p_{it} = -1) &= \Phi_2 (x'_{it} \beta, -z'_{it} \gamma; -\rho_{\varepsilon u}) \\
\Pr (\Delta p_{it} = 0) &= [1 - \Phi (x'_{it} \beta)] + \left\{ \begin{array}{c}
\Phi_2 (x'_{it} \beta, \mu - z'_{it} \gamma; -\rho_{\varepsilon u}) \\
-\Phi_2 (x'_{it} \beta, -z'_{it} \gamma; -\rho_{\varepsilon u})
\end{array} \right\} \\
\Pr (\Delta p_{it} = 1) &= \Phi_2 (x'_{it} \beta, z'_{it} \gamma - \mu; \rho_{\varepsilon u})
\end{align*}
\]
We have panel data - can condition on unobserved firm heterogeneity in both equations →

\[ r_{it}^* = x_{it}' \beta + \alpha_i + u_{it} \]
\[ \Delta p_{it}^d = z_{it}' \gamma + e_i + \varepsilon_{it} \]

Assume \( \alpha_i \sim N(0, \sigma_{\alpha}^2) \) and \( e_i \sim N(0, \sigma_e^2) \)

However, again, as these unobserved effects correspond to the same firm, correlations are likely →

\[
\begin{pmatrix}
  u_{it} \\
  \varepsilon_{it}
\end{pmatrix}
\sim N
\left[
\begin{pmatrix}
  0 \\
  0
\end{pmatrix},
\begin{pmatrix}
  1 & \rho \\
  \rho & 1
\end{pmatrix}
\right]
\]

And

\[
\begin{pmatrix}
  \alpha_i \\
  e_i
\end{pmatrix}
\sim N
\left[
\begin{pmatrix}
  0 \\
  0
\end{pmatrix},
\begin{pmatrix}
  \sigma_{\alpha}^2 & \sigma_{\alpha e} \\
  \sigma_{\alpha e} & \sigma_e^2
\end{pmatrix}
\right]
\]

However, this significantly complicates estimation!
Econometric Model

- Conditional on the individual effects, the (log-)likelihood, where
  \[
  \theta = (\beta', \gamma', \mu, \rho, \sigma^2_\alpha, \sigma^2_e, \sigma_{\alpha e})'
  \]
- \[
  L (\theta \mid \alpha_i, e_i) =
  \sum_{i=1}^{N} \sum_{t=1}^{T_i} \sum_{j=0}^{J-1} d_{ijt} \ln \left[ \Pr (\Delta p_{it} = j \mid x_{it}, z_{it}) \right], \text{ where, } \Pr(\Delta p_{it})
  \]
  \[
  = \begin{cases} 
  \Phi_2 (x'_{it} \beta + \alpha_i, -z'_{it} \gamma - e_i; -\rho_{\varepsilon u}) \\
  [1 - \Phi (x'_{it} \beta + \alpha_i)] + \begin{cases} 
  \Phi_2 (x'_{it} \beta + \alpha_i, \mu - z'_{it} \gamma - e_i; -\rho_{\varepsilon u}) \\
  -\Phi_2 (x'_{it} \beta + \alpha_i, -z'_{it} \gamma - e_i; -\rho_{\varepsilon u}) 
  \end{cases} \\
  \Phi_2 (x'_{it} \beta + \alpha_i, z'_{it} \gamma + e_i - \mu; \rho_{\varepsilon u}), 
  \end{cases}
  \]
- Thus estimation involves integration over both \((\alpha_i, e_i)\) bivariate normal integrals
- For estimation, need to remove the unobserved effects from these expressions →
Empirical Approach

- Write the cholesky decomposition of $\Sigma$ as

$$\text{chol}(\Sigma) = \text{chol} \left( \begin{array}{cc} \sigma_\alpha^2 & \sigma_{\alpha e} \\ \sigma_{e\alpha} & \sigma_e^2 \end{array} \right) = \left( \begin{array}{cc} \delta_{11} & 0 \\ \delta_{12} & \delta_{22} \end{array} \right)$$

- So that

$$\left( \begin{array}{c} \alpha_i \\ e_i \end{array} \right) = \left( \begin{array}{cc} \delta_{11} & 0 \\ \delta_{21} & \delta_{22} \end{array} \right) \left( \begin{array}{c} \nu_\alpha \\ \nu_e \end{array} \right)$$

- Where $\nu_\alpha$ and $\nu_e$ are independent $N(0,1)$ variables
- Now substitute $\alpha_i$ and $e_i$ out using $\alpha_i = \delta_{11}\nu_\alpha$ and $e_i = \delta_{21}\nu_\alpha + \delta_{22}\nu_e$
- As $\nu_\alpha$ and $\nu_e$ are just standard normal variates, they are most easily integrated out using simulation methods (*antithetic Halton draws*):

simulated log-$L$ is

$$L(\theta) = \sum_{i=1}^{N} \log \frac{1}{M} \sum_{m=1}^{M} \prod_{t=1}^{T} \sum_{j=0}^{J-1=2} d_{ijt} \left[ \Pr(\Delta p_{it} = j | x_{it}, z_{it}, \nu_\alpha, \nu_e) \right]$$
Empirical Approach

- Marginal effects and probabilities can be evaluated by setting all random effects equal to their expected values (i.e., zero) and similarly their covariance to zero.
- Preferable approach: account for all random effects and correlations, and again use simulation methods.
- Finally, we consider generalised Ordered Probit-type probabilities (Pudney and Shields, 2000).
- Allow boundary parameters $\mu$, to be affected by firm characteristics, $w_{it}$:

$$
\mu_{ij} = \exp \left( \theta_j + w_{it}' \phi \right)
$$

- Collapses to the usual model if $\phi = 0$. 
Our database results from the merging of four different datasets:

2. The *ACEMO survey* (French Ministry of Labour): includes information about *wages and employment* (quarterly, firm level, 1998-2005)
3. Monthly *producer price indices computed by INSEE* at the 2-digit NACE level
4. Monthly *industrial production indices computed by INSEE* (using the NES36 classification)

Gives us *unbalanced panel of 42,954 observations with 5,019 firms/products*
The Dependent Variable

- The dependent variable is the answer to the question *By How Much Did Your Price Change Last Month?*
- Initially coded into 7 categories: large decrease up to large increase
- “Medium” and “large” responses, very sparse → re-coded to 5 outcomes
Variables to account for the possible time-dependent timing of price reviews:

1. seasonal dummies ($month_j, j = 1$ to $11$, except $8$; $ref. = December$)
2. duration dummies ($dur1$ to $dur14$, $ref. = duration$ of at least $15$ months)

Variables accounting for the volatility (defined as inter-quartile ranges) of the environment:

1. firm specific volatility of costs ($vi\_wage, vi\_iip$)
2. volatility of firm production ($vi\_prod$)
3. volatility of sector production ($vi\_ipi$)
4. and volatility of competitors prices ($vi\_ipp$)
3. Variables accounting for LR changes in the environment:

1. firm specific average growth rates of costs ($t_i\_wage, t_i\_iip$)
2. average growth rates of firm production ($t_i\_prod$)
3. average growth rates of sector production ($t_i\_ipi$)
4. and average growth rates of competitors prices ($t_i\_ipp$)
5. defined as 1 whenever a change in the variable is below the first quartile (strong negative shock) or above the third one (strong positive shock)
4. Variables accounting for SR changes in the environment:
   1. Dummies for transitory shocks in costs ($si\_wage, ti\_iip$)
   2. Dummies for transitory shocks in firm production ($ti\_prod$)
   3. Dummies for transitory shocks in sector production ($ti\_ipi$)
   4. And dummies for transitory shocks in competitors prices ($ti\_ipp$)

5. Industry and year dummies, plus dummies for specific events
   (euro-cash change-over and VAT rate change in April 2000)
Variables accounting for observed variations in the firms environment:

1. Current and lagged changes in costs: wages \((wage, wage_{l1}, etc.)\) and intermediate input prices \((iip, iip_{l1}, etc.)\).
2. Current and lagged changes in firm production \((prod, prod_{l1}, etc.)\).
3. And current and lagged changes in competitors prices \((ipp, ipp_{l1}, etc.)\).

Industry and year dummies, plus dummies for specific events (euro-cash change-over and VAT rate change in April 2000).
There are several reasons to suspect some endogeneity in the regressors:

- measurement errors (e.g., the timing of wage variations within quarters)
- simultaneity of decisions regarding prices, production and wage changes

So use IVs "à la Rivers-Vuong"

Finally, to address the potential endogeneity associated with the implicit dynamic nature of the model, we also follow Wooldridge (2005) and include initial conditions in the model.
Still a work in progress!

In general

- evidence of random effects only in the review equation (differencing?)
- small and negative correlation between the idiosyncratic errors
- good significance levels across both equations
Overall Probabilities
No-change probabilities dominate
Shock effects clear (but arbitrary)
Increase (decrease) probabilities rise (fall) as prices raw material prices increase
Marginal Effects: Wages Over Time

[Graph showing the marginal effects of wages over time with different categories: Big Decrease, Small Decrease, No-Change, Small Increase, Big Increase. The x-axis represents time in years (0, 1, 2, 3, 4+) and the y-axis represents the marginal effect on wages.]
Total (LR) Wage Marginal Effects

- Big Decrease
- Small Decrease
- No-Change
- Small Increase
- Big Increase
“Small” change probabilities uniformly dominate “large” ones
The time-dependent peak at 12 months clearly evident
Decreasing slopes, a result of heterogeneity across firms (Patrick and Hervé...)?
Price stickiness stems for a large part from the decision by firms not to review their prices on a continuous basis.

Time-dependence is an important trigger of price reviews as well as shocks on intermediate input prices.

Conditional on price reviews, prices react much more to changes in intermediate input costs than to changes in wages or demand (competitors’ prices are also important).

However, the impact of wage changes on prices is far from negligible. It comes through the time-dependence component of the price-setting behavior.

When we drop time-dependent variables in the price review equation → wages have a much more pronounced effect in both equations.
5. *Policy implications?*

1. If you want to fully understand pricing behaviour, you need to explicitly take into account the price-review process and thus the inherent inertia in prices.
2. Clear mix of time and state-behaviour in firm pricing behaviour.
3. Increase number of price reviews $\rightarrow$ significant reduction in price stickiness - but how?! May be increase the number of shocks?!!

Merci Beaucoup, and Au Revoir!