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

Presenter: Mark N. Harris

Mark N. Harris Patrick Sevestre

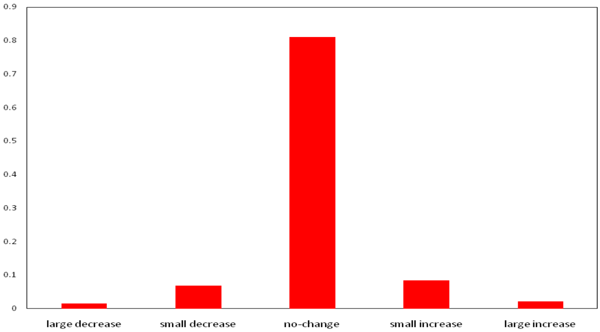
Monash University, Australia and Université I, Pantheon Sorbonne and Banque de France

October 2008

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" $\longrightarrow$

1. Even with a changing economic environment, firms are reluctant to change prices $\longrightarrow$ Banque de France Survey Responses



-

Introduction and Background

- 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 $\longrightarrow$

- 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%

Introduction and Background

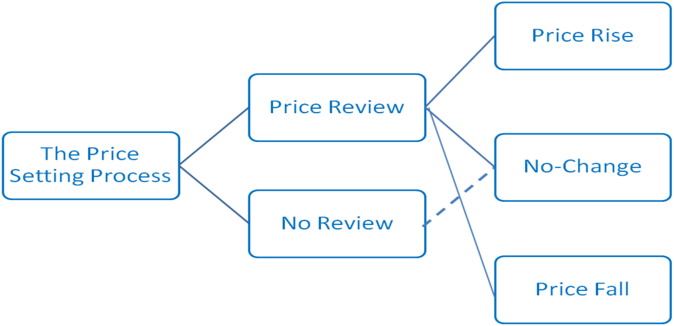
- In the UK, *Hall et al.*, (1997): while only 30% of them declare a similar frequency for their price changes:
  - about 70% of UK firms review their prices at least quarterly

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

- For the Euro area, only one price review in three $\longrightarrow$ 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!

Introduction and Background

- The approach we suggest here, is to model price reviews and price changes simultaneously, and hence explain the high proportion of price inertia $\longrightarrow$



-

Price Reviews

- 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 $\rightarrow$
- 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 $\rightarrow \uparrow$ 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 ($\downarrow$ 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)

Price Reviews

- 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

Price Changes

- 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 $i = 1, \dots, N$ firms observed over $t = 1, \dots T_i$ periods)
- Assume monopolistic competition and a constant price elasticity of demand, given by a $(a < -1)$, profit maximization leads to the usual equality:
- $$P_{it}^* = \frac{a}{1+a} MC_{it}, \text{ where } MC \text{ represents marginal cost}$$

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
  - π_{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:
- $$\begin{aligned} P_{it}^{*} &= \alpha \frac{a}{(a+1)} A_{ijt} Q_{it}^{\alpha-1} w_{it}^{\beta} \pi_{it}^{\gamma}, \text{ or in logs} \\ p_{it}^{*} &= \ln\left[\alpha \frac{a}{(a+1)}\right] + \ln(A_{ijt}) + \ldots + \gamma \ln(\pi_{it}) \end{aligned}$$

Related Literature: Price Changes

- 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 and proxy C_{jt} by sectoral production price indices at the NACE2 level $\left(PPI_{jt}; C_{jt} = PPI_{jt}^{\delta}\right)$

Related Literature: Price Changes

- 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 (Δp^d_{it})!
- 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 (Δp^d_{it}) can be written as
- $$\Delta p^d_{it} = p^*_{it} - p_{it-1} = p^*_{it} - p^*_{it_0}$$

Related Literature: Price Changes

- From above, we have expressions for p^*_{it} so all we have to do is difference the RHS of this equation, giving

$$\begin{aligned}
\Delta p^d_{it} &= p^*_{it} - p^*_{it_0} \\
&= \Delta_s \ln(A_{ijt}) \\
&\quad +(\alpha - 1)\Delta_s \ln Q_{it} \\
&\quad +\beta \Delta_s \ln w_{it} \\
&\quad +\gamma \Delta_s \ln \pi_{it} + u_{it}
\end{aligned}$$

- 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

Price Changes

- 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 Δx
- 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 Price Change Rule

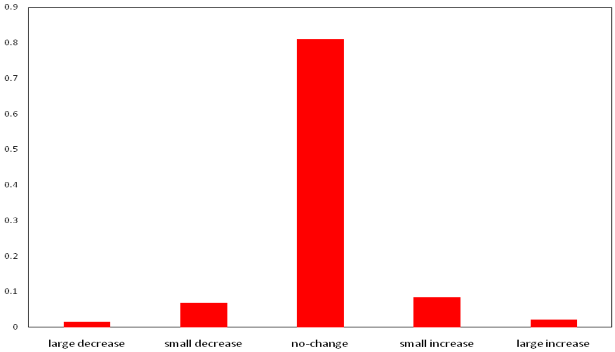
- The so-called (s, S) rule states when the foregone benefits of $P_{it} - P^*_{it}$ exceeds the costs, price is changed
- That is, when Δp^d_{it} is in excess of certain threshold values $(\boldsymbol{\mu})$, observed prices will changes
- Specifically, with $j = -2, \ldots, 2$ outcomes observed in our data ("big" decreases to "big" increases: $J = 5$), we have

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

with μ_0 normalised to 0

Econometric Model

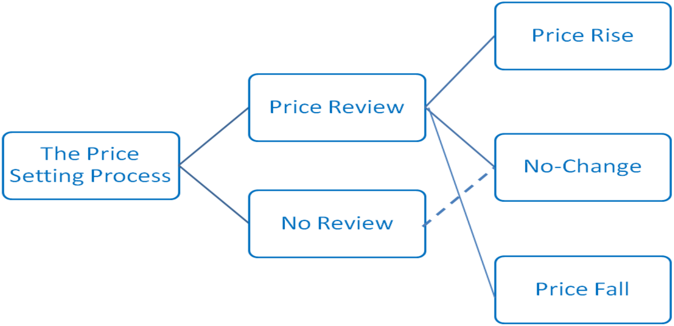
- Thus our dependent variable, is an ordered discrete one → might suggest an ordered probit approach; but let's have a look at the raw data again...



-

Econometric Model

- *And*, we believe that the price-setting process can be decomposed into two sequential decisions $\longrightarrow$



- *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 $\longrightarrow$
- Let's start with a underlying latent variable, r_{it}^*, which is a firm's price review equation

$$r_{it}^* = \mathbf{x}_{it}'\boldsymbol{\beta} + u_{it}$$

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

$$\Pr(r_{it} = 1 \,|\mathbf{x}_{it}) = \Pr(r_{it}^* > 0|\mathbf{x}_{it}) = \Phi(\mathbf{x}_{it}'\boldsymbol{\beta})$$

Econometric Model

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

$$\Delta p_{it}^{d} = \mathbf{z}_{it}'\gamma + \varepsilon_{it}$$

- Where $\mathbf{z}$ are the firms costs, demand etc., variables: denote this our *price change* equation

Econometric Model

- *Conditional on* $r_{it} = 1$, probability of each "observed" Δp_{it} outcome (under normality) are

$$\Pr(\Delta p_{it}) = \begin{cases} \Pr\left(\Delta p_{it} = -1 \,|\, r_{it} = 1\right) = \Phi\left(\mu_1 - \mathbf{z}'_{it}\gamma\right) \\ \Pr\left(\Delta p_{it} = 0 \,|\, r_{it} = 1\right) = \Phi\left(\mu_{j-1} - \mathbf{z}'_{it}\gamma\right) - \\ \qquad \Phi\left(\mu_j - \mathbf{z}'_{it}\gamma\right) \\ \Pr\left(\Delta p_{it} = 1 \,|\, r_{it} = 1\right) = 1 - \Phi\left(\mu_{J-2} - \mathbf{z}'_{it}\gamma\right) \end{cases}$$

Econometric Model

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

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

- 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 ε and u (equations relate to the same individual)
- Probabilities are now functions of the standardized bivariate normal c.d.f. with correlation coefficient $\rho_{\varepsilon u}$, $\Phi_2(a, b; \rho)$;
- $\Pr(\Delta p_{it}) =$

$$\begin{cases} \Pr(\Delta p_{it} = -1) = \Phi_2(\mathbf{x}_{it}'\boldsymbol{\beta}, -\mathbf{z}_{it}'\gamma; -\rho_{\varepsilon u}) \\ \Pr(\Delta p_{it} = 0) = [1 - \Phi(\mathbf{x}_{it}'\boldsymbol{\beta})] + \left\{ \begin{array}{c} \Phi_2(\mathbf{x}_{it}'\boldsymbol{\beta}, \mu - \mathbf{z}_{it}'\gamma; -\rho_{\varepsilon u}) \\ -\Phi_2(\mathbf{x}_{it}'\boldsymbol{\beta}, -\mathbf{z}_{it}'\gamma; -\rho_{\varepsilon u}) \end{array} \right\} \\ \Pr(\Delta p_{it} = 1) = \Phi_2(\mathbf{x}_{it}'\boldsymbol{\beta}, \mathbf{z}_{it}'\gamma - \mu; \rho_{\varepsilon u}) \end{cases}$$

Econometric Model

- We have panel data - can condition on unobserved firm heterogeneity in *both* equations $\longrightarrow$

$$\begin{aligned} r_{it}^* &= \mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i + u_{it} \\ \Delta p_{it}^d &= \mathbf{z}_{it}'\gamma + e_i + \varepsilon_{it} \end{aligned}$$

- Assume $\alpha_i \sim N\left(0, \sigma_\alpha^2\right)$ and $e_i \sim N\left(0, \sigma_e^2\right)$
- However, again, as these unobserved effects correspond to the same firm, correlations are likely $\longrightarrow$

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

- And

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

Econometric Model

- Conditional on the individual effects, the (log-)likelihood, where $\boldsymbol{\theta} = \left(\boldsymbol{\beta}', \boldsymbol{\gamma}', \mu, \rho, \sigma_{\alpha}^2, \sigma_e^2, \sigma_{\alpha e}\right)'$
- $L\left(\boldsymbol{\theta} \left| \alpha_i, e_i \right.\right) =$

$$\sum_{i=1}^{N} \sum_{t=1}^{T_i} \sum_{j=0}^{J-1=2} d_{ijt} \ln \left[\Pr\left(\Delta p_{it} = j \left| \mathbf{x}_{it}, \mathbf{z}_{it} \right.\right)\right], \text{ where, } \Pr(\Delta p_{it})$$

$$= \left\{ \begin{array}{l} \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i, -\mathbf{z}_{it}'\gamma - e_i; -\rho_{\varepsilon u}\right) \\ \left[1 - \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i\right)\right] + \left\{ \begin{array}{l} \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i, \mu - \mathbf{z}_{it}'\gamma - e_i; -\rho_{\varepsilon u}\right) \\ -\Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i, -\mathbf{z}_{it}'\gamma - e_i; -\rho_{\varepsilon u}\right) \end{array} \right\} \\ \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i, \mathbf{z}_{it}'\gamma + e_i - \mu; \rho_{\varepsilon u}\right), \end{array} \right.$$

- Thus estimation involves integration over both (α_i, e_i) bivariate normal integrals
- For estimation, need to remove the unobserved effects from these expressions $\rightarrow$

- Write the cholesky decomposition of Σ as

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

- 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 ν_{α} and ν_{e} are independent $N\left(0,1\right)$ variables
- Now substitute α_i and e_i out using $\alpha_i = \delta_{11}\nu_{\alpha}$ and $e_i = \delta_{21}\nu_{\alpha} + \delta_{22}\nu_{e}$
- As ν_{α} and ν_{e} are just standard normal variates, they are most easily integrated out using simulation methods (*antithetic Halton draws*): simulated log-L is

$$L\left(\boldsymbol{\theta}\right) = \sum_{i=1}^{N} \log \frac{1}{M} \sum_{m=1}^{M} \prod_{t=1}^{T_i} \sum_{j=0}^{J-1=2} d_{ijt}\left[\Pr\left(\Delta p_{it} = j \left|\mathbf{x}_{it}, \mathbf{z}_{it}, \nu_{\alpha}, \nu_{e}\right.\right)\right]$$

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) $\longrightarrow$
- Allow boundary parameters $\boldsymbol{\mu}$, to be affected by firm characteristics, $\mathbf{w}_{it}$:

$$\mu_{ij} = \exp\left(\theta_j + \mathbf{w}_{it}'\boldsymbol{\phi}\right)$$

- Collapses to the usual model if $\boldsymbol{\phi} = \mathbf{0}$

The dataset(s)

- Our database results from the merging of four different datasets:
  1. The *Banque de France monthly business surveys* (1996-2005)
  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 $\rightarrow$ re-coded to 5 outcomes

Price Review Equation, **x**

1. Variables to account for the possible time-dependent timing of price reviews:
   1. seasonal dummies $(month\_j, j = 1 \text{ to } 11, except\ 8;\ ref. = December)$
   2. duration dummies $(dur1 \text{ to } dur14,\ ref.\ = duration\ of\ at\ least\ 15 months)$
2. 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)

Price Review Equation, **x**

3. Variables accounting for LR changes in the environment:

   1. firm specific average growth rates of costs (ti_wage, ti_iip)
   2. average growth rates of firm production (ti_prod)
   3. average growth rates of sector production (ti_ipi)
   4. and average growth rates of competitors prices (ti_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)

Price Review Equation, x

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)

Price Change Equation, z

1. 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.*)
2. Industry and year dummies, plus dummies for specific events (euro-cash change-over and VAT rate change in April 2000)

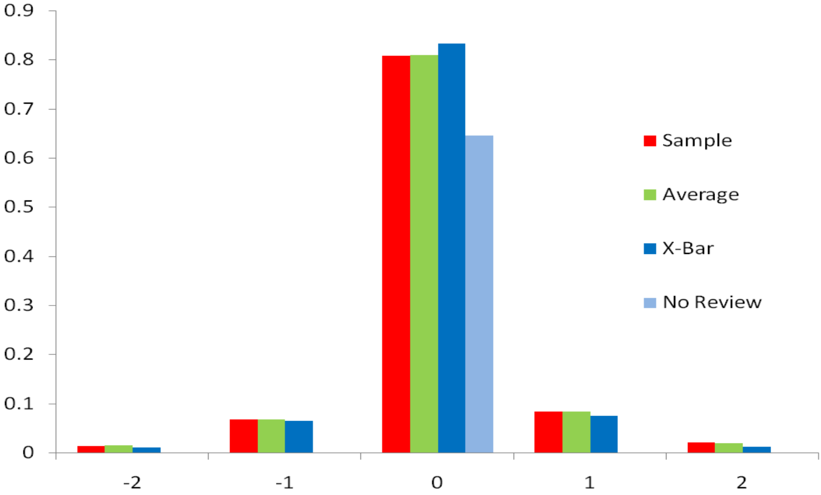
Endogeneity Issues

- 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

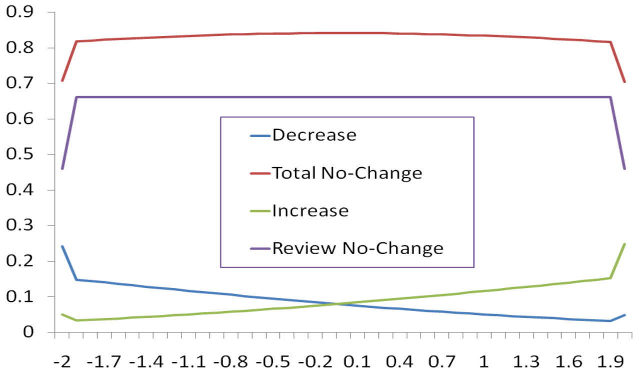
Results

- 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

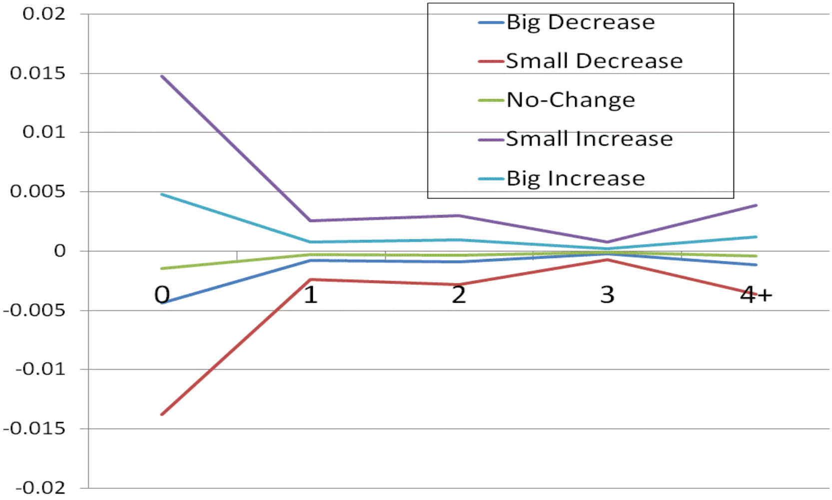


Raw Material Prices

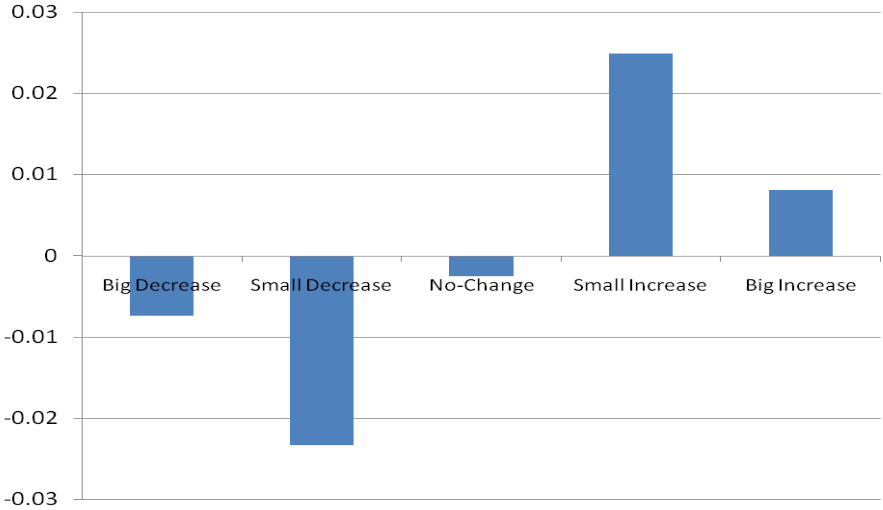


- No-change probabilities dominate
- Shock effects clear (but arbitrary)
- Increase (decrease) probabilities rise (fall) as prices raw material prices increase

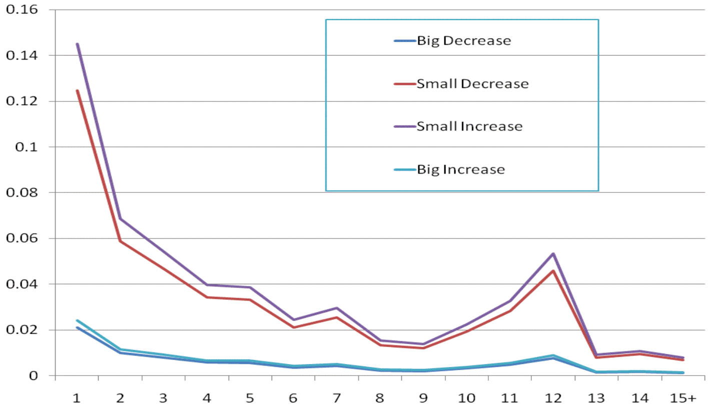
Marginal Effects: Wages Over Time



Total (LR) Wage Marginal Effects

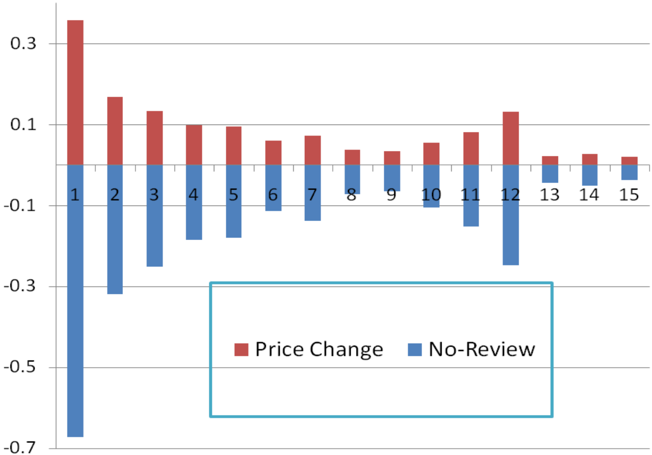


Duration Marginal Effects



- "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...)?

Duration Marginal Effects: No-Change Probabilities



Conclusions

1. *Price stickiness stems for a large part from the decision by firms not to review their prices on a continuous basis*
2. *Time-dependence is an important trigger of price reviews as well as shocks on intermediate input prices*
3. *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)
4. *However, the impact of wage changes on prices is far from negligible. It comes through the time-dependence component of the price-setting behavior*
    1. when we drop time-dependent variables in the price review equation → wages have a much more pronounced effect in both equations

Conclusions

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 $\longrightarrow$ significant reduction in price stickiness - but how?! May be increase the number of shocks?!!

Merci Beaucoup, and Au Revoir!