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

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Abstract

Firms do not change prices very frequently (Blinder et al., 1998; Fabiani et al., 2007; Vermeulen et al., 2007; Nakamura and Steinsson, 2008) and a significant fraction of observed static prices is posited to be the result of firms not reviewing prices rather than of the explicit decision not to change prices (Blinder et al., 1998; Fabiani et al., 2007). Indeed, prices reviews are costly (Zbaracki et al., 2004) and firms inattention may be rational (Sims, 1998, 2003; Woodford, 2009). In this paper, we disentangle these two causes of price stickiness by estimating an inflated ordered probit model on a panel of about 1500 firms from the French manufacturing industry observed monthly over the years 1998 to 2005. The results suggest that a large proportion of observed static prices stems from the firms' decision not to review their prices frequently rather than from an explicit decision to leave the prices unchanged following the price review.

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1 Introduction

The fact that both consumer and producer prices do not change as frequently as the retail outlets or firms' environment modifications might imply, is now well documented (see, for producer prices, Blinder, Canetti, Lebow, and Rudd 1998, Fabiani, Loupias, Martins, and Sabbatini 2007, Vermeulen, Dias, Dossche, Gautier, Hernando, Sabbatini, and Stahl 2007, Nakamura and Steinsson 2008).[1] Indeed, as shown in Loupias and Sevestre (2008), in the French manufacturing industry, only about one fifth of wage changes or demand fluctuations, and about one third of material price variations, induce a contemporaneous price change of the final product (in the same month) and these proportions do not change significantly when allowing for lagged reactions. Another well established fact is that most firms review their prices only one to three times per year and do not always subsequently proceed to a price change (Blinder, Canetti, Lebow, and Rudd 1998, Fabiani, Loupias, Martins, and Sabbatini 2007). Thus the commonly observed absence of price changes is the consequence of two sequential decisions by firms: at any point in time, they decide whether or not to undertake a price review. If not, their prices remain unchanged (unless they have settled an "automatic" price-setting rule). If firms do review their prices, then they may decide either to effectively change them or not.

The costs for firms of collecting and processing the necessary information to compute their optimal prices (Zbaracki, Ritson, Levy, Dutta, and Bergen 2004) explains why firms do not re-optimize on a continual basis, while at the same time their environment changes almost continuously. Following Sims (1998) and Sims (2003), a number of recent papers have emphasized the importance of these informational constraints for explaining why not continuously reviewing prices may be optimal for firms and the consequences of such constraints for price stickiness (Reis 2006, Mackowiak and Wiederholt 2009, Woodford 2009).[2]

The aim of this paper is to propose an empirical assessment of the importance of these informational constraints for explaining price rigidity. Our contribution is twofold: first, we disentangle the infrequency of price reviews resulting from firms' rational inattention from "genuine" price rigidity; second, we try to shed some light on the factors explaining

[1] See also the recent survey paper by Klenow and Malin (2009).

[2] Another recent paper, by Konieczny and Rumler (2006), also presents strong links with these issues.

these two components of observed price rigidity. To this end, we specify and estimate an inflated ordered Probit model on a panel of about 1500 French manufacturing firms. This model allows us to show that a very large fraction of observed static prices comes from the firms' decision not to review their prices rather than of an explicit decision to leave them unchanged after a price review has been conducted.

2 Price-reviews and price-changes

According to a recent series of surveys conducted in the euro area, most manufacturing firms do not continuously review their prices but do so only on a periodic basis and/or when a particular event makes it necessary. Indeed, Fabiani, Druant, Hernando, Kwapil, Landau, Loupias, Martins, Matha, Sabbatini, Stahl, and Stokman (2006) show that only about 25% of firms in the euro area review their prices at least monthly. At the other end of the spectrum, almost 60% of them review their prices at most three times per year. Looking at the frequency of price reviews and price changes for firms that provided information on both, Loupias and Ricart (2004) show that only 11% of the French firms that declare reviewing their prices four times a year changed them more than three times during the same year, while 37% made no price change during that year. Fabiani, Druant, Hernando, Kwapil, Landau, Loupias, Martins, Matha, Sabbatini, Stahl, and Stokman (2006) also find that 43% of European firms review their prices three times a year or more, while only 14% of them change their prices at the same pace.[3] The same observation is made by Hall, Walsh, and Yates (1997) who find that about 70% of UK firms review their prices at least quarterly, while only 30% of them declare a similar frequency for their price changes.

In summary, a significant fraction of the no-change realisations of price changes is the result of firms not reviewing prices rather than of the explicit decision not to change prices after a price review. Thus, the model that we explicitly wish to empirically test for with regard to price changes, is summarized in Figure 1.

[3] A larger fraction of firms (86%) infrequently change their prices (*i.e.*, less than 3 times a year) as compared to those reviewing them infrequently (57% of firms review their prices less than 3 times a year).

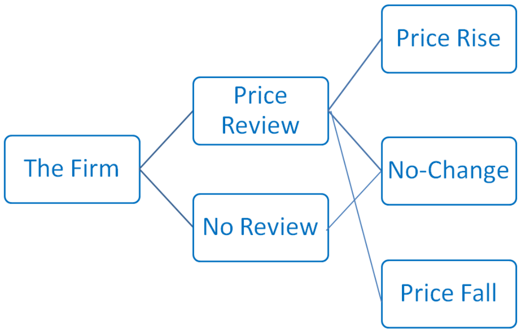


Figure 1: Firms' Price Review Process

In the following, we successively consider the two decisions underlying observed price stickiness: what are the factors affecting the probability of a price review? Conditional on a price review being conducted, what are the respective impacts of the different factors that may drive price change decisions?

2.1 What are the drivers of price reviews?

Why do firms only periodically review their prices? One of the most convincing arguments is simply the costs involved in doing so (Sims 1998, Sims 2003). The acquisition of the necessary information regarding both the costs effectively incurred by the firm and the demand being addressed to it, is costly. Indeed, so is the processing of this information in order to determine the optimal price. Zbaracki, Ritson, Levy, Dutta, and Bergen (2004) provide an evaluation of the managerial costs incurred by a US manufacturing firm selling about 8000 products when revising its prices. Overall, these price-reviewing costs are evaluated to be about 30 man/months, i.e. 250,000 US$ at the time of the study. These costs comprise the costs of gathering and processing the information needed for reviewing the prices (around 11 man/months of labor, about 100,000 US$) and those of the decision making process itself, *i.e.*, computation of new prices, simulation of alternative price strategies, computation of the impact of a given price change for the major customers of the company, etc. (18 man/months - about 150000 US$). These managerial costs then amounted to about 35 US dollar for each product price, that is 1.4% of the firm total operating expenses and almost one fourth of the total costs induced by an effective price change which include customer costs (communication of the new price list to consumers, renegociation of specific price arrangements) as well as physical menu costs.

Clearly the likelihood of a price review depends on the perceived cost/benefit analysis. Unfortunately, such (perceived) costs and (expected) benefits are unobserved outside of the firm. Nevertheless, appropriate proxies, based on characteristics of the firm and its environment, will typically be available. A clear example would be that more frequent reviews are more likely when the firm's operating environment is volatile: not reviewing costs and leaving price unchanged here may quickly drive the firm away from the optimum. How then can one characterize the volatility of the firm's environment? There are three main firm price drivers: production costs; demand level; and competitors' prices. Whenever any one of these dimensions is subject to significant variations, it is likely to be optimal for the firm to consider the option of adjusting its prices. Thus, in the subsequent empirical modelling of the likelihood of price reviews, we assume that the volatility of costs (the number and magnitude of changes in intermediate input prices and in wages) as well as that of demand (through firm and industry production changes) and that of the competitors' prices (through the sectorial price index) are likely to induce price reviews.

In addition to this, firms are likely to react to shocks when they observe one: a large increase in costs and/or a strong decline in demand will both likely trigger a price review. Obviously, firms are more likely to react to shocks that more strongly affect their profitability. In that respect, Mackowiak and Wiederholt (2009) emphasise the distinction between aggregate and idiosyncratic shocks: "when idiosyncratic conditions are more variable or more important than aggregate conditions, rationally inattentive firms optimally allocate more attention to idiosyncratic conditions than to aggregate conditions" (p. 769). However, the risk to the firm of facing a coordination problem as regards its competitors' reactions is less important when reacting to aggregate shocks than when reacting to an idiosyncratic shock. So, the likelihood of a price adjustment to an aggregate shock might be larger than what it is after an idiosyncratic shock, at least when these shocks are of a similar magnitude.

Overall, firms operating in a stable environment have a much lesser need for frequent price reviews. The literature offers several options as regards the modelling of the occurrence of price reviews/price changes in this context. First, one can follow Calvo's (1983) approach and consider that there is an exogenous (fixed) probability for any firm to proceed to a price review at any given point in time. However, this does not seem to be consistent with the observed behavior of producer prices at the firm level. Indeed, the above mentioned surveys (Fabiani, Loupias, Martins, and Sabbatini 2007) as well as our own data, point to some seasonality (many price changes occur in January) and also to some duration dependence (prices that do not change frequently appear to do so on a, broadly, yearly basis). This is consistent with Taylor's (1980) approach to the timing of wage/price changes. Indeed, duration dependence may be a consequence of the existence of explicit, or implicit, contracts between the firm and its customers. As we are dealing here with producer prices, most of the firms' customers are likely to be other firms with which contracts may exist.[4] Seasonality may be a way for firms to limit issues of coordination: It is less costly to change one's prices in January if a large fraction of firms do so at the same time because there is less uncertainty about competitors' reactions. Also, synchronised seasonal changes may lessen adverse customer reactions as the price changes are expected (Konieczny and Rumler 2006).

Finally, the strength of competition may also constitute an incentive for a firm to review its prices more frequently. Indeed, competition should reduce firms' profit margins and make it more difficult for them to absorb cost shocks without revising their prices. Moreover, stronger competition may induce larger losses for firms that do not properly adjust their prices in accordance with a changing environment. Thus firms operating in more competitive markets should review their prices more frequently.

Our modelling of the likelihood of a price review for firm i in period t, is then

$$Pr\left(Price\ Review_{it}\right) = F(COMP_i, VFE_i, IDS_{it}, AGS_{it}, DUR_{it}, SEASON_t, EVENTS_t, SECT_{i(j)})$$

where: $COMP$ represents the strength of the competition faced by the firm in its output market; VFE the variability of the firm's environment (*i.e.*, of its costs and production levels); IDS and AGS are idiosyncratic and aggregate shocks respectively, that possibly affect the firm's environment; DUR, dummy variables accounting for a possible duration dependence; $SEASON$, seasonal dummies; $EVENTS$, specific events such as the euro-

[4] Indeed, Fabiani, Loupias, Martins, and Sabbatini (2007) show that such contracts appear to be an important reason given by firms not to change their prices too frequently.

cash change-over and VAT changes; and finally $SECT$, a set of industry dummies that capture the variability of the environment at the industry level. These variables are discussed in more details in Section 3 below.

2.2 What are the drivers of price changes?

Once the firm has implemented a price review, it has to decide whether or not it is worth proceeding to a price change. The model we consider to explain price changes is quite standard and heavily relies on the existing literature (see, amongst others, Cecchetti 1986, Aucremanne and Dhyne 2005, Loupias and Sevestre 2008). We assume that, due to fixed costs of price adjustments, price changes can be modelled as an (S, s) model. We first derive the frictionless price and the desired price change. Then we specify the price change rule and the resulting price adjustment mechanism.

2.2.1 The optimal (frictionless) price and the desired price change

Following Loupias and Sevestre (2008), consider a firm selling its product on a market where monopolistic competition prevails. Assuming a constant price elasticity of demand, given by a ($a < -1$), the (frictionless) optimal price (P^*_{it}) is:

$$\begin{aligned} P^*_{it} &= \frac{a}{1+a} MC_{it} \text{ or, in logarithms:} \\ p^*_{it} &= \ln(P^*_{i,t}) = \ln(\frac{a}{1+a}) + \ln(MC_{it}) \end{aligned}$$

where MC_{it} is the marginal cost. We assume furthermore that the firm cost function can be represented by a simple static Cobb-Douglas function of the form:

$$C_{it} = A_{i(j)t}\ Q^{\alpha}_{it}\ w^{\beta}_{it}\ iip^{\gamma}_{it}$$

where: Q_{it} represents firm production level; w_{it} is the wage cost; iip_{it} is the price of intermediate inputs; and $A_{i(j)t}$ are unobserved variables affecting costs. Solving for P^*_{it} gives

$$P^*_{it} = \alpha \frac{a}{(a+1)}\ A_{i(j)t}\ Q^{\alpha-1}_{it}\ w^{\beta}_{it}\ iip^{\gamma}_{it}$$

or, in natural logarithmic form,

$$\begin{aligned} p_{i,t}^{*} &= \ln(P_{i,t}^{*}) = \ln(\alpha\frac{a}{(a+1)}) \\ &\quad + \ln(A_{i(j)t}) + (\alpha-1)\ln(Q_{it}) \\ &\quad + \beta\ln(w_{it}) + \gamma\ln(iip_{it}). \end{aligned}$$

We assume that $A_{i(j)t}$ 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 sectorial (common) time-varying component of prices C_{jt}. As the number of time periods and sectors in our data are large (firms in our sample belong to 14 sectors defined at the NACE-2digit classification level and T is greater than 100), considering these C_{jt} parameters as coefficients to be estimated would entail estimating 1400 parameters. We rather approximate this last (unobserved) component by the sectorial production price indices at the NACE2 level (PPI_{jt}) : $C_{jt} = PPI_{jt}^{\delta}$, where δ is a positive parameter (for a justification of this approximation, see Dhyne, Fuss, Pesaran, and Sevestre 2007).

As is common, a problem we face empirically is that the data we have contain information about price changes and not about price levels (see below). So, in the desired price change equation, $\ln(P_{it}^{*}/P_{it-1})$ $(= p_{it}^{*} - p_{it-1})$, P_{it-1} is unobserved. However, along a price spell that started at time t_0, one has:

$$p_{it-1} = p_{it-2} = ... = p_{it_0-1} = p_{it_0},$$

giving:

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

Moreover, assuming (as is usual in state-dependent pricing models) that when firms decide to adjust their prices, they fully adjust to the optimal price level, $p_{it_0} = p_{it_0}^{*}$, the desired price change $\left(\Delta p_{it}^{d}\right)$ can be written as

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

However, as shown in Loupias and Sevestre (2008), assuming a constant impact of past costs and demand changes is a heroic assumption. So here we do not impose this restriction and decompose the desired price change Δp_{it}^d into:

$$
\begin{aligned}
\Delta p_{it}^d &= p_{it}^* - p_{i,t-1} \\
&= p_{it}^* - p_{it_0}^* \\
&= (p_{it}^* - p_{it-1}^*) + \Psi_1(p_{it-1}^* - p_{it-2}^*) + \Psi_2(p_{it-2}^* - p_{it-3}^*) \\
&\quad + \Psi_3(p_{it-3}^* - p_{it-4}^*) + \Psi_4(p_{it-4}^* - p_{it_0}^*).
\end{aligned}
$$

Then, given that $\Delta_s \ln(A_{i(j)t}) = \delta \Delta_s \ln(PPI_{jt})$, the desired price change in the model we estimate can be written as :

$$
\begin{aligned}
\Delta p_{it}^d &= p_{i,t}^* - p_{i,t_0}^* \\
&= \sum_{j=0}^{3} \alpha_j^* \Delta \ln Q_{it-j} + \alpha_4^* \Delta_r \ln Q_{it-4} \\
&\quad + \sum_{j=0}^{3} \beta_j \Delta \ln w_{i,t-j} + \beta_4 \Delta_r \ln w_{i,t-4} \\
&\quad + \sum_{j=0}^{3} \gamma_j \Delta \ln iip_{i,t-j} + \gamma_4 \Delta_r \ln iip_{i,t-4} \\
&\quad + \sum_{j=0}^{3} \delta_j \Delta \ln(PPI_{jt-j}) + \delta_4 \Delta_r \ln(PPI_{jt-4}) + u_{it}
\end{aligned}
$$

where $\Delta_r x$ represents the variation of x over the periods $t-4$ to the start of the price spell, if any.

The desired price change, which corresponds to the variation of the optimal price since the start of the spell, is thus a function of current and lagged changes in wages; of changes in the price of intermediate inputs; of those in the demand being addressed to the firm; and of variations in the sectorial inflation, which correspond to common shocks in the industry.

2.2.2 The price change rule

Following Cecchetti (1986), we assume the price-setting behavior can be represented by an (S, s) rule. In other words, due to the existence of fixed costs in price changes, firms decide, post price review, whether it is profitable for them to change prices or not. Here, the data available to us about price changes are qualitative so that we can only distinguish between five possible outcomes: small increases (SI) and decreases (SD); medium/large increases (LI) and decreases (LD); and no-change (0). This price change rule can then be summarized as follows

$$\begin{array}{lcll}
\Delta p_{it} & = & LD < SD < 0 & \text{if } \quad \Delta p_{it}^{d} \leq \mu_{1i(j)t} \\
\Delta p_{it} & = & SD < 0 & \text{if } \quad \mu_{1i(j)t} < \Delta p_{it}^{d} \leq \mu_{2i(j)t} \\
\Delta p_{it} & = & 0 & \text{if } \quad \mu_{2i(j)t} < \Delta p_{it}^{d} \leq \mu_{3i(j)t} \\
\Delta p_{it} & = & SI > 0 & \text{if } \quad \mu_{3i(j)t} < \Delta p_{it}^{d} \leq \mu_{4i(j)t} \\
\Delta p_{it} & = & LI > SI > 0 & \text{if } \quad \Delta p_{it}^{d} > \mu_{4i(j)t}
\end{array}$$

with $p_{it} = \ln P_{it}$, and we allow for heterogeneity in the thresholds $\mu_{\tau i(j)t}$ across years, industries and firms/products

3 The data

The estimation sample is obtained by merging four separate datasets: three firm-level and one industry-level. The former are respectively: the series of the Banque de France monthly business surveys; a specific survey about price-setting practices in the French manufacturing industry (conducted by the Banque de France in 2004); and a dataset containing information about firms wages and employment, obtained from the French Ministry of Labour. The industry-level dataset consists of the set of monthly producer price indices computed by INSEE, the French national statistical institute, at the 2-digit NACE level. The merging of these separate datasets yields a unique panel dataset, with extensive information regarding firm pricing behaviour, wages and other prices, as well as information regarding the degree of competition firm face on their market.[5]

The aim of this section is to provide a general overview of each of these datasets and to describe the way in which we have used them to build the estimation sample. The main characteristics of our econometric dataset are then presented.

[5] Our dataset is in fact a subset of that used in Loupias and Sevestre (2008). Indeed, merging the dataset they used with the survey about price-setting practices in France induced a loss of observations leading to the smaller dataset we use here (see below for details).

3.1 The Banque de France business surveys

The pooling of the monthly Banque de France manufacturing industry business surveys over the period January 1996 to December 2005 constitutes our core database. The statistical unit is a specific product, defined at the 4-digit NACE level, produced in a given plant/establishment. About 300 different product groups are considered. Firms are interviewed by phone during the first week of each month. Inquiries are about the evolution of product prices, of intermediate input prices, of production, of orders received and of employment, both during the month under review (most often the month before the one when the survey is conducted[6]) and also during the 12 months elapsed since the same month one year before. Firms are also asked about some other variables such as the level of their finished product stocks and that of their capacity utilization, as compared to a normal situation.

The majority of surveyed entities consists of firms with only one establishment and one product. However, a few large firms with several establishments may be surveyed more than once in a given month and some (large) establishments may report for more than one product as well. Then, we define an observational unit as a triplet "firm-establishment-product". For the sake of simplicity, this will be referred to as a "firm" hereafter. On the whole, the set of business surveys from January 1996 to December 2005 contains about 480,000 observations, corresponding to about 8,800 different firm products. Due to the continuous updating of the sample (as firms enter and exit the sampled population), the sample is not balanced over time. The average number of units interviewed is about 4,000 per month.

For the purposes of the present study, this data yields the following primary variables: variation in the price of the specific product under consideration; variation in the price of intermediate inputs used in the firm production process; and variation in firm production levels. For each of these three variables, the information available is qualitative. Given the small number of both "large" and "moderate" increases and decreases, these outcomes were combined to yield five change outcomes in total (none; small increase/decrease; and large or moderate increase/decrease).

[6] An exception is for surveys conducted in September in which firms are asked about variations that occured since July as, since 1998 (the starting date of our econometric sample), there is no survey in August. Until 1997, the survey was not conducted in July nor in August.

3.2 A specific survey about price-setting practices in France

Carried out in 2003-2004, this survey focussed on French manufacturing firms pricing behaviour. The target population was the same as that for the monthly Banque de France business survey discussed above (manufacturing firms with more than 20 employees). 1,662 firms answered the questionnaire. As in the data used in Blinder, Canetti, Lebow, and Rudd (1998), the questionnaire included a variety of factual information about the firm (its size, the number of competitors, how often it changed prices, for example), although it concentrated on price reviews and price adjustments. This data is discussed in full in Loupias and Ricart (2006). The primary information extracted from this survey for the current purposes, concerned the number of competitors faced by each firm.

3.3 The dataset on wages (ACEMO survey)

Unfortunately the Banque de France business survey has no information regarding labor costs. Clearly this is a significant component of total costs, so that we augmented our base dataset with data from the ACEMO survey.[7] This survey is administered by the French Ministry of Labor, and contains detailed information about the level of the monthly base wage (inclusive of employees social security contributions). The data exclude bonuses, allowances, and other forms of compensation. The information refers to a specific job position, not a specific worker. The survey asks firms about the monthly base wage of up to 12 job positions corresponding to one of four occupational categories (manual workers, clerical workers, intermediate occupations and managers). For establishments with several job positions inquired, we compute an average evolution of the wage cost using the available information about the structure of total employment of the establishment. Using the base wage is a reliable indicator of the firm's wage cost since in France, the base wage represents nearly 80% of gross earnings (Heckel, Le Bihan, and Montornès 2008). Moreover, most bonuses (like "13th month" payments or holidays bonuses) are linked to the base wage.

The quarterly periodicity of this survey raises an important issue as the data obtained from the Banque de France business surveys are monthly. Two options were available for matching the two datasets: to keep the monthly frequency and make some assumptions

[7] For a thorough presentation of the ACEMO survey, see Heckel, Le Bihan, and Montornès (2008).

about the unobserved timing of wage changes within quarters; or, to aggregate the business surveys over time to convert them into a quarterly series. The first option was preferred as it allows us to study more thoroughly the dynamics of price adjustments. So here we assume that wage changes are more likely to occur during the first month of each quarter. Two justifications can be given to sustain this assumption. First, in France, the minimum wage is usually adjusted according to the CPI inflation and that of the blue-collar workers average wage every year in July (*i.e.*, the first month of the third quarter).[8] Consequently, not only workers paid at the minimum wage see their wage increased in July, but also those who are in the lowest part of the wage distribution. Also, many wage increases get effective on the first of January each year (Heckel, Le Bihan, and Montornès 2008). It then seems not a too strong assumption to consider that, in the absence of any other information, wage changes that occur during a given quarter do so in the first month of this quarter.[9]

3.4 The Producer Price Index

The last important information we need for estimating our model is the evolution of producer prices at the industry level. This variable allows us to measure sectorial shocks that may affect all firms in a given industry. In order to maximize the matching of the corresponding datasets with the ones presented above, this index has been collected from the INSEE website using the 2-digit NACE decomposition of the manufacturing industry. However, some indices were not available for the initial years of the period and/or are terminated before the end of 2005, the last year for which the other data are available.

3.5 The estimation sample

Merging the ACEMO and Banque de France business surveys with the PPI indices, removing missing values, unmatched observations, and the like and, finally, further trimming the

[8] Unless the CPI inflation reaches a level where an increase in the minimum wage is granted. This did not happen during our estimation period.

[9] In order to check the sensitivity of our results to this assumption, we have estimated models where wage changes were imputed either at the second or third month of the quarter. The results were clearly less satisfactory. Results associated with the second option, *i.e.*, consisting of an aggregation over time to get a fully quarterly database are presented and discussed in Horny and Sevestre (2008). They are qualitatively similar to those presented below.

Table 1: Probability of a price change, conditional on cost and production variations[a]

	Probability of occurrence	Price change conditional on cost or production changes
Change in input prices	25.6%	38.9%
Change in wages	21.9%	21.8%
Change in production	63.9%	20.9%

[a]Source: Banque de France business surveys merged with the ACEMO survey. The dataset contains 16711 observations about 1,543 firms and the sample period is October 1998 to December 2005

data due to the need to discard left-censored price spells[10] yields the estimation sample used in Loupias and Sevestre (2008). We further matched this sample with the supplementary Banque de France survey on French manufacturing price-setting practices described above, and this yielded a final sample for estimation of some 16700 observations regarding 1543 firms.

Tables 5 and 6 in the appendix show that the main characteristics of our econometric sample are quite similar to those of the initial databases used to build it. Given that the Banque de France business surveys are based on a representative sample of the French manufacturing industry, one can then reasonably expect our econometric sample to also be representative. In our sample, the frequency of price changes is slightly less than 20%, which corresponds to the figures provided in previous studies about producer prices in France and the Euro area (Vermeulen, Dias, Dossche, Gautier, Hernando, Sabbatini, and Stahl 2007, Loupias and Sevestre 2008). Table 1 above shows that, due to the non-synchronization of intermediate input price changes with those of wages, changes in production costs as well as changes in the production level appear to be significantly more frequent than price changes: conditional on a change in costs or production level, the probability that the firm changes its price is significantly lower than 1. This clearly points to some rigidity in producer prices.

[10]Indeed, our model assumes that price changes are triggered on the basis of the evolution of the cost and demand variables since the previous price change. Then, all left-censored spells, i.e. all observations corresponding to spells for which the first observation did not immediately followed a price change had to be deleted.

3.6 Variable definition and measurement

3.6.1 Variables affecting the likelihood of a price review

As stated in Section 2.1, we can distinguish between two sets of drivers of price reviews. The first set contains variables that relate to competition, to the variability of the firm's environment, and to the occurrence of shocks or special events:

- $Competition$ is a dummy variable for the presence of more than 4 competitors (the median of the declared number of the firm'competitors on its output market);

- $Var\,(wage)\,, Var\,(IIP)\,, Var\,(prod)$ represent the firm-specific frequency of wage/intermediate input price/production changes as proxies to their volatility at the firm level;

- $Shock_f\,(wage)\,, Shock_f\,(IIP)\,, Shock_f\,(prod)$ are dummy variables representing the occurrence of a wage/intermediate input price/production change at the firm (f) level, with magnitude outside the 1^{st}-9^{th} inter-decile interval in the same industry (to capture large idiosyncratic shocks affecting firms' wages/intermediate input prices/production);

- $Shock_s\,(wage)\,, Shock_s\,(IIP)\,, Shock_s\,(prod)$ are dummy variables representing the occurrence of an average wage/intermediate input price/production change, at the sector (s) level, with magnitude outside the 1^{st}-9^{th} inter-decile interval in the same industry (this measures aggregate shocks affecting wages/intermediate input price/production);

- $Shock_s\,(PPI)$ is a dummy variable representing the occurrence of a producer price change, at the industry level, with magnitude outside the 1^{st}-9^{th} inter-decile interval in the same industry (proxy for aggregate shocks affecting industry/competitors'prices);

- VAT is a dummy variable for the decrease in the VAT rate that occurred in April 2000; while $VAT\,(month)$ is a dummy variable for the months of March, April and May of the same year to account for possible leads or lags in the firms'price reaction to this VAT change;

- $EURO$ is a dummy variable taking the value 1 for observations dated January 2002 (Euro cash-change over) and 0 otherwise; and $EURO\,(month)$ is a dummy variable taking the value 1 for observations dated between July 2001 and June 2002, that is 6 months before and 6 months after the Euro cash change-over.

Finally, a set of sector dummies $(s = 1, ..., S)$ and year dummies are included to capture the variability of the environment at the industry level and/or features of the price-setting behavior that are specific to a given industry or that are common to all firms during a given year.

The second group of variables correspond to the occurrence of price reviews associated with time-dependent price-setting behavior: firstly, dummies $Duration_1, Duration_2, ...$ to account for the duration elapsed since last price change; these correspond to a piece-wise hazard function, accounting for possible duration dependence; and secondly a series of monthly dummies to account for seasonality (December being the omitted/reference month, and noticing there is no survey conducted in August).

3.6.2 Variables affecting the likelihood of a price change

The variables that are assumed to trigger price changes, conditional on a review, are as follows

- $\Delta Wage_j, j = 0, \ldots, 3$, current and lagged variations of the firm wage cost or zero whenever the spell lasts less than j months ($\Delta Wage_R$ is the remaining wage change since the start of the spell, whenever the spell is longer than 4 months);

- $\Delta IIP_j, j = 0, \ldots, 3$, current and lagged variations of the firm intermediate input prices or zero whenever the spell lasts less than j months (ΔIIP_R is as above);

- $\Delta Prod_j, j = 0, \ldots, 3$, current and lagged variations of the firm production level or zero whenever the spell lasts less than j months ($\Delta Prod_R$, as above); and

- $\Delta PPI_j, j = 0, \ldots, 3$, current and lagged variations of the industry-level producer price index or zero whenever the spell lasts less than j months (ΔPPI_R, as above).

The other variables affecting price changes correspond to "special events" such as the VAT change in 2000 and the Euro cash change-over (both as defined above); as well as sector and year dummies.

4 The econometric approach

4.1 The model: an inflated ordered probit model.

As outlined above, we postulate that the pricing behavior of firms entails two decisions. The first one is whether firms undertake a price review in order to assess whether a price change is warranted. The second decision, conditional on a price review having been undertaken, is whether to change prices or not.

So, a useful starting point is an underlying (unobserved) latent variable, q_{it}^* which represents the propensity of firm i to proceed to a price review at time t. This variable can be expressed as

$$q_{it}^* = \mathbf{x}_{it}'\boldsymbol{\beta} + u_{it} \tag{1}$$

where $\mathbf{x}_{it}$ is a vector of observed characteristics of the firm and its environment. Under the assumption of normality, the probability that the firm sees a justification for a price review is (Maddala 1983)

$$\Pr(q_{it} = 1 \,|\mathbf{x}_{it}) = \Pr(q_{it}^* > 0|\mathbf{x}_{it}) = \boldsymbol{\Phi}(\mathbf{x}_{it}'\boldsymbol{\beta}), \tag{2}$$

and, for no price review

$$\Pr(q_{it} = 0 \,|\mathbf{x}_{it}) = \Pr(q_{it}^* \leq 0|\mathbf{x}_{it}) = 1 - \boldsymbol{\Phi}(\mathbf{x}_{it}'\boldsymbol{\beta}), \tag{3}$$

where $\Phi(\cdot)$ represents the standard normal cumulative distribution function. Thus, as is normal in a zero-one choice setting, *this index function must be positive before a change is seen as warranted.*

As it stands however, this equation only represents a propensity for a price review: it says nothing about the existence of any desired change and about its direction. Moreover, even though a firm may have a strong propensity for a price review, current economic/market conditions may dictate that no change in current prices is optimal. This suggests a two-regime scenario where the differing regimes split firms into a price review ($q_{it} = 1$) or no price review ($q_{it} = 0$) dimension - equation (1). For those in regime $q_{it} = 0$, a no-change outcome is necessarily observed;[11] for those in the alternative regime $q_{it} = 1$, the firm may (optimally) choose any of a price: increase, decrease, or no-change.

As those firms in the ‘change’ regime are faced with an up/down/no-change decision, an appropriate modeling strategy would appear to utilise an ordered probit (OP) model (Maddala 1983). Without loss of generality, define outcomes as $y_{it} = 0$ (a price reduction), $y_{it} = 1$ (no-change) and $y_{it} = 2$ (increase); conditional on regime ($q_{it} = 1$), an underlying latent variable y_{it}^* can be specified as

$$y_{it}^* = \mathbf{z}_{it}'\boldsymbol{\gamma} + \varepsilon_{it}, \tag{4}$$

[11] However, we discuss below about the possibility for firms to change prices on a predetermined basis between price reviews..

where $\mathbf{z}_{it}$ is a vector of observed characteristics with unknown weights $\boldsymbol{\gamma}$, and ε_{it} a random disturbance term. Under the assumption of normality, the associated probabilities of being in each state j ($j = 0, 1, 2$) are:[12]

$$\Pr(y_{it}) = \begin{cases} \Pr\left(y_{it} = 0 \left| \mathbf{z}_{it}, q_{it} = 1 \right.\right) = \Phi\left(-\mathbf{z}_{it}'\gamma\right) \\ \Pr\left(y_{it} = 1 \left| \mathbf{z}_{it}, q_{it} = 1 \right.\right) = \Phi\left(\mu - \mathbf{z}_{it}'\gamma\right) - \Phi\left(-\mathbf{z}_{it}'\gamma\right) \\ \Pr\left(y_{it} = 2 \left| \mathbf{z}_{it}, q_{it} = 1 \right.\right) = 1 - \Phi\left(\mu - \mathbf{z}_{it}'\gamma\right). \end{cases} \tag{5}$$

However, neither q_{it}^* nor q_{it} are observed, so we require $\Pr(y = j)$ *unconditional on regime.* Let us first assume that ε and u identically and independently follow standard Gaussian distributions, then the overall probability of observing a no-change price behaviour, consists of two component parts such that

$$\Pr(y_{it}) = \begin{cases} \Pr\left(y_{it} = 0 \left| \mathbf{z}_{it}, \mathbf{x}_{it} \right.\right) = \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta}\right) \Phi\left(-\mathbf{z}_{it}'\gamma\right) \\ \Pr\left(y_{it} = 1 \left| \mathbf{z}_{it}, \mathbf{x}_{it} \right.\right) = \left[1 - \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta}\right)\right] + \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta}\right)\left[\Phi\left(\mu - \mathbf{z}_{it}'\gamma\right) - \Phi\left(-\mathbf{z}_{it}'\gamma\right)\right] \\ \Pr\left(y_{it} = 2 \left| \mathbf{z}_{it}, \mathbf{x}_{it} \right.\right) = \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta}\right)\left[1 - \Phi\left(\mu - \mathbf{z}_{it}'\gamma\right)\right]. \end{cases} \tag{6}$$

In this way, along the lines of the zero-inflated Poisson (ZIP) count models (see, for example, Mullahey 1986) the probability of a no-change outcome has been 'inflated'. Note that this statistical model is similar in spirit to that proposed by Harris and Zhao (2007) in the context of an OP model, except here the inflated outcome is not at one end of the outcome spectrum and has also been considered by Brooks, Harris, and Spencer (2007a).[13]

So, to observe a $y_{it} = 1$ (no-change) outcome we require either that $q_{it} = 0$ (the absence of price review dominates) or jointly that $q_{it} = 1$ (the firm undertakes a price review) *and* that $0 < y_{it}^* \leq \mu$. In this way, observationally equivalent no-change observations can arise from two distinct sources: the price review equation *combined* with the price change equation, or the price review equation in isolation.

Two remarks are noteworthy here: an advantage of this inflated ordered probit (IOP) specification over the standard ordered probit state-dependent model is that it allows for the coexistence of state and time-dependent price-setting behaviors. Indeed, time-dependent behaviors are captured through the seasonal and duration variables that are likely to lead to "regular" price-reviews and, possibly, price changes in a second step. Including these variables directly in an ordered Probit model would not be a satisfactory

[12] The generalisations to more outcomes, in our case five, are obvious.

[13] Indeed, the model description here relies heavily on Brooks, Harris, and Spencer (2007b).

way to account for such time-dependent behaviors. Indeed, this would amount to considering that being at a time where a price review/price change should occur increases the likelihood of a price increase (or of a price decrease, depending on the sign of the coefficient), which need not be the case. Second, this model amounts to assuming that inattentive producers do not change their prices. In other words, we exclude the possibility for firms to undertake "automatic" and frequent price changes that would not require any information collection and analysis. We think this is not an unreasonable assumption because such repeated consecutive price changes are very uncommon in our data.

Several modifications can be made to the basic probabilistic set-up of equation (6). Firstly, following Harris and Zhao (2007) and Brooks, Harris, and Spencer (2007a), as ε and u relate to the same firms (in the same time period), it is possible to allow them to be correlated, such that probabilities are now

$$\Pr(y_{it}) = \begin{cases} \Pr\left(y_{it} = 0 \,|\mathbf{z}_{it}, \mathbf{x}_{it}\right) = \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta}, -\mathbf{z}_{it}'\boldsymbol{\gamma}; -\rho_{\varepsilon u}\right) \\ \Pr\left(y_{it} = 1 \,|\mathbf{z}_{it}, \mathbf{x}_{it}\right) = \left[1 - \Phi\left(\mathbf{x}_{it}'\boldsymbol{\beta}\right)\right] + \left\{ \begin{array}{c} \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta}, \mu - \mathbf{z}_{it}'\boldsymbol{\gamma}; -\rho_{\varepsilon u}\right) \\ -\Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta}, -\mathbf{z}_{it}'\boldsymbol{\gamma}; -\rho_{\varepsilon u}\right) \end{array} \right\} \\ \Pr\left(y_{it} = 2 \,|\mathbf{z}_{it}, \mathbf{x}_{it}\right) = \Phi_2\left(\mathbf{x}_{it}'\boldsymbol{\beta}, \mathbf{z}_{it}'\boldsymbol{\gamma} - \mu; \rho_{\varepsilon u}\right) \end{cases} \tag{7}$$

where $\Phi_2(a, b; \rho)$ denotes the cumulative distribution function of the standardized bivariate normal distribution with correlation coefficient $\rho_{\varepsilon u}$ between the two univariate random elements.

Secondly, as with Brooks, Harris, and Spencer (2007a), the data to hand consists of repeated observations per firm: that is, we have panel data. Then, we can condition on the possible unobserved heterogeneity of the firm as is usual in the panel data literature (Wooldridge 2002). To this aim, we can include random unobserved effects in both of equations (1) and (4), such that they respectively become

$$q_{it}^* = \mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i + u_{it} \tag{8}$$

and

$$y_{it}^* = \mathbf{z}_{it}'\boldsymbol{\gamma} + e_i + \varepsilon_{it}. \tag{9}$$

Unfortunately, this structure quite significantly further complicates estimation. However, conditional on the individual effects, the (log-)likelihood has a tractable formulation allowing its maximization (see Appendix B for details).

5 Estimation results

We estimated several variants of the proposed IOP model, allowing the price review and price change equations to be either independent or correlated; and including or not a full set of (correlated) random effects in both equations. Although we concentrate our discussions on the full model (correlated equations and full, correlated, random efffects), we note that the basic structural coefficients are essentially unchanged across model specifications.[14]

5.1 The estimated frequencies of price reviews and price changes

Before going to the details of the estimation results, we provide an overview of their implications in terms of the likelihood of firms implementing price reviews and price changes. Indeed, the modeling approach adopted in the paper is instructive in that it explicitly allows for observationally equivalent no-change price observations to arise from two distinct sources. What then do the estimation results suggest with regard to the split of these no-change observations across no price review and no-change conditional on a price review?

Figure 2 plots observed sample proportions for all price change categories along with average predicted probabilites for such. For the latter, this total probability of no-change, is then decomposed into that arising from the no review and that conditional on a review. Firstly, we note that the average predicted probabilities closely mimic the observed sample proportions: an indication that the model "fits the data" particularly well.

With regard to the no-change probabilities, it is clear that the bulk of no-change observations arise from firms not reviewing their prices (almost 90% of the total 0.82 probability). This shows the importance of accounting for price reviews when explaining the observed price stickiness. Indeed, the average estimated probability of implementing a price review is 0.28 which is lower, but compares to, the frequency of price reviews obtained from the survey conducted by Loupias and Ricart (2004) regarding the price-setting behavior of French manufacturing firms (which is slightly more than 35%).[15]

[14] Full model results are available from the authors on request.

[15] The comparison is made difficult because the data provided in their table makes an exact computation of this frequency difficult.

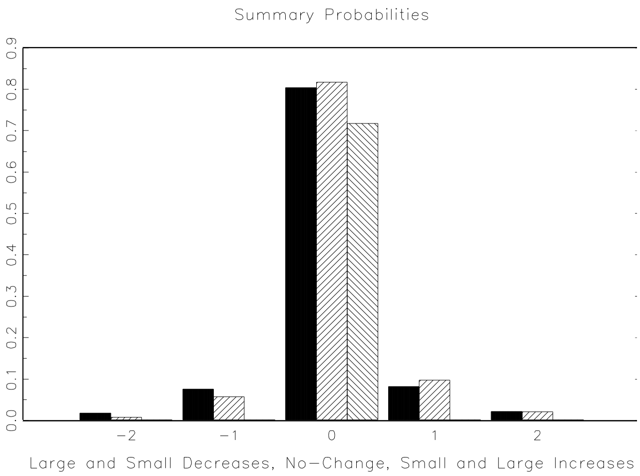
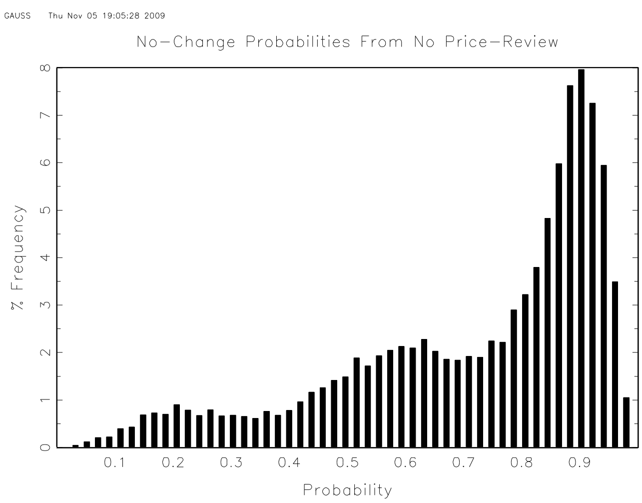


Figure 2: Summary Probabilities: Sample Proportions; Average Estimated Probabilities (No-Change Ones Split by No Review Probabilities)

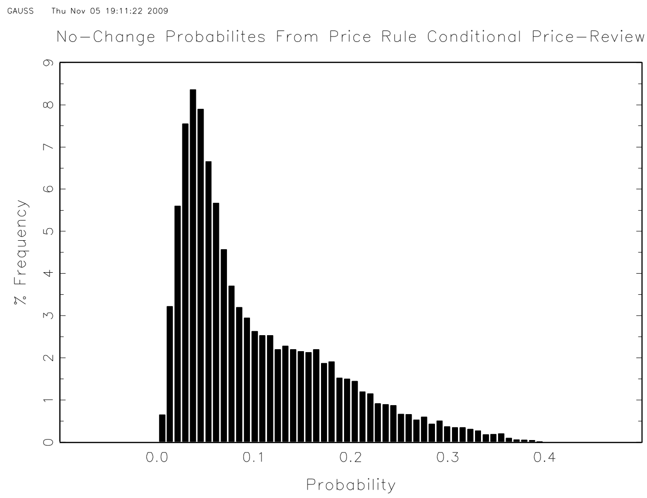
Figure **??** plots the entire estimated probability distribution of no price review. This is left-skewed, with a significant build-up of observations around the 0.9 mark. Thus, for most firms, there is a significantly high probability that no price review will be undertaken and therefore, that no price change will be observed.



No-Change Probabilities as Result of No Price Review

Then, Figure **??** plots the probability distribution of no-change observations *condi-*

tional on a price review having been undertaken. The distribution is now clearly right-skewed and illustrates that once a price review has been undertaken, firms are somewhat unlikey not to change their prices Indeed, the estimated probability for a firm to implement a price change conditional on a price review is equal to 0.65.[16] This is in direct agreement with figures given in Fabiani, Druant, Hernando, Kwapil, Landau, Loupias, Martins, Matha, Sabbatini, Stahl, and Stokman (2006) and with arguments suggested in Woodford (2009), that firms are likely to change prices after a price review.



No-Change Probabilities Conditional on a Price Review

5.2 Explaining price reviews

As the estimated model coefficients are somewhat meaningless by themselves, we present a selection of marginal effects on both the price review equation, and then on the price change equation.[17] Let us first consider the price review results. Table 2 presents some marginal effects for a selection of both state-dependent and time-dependent determinants of price reviews.[18] Indeed, as previously outlined, there are essentially two groups of factors that may constitute incentives for firms to review their prices: the volatility and shocks affecting their environment together with the degree of market competition; and

[16]Since the probability *not* to change prices conditional on a price review is equal to: $(0.82 - 0.72)/(1 - 0.72) = 0.35$.

[17]The coefficients estimates are nevertheless provided in the appendix.

[18]Full results are available from the authors' on request.

Table 2: No-Change Marginal Effects[a]

Time-Dependent		State-Dependent	
Jan	-0.250	$Shock_f(prod)$	-0.035
	(0.04)**		(0.01)**
Feb	-0.095	$Shock_f(IIP)$	-0.244
	(0.03)**		(0.02)**
Mar	-0.107	$Shock_f(wage)$	0.013
	(0.03)**		(0.02)
April	-0.075	$Shock_s(prod)$	-0.027
	(0.03)**		(0.02)
May	-0.011	$Shock_s(IIP)$	-0.035
	(0.03)		(0.02)*
Jun	-0.042	$Shock_s(wage)$	-0.019
	(0.03)		(0.02)
Jul	-0.058	$Shock_s(PPI)$	-0.040
	(0.03)*		(0.02)**
Sep	-0.079	*Competition*	-0.038
	(0.03)**		(0.02)**
Oct	-0.094	$Var(IIP)$	-0.196
	(0.03)**		(0.03)**
Nov	-0.026	$Var(wage)$	0.066
	(0.03)		(0.04)
$Duration_1$	-0.335	$Var(prod)$	-0.008
	(0.04)**		(0.03)
$Duration_6$	-0.047		
	(0.04)		
$Duration_{12}$	-0.180		
	(0.04)**		

[a]Significant at 5% (**) and 10% (*).

seasonal and duration dependence factors that explain price reviews by firms which tend to have a regular timing for such reviews.

The results in table 2 clearly point to the two main drivers of price reviews. First, many price reviews appear to be time-dependent. There is a quite large decrease in the probability of *not* changing prices in January which shows that many firms review and (probably) revise their prices in January each year: in January, firms are 25pp less likely to record a zero price change as a result of them not undertaking a price review. February to April as well as September and October also appear to be periods with a significant increase in price reviews (corresponding to a decrease in the likelihood of no-price change stemming from the absence of price review). It is also interesting to note that both the one-month and the twelve-month duration dummies appear to be strongly significant. This may reflect that some firms face quite volatile environments and thus proceed to quite frequent price reviews while for others, facing a less volatile environment, yearly price reviews would be sufficient.[19] The importance of such time-dependent factors is also emphasized in the numerous surveys conducted in the Euro area about firms pricing behaviors (see Loupias and Ricart (2004), for France and Fabiani, Druant, Hernando, Kwapil, Landau, Loupias, Martins, Matha, Sabbatini, Stahl, and Stokman (2006) for a survey over the whole Euro area) which point to the existence of a significant fraction of firms that adopt, at least in "normal circumstances", a time-dependent timing of their price reviews.[20] Those firms appear to examine their prices and the evolution of their environment using a calendar which depends on either the time elapsed since their previous price review (for example, every quarter or year: duration dependence) or on a particular period of the year (for example, the first month of every quarter or every January)

The variations in intermediate input prices appear to be the other important factor triggering price reviews. Both the volatility of these prices and the occurrence of a shock at the firm level increase the likelihood of a price review in a significant way: a unit rise in this volatility increases in the probability of a price review of nearly 20pp while the occurrece of an idiosyncratic shock on input prices raises the probability of a price review by 24pp. On the contray, the volatility of wages and production does not seem to have any impact on the probability to implement a price review. Shocks on wages do not either while the occurrence of an idiosyncratic shock on production has a significant though not very large impact on the probability of a price review.[21] Common shocks on input prices as well as on producer prices as reflected in the producer price index also appear to have an impact on the likelihood of a price review but this impact has a signficantly smaller magnitude that the above mentioned price-review determinants. Note that aggregate shocks affecting

[19] However, the strong effect associated with the duration of one month might also be a consequence of some heterogeneity in the individual firm's hazard functions (Fougère, Le Bihan, and Sevestre 2007).

[20] See Konieczny and Rumler (2006) for a theoretical model explaining why this may be optimal for firms to adopt such a strategy.

[21] Recalling that the volatility of the three variables (input prices, wages, production) is defined in the same way (the frequency of changes) while shocks, either idisosyncratic or aggregate are all defined as dummy variables, the direct comparison of the magnitude of their coefficients is then meaningful.

input prices may, in fact, be partly accounted for by changes in the sectorial price index which may explain the reduced significance of the former. These results seem to validate the view by Golosov and Lucas (2007), Dhyne, Fuss, Pesaran, and Sevestre (2007) and Mackowiak and Wiederholt (2009) that idiosyncratic shocks play an important role in firms' price-setting behavior. Our results also confirm previous findings that the VAT changes and the Euro cash change-over do not seem to have had, in France any significant impact on firms' pricing behavior. Finally, it is also worth mentioning that, as expected, firms facing an higher degree of competition appear to be likely to review prices more often than those facing less competitive markets. Indeed, those are likely to have lower mark-ups and to be more sensitive to costs shocks. Indeed, firms in competitive markets, are some 4pp more likely to conduct a price review. Overall, our results seem to point to the co-existence of both time and state-dependent factors explaining the triggering of price reviews by firms.

Finally Table 6 in the Appendix contains the estimated boundary parameters ($\boldsymbol{\mu}$), the various error-components terms ($\sigma_e^2, \sigma_\alpha^2, \sigma_{e\alpha}$), the idiosyncratic disturbance correlation (ρ). The boundary parameters are strongly significant, as are all error-component terms, suggesting that (dependent) unobserved firm effects are present in both the price review and price change equations. Finally, ρ is positive and significant, indicating that, everything else equal, the more likely a firm is to undertake a price review, the higher the probability it will increase its prices.

Let us now continue our analysis of the firms' price-setting behavior by looking at the determinants of price changes, conditional on the firms implementing a price review.

5.3 Explaining price changes

Table 3 contains the marginal effects for a selection of variables in the price change equation.[22] In general, marginal effects on the large increases/decreases are typically very small, as expected, although in instances these are still statistically significant. However, in order to assess the magnitude of these effects, it is useful to remind that the average probability of a small price increase (resp. decrease) is 8.3% (resp. 7.6%) and those of

[22]The parameter estimates are provided in the appendix.

large increases and decreases are respectively 2% and 1.9%. This makes a marginal effect of 1.5 to 2% correspond to a variation in the observed probability of a moderate price change of 20 to 25% in relative terms. We have to note note that, in general, this price change equation is less well-estimated than the price review one (in terms of significance levels).

According to our estimates, the two main drivers of price changes are wage increases and increases in the sectoral producer price index. These two effects are in line with both what is expected from the theoretical model and with the previous empirical evidence (e.g. see Loupias and Sevestre (2008)). One may indeed expect firms to adjust their prices whenever their labor costs vary significantly and/or whenever their competitors'prices, as measured by the evolution of the sectoral producer price index, vary. Regarding the impact of this latter variable, it is worth noticing that, as in Loupias and Sevestre (2008), the impact of changes in the producer price index on the firm price changes is roughly equally distributed over the current and lagged changes. This may indicate that firms react not every period to deviations of their own prices to those of their competitors but rather make infrequent adjustments either on a time-dependent basis or once the deviation of their prices to those of their competitors has reached a given threshold.

Table 3: Price Change Marginal Effects[a]

	Large Decrease	Small Decrease	No Change	Small Increase	Large Increase
ΔIIP	-0.005	-0.039	-0.016	0.046	0.013
	(0.00)	(0.03)	(0.01)	(0.03)	(0.01)
ΔIIP_1	0.000	-0.002	-0.001	0.002	0.001
	(0.00)	(0.01)	(0.01)	(0.02)	(0.00)
ΔIIP_2	-0.001	-0.010	-0.004	0.012	0.003
	(0.00)	(0.01)*	(0.00)*	(0.01)**	(0.00)*
ΔIIP_3	-0.002	-0.013	-0.005	0.015	0.004
	(0.00)*	(0.01)*	(0.00)*	(0.01)**	(0.00)
ΔIIP_R	-0.002	-0.013	-0.005	0.015	0.004
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**
$\Delta Wage$	-0.002	-0.015	-0.006	0.018	0.005
	(0.00)**	(0.00)**	(0.00)**	(0.01)**	(0.00)**
$\Delta Wage_1$	0.000	-0.002	-0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Wage_2$	0.000	-0.004	-0.001	0.004	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Wage_3$	0.000	-0.002	-0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Wage_R$	0.000	-0.002	-0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Prod$	-0.002	-0.012	-0.005	0.015	0.004
	(0.00)	(0.01)	(0.00)	(0.01)	(0.00)
$\Delta Prod_1$	0.000	-0.001	-0.001	0.002	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Prod_2$	0.000	-0.002	-0.001	0.002	0.001
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
$\Delta Prod_3$	0.001	0.004	0.002	-0.005	-0.001
	(0.00)	(0.00)*	(0.00)	(0.00)*	(0.00)
$\Delta Prod_R$	0.000	-0.001	0.000	0.001	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
ΔPPI	-0.002	-0.014	-0.006	0.016	0.005
	(0.00)**	(0.00)**	(0.00)**	(0.00)**	(0.00)**
ΔPPI_1	-0.001	-0.009	-0.004	0.011	0.003
	(0.00)	(0.00)*	(0.00)	(0.01)*	(0.00)*
ΔPPI_2	-0.002	-0.015	-0.006	0.017	0.005
	(0.00)	(0.01)**	(0.00)	(0.01)**	(0.00)**
ΔPPI_3	-0.001	-0.008	-0.003	0.009	0.003
	(0.00)	(0.01)	(0.01)	(0.01)	(0.00)
ΔPPI_R	0.000	0.000	0.000	0.000	0.000
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)

[a]Significant at 5% (**) and 10% (*).

What is more surprising in our results is that an increase in the intermediate input prices does not seem to impact immediately the likelihood of a price change in a significant way. Indeed, while the magnitude of the estimated coefficient of the current value of intermediate input changes and that of the resulting marginal effects are not negligible, the precision of the estimates is quite low and does not allow to conclude to a statistically significant effect. It appears that only lagged input price changes significantly increase the likelihood of the firm to proceed to a price change. These results are not in accordance with the previous evidence by Loupias and Sevestre (2008) who showed that intermediate input price changes do have a significant impact on the likelihood of a price change. One possible explanation of this discrepancy may simply result from the difference in the two models considered. Indeed, the results in the previous section have clearly shown that shocks on intermediate input prices significantly increase the likelihood of a price review. Then, it might be that once firms have reviewed their prices following a input cost shock, they plan their price changes two or three months ahead, for example because they have contracts with their customers which prevent them from immediately passing such cost changes to their prices.

6 Conclusion

Firms tend to change their prices infrequently. A number of recent surveys have shown that, to a large extent, this is a consequence of firms not necessarily reviewing their prices very frequently. In other words, the commonly observed low frequency of price changes is the consequence of two sequential decisions: at any point in time, firms decide first whether or not they should proceed to a price review. If not, their prices remain necessarily unchanged. If firms review their prices, they may then decide either to effectively change them or not.

Unfortunately, despite the existence of surveys providing some information about the frequency of price reviews and price changes, the information they provide does not allow to estimate firm-level price-setting models that explicitly account for both decisions. Our approach to overcome this issue is to specifying and estimating a so-called inflated ordered probit model where the no-change price observations are explicitly modelled as the combination of these two processes. That is, firms first decide whether or not they should proceed to a price review. If they do, they decide, in a second step, whether they should change (raise or lower) their prices or not. The estimation results show that the likelihood of price reviews increases with the strength of competition, the variability of intermediate input costs and the occurrence of large shocks. Idiosyncratic shocks seem to have a stronger effect than aggregate (industry-level) shocks do. There is also some evidence of the existence of a time-dependent scheduling of price reviews. Regarding the decision to change prices, the results we obtain are essentially similar to those obtained by Loupias and Sevestre (2008), Horny and Sevestre (2009) and others: intermediate input prices appear to be an important driver of price changes, possibly with lags. Wages and sectorial prices also have a significant impact.

To conclude, it is worth mentioning that this set of results is in full accordance with the model and arguments provided in Woodford (2009). When gathering and analysing the information required for reviewing their prices, firms face costs that prevent them from doing so on a permanent basis. However, for firms in a more volatile environment, the cost of not adjusting prices increases the incentive for them to review their prices more frequently. Our estimates indeed tend to show that the volatility of the environment and the occurrence of large cost shocks tend to increase the likelihood of price reviews. However, a significant fraction of price reviews are implemented on a time-dependent basis. Overall, neither pure state–dependent models or pure time-dependent models then appear to fit the data as well as such an information constrained model "à la Woodford".

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7 Appendix A: Sample characteristics

Table 5: Sectoral breakdown of the initial database and of the econometric sample as of January 2005.

	Business surveys	Econometric
Industry	full database	sample
DA. - Food products, beverages and tobacco	16,7%	16.7%
DB. - Textiles and textile products	6,8%	3.3%
DC. - Leather and leather products	1,7%	2.2%
DD - Wood and wood products	3,7%	3.9%
DE - Pulp, paper and paper products	8,2%	9.5%
DF - Coke, refined petroleum and nuclear fuel	-	-
DG - Chemicals, chemical products	7,4%	4.7%
DH - Rubber and plastic products	5,7%	6.1%
DI - Other non-metallic mineral products	4,8%	4.5%
DJ - Basic metals and fabricated metal products	16,2%	17.0%
DK- Machinery and equipment n.e.c.	9,4%	10.6%
DL - Electrical and optical equipment	9,0%	7.2%
DM - Transport equipment	5,8%	7.5%
DN. - Manufacturing n.e.c	4,6%	6.7%
Number of firms	4 032	359

Source: Banque de France business surveys merged with the ACEMO survey conducted by the French Ministry of Labour and Social Affairs. The dataset contains 16711 observations from 1543 firms observed monthly between October 1998 and December 2005.

Table 6: Frequency of price, costs and demand/production changes /increases/decreases in the initial database and in the econometric

	Business surveys full database	Econometric sample
Price changes	18,6%	19.6%
of which increases	10,9%	10,3%
of which decreases	7,7%	9.3%
Intermediate input price changes	24,1%	25.6%
of which increases	17,0%	18,1%
of which decreases	7,1%	7.5%
Wage changes(14)	18,1%	21.9%
of which increases	14,7%	19,1%
of which decreases	3,4%	2,8%
Demand/Production changes	62,1%	63.9%
of which increases	36,1%	36.0%
of which decreases	26,0%	27,9%
Number of observations	479 744	16 711

(14) The initial database considered here for wage changes is extracted from the ACEMO survey database; it includes about 600,000 observations about wage changes at the establishment level.

8 Appendix B: The likelihood with individual effects

Assuming the presence of unobserved heterogeneity, we rewrite the latent variables associated with the occurrence of price reviews and price changes respectively as:

$$q_{it}^{*} = \mathbf{x}_{it}'\boldsymbol{\beta} + \alpha_i + u_{it} \tag{10}$$

and

$$y_{it}^{*} = \mathbf{z}_{it}'\boldsymbol{\gamma} + e_i + \varepsilon_{it}. \tag{11}$$

Again, as is common in the literature, we assume that $\alpha_i \sim N\left(0, \sigma_\alpha^2\right)$ and $e_i \sim N\left(0, \sigma_e^2\right)$. However, once more as these unobserved effects correspond to the same firm, it appears likely on *a priori* grounds that these two sets of effects will be correlated. Thus we assume a bivariate normal distribution for (α, e) with mean $\mathbf{0}$ and covariance matrix Σ. Coupled with the assumptions concerning the idiosyncratic disturbances we have

$$\begin{pmatrix} u_{it} \\ \varepsilon_{it} \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & \rho \\ \rho & 1 \end{pmatrix}\right] \tag{12}$$

and

$$\begin{pmatrix} \alpha_i \\ e_i \end{pmatrix} \sim N\left[\begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_\alpha^2 & \sigma_{\alpha e} \\ \sigma_{\alpha e} & \sigma_e^2 \end{pmatrix}\right] \tag{13}$$

Unfortunately, this structure quite significantly further complicates estimation. However, conditional on the individual effects, the (log-)likelihood has a tractable formulation allowing its maximization. Defining $\boldsymbol{\theta} = \left(\boldsymbol{\beta}', \boldsymbol{\gamma}', \mu, \rho, \sigma_\alpha^2, \sigma_e^2, \sigma_{\alpha e}\right)'$, one has

$$L\left(\boldsymbol{\theta} \mid \alpha_i, e_i\right) = \sum_{i=1}^{N}\sum_{t=1}^{T_i}\sum_{j=0}^{J-1=2} d_{ijt} \ln\left[\Pr\left(y_{it} = j \mid \mathbf{x}_{it}, \mathbf{z}_{it}\right)\right] \tag{14}$$

where

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

d_{ijt} is the indicator function such that

$$d_{ijt} = \begin{cases} 1 \text{ if individual } i \text{ chooses outcome } j \\ 0 \text{ otherwise.} \end{cases} \quad i = 1, ..., N;\ j = 0, \ldots, J-1; t = 1..., T_i. \tag{15}$$

Thus estimation involves integration over both (α_i, e_i) bivariate normal integrals. Thus for estimation, it is necessary to remove the unobserved effects from these expressions. A convenient approach is to write the cholesky decomposition of Σ as

$$chol\left(\Sigma\right) = chol\begin{pmatrix} \sigma_\alpha^2 & \sigma_{\alpha e} \\ \sigma_{\alpha e} & \sigma_e^2 \end{pmatrix} = \begin{pmatrix} \delta_{11} & 0 \\ \delta_{12} & \delta_{22} \end{pmatrix} \tag{16}$$

so that

$$\begin{pmatrix} \alpha_i \\ e_i \end{pmatrix} = \begin{pmatrix} \delta_{11} & \\ \delta_{21} & \delta_{22} \end{pmatrix} \begin{pmatrix} \nu_\alpha \\ \nu_e \end{pmatrix} \tag{17}$$

where ν_α and ν_e are independent $N(0,1)$ variables. It is clear that $\sigma_\alpha^2 = \delta_{11}^2$; $\sigma_e^2 = \delta_{21}^2 + \delta_{22}^2$; and $\sigma_{\alpha e} = \delta_{11}\delta_{21}$. In this way it is possible to substitute α_i and e_i out of equation (14) using $\alpha_i = \delta_{11}\nu_\alpha$ and $e_i = \delta_{21}\nu_\alpha + \delta_{22}\nu_e$. The individual effects need to be integrated out for the unconditional likelihood: a process facilitated by use of the Cholesky decomposition. Simulation techniques appear appropriate here (Greene and Hensher, 2008) as only independent standard normal random draws are required.[23] The simulated log-likelihood function is

$$L\left(\boldsymbol{\theta}\right) = \sum_{i=1}^{N} \frac{1}{M} \sum_{m=1}^{M} \prod_{t=1}^{T_i} \sum_{j=0}^{J-1=2} d_{ijt} \left[\Pr\left(y_{it} = j \left| \mathbf{x}_{it}, \mathbf{z}_{it}, \nu_\alpha, \nu_e \right.\right)\right] \tag{18}$$

[23] We use antithetic Halton draws in the application below (Greene and Hensher 2008).

Table 4: Inflated Ordered Probit: Price Review Coefficients[a]

Time-Dependent			State-Dependent		
$Constant$	-1.970	(0.23)**	VAT	0.041	(0.29)
Jan	0.797	(0.12)**	$VAT(month)$	-0.069	(0.17)
Feb	0.302	(0.10)**	$EURO$	-0.184	(0.19)
Mar	0.342	(0.10)**	$EURO(month)$	-0.036	(0.08)
Apr	0.238	(0.11)**	$Shock_f(prod)$	0.111	(0.04)**
May	0.035	(0.11)	$Shock_f(IIP)$	0.777	(0.05)**
Jun	0.133	(0.10)	$Shock_f(wage)$	-0.041	(0.07)
Jul	0.185	(0.11)*	$Shock_s(prod)$	0.085	(0.05)
Sep	0.253	(0.10)**	$Shock_s(IIP)$	0.113	(0.06)**
Oct	0.301	(0.10)**	$Shock_s(wage)$	0.062	(0.07)
Nov	0.083	(0.10)	$Shock_s(PPI)$	0.127	(0.05)**
$Duration_1$	1.067	(0.11)**	$Competition$	0.120	(0.05)**
$Duration_2$	0.415	(0.11)**	$Var(IIP)$	0.625	(0.11)**
$Duration_3$	0.352	(0.12)**	$Var(wage)$	-0.212	(0.14)
$Duration_4$	0.180	(0.12)	$Var(prod)$	0.026	(0.09)
$Duration_5$	0.211	(0.12)*			
$Duration_6$	0.151	(0.13)			
$Duration_7$	0.143	(0.13)			
$Duration_8$	0.022	(0.13)			
$Duration_9$	-0.086	(0.14)			
$Duration_{10}$	0.141	(0.13)			
$Duration_{11}$	0.143	(0.13)			
$Duration_{12}$	0.572	(0.14)**			
$Duration_{13}$	0.197	(0.14)			
$Duration_{14}$	-0.143	(0.18)			
$Duration_{15-24}$	0.161	(0.11)			

[a]Standard errors in parentheses. Significant at 5% (**) and 10% (*). Sector and year dummies included but not reported.

9 Appendix C: Estimated coefficients

Table 5: Inflated Ordered Probit: Price Change Coefficients[a]

	Coefficient	Standard Error
$Constant$	1.022	(0.29)**
VAT	-0.156	(0.30)
$VAT(month)$	-0.173	(0.15)
$EURO$	-0.103	(0.23)
$EURO(month)$	-0.084	(0.08)
ΔIIP	0.627	(0.44)
ΔIIP_1	0.029	(0.22)
ΔIIP_2	0.159	(0.08)**
ΔIIP_3	0.203	(0.10)*
ΔIIP_R	0.211	(0.05)**
$\Delta Wage$	0.240	(0.08)**
$\Delta Wage_1$	0.027	(0.04)
$\Delta Wage_2$	0.058	(0.05)
$\Delta Wage_3$	0.034	(0.06)
$\Delta Wage_R$	0.032	(0.05)
$\Delta Prod$	0.202	(0.13)
$\Delta Prod_1$	0.023	(0.03)
$\Delta Prod_2$	0.030	(0.03)
$\Delta Prod_3$	-0.066	(0.03)**
$\Delta Prod_R$	0.011	(0.02)
ΔPPI	0.224	(0.05)**
ΔPPI_1	0.144	(0.08)*
ΔPPI_2	0.237	(0.11)**
ΔPPI_3	0.123	(0.14)
ΔPPI_R	0.002	(0.04)

[a]Significant at 5% (**) and 10% (*).

Sector and year dummies included but not reported.

Table 6: Inflated Ordered Probit: Ancilliary Results and Summary Statistics[a]

	Coefficient	Standard Error
μ_1	1.404	$(0.05)^{**}$
μ_2	2.516	$(0.06)^{**}$
μ_3	3.968	$(0.05)^{**}$
σ_e^2	0.5542	$(0.05)^{**}$
σ_α^2	0.2072	$(0.03)^{**}$
$\sigma_{e\alpha}$	-0.1942	$(0.03)^{**}$
ρ	0.1542	$(0.06)^{**}$
$MaxL$	-9917.4	
AIC	19967.7	
BIC	21128.0	
$CAIC$	21261.0	

Significant at 5% (**) and 10% (*).