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Wage and price joint dynamics at the firm level: an empirical analysis*

Guillaume Horny† Patrick Sevestre‡

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†Banque de France, DGEI-DEMS-SAMIC, 31 rue Croix des Petits Champs, 75 049 Paris Cedex 01, France and UCLouvain, Belgium. E-mail: guillaume.horny@banque-france.fr.

‡Banque de France, DGEI-DEMS-SAMIC, and Université de Paris I-Panthéon Sorbonne. E-mail: sevestre@univ-paris1.fr

Abstract

This article provides evidence about the interrelationships between wages and prices at the microeconomic level. We rely on the right-to-manage model to specify and estimate a multivariate model explaining the timing and magnitude of wage and price changes at the firm level. The data we use is a quarterly panel of about 1800 firms from the French manufacturing industry, observed over the years 1998 to 2005. We find the occurrence of wage changes to be essentially time dependent, though weakly related to the state of the economy. However, the magnitude of wage changes strongly depends on macroeconomic variables, namely inflation and unemployment, and to a lesser extent on the evolution of the firm product price and on its productivity gains. Changes in the firm product price are mostly driven by the evolution of its costs and more specifically by that of its intermediate input. The wage cost, as well as the production and the industry level inflation, have a weaker influence.
Keywords: wages, price stickiness, dynamic model, factor loadings
JEL Classification E31, C23, C25

Résumé

Résumé: Cet article documente lŠinterdépendance des variations des salaires et des prix au niveau microéconomique. Nous spécifions et estimons un modèle multivarié, inspiré du modèle du droit à gérer, pour expliquer lŠoccurrence et lŠimportance des changements de salaires au niveau de lŠentreprise. Les changements de prix sont supposés pour leur part être déterminés selon un modèle *state-dependent*. Nos données sont constituées dŠun panel trimestriel dŠenviron 1800 entreprises de lŠindustrie manufacturière, observées de 1998 à 2005. Nous trouvons que lŠoccurrence des changements de salaires dépend essentiellement dŠeffets saisonniers, et dans une moindre mesure du contexte économique. Cependant, lŠimportance des variations de salaires dépend fortement des variables macroéconomiques que sont lŠinflation et le chômage, et dans une moindre mesure de lŠévolution du prix de production de lŠentreprise ainsi que de ses gains de productivité. Les variations du prix de production de lŠentreprise résultent essentiellement de variations de ses coûts de production et plus précisément des coûts des consommations intermédiaires. Le coût salarial, de même que la production et lŠinflation sectorielle, exercent en comparaison une influence plus faible.
Mots clés: salaires, rigidité des prix, modèle dynamique, facteurs
Classification JEL: E31, C23, C25

1 Introduction

At the macroeconomic level, myriads of papers have shown that wages and prices strongly depend on each other. Wage variations depend on both expected and past inflation, and wages or more generally labor costs variations appear to be a major driver of price inflation. At the firm level however, the growing but still limited evidence on the link between wages and prices tends to show that the relationships are much weaker. According to several surveys recently conducted in the Euro area, about 60% of firms declare there is no link between the decision to change their prices and that of changing their wages. Only 15% of firms declare a strong link between these changes (see Druant *et al.*, 2009). Gaiotti (2008), Fougère *et al.* (2008), Loupias and Sevestre (2010) and Harris and Sevestre (2009) provide simple statistics and econometric evidence on the limited impact of wage variations on producer price changes.

Explanations of this discrepancy between the micro and the macro evidence are numerous. First, while at the microeconomic level, only the direct effect of changes in the firm labor cost onto its prices is assessed, the macroeconomic impact of wage changes on prices incorporates both direct and indirect effects. Indeed, wage inflation in upstream firms induces an inflation in intermediate input prices of downstream firms and consequently, also contributes to their own product price inflation. Accordingly, the share of labor costs in total production cost at the firm level is much lower than its share in the value-added at the macro level. While wages represent about 60% of the GDP in France, the share of labor costs in French manufacturing firms is about 20% (SESSI, 2005). Another rationale for the reduced impact of wage changes on prices at the firm level may be found in the quite small magnitude of wage changes as compared to that of other input price changes. According to Heckel *et al.* (2008), the average wage change in the French manufacturing industry was slightly above 2.2% over the period considered while the average change of intermediate goods prices was about 4% (Gautier, 2008). Overall, the typical impact of wage increases on firms production cost then appears to be of a limited magnitude. A further argument explaining this limited impact of wage changes on prices may be found in the evolution of labor productivity, stemming from the technological change and/or from possible adjustments in the quantity or composition of the labor force. An increase in labor productivity clearly lowers the need for firms to incorporate wage increases in prices, as long as this productivity increase is only partially transmitted to wages (e.g. see Fuss, 2008). Indeed, several studies have pointed to a limited sensibility of wages to productivity changes (e.g. see Biscourp *et al.*, 2005, Cardoso and Portela, 2009, Guiso *et al.*, 2005, and, more recently, Katay, 2008, and Fuss and Wintr, 2008). In other words, it could be that firms partially offset the consequences of wage increases through the "capture" of a fraction of productivity gains they are

able to generate.

The aim of this paper is to add one bit of evidence regarding the interrelationships between wage and price changes at the firm level. The framework of our modelling is inspired from the right-to-manage model. Wages are bargained between the firm and its employees and the firm then determines its optimal level of employment and, in our case, that of its output price, by maximizing its profit. Moreover, because, at the firm level, neither wages nor prices change each and every quarter, we explicitly model their respective timings, allowing for a possible interdependence between these timings.

Our results point to essentially time dependent occurrences of wage changes, notably driven by institutional rules, the importance of which, in Europe, is underlined in Druant *et al.* (2009). Variables capturing the state of the economy come to be at most of secondary importance. The magnitude of wage changes mostly depends on macroeconomic variables such as inflation and unemployment. It is only to a lesser extent that firm level variables, such as producer price changes and productivity gains, influence wage changes. As regards price changes, their main driver is the evolution of the firm's costs an more specifically the intermediate input costs. The wage cost has a much weaker influence. The same conclusion holds for the production and the industry level inflation, as in Loupias and Sevestre (2010).

The paper is organized as follows. Section 2 provides a brief description of the institutional framework of wage setting in France, data sources as well as some descriptive statistics about wage and price changes at the firm level. The model is presented in Section 3 and estimation results are provided and discussed in Section 4. Section 5 concludes.

2 Wage and price changes at the firm level : basic features.

After a short presentation of the basic features of wage-setting in France, we provide a description of the two main firm level data sources we use. First, the ACEMO survey provides information about wages and employment at the establishment-level. Second, the Banque de France business surveys provide information on firms decisions regarding changes in their prices, among other items. We then provide a brief characterization of the observed wage and price changes.

2.1 Wage-setting in France

In France, wage-setting occurs within a decentralized institutional framework. The 1982 Auroux Acts have made annual wage bargaining compulsory at both the industry and firm levels. Industry-level agreements are binding unless firm-level agreements exist and are more favourable to the firm em-

ployees, which is often the case. Montornès and Sauner-Leroy (2009) indicate that wages actually paid are higher than the negotiated sectoral wages in nearly one half of firms. The differential is around 6% of the sectoral base wage. The government is a third actor of the wage-setting process in France. It intervenes indirectly, first via sectoral agreement extension mechanisms to ensure fair competition within industries, and second, via increases in the minimum wage. Then, despite a low rate of trade union membership, the coverage of wage agreements in France is virtually total. Indeed, employees are covered by their firm and sector-level agreements even if they do not belong to a union, and the sectoral agreement extension mechanisms further apply. Montornès and Sauner-Leroy (2009) point that 98% of the enterprises are covered by an agreement in a given year, either at the company or at the industry-level. The minimum wage applies to all workers and all firms (between 10% and 15% of the workers are paid at the minimum wage). Changes in the minimum wage are set according to official rules, leading to full indexation to past CPI inflation and to a partial indexation to the past average wage growth of blue-collar workers. During the time period we consider here, changes in the minimum wage occurred basically each year on the first of July. Because firms are encouraged to simultaneously increase wages that are close to the minimum, wage changes appear to be rather frequent in July, even for workers who earn more than the minimum wage. Moreover, the collective bargaining timetable also impacts the timing of wage changes. Avouyi-Dovi *et al.* (2010) show that wage agreements most often come into effect in January.

2.2 The ACEMO survey

The ACEMO survey is a longitudinal employer data set gathered by the French Ministry of Labor and Social Affairs. Data are collected through a mandatory postal report sent to establishments with at least ten registered employees. We only make use here of the data about establishments from the French manufacturing industry, as defined in the NES36 classification. The period covered starts in the fourth quarter of 1998 and ends in the fourth quarter of 2005.

In this survey, the level of the base wage is collected for up to 12 representative job positions in the establishment, depending on its size: small establishments are asked about fewer positions than large ones. This set-up allows the computation of the firm' employees average wage[1] as the average wage, computed over the representative employees, weighted by the proportion of workers they represent. In that respect, our study differs from other recent studies that focus on the wage of an employee belonging to the most representative position (Druant *et al.*, 2009) or of a random sample of the

[1]Because the very vast majority of establishments inquired in this survey are the only establishment of the firm, we use indifferently these two denominations here.

employees (Christopoulou *et al.*, 2010). Our measure also deviates from individual wages used in applications involving matched employer-employee data. It should be understood as allowing the computation of a good approximation of the evolution of the firm' wage costs. Indeed, this measure is sensitive to changes in wages, as well as in the composition of the firm employment. Wage decreases may correspond to wage cuts but also to less skilled or less experienced new workers occupying the inquired job position; and vice-versa for average wage increases. It must be reminded here that the firm average wage cost is the relevant measure when studying wage-price interrelationships at the firm level. Despite some components of the labor cost, such as employer contributions and bonuses, are not recorded in this survey, the growth rate of the base wage is indeed a relevant measure of the evolution of the firm wage cost. First, employer contributions do not vary a lot and changes are exogenous to the firm. We control for these in the regressions using time dummies. Second, performance bonuses represent only around 3% of the individual earnings, and overtime bonuses 1%. Clearly, even if individual employees' wages may be significantly affected by bonuses, these do not affect significantly the evolution of the average wage of the firm.

Measurement errors nevertheless remain an important issue in the study of wage dynamics (Gottschalk, 2005), typically leading to tiny and irrelevant wage changes. Several checks are performed by the French Ministry of Labor and Social Affairs during the data collecting process, especially when a change larger than 2% is observed for a given position between two consecutive quarters. We further set to 0 all growth rates of the mean wage of a magnitude less than 0.01%. In addition to these corrections, the measurement error issue is further delt with in our econometric analysis by using instrumental variables estimation methods.

2.3 The Banque de France business survey

The monthly Banque de France manufacturing industry business surveys provide firm-level records about firms' product price changes as well as about changes in their intermediate input prices, their production level, the orders they receive, etc. The surveyed unit is a particular product, identified at the 4-digit NACE level, produced in a particular plant. A given firm can be surveyed several times during the same month if it is made of multiple establishments, or if it consists of a single multiproduct (large) establishment. However, the very large majority of the firms in the sample are made of one establishment only and are surveyed for only one product. About 4000 firms are inquired every month. The information recorded in the survey is essentially qualitative: each inquired variable may take on seven different values, starting from a strong decrease up to a strong increase through medium or small decreases, the absence of change and small or medium increases. However, as explained below in more details, for all the variables involved in the

price equation of our model, we have restricted our attention to three outcomes: decrease, no change and increase (see Section 3.3 for more details).

The period covered by our dataset is January 1996-December 2005. Due to the process of data cleaning and to the merging with the ACEMO survey, our dataset finally contains information regarding about 1800 firms, observed over the totality or a fraction of the period 1998:Q4 to 2005:Q4.

The other data we use in our subsequent econometric analysis comprise the producer price indices (PPI) at the NACE2-digit level as well as macroeconomic data such as the consumer price index (CPI) and the unemployment rate.[2]

2.4 Identifying wage and price spells

Because we do not only focus on the magnitude of price (resp. wage) changes but also on their timing, we need to identify price (resp. wage) trajectories and spells. Trajectories are defined as sequences of price (resp. wage) consecutive records corresponding to a given product/firm. Spells correspond to a sequence of price (resp. wage) consecutive records corresponding to an unchanged price (resp. wage) level for the same product/firm, starting just after the price (resp. wage) was changed and ending with the next price (resp. wage) change. Two difficulties had to be tackled at this stage. First, missing observations led us to define multiple trajectories for the same product/firm. Indeed, when the monthly data are not available for the first (resp. last) month of any quarter, we consider the quarter as indicating the beginning (resp. end) of a trajectory. Second, because the Banque de France business survey is monthly while the ACEMO survey is quarterly, we had to decide whether we would rely on monthly or quarterly series for merging the data. We decided to aggregate the monthly data into quarterly series by computing quarterly averages.[3] When the monthly data indicate several changes within a quarter, we thus retain a single change equal to the quarterly average. This rule led to a specific difficulty regarding the beginning and end of price trajectories and price spells. When price records were not available for all months of a quarter corresponding to the start (resp. the end) of a spell or trajectory, we averaged the data over the consecutive months for which they were available. Along the same lines, because the Banque de France business survey is not run in August, the averages for the third quarter were computed over the months of July and September when they were both part of the same spell.

Finally, because of the presence of state-dependent variables in our model, we had to discard left-censored spells. Indeed, estimating such models requires knowing the evolution of the determinants of price (resp. wage) since the beginning of the price (resp. wage) spell.

[2]These data have been obtained from the INSEE website: www.insee.fr.

[3]See Loupias and Sevestre (2010) for an alternative methodology and its justifications.

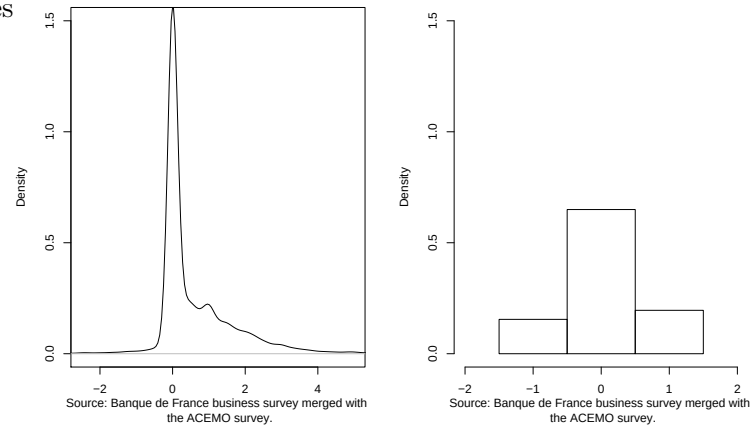
2.5 Descriptive statistics

Once trajectories and spells were built for prices and wages, we merged the two datasets and ended up with a sample comprising 15 635 observations, corresponding to 1 778 firms and 1 906 plants/products. This sample contains 7 054 price spells, of average duration 3.07 quarters, and 9 560 wage spells of average duration 1.92 quarters.

The price spell average duration we obtain here is quite similar to that obtained in previous studies about producer prices in France and in other countries (see Avouyi-Dovi *et al.,* 2010, Loupias and Sevestre, 2010, and Vermeulen *et al.*, 2007). The durations of the wage spells we computed from the ACEMO survey are shorter than the intuition of conventional duration of one year, as described in Heckel *et al.* (2008). The explanation is quite simple: the measure we use here is the change in the average wage of workers occupying the surveyed job positions within the establishment. This measure is likely to change whenever the wage of the employee occupying any of the surveyed positions changes, or because of staggered wage changes within a firm.[4] Such results should not be considered as altering the validity of our wage measure, as it is meant to approximate changes in the firm mean labor cost and in no way the individual workers' wage changes.

Basic statistics about changes in wages and prices are presented in Figure 1 and Table 1. Not surprisingly, the absence of change is the mode for both distributions and the mean wage growth rate density is strongly asymmetric: 49% of the observations are raises and 6% are decreases.

Figure 1: Descriptive statistics on the mean wage growth rate and price changes

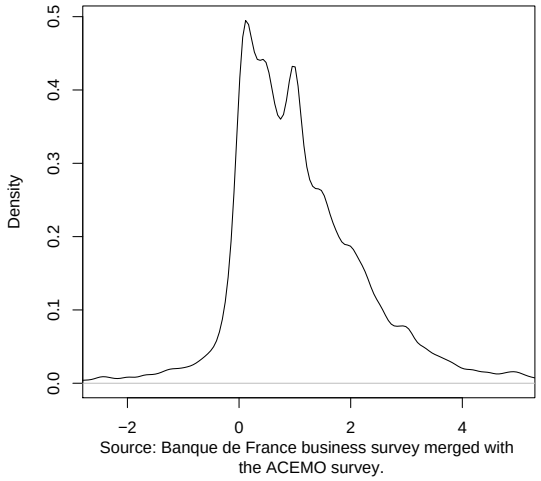


The estimated mean wage density has its support between -2% and 5%,

[4]The survey contains information on whether a given a position has seen a staff replacement and Heckel *et al.* (2008) use this information to compute individual-specific wage spells. Their wage spells corrected for turnover are on average of 2 quarters. The durations of our wage spell are thus only very marginally affected by the employees turnover.

with a major mode in 0 and a minor one at 1%. Most of the increases are of limited magnitude, as 49% of them are between 0 and 1%. A closer look at the estimated distribution of non-null wage changes is obtained from Figure 2. It has modes at 0.15% and 1%, as well as humps at 0.5%, 1.5%, 2% and 3%.

Figure 2: Estimated density of non-zero wage changes



On the other hand, the price distribution is pretty symmetric, with only slightly more increases (19%) than decreases (16%). The estimated density of price changes is symmetric with its mode at 0 : whereas the wage cost has a clear tendency to increase, it is less so for prices. There is no evidence here of a strong simultaneity of price and wage increases. Many off-diagonal elements in Table 1 are significantly positive.

Table 1: Price and wage joint variations

	Price			
Wage	decrease	constant	increase	Total
decrease	1	4	1	6
constant	7	30	8	45
increase	8	31	10	49
Total	16	65	19	100

Table 2 also shows how often the price of the final product is changed in conjunction with a change in either wages, intermediate input costs or demand. As previously pointed out by Loupias and Sevestre (2010), the price of the final product seems to be more sensitive to the cost of intermediate inputs than to wages. Only a third of wage variations translate to price adjustments within a quarter while about one half of variations in the cost of intermediate inputs induce producer price changes. Overall, these statistics

do not point to a strong simultaneity between wage and price variations at the firm level in the manufacturing industry.

Table 2: Change in producer price along with other changes

Variables	Costs		Demand
	raw materials	labor	final product
Price increase	49	36	36

Note: Proportions do not sum to one because we condition on variations of a single variable.

3 Modeling wage and price decisions

This section aims at providing some theoretical underpinnings about how producer prices and wages are determined at the firm level.

3.1 Explaining the magnitude of wage changes

Our approach to the modeling of wage changes at the firm level essentially relies on the right-to-manage model. Indeed, we consider that wages are bargained between firms and employees, and that firms determine their product price and their employment level so as to maximize their profit.

We follow the literature (see Nickell and Andrews, 1983, and, for a recent empirical reference Dobbelaere and Mairesse, 2010) and assume that bargained wages can be seen as the outcome of the maximization of :

$$\lambda \log \left([u(w_{it}) - u(w_{it}^a)]N \right) + (1 - \lambda) \log \pi_{it}, \tag{1}$$

where $u(w_{it})$ is a worker's utility from wage w_{it}, w_{it}^a is the wage from an outside option in case of a bargaining dispute, N is the employment, π_{it} denotes profits and $\lambda \in [0, 1]$ is a parameter increasing in the union bargaining power. When workers have a strong bargaining power (λ close to 1), the bargaining process essentially accounts for workers' utility. On the contrary, when workers have no bargaining power (λ close to 0), only the firm's profit is considered. This formulation relies on the assumption that in the event of unsuccessful bargaining, the firm makes no profit (the outside option for firms is $\pi_{it}^a = 0$) while workers receive the alternative option w_{it}^a. Maximizing this quantity with respect to wages leads to the following bargained wage :

$$w_{it} = w_{it}^a + \frac{\lambda}{1 - \lambda} \frac{\pi_{it}}{N}. \tag{2}$$

This can be rewritten in difference :

$$\Delta w_{it} = \Delta w_{it}^a + \frac{\lambda}{1 - \lambda} \Delta \left(\frac{\pi_{it}}{N} \right). \tag{3}$$

Wages in firm i evolve between $t-1$ and t as the alternative option does plus a fraction of the evolution of the profits of the firm. The larger is the workers' bargaining power, the larger the fraction of profits they obtain. We consider here that the alternative wage can be represented as either the average wage in the economy or the sectoral wage. Their evolutions are supposed to depend primarily on past and expected CPI inflation and on the level of unemployment.[5] The evolution of wages in firm i also depends on the evolution of its profits, which in turn depends on the evolution of the labor productivity but also on the expected, current and past evolution of its product price, which may be considered by workers as an indication about the evolution of the firm profitability.

Our equation explaining the magnitude of wage changes (when they occur) is then written as :

$$\begin{aligned}\Delta w_{it} =& b_0 + b_1 cpi\_infl_{+1} + b_2 cpi\_infl + b_3 cpi\_infl_{-1} + b_4 cpi\_infl_{-r} \\ &+ b_5 u + b_6 u_{-1} + b_7 u_{-2} \\ &+ b_8 \Delta Price_{+1} + b_9 \Delta Price + b_{10} \Delta Price_{-1} + b_{11} \Delta Price_{-r} \\ &+ b_{12} \Delta Prod + b_{13} \Delta Prod_{-1} + b_{14} \Delta Prod_{-r} \end{aligned} \quad (4)$$

The specification involves :[6]

- the CPI inflation rate since the last wage change, decomposed into its current value, cpi_infl, that of the previous quarter, cpi_infl_{-1},and the remaining evolution since the start of the spell, cpi_infl_{-r}. This accounts for backward indexation of wages on prices. We also include the expected inflation over the next year, cpi_infl_{+1}, to check for possible forward indexation.

- the current and past levels of the unemployment ratio, u, u_{-1} and u_{-2}, as the labor market situation is likely to have an impact on the value of the workers' outside options.

- the expected variation in the producer's price, $\Delta Price_{+1}$, as well as its evolution since the last wage change, also decomposed into its current variation, $\Delta Price$, that of the previous quarter, $\Delta Price_{-1}$, and the remaining evolution since the start of the spell, $\Delta Price_{-r}$. As stated above, in a bargaining environment, workers may claim for some profit sharing if they observe an increase in the firm's prices which they can consider as an indication of increased profits. On the contrary, firms facing strong negative shocks may manage to decrease their average

[5] We also experienced a specification where wage variations depend on unemployment variations. This however led to restrictions on the parameters that are not acceptable at the usual confidence levels.

[6] See Appendix B for a detailed description of the variables measurement.

wage cost in order to accommodate a necessary decrease in their output price.

- the evolution of the firm's productivity since the last wage change, again decomposed into its current variation, $\Delta Prod$, that of the previous quarter, $\Delta Prod_{-1}$, and the remaining evolution since the start of the spell, $\Delta Prod_{-r}$. As stated above, wages variations should be related, at least partly, to the evolution of the firm's productivity.

- industry and year dummies, to account for sectoral specificities and for macroeconomic shocks.

However, as previously underlined, several studies (see Avouyi-Dovi *et al.,* 2010, as well as Horny *et al.,* 2010, for France, or Druant *et al.,* 2009, for Europe) and our data show that firms do not negotiate nor change wages each and every quarter. We thus need to add an equation in our model to explain the timing of wage changes.

The structure of our model for explaining wage changes is then a Type 2 - Tobit model, defined as follows. The timing of wage changes is determined in the following way :

$$d_{it} = \begin{cases} 1 \text{ (a wage change occurs)} & \text{if } d_{it}^* > 0 \\ 0 \text{ (no wage change occurs)} & \text{if } d_{it}^* \leq 0 \end{cases}, \tag{5}$$

$$\text{with } d_{it}^* = X_{it}^d \beta_d + u_{it}^d, \tag{6}$$

where X_{it}^d is a vector of covariates which is described in details just below. Then, whenever a wage change occurs, its magnitude is defined as:

$$\Delta w_{it} = \begin{cases} \Delta w_{it}^* & \text{if } d_{it} = 1 \\ 0 & \text{if } d_{it} = 0 \end{cases}, \tag{7}$$

$$\Delta w_{it}^* = X_{it}^w \beta_w + u_{it}^w, \tag{8}$$

where X_{it}^w is a matrix containing the variables listed under equation (4) above.

3.2 Explaining the timing of wage changes

As stated in Section 2.1, essential components of the timing of wage changes are institutional. These include the timing of the negotiations, mandatory once a year, as well as the timing of the conventional increases in the minimum wage. In "normal times", the timing of wage negotiations and the subsequent wage changes are thus essentially time-dependent. However, state dependence may also play a role: acceleration of CPI inflation, changes in the firm's own product prices and the occurrence of a persistent shock on productivity may also lead workers to bargain over wages. The list X_{it}^d of

covariates that we consider to explain the timing of wage changes then includes:

- duration dummies, to account for the regularity of wage changes. In the above mentioned surveys, firms typically declare they would change their employees' wages once a year.

- quarter dummies, to allow for the peaks in the timing of wage changes. Wage changes are more likely to occur during the first and third quarters.

- strong and persistent productivity shocks, i.e. strong decreases of the plant's productivity lasting at least 2 consecutive quarters. Indeed, in a competitive environment, wages should be related to the evolution of the firm's productivity, even though firms do not seem to fully adjust wages to productivity changes (e.g. see Biscourp *et al.*, 2005, Guiso *et al.*, 2005, and, more recently, Katay, 2008, Fuss and Wintr, 2008, and Cardoso and Portela, 2009). Strong variations in productivity (e.g. due to strong variations in the firm's output level) may nevertheless be an incentive for firms or workers to bargain over wages, especially when these variations are expected to be lasting.

- occurrences of expected, current and past changes in the firm product prices. In an imperfect competition framework, firms able to raise their prices may be in a position to accept more easily to share the rent through wage increases. Conversely, those having to lower their prices to achieve a better competitiveness may exert a pressure to make their labor costs decrease.

- the possible change in CPI inflation (either past or expected); although the period we consider here was essentially a period of quite stable inflation, one should not rule out the possibility that changes in the rhythm of inflation may lead workers to claim for new negotiations.

- industry and year dummies. These variables may capture specific industry level characteristics (such as the degree of unionization), as well as macroeconomic evolutions influencing the timing of wage changes.

- plant size. The inclusion of this variable is a consequence of measuring wage evolutions using the ACEMO survey: depending on their size, establishments are asked about wages corresponding to one up to twelve representative positions. Changes of the average labor cost are thus more likely to be observed in larger firms.

3.3 Price determination

We rely here on the literature on state-dependent price-setting behavior in an imperfect competition context (see Cecchetti, 1986, and, more recently, Fougère *et al.*, 2008, Dhyne *et al.*, 2007 and Rupprecht, 2007, among many others) and more particularly on Loupias and Sevestre (2010). In this framework, firms set their product price but face a menu cost when they change their price. The occurrence of a price change then corresponds to a situation where the discrepancy between the optimal price P_{it}^* and the price that would be effective if no change is decided, that is the price at time $t-1$, P_{it-1}, exceeds the cost of a price change. An empirical concern is that the optimal price P_{it}^* is not observable. To circumvent this problem, an approach is to model the optimal price so as to express it as a function of observed variables.[7]

Assume a static Cobb-Douglas cost function :

$$C_{it} = A_{i(j)t} \;\; Q_{it}^{\alpha} \;\; w_{it}^{\beta} \;\; iip_{it}^{\gamma}, \tag{9}$$

where Q_{it} represents the firm production level, w_{it} represents the wage cost, iip_{it} the price of intermediate inputs, and $A_{i(j)t}$ represents unobserved variables affecting costs.

The firm is selling its product on a market where monopolistic competition prevails. Under a constant price elasticity of demand, a ($a < -1$), profit maximization leads to :

$$p_{it}^* = \ln P_{it}^* = \ln\left(\frac{a}{1+a}\right) + \ln MC_{it}, \tag{10}$$

where MC_{it} is the marginal cost. We get :

$$p_{it}^* = \ln\left(\frac{\alpha a}{a+1}\right) + \ln A_{i(j)t} + (\alpha - 1)\ln Q_{it} + \beta \ln w_{it} + \gamma \ln iip_{it}. \tag{11}$$

The impact on input price changes on the output price is proportional to their share in the cost. We thus expect a stronger impact of changes in intermediate input prices than of wage changes. Indeed, the share of intermediate input costs in total production of French manufacturing firms was about 70% in 2005 while that of labor cost was 20% (SESSI, 2008). The impact of production changes on prices depends on α, that is the inverse of the returns to scale. The closer to constant these returns are, the smaller is the impact of production changes on marginal cost and thus on the product price.

[7] Another option is chosen in Dhyne *et al.* (2007). Because the information they have is limited to prices, they assume a particular decomposition of the optimal price associated with the underlying unobserved costs and demand and estimate a state-dependent model explaining price changes.

The parameters $A_{i(j)t}$ cannot be estimated without restrictions. Then, we decompose them into a firm specific effect, a sector-specific effect, and a third term representing a sectoral time-varying component of prices. Following Dhyne *et al.* (2007), we approximate this last unobserved component by the sectoral Production Price Indices at the NACE2 level (PPI_{jt}).[8]

The occurrence of a price change depends on the difference $p^*_{it} - p_{it-1}$. Unfortunately, not only, as shown above, the optimal price p^*_{it} is not directly observable but the price level itself, p_{it-1} is not observable in our data since only changes are recorded. In order to solve this problem, we assume that firms fully adjust to the optimal price level when they adjust their prices, as usual in state-dependent pricing models. Furthermore, by definition of a price spell, the price does not vary along such a price spell. A price change thus corresponds to a deviation of the optimal price with respect to the price prevailing at the start of the spell. Consider a spell that started at time t_0 :

$$\Delta p_{it} = p^*_{it} - p_{it-1} = p^*_{it} - p^*_{it_0}. \tag{12}$$

From equations (11) and (12), it follows that :

$$\Delta p_{it} = \delta \Delta_s \ln PPI_{jt} + (\alpha - 1)\Delta_s \ln Q_{it} + \beta \Delta_s \ln w_{it} + \gamma \Delta_s \ln iip_{it} + u_{it}, \tag{13}$$

where $\Delta_s x$ represents the variation of x over the course of the spell. The desired price change is a function of the cumulative changes in the labor cost, price of the intermediate inputs, production level and sectoral inflation.[9] Following Loupias and Sevestre (2010), cumulative changes are decomposed into their current value, their first lag and the remaining variation since the previous price change. This set-up allows for different impacts of the current and past variations of the variables, occurring for example when past variations in the costs are discounted the further the shocks occurred in the past.

This leads to an ordered probit model explaining the occurrence and magnitude of price changes, very similar to the one in Loupias and Sevestre (2010). It can be written as:

$$\Delta p_{it} = j \text{ if } \alpha_{j(k)-1} < \Delta p^*_{it} \leq \alpha_{j(k)}, \forall j = -1, 0, 1, \tag{14}$$

$$\Delta p^*_{it} = X^p_{it}\beta_p + \Delta w_{it}\gamma_p + u^p_{it}, \tag{15}$$

where $\alpha_{-2(k)} = -\infty$, $\alpha_{1(k)} = \infty$, and where the $\alpha'_{j(k)}$s are parameters defining the price inaction band which depends on the unobserved menu cost,

[8]The number of time periods and sectors are both large in our data, as T is greater than 100 and the number of sectors is also quite large. Not using this approximation would lead to a large loss of degrees of freedom.

[9]Our price equation also contains a set of yearly dummies aimed at capturing macroeconomic shocks.

possibly specific to the industry (k) to which the firm belongs.X_{it}^p is the vector of the covariates appearing in equation (13).[10]

As stated in Section 2.3, the available information regarding variations of the product price, of the intermediate input prices as well as those of the firm production level is qualitative: each inquired variable may take on seven different values, starting from a strong decrease up to a strong increase through medium or small decreases, the absence of change and small or medium increases. However, we have redefined these variables so as to consist of three outcomes: decrease, no change and increase. Indeed, wages and the producer price indices which also enter this equation are initially provided as quantitative variables. Then, in order to make all the variables *in the price equation* measured in the same way and facilitate the interpretation of their coefficients, we have considered only 3 outcomes for all these variables: increases, decreases, and the absence of change in the quarterly averages.

3.4 Econometric specification

3.4.1 Wage and price interdependence

We consider two sources of simultaneity in our model. First, we want to allow for a possible interdependence between the magnitude of wage changes and their timing. Second, a dependence between the firm' price and wage "decisions" may exist: first because the determination of each variable may explicitly account for the evolution of the other, and second because of unobserved factors that may affect simultaneously both wage and price changes, such as changes in the firm production technology or in its compensation policy.

We handle the simultaneity problems using both instrumental variables methods and an explicit modeling of the correlations. We introduce the correlations in writing the error terms as follows:

$$u_{it}^d = \lambda_d \epsilon_{it} + \sigma_d e_{it}^d, \tag{16}$$

$$u_{it}^w = \lambda_w \epsilon_{it} + \sigma_w e_{it}^w, \tag{17}$$

$$u_{it}^p = \lambda_p \epsilon_{it} + \sigma_p e_{it}^p, \tag{18}$$

where $\epsilon_{it}, e_{it}^d, e_{it}^w$ and e_{it}^p are independent standard gaussian variates, and λ_d, λ_w and λ_p are factor loadings. The variance matrix of the residuals of the three equations is then given by:

$$\text{var}[(u_{it}^d, u_{it}^w, u_{it}^p)]' = \begin{pmatrix} \lambda_d^2 + \sigma_d^2 & \lambda_d\lambda_w & \lambda_d\lambda_p \\ \lambda_w\lambda_d & \lambda_w^2 + \sigma_w^2 & \lambda_w\lambda_p \\ \lambda_p\lambda_d & \lambda_p\lambda_w & \lambda_p^2 + \sigma_p^2 \end{pmatrix}. \tag{19}$$

The variance matrix is a function of six parameters : $\lambda_d, \lambda_w, \lambda_p, \sigma_d, \sigma_w$ and σ_p, while we can only estimate $\text{var}(u_{it}^w)$ and three correlations between

[10] See Appendix B for a detailed description of the variables measurement.

the residuals.[11] Constraints have to be imposed to ensure identification, and we normalize λ_d, σ_d and σ_p to 1.[12] Identification proceeds as follows: labor cost variations are continuous and we can first estimate $\text{var}(u_{it}^w) = \lambda_w^2 + \sigma_w^2$. The identification of λ_w and λ_p follows.

3.5 Likelihood

We present here the likelihood of the model involving all the factor loadings. When $d_{it} = 1$, a non-zero growth rate of wages is observed leading to the joint density:

$$\begin{aligned} f(d_{it}, \Delta w_{it}, \Delta p_{it}) = & f\left(d_{it} = 0, \Delta w_{it} = 0, \Delta p_{it} \in]\alpha_{j-1}, \alpha_j]\right)^{1-d_{it}} \\ & \times f\left(d_{it} = 1, \Delta w_{it} = \Delta w_{it}^*, \Delta p_{it} \in]\alpha_{j-1}, \alpha_j]\right)^{d_{it}}. \end{aligned} \tag{20}$$

After some computations detailed in Appendix A, the likelihood can be written:

$$\begin{aligned} f(d, \Delta w, \Delta p) = & \prod_{i=1}^{n} \prod_{t=1}^{T} \int_{\Re} \left\{ \left[1 - \Phi\left(X_{it}^d \beta_d + \epsilon \right) \right] \right\}^{1-d_{it}} \\ & \left\{ \frac{1}{\sigma_w} \phi\left(\frac{\Delta w_{it} - X_{it}^w \beta_w - \lambda_w \epsilon}{\sigma_w} \right) \Phi\left(X_{it}^d \beta_d + \epsilon \right) \right\}^{d_{it}} \\ & \prod_{j=1}^{J} \left[\Phi(\alpha_j - X_{it}^p \beta_p - \Delta w_{it} \gamma_p - \lambda_p \epsilon) \right. \\ & \left. - \Phi(\alpha_{j-1} - X_{it}^p \beta_p - \Delta w_{it} \gamma_p - \lambda_p \epsilon) \right]^{\delta_{ijt}} \phi(\epsilon) d\epsilon, \end{aligned} \tag{21}$$

where δ_{ijt} is a dummy variable indicating a price change of magnitude j. The first and second blocks are identical to the likelihood of a type 2 Tobit model, as well as to the likelihood of a simple hurdle model (see for example Wooldridge, 2001 [pp. 536-538]) where the latent variable is normal. The third block of equation (21) is the likelihood of an ordered probit model. From relation (21), σ_w is identified because the wage variations are observed when they occur.

Further endogeneity sources can also be a concern for variables other than prices and wages. Indeed, variables determined at the micro level may share some common shocks, or be subject to measurement errors. We assume the potentially endogenous explanatory variables to be the outcome of

[11] We can estimate $\text{var}(u_{it}^w)$ from the observed Δw_{it}. As regards d_{it}^*, only its sign is known and the variance cannot be recovered, as for a standard probit model. The variable Δp_{it} is qualitative and the variance of its latent counterpart cannot be obtained from the observables, unless the thresholds are known.

[12] Notice that there is no need to normalize σ_p when the thresholds are known in relation (14).

a linear model with a standard gaussian error. One can thus write likelihood (21) as the product of a likelihood conditional on the endogenous variables and their marginal likelihood, leading to a consistent instrumental variable two-step procedure. The estimates displayed in the remaining of the paper are obtained using two-step approaches, and the likelihood (21) needs to be maximized in the second step. It involves only one integral, due to the specification of common factors. This can be approximated using Gauss-Hermite quadrature, and we use 20 evaluation points in the application. Estimation is implemented in GLLAMM (Rabe-Hesketh *et al.*, 2004), which runs in Stata (StataCorp, 2005). Our procedure leads to a GMM type estimator. We approximate the asymptotic variance matrix of the resulting estimates using paired bootstrap with 500 replicated samples.

4 Econometric results

4.1 Wage equations

Several sets of estimates of our equations have been obtained, which rely on different sets of assumptions regarding mainly the endogeneity of the regressors in the model. A first set of estimates relies on the assumption that the duration of wage spells is endogenous, as explained below. This induces that all the other firm-level covariates that may be considered as decision variables for the firm (e.g. the expected and current output price changes) are also endogenous. The estimates of Model 2 are obtained assuming that the duration of wage spells is exogenous, whereas the variables related to the output price are still considered as endogenous. The last two sets of estimates we provide correspond to a model from which insignificant coefficients in the previous regressions are removed. The estimates of Model 3 are obtained without specifying the correlation between the price and wage equations to be generated by factor loading. The last pair of columns contains estimates of a model where the endogeneity of wages (resp. of prices) in the price (resp. wage) equation is captured through factor loadings as described above.

Table 3 provides the estimates of the equation explaining the occurrence of wage changes, while the corresponding marginal effects are reported in Appendix C. First of all, based on the first two sets of estimates, a simple likelihood ratio test of the assumption of exogeneity of the wage spell duration cannot be rejected ($\text{LR}(7) = 6.2 < 14.07$).

A related conclusion that emerges from these estimates is that the occurrence of wage changes is strongly time-dependent. The timing of wage changes seems to obey a "pre-determined" calendar rather than being a consequence of the firm's decision to proceed to wage changes given the evolution of its environment. In accordance with the stylized facts reported e.g. in Druant *et al.* (2009), changes tend to cluster in the first quarter of the year. We also control for the time elapsed since the last wage change. The prob-

ability of a labor cost variation first decreases as time goes by,[13] but the hazard exhibits a clear spike at one year: there exist a strong tendency of wages to vary yearly, even though we observe infra-yearly variations. An explanation might be that single wage agreements can be implemented in two successive wage increases (cf Heckel *et al.*, 2008).

The impact of state-dependent factors such as the acceleration of inflation, the occurrence of a large productivity shock or a change in the firm output price are either insignificant or of a quite limited magnitude. One must keep in mind however that, for a very large majority of firms, price and productivity variations are of a quite small magnitude. It is thus not really surprising that these changes do not induce changes in the timing of wage changes. However, our estimation results point to a modest increase in the likelihood of a wage change when the CPI inflation accelerates. It is also worth mentioning that the full instrumental variables estimates are quite close to those obtained with the factor model. This may be seen as an indication of the robustness of these estimates. Finally, as expected, smaller firms are less likely than large ones to be subject to a change of their average wage cost due to a change in their workforce.

[13] As emphasized in Fougère *et al.* (2007), such a decreasing hazard should not be misinterpreted. It is likely to result from the pooling of heterogeneous constant hazards.

Table 3: Estimated coefficients of the decision equation

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat
Time dependent factors								
Elapsed duration:								
1 quarter	0.33	0.27	0.43	5.96	0.42	6.45	0.42	7.21
2 quarters	0.33	0.32	0.40	5.70	0.40	6.07	0.40	6.68
3 quarters	0.14	0.19	0.20	2.65	0.20	2.91	0.20	3.16
4 quarters	0.82	1.55	0.86	10.57	0.86	10.81	0.86	11.94
Seasonal dummies :								
1st quarter	0.59	8.64	0.60	16.66	0.60	17.33	0.60	20.09
2nd quarter	0.29	3.13	0.29	9.97	0.29	9.77	0.29	9.51
3rd quarter	0.29	3.10	0.29	7.45	0.29	7.72	0.29	8.07
State dependent factors								
Expected change in producer price	0.01	0.34	0.01	0.57	-	-	-	-
Change in producer price	0.03	0.79	0.03	1.12	-	-	-	-
Change in producer price (-1)	0.02	0.23	0.02	0.56	-	-	-	-
Change in CPI inflation	0.05	0.93	0.05	2.97	0.05	2.67	0.05	2.68
Persistent shock on productivity	0.04	0.39	0.04	1.18	-	-	-	-
Control variables								
Firm size: < 149	-0.21	-0.69	-0.20	-4.06	-0.20	-4.06	-0.20	-6.25
Firm size: 150-499	-0.08	-0.30	-0.07	-1.55	-0.08	-1.68	-0.08	-2.57
Constant	-0.47	-0.44	-0.56	-6.37	-0.53	-6.84	-0.53	-7.64
Other								
Log-likelihood	-38 393.6		-38 396.7		-38 402.5		-38 428.0	
Treatment of the endogeneity of :								
- Δw_{it}	FL		FL		FL		FL	
- Δp_{it}	IV		IV		IV		FL	
- remaining variables	IV		IV		IV		IV	
Wage spell duration	Endog.		Exog.		Exog.		Exog.	
Micro variables	Cont.		Cont.		Cont.		Cont.	
Instrumental variables	Cont.		Cont.		Cont.		Cont.	
Bootstrap	Yes		Yes		Yes		No	
Industry indicators	Yes		Yes		Yes		Yes	
Year indicators	Yes		Yes		Yes		Yes	
Number of observations	15 635		15 635		15 635		15 635	

Notes:
- the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of the inflation, unemployment and PPI growth rate, lagged values over the three preceding quarters of the productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.
- "continuous" stands for the quarterly average of monthly variations.
- Treatment of the endogeneity : "IV" stands for instrumental variables; "FL" for factor loadings.

4.1.1 Magnitude of wage growth

Table 4 provides the estimates of equation (8), the mean wage growth rate variations whenever it differs from 0, while the marginal effects are reported

in Appendix C. As could be expected, we get a positive impact of the CPI inflation on the nominal wage growth rate. One must be careful in interpreting the coefficients we obtain. The last coefficient relates to the impact of the CPI growth rate from the start of the wage spell through $t-2$. However, given that the average duration of wage spells is less than 2 quarters (it equals 1.92 quarters), the degree of indexation, for the average wage spell, is equal to $0.15 + 0.56 + 0.27 = 0.98$. Our estimates also point to the expected negative impact of unemployment and its' lagged value on wage growth. A possible interpretation is that both the level of unemployment and its change over the current period tend to exert a negative pressure on wage increases.

Table 4: Estimated coefficients of the mean wage growth equation

	Model 1		**Model 2**		**Model 3**		**Model 4**	
	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat
Macro variables								
Expected CPI inflation	0.27	2.41	0.25	3.37	0.27	3.71	0.26	3.56
CPI inflation	0.17	1.84	0.17	2.38	0.15	2.33	0.16	2.85
CPI inflation (-1)	0.77	2.87	0.56	10.35	0.56	10.24	0.56	10.93
Remaining CPI inflation	0.68	0.87	0.49	10.35	0.50	10.26	0.50	12.81
Unemployment	-1.04	-4.67	-1.11	-5.67	-1.13	-5.95	-1.19	-6.13
Unemployment (-1)	0.52	1.58	0.58	2.09	0.58	3.69	0.62	3.68
Unemployment (-2)	0.02	0.07	-0.03	-0.18	-	-	-	-
Micro variables								
Expected producer price change	-0.22	-0.31	-0.69	-1.35	-	-	-	-
Producer price change	1.03	1.18	0.98	2.03	0.42	2.30	0.10	2.62
Producer price change (-1)	-0.83	-0.86	0.02	0.46	-	-	-	-
Remaining producer price changes	0.66	0.80	-0.02	-0.30	-	-	-	-
Productivity change	0.22	1.84	0.21	2.07	0.25	2.61	0.23	2.47
Productivity changes (-1)	0.12	2.17	0.11	2.25	0.10	1.97	0.11	2.43
Remaining productivity changes	-0.07	-0.63	0.01	0.33	-	-	-	-
Control variables								
Firm size: < 149	0.11	1.15	0.17	3.16	0.13	2.66	0.15	2.95
Firm size: 150-499	0.06	1.13	0.09	2.02	0.07	1.76	0.07	1.67
Constant	5.50	2.97	6.22	4.63	6.16	4.77	6.32	5.38
Other								
Std. dev. of u_{it}^w	1.47		1.47		1.47		1.36	
Log-likelihood	-38 393.6		-38 396.7		-38 402.5		-38 428.0	
Treatment of the endogeneity of :								
- d_{it}	FL		FL		FL		FL	
- Δp_{it}	IV		IV		IV		FL	
- remaining variables	IV		IV		IV		IV	
Wage spell duration	Endog.		Exog.		Exog.		Exog.	
Micro variables	Cont.		Cont.		Cont.		Cont.	
Instrumental variables	Cont.		Cont.		Cont.		Cont.	
Bootstrap	Yes		Yes		Yes		No	
Industry indicators	Yes		Yes		Yes		Yes	
Year indicators	Yes		Yes		Yes		Yes	
Number of observations	15 635		15 635		15 635		15 635	

Note: the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of the inflation, unemployment and PPI growth rate, lagged values over the three preceding quarters of the productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.

An interesting aspect of our results is that firms are more likely to increase wages when they increase their own output price in the same quarter. In accordance with the theoretical framework we use, this can be seen as the evidence of some rent sharing between the firm and the workers. Moreover, changes in the firm's productivity also have a significant impact on the magnitude of the firm's wage evolution. Given the qualitative nature of the variables available to compute our measure of the evolution of the productivity (see Appendix B), it is unfortunately not possible to compare the estimates we obtain here with previous estimates of the impact of produc-

tivity on wages (e.g. see Biscourp *et al.*, 2005, Guiso *et al.*, 2005, and, more recently, Katay, 2008, and Cardoso and Portela, 2009). It remains however that this impact is significantly positive. Finally, the average wage increases seem to be larger in smaller firms than what they are in large ones. A possible explanation of this result lies in the composition of the workforce in these two categories of firms: smaller firms tend to employ, on average, more unskilled workers, i.e. more workers who are paid at the minimum wage. Then, this result may be explained by the quite significant increases of the minimum wage over the period we consider.[14]

In order to further assess the relevance of our estimates, we have computed the expected instantaneous wage growth, conditional on the occurrence of a change in wages. The average expected growth rate is of 1.09%, as predicted by Model 3. The mean of d_{it} is of 0.54, leading to increases of the mean nominal wage of 2.36% per year. These results are in line with the raw statistics reported by the Ministry of Labour and Social Affairs (DARES, 2009), that indicate a growth of 2.34% of the mean nominal individual wage per year for the manufacturing industry over the time period of our study.

4.2 Price equation

Table 5 provides the estimated coefficients of the price equation.[15] The first set of estimates is obtained using a standard Probit specification where no account is made for the endogeneity of regressors, in particular of wages. Estimates referred to as Model 3 and Model 4 do take this issue into account.

[14]The minimum wage was increased by about 5.5% in 2003, 2004 and 2005. These increases are significantly larger than those of the other wages.

[15]The estimated marginal effects are provided in Appendix C.

Table 5: Estimated coefficients of the price equation, micro variables in increases or decreases except wage changes

Model	**Ord. Probit**		**Model 3**		**Model 4**	
	Coef.	Z-stat	Coef.	Z-stat	Coef.	Z-stat
Explanatory variables						
Wage change	0.02	2.94	0.20	2.36	0.02	2.21
Wage change (-1)	0.00	0.13	0.04	1.35	-0.01	-1.08
Remaining cumul. wage change	0.00	0.83	0.05	1.31	-0.00	-0.26
Interm. input price change	0.45	28.09	0.57	2.82	0.73	4.68
Interm. input price change (-1)	0.02	0.77	0.32	2.61	0.22	2.39
Rem. cum. interm. input price change	0.00	0.06	0.51	6.05	0.47	8.54
PPI change	0.11	10.57	0.10	8.55	0.10	8.89
PPI change (-1)	0.03	1.97	0.17	4.44	0.16	5.70
Remaining cumul. PPI change	-0.00	-0.36	0.29	5.49	0.29	8.17
Production change	0.09	8.48	0.18	3.12	0.26	6.57
Production change (-1)	0.02	1.39	0.13	4.56	0.13	5.99
Remaining cumul. prod. change	0.01	1.19	0.13	3.15	0.14	5.61
Cut points						
α_1	-1.16	-31.02	-0.73	-6.19	-0.91	-20.46
α_2	0.84	22.81	1.30	10.94	1.13	25.24
Other						
Log-likelihood	-13 088.6		-38 402.5		-38 408.5	
Treatment of the endogeneity of :						
- Δw_{it}	No		IV		FL	
- d_{it}	No		IV		FL	
- remaining variables	No		IV		IV	
Micro variables	Incr. - decr.		Incr. - decr.		Incr. - decr.	
Instrumental variables	No		Cont.		Cont.	
Bootstrap	No		Yes		No	
Industry indicators	Yes		Yes		Yes	
Year indicators	Yes		Yes		Yes	
Number of observations	15 635		15 635		15 635	

Note: the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of CPI inflation, unemployment, PPI growth rate, productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.

The results we obtain are very similar to those presented in Loupias and Sevestre (2010). The main driver of price variations is the cost of intermediate inputs, contemporaneous and lagged. These effects dominate those of the other variables. This results is not really a surprise given that the intermediate input represent the largest component in the production cost at the firm level. The share of intermediate input costs in total production of French manufacturing firms was about 70% in 2005 (SESSI, 2008). Moreover, the magnitude of these shocks, as measured by price changes of intermediate products, is generally larger than that of wage changes. According to estimates of Model 3, the influence of wage variations comes second in mag-

nitude. This limited impact of wage changes on price changes is essentially a consequence of their limited share in total production costs (about 20% in 2005, SESSI, 2008). It may also be explained by the possibility for firms to find other ways to adjust to wage increases than raising their prices. Indeed, firms may use other margins of adjustment such as productivity increases. It is worthwhile mentioning that these wage changes are clearly endogenous to price variations. Indeed, comparing the estimates of a simple ordered Probit model with those obtained using instrumental variables (Model 3), we see that accounting for the endogeneity of wages significantly increases the estimated response of prices to wage changes, as expected from the theoretical model. However, as shown by the estimates of Model 4, using a common factor approach for controlling the endogeneity of wages does not seem to work properly. The factor loading specification may here be too restrictive.

Variations of the sectoral price index, both current and lagged, also appear to impact prices in a significant way, though to a lower extent. These variations can be seen to account for common shocks within the industry, so that, subsequently, firm specific regressors account for the only idiosyncratic shocks (on intermediate input prices, wages or demand). These results may be considered to indicate that idiosyncratic shocks on intermediate input costs in particular have a stronger influence on prices than common shocks (see Mackowiak and Wiederholt, 2009, who explain why this may be the case).

Finally, variations in the level of the firm production also have a significant impact on their price decisions. This result differs from the findings in Altissimo *et al.*, (2006) and Loupias and Sevestre (2010) who find that the impact of production changes on prices is smaller than that of changes in their costs. A possible explanation might be that the averaging of the monthly variations we initially observe reduces the transitory component of these changes. The variable in our study then essentially accounts for persistent variations in the production level. Such "persistent" variations are indeed more likely to induce price changes than transitory ones.

The robustness of these results have been assessed by considering alternative specifications of our model. First, we have considered alternative definitions of the dependent variable, regressors and instruments. The results we obtain lead to very similar conclusions than the estimates presented and discussed above (see Appendix D.1): the timing of wage changes appears to be essentially determined on a calendar basis and the evolution of the firm environment does not seem to impact strongly the occurrence of wage changes. The magnitude of wage changes as well as the occurrence and magnitude of price changes are much more state-dependent. The magnitude of wage changes depends on CPI inflation, both observed over the past and expected for the period to come. The situation on the labor market as measured by the unemployment ratio and its variation also affect wages significantly. Finally, these estimates also confirm the possible existence of

some rent-sharing mechanisms between firms and their workers as both the evolution of the firms output price and of their productivity appear to have an impact of the magnitude of wage changes. As regards price changes, the importance of intermediate input price variations is confirmed together with the smaller impact of wage and output changes on the firms price change decisions.

We have also explored more thoroughly the possible impact of productivity shocks on the occurrence of wage changes by using alternative definitions of these shocks such as the occurrence of two consecutive significantly negative variations in the firm productivity, the magnitude of such negative variations, the absolute value of the recent evolution of the firm productivity, etc. However, none of them led to significant results so that the results are not reported here. We also included in the model additional regressors to check whether accounting for specific features might be relevant and/or alter our main conclusions. The results, provided in Appendix D.2 show that firms having experienced during two consecutive quarters a decrease in their employment level tend to freeze their wages. Moreover, as expected, firms with a significant fraction of workers paid at the minimum wage are more likely to proceed to wage increases during the third quarter. As a consequence, the average wage increases are larger during the third quarter when firms employ a significant fraction of low wage workers. This is clearly a consequence of the quite significant increases in the minimum wage that occurred in 2003, 2004 and 2005. Indeed, the minimum wage (SMIC) was increased by about 5.5% in July of these three years; these increases being significantly larger than those of wages higher than the minimum wage.

5 Conclusion

Our paper empirically investigates the linkage between wage and producer price changes at the firm level. We explicitly allow for correlations between the occurrence of changes in the mean wage, their magnitude and price changes. In order to tackle the endogeneity of both the price and wage changes in two equations of our model, we consider two alternative treatments: we use instrumental variables in a two-step procedure, and we also specify a model with a factor loading that allows to model explicitly the correlation between prices and wages.

Our results point toward time dependence in the scheduling of wage adjustments and towards state dependence in their magnitude as well as in price changes. The wage variations can be essentially described as driven by a Phillips' curve. Firms' prices are sensitive to an increase in wages, but this effect is less important than that of the cost of intermediate inputs, which dominates in the manufacturing industry. Prices clearly depend on wages, which appear to be endogenous in the price equation. Though the timing of

wage changes does not appear to depend on that of the firm's price changes, their magnitude seems to be affected by that of price changes. However, this effect is limited and much less important than that of CPI inflation.

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A Derivation of the likelihood

We distinguish whether Δw_{it} is zero or not. When $d_{it} = 0$, Δw_{it} is necessarily null and the observed wages do not convey further information. The couple $(\Delta p_{it}, d_{it})$ thus contributes to the likelihood:

$$\begin{aligned} f(\Delta p_{it}, d_{it}) &= \int_{\Re} \Pr(\Delta p_{it} \in]\alpha_{j-1}, \alpha_j]|\epsilon) \Pr(d_{it} = 0|\epsilon)\phi(\epsilon)d\epsilon \\ &= \int_{\Re} \prod_{j=1}^{J} [\Phi(\alpha_j - X_{it}^p\beta_p - \Delta w_{it}\gamma_p - \lambda_p\epsilon) \\ &\quad - \Phi(\alpha_{j-1} - X_{it}^p\beta_p - \Delta w_{it}\gamma_p - \lambda_p\epsilon)]^{\delta_{ijt}} \Phi(-X_{it}^d\beta_d - \epsilon)\phi(\epsilon)d\epsilon, \end{aligned} \tag{22}$$

where $\Delta w_{it}\gamma_p = 0$. When $d_{it} = 1$, the wage bill evolution is observed and the triplet $(\Delta p_{it}, \Delta w_{it}, d_{it})$ contributes to the likelihood:

$$\begin{aligned} f(\Delta p_{it}, \Delta w_{it}, d_{it}) = \int_{\Re} \Pr\left(\Delta p_{it} \in]\alpha_{j-1}, \alpha_j]|\Delta w_{it}, d_{it} = 1, \epsilon\right) \\ g(\Delta w_{it}, d_{it} = 1|\epsilon)\phi(\epsilon)d\epsilon. \end{aligned} \tag{23}$$

When the labor cost growth rate is non-zero, d_{it} is equal to 1 and we can rewrite the first component of equation (23):

$$\Pr\left(\Delta p_{it} \in]\alpha_{j-1}, \alpha_j]|\Delta w_{it}, d_{it} = 1, \epsilon\right) = \Pr\left(\Delta p_{it} \in]\alpha_{j-1}, \alpha_j]|\Delta w_{it}, \epsilon\right). \tag{24}$$

The density function corresponding to the second component of equation (23) is:

$$\begin{aligned} g(\Delta w_{it} = \Delta w_{it}^*, d_{it} = 1|\epsilon_{it}) &= \int_{d_{it}^* \geq 0} g(\Delta w_{it}, u|\epsilon_{it})du \\ &= h(\Delta w_{it}|\epsilon) \int_{d_{it}^* \geq 0} l(u|\Delta w_{it}, \epsilon_{it})du \\ &= h(\Delta w_{it}|\epsilon) \int_{d_{it}^* \geq 0} l(u|\epsilon_{it})du. \end{aligned} \tag{25}$$

The last line comes from the independence of d_{it}^* and Δw_{it} conditional on ϵ_{it}. We can thus rewrite relation (23):

$$\begin{aligned} f(\Delta p_{it}, \Delta w_{it}, d_{it}) = \int_{\Re} \prod_{j=1}^{J} [\Phi(\alpha_j - X_{it}^p\beta_p - \Delta w_{it}\gamma_p - \lambda_p\epsilon) \\ - \Phi(\alpha_{j-1} - X_{it}^p\beta_p - \Delta w_{it}\gamma_p - \lambda_p\epsilon)]^{\delta_{ijt}} \\ \left[\frac{1}{\sigma_w}\phi\left(\frac{\Delta w_{it} - X_{it}^w\beta_w - \lambda_w\epsilon}{\sigma_w}\right)\Phi\left(X_{it}^d\beta_d + \epsilon_{it}\right)\right]\phi(\epsilon)d\epsilon. \end{aligned} \tag{26}$$

B Variables definition and measurement.

Except for wages, all firm-level variables in our models (i.e. changes in the firm's output price, in the intermediate input prices, in the production level, in the productivity, in employment) come from the Banque de France business survey. The data collected in this survey are qualitative and may take 7 values ranging from -3 (strong decrease) to +3 (strong increase). To make their periodicity consistent with that of the data about wages, we have computed their quarterly averages. Possible values are still in the range -3 to +3 but they are then no more limited to integer values. Moreover, for robustness checks, we use an alternative definition of these variables where we just distinguish between increases and decreases (i.e. these variables take the value -1 if the quarterly average is negative and take the value 1 if the quarterly average is positive).

Wage changes are computed as the average of wage changes for each of the job positions surveyed in the ACEMO survey. Depending on the size of the establishment, 1 to 12 positions are considered, with a very strong majority being asked about at least 3 positions. Whenever more than one job position is inquired, the weights used are given by the relative proportion of each category inquired in the total employment of the firm.

B.1 Explanatory variables of the occurrence of wage changes

Time dependent factors

- duration dummies : indicators of the duration elapsed since the last wage change; the reference is given by durations of more than 4 quarters. The profile provides a non parametric estimate of the conditional hazard function.
- seasonal dummies: equals 1 if the observation corresponds to quarter $j, 0$ otherwise; the reference is the 4th quarter.

State dependent factors

- Expected change in producer price: quarterly average of the expected change in the firm's output price for the period to come as declared at time t by the firm itself;
- Change in producer price in t (resp. in $t-1$): quarterly average of the changes in the firm's product price during quarter t (resp. quarter $t-1$);
- Change in inflation: difference between the CPI inflation averaged over quarters $t-1$ and $t-2$ and averaged over quarters $t-3$ and $t-4$, so as to capture variations within a year.

- Persistent shock on productivity: indicator taking the value 1 if the firm experienced a decrease of its productivity below the first quartile of productivity changes in the sample at quarters $t-1$ and $t-2$.

Control variables

- Firm size:< 149: dummy variable for firms with at most 149 employees (ref. = firms with at least 500 employees);
- Firm size: 150-499: dummy variable for firms with 150 to 499 employees (ref. = firms with at least 500 employees)

B.2 Explanatory variables of the magnitude of wage changes

Macro variables

- expected CPI inflation: expectations on the CPI inflation are not available and we assume rational expectations, that is we replace the expected inflation over the next 4 quarters by its' observed value. This value is subject to measurement errors with respect to the individual expectations, and the endogeneity induced is tackled with the instrumental variables.
- CPI inflation in t (resp. in $t-1$): CPI inflation over quarter t (resp. $t-1$), computed as the change in the monthly CPI between the last month of the quarter (resp. of the previous quarter) and that observed 3 months before.
- Remaining CPI inflation: sum of the quarterly CPI inflation from the start of the wage spell through $t-2$; 0 if the spell lasts less than 3 quarters.
- Unemployment ratio in t (resp. in $t-1$ and $t-2$): quarterly average of the aggregate unemployment ratio at quarter t (resp. in $t-1$ and $t-2$).

Micro variables

- Expected change in producer price: quarterly average of the expected change in the firm's output price for the period to come as declared at time t by the firm itself;
- Change in producer price in t (resp. in $t-1$): quarterly average of the changes in the firm's product price during quarter t (resp. quarter $t-1$);

- Remaining producer price changes: sum of the quarterly averages of the changes in the firm's product price from the start of the wage spell through $t-2$;
- Productivity changes in t (resp. in $t-1$): difference between the quarterly average of the firm's production variation between $t-1$ and t (resp. $t-1$ and $t-2$) and that of its employment over the same period;

Control variables

- Firm size:< 149: dummy variable for firms with at most 149 employees (ref. = firms with at least 500 employees);
- Firm size: 150-499: dummy variable for firms with 150 to 499 employees (ref. = firms with at least 500 employees)

B.3 Explanatory variables of price changes

- Wage change in t (resp. in $t-1$): average wage change in the firm during quarter t (resp. quarter $t-1$).
- .Remaining cumul. wage change: sum of the quarterly averages of the changes in the firm's wage from the start of the price spell through $t-2$.
- Interm. input price change in t (resp. in $t-1$): average change in the firm's intermediate inputs prices during quarter t (resp. quarter $t-1$)
- Remaining cumul. interm. input price change: sum of the average changes in the firm's intermediate inputs prices from the start of the price spell through $t-2$.
- PPI change in t (resp. in $t-1$): PPI inflation at the NACE-2digit level over quarter t (resp. $t-1$), computed as the change in the monthly PPI between the last month of the quarter (resp. of the previous quarter) and that observed 3 months before.
- Remaining PPI inflation: sum of the quarterly PPI inflation from the start of the wage spell through $t-2$; 0 if the spell lasts less than 3 quarters.
- Production change in t (resp. in $t-1$): average production change in the firm during quarter t (resp. quarter $t-1$).
- Remaining cumul. prod change: sum of the quarterly averages of the changes in the firm's production from the start of the price spell through $t-2$..

C Estimated marginal effects

Table C1: Marginal effects of the wage equations

Variable	d_{it}		$\Delta w_{it} \mid d_{it} = 1$	
	Ma. Eff.	Z-stat	Ma. Eff.	Z-stat
Macro variables				
Expected CPI inflation			0.27	3.60
CPI inflation			0.15	2.76
CPI inflation (-1)			0.56	11.01
Remaining CPI inflation			0.50	12.78
Unemployment			-1.13	-5.86
Unemployment (-1)			0.58	3.46
Micro variables				
Producer price change			0.42	2.28
Productivity change			0.24	2.94
Productivity change (-1)			0.10	2.22
Time dependent factors				
Elapsed duration:				
1 quarter	0.42	7.22	0.10	4.30
2 quarters	0.40	6.68	0.09	4.23
3 quarters	0.20	3.16	0.05	2.76
4 quarters	0.86	11.94	0.17	4.93
Seasonal dummies :				
1st quarter	0.60	20.07	0.13	5.12
2nd quarter	0.29	9.50	0.07	4.61
3rd quarter	0.29	8.04	0.07	4.43
State dependent factors				
Change in CPI inflation	0.05	2.68	0.01	2.42
Control variables				
Firm size: < 149	-0.20	-6.22	0.08	1.66
Firm size: 150-499	-0.08	-2.57	0.05	1.16

Table C2: Marginal effects of the price equation, in percent

	$\Delta p < 0$		$\Delta p = 0$		$\Delta p > 0$	
	Ma. Eff.	Z-stat	Ma. Eff.	Z-stat	Ma. Eff.	Z-stat
Wage change	-4,34	-2.98	-0,81	-2.83	5,15	2.99
Wage change (-1)	-0,87	-1.67	-0,16	-1.64	1,03	1.67
Remaining cumul. wage change	-0,98	-1.81	-0,18	-1.78	1,16	1.81
Interm. input price change	-12,51	-3.51	-2,33	-3.27	14,85	3.51
Interm. input price change (-1)	-6,89	-3.26	-1,29	-3.06	8,18	3.26
Rem. cum. interm. input price change	-11,20	-8.95	-2,09	-6.34	13,29	8.96
PPI change	-2,09	-8.67	-0,39	-6.24	2,48	8.68
PPI change (-1)	-3,67	-5.95	-0,68	-4.95	4,35	5.95
Remaining cumul. PPI change	-6,34	-8.19	-1,18	-6.04	7,52	8.19
Production change	-3,93	-3.67	-0,73	-3.40	4,66	3.67
Production change (-1)	-2,90	-5.92	-0,54	-4.94	3,44	5.92
Remaining cumul. prod. change	-2,72	-5.13	-0,51	-4.45	3,23	5.13

D Robustness checks

D.1 Alternatives definitions of micro variables

Table D1 : Estimated coefficients of the decision equation, micro variables in increases or decreases

	Model 5		Model 6	
	Coef.	**Z-stat**	**Coef.**	**Z-stat**
Time dependent factors				
Elapsed duration:				
1 quarter	0.42	6.04	0.42	6.08
2 quarters	0.40	5.73	0.40	5.77
3 quarters	0.20	2.68	0.20	2.69
4 quarters	0.86	10.64	0.86	10.65
Seasonal dummies :				
1st quarter	0.60	17.16	0.60	17.11
2nd quarter	0.29	9.92	0.29	9.85
3rd quarter	0.29	7.49	0.29	7.44
State dependent factors				
Expected change in producer price	-	-	-	-
Change in producer price	-	-	-	-
Change in producer price (-1)	-	-	-	-
Change of inflation	0.05	2.97	0.05	2.96
Persistent shock on productivity	-	-	-	-
Control variables				
Firm size: < 149	-0.20	-4.05	-0.20	-4.10
Firm size: 150-499	-0.08	-1.58	-0.08	-1.59
Constant	-0.53	-6.28	-0.53	-6.30
Other				
Log-likelihood	-25 526.6		-25 523.7	
Specified wage-price correlation	No		No	
Micro variables	Incr. - decr.		Incr. - decr.	
Instrumental variables	Continuous		Incr. - decr.	
Wage spell duration	Exogenous		Exogenous	
Bootstrap	Yes		Yes	
Industry indicators	Yes		Yes	
Year indicators	Yes		Yes	
Number of observations	15 635		15 685	

Note: the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of the inflation, unemployment and PPI growth rate, lagged values over the three preceding quarters of the productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.

Table D2 : Estimated coefficients of the mean wage growth equation, micro variables in increases or decreases

	Model 5		Model 6	
	Coef.	**Z-stat**	**Coef.**	**Z-stat**
Macro variables				
Expected CPI inflation	0.27	3.62	0.26	3.55
CPI inflation	0.15	2.37	0.14	2.08
CPI inflation (-1)	0.56	10.28	0.55	10.23
Remaining CPI inflation	0.50	10.67	0.50	10.70
Unemployment	-1.12	-5.65	-1.08	-5.60
Unemployment (-1)	0.59	3.54	0.55	3.34
Unemployment (-2)	-	-	-	-
Micro variables				
Expected producer price change	-	-	-	-
Producer price change	0.38	2.45	0.33	2.42
Producer price change (-1)	-	-	-	-
Remaining producer price changes	-	-	-	-
Productivity change	0.19	1.92	0.28	3.10
Productivity changes (-1)	0.07	1.63	0.11	2.11
Remaining productivity changes	-	-	-	-
Control variables				
Firm size: < 149	0.13	2.75	0.13	2.74
Firm size: 150-499	0.07	1.74	0.06	1.64
Constant	5.90	4.48	5.97	4.55
Other				
Std. dev. of u_{it}^w	1.47		1.47	
Log-likelihood	-25 526.6		-25 523.7	
Specified wage-price correlation	No		No	
Micro variables	Incr. - decr.		Incr. - decr.	
Instrumental variables	Continuous		Incr. - decr.	
Wage spell duration	Exogenous		Exogenous	
Bootstrap	Yes		Yes	
Industry indicators	Yes		Yes	
Year indicators	Yes		Yes	
Number of observations	15 635		15 685	

Note: the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of the inflation, unemployment and PPI growth rate, lagged values over the three preceding quarters of the productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.

Table D3 : Estimated coefficients of the price equation, continuous micro variables

Model	**Model 5**		**Model 6**	
	Coef.	**Z-stat**	**Coef.**	**Z-stat**
Explanatory variables				
Wage change	0.02	2.34	0.15	2.07
Wage change (-1)	0.01	1.06	0.04	1.76
Remaining cumul. wage change	0.01	1.38	0.05	1.70
Interm. input price change	0.56	30.45	0.79	3.91
Interm. input price change (-1)	0.01	0.47	0.22	1.79
Remaining cumul. interm. input price change	-0.02	-1.03	0.45	5.26
PPI change	0.16	16.48	0.12	8.80
PPI change (-1)	-0.02	-1.24	0.08	2.18
Remaining cumul. PPI change	-0.01	-1.35	0.08	1.35
Production change	0.09	8.81	0.08	1.55
Production change (-1)	0.03	1.94	0.10	3.88
Remaining cumul. prod. change	0.01	0.96	0.11	3.61
Other				
Log-likelihood	-19 850.9		-19 658.1	
Specified wage-price correlation	No		No	
Price variable	Average		Average	
Micro variables	Continuous		Continuous	
Instrumental variables	No		Continuous	
Bootstrap	No		Yes	
Industry indicators	Yes		Yes	
Year indicators	Yes		Yes	
Number of observations	15 635		15 685	

Note: the list of instruments used to tackle the endogeneity problem includes the lagged values over the four preceding quarters of the inflation, unemployment, PPI growth rate, productivity, price of the raw materials and production, along with seasonal indicators, year and industry dummies.

D.2 Accounting for changes in the minimum wage and for persistent shocks on employment

Table D4 : Estimates of the decision equation controlling for shocks on employment and for the presence of low wage workers

	Model 6	
	Coef.	**Z-stat**
Time dependent factors		
Duration:		
1 quarter	0.40	5.76
2 quarters	0.39	5.43
3 quarters	0.19	2.48
4 quarters	0.84	10.00
Seasonal dummies :		
1st quarter	0.71	10.94
2nd quarter	0.32	6.14
3rd quarter	0.07	1.25
Low wage workers specific seasonal dummies :		
1st quarter	-0.36	-6.55
2nd quarter	-0.26	-5.18
3rd quarter	0.09	1.61
4th quarter	-0.20	-3.57
State dependent factors		
Expected change in producer price	-	-
Change in producer price	-	-
Change in producer price (-1)	-	-
Change in inflation	0.05	3.20
Persistent shock on productivity	-	-
Persistent decrease in employment	-0.08	-3.13
Control variables		
Firm size: < 149	-0.18	-3.76
Firm size: 150-499	-0.06	-1.38
Constant	-0.34	-3.64
Other		
Log-likelihood	-25 419.0	
Instrumental variables	Yes	
Wage spell duration	Exogenous	
Bootstrap	Yes	
Industry indicators	Yes	
Year indicators	Yes	
Number of observations	15 685	

Table D5 : Estimates of the mean wage growth equation controlling for shocks on employment and for the presence of low wage workers

	Model 6	
	Coef.	**Z-stat**
Macro variables		
Expected CPI inflation	0.30	3.89
CPI inflation	0.28	3.97
CPI inflation (-1)	0.58	10.43
Remaining CPI inflation	0.48	9.77
Unemployment	-1.23	-6.62
Unemployment (-1)	0.69	4.10
Unemployment (-2)	-	-
Micro variables		
Expected producer price change	-	-
Producer price change	0.36	2.06
Producer price change (-1)	-	-
Remaining producer price changes	-	-
Productivity change	0.19	1.92
Productivity change (-1)	0.10	2.09
Remaining productivity changes	-	-
Control variables		
Firm size: < 149	0.16	3.12
Firm size: 150-499	0.08	2.00
Impact of the proportion of low wage workers at :		
1st quarter	-0.47	-5.24
2nd quarter	-0.16	-1.77
3rd quarter	0.30	3.10
4th quarter	-0.11	-1.01
Constant	6.11	4.59
Other		
Std. dev. of u_{it}^{w}	1.48	
Log-likelihood	-25 419.0	
Instrumental variables	Yes	
Wage spell duration	Exogenous	
Bootstrap	Yes	
Industry indicators	Yes	
Year indicators	Yes	
Number of observations	15 685	

Documents de Travail

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jeannine.agoutin@banque-france.fr
michael.brassart@banque-france.fr
veronique.jan-antuoro@banque-france.fr
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