

Do Minimum Wages Make Wages More Rigid? Evidence from French Micro Data

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Abstract

How do minimum wages (MW) shape the aggregate wage dynamics? In this paper, we document new empirical findings on the effects of MW on wage rigidity using quarterly micro wage data matched with sector- and job-specific bargained MW. First, both national and sectoral MW have a significant effect on the timing and on the size of wage adjustments. In particular, they contribute to the strong seasonality of wage changes. Second, at the aggregate level, MW contribute to amplify, by a factor of 2, the response of wages to past inflation but they also delay the transmission of shocks to wages. The aggregate elasticities of wages with respect to past inflation, the national MW and industry-level MW are respectively 0.44, 0.19 and 0.15. Finally, we document significant spillover effects of the NMW on higher wages transiting through industry-level MW.

JEL codes: E24, E52, J31, J50

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1 Introduction

The degree of wage flexibility shapes how economic shocks might generate macroeconomic fluctuations in employment. In standard New-Keynesian macroeconomic models, infrequent wage adjustment is a key assumption to explain why monetary policy shocks might have real effects (see for instance Erceg et al. [2000] or Smets and Wouters [2003]). Christiano et al. [2005] show that wage stickiness is even more important than price rigidity to explain the dynamic responses of real macro variables after a monetary policy shock. However, the empirical literature has much more focused on measuring price rigidity than wage rigidity and only a rather small number of recent papers have provided micro evidence on wage rigidity (see Taylor [2016] for a survey).

Contrary to the United States, most workers in Europe are covered by collective wage agreements which define industry- and job-specific wage floors. One possible source of wage rigidity might be the existence of these minimum wages. Sectoral minimum wage increases can be considered by workers as benchmark values or norms, which might then shape the way wages respond to shocks. In addition, in many European countries, minimum wages are set at different levels (national, industry, firm) which can interact each other, reinforcing wage rigidity. However, empirical evidence on how minimum wage policies affect the degree of wage rigidity is very scarce. This paper aims at filling this gap and provides new empirical evidence on how minimum wage policies shape the aggregate response of wages to shocks.

One important empirical challenge to measure implications of minimum wages for wage rigidity is to link individual wage data trajectories to sectoral minimum wage micro data. We here use a large data set of micro wages collected by the French Ministry of Labour to compute the official aggregate base wage index. These data are available over the period 2005Q4-2015Q4 at a quarterly frequency which enables us to investigate wage rigidity at an infra annual frequency. We match this data set with quarterly data on sectoral wage floors. For that, we have collected a unique data set on collectively

bargained minimum wages for more than 350 industries covering almost all workers in the private sector. We also match our sample of data with qualitative information on firm-level wage agreements. Using this data set, we first document new stylised facts on wage and minimum wage adjustments. Wages are somewhat rigid since individual wages adjust on average once a year. In addition, wage changes show strong seasonality and most wage changes are observed during the first quarter of the year. We observe very similar patterns for minimum wage adjustments: the national minimum wage (NMW) and sectoral wage floors also adjust infrequently but they are often updated at the beginning of the year and the aggregate minimum wage change correlates strongly with the aggregate base wage change. These observations motivate our quantitative analysis.

Our empirical strategy is the following. We first estimate a microeconomic wage rigidity model where the timing and the size of wage adjustment depends on usual determinants of wage adjustments like inflation or unemployment but also on national or sectoral wage floor adjustments. We then show that the aggregate response of wages to a given shock cannot be easily derived from parameter estimates of this micro wage rigidity model because in this set-up, a shock has long-lasting effects on the wage dynamics. Thus, we simulate wage trajectories using our parameter estimates and then aggregate all simulated wage trajectories to investigate how aggregate wages respond to a shock. In addition, we also take into account for possible reactions of minimum wages to shocks and in a similar way, we estimate determinants of infrequent minimum wage adjustments and we simulate minimum wage trajectories. Overall, this simulation exercise allows us: (i) to assess aggregate persistence in wages due to micro wage rigidity; (ii) to investigate whether minimum wages are an additional channel through which a shock will affect aggregate wages and the duration taken by wages to respond to this shock.

Using a microeconomic wage rigidity model, we provide new results on the main determinants of the timing and the size of wage adjustments. First, the timing of wage adjustments depends strongly on time-dependent factors: the probability of a wage change

increases by 40 pp if the duration since the last wage adjustment is exactly one year. While standard macro models rely on a Calvo wage rigidity model, Taylor-type contracts seem more consistent with patterns of wage adjustment. In addition, past inflation also affects the probability of a wage adjustment. This effect is however smaller when we take into account changes in minimum wages which have also a significant impact on the probability of a wage adjustment. Since NMW and sectoral minimum wages usually adjust in the first quarter of the year, they both reinforce the seasonality of wage adjustment at the beginning of the year. These results are also consistent with the presence of state dependence in wage adjustment. On the size of wage adjustment, inflation, the NMW and sectoral wage floors have all a positive and significant impact on wage changes. Finally, local unemployment has only a small effect on both the probability and the size of wage adjustments.

What are the aggregate consequences of such wage rigidity? First, we find that the long run effect of a 1%-shock in past inflation is a little less than 0.4 pp when we do not account for the presence of minimum wages. When we allow wages to depend on minimum wages, the direct effect of inflation is lowered to 0.2 pp whereas the effect of a 1% shock in wage floors or NMW is about 0.15 pp. Minimum wages do play a significant role in the aggregate wage adjustment. Besides, these long term effects of shocks are amplified when we allow the NMW to respond to changes in inflation and sectoral wage floors to react to changes in inflation and NMW. A 1% shock in inflation now raises wages by 0.44 pp. The NMW and sectoral wage floors adjust because of this change in inflation, then these minimum wage adjustments will affect individual wages. Half of the overall effect of inflation on wages comes from this indirect channel. A similar finding is obtained for the NMW: the long-run impact of a 1% change in NMW is 0.19 pp and one third of this effect comes from a reaction of wage floors to the change in the NMW. Another finding is that firm-level agreements seem to play a rather small role in this amplification mechanism. Finally, we find some heterogeneity along the wage distribution in the long

run effects of shocks. In particular, an increase in NMW affects more the bottom of the wage distribution but it still has an impact at the top of the wage distribution. This spillover effect to higher wages can be here rationalized by the presence of sectoral wage floors that transmit part of the shock to higher wages.

We also provide empirical results on the persistence of aggregate wages with or without taking into account for minimum wages. We find that a shock will take a little more than one year to be fully transmitted to aggregate wages, consistent with the typical wage duration. However, the transmission of shocks takes a little more time when we allow minimum wages to react to shocks. In that case, a shock will first affect minimum wages which in turn will affect individual wages. However, the additional delay in the wage reaction due to minimum wages is rather limited since both wages and minimum wages usually adjust during the same quarter. Since there is only a small degree of staggering in wage and minimum wage changes, the existence of a multi-level minimum wages affects only little the persistence of aggregate wages.

Our paper is a contribution to the empirical literature on wage rigidity. To rationalize infrequent wage adjustment at the micro level, most New Keynesian macro models rely on a simple Calvo assumption whereas Taylor [1980] assumes that wage change are infrequent because of fixed term contracts and adjustment costs models predicts that the timing of wage change may also depend on macro variables. Microeconomic measures of wage stickiness are needed to discipline macro models. Previous literature has provided empirical evidence using two types of micro data. First, some evidence was obtained using wage agreement data for the United States and Canada (Christofides and Wilton [1983], Taylor [1983], Cecchetti [1987], Christofides and Stengos [2003]), and more recently Avouyi-Dovi et al. [2013] or Fougère et al. [2018] for France. On the other hand, some very recent contributions provide evidence on wage rigidity using actual wage data (Barattieri et al. [2014] or Grigsby et al. [2018] for the United States, Le Bihan et al. [2012] for France, Sigurdsson and Sigurdardottir [2016] for Iceland or Lunneman and

Wintr [2015] for Luxemburg). Both strands of literature conclude to a strong degree of time-dependence in wage-setting behaviour. Our contribution is here to link wage rigidity coming from wage bargaining to actual wage rigidity. To our knowledge, there is no evidence on how wage agreements shape the aggregate response of wages to shocks. Gartner et al. [2013] using on German data link wage cyclicality and wage bargaining but they only consider wage bargaining regimes and not minimum wages per se. Knell and Stiglbauer [2012] relate Austrian data on wages and bargained wages but they do not derive aggregate implications for the wage dynamics of the existence of bargained minimum wages.

Another contribution of our paper is to look at the passthrough of NMW increases to wages. Several empirical studies find that NMW affects not only wages close to the NMW but have also spillover effects to higher wages (see for instance Grossman [1983], Card and Krueger [1995], Dickens and Manning [2004], Neumark et al. [2004], and Autor et al. [2016], or Givord et al. [2016] in France). Sectoral minimum wages set by industry-level agreements can help to explain how NMW increases are transmitted to higher wages. For instance, using experimental data, Dittrich et al. [2014] find evidence that wage bargaining is an additional channel through which NMW spillover effects might arise (even when the NMW is low). Our contribution is here to quantify the empirical relevance of collective agreement as a channel for spillover effects of NMW to higher wages.

The rest of the paper is organized as follows. Section 2 presents a model where wages are rigid at the micro level and depend on minimum wages and we derive macro implications for the persistence in wages. In Section 3, we present our micro data sets and the main stylised facts on wage rigidity and minimum wages. Section 4 provides our microeconomic model and estimation results. In Section 5, we present our simulation exercise and empirical results on how aggregate wages respond to shocks. Section 6 concludes.

2 A Model of Infrequent Wage Changes with Minimum Wages

From a theoretical point of view, infrequent and staggered wage adjustments at the micro level lead to more persistent wage dynamics at the aggregate level. In this section, we first set up a quite general model of staggered wage adjustment at the micro level to examine aggregate implications for the wage persistence. Then, we allow the wage adjustment process to depend on minimum wage changes and investigate possible consequences for the adjustment of macro wages to shocks.

2.1 A Simple Model of Wage Rigidity

Most macro models assume that wages do not adjust at every period, this can be rationalized by several theoretical models. Taylor [1980] and Calvo [1983] assume that wages remain constant for a certain period of time (this duration is fixed in Taylor but random in Calvo) whereas state-dependent models assume that wages can not adjust continuously because wage changes entail some negotiation costs, costs of performance appraisal, or administrative costs of payrolls for instance (Kahn [1997] and Fehr and Goette [2005]). In all these models, when wages do not adjust, there is a gap between the wage that would have been observed in absence of any friction (w_{it}^*) and the actual wage (w_{it}) whereas when wages adjust, the new wage w_{it} is equal to w_{it}^* . Overall, we can write:

$$w_{i,t} = R_{i,t}w_{i,t}^* + (1 - R_{i,t})w_{i,t-1} \quad (1)$$

where $R_{i,t}$ is a dummy variable equal to 1 in case of wage update and 0 otherwise. By recurrence, it is quite easy to show that $w_{i,t-1} = w_{i,\tau_{it}}^*$, τ_{it} being the last time the wage of

worker i was adjusted (i.e. i-e $\tau_{it} = \max_s [s < t, R_{is} = 1]$). Hence, we have:

$$w_{it} - w_{it-1} = R_{it} (w_{it}^* - w_{i\tau_{it}}^*) \quad (2)$$

The occurrence of wage change R_{it} is a Bernoulli variable and we can define P_{it} as the probability that $R_{it} = 1$. In wage rigidity models, this probability might depend on different determinants. In a Taylor model, this probability depends on the elapsed duration since the last wage change, it is equal to 1 for an elapsed duration equal to the contract duration and 0 otherwise. In a Calvo set-up, this probability is constant and does not depend on the elapsed duration. In a model with adjustment costs, this probability depends on the gap between the frictionless wage at date t and the actual wage set the last time it was adjusted and so it depends on the evolution of macro variables since the last wage adjustment. Let us define R_{it}^* the propensity to update wages so that: $P_{it} = P(R_{it} = 1) = P(R_{it}^* > 0)$. We can set up a reduced-form model encompassing predictions of time- and state-dependent models by assuming R_{it}^* will depend on the elapsed duration but also on changes in macro variables since the last wage adjustment. In the same way, $(w_{it}^* - w_{i\tau_{it}}^*)$ will be assumed to depend on the evolution of several determinants like inflation, unemployment, minimum wages... since the last wage adjustment. This set-up is very similar to the one proposed in Le Bihan et al. [2012] or Sigurdsson and Sigurdardottir [2016] on wage rigidity.

2.2 Implications for the Aggregate Wage Dynamics

Using this simple wage rigidity model at the micro level, we can now derive implications for the aggregate wage dynamics. Let us denote W_t the aggregate wage at date t , computed as a simple average of all individual wages. The aggregate wage change will depend on wages updated at date t . The aggregate wage change (between date t and $t - 1$) can

be written in expectation as:

$$E(\Delta W_t) = E(w_{it} - w_{it-1}) = E(R_{it}(w_{it}^* - w_{i\tau}^*)) = \sum_{\tau=-\infty}^{t-1} \pi_{\tau,t} p_{\tau,t} E(w_{it}^* - w_{i\tau}^*)$$

where $p_{\tau,t} = P(R_t = 1 | \tau_t = \tau)$ is the probability of a wage update at date t given the date of the last wage update equal to τ and $\pi_{\tau,t} = P(\tau_t = \tau)$ is the distribution of the dates of last wage changes before date t . Hence, from the sequence of wage change probabilities $p_{\tau,t}$ and of potential wage changes $E(w_{it}^* - w_{i\tau}^*)$, we can analytically derive the sequence of aggregated wages $E(\Delta W_t)$, since the distribution of τ at date t can be iteratively deduced from the one at the previous period.¹

How do aggregate wages respond to a macro shock in this set-up? A shock S affecting both the propensity and the size of wage change at date t_0 will take time to be incorporated to aggregate wages since a proportion of wages cannot adjust to the shock. This persistence in the aggregate response of wages comes from three sources: first, the probability of wage adjustment will respond to the shock at date t_0 but for wages that do not adjust at date t_0 , the propensity to adjust wages still incorporates the shock at date $t_0 + 1$ (because this propensity depends on all shocks since the last wage adjustment); the distribution of the dates of last wage changes before date t will also be modified by the fact that the probability of wage adjustment has been affected by the shock; third, the size of wage adjustment will be affected by the shock at date t_0 and after since like the probability of wage change, the size of wage change depends on changes since the last wage adjustment. Using our model, we can decompose the response of aggregate wages for all dates $t = t_0 + k$ after the shock as the difference in aggregate wage change (between date t and $t - 1$) with the shock and the counterfactual aggregate wage without

¹See Appendix for detailed calculations

any shock. This difference can be written as:

$$\begin{aligned}
E(\Delta W_t^S) - E(\Delta W_t) &= \sum_{\tau=-\infty}^{t-1} \pi_{\tau,t}^S p_{\tau,t}^S E(w_{it}^{*S} - w_{i\tau}^{*S}) - \pi_{\tau,t} p_{\tau,t} E(w_{it}^* - w_{i\tau}^*) \\
&= \sum_{\tau=-\infty}^{t-1} \pi_{\tau,t} p_{\tau,t} E((w_{it}^{*S} - w_{i\tau}^{*S}) - (w_{it}^* - w_{i\tau}^*)) \\
&\quad + \sum_{\tau=-\infty}^{t-1} \pi_{\tau,t} (p_{\tau,t}^S - p_{\tau,t}) E(w_{it}^* - w_{i\tau}^*) \\
&\quad + \sum_{\tau=-\infty}^{t-1} (\pi_{\tau,t}^S - \pi_{\tau,t}) p_{\tau,t} E(w_{it}^{*S} - w_{i\tau}^{*S}) \\
&\quad + \sum_{\tau=-\infty}^{t-1} \pi_{\tau,t} (p_{\tau,t}^S - p_{\tau,t}) E((w_{it}^{*S} - w_{i\tau}^{*S}) - (w_{it}^* - w_{i\tau}^*))
\end{aligned}$$

where all variables with a superscript S denote counterfactual variables where we include the impact of the shock. From this, we can easily show that if the shock does not affect the probability of wage change (like in the Calvo or Taylor models), this difference will only depend on the first term: the aggregate response will come from the response of the size of wage adjustment and the persistence will be derived from the distribution of dates since the last adjustment and the probability of a wage adjustment given the duration since the last wage adjustment. This margin of adjustment will be denoted as the intensive margin. In a menu-cost model, there is an additional term (i.e. the sum of the last three terms in our equation): the shock will modify the probability of adjustment and so the distribution of dates since the last wage adjustment. In the second term, a shock affecting positively the probability of wage change will make wage changes more frequent and this will lead to a higher aggregate wage growth. The third term shows the impact of the modification of the distribution of dates since the last wage adjustments. Finally, the last term corresponds to the interaction between higher probability of wage changes and larger size of wage changes, it should contribute only a little to the overall effect.²

²In Appendix, we derive explicitly the effect of a shock at date t_0 when we specify more explicitly processes generating the probability and the size of wage adjustments. However, this derivation is much harder when we look at other dates after the shock.

2.3 How Do Minimum Wages Affect the Aggregate Wage Dynamics?

In France as in many European countries, workers' wages depend on minimum wages set either at the national level or at the industry level. The existence of minimum wages can modify the response of wages to shocks for at least two reasons. First, minimum wage adjustments might be affected by the same shocks as the one affecting individual wages (like unemployment, inflation...). Thus, minimum wages can be an additional channel through which shocks affect individual wages. Second, because of negotiation costs, minimum wage adjustments are infrequent, meaning that a shock affecting minimum wages will take some time to be incorporated to minimum wages and much more time to be incorporated to individual wages. Overall, these infrequent minimum wage adjustments may thus amplify and modify the shape of the aggregate wage response to a common macro shock.

Introducing minimum wages adjusting infrequently complicates a lot the derivation of aggregate response of wages to a shock (even in our simple set-up). Let assume that a shock S affects both individual wages and minimum wages. The shock will affect directly the aggregate wage dynamics according our set-up described above. However, the shock will also have an impact on the timing and size of minimum wage adjustments that would then affect individual wages and so the aggregate wage dynamics. This indirect effect of the shock transmitted through minimum wages may take a little more time to affect the aggregate wage since it should first transit through the minimum wage adjustment (which is infrequent). Overall, the minimum wage adjustment should increase the persistence and the size of the effect of a shock affecting both individual and minimum wages.

However, the overall effect of the shock on the aggregate wage change will be a non-trivial composition of the direct response of individual wages and the indirect responses of individual wages transiting through minimum wages. The aggregate implications of the existence of minimum wages is thus hard to derive analytically. We here present

some simulation results in a simple model described in the Appendix where the shock affects both the probability and size of wage and minimum wage adjustments and where individual wages depend on minimum wages. Figure 1 plots the the impulse response function of aggregate wages in two cases, the first one we do not allow minimum wages to respond to the shock and the second one where we allow minimum wages to respond to the shock. We also choose parameters so that the long term response is the same in both case. This simulation exercise shows that the response of wages to the same shock is more persistent in the case with minimum wage. On the second panel of the figure, we now suppose that the response of individual wages is the same in both cases. As expected, adding a additional indirect channel of transmission of the shock to wages (through minimum wages) leads to a higher effect of the shock on aggregate wages.

In the rest of the paper, we will use micro data on wages and minimum wages to first estimate the main determinants of infrequent wage and minimum wage adjustments. Then using micro estimates from these model, we will aggregate micro simulations of individual wage trajectories to assess the aggregate wage effects of shocks when we allow or not minimum wages to respond to these shocks.

3 Data

In this study, we use three quarterly data sets containing individual wages, sectoral wage floors set in industry-level wage agreements and information on collective wage agreements at the firm level.

3.1 Wages

Our first data set consist of individual wages collected in the ACEMO survey at a quarterly frequency over the period 2005Q1-2015Q4.³ This survey is carried out by the Min-

³Individual data of this survey over the period 1998Q4-2005Q4 have also been used by Le Bihan et al. [2012].

istry of Labour to compute the aggregate growth of base wages for the French economy. Every quarter, data are collected in about 40,000 different firms with at least ten employees (in the private non-farm market sector); firms are sampled to be representative of the French economy. The survey collects individual monthly base wages (including employee social security contributions), excluding bonuses, allowances, performance-related compensations or overtime payments. Base wages represent about 85% of total labour earnings (Sanchez [2014]). In a given firm, wage data are collected for workers who occupy representative job positions within the firm: at first, depending on their size, firms have to define 1 to 12 different representative job positions (3 different occupations in 4 broad job categories: blue-collar workers, white-collar workers, technicians and managers); then, every quarter, firms have to report individual base wages for all these representative occupations. Using this data set, we are able to track individual wage trajectories for representative occupations within firms. By construction, we focus on wage dynamics of job insiders and we cannot track wage adjustments due to job mobility. However, the effects of collective wage agreements on the wage dynamics might be concentrated on insiders' wages.⁴ Overall, the main variables included in our data set are the following: a firm identifier, an occupation identifier, the monthly base wage level (in euros), the individual wage growth between quarter t and $t - 1$ and the identifier of the bargaining industry covering the firm's employees.

Table 1 provides simple statistics on individual wage changes. First, the average wage change (q-o-q) is about 0.5%. Every quarter, 27% of base wages adjust (which implies an average duration between two wage changes of about one year)⁵ and the average non-zero wage change is 1.8%. Figure 2 plots the average wage growth (q-o-q), the frequency of wage changes and the average non-zero size of wage changes over time. The main time variations of the average wage growth come from strong seasonal movements. Quarterly

⁴See the Data Appendix A for a discussion on measurement issues and further details on data treatment.

⁵Le Bihan et al. [2012] provide a much higher frequency of 38% but cover the period of workweek reduction which implied a lot of wage changes.

wage growth is much higher on the first quarter (0.9% on average versus less than 0.5% for the other quarters (Table 1)) These seasonality in wage changes comes mainly from the seasonality of the frequency of wage adjustments: 45% of all wages adjust in the first quarter versus only 20% on average in the other quarters.⁶ Moreover, the distribution of durations between two wage changes shows a large peak at durations exactly equal to one year (see Figure C in Appendix C). The size of non-zero wage changes does not show such a strong seasonality over time and most of the seasonal movements are due to the fact that wage changes in the first quarter are associated with longer wage durations. When looking at the cross section distribution of wage changes (Figure 3), about two thirds of wage changes are between 0 and 2% but there are very few wage decreases.

3.2 Collective Bargaining and Minimum Wage

In France like in many European countries, different levels of wage regulation coexist. At the national level, a binding and uniform National Minimum Wage (NMW, in French SMIC for *Salaire Minimum Interprofessionnel de Croissance*) is set by the Ministry of Labour and its value is updated once a year (in January since 2010) following a legal rule (see below). The NMW is binding for all workers but only 10 to 15% of workers are directly affected by NMW increases. At the industry level, collective agreements define sector- and job-specific minimum wages which should be higher than the NMW. At the firm level, unions and firms can negotiate on collective wage agreements but wages cannot be set below sectoral minimum wages or the NMW. We match our sample of individual wage data with information on sectoral minimum wages and on firm-level wage agreements (see Appendix A for details on the matching procedure).

Our first data source on collective bargaining consists of industry-level minimum wages over the period 2005-2015.⁷ At the industry level, collective wage agreements define wage

⁶The peak in the first quarter is even more pronounced after 2010. Before 2010, the frequency of wage adjustments is high in the third quarter (30% versus 20% before 2010), which corresponds to the usual quarter of NMW change.

⁷This data set is described in full details by Fougère et al. [2018].

floors for several representative occupations within the industry. Every industry defines a specific classification of representative occupations using criteria such as worker skills, job requirements, or experience. All workers within an industry are then assigned to one position of the job classification and their wage cannot be set below the wage floor associated to their job position. A new wage agreement defines updated values of wage floors which must be set above the NMW. By law, industries must open negotiations on wages every year but have no obligation to reach an agreement. In absence of any new agreement, wage floors remain unchanged until the next agreement and there is no explicit contract duration.⁸ Besides, industry-level wage agreements are automatically and quickly extended by decision of the Ministry of Labor to all workers covered by the industry and firms cannot opt out from these wage agreements. We have collected wage floors contained in more than 3,000 wage agreements covering more than 360 bargaining industries (i.e. about 90% of wage observations collected by the ACEMO survey). The main variables are the following: the identifier of the industry, the date at which the agreement comes into force, the scale of wage floors for all representative occupations and a broad category for job occupations (blue-collar workers, employees, technicians, managers). Wage floors can be defined as hourly, monthly, or yearly base wages (in euros), bonuses and other fringe benefits are excluded. The definition of wages collected in the ACEMO survey is thus close to the definition of industry-level wage floors. Using this data set, we are able to track wage floor trajectories for typical job occupations in a given industry and we can calculate the growth of wage floors between two wage agreements.

Our second data source on collective bargaining is an administrative data set containing comprehensive information on firm-level agreements. At the firm level, employers and unions must also open wage negotiation at least once a year⁹ but there is no obligation to

⁸If some wage floors are below the NMW, in particular because of delays in reaching a new agreement in a given industry, the NMW applies.

⁹This obligation is enforced only for firms with a union representative (i.e. firms with at least 50 employees).

reach an agreement. In most firm-level wage agreements, unions and employers bargain on wage increases that can be the same for all workers or different from a job category to another. On average, the share of workers covered by firm-level wage agreements is between 15% and 20% of the total labour force and this proportion has been rather stable for several years (Avouyi-Dovi et al. [2013]). By law, French firms must report to the Ministry of Labour all collective agreements. Information contained in these agreements is standardized by the Ministry of Labour to build a longitudinal firm-level research data set. Available variables include for each agreement: a firm identifier, the date and the main topics of the agreement. Firm-level agreements cover a wide range of topics including wages, bonuses, employment, hours, union rights, labour conditions, on-the-job training... In this study, we restrict the data set to firm-level agreements that deal with wage policy.¹⁰ Wages are the most frequent topic of firm-level agreements (about 70% of all firm-level agreements deal with wages and bonuses, Carluccio et al. [2015]). Information on the size of the negotiated wage increase or on categories of workers covered by the agreement is not available. We here use a dummy variable equal to one if a firm-level wage agreement is signed in a given quarter.

Overall our estimation sample contains about 2 millions of individual wage observations for more than 45,000 different firms. The simple aggregation of all individual wage changes of our sample turns out to be very close to the aggregate growth of base wage published by the Ministry of Labour (see Figure A in Appendix C). Some differences are observed in the beginning of the sample period where the number of observations in our sample is smaller.¹¹

Two main stylized facts emerge when we relate wage agreements to wage dynamics. First, there is a common seasonality between changes in the NMW, industry-level wage floor increases, the frequency of firm-level agreements and the aggregate wage growth

¹⁰We cannot distinguish agreements dealing with annual base wage increase and agreements dealing with bonuses or performance-related compensations.

¹¹Moreover, we are not using exactly the same weighting scheme as the one used by the Ministry of Labour, which can explain the small deviations between the two series.

(Figure 4): they all increase in the first quarter of the year (Table 1) and to a lesser extent in the second quarter for firm-level agreements). This might suggest that wage agreements are at least partly driving the timetable of actual wage changes.¹² The second main fact is the correlation between the average size of wage changes and the wage bargaining regime. In Table 2, we compute the average size and the frequency of wage adjustments by level of wage agreements. The average wage change is small when there is no wage agreement (0.3%) whereas it is above 0.5% when there is an industry-level agreement and close to 1% when there is in addition a firm-level agreement. This seems to be due to large differences in the frequency of wage changes rather than differences in the size of non-zero wage changes.¹³

4 What Are the Main Determinants of the Micro Wage Dynamics?

We here present first our empirical model relating at the micro level individual wages and also sector minimum wages to their main determinants. The estimates of this model will then be used as a data generating process in our simulation exercise to investigate aggregate response to shocks.

4.1 Empirical Model

Our empirical model can be easily derived from the model presented in section 2.1. We estimate determinants of a joint process of wage adjustment: first, the decision to change wages R and second, the size of wage adjustment conditional on observing a wage change ΔW . For a given worker j in firm i at date t , the model can then be written as follows:

¹²Moreover, the distribution of durations between two wage changes (Figure C in Appendix C) also shows that wage durations of exactly one year are much more frequent when there is a wage agreement.

¹³The distributions of non-zero wage changes are very similar across wage agreement regimes (Figure B in Appendix C).

If $R_{ijt}^* \leq 0$ then $R_{ijt} = 0$ and $\Delta W_{ijt} = 0$

If $R_{ijt}^* \geq 0$ then $R_{ijt} = 1$ and $\Delta W_{ijt} = \Delta W_{ijt}^*$

where R_{ijt}^* is the propensity to adjust wages and ΔW_{ijt}^* the frictionless wage adjustment. Our empirical model is a type II Tobit model.¹⁴ The first equation of the model is a Probit model for the decision of wage adjustment R where R^* depends on the cumulative change in explanatory variables between date t and the date of the last wage adjustment τ_{ij} . The model can be written as:

$$R_{ijt}^* = \beta \Delta_{(t, \tau_{ij})} X + \sum_{d=1}^{\infty} \gamma_d d_{ijt} + \mu_{ij} + \lambda_t + \epsilon_{ijt}$$

where $\Delta_{(t, \tau_{ij})}$ is the log difference operator between date t and the date of the last wage change τ_{ij} (and $d_{ijt} = t - \tau_{ij}$ the duration since the last wage adjustment). The use of cumulative variables can be justified by predictions of state-dependent models of wage rigidity (see for instance Le Bihan et al. [2012] or Sigurdsson and Sigurdardottir [2016]). Variables X include the French CPI index, the nominal national minimum wage, the industry- and job-specific wage floor, a dummy variable equal to one if a firm-level wage agreement has been signed in a firm j since the last wage change, and the local level of unemployment. We also include firm and worker controls μ_{ij} like the size and sector of the firm, wage position in the wage distribution. We also include duration dummies $(t - \tau_{ij})$ to control for Taylor contracts and quarter dummies λ_t to capture the seasonality of the decision of wage adjustments.¹⁵ Our second equation relates wage adjustment conditionally of observing a wage adjustment to determinants of wages changes.

$$\Delta W_{ijt}^* = b \Delta_{(t, \tau_{ij})} X + u_{ijt}$$

where ΔW_{ijt}^* is the frictionless wage change. The determinants X of the size of the

¹⁴Our empirical model is close to the one proposed by Le Bihan et al. [2012] or Fehr and Goette [2005].

¹⁵We also run different robustness specifications where λ_t are date dummies or quarter dummies in interaction with a post 2010 dummy (since the usual quarter of NMW adjustment was modified in 2010).

wage change are the same to the ones for the decision to change wages. However, we here assume that duration and quarter-specific dummies do not affect the size of wage adjustment but only the decision to change wages.¹⁶

The Tobit model is estimated using a two-step Heckman estimation procedure. Standard errors are obtained using pair cluster (firm) bootstrap simulations.¹⁷ Two identification issues should be addressed. First, we here use macro variables like CPI inflation or NMW variations that might lack of individual variability. By using cumulated changes in macro variables since the last wage adjustment, we here expand the support of the distribution of changes in macro variables. Cumulated variations are now specific to each individual, which should help us to identify the effect of macro variables. This line of reasoning has been used by several papers looking at price or wage rigidity to identify the effect of macro variables like CPI inflation or NMW increases (see for instance Fougère et al. [2010] on prices). Second, parameters of the Tobit model are identified using the following assumption. We here assume that the duration elapsed since the last wage adjustment and quarter dummies have no direct effect on the size of the wage changes besides the impact of cumulated macro variables introduced in the model. We argue that these two sets of variables correspond to calendar or seasonal effects (related to negotiation costs or legal constraints), independent of the decision about the size of wage adjustments. These variables would capture predictions of the Taylor wage contracts model. Our exclusion restrictions are justified by these arguments and insure identification of the Tobit model. Dummy variables for durations and for quarters are thus included in the first equation of the Tobit model but not in the second equation since they only affect the timing of wage changes, but not their size.

¹⁶To control for elapsed duration, we introduce duration as a linear trend. We also run robustness specification including date dummies in both equations.

¹⁷Maximum likelihood estimation would require to specify a rather complex covariance matrix for residuals. Resorting to bootstrap simulations allows us to have a very flexible covariance matrix without specifying it explicitly.

4.2 Estimation Results

We here present the results of Tobit models which inform us on the time- and state dependence of wage adjustments. Tables 3 provides marginal effects from the estimation of the Probit model and also results from the second stage OLS model from our Tobit II model.

Columns (1a) and (1b) report results of the model without any variables related to wage bargaining (NMW, industry or firm-level agreements). One first finding is the strong degree of time-dependence of wage changes: the probability of a wage change increases by about 40 pp if the duration since the last wage change is exactly one year. A smaller peak appears for duration equal to 2 years. Inflation has a positive effect on both the probability and the size of wage changes: a 1%-increase in inflation raises the probability of a wage change by about 5 pp. The impact of inflation on the size of wage adjustment is larger, the elasticity is close to 0.3 pp.. Local unemployment has no significant effect on the probability of a wage increase but a very small negative on the size of wage increases.

Columns (2a) and (2b) report results including variables capturing wage-setting institutions, and results are quite modified. First, the effect of inflation is now smaller on both the probability and on the size of a wage adjustment whereas the unemployment rate has now a negative but still small effect on both the probability and size of wage changes. Second, the strong degree of time-dependence is now mitigated by the presence of wage bargaining variables and finally, the strong heterogeneity in the frequency of wage change across firms' size has almost disappeared (see Figure D in Appendix C). Wage-setting institutions have also a significant direct effect on the wage dynamics. First, the NMW has a positive effect on base wage changes: a 1%-increase in the NMW raises the probability of a wage adjustment by 2 pp whereas it raises the size of wage changes by 0.11 pp. At the sectoral level, wage floors have a rather large effect on the probability of wage changes (marginal effect of 2.3 pp close to the inflation marginal effect) whereas the effect on wage changes is 0.14 pp. Finally, firm-level wage agreements have very large effects on

the probability of wage changes: when a firm agreement has been signed since last wage change, the probability of a base wage change increases by 11 pp and a firm-level wage agreement increases the average wage changes by 0.3 pp.

In columns (3a) and (3b), we control for date dummies to capture all unobserved common time effects. The overall effects of macro variables like inflation and NMW on the probability of a wage adjustment are now somewhat smaller whereas the impact of these variables on the size of wage increases do not change. This result is mostly driven by the extensive margin where time dummies capture a large share of common seasonal effects. On the other hand, the effects of sectoral or firm-level agreements remain broadly unchanged after the inclusion of time dummies. These results suggest that our conclusions on the impact of wage bargaining variables are not driven by seasonality or unobserved common time schedules of NMW and industry-level agreements.

4.3 Minimum Wage Adjustments

In our simulation exercise, we will allow minimum wages to depend on some determinants which can be similar to the ones introduced in the previous model. Moreover, for sectoral minimum wages, we will model wage adjustment using a similar model as the one estimated on individual wages.

First, the process of NMW adjustment is set by the French law. The NMW adjusts automatically every year (in July until 2009, then in January since 2010) according to an explicit formula linking NMW increase to the past inflation rate and the past real wage increase of blue-collar workers:

$$\Delta NMW_t = \text{Max}(0, \Delta CPI_{t-1}) + \frac{1}{2} \text{Max}(0, \Delta W_{t-1} - \Delta CPI_{t-1}) + \epsilon_t \quad (3)$$

where ΔNMW_t is the NMW increase for year t , ΔCPI_{t-1} is the inflation rate calculated since the last NMW increase, ΔW_{t-1} is the increase of the blue-collar hourly base wage

calculated since the last NMW increase and ϵ_t is a possible discretionary governmental additional increase.¹⁸

At the industry level, sectoral minimum wages adjust infrequently and we assume that they follow a similar two-stage process as the one assumed for individual wages. The determinants of sectoral minimum wage adjustments (probability and size) include cumulative change (since the last minimum wage update) in the CPI index, the NMW, the aggregate wage growth and unemployment. As for individual wages, we assume that duration dummies affect only the probability of a minimum wage adjustment (Taylor contracts or durations between two negotiations) and not the size of wage adjustment (see Fougère et al. [2018] for a similar model). Results are reported in Appendix, Table D. Like for individual wages, we find large time-dependence effects on the probability of a minimum wage adjustment and rather small but significant effects of state-dependent variables on the probability of a wage adjustment. Moreover, we find that a 1% increase in inflation, NMW or aggregate wage growth has a significant positive effect on the size of wage adjustment, ranging from 0.24 to 0.31 pp.

Finally, we have also estimated a model for the occurrence of a wage agreement at the firm level. However, we find that the main determinants are the size of the firm and seasonality but we do not find that NMW or sectoral minimum wages affect the probability of a wage agreement.

5 Aggregate Wage Response to Shocks

As shown in Section 2.2, in this wage rigidity model, the aggregate response to a shock cannot be trivially derived from the estimates of our micro model. In particular, the transmission of a shock can take several quarters and this shock will affect not only frequency and size of wage adjustment at date t but also frequency and size at dates $t + 1$,

¹⁸If between two usual NMW adjustments, cumulated inflation since the last NMW adjustment is higher than 2%, the NMW is automatically and immediately adjusted (this was the case in May 2008 and in December 2011).

$t + 2\dots$ Thus, the elasticities of wages to macro variables are larger than the marginal effects derived from our Tobit regressions and can be obtained only after several quarters of wage adjustments. Moreover, NMW and wage floors may also depend on the same determinants than individual wages, leading to possible indirect effects of shocks on base wages. In this section, we describe our micro simulation exercise to derive aggregate implications of our model in terms of wage adjustment to different shocks.

5.1 Simulation Exercise

Our simulation exercise is the following.¹⁹ We first simulate individual wage trajectories for all sample observations using our Tobit estimates and initial values for base wages. Using these simulated wage trajectories, we compute the average wage change at every period, defined as: $\Delta W_t^0 = \frac{1}{N_t} \sum_i \Delta W_{it}^0$ where N_t is the number of individuals at t . We redo the same simulations but introduce a shock for all wage trajectories at the same date (2010Q1 in our baseline simulations). We then calculate the average wage change for this new set of simulations ($\Delta W_t^1 = \frac{1}{N_t} \sum_i \Delta W_{it}^1$). The average aggregate response to a shock is obtained by calculating date by date the difference between average wage change with the shock and the same average without the shock ($\Delta W_t^1 - \Delta W_t^0$). This will allow us to follow the aggregate dynamics of wage response to a given shock whereas the long-run (direct) impact of a shock on wages will be defined as the value of this difference after several quarters.

In our simulation exercise, we also take into account for possible adjustment of minimum wages to shocks in inflation or NMW, which can amplify the wage response to a given shock. An increase of the NMW or inflation can lead wage floors to adjust, which would in turn affect wages. This indirect effect of a shock coming through wage floor adjustment can rationalize spillover effects of the NMW on wages higher than the NMW. To quantify this effect, we run separate simulations of wage floors. Like for base wages,

¹⁹See Appendix F for a full description of the simulation exercise.

we simulate wage floors trajectories using our Tobit estimates (see Appendix, Table D) incorporating or not a shock (in inflation or NMW). We then run the same simulation exercise on base wages as previously described but now using simulated wage floors trajectories (instead of observed wage floors). We are then able to estimate the indirect effect of a given shock on base wages coming through wage floor adjustment process. In the rest of the paper, this effect will be referred as the indirect effect of the shock (see also Appendix Figure G for a diagram summarizing this indirect effect).

Finally, feedback loop effects are also possible since NMW increase and wage floor adjustments depend on past aggregate wage increases. After a shock, increases in individual base wages will translate into higher aggregate wages, which would lead to an increase in the NMW (because of the legal formula) and to higher wage floors (since past aggregate wage change is one important determinant of wage floors) and so to a new increase in base wages.²⁰ In our simulation exercise, we allow such feedback loop effects from past increase of actual wages to the NMW and industry-level wage floors. In particular, NMW increases are simulated following the explicit and legal formula incorporating past inflation and past real aggregate wage increase, moreover NMW usually adjusts at specific dates (July or January). For wage floors, we allow simulated wage floors to depend on past aggregate wage increases simulated by the model. In the rest of the paper, feedback loop effects refer to this channel (see also Appendix Figure H for a diagram summarizing this feedback loop effect). The sum of indirect and feedback loop effects is referred as second-round effects of a shock on base wages.

5.2 Aggregate Wage Response to Shocks

We first describe how aggregate wages directly respond to different shocks (introduced separately): a 1%-shock in CPI inflation, NMW, wage floors and an increase in the

²⁰We do not consider possible feedback loop effects coming from the response of inflation, firm-level agreements and unemployment to a shock. They are however all other potential channels for feedback loop effects.

frequency of firm agreements to 100% among firms with at least one observed wage agreement over the period.

Table 4 provides the estimation of the long-term effect of each shock (after 1 quarter and after several quarters).²¹ Without taking into account minimum wages or collective bargaining, we find that the long run effect of a 1% shock in inflation on aggregate base wages is 0.35 pp. Taking into account minimum wages leads to lower this estimate to 0.22 pp, suggesting that inflation in the first model captures part of minimum wage effects. The long-run effects of minimum wages on base wages are substantial: a 1% increase in sectoral minimum wages leads to a increase of base wages of 0.15 pp whereas the same increase in the NMW leads to an increase of 0.13 pp in aggregate base wages. Each of this effect represents more than half the overall effect of inflation.

Using these simulations, we can also look at the aggregate adjustment dynamics. Figure 5 plots the aggregate response of base wages to shocks over time. It takes some time for wages to fully adjust to a given shock: the full adjustment is obtained after 5 quarters for all shocks. In most cases, about 60% of the overall effect is observed during the quarter after the shock and about 90% of the shock is incorporated after four quarters (Table 4 and Figure 5). Second, as expected the long-term simulated effects are larger than the simple Tobit marginal effects which correspond to the simulated effect obtained one quarter after the shock.

Finally, we can decompose the long-run effect of a shock into an extensive contribution (i.e. wages are higher because wage changes are more frequent with the shock) and an intensive contribution (i.e. wages are higher because non-zero wage changes are larger). We find that the relative contribution of the extensive and intensive margins are rather balanced for inflation whereas the extensive margin has a larger contribution for NMW, wage floors or firm-level agreements (Figure 5 and Table 4). Overall, minimum wages have a positive effect on base wages because they make wage adjustments more frequent

²¹Standard errors are obtained using bootstrap simulations.

and to some lesser extent because wage increases are a little higher with minimum wage adjustments than without.

5.3 Minimum Wages and Aggregate Wage Dynamics

To which extent do minimum wage adjustments modify the aggregate wage response to shocks? We here present results of simulations where we allow sectoral minimum wages to react to changes in macro variables and the NMW to respond to changes in inflation and aggregate wages (following the legal rule).

Table 5 reports simulation results for two different shocks (CPI and NMW) where we decompose long-run effects into direct effects, and second-round effects (ie indirect effects from wage floor response and feedback loop effects). First, effects of shocks are much larger when taking into account second-round effects. A 1%-increase in NMW now raises base wages by 0.19 pp (versus 0.13 pp only for direct effects).²² The amplification effect is mainly driven by the response of wage floors to NMW (about 0.05 pp) whereas the feedback loop effects are much smaller (0.01 pp).²³ Overall, the response of sectoral minimum wages amplifies the wage response to NMW increases by a factor of 1.5. The degree of inflation indexation of base wages is also amplified by minimum wages. A 1%-increase in inflation now raises wages by 0.44 pp when we allow minimum wages to respond to the inflation shock (versus 0.22 when we do not allow this possibility). The indirect effect of inflation coming from sectoral wage floors is estimated close to 0.05 pp whereas the feedback loop due in particular to the reaction of NMW to the inflation shock is 0.16 pp. This strong reaction of NMW to inflation can be explained by the legal formula for NMW where NMW adjusts fully to past inflation. Wage indexation to past inflation is augmented by a factor 2 when we take into account interactions with wage-setting institutions. These long run effects are found to be quite robust to changes

²²The NMW shock should be interpreted as a discretionary increase decided by the government.

²³see Figure F in Appendix D for the aggregate response of wage floors to a 1% increase in the NMW and inflation

in Tobit time effects specification (see Table C in Appendix).

Another important finding when we include minimum wages in our framework is the larger persistence of aggregate base wages. It now takes longer for wages to adjust to a given shock. Figure 6 plots the overall effect of CPI and NMW shocks on aggregate wages. The direct effect of a given shock is plotted in grey whereas the overall response including second-round effects is in black (the difference between the two corresponding to the contribution of indirect and feedback loop effects). An increase in inflation now takes more than 8 quarters to be fully incorporated into base wages (versus 5 without minimum wages). Similarly, we find a somewhat longer adjustment of base wages to a NMW shock when we take into account minimum wage adjustment. To test the robustness of the increase in persistence, we run simulations where the shock is introduced either in Q1, Q2, Q3 or Q4. We find that the duration before full adjustment is a little longer for a shock introduced in Q2 or Q3 whereas a shock has less persistent effect when introduced in Q4 (Figure 7). This result is due to the strong seasonality of wage adjustment. All things being equal, wage changes but also minimum wage changes are much more frequent in Q1, which allows more firms to adjust to shocks. Olivei and Teynro [2010], Juillard et al. [2013], and Bjorklund et al. [2018] provide similar findings and show that this pattern of the wage adjustment may have some aggregate consequences.

5.4 Heterogeneity Along the Wage Distribution

We now investigate to which extent long-run effects of shocks are heterogeneous along the wage distribution. Following the empirical literature on minimum wage spillover effects, we might expect in particular some heterogeneity in the transmission of NMW increases along the wage distribution. Moreover, our simulation exercises allow us to investigate whether spillover effects can come from second round effects. In this exercise, we have first estimated Tobit model on base wages where our main exogenous variables interact with 10 different positions of wages in the wage distribution (these positions correspond

to deciles of base wages).²⁴ We have run the same estimation for industry-level wage floor process including interactions with positions along the wage distribution. Finally, we have run the same simulation exercise as previously described.

Figure 8 plots the long-run effects of 1%-shock on NMW along the wage distribution and decompose this effect between direct effects (coming from the effect of NMW or inflation on base wages), indirect effects coming from both reaction of wage floors to the shock and feedback loop effects due to the aggregate wage increase. First, as expected, we find a decreasing effect of the NMW along the wage distribution. The overall effect is a little larger than 0.4 pp for wages close to the NMW (decile 1) and then falls to about 0.2 for wages between 1.04 and $1.2 \times$ the NMW (deciles 2 and 3). For wages higher than $1.3 \times$ the NMW (deciles 5 to 10), the overall effect of NMW is still positive close to 0.1 pp and this effect is rather stable even for wages higher than $3 \times$ the NMW. We can decompose the effect of NMW into three components: direct effects from NMW to wages, indirect effects coming from the reaction of wage floors and feedback loop effects coming from the response of wages. For wages close to the NMW we find a large contribution of direct effects (about 70% of the total effect) and this contribution is decreasing along the wage distribution to less than 50% for wages higher than $1.3 \times$ the NMW. Indirect effects of NMW transiting through wage floors are rather homogeneous all along the wage distribution since NMW has a rather homogenous effect on all wage floors. Finally, feedback loop effects are rather small but a little larger for wages close to the NMW. By comparison, using different data sources at annual frequency, Givord et al. [2016] find that spillover effects are affecting wages until $2 \times NMW$ but find somewhat larger spillover effects of NMW in France (see also Koubi and Bertrand [2006]).

If we consider the impact of indexation to past inflation along the wage distribution (Figure 9), we find that the impact of CPI inflation is rather homogenous along the wage distribution, in particular for wages higher than $1.2 \times$ the NMW. However, this small

²⁴The deciles are the following: $0.97*NMW$, $1.04*NMW$, $1.12*NMW$, $1.2*NMW$, $1.3 NMW$, $1.5*NMW$, $1.6*NMW$, $1.9*NMW$, $2.2*NMW$, $2.9*NMW$.

degree of heterogeneity is the result of two opposite effects: first, direct effects of CPI inflation are increasing along the wage distribution, their contribution is rather small for NMW earners whereas they are close to 0.2 pp for wages higher than 1.3 times the NMW; second, feedback loop effects are very large for wages close to the NMW but decrease along the wage distribution and are close to 0.1 pp for higher wages. This amplification mechanism is mainly due to the fact that NMW adjustment depends on past inflation. Overall, wage bargaining institutions and NMW are contributing to increase the degree of indexation to past inflation for the whole distribution of wages.

6 Conclusion

In this paper, we have documented the impact of minimum wages in shaping the aggregate wage dynamics. For that, we have matched comprehensive data sets consisting of millions of quarterly base wages, industry-level wage floors for more than 350 different industries and thousands of firm-level wage agreements over the period 2005Q4-2015Q4.

First, we document new findings on wage rigidity and how wage bargaining institutions can shape the degree of wage rigidity. We find that usual wage rigidity indicators like the frequency of wage adjustment are affected by the wage bargaining framework. In particular, time schedules of wage agreements and actual wage changes are highly synchronized: most wages changes are observed during the first quarter of the year when a vast majority of both industry- and firm-wage agreements are signed. Moreover, the typical duration between two wage changes is one year which corresponds to the usual duration of wage agreement. This observation is quite consistent with predictions of Taylor [1980] model. Moreover, a shock takes a little more than one year to be fully incorporated to aggregate wages and the duration of the adjustment is even longer when taking into account minimum wage adjustment.

Second, we provides new evidence on the main factors determining the wage dynamics

in France and how wage agreements shape this aggregate adjustment. Past inflation is one important determinant of wage dynamics: a 1%-increase in inflation is raising base wage growth by about 0.25 pp. Second, unemployment plays a relative limited role in explaining wage changes. Third, wage bargaining plays a substantial role in the wage dynamics. The NMW has a positive impact on wage changes (0.08 pp on average for direct effects), a 1% increase in sectoral wage floors has a positive effect of 0.14 pp whereas firm-level agreements increase wages by 0.3 pp. Wage agreements are mainly affecting wages through a higher frequency of wage changes.

Finally, we provide evidence that collective wage agreements can amplify initial effects of shocks and may lead to heterogeneous effects of shocks. First, we show that NMW and wage floor adjustment to specific shocks can lead to much higher long-term effect of inflation and NMW. The overall degree of inflation indexation is 0.4 pp when taking into account the wage floor and NMW response to the CPI shock. Similarly, the overall effect of the NMW is 0.13 instead of 0.08 pp when not taking into account the second-round effects. Moreover, we show that indirect effects coming from sectoral wage floors are very important to understand why NMW can have a positive effect on wages higher than 1.3 times the NMW. More than 75% of the overall effect of the NMW on higher wages is due to these indirect effects whereas the NMW has almost no direct effects at the top of the wage distribution.

References

- Autor, David H., A. Manning, and C.L. Smith**, “The Contribution of the Minimum Wage to US Wage Inequality over Three Decades: a Reassessment,” *American Economic Journal: Applied Economics*, 2016, 8 (1), 58–99.
- Avouyi-Dovi, Sanvi, Denis Fougère, and Erwan Gautier**, “Wage Rigidity, Collective Bargaining and the Minimum Wage: Evidence from French Agreement Data,” *Review of Economics and Statistics*, 2013, 95 (4), 1337–1351.
- Barattieri, Alessandro, Susanto Basu, and Peter Gottschalk**, “Some Evidence on the Importance of Sticky Wages,” *American Economic Journal: Macroeconomics*, 2014, 6 (1), 70–101.
- Bjorklund, Maria, Mikael Carlson, and Oskar Nordstrom-Skans**, “Fixed Wage Contracts and Monetary Non-Neutrality,” *American Economic Journal*, 2018.
- Calvo, Guillermo**, “Staggered Prices in a Utility-Maximizing Framework,” *Journal of Monetary Economics*, 1983, 12 (3), 383–398.
- Card, David and Alan Krueger**, “Myth and Measurement: The New Economics of the Minimum Wage,” in “,” Princeton University Press, 1995.
- Cardoso, Ana Rute and Pedro Portugal**, “Contractual Wages and the Wage Cushion under Different Bargaining Settings,” *Journal of Labor Economics*, October 2005, 23 (4), 875–902.
- Carluccio, Juan, Denis Fougère, and Erwan Gautier**, “Trade, Wages and Collective Bargaining: Evidence from France,” *Economic Journal*, 2015, 125 (584), 803–837.
- Cecchetti, Stephen G.**, “Indexation and Incomes Policy: A Study of Wage Adjustment in Unionized Manufacturing,” *Journal of Labor Economics*, 1987, 5 (3), 391–412.

- Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans**, “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy,” *Journal of Political Economy*, 2005, 113 (1), 1–45.
- Christofides, Louis and David Wilton**, “The Empirical Determinants of Contract Length,” *Journal of Monetary Economics*, 1983, 12, 309–319.
- and **T. Stengos**, “Wage Rigidity in Canadian Collective Bargaining Agreements,,” *Industrial and Labor Relations Review*, 2003, 56, 429–448.
- Dickens, R. and A. Manning**, “Spikes and Spill-overs: The Impact of the National Minimum Wage on the Wage Distribution in a Low-Wage Sector,” *The Economic Journal*, 2004, 114 (494), C95–C101.
- Dittrich, Marcus, Andreas Knabe, and Kristina Leipold**, “Spillover Effects of Minimum Wages in Experimental Wage Negotiations,” *CESifo Economic Studies*, 2014, 60 (4), 780–804.
- Erceg, Christopher J., Dale W. Henderson, and Andrew T. Levin**, “Optimal monetary policy with staggered wage and price contracts,” *Journal of Monetary Economics*, 2000, 46, 281–313.
- Fehr, Ernst and Lorenz Goette**, “Robustness and Real Consequences of Nominal Wage Rigidity,” *Journal of Monetary Economics*, 2005, 52 (4), 779–804.
- Fougère, Denis, Erwan Gautier, and Hervé Le Bihan**, “Restaurant Prices and the Minimum Wage,” *Journal of Money, Credit and Banking*, 2010, 42, 1199–1234.
- , – , and **Sébastien Roux**, “Wage Floor Rigidity in Industry-Level Agreements: Evidence from France,,” *Labour Economics*, 2018, 55, 72–97.
- Gartner, H., T. Schank, and C. Schnabel**, “Wage Cyclicity under Different Regimes of Industrial Relations,” *Industrial Relations*, 2013, 52 (2), 516–540.

- Givord, Pauline, Aeberhardt Romain, and Marbot Claire**, “Spillover Effect of the Minimum Wage in France: An Unconditional Quantile Regression Approach.,” nG2016-05, Working Paper CREST 2016.
- Grigsby, John, Eric Hurst, and Ahu Yildirmaz**, “Sticky Wages During the Great Recession,” *U. Chicago, Working Paper*, 2018.
- Grossman, Jean B.**, “The Impact of the Minimum Wage on Other Wages,” *Journal of Human Resources*, 1983, 63 (3), 359–378.
- Juillard, Michel, Hervé Le Bihan, and Stephen Millard**, “Non-Uniform Wage-Staggering: European Evidence and Monetary Policy Implications.,” No. 442, Banque de France Working Paper 2013.
- Kahn, Shulamit**, “Evidence of Nominal Wage Stickiness from Microdata,” *The American Economic Review*, 1997, 87 (5), 993–1008.
- Knell, Markus and Alfred Stiglbauer**, “Reference Norms, Staggered Wages, and Wage Leadership: Theoretical Implications and Empirical Evidence,” *International Economic Review*, 2012, 53 (2), 569–592.
- Koubi, Malik and Lhommeau Bertrand**, “La revalorisation du Smic et ses effets de diffusion dans l’échelle des salaires sur la période 2000-2005,” *Dares, Premieres Syntheses* n.27.1 2006.
- Le Bihan, Hervé, Jeremi Montornes, and Thomas Heckel**, “Sticky Wages: Evidence from Quarterly Microeconomic Data,” *American Economic Journal: Macroeconomics*, 2012, 4 (3), 1–32.
- Lunneman, E. and Ladislav Wintr**, “Wages Are Flexible Aren’t They? Evidence from Monthly Micro Wage Data.,” 1074, European Central Bank Working Paper Series 2015.

- Neumark, David, Mark Schweitzer, and W. Wascher**, “Minimum Wage Effects throughout the Wage Distribution,” *Journal of Human Resources*, 2004, 39 (2), 425–450.
- Olivei, Giovanni and Silvana Teyrnro**, “Wage-Setting Patterns and Monetary Policy: International Evidence,” *Journal of Monetary Economics*, 2010, 57 (7), 785–802.
- Sanchez, Ruby**, “La structure des remunerations dans le secteur prive en 2012.” Technical Report, DARES Analyses n.101 2014.
- Sigurdsson, Josef and Rannveig Sigurdardottir**, “Time-Dependent or State-Dependent Wage Setting? Evidence from Periods of Macroeconomic Instability,” *Journal of Monetary Economics*, 2016, 78, 50–66.
- Smets, Frank and Raf Wouters**, “An Estimated Dynamic Stochastic General Equilibrium Model of the Euro Area,” *Journal of the European Economic Association*, 2003, 1 (5), 1123–1175.
- Taylor, John B.**, “Aggregate Dynamics and Staggered Contracts,” *Journal of Political Economy*, 1980, 88 (1), 1–23.
- , “Union Wage Settlements during a Disinflation,” *The American Economic Review*, 1983, 73 (5), 981–993.
- , “The Staying Power of Staggered Wage and Price Setting Models in Macroeconomics,” in “Handbook of Macroeconomics Volume 2,” John B. Taylor and Harald Uhlig, (Eds), Elsevier Science, Amsterdam, 2016.

Tables

Table 1: Aggregate Moments of Wage Changes

(in %)	Wage changes			Wage agreements	
	Average	Frequency	Size	Industry-level wage change	Freq. of firm-level agreements
Overall	0.47	0.27	1.75	0.40	0.15
Overall (unw.)	0.45	0.24	1.90	0.38	0.11
Q1	0.85	0.45	1.87	0.92	0.21
Q2	0.49	0.27	1.82	0.32	0.20
Q3	0.37	0.23	1.62	0.24	0.10
Q4	0.21	0.14	1.50	0.16	0.09
2006	0.47	0.27	1.75	0.43	0.14
2007	0.59	0.30	1.97	0.53	0.14
2008	0.71	0.35	2.05	0.60	0.15
2009	0.43	0.25	1.75	0.44	0.13
2010	0.39	0.25	1.55	0.23	0.14
2011	0.53	0.28	1.86	0.50	0.15
2012	0.53	0.30	1.78	0.47	0.15
2013	0.38	0.24	1.59	0.40	0.15
2014	0.33	0.22	1.50	0.19	0.19
2015	0.30	0.21	1.41	0.14	0.15

Note: Moments are calculated using the data set matching ACEMO individual data, firm-level and industry-level wage agreements data sets. The first column contains the average quarterly wage changes for all workers of our data set. The second column is the proportion of workers whose wage is modified in a given quarter compare to the previous quarter. The third column is the average wage change conditional on observing a wage change. The fourth and fifth column are the proportions of workers covered in a given quarter either by a firm-level wage agreement or an industry-level agreement. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Table 2: Aggregate Moments of Wage Changes - By wage agreement levels

Firm	Wage agreement	Average wage changes (in %)		
	Industry	Overall	Frequency	Size
No	No	0.34	0.20	1.70
No	$\Delta WF \leq 1.5\%$	0.55	0.36	1.51
No	$1.5\% \leq \Delta WF \leq 2.2\%$	0.79	0.42	1.88
No	$\Delta WF \geq 2.2\%$	0.77	0.39	1.97
Yes	No	0.72	0.42	1.73
Yes	$\Delta WF \leq 1.5\%$	0.84	0.50	1.67
Yes	$1.5\% \leq \Delta WF \leq 2.2\%$	1.16	0.58	1.99
Yes	$\Delta WF \geq 2.2\%$	1.25	0.57	2.18

Note: Moments are calculated using the data set matching ACEMO individual data, firm-level and industry-level wage agreements data sets. Moments are calculated according to the coverage in a given quarter by a firm- or an industry-level wage agreement. For industry-level wage agreements, we consider 3 cases: the industry-level wage agreement stipulates a wage floor increases below 1.5%, between 1.5 and 2.2% and above 2.2% (we choose cut-off points so that about one third of observations covered by a wage agreement is contained in one of the three category). Column (3) contains the average quarterly wage changes in a given bargaining regime. Column (4) is the proportion of workers whose wage is modified in a given quarter compare to the previous quarter for a given wage agreement regime. Column (5) is the average wage change conditional on observing a wage change by wage agreement regimes. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Table 3: Determinants of Wage Changes: Tobit Estimates

	Probability of wage change			Size of wage change		
	Marginal effects			Parameter Estimates		
	(1a)	(2a)	(3a)	(1b)	(2b)	(3b)
CPI Inflation	0.047*** (0.000)	0.025*** (0.001)	0.016*** (0.001)	0.337*** (0.003)	0.221*** (0.003)	0.219*** (0.003)
Cum. Unemployment	0.000 (0.000)	-0.001*** (0.000)	-0.001*** (0.000)	-0.002*** (0.000)	-0.006*** (0.000)	-0.006*** (0.000)
NMW		0.020*** (0.000)	-0.014*** (0.001)		0.113*** (0.002)	0.110*** (0.002)
Wage floors		0.023*** (0.000)	0.021*** (0.000)		0.136*** (0.002)	0.136*** (0.002)
Firm agreement		0.108*** (0.001)	0.110*** (0.001)		0.326*** (0.005)	0.325*** (0.005)
Duration						
2 quarters	0.031*** (0.001)	0.015*** (0.001)	0.037*** (0.001)			
3 quarters	0.012*** (0.001)	-0.027*** (0.001)	0.017*** (0.001)			
1 year	0.385*** (0.002)	0.310*** (0.002)	0.395*** (0.001)			
5 quarters	0.067*** (0.002)	-0.004*** (0.003)	0.091*** (0.002)			
6 quarters	-0.045*** (0.002)	-0.100*** (0.003)	-0.014*** (0.002)			
7 quarters	-0.067*** (0.002)	-0.124*** (0.003)	-0.038*** (0.002)			
2 years	0.051*** (0.003)	-0.044*** (0.005)	0.104*** (0.004)			
>2 years	-0.102*** (0.001)	-0.158*** (0.004)	-0.051*** (0.002)			
Mills ratio				0.764*** (0.003)	0.752*** (0.003)	0.749*** (0.003)
Time linear trend*				0.960*** (0.012)	0.476*** (0.013)	0.500*** (0.013)
Time dummies	No	No	Yes	No	No	Yes
Observations	1,986,531	1,986,531	1,986,531	466,585	466,585	466,585

Note: We report in this table the marginal effects calculated from the estimation of the Probit model using different specifications and the parameter estimates obtained from the second step of the Tobit model. Determinants are calculated as cumulative variable since the last wage adjustment. Duration is a dummy variable for durations since the last wage changes. Quarter dummies are also introduced in the Probit model when there is no time dummies. Sector, size and wage deciles controls are introduced in all specifications. Time linear trends are interacted with sector, size and wage deciles: here is reported the time trend for the reference (smallest firm size, first decile, and metal industry). *p<0.1; **p<0.05; ***p<0.01.

Table 4: Long-Term Aggregate Direct Effects

	Short-term	Long-term Effect		
	T=1	Overall	Frequency	Size
<i>No Minimum Wages</i>				
(Specification 1)				
CPI Inflation	0.237 (0.003)	0.353 (0.005)	0.178 (0.003)	0.156 (0.004)
<i>Including Minimum Wages</i>				
(Specification 2)				
CPI Inflation	0.134 (0.003)	0.221 (0.002)	0.102 (0.002)	0.116 (0.006)
NMW	0.077 (0.003)	0.126 (0.003)	0.08 (0.003)	0.045 (0.007)
Wage floors	0.093 (0.003)	0.149 (0.003)	0.091 (0.003)	0.055 (0.006)
Firm wage agreement	0.218 (0.004)	0.294 (0.003)	0.256 (0.002)	0.027 (0.002)

Note: This table reports results from simulation exercise described in section 5.1. We report the long-run impact of 1% increase in a given variable on wage changes, except for firm level agreements where we simulate an economy where all firms with at least one observed wage agreement in the observed sample shift from no agreement to wage agreement. T=1 is the marginal effect contemporaneous to the shock. The sum of size and frequency effects is not exactly equal to the overall effect, a remaining second-order effect $(P_t^1 - P_t^0) \times (\Delta W_t^1 - \Delta W_t^0)$ is not reported and is equal to the difference between the sum of size and frequency effects and the overall effect. Confidence interval are provided in brackets and are obtained using bootstrap simulations.

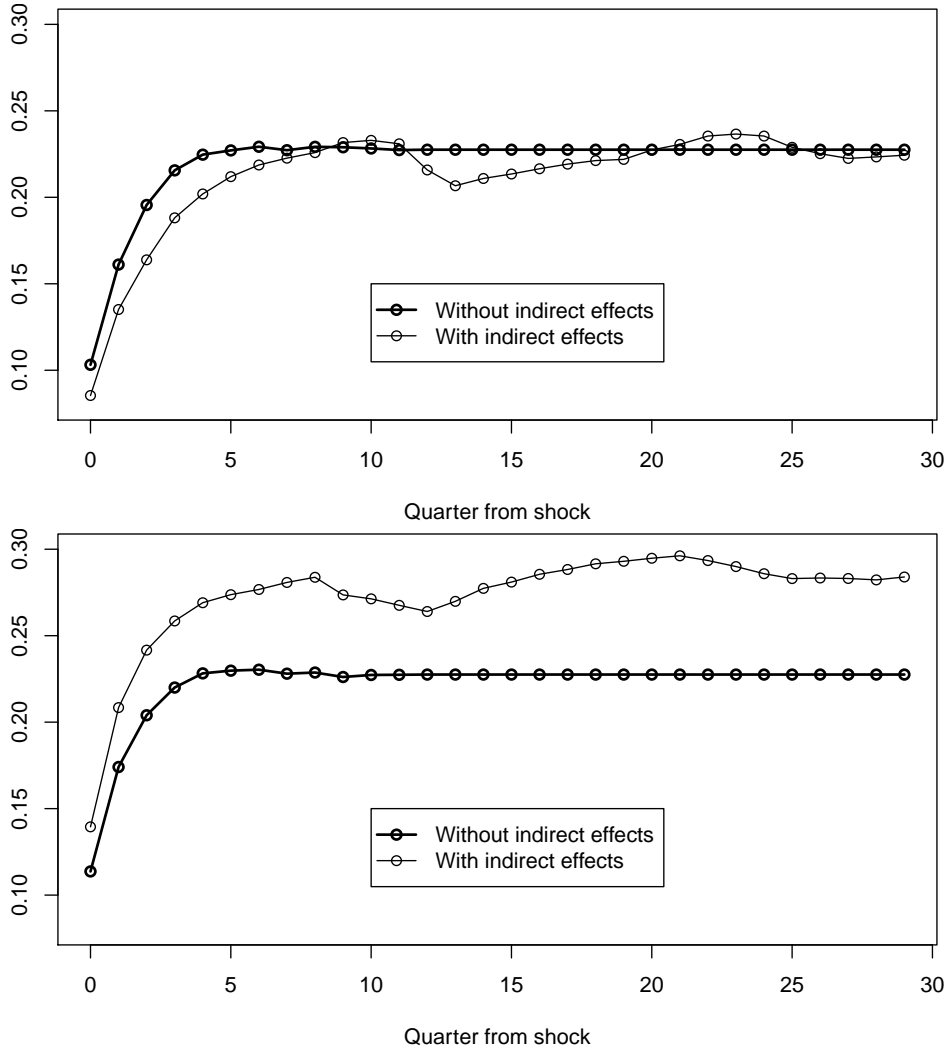
Table 5: Long-Term Aggregate Indirect and Second-Round Effects

	Direct	Indirect (wage floors)	Overall effect (+feedback loop)
CPI Inflation	0.221 (0.003)	0.053 (0.015)	0.437 (0.01)
NMW	0.126 (0.011)	0.050 (0.003)	0.192 (0.013)

Note: This table reports results from simulation exercise described in section 5.1 where we allow wage floors and the NMW to react to changes in CPI and NMW but also to aggregate wage changes due to the response to the shock (feedback loop effects). Column (1) reports direct long run effects coming from the adjustment of wages to shocks under the assumption that wage floors and the NMW are not responding to shocks. Column (2) reports the indirect effect of the shock on base wages coming from the adjustment of wage floors to a given shock. The last column reports the overall effect of the shock on base wages including the direct effect, indirect effect coming from wage floor adjustments and feedback loop effects coming from the adjustment of NMW, wage floor and aggregate wage changes. Confidence interval are provided in brackets and are obtained using bootstrap simulations.

Figures

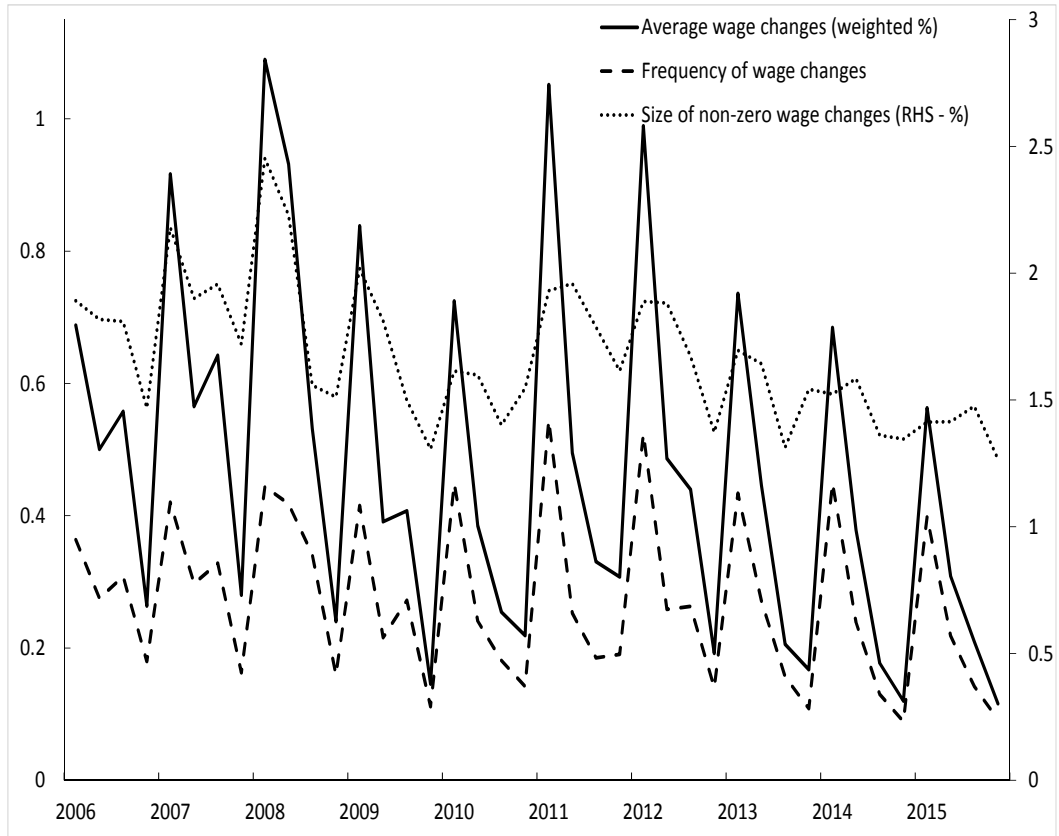
Figure 1: Aggregate Wage Dynamics With Lumpiness in Both Wages and Minimum Wages



Note: We here report aggregate wage response to a shock affecting only individual wages (adark line) or both wages and minimum wages (grey line). The top panel reports aggregate wage response where the calibration assumes the same long run effect for the shock whereas the bottom panel reports results where long-run effects are not set to be the same. The general set-up is described in section 2.

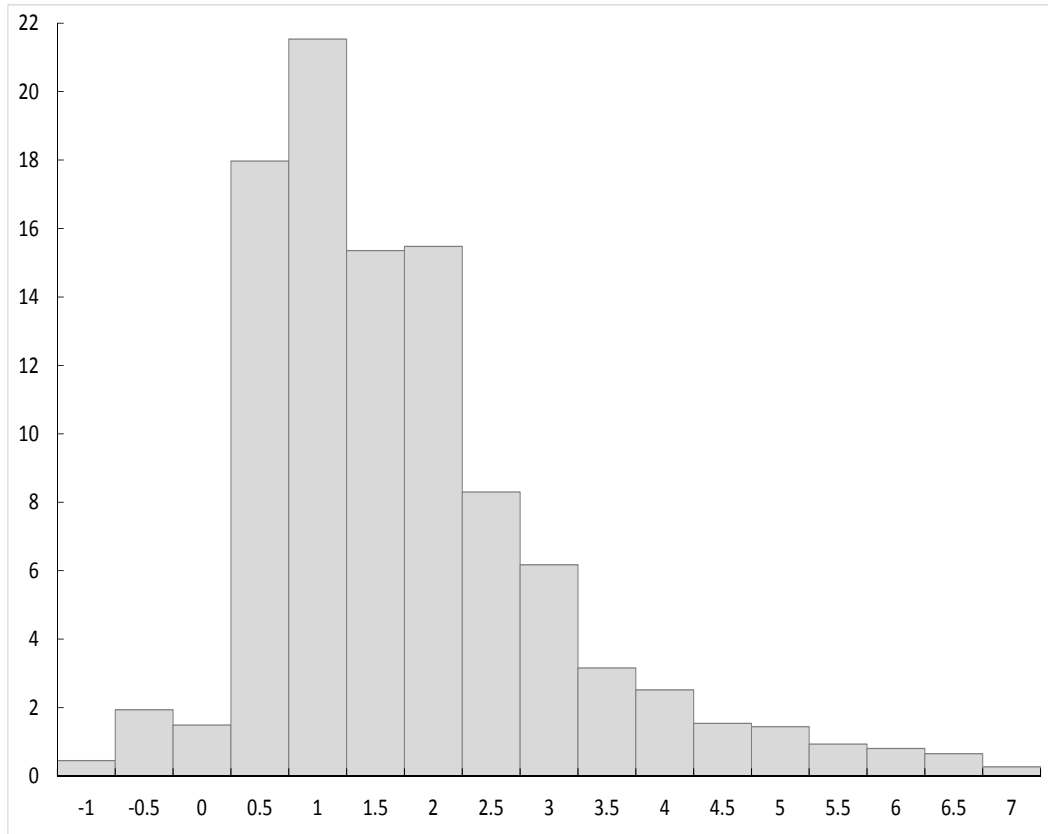
In this calibration, we define explicitly processes for individual wages and minimum wages. The frictionless wage is written as: $w_{it}^* = \eta_w z_{it} + \gamma t + \alpha \times S1\{t \geq 0\}$ and the propensity to increase wage is $R_{it}^* = -c + d1\{t - \tau_{it} = 4\} + \eta_p(z_{it} - z_{i\tau_{it}}) + \beta \times S1\{\tau_{it} \leq 0\} + \epsilon_{it}$ where τ_{it} is the date since the last wage w_i adjustment and S is the shock, we allow the probability of a wage change to be higher every 4 quarters (like in Taylor). z_{it} is a minimum wage affecting w_{it}^* , adjustments in z_{it} are also infrequent. The frictionless minimum wage is defined by $z_{it}^* = \gamma^z t + \alpha^z \times S1\{t \geq 0\}$ and $z_{it} = z_{i\tau_{it}^z} + R_{it}^z(z_{it}^* - z_{i\tau_{it}^z})$. Min wage adjusts when $R_{it}^z = 1$ when $R_{it}^{z*} > 0$ with $R_{it}^{z*} = -c^z + d^z 1\{t - \tau_{it}^z = 4\} + \beta^z \times S1\{\tau_{it}^z \leq 0\} + \epsilon_{it}^z$. To obtain impulse response functions, we compare the case where $S = 1$ with $S = 0$. We set $(\alpha = 0.34, \beta = 0.05, \gamma = 0.5)$, except in the top panel when there are indirect effects where $\alpha = 0.25$ so that long-term effects are similar. In the case without indirect effects, we set $\eta_p = \eta_w = 0$ whereas with indirect effects, $\eta_w = 0.1$ and $\eta_p = 0.24$ and $(\alpha^z = 0.25, \beta^z = 0.09, \gamma^z = 0.5)$

Figure 2: Aggregate Wage Growth, Frequency and Size of Wage Adjustments



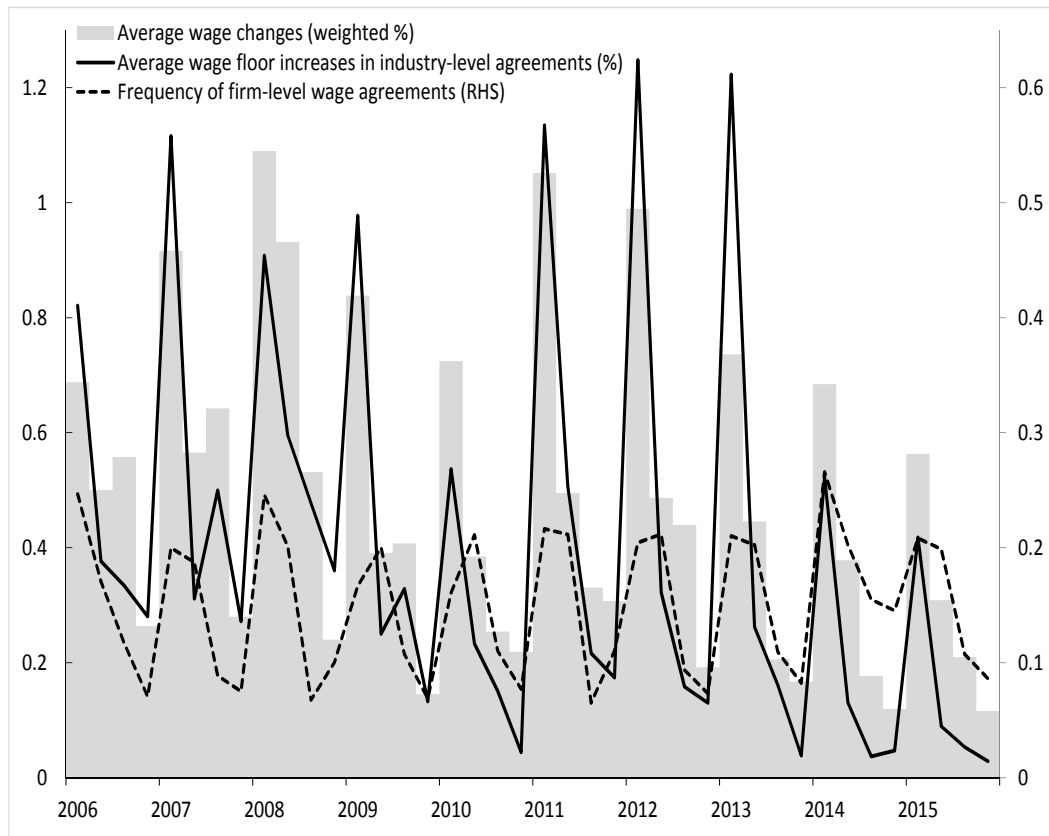
Note: We compute for each quarter the average wage growth as the average of all wage changes of our sample (including 0 change), the frequency of wage changes is calculated as the ratio of the number of wage changes over the number of observations in a given quarter, the average size of wage changes is calculated as the average of all wage changes but excluding wage changes equal to 0. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure 3: Distribution of Non-Zero Wage Changes



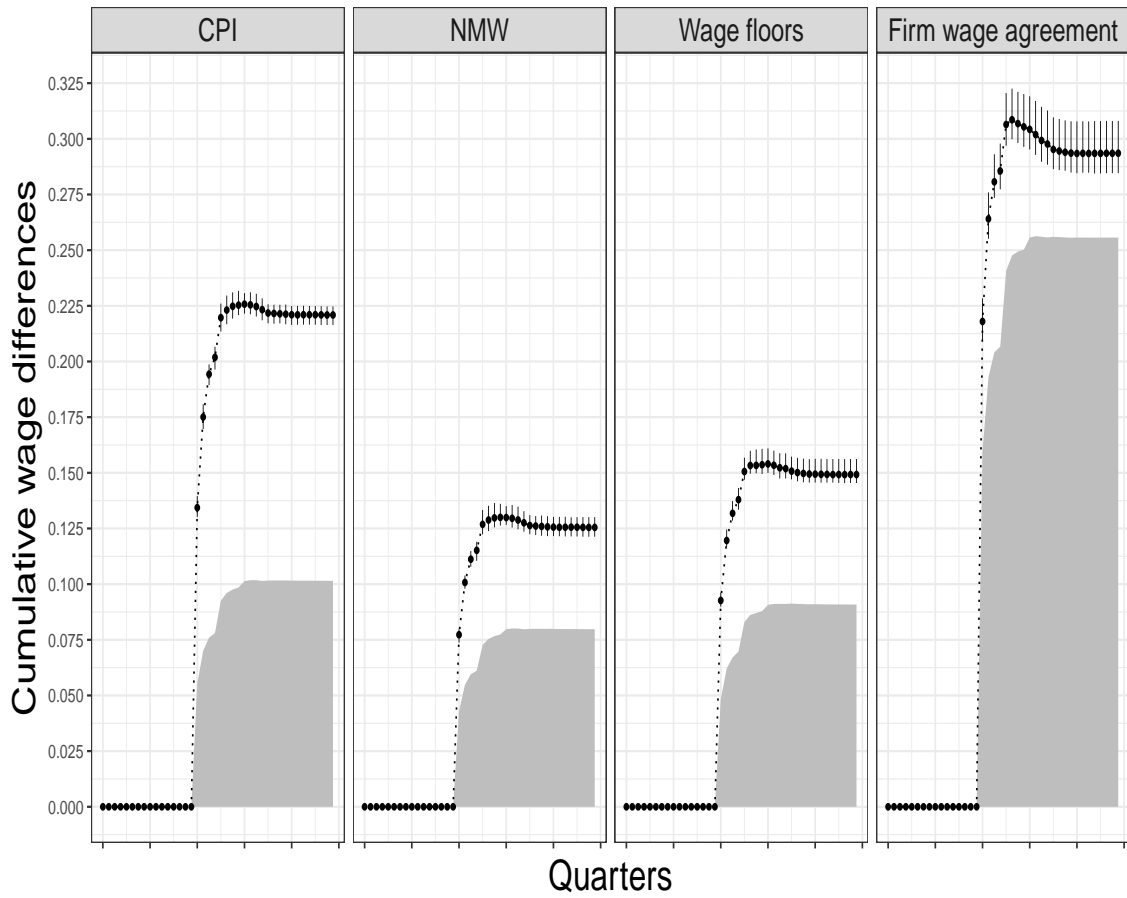
Note: We here compute the distribution of all non-zero wage changes (quarter-on-quarter). Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure 4: Aggregate Wage Growth, Sectoral Minimum Wage Increase and Frequency of Firm-Level Wage Agreements



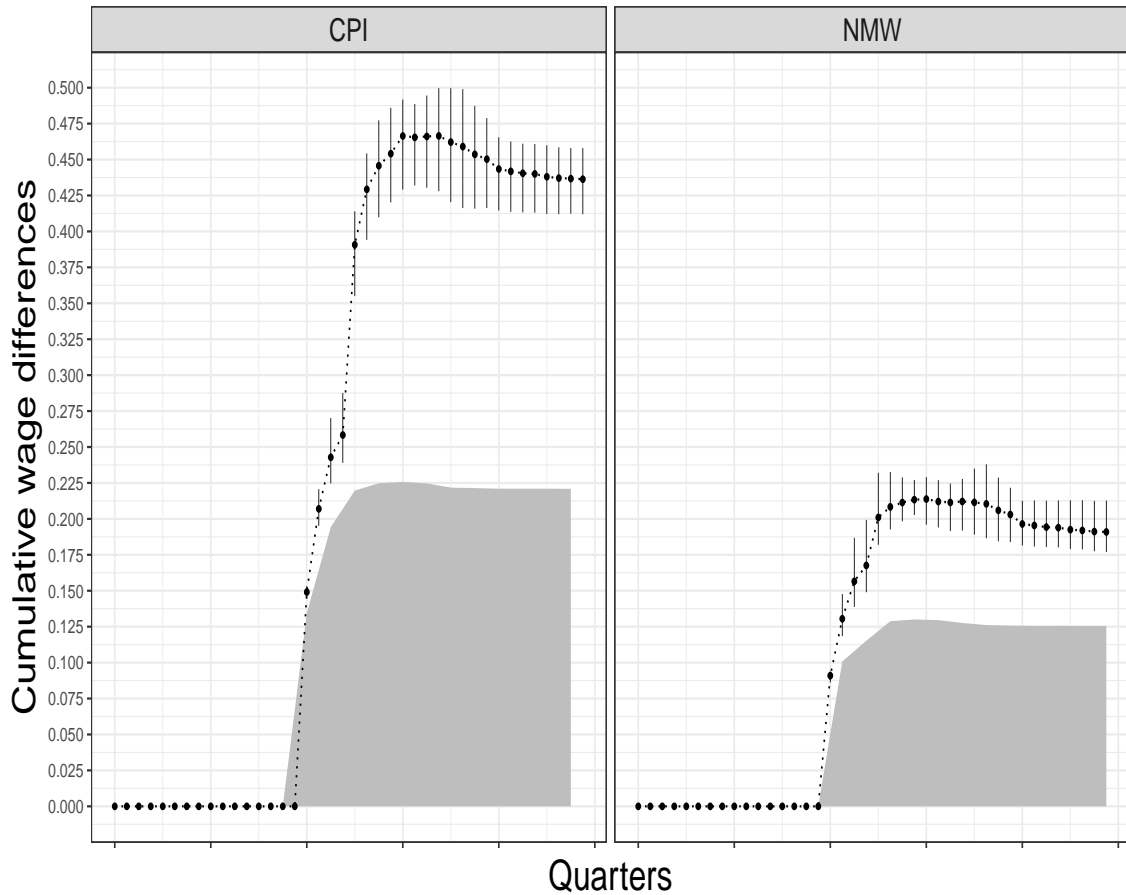
Note: We compute for each quarter the average wage growth as the average of all wage changes of our sample (including 0 change) (grey histogram). We also plot on this graph the average wage floor increase decided in a given quarter for all workers of our sample (including 0 increase when there is no wage bargaining) and the frequency of firm-level wage agreements as the ratio between the number of workers covered by a firm-level wage agreement on the total number of workers. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure 5: Aggregate Wage Adjustment to Shocks (Direct Effects)



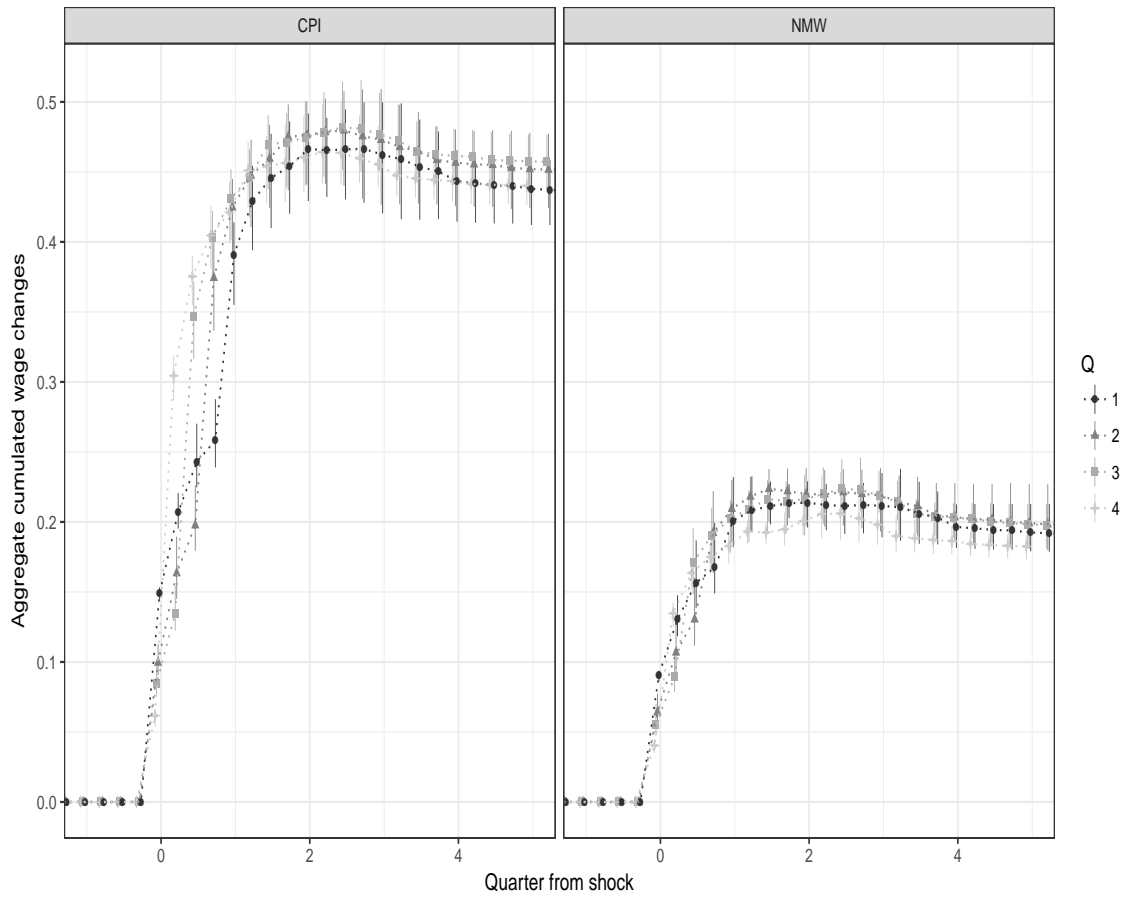
Note: We here report the results of our simulation exercise: using our estimated model, we simulate two groups of wage change trajectories, the first one with no shock and the second one with a 1%-increase in macro determinants (see section 5.1 for a full description). The shock is introduced in 2010Q1. We compute the average of all wage change trajectories by date and report the difference between the average with shock and the average with no shock. The black line corresponds to the aggregate average response. The grey shaded area corresponds to the contribution of the extensive margin to the overall effect. We also report confidence intervals (black bars) using bootstrap simulations.

Figure 6: Aggregate Response of Wages to NMW and Inflation Shocks (Direct and Second-Round Effects)



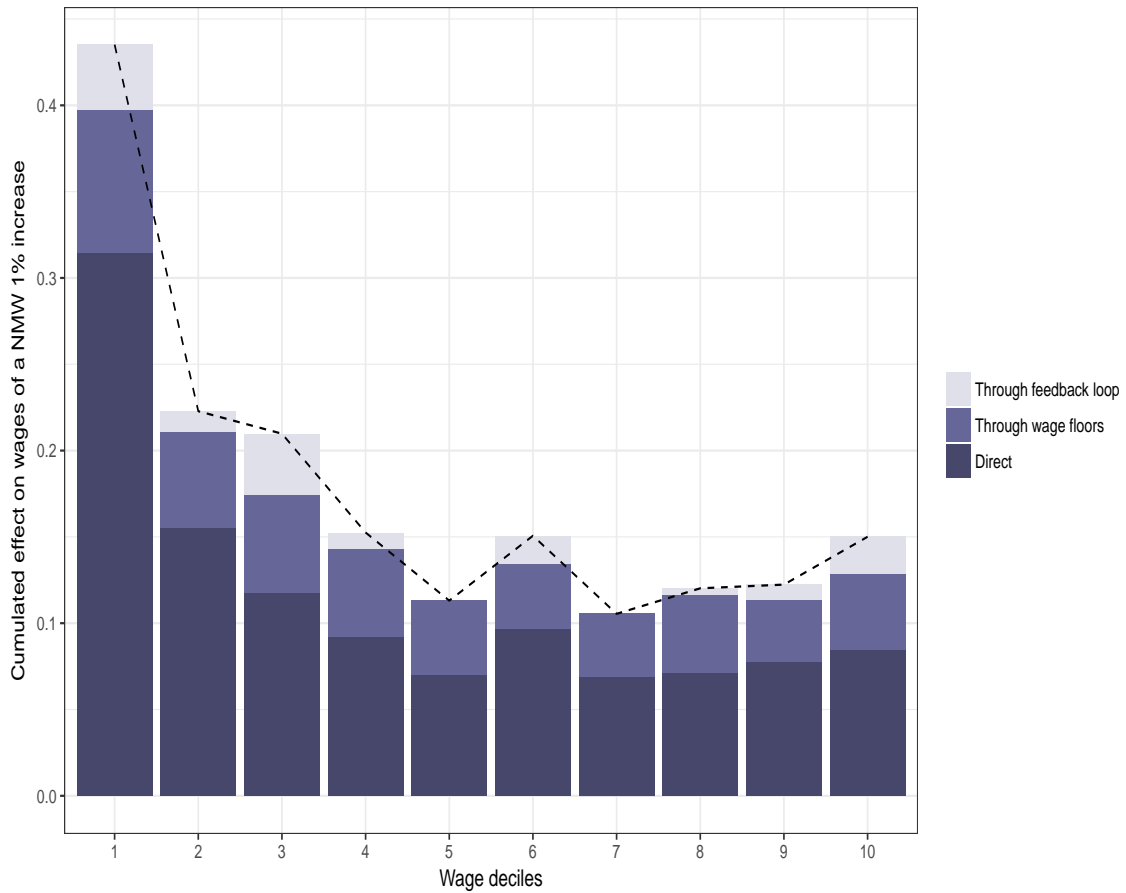
Note: We here report the results of our simulation exercise when we allow indirect effects of shocks feeding wages through wage floor adjustment and we also allow feedback loop effects: using our estimated model, we simulate two groups of wage change trajectories, the first one with no shock and the second one with a 1%-increase in CPI inflation or NMW. We also allow wage floors and NMW to react to these shocks. Therefore, individual wage changes would also respond to second round effects due to the reaction of NMW and wage floors to the initial increase in aggregate base wages. We compute the average of all wage change trajectories by date and the difference between the average with shock and the average with no shock. We plot on this graph the overall effect including direct and indirect effects (black line) and also direct effects (grey shaded area). Confidence intervals are also reported (black bars) they are obtained using bootstrap simulations.

Figure 7: Aggregate Wage Adjustment to Shocks by Quarter



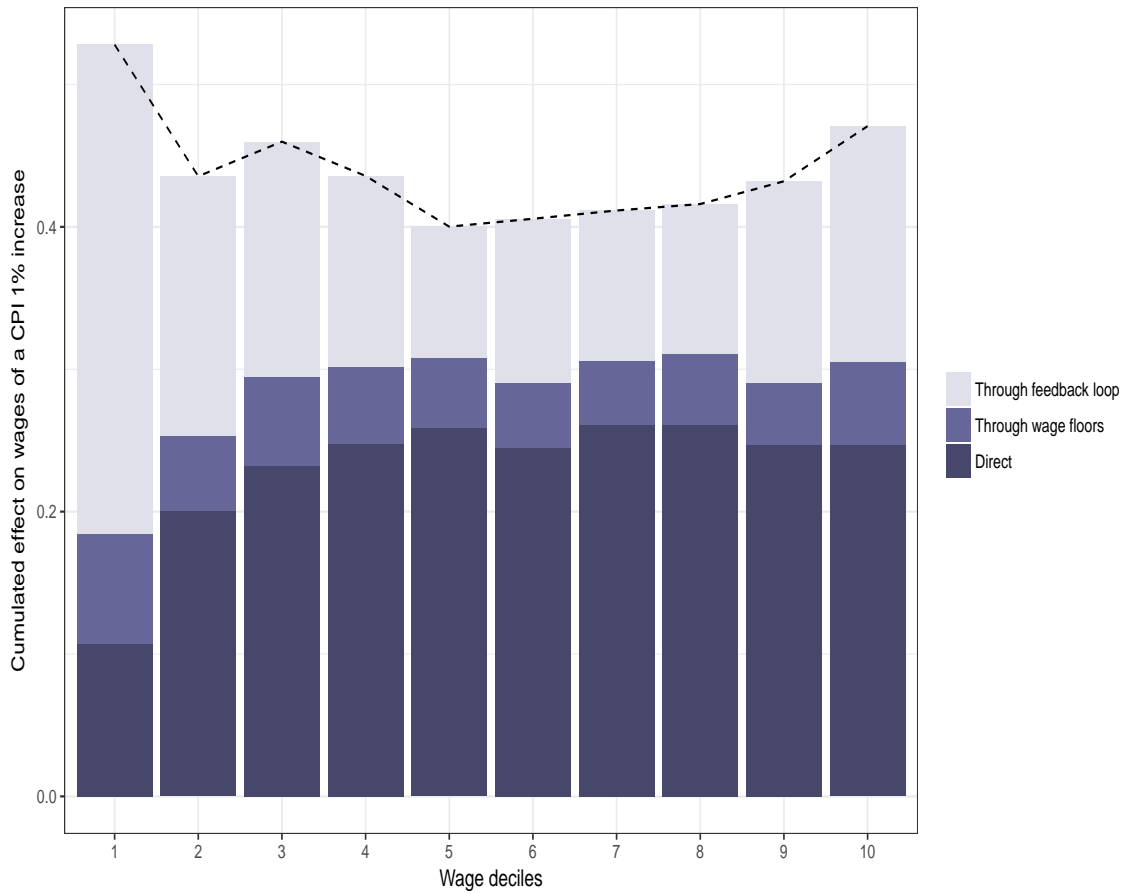
Note: We here report the results of our simulation exercise: using our estimated model, we simulate two groups of wage change trajectories, the first one with no shock and the second one with a 1%-increase in macro determinants. We compute the average of all wage change trajectories by date and the difference between the average with shock and the average with no shock. We plot on this graph the aggregate response to a shock when we assume that the shock is introduced either in 2010Q1, 2010Q2, 2010Q3, or 2010Q4. The long-run effects incorporate indirect and feedback loop effects.

Figure 8: Aggregate Wage Effects of the NMW Along the Wage Distribution



Note: We plot long-run effects of a 1% increase of the NMW on base wages. These effects are obtained using our simulation exercise where we allow for indirect effects through wage floor adjustment, NMW response and feedback loop effects. Simulations are made using parameter estimates from a Tobit model where all exogenous variables interact with dummy variables corresponding to deciles of the wage distribution. We report separately long run effects coming from direct effects of the shock on base wages (dark blue histograms), indirect effects through wage floor adjustment (light blue) and finally NMW and feedback loop effects (grey). The black dotted line is the sum of all these three effects.

Figure 9: Aggregate Wage Effects of Inflation along the Wage Distribution



Note: We plot long-run effects of a 1% increase of the CPI inflation on base wages. These effects are obtained using our simulation exercise where we allow for indirect effects through wage floor adjustment, NMW response and feedback loop effects. Simulations are made using parameter estimates from a Tobit model where all exogenous variables interact with dummy variables corresponding to deciles of the wage distribution. We report separately long run effects coming from direct effects of the shock on base wages (dark blue histograms), indirect effects through wage floor adjustment (light blue) and finally NMW and feedback loop effects (grey). The black dotted line is the sum of all these three effects.

APPENDIX - Not intended to be published

A Data Appendix

A.1 Measurement issues

Measurement issues in our individual wage data are very limited here for two reasons. First, wages are reported by firms and not by workers. Second, the statistical office of the French Ministry of Labour is very careful in the conduct of this survey to maintain its high quality since the evolution of base wage partially grounds the NMW increase formula. Surveyors monitor quite closely unusual wage increases or decreases and they can interview the firm several times to check the answer to the questionnaire. One potential measurement issue arises when wage trajectories are not associated with the same employee over time (for instance, a given firm chooses a new employee to report the base wage associated with a given job position). The information on employee substitution is not reported in the data set. We consider here that the wage trajectory is continuous as long as the wage change between two quarters stands between -1% and +7%. If not, we assume that the job is not occupied by the same individual and we assume a new wage trajectory. The proportion of wage changes outside the range -1% to 7% is very small (less than 1% of all initial survey observations) and results are not sensitive to the choice of the threshold.

We also compute a variable reporting the position of the job occupation in the wage distribution based on its position with respect to the value of its base wage relative to the NMW at its first date of observation. Deciles corresponding to the ratio base wage over NMW are used as thresholds defining dummy variables. For that, at the first date the base wage is observed for worker in a given firm, we calculate the ratio of the base wage over the NMW. We then compute the deciles of this ratio over workers and

construct dummy variables equal to one if the initial wage of a given worker is between two deciles of this ratio. The deciles are the following: 0.97*NMW, 1.04*NMW, 1.12*NMW, 1.2*NMW, 1.3 NMW, 1.5*NMW, 1.6*NMW, 1.9*NMW, 2.2*NMW, 2.9*NMW. Wages below 0.97*NMW and above 8*NMW are discarded from our data set, they represent less than 1% of our overall sample. These dummy variables allow us to investigate the heterogeneity across workers according to the distance of their wage to the NMW.

Measurement issues on wage agreement data. - Industry-level agreements

The data set consists of wage floors collected by hand on a governmental web site publishing texts of all wage agreements for almost all industries. Measurement issues are very limited.

- Firm-level agreements

We have removed all firm-level wage agreements dealing with specific bonuses due to Villepin Law 2006 and Sarkozy law in 2008. These two laws have lead to a large increase in the number of wage agreements but most of them were signed by small firms and we dealing with a specific annual bonus not wage increases.

Unemployment: We use unemployment data at the local level (*Zone d'Emploi* and associate to each firm either the local unemployment rate corresponding to its location or the average (weighted) unemployment rate if this firm has several locations. Le Bihan et al. [2012] use a similar indicator but construct the cumulated change in unemployment. We here rely only on the current level of unemployment.

A.2 Data Matching Procedure

The ACEMO survey does not collect the industry-specific wage floor associated with a given worker or the position of the worker in the industry-specific wage scale. Thus, it is difficult to match the two data sets comparing only levels of actual wages and wage floors. Using Portuguese data, Cardoso and Portugal [2005] use the mode of wages to

assign a given wage floor to a certain category of employees. This procedure cannot be implemented here since we do not have information on the job category of the worker in the ACEMO survey. Thus, we use the following procedure to assign a wage floor growth to every worker of our sample. We first calculate by bargaining industry (and when possible by broad job categories in the industry) percentiles of the distribution of individual wage levels (ACEMO survey) and percentiles of the distribution of wage floors (industry-level wage agreements data set). We then calculate the wage floor increase associated with the percentiles of the wage floor distribution. Finally, we assign to actual wages in a given percentile of the wage distribution the wage floor increase corresponding to the same percentile in the wage floor distribution. Our main assumption is that in a given industry and job category, lower actual wages are more likely to be affected by increases of lower wage floors.²⁵ Finally, we match this sample with our data set of firm-level wage agreements using a common firm identifier. The date at which the wage agreement comes into effect is not available and we only have information on the date of signature: we here assume that the wage agreement comes into effect the month after the date of signature.

²⁵Most of the variance of wage floor increases in a given industry is however due to variations over time rather than across job occupations in the industry (about 80% of the variance is explained by variations over time and 20% by variations across occupations in the same industry. The variance of wage floor increase across occupations is even smaller when we consider the variance of wage floor increase within a broad job category in a given industry).

B Long-Term Simulated Effects

In this section, we are providing some explanations on why the long-term effect of a shock is not equal to the overall marginal effect coming from the Tobit parameter estimates. We are showing this in a simpler version of our model but conclusions remain similar in our set-up.

First, to alleviate notation, our model can be rewritten as follows. We write $\Delta w_{it} = u_{it} \times 1\{y_{it} > 0\}$ where u_{it} is the "notional" wage change applying when a decision to change is made, based on the sign of y_{it} .

$$\begin{aligned} y_{it}^0 &= A_t + \epsilon_{1t} \\ u_{it}^0 &= B_t + \epsilon_{2t} \\ \tau_t^0 &= t - \max\{s, s < t \text{ such that } y_{it}^0 > 0\} \end{aligned} \tag{4}$$

The superscript 0 indicates the counterfactual situation without a shock. ϵ_{1t} and ϵ_{2t} are such that $\text{corr}(\epsilon_{1t}, \epsilon_{2t}) = \rho$. τ_t is the number of quarters since last wage change. We note $A_t^{(0)} = \mu + \sum_{s=t_0-\tau_t^0}^t (\Delta x_s \times \beta) + z_t \times \alpha + \sum_{j=1}^J a_j 1\{\tau_t^0 = C_j\}$, where some variables are specified as cumulated evolution since last wage change, and the last term is our exclusion restriction based on duration since last wage change. We note $B_t^{(0)} = u_0 + \sum_{s=t-\tau_t^0}^t (\Delta x_s \times \delta) + z_t \times c$. We consider a similar setting, where at $t = t_0$, $\Delta x_{t_0}^1$ is replaced by $\Delta x_{t_0}^1 + K$ where K is the shock. The whole process (S) can then be written as follow

$$\begin{aligned} y_{it}^S &= A_t^{(S)} + \sum_{s=t-\tau_t^0}^t K \beta_1 1\{s = t_0\} + \epsilon_{1t} \\ u_{it}^S &= B_t^{(S)} + \sum_{s=t-\tau_t^0}^t K \delta_1 1\{s = t_0\} + \epsilon_{2t} \\ \tau_t^S &= t - \max\{s, s < t : y_{it}^S > 0\} \end{aligned} \tag{5}$$

(S) represents the process when the economy is hit by a shock K on x_1 . For all $t < t_0$ (i.e. before the shock), (0) and (S) are the same. The only reason why $A_t^{(0)}$ and $B_t^{(0)}$ differ from $A_t^{(S)}$ and $B_t^{(S)}$ is through τ_t . However, at t_0 they are the same. As soon as for $T \geq t_0$, $y_{it}^S > 0$ & $y_{it}^0 > 0$, (0) and (S) are the same for all $t > T$. This is because $\tau_t^S = \tau_t^0$ for $t > T$ and $K1\{s = t_0\}$ is null in the cumulated sums as soon as there is a wage change after t_0 . The shock will non-trivially modify the series of τ_t .

We want to derive, conditionally on $\{\Delta x_s, z_s \forall s\}, \{\tau_s, \forall s \leq t_0\}$

- The size of the reaction at $t = t_0$:

$$\mathbb{E}[\Delta w_{it_0}^S] - \mathbb{E}[\Delta w_{it_0}^0] \quad (6)$$

- The long-term impact: $\sum_{s=t_0}^{\infty} \mathbb{E}[\Delta w_{is}^S] - \mathbb{E}[\Delta w_{is}^0]$

In the following subsection, we provide the exact computation for the size of the reaction at $t = t_0$ that corresponds to the marginal effects at t_0 at first order. For the second computation, we rely on simulations.

B.1 Size of the instantaneous effect

B.1.1 Difference in expectation

$$\begin{aligned} \mathbb{E}[\Delta w_{it_0}^S] &= \mathbb{E}[u_{it_0}^S | y_{it_0}^S > 0] \times \mathbb{P}[y_{it_0}^S > 0] \\ &= (B_{t_0} + K\delta_1 + \mathbb{E}[\epsilon_{2t_0} | y_{it_0}^S > 0]) \times \Phi(A_{t_0} + K\beta_1) \end{aligned} \quad (7)$$

where Φ is the cdf of the normal distribution. Then, the difference can be written as:

$$\begin{aligned} \mathbb{E}[\Delta w_{it_0}^S] - \mathbb{E}[\Delta w_{it_0}^0] &= K\delta_1 \times \Phi(A_{t_0}) \\ &+ \mathbb{E}[\epsilon_{2t_0} | y_{it_0}^S > 0] \times \Phi(A_{t_0} + K\beta_1) - \mathbb{E}[\epsilon_{2t_0} | y_{it_0}^0 > 0] \times \Phi(A_{t_0}) \quad (8) \\ &+ (B_{t_0} + K\delta_1) (\Phi(A_{t_0} + K\beta_1) - \Phi(A_{t_0})) \end{aligned}$$

The first term corresponds to wages that would have adjusted without the shock, the second term corresponds to the selection of higher idiosyncratic shocks (since the selection rule is relaxed by the shock and if ϵ_1 and ϵ_2 are negatively correlated, ϵ_2 are higher with a shock than without) the third term corresponds to the increase in the frequency of wage changes entailed by the shock, times the current notional wage change.

with $\lambda(x) = \frac{\phi(x)}{\Phi(x)}$ the Mills ratio,

$$\mathbb{E}[\epsilon_{2t_0} | y_{it_0}^S > 0] = \rho\sigma_2\lambda(A_{t_0} + K\beta_1) \quad (9)$$

Hence,

$$\begin{aligned} \mathbb{E}[\Delta w_{it_0}^S] - \mathbb{E}[\Delta w_{it_0}^0] &= K\delta_1 \times \Phi(A_{t_0}) \\ &+ \rho\sigma_2 (\phi(A_{t_0} + K\beta_1) - \phi(A_{t_0})) \\ &+ (B_{t_0} + K\delta_1) (\Phi(A_{t_0} + K\beta_1) - \Phi(A_{t_0})) \end{aligned} \quad (10)$$

For dates $t+1, t+2, \dots$, the computation is more complex because τ_t^0 is not necessarily the same as τ_t^S .

B.1.2 Marginal effects

We want to relate equation 10 to the average marginal effect at any date t on any trajectory. By differentiating $\mathbb{E}[\Delta w_{it} | \{\Delta x_s, z_s \forall s\}, \{\tau_s, \forall s \leq t_0\}]$, we obtain:

$$\begin{aligned}
\frac{d\mathbb{E}[\Delta w_{it} | \{\Delta x_s, z_s \forall s\}, \{\tau_s, \forall s \leq t_0\}]}{dx_{1t}} &= \beta_1 \phi(A_t) \times (B_t + \rho \sigma_2 \lambda(A_t)) + (\delta_1 + \rho \sigma_2 \beta_1 \frac{d\lambda}{dx}(A_t)) \Phi(A_t) \\
&= \delta_1 \Phi(A_t) \\
&+ \rho \sigma_2 \beta_1 (\phi(A_t) \lambda(A_t) + \phi'(A_t) - \phi(A_t) \lambda(A_t)) \\
&+ B_t \beta_1 \phi(A_t) \\
&= \delta_1 \Phi(A_t) + \rho \sigma_2 \beta_1 \phi'(A_t) + B_t \beta_1 \phi(A_t)
\end{aligned} \tag{11}$$

Without the second-order terms (K^2) in (10), we have an equality between equations (10) and (11). Note that $f : (A_t, B_t) \rightarrow \delta_1 \Phi(A_t) + \rho \sigma_2 \beta_1 \phi'(A_t) + B_t \beta_1 \phi(A_t)$ that is averaged over all i and t when providing the average marginal effect of a variable, whereas in the simulations the instantaneous marginal effect is taken at a particular combination of explanatory variables (for instance 2010Q1 in our baseline simulation exercise).

B.2 Impact of a shock after more than 1 period since the shock

At the end of a simulation, the wage change can be written:

$$\begin{aligned}
\sum_{s=t_0}^{T_f} \mathbb{E}[\Delta w_{is}^S] &= \sum_{s=t_0}^{T_f} \sum_{k=0}^K \mathbb{E}[\Delta w_{is}^S | \tau_{t_s}^S = \tau_k] \times \mathbb{P}[\tau_{t_s} = \tau_k] \\
&= \sum_{s=t_0}^{T_f} \sum_{k=0}^K \mathbb{P}[\tau_{t_s}^S = \tau_k] \times \Phi(A_{t_s} + K \beta_1 1\{t_0 \in [t_s - \tau_k, t_s]\}) \times \\
&\quad (B_{t_s}(\tau_k) + K \delta_1 1\{t_0 \in [t_s - \tau_k, t_s]\} + \rho \sigma_2 \lambda(A_{t_s}(\tau_k) + K \beta_1 1\{t_0 \in [t_s - \tau_k, t_s]\}))
\end{aligned} \tag{12}$$

Due to the complex structure of the process of $(\tau_t)_{t \geq t_0}$, we do not have a closed-form formula for this process. However, for simple cases of A_t and B_t we can compute the expected long-term effect of a shock.

Let us assume for illustrative purpose that $A_t = B_t = 0$ and consider the cumulated

structure only for the shock. Hence, the simplified framework can be written as:

$$\begin{aligned} y_{it}^{(S)} &= K\beta_1 \times 1\{\Delta w_{i,t_0} = 0, \dots, \Delta w_{i,t-1} = 0\} + \epsilon_{1t} \\ u_{it}^{(S)} &= K\delta_1 \times 1\{\Delta w_{i,t_0} = 0, \dots, \Delta w_{i,t-1} = 0\} + \epsilon_{2t} \end{aligned} \quad (13)$$

Let's denote the event of no wage change since the shock $C_t = \{\Delta w_{i,t_0} < -K\beta_1, \dots, \Delta w_{i,t-1} < -K\beta_1\}$.

$$\begin{aligned} \mathbb{E}[\Delta w_{it}^S] - \mathbb{E}[\Delta w_{it}^0] &= \mathbb{E}[\Delta w_{it}^S | C_t] \times \mathbb{P}(C_t) + \mathbb{E}[\Delta w_{it}^S | C_t^C] \times (1 - \mathbb{P}(C_t)) - \mathbb{E}[\Delta w_{it}^0] \\ &= (\mathbb{E}[\Delta w_{it}^S | C_t] - \mathbb{E}[\Delta w_{it}^0]) \times \mathbb{P}(C_t) \end{aligned} \quad (14)$$

where we use that after a wage change (C_t^C), $\Delta w_{it}^0 = \Delta w_{it}^S$. Given that:

$$\mathbb{E}[(a + \epsilon_{2t})1\{b + \epsilon_{1t} > 0\}] = (a + \rho\sigma_2 \frac{\phi(b)}{\Phi(b)}) \times \Phi(b)$$

and that:

$$\mathbb{P}(C_t) = \Phi(-K\beta_1)^{t-t_0}$$

We can calculate:

$$\mathbb{E}[\Delta w_{it}^S] - \mathbb{E}[\Delta w_{it}^0] = (K\delta_1 \Phi(K\delta_1) + \rho\sigma_2 \times (\phi(K\beta_1) - \phi(0))) \Phi(-K\beta_1)^{t-t_0} \quad (15)$$

In this simple example, the marginal effect of the shock is decreasing with time. Note that at long term, the total effect would be:

$$K\delta_1 + \frac{\rho\sigma_2(\phi(K\beta_1) - \phi(0))}{\Phi(K\beta_1)} \quad (16)$$

The first term is the shock as incorporated through the notional wage change in all trajectories whereas the second term reflects how the selection effect is altered by a shock.

C Supplementary Empirical Results

Table A: Aggregate Moments of Wage Changes - by firm size

(in %)	Wage changes			Wage agreements	
	Average	Frequency	Size	Industry-level wage change	Freq. of firm-level agreements
All	0.47	0.27	1.75	0.38	0.15
Less 20 workers	0.46	0.22	2.06	0.38	0.00
Btw 20 and 50	0.45	0.23	1.96	0.39	0.01
Btw 50 and 100	0.44	0.24	1.88	0.39	0.03
Btw 100 and 200	0.44	0.24	1.84	0.37	0.08
Btw 200 and 500	0.46	0.26	1.76	0.39	0.13
More than 500	0.48	0.29	1.68	0.38	0.22

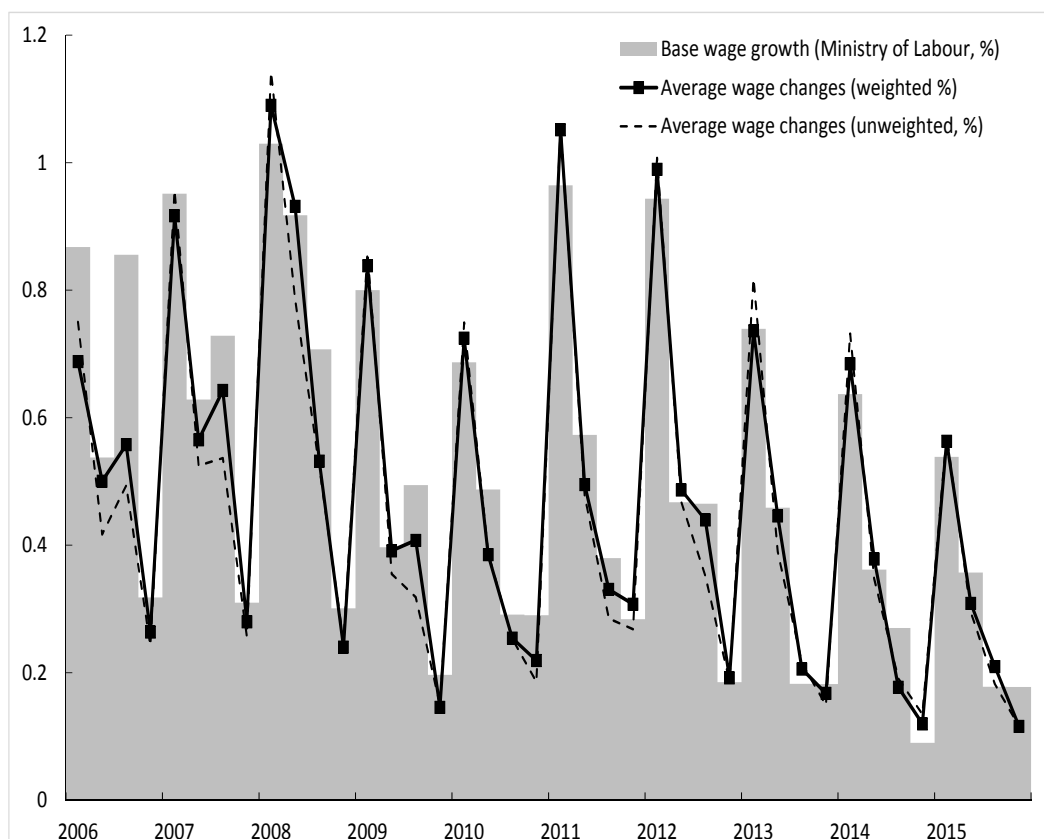
Note: Moments are calculated using the data set matching ACEMO individual data, firm-level and industry-level wage agreements data sets. The first column contains the average quarterly wage changes for all workers of our data set. The second column is the proportion of workers whose wage is modified in a given quarter compare to the previous quarter. The third column is the average wage change conditional on observing a wage change. The fourth and fifth column are the proportions of workers covered in a given quarter either by a firm-level wage agreement or an industry-level agreement. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Table B: Aggregate Moments of Wage Changes - by wage level

(in %)	Wage changes			Wage agreements	
	Average	Frequency	Size	Industry-level wage change	Freq. of firm-level agreements
All	0.47	0.27	1.75	0.38	0.15
Btw 0.99 and 1.04*NMW	0.47	0.30	1.53	0.44	0.12
Btw 1.04 and 1.12*NMW	0.45	0.27	1.70	0.40	0.15
Btw 1.12 and 1.2*NMW	0.46	0.26	1.76	0.40	0.14
Btw 1.2 and 1.3*NMW	0.48	0.27	1.79	0.39	0.14
Btw 1.3 and 1.5*NMW	0.47	0.28	1.66	0.38	0.17
Btw 1.5 and 1.6*NMW	0.48	0.27	1.78	0.38	0.16
Btw 1.6 and 1.9*NMW	0.48	0.26	1.86	0.37	0.16
Btw 1.9 and 2.2*NMW	0.48	0.25	1.95	0.35	0.17
Btw 2.2 and 2.9*NMW	0.47	0.23	2.05	0.33	0.15
More than 2.9*NMW	0.44	0.20	2.16	0.35	0.16

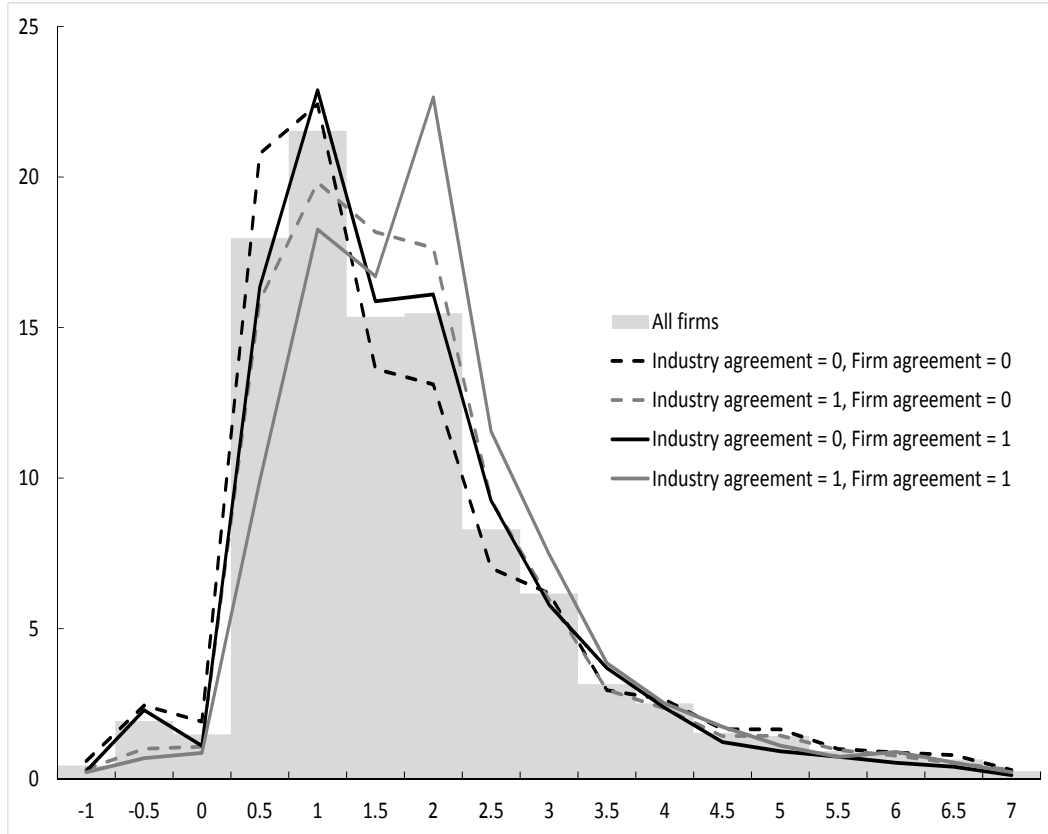
Note: Moments are calculated using the data set matching ACEMO individual data, firm-level and industry-level wage agreements data sets. The first column contains the average quarterly wage changes for all workers of our data set. The second column is the proportion of workers whose wage is modified in a given quarter compare to the previous quarter. The third column is the average wage change conditional on observing a wage change. The fourth and fifth column are the proportions of workers covered in a given quarter either by a firm-level wage agreement or an industry-level agreement. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year. The deciles are the following: 0.97*NMW, 1.04*NMW, 1.12*NMW, 1.2*NMW, 1.3 NMW, 1.5*NMW, 1.6*NMW, 1.9*NMW, 2.2*NMW, 2.9*NMW.

Figure A: Comparison of average wage changes in our sample and aggregate base wage growth (Min of Labour)



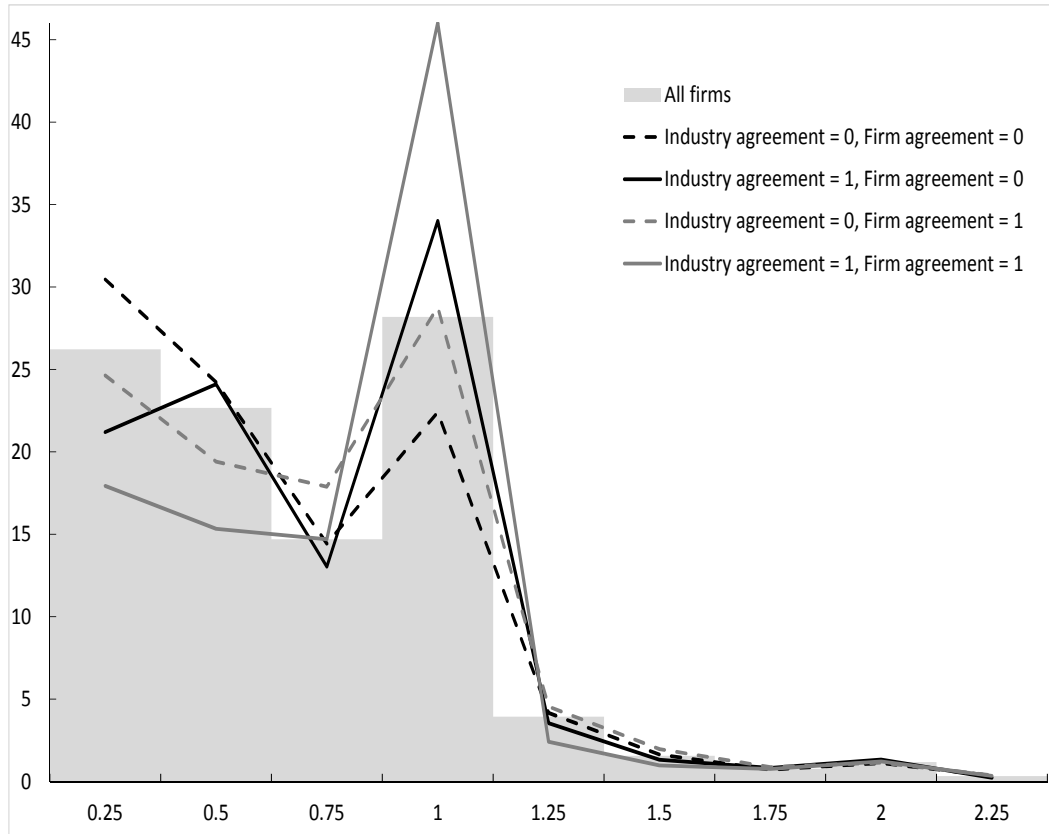
Note: We compute for each quarter the average wage growth as the average of all wage changes of our sample (including 0 change) (weighted or not weighted) and compare this average to the time-series of aggregate base wage growth released by the Ministry of Labour. Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure B: Distribution of wage changes by wage agreement regime



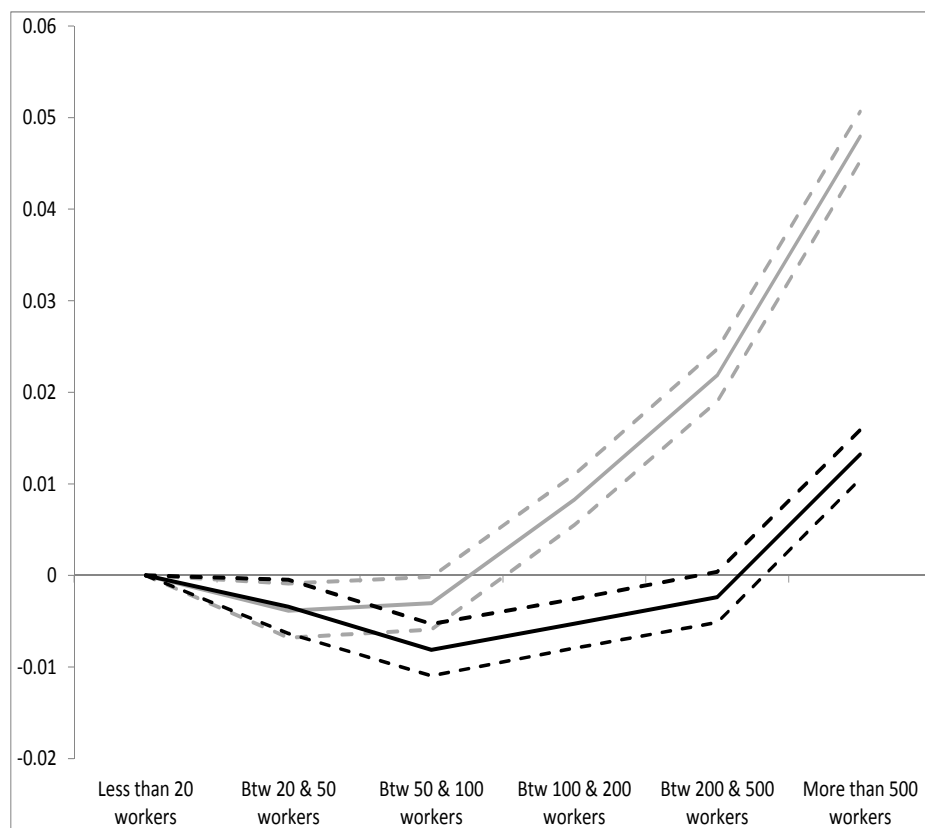
Note: We here compute the distribution of all non-zero wage changes (quarter-on-quarter). We plot the distribution of wage changes considering different bargaining regimes (considering whether to a worker is covered or not by a firm-level or an industry-level agreement). Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure C: Distribution of durations between two wage changes



Note: We here compute the distribution of durations between two wage changes. We plot the distribution of durations considering different bargaining regimes (considering whether to a worker is covered or not by a firm-level or an industry-level agreement). Statistics are weighted using the number of workers corresponding to each category of workers within the firm in a given year.

Figure D: Marginal Effects of the Firm's Size on the Probability of a Wage Change: Including or not Wage Bargaining Variables



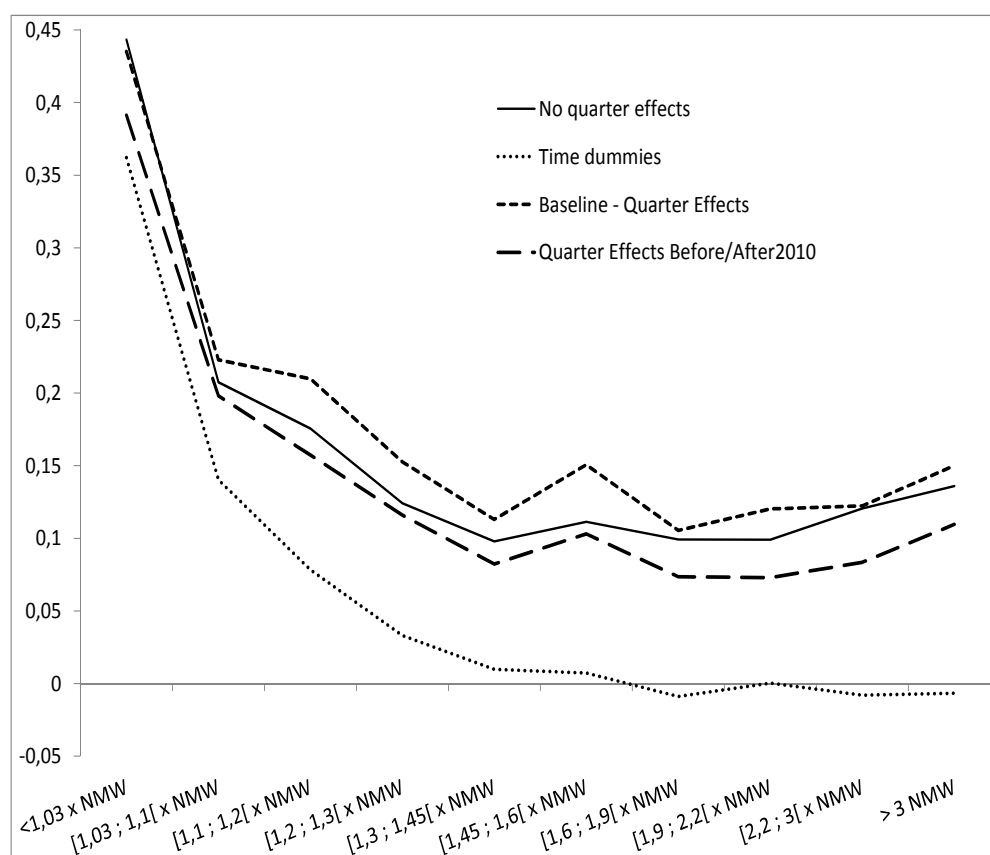
Note: We plot on this graph the marginal effects associated with the dummy variable for firms' size. These marginal effects are obtained from the Probit regression. We here compare marginal effects obtained using the regression without wage bargaining variables (in grey line, confidence intervals are in dashed lines) and the ones obtained including these variables (in black line, confidence intervals are in dashed lines).

Table C: Long-Term Aggregate Indirect and Second-Round Effects - Robustness

	Direct	Indirect (wage floors)	Overall effect (+feedback loop)
<i>Baseline Specification with Quarter Effects</i>			
CPI Inflation	0.221 (0.003)	0.053 (0.015)	0.437 (0.01)
NMW	0.126 (0.011)	0.050 (0.003)	0.192 (0.013)
<i>Robustness</i>			
<i>- No Quarter Effects</i>			
CPI Inflation	0.26 (0.004)	0.057 (0.015)	0.463 (0.012)
NMW	0.107 (0.013)	0.053 (0.003)	0.168 (0.011)
<i>- Quarter effects specific to before/after 2010</i>			
CPI Inflation	0.218 (0.003)	0.049 (0.013)	0.413 (0.003)
NMW	0.101 (0.003)	0.046 (0.003)	0.154 (0.006)
<i>- Time dummies</i>			
CPI Inflation	0.203 (0.003)	0.045 (0.01)	0.339 (0.004)
NMW	0.036 (0.003)	0.042 (0.003)	0.077 (0.002)

Note: This table reports results from simulation exercise described in section 5.1 where we allow wage floors and the NMW to react to changes in CPI and NMW but also to aggregate wage changes due to the response to the shock (feedback loop effects). Column (1) reports direct long run effects coming from the adjustment of wages to shocks under the assumption that wage floors and the NMW are not responding to shocks. Column (2) reports the indirect effect of the shock on base wages coming from the adjustment of wage floors to a given shock. The last column reports the overall effect of the shock on base wages including the direct effect, indirect effect coming from wage floor adjustments and feedback loop effects coming from the adjustment of NMW, wage floor and aggregate wage changes. Confidence interval are provided in brackets and are obtained using bootstrap simulations.

Figure E: Aggregate Wage Effects of the NMW Along the Wage Distribution - Robustness



Note: We plot long-run effects of a 1% increase of the NMW on base wages. These effects are obtained using our simulation exercise where we allow for indirect effects through wage floor adjustment, NMW response and feedback loop effects. Simulations are made using parameter estimates from a Tobit model where all exogenous variables interact with dummy variables corresponding to deciles of the wage distribution. We report separately long run effects including direct, indirect and feedback loop effects. The different lines correspond to different Tobit specifications used for the simulation exercise.

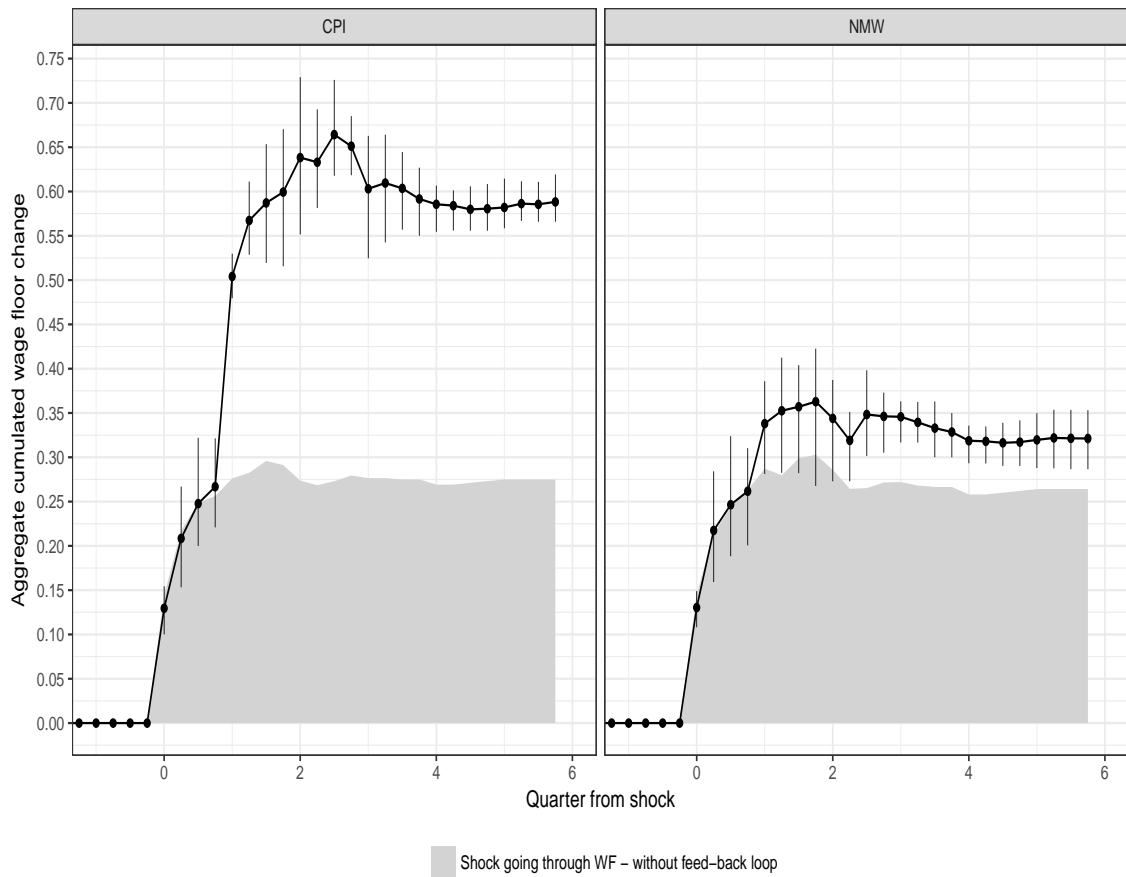
D Sectoral Minimum Wage Adjustment

Table D: Sectoral Minimum Wage Adjustment: Estimation Results

	Probit Marginal effects	OLS Param. Estimates
CPI inflation	0.023*** (0.045)	0.253*** (0.006)
Unemployment	-0.002 (0.002)	0.054*** (0.002)
NMW	0.029*** (0.004)	0.238*** (0.006)
Past aggregate wage changes	0.010** (0.004)	0.312*** (0.014)
Duration 2Q	0.021** (0.010)	
Duration 1Year	0.337*** (0.012)	
Duration 2Years	0.152*** (0.026)	
Mills ratio		0.168*** (0.011)
Time linear trends by industry		YES
Observations	14,049	42,603

Note: We report in this table parameter estimates from the Tobit model estimated on wage floor adjustments. The endogenous variable in the Probit part of the model is a dummy variable for wage agreement in a given industry at date t and in the OLS part the endogenous variable is the wage change for position j in industry i at date t . Determinants are calculated as cumulative variable since the last wage adjustment, all in nominal terms. Controls for sectors and quarters are included. * $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$

Figure F: Aggregate Wage Floor Response to NMW and CPI Shocks



Note: We here report the results of our simulation exercise on wage floors in industry-level agreements. Using our estimated model on wage floors, we simulate two groups of wage floor trajectories, the first one with no shock and the second one with a 1%-increase in macro determinants. We compute the average of all wage floor trajectories by date and the difference between the average with shock and the average with no shock. We plot on this graph the aggregate response over time of wage floors to a 1%-increase in NMW and inflation. We also report confidence intervals using bootstrap simulations.

E Direct, Indirect and Feedback Loop Effects

Figure G: Direct and Indirect Effects of NMW on Wages

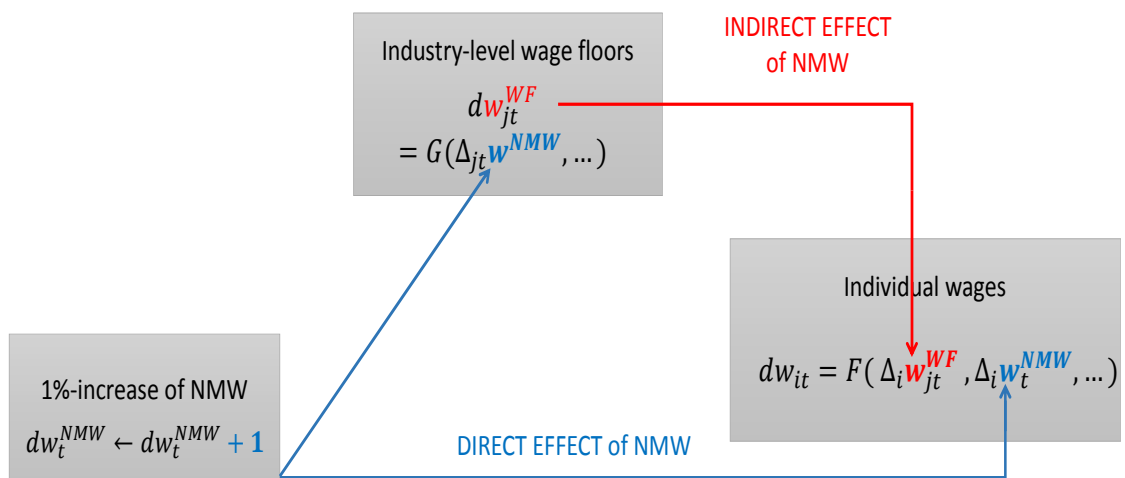
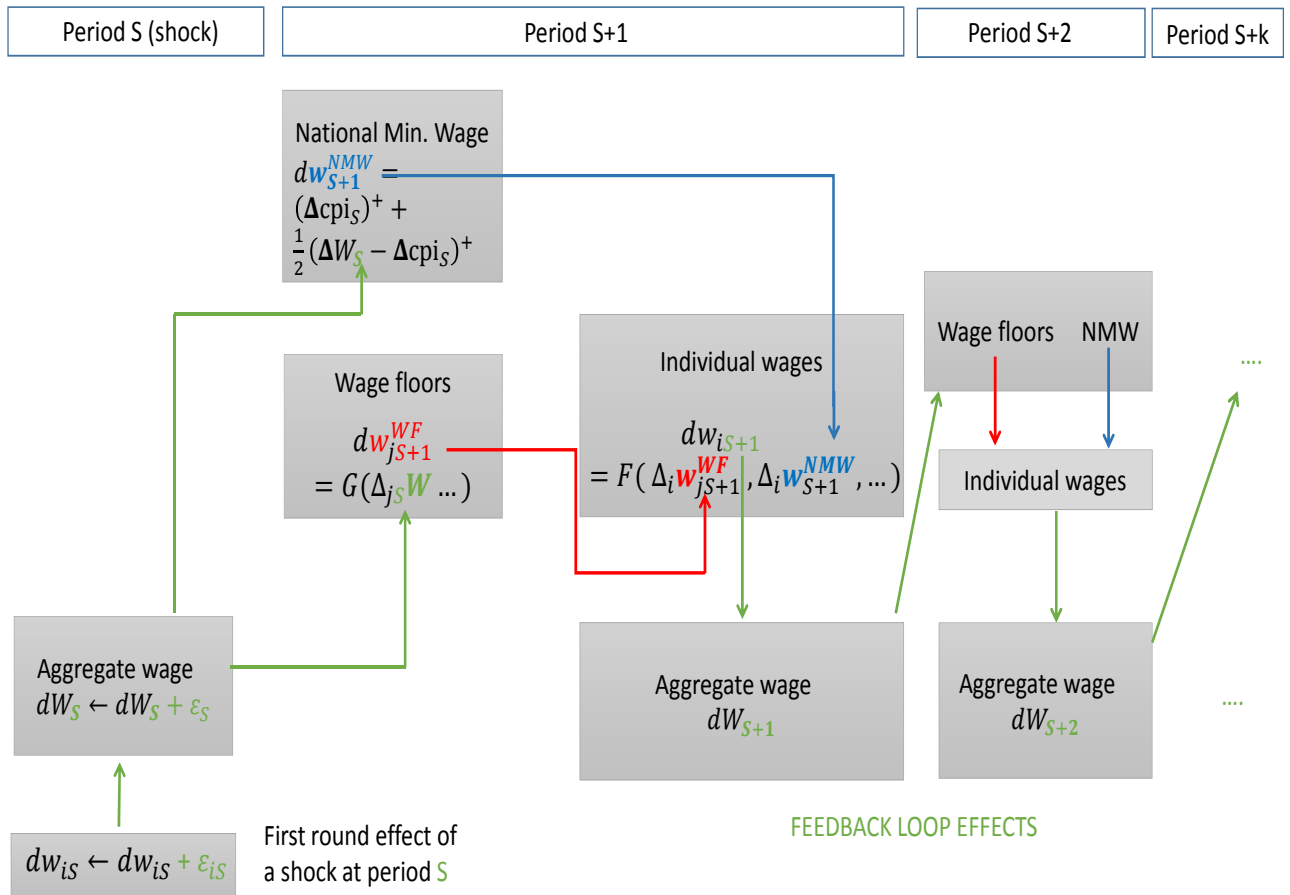


Figure H: Feedback Loop Effects of a Base Wage Increase



F Simulation Exercise: Detailed Algorithms

In this section, we present our simulation setting. We will note

- cpi_t , w_t^{NMW} , w_{jt}^{WF} , w_{it} and W_t , respectively CPI at quarter t , minimum wage at t , wage floor at t for industry and classification j , wage for individual i at quarter t , and aggregated wage W_t .
- The notation dX stands for the quarter-to-quarter variation of X
- The notation ΔX is the cumulated variation of X since last wage change. The wage considered is either the minimum wage, a wage floor or an individual wage depending on the wage variation that the equation defines.

We begin with the full simulation setting without shocks (the reference simulation) in algorithm 1. We show how this algorithm is modified to take shocks into account in algorithm 2. To obtain a setting without feedback loop, we use algorithm 1 without the steps involving the update of W_t and dw_t^{NMW} , that are instead taken as given and therefore not affected by the shock²⁶. To obtain a setting with only direct effects, we use algorithm 1 with the previous alteration and without updating w^{WF} that is taken as given. In this last case, we only set new individual wages with w^{WF} , W , w^{NMW} taken as the observed values and therefore not affected by the shock that only enters directly the equation of individual wages through the specified shock.

²⁶Except when dw_t^{NMW} is explicitly shocked, but it is then computed with observed values plus the value of the shock without further modifications due to the variation of the aggregate wage entering the legal rule.

Algorithm 1 Simulation setting - with indirect effects and feedback loop - NO SHOCK

Require: $\{dcpit\}_{1 \leq t \leq T}$, initial values at $t = 1$ (set at observed values) for all variables and their cumulated sums.

while $t \neq T$ **do**

if NMW is to be updated at t **then**

$$dw_t^{NMW} = \max(\Delta cpi_{t-1}, 0) + \frac{1}{2}(\Delta W_{t-1} - \Delta cpi_{t-1})$$

else

$$dw_t^{NMW} = 0$$

end if

(STEP t) Setting of new wage floors and individual wage changes and update cumulated values for $t + 1$

- Update the cumulated structure of wage floors and individual wages due to current minimum wage change:

$$\begin{aligned}\Delta w_{j,t}^{NMW} &= \Delta w_{j,t}^{NMW} + dw_t^{NMW} \\ \Delta w_{i,t}^{NMW} &= \Delta w_{i,t}^{NMW} + dw_t^{NMW}\end{aligned}$$

- Set new wage floors for industry and job classification j at quarter t :

$dw_{jt}^{WF} = F(\Delta_j cpi_t, \Delta_j w_t^{NMW}, \Delta_j W_{t-1}, \dots)$ as specified in the Tobit model for wage floors (see Table D)

- Update the cumulated structure of wage floors at the individual level:

$$\Delta w_{i,t}^{WF} = \Delta w_{i,t}^{WF} + dw_{j(i)t}^{WF}$$

- Set new individual wages for i in industry and job classification j :

$dw_{it} = G(\Delta cpi_{it}, \Delta w_{it}^{WF}, \Delta w_{it}^{NMW}, \dots)$ as specified by the Tobit model described in Section 4.1

dW_t is set to the weighted mean of dw_{it}

- According to dw_{jt}^{WF} , update cumulated structure at $t + 1$ for wage floors for X_t in CPI_t, W_{t-1} :

$$\Delta X_{j,t+1} = (\Delta X_{j,t} + dX_{j,t+1}) \times 1\{dw_{jt}^{WF} = 0\} + dX_{j,t+1} \times 1\{dw_{jt}^{WF} \neq 0\}$$

- According to dw_{jt}^{WF} , update cumulated structure at $t + 1$ for wage floors for $X_t = w_t^{NMW}$ (dw_{i+1}^{NMW} is still to be determined):

$$\Delta X_{j,t+1} = (\Delta X_{j,t}) \times 1\{dw_{jt}^{WF} = 0\}$$

- According to dw_{it} , update cumulated structure at $t + 1$ for individual wages, except for $X \notin w^{WF}, w^{NMW}$:

$$\Delta X_{i,t+1} = (\Delta X_{i,t} + dX_{i,t+1}) \times 1\{dw_{it} = 0\} + dX_{i,t+1} \times 1\{dw_{it} \neq 0\}$$

- For $X \in w^{WF}, w^{NMW}$ (dw_{t+1}^{WF} and dw_{t+1}^{NMW} are still to be determined):

$$\Delta X_{i,t+1} = (\Delta X_{i,t}) \times 1\{dw_{it} = 0\}$$

end while

Algorithm 2 Simulation setting - with indirect effects and feedback loop - WITH SHOCK

Require: $\{dcpit\}_{1 \leq t \leq T}$, t_s time of shock, shocked variable $\in \{CPI, NMW\}$, value of the shock K , and initial values at $t = 1$ (set at observed values) for all variables and their cumulated sums.

if Shocked variable is CPI **then**

$$dcpit_s = dcpit_s + K$$

end if

while $t \neq T$ **do**

if NMW is to be updated at t **then**

$$dw_t^{NMW} = \max(\Delta cpi_{t-1}, 0) + \frac{1}{2}(\Delta W_{t-1} - \Delta cpi_{t-1})$$

else

$$dw_t^{NMW} = 0$$

end if

if $t = t_s$ and shocked variable is NMW **then**

$$dw_t^{NMW} = dw_t^{NMW} + K$$

end if

(STEP t) Setting of new wage floors and individual wage changes and update cumulated values for $t + 1$ as defined in algorithm 1.

end while
