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The role of wage bargaining institutions in the Phillips curve flattening★,★★

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Abstract

We investigate the role of collective wage bargaining institutions on the relationship between wage growth and unemployment, that is, the wage Phillips curve. Based on a labour market model with frictions and collective bargaining, we hypothesize that when the economy deteriorates, wages fall less in parts of the economy covered by collective wage agreements negotiated by trade unions at a centralized level than in economies with bargaining fully decentralized within companies. We move from theory to empirical analysis using regional NUTS-2 data from European countries, which show evidence that the wage Phillips curve flattens when unemployment is high — and gets steeper when the labor market is overheated —, in economies where the sectoral or cross-sectoral levels play a role in the collective wage bargaining. We also find that from a level of centralization intermediate between the company and the sector levels, the wage Phillips curve is twice as flat.

Keywords: Phillips curve, Unemployment, Inflation, Wages, Collective bargaining
JEL: E24, E31, E32, J50

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1. Introduction

During the last decade, the literature has been enriched by several works and debates on the theoretical relevance of the Phillips curve (hereafter PC), showing the latter is — once again — under the spotlight. Although the negative trade-off between inflation and unemployment was already non-existent in the 1970s following the oil crises, some empirical observations over the last decade show the relationship between unemployment and inflation seems to no longer exist in some developed countries, resulting in a so-called "flattened Phillips curve", i.e. less sensitivity of inflation to unemployment. Particularly noteworthy phenomena were the *missing deflation* during the Great Recession (large contraction in GDP with a strong increase in the unemployment rate, but only a small drop in core inflation) and the *missing inflation* during the recovery (an unemployment rate that has reached historically low levels but no high inflation).[1]

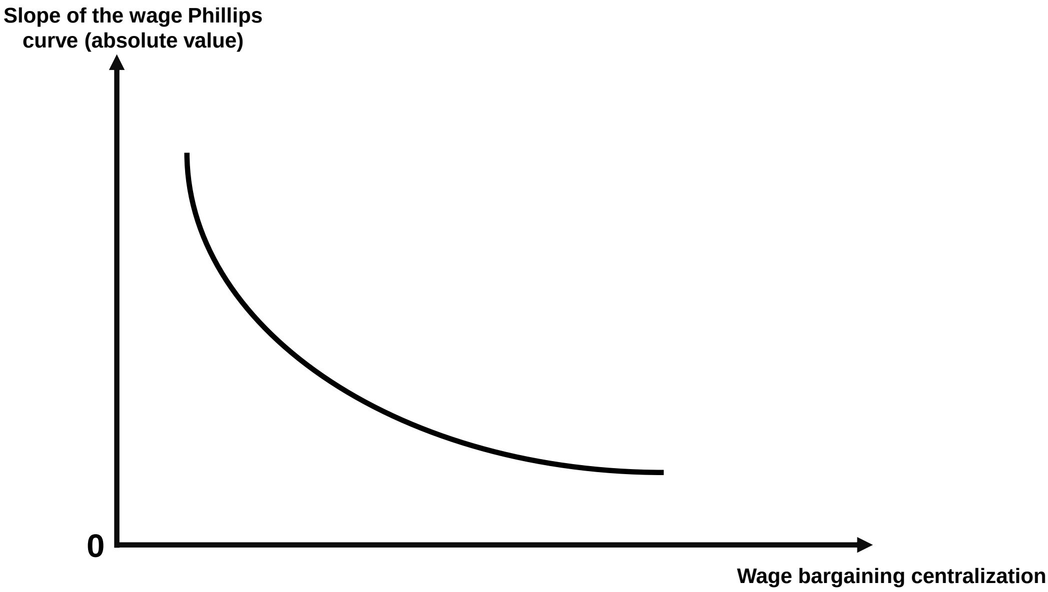
Several explanations have been put forward, suggesting a range of factors that flatten the Phillips curve: the growing credibility of monetary policy that anchors inflation expectations (Bernanke et al., 2010; Blanchard, 2016; Ball and Mazumder, 2019); structural changes such as demography, involving composition effects in the workforce, for example baby boomers replaced by new entrants with lower wages (Daly et al., 2016; Yellen, 2017); and globalization (Forbes et al., 2021). The puzzles of missing inflation or missing deflation can also be solved by specifying the PC using other indicators, namely, consumers' inflation expectations instead of forecasters' ones (Coibion and Gorodnichenko, 2015), short-term unemployment instead of total unemployment (Ball and Mazumder, 2019), or well-measured and domestically determined inflation components instead of poorly measured and internationally determined ones (Stock and Watson, 2020).

Instead of disappearing, the PC seems to be characterized by nonlinearities and threshold effects linked to the inflation regime and the rigidity of prices and wages (Akerlof et al., 1996; Benigno and Ricci, 2011; Fuhrer et al., 2012; Daly and Hobijn, 2014; Hooper et al., 2020; Forbes et al., 2021; Benigno and Rossi, 2021). Specifically, Gagnon and Collins (2019) that downwardly rigid wages bend the PC. Thanks to a DSGE model, Iwasaki et al. (2021) introduce downward wage rigidity (hereafter DWR) through an asymmetric wage cost function and empirically show DWR is essential to explain the flattening of the PC. **In this paper, we follow this research avenue and explore one potential source of DWR by focusing on the role of wage bargaining institutions in shaping the wage PC slope and curvature.** Our analysis focuses on the wage PC because it is directly related to collective wage bargaining systems and less influenced by other factors (e.g., the degree of competition in the product market) as the price PC may be. More specifically, we decompose our analysis into three assumptions: (i) the wage PC is steeper in economies with fully decentralized wage bargaining; (ii) the wage PC is flat in economies with industry or cross-industry levels of wage bargaining; and (iii) the influence of wage bargaining institutions on the link between unemployment and wage growth is mainly observed in periods of high unemployment, because of DWR. Our testable assumptions are schematized in the Figure 1.

To provide a theoretical framework for these assumptions, we propose a model of equilibrium unemployment with frictions *à la Mortensen-Pissarides*, including firms whose workers are paid

[1] See for example Friedrich (2016) about the missing deflation puzzle, and, International Monetary Fund (2017) and Iwasaki et al. (2021) about the missing inflation puzzle. For a focus on the euro area, see Riggi and Venditti (2015) and Ciccarelli et al. (2017).

Figure 1: A simple scheme of testable assumptions (slack labor market)



with wages set at the individual level (fully decentralized) and firms that are covered by collective wage agreements negotiated at a centralized level.[2] The model allows us to analyze the dynamics of bargained wages according to the level of centralization when the state of the economy deteriorates. Our model shows that under few conditions (relatively high productivity and elasticity of the matching function), an economic recession leads to a smaller decline in wages in firms covered by a collective wage agreement than in the uncovered firms, due to the reallocation of workers and positive externalities linked to the coverage of firms by collective agreements.

As a second stage, we conducted an empirical investigation to find evidence that would corroborate our assumptions and the main result of our theoretical model. Relying on European regional data (NUTS-2) merged with the ICTWSS database describing the centralization of wage bargaining in each country, we use spatial and temporal heterogeneity between the collective bargaining systems of European countries to investigate the role of wage bargaining centralization on the slope and curvature of the wage PC. Such data with a common central bank mitigate the endogeneity bias of monetary policy and offers a large variability in the dataset allowing easy observations of the wage PC, as used by Levy (2019), McLeay and Tenreyro (2020), and Hooper et al. (2020). We exploit these data using a system GMM approach (Blundell and Bond, 1998) to take into account possible endogeneity problems, particularly with respect to the dynamic specification of the wage PC. We find evidence showing wage growth is more sustained when wage bargaining takes place mainly at rather centralized levels (i.e., when the sectoral and/or cross-sectoral levels play a role) compared with decentralized bargaining systems. We find that higher levels of wage bargaining

[2] Ravenna and Walsh (2008) explore the role of labor market frictions in a New Keynesian model and explains the search-friction Calvo model of Krause et al. (2008) is too stylized to fully describe the dynamics of the marginal costs of the firms.

centralization reduce the slope of the wage PC when unemployment is high. By contrast, when the unemployment gap is negative, that is, when the labor market is overheated, the wage PC is steeper for higher levels of centralization, meaning unions and collective bargaining are more able to take advantage of a tight labor market in terms of wage increases than decentralized bargaining. In other words, in economies with rather high unemployment, collective bargaining flattens the PC, whereas it makes it steeper (more vertical) when unemployment is low.

By characterizing DWR through collective bargaining, we deepen the findings of Gagnon and Collins (2019) and Forbes et al. (2021), who show wage and price rigidities are a relevant explanation for the flattening of the PC in periods of economic slowdown and when inflation is low. The rationale behind our assumptions is the following. Wage rigidities are widely recognized as a consequence of labor market institutions, in particular, trade unions' behavior and collective bargaining. They could therefore be a factor shaping the wage PC and influencing the price PC. For instance, D'Adamo and Rovelli (2015) present evidence that more prominent labor market institutions (including more wage coordination and higher union density) flatten the Phillips curve. Stansbury and Summers (2020) highlight the decline in the bargaining power of US workers relative to that of employers as an explanation for low wage growth in good labor market conditions and thus the broken relationship between unemployment and inflation. Indeed, if wage growth is slow, it may struggle to cover productivity growth, which would make exerting upward pressure on prices impossible. However, regardless of country and despite a declining bargaining power, unions still generate a wage premium, namely, difference in wages linked to the existence of trade unions and collective agreements compared with a situation without this institutional framework (Bryson, 2014). Empirical evidence reveals the wage premium depends on the features of the collective bargaining system, including the coverage of collective agreements and the level of centralization at which bargaining takes place (Gürtzgen, 2009; Dahl et al., 2013). Wages are more likely to be adjusted downwards during recessions in economies where bargaining takes place closer to the company level and/or collective agreements are not automatically extended to all workers in an industry (Aidt and Tzannatos, 2008; Gnocchi et al., 2015; Villanueva and Adamopoulou, 2022). By contrast, DWR is stronger in countries with a high union density and centralized wage setting (Holden and Wulfsberg, 2014). France and Italy are striking examples. Although the French labor market is characterized by "multi-employer" bargaining, namely, employers and trade unions that set collective agreements at the national or sectoral level, wage floors are quite rigid, adjusting only once a year on average (Fougère et al., 2018) and real wages have grown at a steady pace in a period of low price inflation started in 2013 despite the high level of unemployment (Gautier et al., 2019). Bulligan and Viviano (2017) argue on the basis of European data that the introduction of flexible wage schemes during the Great Recession in some countries (e.g., Italy) made the wage PC steeper.

Understanding the role played by wage bargaining institutions in the wage PC is essential to inform decisions of central bankers. Our empirical results have economic policy implications, because they suggest the central bank should incorporate the characteristics of collective bargaining in the labor market when designing monetary strategy.

The paper proceeds as follows. Section 2 proposes a theoretical model. Section 3 details the data used in our empirical investigation, our empirical methodology, and the main results. Section 4 concludes.

2. Labour market model with collective wage agreements

To formalize our questions, we explain the link between wage dynamics and bargaining centralization using a labor market model with matching and frictions *à la Mortensen-Pissarides* (Mortensen and Pissarides, 1994, 1999). We integrate (i) wage negotiations at the sectoral level leading to collective agreements covering some of the firms in the economy and (ii) fully decentralized negotiations at the firm level for firms not covered. This model is useful to study wages' variation following a negative economic shock according to the level of wage bargaining.

2.1. Model setup

Time is continuous with an infinite horizon. The economy is composed of a labor market with a unit mass of risk-neutral workers and a mass of risk-neutral firms. They discount the future at an exogenous rate $r > 0$. Each firm offers one job. This job may be vacant, in which case, the firm incurs a cost $\kappa > 0$ that corresponds to the search cost of a worker in a market with frictions. The job may also be occupied by a worker, in which case, it produces goods at a level of productivity x. Productive jobs are destroyed at the exogenous rate $\delta > 0$.

Frictions in the labor market induce the coexistence of unemployed workers and job vacancies. The number of matches is captured by the matching function $m = m(u, v) = u^{1-\alpha}v^{\alpha}$, where u is the number of unemployed workers, v is the number of job vacancies, and $\alpha \in [0, 1]$ the elasticity. The matching efficiency is assumed to be 1. The function m is continuous, non-negative, increasing in u and v, homogeneous of degree 1, and checks $m(0, v) = m(u, 0) = 0$. Only the unemployed are looking for a job; no on-the-job search occurs. Search intensity is constant and exogenous. The constant-returns assumption enables derviation of the matching probability

— for job vacancies: $q(\theta) \equiv \dfrac{m(u,v)}{v} = \dfrac{u^{1-\alpha}v^{\alpha}}{v} = \dfrac{v^{\alpha-1}}{u^{\alpha-1}} = \theta^{\alpha-1} \quad ; q'(\theta) \leq 0$

— for unemployed workers: $f(\theta) \equiv \dfrac{m(u,v)}{u} = \dfrac{v^{\alpha}}{u^{\alpha}} = \theta^{\alpha} \quad ; f'(\theta) \geq 0$

with $\theta = \dfrac{v}{u}$ denoting the labor market tightness. A higher labor market tightness implies either more vacancies for a given number of unemployed persons or fewer unemployed persons for a given number of vacancies. In both situations, the chances for an unemployed person to find a vacancy is greater; thus, the duration of unemployment is shorter.

Firms operate in an institutionalized labor market where some of them set their wages through collective bargaining at the sector level. More precisely, two types of firms exist: (i) firms participating in collective bargaining and covered by a collective agreement on wages set at the industry level and (ii) firms excluded from collective bargaining and not covered. We denote by $b = \{c, nc\}$ the covered and non-covered firms, respectively.

For ease of analysis, we assume the covered and uncovered parts of the labor market correspond to two different labor markets. The total level of employment in the economy is noted as $l = l_c + l_{nc}$, with l_c being the employment among covered firms and l_{nc} being non-covered firms. Let ϕ denote the share l_c/l corresponding to the proportion of covered employment in the total employment. At the steady state, in each labor market, the number of new jobs created must be equal to the number of jobs destroyed, for example, $u_c f(\theta_c) = \phi l\delta$ and $u_{nc} f(\theta_{nc}) = (1-\phi)l\delta$, with u_b denoting the level of unemployment in the labor market b. Knowing $l + u_c + u_{nc} = 1$, we can derive the steady-state level of employment as

$$l = l_c + l_{nc} = \frac{(\theta_c\theta_{nc})^\alpha}{(\theta_c\theta_{nc})^\alpha + \delta\phi\theta_{nc}^\alpha + \delta(1-\phi)\theta_c^\alpha} \tag{1}$$

See Appendix A.1 for details.

Value functions

Firms. For a firm, the present-discounted value of a job's expected profit depends on its state. Let J_b^v be the value of a vacant job. It satisfies

$$rJ_b^V = -\kappa + q(\theta_b)\left[J_b^E - J_b^V\right] \tag{2}$$

At each moment in time, a vacant job implies a search cost $\kappa > 0$ for the firm. A vacant job matches an unemployed worker with the probability $q(\theta_b)$. In the event of a match, the firm would gain the difference between the value of a productive job and the value of a vacant job $J_b^E - J_b^V$.

For a covered firm, the value of a filled job satisfies

$$rJ_c^E = x\,(1 + l_c) - w_c + \delta\left[J_c^V - J_c^E\right] \tag{3}$$

Each filled job provides to the employer a value equals to the sum of the instantaneous profit $x\,(1 + l_c) - w_c$ and the average gain related to a change in the job's state $\delta\left[J_c^V - J_c^E\right]$. We denote w_c as the wage, which is set by a collective agreement negotiated between employers' federation and trade unions at the sectoral level. The productivity of a firm covered by a collective wage agreement is positively correlated with the proportion of firms covered in the economy, l_c, indicating the existence of positive externalities linked to participation in collective bargaining. We justify this positive externality with the stylized fact that collective bargaining and workers' voice contribute positively to the improvement in job quality and productivity. Indeed, participation in collective bargaining implies the existence of firm-level workers' representatives trained in trade union bodies, who provide support, guidance, and training for workers. This participation reduces labor turnover, absenteeism, and health problems, all favoring productivity (Cazes et al., 2019). Recent empirical evidence points to a positive causal link between the presence of unions/worker representatives in firms and productivity (Morikawa, 2010; Barth et al., 2020).

For a non-covered firm, the value of a filled job satisfies

$$rJ_{nc}^E = x - w_{nc} + \delta\left[J_{nc}^V - J_{nc}^E\right] \tag{4}$$

For non-covered firms, each productive job provides to the employer a value equals to the sum of the instantaneous profit $x - w_c$ and the average gain related to a change in the job's state $\delta\left[J_{nc}^V - J_{nc}^E\right]$. We denote w_{nc} as the wage bargained for the match at the firm level.

Workers. The expected income stream of an unemployed worker satisfies

$$rW_b^U = z + f(\theta_b)\left[W_b^E - W_b^U\right] \tag{5}$$

Unemployed workers are actively seeking a job. At each moment, they receive a net gain z from unemployment benefits and expect to move into employment with probability $f(\theta_b)$. In the event of a match, unemployed workers earn the difference between the value of being a new worker and the value of being unemployed $W_b^E - W_b^U$.

The expected income stream of a worker in a starting job satisfies

$$rW_b^E = w_b + \delta\left[W_b^U - W_b^E\right] \tag{6}$$

Hired workers earn a wage w_b, the amount of which is either derived from the collective wage agreement (w_c) or negotiated with the employer at the firm level (w_{nc}). They face the risk of having their jobs destroyed at the rate δ and therefore getting the value $W_b^U - W_b^E$.

We assume unemployed workers search randomly between both labor markets. This assumption implies an arbitrage condition ensuring $W_c^U = W_{nc}^U$. Using Eq. (5) and Eq. (6), we obtain the following expression:

$$\theta_c^\alpha \frac{w_c - z}{r + \theta_c^\alpha + \delta} = \theta_{nc}^\alpha \frac{w_{nc} - z}{r + \theta_{nc}^\alpha + \delta} \tag{7}$$

See Appendix A.2 for details.

Both sides of the equation (7) are increasing in θ_b^α, which implies that the part of the economy covered by a collective agreement — or not covered — cannot exhibit both a higher job-finding rate and higher wages, because such a scenario would not satisfy the arbitrage condition.

2.2. Wage determination

Decentralized wage bargaining

At the decentralized level (firm level), the worker bargains directly with the employer. If an agreement is reached, the worker will earn the negotiated wage and the employer will receive the production value of a filled job. If negotiation fails, the worker will remain unemployed and earn the equivalent compensation (z), while the employer will continue to bear the cost of a vacant job (κ). The wage agreement shares the local surplus by solving the following Nash maximization problem:

$$w_{nc} = argmax\left[W_{nc}^E - W_{nc}^U\right]^\gamma \left[J_{nc}^E - J_{nc}^V\right]^{1-\gamma} \tag{8}$$

where $\gamma \in [0, 1]$ denotes the worker's bargaining power.

Solving the maximization problem results in the following Nash sharing rule:

$$\gamma\left(J_{nc}^E - J_{nc}^V\right) = (1-\gamma)\left(W_{nc}^E - W_{nc}^U\right) \tag{9}$$

After some manipulations, we obtain the following equation for the decentralized wage agreement in equilibrium:

$$w_{nc} = \gamma x + \gamma\kappa + (1-\gamma)z \tag{10}$$

Collective wage bargaining

Unions and firms bargain over the wage that will be applied to all firms covered by the wage agreement. The Nash-bargained wage agreement results from the maximization of the product of the net gain of agreement for both parties.

Unions' gain and fallback position in bargaining. Trade unions' utility, denoted W^{TU}, is the wage agreement multiplied by the number of firms covered by the agreement, such as $rW^{TU} = l_c\, w_c$. In case of disagreement, workers of covered firms enjoy an instantaneous utility equal to the value of the unemployment benefit, as $r\overline{W}^{TU} = l_c\, z$.

Employers' gain and fallback position in bargaining. If an agreement is reached, the employers' federation, which represent the sum of all covered firms, obtains the utility $rJ^F = l_c\,[x(1+l_c)-w_c]$, corresponding to the number of covered firms multiplied by the net gain of a filled job. If no agreement is reached, each firm has to bear the vacancy cost κ, implying the employers' federation utility is $r\overline{J}^F = -\,l_c\,\kappa$.

The collective wage agreement maximizes the product of the trade unions' and the firm's surplus, such that

$$w_c = argmax \left[W^{TU} - \overline{W}^{TU}\right]^{\beta} \left[J^F - \overline{J}^F\right]^{1-\beta} \tag{11}$$

where $\beta \in [0, 1]$ denotes the trade unions' bargaining power.

The maximization problem results in the following Nash sharing rule:

$$\beta\left(J^F - \overline{J}^F\right) = (1-\beta)\left(W^{TU} - \overline{W}^{TU}\right) \tag{12}$$

After some manipulations, we obtain the following equation for the collective wage agreement in equilibrium:

$$w_c = \beta x(1 + l_c) + \beta\kappa + (1-\beta)z \tag{13}$$

2.3. Equilibrium and wage dynamics

Job-creation condition

The number of jobs is determined by firms according to the expected profit from a new vacancy. Assuming free entry, the firm creates a vacancy as soon as the value of a vacancy is positive. At equilibrium, neither firm enters the market and creates a vacancy, implying all rents from a new vacancy creation are zero ($J_b^V = 0$). Integrating this condition in the value of a vacant job [Eq. (2)] leads to

$$J_b^E = \frac{\kappa}{\theta_b^{\alpha-1}} \tag{14}$$

Job-creation condition in non-covered part of the economy. By inserting Eq. (14) into the value of a filled job for a non-covered firm [Eq. (4)], and after some manipulations, we obtain the job-creation condition:

$$(r+\delta)\frac{\kappa}{\theta_{nc}^{\alpha-1}} = x - w_c \tag{15}$$

Job-creation condition in covered part of the economy. In a symmetrical way, we insert Eq. (14) into the value of a filled job for a covered firm [Eq. (3)], and after some manipulations, we get

$$(r+\delta)\frac{\kappa}{\theta_c^{\alpha-1}} = x(1+l_c) - w_c \tag{16}$$

The job-creation condition implies the average cost of a vacant job (LHS) and the expected profit of a newly created job (RHS) must be equal. The average cost of a vacant job increases with labor market tightness: greater tightness reduces the probability of finding an unemployed worker for a job vacancy and therefore makes vacancies last longer and increases their average cost. The expected profit from a newly occupied job decreases as the labor market becomes tighter: greater tightness enables for unemployed workers to find a job more easily, and therefore improves their position and their reservation wage.

Equilibrium

The equilibrium of the economy is entirely described by the following six equations, where the endogenous variables correspond to the set $(w_c, w_{nc}, \theta_c, \theta_{nc}, l_c, l_{nc})$:

(i) The wage rules in companies covered (c) or not (nc) by a collective wage agreement are as follows:

$$w_c = \beta x(1+l_c) + \beta\kappa + (1-\beta)z \tag{17}$$

$$w_{nc} = \gamma x + \gamma\kappa + (1-\gamma)z \tag{18}$$

(ii) The job-creation curves in covered (c) and non-covered (nc) companies are as follows:

$$(r+\delta)\frac{\kappa}{\theta_c^{\alpha-1}} = x(1+l_c) - w_c \tag{19}$$

$$(r+\delta)\frac{\kappa}{\theta_{nc}^{\alpha-1}} = x - w_{nc} \tag{20}$$

(iii) The arbitration condition results in the following equality in equilibrium:

$$\theta_c^{\alpha}\frac{w_c - z}{r+\theta_c^{\alpha}+\delta} = \theta_{nc}^{\alpha}\frac{w_{nc} - z}{r+\theta_{nc}^{\alpha}+\delta} \tag{21}$$

(iii) The steady-state level of total employment is

$$l = l_c + l_{nc} = \frac{(\theta_c\theta_{nc})^{\alpha}}{(\theta_c\theta_{nc})^{\alpha} + \delta\phi\theta_{nc}^{\alpha} + \delta(1-\phi)\theta_c^{\alpha}} \tag{22}$$

By performing some manipulations, we can reduce our model to two equations and two variables. Indeed, from Eq. (18), we note $w_{nc} = \bar{w}_{nc}$ does not depend on any endogenous variable, so Eq. (20) yields a constant labor market tightness in non-covered firms:

$$\theta_{nc} = \left[\frac{x - w_{nc}}{\kappa(r+\delta)}\right]^{\frac{1}{1-\alpha}} = \bar{\theta}_{nc} \tag{23}$$

Inserting relations (17) and (18) into Eq. (21) leads to a first relation between the level of employment l_c and the labor market tightness θ_c into the covered portion of the firms[3]:

$$l_c = h(\theta_c) = \frac{r + \delta + \theta_c^\alpha}{\beta x \theta_c^\alpha} \cdot \Omega_1 - \frac{\kappa - z}{x} - 1, \quad \text{with } h'(\theta_c) < 0 \tag{24}$$

The second equation simply comes from substitution of Eq. (17) into relation (19), which leads to:

$$l_c = g(\theta_c) = \frac{\kappa(r + \delta)\theta_c^{1-\alpha} + \beta\kappa + (1 - \beta)z}{x(1 - \beta)} - 1 \quad \text{with } g'(\theta_c) > 0 \tag{25}$$

Proposition 1. The economy at its steady state corresponds to a solution (l_c, θ_c) obtained by $h(\theta_c) = g(\theta_c)$, where $h(\theta_c)$ and $g(\theta_c)$ are respectively defined by relations (24) and (25). This equilibrium exists and is unique.

Proof: See Appendix A.4.

Wage dynamics in economic recession by type of wage negotiation

Having determined the equilibrium of the economy, we can analyze the consequences of an economic recession on the labor market. The main objective is to see how wages in the covered and uncovered parts evolve following the recession, as well as to determine the respective extent of these variations. To do so, we assume an economic recession results in a negative productivity shock, $dx < 0$.

Proposition 2. Assuming α arbitrarily close to 1, an economic recession leads to:

(i) a reduction in the tightness of both parts of the labor market (covered and uncovered): $d\theta_c/dx > 0$ and $d\theta_{nc}/dx > 0$;

(ii) a decrease in wages in both parts of the labor market (covered and uncovered): $dw_c/dx > 0$ and $dw_{nc}/dx > 0$;

(iii) an increase in covered employment ($dl_c/dx < 0$) and a decrease in uncovered employment ($dl_{nc}/dx > 0$); and

(iv) a decrease in the total employment (or increase of unemployment): $dl/dx > 0$

Proof: See Appendix A.5.

Assume an economic recession characterized by $dx < 0$, corresponding to a decrease in production in each firm. In the part of the labor market not covered by collective agreements, we observe a decline in wages and employment. Indeed, facing a decline in labor demand following the recession, workers are compelled to accept simultaneous reductions in employment and wages. In particular, the wage reduction can be seen directly in relation (18).

In the covered part of the labor market, the decrease in the employers' demand for labor also results in a decrease in wages: trade unions have to lower their wage claims. Nevertheless, unlike in the uncovered part of the labor market, employment increases. This positive effect on employment

[3] See Appendix A.3.

has two explanations: (i) lowering wages allows employers to avoid layoffs and (ii) a higher level of employment avoids the fall in labor productivity in the covered sector due to positive externalities. More formally, Eq. (17) shows aggregate productivity in the covered sector is the product of the individual productivity of worker x and the quantity of employment $1 + l_c$. Thus, in case of a decline in individual productivity x, maintaining a high level of employment avoids a decline in global productivity.

In brief, the recession leads to a reallocation of jobs between the covered and uncovered sectors, leading to an increase in the share of covered jobs at the expense of uncovered jobs, but without compensating for the destruction of uncovered jobs. The recession therefore results in an increase in unemployment, that is, a decrease in total employment l.

Proposition 3. Assuming productivity is arbitrarily high, a recession leads to a smaller decline in wages in firms covered by a collective wage agreement than in uncovered firms: $|dw_c/dx| < |dw_{nc}/dx|$.

Proof: See Appendix A.6.

Wages in covered firms decrease less than in uncovered firms in case of a symmetric economic shock. Indeed, the wage resulting from the collective agreement w_c depends on the coverage of the agreements l_c due to our assumption of positive labor externalities (network between firms, access to training for workers, etc.). However, when productivity declines, job creation (rise of l_c) attenuates the decrease in wage w_c. In other words, the ability of collective agreements to mitigate the decrease in wages during a bad economic situation relative to individual agreements ($|dw_c/dx| < |dw_{nc}/dx|$) makes employment in firms covered by a collective agreement more attractive. The assumption of high productivity may refer to industrial firms, rather than firms in the service sector, where productivity gains are generally lower (Sorbe et al., 2018).

3. Empirical Investigation

From Theory to Data. We conduct an empirical investigation to find evidence to support our intuitions about the relationship between collective bargaining and the slope of the PC, summarized in Figure 1 and formalized in Proposition 3 from Section 2. As a reminder, we seek to see if the data confirm that a higher level of centralized collective wage bargaining flattens the wage PC when unemployment is high.

3.1. Data

Our empirical investigation relies on a regional-level (NUTS-2) yearly dataset for 280 European regions ($N = 280$) in 30 countries over the period 1995-2019 ($T = 25$), with gaps in observations for several regions.[4] We use regional-level data for two main reasons: to increase the variability in our dataset and because the (price or wage) PC seems to be more easily observed using disaggregated data (Levy, 2019; Hooper et al., 2020).

Data on the usual determinants of the Wage Phillips curve. We focus on the wage growth because price data are not available at the regional level for European regions. We construct wage growth using the hourly wage, which is the total compensation paid to employees divided by the

[4]Details of the regions by country are available in Appendix B.1.

number of hours worked.[5] To represent labor market slack, we use the unemployment gap, which is constructed by subtracting the regional mean of the unemployment rate over the period from the actual unemployment rate.[6] Therefore, a growing positive unemployment gap corresponds to a deterioration in the labor market's state. We also use the growth of gross value added to account for the output growth in the region and as a proxy for productivity gains. Indeed, even if the correlation between productivity growth and wage growth is not one-to-one, a positive and significant relationship exists between the two (Pasimeni, 2018). We include variables representing the respective shares of industry, construction, and agriculture in value added, to control for sectoral heterogeneity between regions in terms of the productive fabric. Finally, we add two variables representing the shares of the population aged 25-64 with a low level of education (max lower secondary education) and with a medium level of education (max post-secondary), respectively. They represent a proxy for the quality of the workforce available in the region, which is a potential determinant of wage growth.

Data on the collective bargaining centralization. We consider two indicators of the importance of collective bargaining centralization, both representing more centralized collective bargaining as their value increases:

- LEVEL, which is a discrete measure on a 0-4 scale representing the predominant level where bargaining takes place in terms of workers' coverage (e.g., firm-level, mixed situation between firm-level and sector-level, sector-level, and cross-sectoral-level with a role of the sectoral level in some cases).

- BARGCENT, which is a composite variable taking into account the predominant level of wage bargaining and the flexibility for firm-level bargaining, if any. This flexibility captures the incidence of additional enterprise bargaining, weighted by the control of unions that signed "higher- order" agreements, the "hierarchical ordering" of agreements, the tightness of wage norms in central and sectoral agreements, and the incidence of general and temporary opening. BARGCENT is constructed from the variable LEVEL and can therefore be considered a more comprehensive indicator of the centralization of negotiations, because it takes into account possible decentralization mechanisms within rather centralized systems. Indeed, in several countries, collective bargaining takes place at several levels, with a more or less strict articulation of the agreements set at each level.

These two indicators are taken from the ICTWSS database, which gathers information on institutional characteristics of trade unions, wage setting, state intervention, and social pacts in 56 countries over the period 1960-2018. These indicators represent the functioning of collective bargaining at the national level and therefore are country-level data. In most countries, the rules governing collective bargaining are set at the national level. If regional differences exist in its

[5] We rely on the hourly wage (instead of the wage per employee) to avoid potential issues relative to workforce composition effects, especially in times of recession when job-retention plans (e.g., through more part-time work) are common.

[6] We cannot use NAIRU to construct the unemployment gap, because NAIRUs are not measured at the regional level.

Table 1: Summary statistics of variables

Variables	Mean	SD	Min	Median	Max
Macroeconomic outcomes					
Growth of hourly wage (%)	3.0	5.4	-19.9	2.6	51.5
Unemployment rate (%)	8.8	5.7	1.2	7.2	37.0
Unemployment gap (p.p.)	0.0	3.2	-14.4	-0.1	14.9
Growth of annual GVA (%)	3.4	5.8	-22.9	3.4	88.9
Share of industry GVA in total GVA (%)	21.8	8.7	1.7	21.5	62.6
Share of construction GVA in total GVA (%)	6.4	2.1	0.9	6.3	16.1
Share of agriculture GVA in total GVA (%)	3.1	3.3	-0.9	2.1	21.8
Share of low-educated population (%)	27.4	15.3	2.4	23.5	87.7
Share of medium-educated population (%)	46.9	14.7	6.9	45.3	80.3
Wage bargaining institutions					
Centralization of wage bargaining (BARGCENT)	2.1	0.9	0.8	2.2	4.7
Predominant level of wage bargaining (LEVEL)	2.5	1.0	1	3	4
Coverage rate (%) (COV)	62.5	25.3	7.1	67.8	100

functioning within the same country - for example, because of an industry that is particularly strong in a specific region, a presence of many large firms in a specific region, or different social norms between regions -, this difference is taken into account by the regional fixed effects as well as the variables representing the respective shares of industry, construction, and agriculture in value added.

The main statistical characteristics of the variables mentioned so far are summarized in Table 1. Their precise description is provided in Table 6.

Figure 2 shows the distribution of nominal hourly wage growth (regional level) according to the predominant level where bargaining takes place. It shows that wage growth is more concentrated around 0 and above when negotiations take place at rather centralized levels (sector and above, Fig. 2c and Fig. 2d), as opposed to decentralized levels, where the distribution is more spread out (Fig. 2a and Fig. 2b). This difference seems to be most noticeable in the case of a positive unemployment gap, that is, a rather slack labor market (solid grey line). Indeed, in the case of a negative unemployment gap (a rather tight labor market), wage growth is mainly distributed over the positive domain for all predominant levels of bargaining.

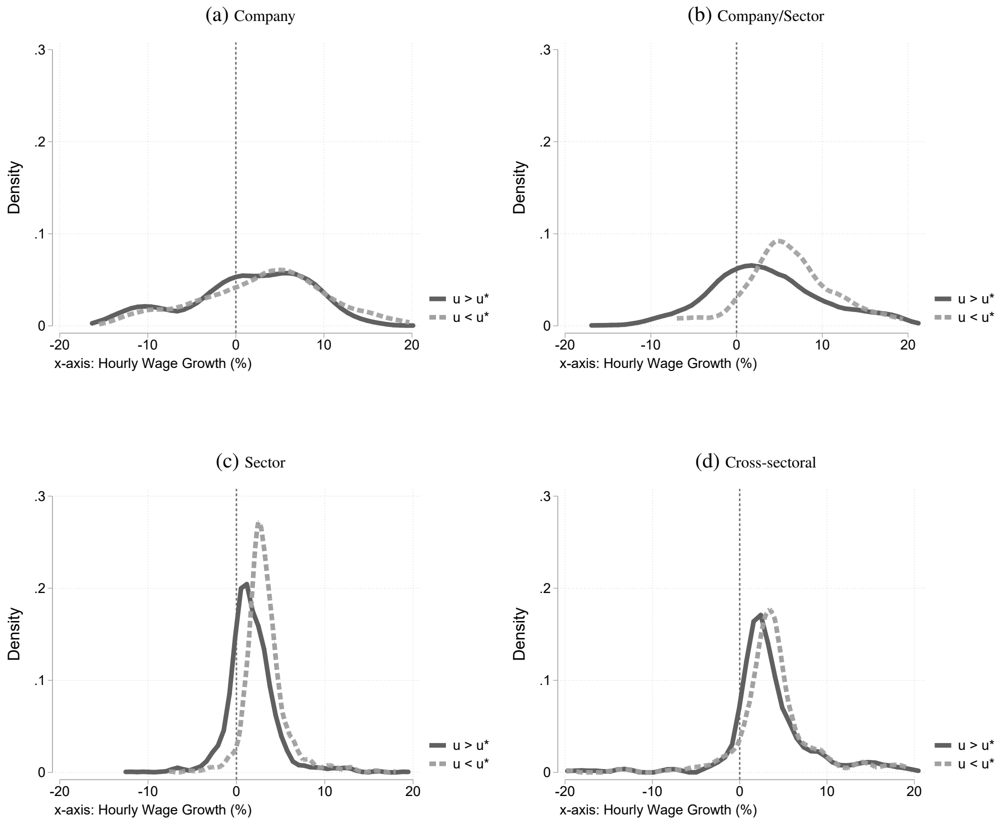
3.2. *Baseline specification and methodology*

We investigate the link between the shape and curvature of the wage PC and collective wage bargaining institutions. For the baseline specification, we follow the standard specification in the literature, adjusted by taking into account the regional nature of our data and their limitations (see Levy, 2019). Our baseline specification is as follows:

$$\begin{aligned}\Pi^W_{i,c,t} &= \alpha\,\Pi^W_{i,c,t-1} + \beta\, UGap_{i,c,t} + \theta\, Cent_{c,t} \\ &+ \lambda\,[UGap_{i,c,t} \times Cent_{c,t}] + \gamma\, X^{'}_{i,c,t} + \mu_i + \nu_t + \epsilon_{i,c,t}\end{aligned} \tag{26}$$

The dependent variable $\Pi^W_{i,c,t}$ is the wage-inflation in region i, country c during the year t. We include the unemployment gap via $UGap_{i,c,t}$ and wage inflation expectations via $\Pi^W_{i,c,t-1}$. By

Figure 2: Regional nominal wage growth by predominant level of bargaining, over 1995-2019



Notes: $u > u^*$ corresponds to a positive unemployment gap (slack labor market) and $u < u^*$ to a negative unemployment gap (tight labor market). We have restricted the distribution to the interval [-20%; 20%]. For details about the predominant level of bargaining, see Table 6.

using the lagged wage inflation as a proxy for expectations, we follow the assumption of adaptive expectations, that is, assuming expectations are backward looking.[7] The evolution of wages seems indeed to follow past inflation, as shown by Gautier et al. (2019) for the national minimum wage and industry-level minimum wages in France. The lagged wage inflation also captures persistence in wage dynamics as highlighted by Galí (2011), for example, staggered-contract models.

$Cent_{c,t}$ is either the categorical variable LEVEL or the variable BARGCENT, both representing the centralization of wage bargaining. $X_{i,c,t}$ corresponds to a vector of control variables, including those described in Section 3.1. μ_i represents the region-specific fixed effects, capturing all time-invariant region characteristics. ν_t are year dummies, to control for time effects common to all regions, as well as to deal with potential non-stationary issues and to avoid correlation across individuals in the idiosyncratic disturbances (Bond et al., 2001; Roodman, 2009*a*). Finally, $\epsilon_{i,c,t}$ is the idiosyncratic error.

Our coefficients of interest are β and λ, which are respectively the wage-PC's slope and the the influence of bargaining centralization on wage growth according to the unemployment gap. We rely on λ to test conditional effects of the collective bargaining centralization on the contribution of the unemployment gap to the wage growth: significant interaction means the effect of the unemployment gap is different for various values of the bargaining centralization.

Because the conditional effect of the unemployment gap on wage growth may be significant for only some values of bargaining centralization, we cannot infer the slope of the wage PC simply by looking at the magnitude and significance of β or λ. Instead, we should examine the conditional effect based on the marginal effect at every observed value of the bargaining centralization (Brambor et al., 2006). Thus, we also present conditional effects with margins plot.

We first run a fixed-effects regression model. Then, we derive estimates of coefficients using the standard system generalized method of moments (system GMM) approach of Blundell and Bond (1998). This approach has the advantage of taking into account the dynamic specification of the wage PC equation; that is, it deals with the lagged wage growth that is correlated with the error term. It also takes into account other potential endogenous covariates among right-hand-side variables (correlated with past and possibly current realizations of the error), as well as issues of omitted variables, error measurement, and unobserved heterogeneity via fixed individual effects. The system GMM mitigates endogeneity and isolates the causal effects using a system of equations in first differences and in levels, exploiting lags of the regressors as internal instruments. The endogenous variables are instrumented by their lags in level in the first-difference equation and by their lags in first difference in the level equation. The argument is that first-difference lags of endogenous variables are unlikely correlated with the contemporaneous value of the dependent variable in level, just as lags in level of endogenous variables are unlikely correlated with the contemporaneous value of the dependent variable in first difference. Finally, the system GMM is designed for situations with a small time dimension (T) and many individual units (N), as in our panel ($N = 280$, $T = 25$).

Using the GMM approach goes with issues of instruments proliferation and serial autocorrelation of errors. Instruments may become too numerous and create overidentification in the

[7] An alternative approach would be to add the forward term of wage inflation. It follows the New Keynesian theoretical framework, but, as suggested by Levy (2019), this specification may be subject to error bias.

model, because they are used in differences and levels and their number grows quadratically with T. Therefore, as advised by Roodman (2009*a*,*b*), we limit the number of lags used. These potential issues imply a diagnosis of the GMM estimates, by checking the Hansen test of overidentification and the Arellano and Bond test of autocorrelation.

3.3. Results

Table 2 presents the estimates without taking into account the bargaining centralization. We address concerns about endogeneity by using a fixed-effects panel in Tab. 2. column (1) and system GMM in Tab. 2. columns (2) to (4). The Phillips curve is still alive: a 1% increase in the unemployment gap by 1% implies a decrease in the growth of hourly wage by around 0.10%. This result is close to the one from Hooper et al. (2020) in the US.

Regarding other control variables, growth of output is key to understand wages (Galí, 2011; Hooper et al., 2020). The share of industry and of agriculture in the gross value added are negatively associated with the wage growth. It is the opposite for the share of low- and medium-educated people. These relationships are not at play in our model, but they are likely explained by the gain/loss in the bargaining power of workers.[8]

Tab. 2. columns (1) and (2) report our estimates with the fixed-effects panel and the system GMM, respectively, to compare the magnitude of possible biases related to endogeneity. Tab. 2. columns (3) and (4) present estimates of regressions considering a quadratic and a concave function of the unemployment gap, respectively, the term squared of unemployment gap, and unemployment gap divided by the unemployment. The coefficient associated with the concave function of the unemployment gap is significant and thus suggests the existence of non-linearities in the slope of the wage PC.

The last three rows of Table 2 report *p-values* of the usual tests for GMM diagnostic. First, *p-values* of the first- and second-order serial autocorrelation tests suggest error terms are not serially correlated, because we can undoubtedly reject the null of AR(1) residuals, whereas we cannot reject the null of AR(2). Second, the *p-value* associated with Hansen's J-statistic to test for over-identifying restrictions does not reject our choice of instruments, giving support to our instrumentation strategy.

Table 3 displays Eq. (26), which presents the estimates with the bargaining centralization variables and their interaction with the unemployment gap. Tab. 3. column (1) presents interaction coefficients between the unemployment gap and each of the possible predominant levels of wage bargaining. The positive coefficients indicate a higher level of centralization (because the sectoral level is implied) lowers the relationship between nominal wage growth and the unemployment gap, that is, the wage PC's slope. Specifically, the difference in slope between the centralized level (sector and above) and the decentralized level (firm) appears for positive, but also negative, unemployment gaps, as shown in Figure 3. In other words, the wage PC flattens out from a positive unemployment gap (slack labor market) in regions where bargaining is rather centralized, whereas it appears steeper when the labor market is overheated.

[8] The loss is in line with the US case analyzed by Stansbury and Summers (2020). In a similar way, Font et al. (2015) and Adamopoulou et al. (2016) explore how changes in the composition of firms could affect the dynamics of wages and of employment. The hiring and firing decisions of a firm is a potential factor of the flattening/steepening of the PC (Bulligan and Viviano, 2017).

Table 2: Estimates of baseline specification and non-linearities

	(1)		(2)		(3)		(4)	
	Fixed-Effects Linear		sGMM Linear		sGMM Quadratic		sGMM Concave	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Lagged Wage Inflation	-0.029	[0.021]	0.019	[0.024]	0.019	[0.024]	0.018	[0.024]
Unemployment Gap	-0.133***	[0.041]	-0.079**	[0.036]	-0.087**	[0.041]		
Growth of Annual GVA	0.713***	[0.061]	0.675***	[0.073]	0.674***	[0.073]	0.675***	[0.073]
Share Industry in GVA	-0.446***	[0.059]	-0.032**	[0.014]	-0.032**	[0.014]	-0.033**	[0.014]
Share Construction in GVA	-0.208**	[0.088]	0.038	[0.045]	0.033	[0.045]	0.021	[0.043]
Share Agriculture in GVA	-0.541***	[0.089]	0.094***	[0.030]	0.092***	[0.031]	0.097***	[0.029]
Share of low-educated	0.115***	[0.033]	0.029***	[0.008]	0.029***	[0.008]	0.026***	[0.008]
Share of medium-educated	0.072**	[0.028]	0.059***	[0.011]	0.059***	[0.011]	0.057***	[0.012]
Eurozone	-0.766	[0.729]	-0.361***	[0.125]	-0.379***	[0.132]	-0.392***	[0.130]
Unemployment Gap (U^2)					0.002	[0.005]		
Unemployment Gap $\left(\frac{(U-U^*)}{U}\right)$							-1.120***	[0.338]
Intercept	7.100***	[2.500]	0.000	[0.000]	0.000	[0.000]	-3.850***	[0.573]
Observations	3 587		3 587		3 587		3 587	
R-squared	0.563		0.586		0.586		0.587	
Year FE	YES		YES		YES		YES	
Region FE	YES		YES		YES		YES	
Number of Regions	228		228		228		228	
Number of Instruments			243		243		243	
AR(1) (p-value)			0.000		0.000		0.000	
AR(2) (p-value)			0.186		0.186		0.184	
Hansen Test (p-value)			0.233		0.223		0.228	

Notes: Dependent variable is growth of hourly wage (in %). Columns (2)-(4) report coefficients from system GMM estimation, with Lagged Wage Inflation, Unemployment Gap, and Growth of Annual GVA considered predetermined.
Robust standard errors are in brackets. Statistical significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Tab. 3. columns (3) and (4) include the composite variable BARGCENT instead of the categorical variable LEVEL to obtain estimates from a more comprehensive measure of bargaining centralization.[9] A higher level of centralization is significantly associated with higher nominal wage growth. The interaction coefficient is positive and significant, confirming a more centralized level of wage bargaining reduces the slope of the wage-PC.

In sum, our empirical evidence supports our intuition and Proposition 3 from our theoretical model: the curve flattens when unemployment becomes high in systems where the collective bargaining system is rather centralized, because wages are less likely to adjust downwards. Our empirical investigation also brings us an additional result: for low levels of unemployment, a higher level of bargaining centralization makes the wage PC steeper, meaning more wage gains when the labor market is tight.

We present our first robustness checks in Table 7. In Tab. 7. column (1) we add two additional control variables, namely, the long-term unemployment rate (> 12 months) and the net

[9] As detailed in Section 3.1, BARGCENT takes into account possible decentralization mechanisms in addition to the predominant level of negotiation.

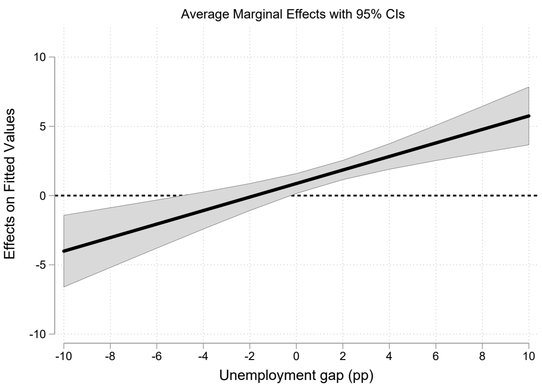
Table 3: Effects of bargaining centralization on the Wage PC's slope

	(1)		(2)	
	LEVEL × UGap		BARGCENT × UGap	
	Coef.	SE	Coef.	SE
Unemployment Gap	-0.623***	[0.101]	-0.289***	[0.077]
Measure 1 - LEVEL				
Predominant level of bargaining is				
2. Sector/Company	0.870**	[0.366]		
3. Sector	0.555	[0.371]		
4. Sector/Cross-sectoral	1.290**	[0.505]		
Interacted with Unemployment Gap				
2. Sector/Company	0.488***	[0.114]		
3. Sector	0.574***	[0.125]		
4. Sector/Cross-sectoral	0.669***	[0.177]		
Measure 2 - BARGCENT				
Centralization of Wage Bargaining			0.410***	[0.130]
Interacted with Unemployment Gap			0.116***	[0.035]
Other Control Variables	YES		YES	
Intercept	2.587**	[1.279]	2.163*	[1.251]
Observations	3 585		3 585	
R-squared	0.596		0.589	
Year FE	YES		YES	
Region FE	YES		YES	
Number of Regions	228		228	
Number of Instruments	246		244	
AR(1) (p-value)	0.000		0.000	
AR(2) (p-value)	0.262		0.229	
Hansen Test (p-value)	0.198		0.220	

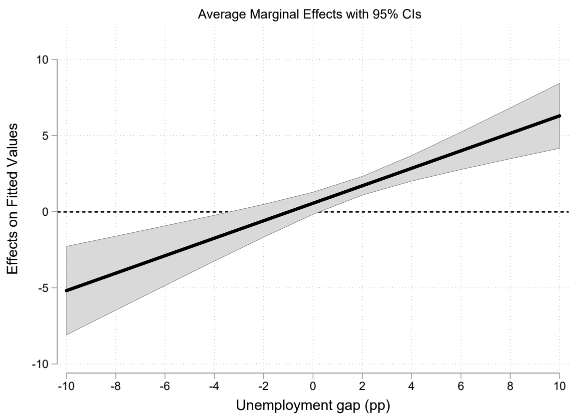
Notes: Dependent variable is growth of hourly wage (in %). Coefficients of control variables are not reported. All columns reports coefficients from system GMM estimation, with Lagged Wage Inflation, Unemployment Gap, and Growth of Annual GVA considered predetermined. A test of joint significance of sets of interactions of indicator variables reports a p-value of 0.0000, meaning the overall interaction is statistically significant. Robust standard errors are in brackets. Statistical significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 3: Difference in wage PC's slope:
According to the predominant level of bargaining and the unemployment gap

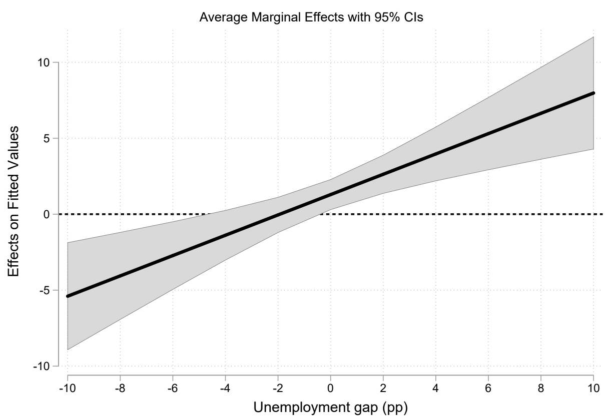
(a) Company/Sector *versus* Company



(b) Sector *versus* Company



(c) Cross-sectoral *versus* Company



Notes: Each graph compares a predominant level of bargaining relative to the reference level (company level) on its influence on the slope of the wage PC, according to the unemployment gap.
Interpretation: If the confidence interval includes 0 on the y-axis, the implication is that no significant difference exists in the slope of the wage PC between the predominant bargaining level considered and the reference level (company level). If the confidence interval is above 0 on the y-axis, the slope of the wage PC is less steep. A positive marginal effect associated with more centralization (relative to the company level) adds to the (negative) coefficient of the wage-PC' slope); if it is below, it is steeper (a negative marginal effect associated with more centralization (relative to the company level) adds to the (negative) coefficient of the wage PC's slope).

migration to the region. We include long-term unemployment to control for possible hysteresis effects (Blanchard and Summers, 1986; Ball, 2009; Blanchard, 2018), which would affect the evolution of the unemployment gap and wage growth, because the long-term unemployed have lower employability. It can also be a proxy for underemployment, which reduces the pressure on wages and thus can flatten the PC (Bell and Blanchflower, 2018). We include net migration to control for its possible effects on the available labor force and ultimately on wages of native workers and foreign workers (Brücker and Jahn, 2011; Ottaviano and Peri, 2012). Interestingly, we can note Bentolila et al. (2008) find the immigration boom has contributed to the flattening of the PC during the period 1995-2006 in Spain. The results are similar with this extended specification. In Tab. 7. column (2), we address a major concern with GMM estimates, which is the sensitivity of the results to the instrumentation strategy. We estimate our main specification with the variable BARGCENT without imposing any restriction on the maximum number of lags for instruments. The number of instruments becomes very large, but the estimated coefficients remain similar, suggesting our results are not sensitive to the instrumentation strategy. Our results are also consistent with the case of the Great Recession (Tab. 7. column (3)). In Tab. 7. column (4), we present estimates with the coverage of collective wage agreements in place of a centralized bargaining indicator. For that, we rely on Eq. (26) and use the variable Cov (Coverage) instead of the variable $Cent$. Cov represents the proportion of employees covered by valid collective (wage) bargaining agreements in the total of all wage and salary earners in employment with the right to bargaining. It is a more traditional indicator in the study of unions and collective bargaining than the centralization index. The bargaining coverage is generally high in countries where sectoral agreements are extended to all the employees in an industry; these extensions introduce wage rigidities (Villanueva and Adamopoulou, 2022). The results show a broader coverage of collective wage agreements also tends to flatten the PC, even if the significance of the coefficient associated with the interaction term only emerges at the 10% threshold. However, note this coverage indicator does not necessarily represent the centralization of negotiations, because collective agreements can be signed at the company level.

As a second important robustness test, we look for the existence of a threshold in the level of centralization at which the wage PC's slope would become flat in Appendix B.3. To do so, we use a panel threshold model with internal instrumental variables, following Kremer et al.'s (2013) approach. Our results highlight a threshold at a level of bargaining close to the sectoral level, from which the slope is twice as flat.

4. Conclusion

In this paper, we explored one potential source of DWR, which can play an essential role in the flattening of the Phillips curve. We investigate the role of collective bargaining on the link between the unemployment gap and nominal wage growth, namely, the wage Phillips curve.

In the theoretical part, we formalized our hypotheses on the influence of centralized wage bargaining on wage dynamics when the economy enters a recession, using a labor market model with frictions and collective bargaining. Our theoretical analysis shows that when the economy deteriorates, wages fall less in sectors of the economy covered by centrally negotiated collective wage agreements than in economies with fully decentralized negotiations within companies. The mechanisms go through the reallocation of workers and positive externalities linked to the coverage of firms by collective agreements.

We fill the gap with an empirical test of the model. We tested the conditional effect of the unemployment gap on nominal wage growth according to the level of centralization. To do so, we used spatial and temporal heterogeneity between the collective bargaining systems of European countries relying on European regional socio-economic and demographic data merged with indicators of the centralization of collective bargaining. Using a specification of the wage Phillips curve adapted to regional data with a system generalised method of moments, our estimates show higher levels of wage bargaining centralization (sector and above) flatten the wage Phillips curve when unemployment is high. As a main robustness test, we used a panel threshold model with internal instrumental variables to identify the existence of a threshold in the centralization of bargaining at which the wage Phillips curve becomes flatter. We find thresholds that confirm the results of our main estimates.

These results suggest monetary authorities should consider the characteristics of collective bargaining when designing monetary policy.

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Appendix A. Theoretical model

Appendix A.1. Level of employment

From labor market flows at the steady state $u_c f(\theta_c) = \phi l \delta$ and $u_{nc} f(\theta_{nc}) = (1-\phi) l \delta$, we know $u_c = \dfrac{\phi l \delta}{f(\theta_c)}$ and $u_{nc} = \dfrac{(1-\phi) l \delta}{f(\theta_{nc})}$. Replacing u_c and u_{nc} with their respective expressions in $1 = l + u_c + u_{nc}$ allows us to derive

$$l = 1 - \frac{\phi l \delta}{f(\theta_c)} - \frac{(1-\phi) l \delta}{f(\theta_{nc})}$$

Replacing $f(\theta_b)$ with θ_b^α and isolating l on the left-hand side of the equation gives the equilibrium level of employment:

$$l = \frac{(\theta_c \theta_{nc})^\alpha}{(\theta_c \theta_{nc})^\alpha + \delta \phi \theta_{nc}^\alpha + \delta (1-\phi) \theta_c^\alpha}$$

Appendix A.2. Arbitrage condition

Subtracting Eq. (6) from Eq. (5) gives the following expression:

$$r\left(W_b^U - W_b^E\right) = z - w_b - (f(\theta_b) + \delta)\left[W_b^U - W_b^E\right]$$

Replacing $f(\theta_b)$ with θ_b^α and isolating $W_b^U - W_b^E$, we get in each labor market

$$\begin{cases} W_c^U - W_c^E = \dfrac{z - w_c}{r + \theta_c^\alpha + \delta} \\ \\ W_{nc}^U - W_{nc}^E = \dfrac{z - w_{nc}}{r + \theta_{nc}^\alpha + \delta} \end{cases}$$

Inserting these expressions of $W_b^U - W_b^E$ into Eq. (5) gives the following expressions

$$\begin{cases} rW_c^U = z - \theta_c^\alpha \dfrac{z - w_c}{r + \theta_c^\alpha + \delta} \\ \\ rW_{nc}^U = z - \theta_{nc}^\alpha \dfrac{z - w_{nc}}{r + \theta_{nc}^\alpha + \delta} \end{cases}$$

However, by the arbitration condition implying $W_c^U = W_{nc}^U$, we obtain

$$\theta_c^\alpha \frac{w_c - z}{r + \theta_c^\alpha + \delta} = \theta_{nc}^\alpha \frac{w_{nc} - z}{r + \theta_{nc}^\alpha + \delta}$$

Appendix A.3. Determination of the first relation $h(\theta_c)$ in the reduced model

From relation (17) and (18), we obtain :

$$w_c - z = \beta(x(1 + l_c) + \kappa - w - z)$$
$$w_{nc} - z = \gamma(x + \kappa - z)$$

Introducing these two last equations into (21) :

$$\theta_c^\alpha \cdot \frac{\beta\,(x[1 + l_c] + \kappa - z)}{r + \delta + \theta_c^\alpha} = \Omega_1 \tag{A.1}$$

where $\Omega_1 = \bar{\theta}_{nc}^\alpha \cdot \frac{\gamma\,(x + \kappa - z)}{r + \delta + \theta_{nc}^\alpha}$. Isolating l_c, the first relation $h(\theta_c)$ of the reduced model is obtained the relation (24):

$$l_c = h(\theta_c) = \frac{r + \delta + \theta_c^\alpha}{\beta x \theta_c^\alpha} \cdot \Omega_1 - \frac{\kappa - z}{x} - 1$$

Appendix A.4. Uniqueness and existence of equilibrium

From relations (24) and (25), the equilibrium condition $h(\theta_c) = g(\theta_c)$ can be rewritten as:

$$\begin{aligned} & h(\theta_c) - g(\theta_c) = 0 \\ \Longleftrightarrow\; & B(\theta_c) = \frac{(r + \delta)\Omega_1}{\beta \theta_c^\alpha} - \frac{(r + \delta)\kappa\theta_c^{1-\alpha}}{1 - \beta} + \frac{\Omega_1}{\beta} - \frac{\beta\kappa + (1 - \beta)z}{1 - \beta} - (\kappa - z) = 0 \end{aligned}$$

To establish the existence of equilibrium, we note:

$$\lim_{\theta_c \to 0} B(\theta_c) = +\infty \text{ and } \lim_{\theta_c \to +\infty} B(\theta_c) = -\infty$$

With the function being continuous, by the theorem of intermediate values, we know at least one solution exists such that $B(\theta_c) = 0$.

Moreover, we can easily compute $B'(\theta_c) = x[h'(\theta_c) - g'(\theta_c)] < 0$. In other words, with the function $B(\theta_c)$ being strictly decreasing on $[0; +\infty]$, only one unique value θ_c exists for which $B(\theta_c) = 0$.

Appendix A.5. Effect of recession on wages, employment, and tightness

To analyze the effect of recession on different variables of the model, we first have to compute how the equilibrium $h(\theta_c) = g(\theta_c)$ evolves with x.

As shown in Appendix A.3, the equilibrium can be rewritten in implicit form:

$$B(\theta_c, x) = \frac{(r + \delta)\Omega_1(x)}{\beta}\theta_c^{-\alpha} - \frac{(r + \delta)\kappa}{1 - \beta}\theta_c^{1-\alpha} + \frac{\Omega_1(x)}{\beta} - \frac{\beta\kappa + (1 - \beta)z}{1 - \beta} - (\kappa - z) = 0$$

From $B(\theta_c, x) = 0$, we define $\theta_c = \theta_c(x)$, where

$$\frac{\partial \theta_c}{\partial x} = -\frac{\frac{\partial B(\theta_c, x)}{\partial x}}{\frac{\partial B(\theta_c, x)}{\partial \theta_c}}$$

Recalling that $\Omega_1(x) = \bar{\theta}_{nc}^{\alpha} \cdot \dfrac{\gamma\,(x+\kappa-z)}{r+\delta+\theta_{nc}^{\alpha}}$, and as shown by relation (23) $\bar{\theta}_{nc} = \left[\dfrac{x-w_{nc}}{\kappa(r+\delta)}\right]^{\frac{1}{1-\alpha}}$, we can easily deduce that $\Omega_1'(x) > 0$

After some manipulations, we obtain the following partial derivatives of B

$$\frac{\partial B(\theta_c,x)}{\partial\theta_c} = -\frac{\alpha(r/\delta)\Omega_1(x)\theta_c^{-\alpha-1}}{\beta} - \frac{(1-\alpha)(r/\delta)\kappa\theta_c^{-\alpha}}{1-\beta} < 0$$
$$\frac{\partial B(\theta_c,x)}{\partial x} = \Omega_1'(x)\left[\frac{(r+\delta)\theta_c^{-\alpha}+1}{\beta}\right] > 0$$

Introducing these two last equations in the partial derivatives of θ_c with respect to x yields to:

$$\frac{d\theta_c}{dx} = -\frac{\frac{\partial B(\theta_c,x)}{\partial x}}{\frac{\partial B(\theta_c,x)}{\partial\theta_c}} = \frac{\left[\left((r+\delta)\theta_c^{-\alpha}+1\right)\Omega_1'(x)(1-\beta)\right]}{(r+\delta)\theta_c^{-\alpha}\left[(1-\beta)\alpha\Omega_1(x)\theta_c^{-1}+\beta(1-\alpha)\kappa\right]} > 0$$

So, in case of recession, the tightness in covered sector decreases ($d\theta_c/dx > 0$).

To determine the sign of the derivative of employment in the covered sector with respect to productivity, we can start from Eq. (25):

$$l_c = g(\theta_c) = \frac{\kappa(r+\delta)\theta_c^{1-\alpha}+\beta\kappa+(1-\beta)z}{x(1-\beta)}$$
$$\Leftrightarrow g(\theta_c) = \frac{\kappa(r+\delta)}{1-\beta}\cdot\frac{\theta_c^{1-\alpha}}{x} + \frac{\beta\kappa+(1-\beta)z}{x(1-\beta)}$$

One can easily see that the second term of the right-hand side of the equation is decreasing with x. Additionally, we can see that the first term of the right-hand side is decreasing in x if the elasticity of $\theta_c^{1-\alpha}$ with respect to x is less than 1. More formally, the elasticity of $\theta_c^{1-\alpha}$ with respect to x is:

$$\xi_x^{\theta_c^{1-\alpha}} = \frac{(1-\alpha)\theta_c'(x)x}{\theta_c} = (1-\alpha)\xi_x^{\theta_c}$$

where $\xi_x^{\theta_c}$ corresponds to the elasticity of θ_c with respect to x. For values of α arbitrarily close to 1, the elasticity is less than 1, ensuring $\theta_c^{1-\alpha}/x$ decreases with x. Thus, we obtain that $dl_c/dx < 0$.

The effects of recession on the other variables are easier to determine. Using relation (18), we immediately see a recession tends to reduce wages in the uncovered sector ($dw_{nc}/dx > 0$). Using relation (23), we can easily determine that $d\theta_{nc}/dx > 0$, so the recession leads to a decrease in the tightness of uncovered sector.

From relation (22), we can solve the effect of recession on total employment (and so unemployment). Inverting this relationship, we obtain:

$$\frac{1}{l(x)} = 1 + \frac{\delta\phi}{\theta_c(x)^{\alpha}} + \frac{\delta(1-\phi)}{\bar{\theta}_{nc}(x)^{\alpha}}$$

Knowing $\theta_c'(x) > 0$ and $\bar{\theta}_{nc}'(x) > 0$, we conclude that the level of employment drops in case of recession: $dl/dx > 0$.

Finally, combining this last result $dl/dx > 0$, with $dl_c/dx < 0$, and recalling that $l = l_c + l_{nc}$, we can infer that the employment in the uncovered sector falls during a recession ($dl_{nc}/dx > 0$).

Appendix A.6. Extent of wage variations

In the follow-up, we determine the amplitude of variation of wages in a recession. Using the wages relations (17) and (18):

$$\frac{dw_{nc}}{dx} = \gamma$$
$$\frac{dw_c}{dx} = \beta(1 + l_c) + \beta x l_c'$$

We note that $dw_{nc}/dx > dw_c/dx$ for arbitrary high values of x. Indeed :

$$\beta(1 + l_c) + \beta x l_c' < \gamma$$
$$\Leftrightarrow l_c' < \frac{\gamma - \beta(1 + l_c)}{\beta x}$$

Since $l_c' < 0$, we can write this last inequality in absolute values :

$$|l_c'| > \left|\frac{\gamma - \beta(1 + l_c)}{\beta x}\right|$$

which is satisfied for arbitrary high values of x.

Appendix B. Appendix: Empirical part

Appendix B.1. Additional data information

Table B.4: NUTS-2 Regions in our Panel

Country	Regions
Austria	Burgenland, Kärnten, Niederösterreich, Oberösterreich, Salzburg, Steiermark, Tirol, Vorarlberg, Wien
Belgium	Prov. Antwerpen, Prov. Brabant wallon, Prov. Hainaut, Prov. Limburg, Prov. Liège, Prov. Luxembourg, Prov. Namur, Prov. Oost-Vlaanderen, Prov. Vlaams-Brabant, Prov. West-Vlaanderen, Region de Bruxelles-Capitale
Bulgaria	Severen tsentralen, Severoiztochen, Severozapaden, Yugoiztochen, Yugozapaden, Yuzhen tsentralen
Croatia	Jadranska Hrvatska, Kontinentalna Hrvatska
Cyprus	Kypros
Czech Republic	Jihovychod, Jihozapad, Moravskoslezsko, Praha, Severovychod, Severozapad, Stredni Cechy, Stredni Morava
Denmark	Hovedstaden, Midtjylland, Nordjylland, Sjaelland, Syddanmark
Estonia	Eesti
Finland	Etela-Suomi, Helsinki-Uusimaa, Länsi-Suomi, Pohjois- ja Itä-Suomi
France	Alsace, Aquitaine, Auvergne, Basse-Normandie, Bourgogne, Bretagne, Centre - Val de Loire, Champagne-Ardenne, Corse, Franche-Comté, Guadeloupe, Guyane, Haute-Normandie, La Réunion, Languedoc-Roussillon, Limousin, Lorraine, Martinique, Mayotte, Midi-Pyrénées, Nord-Pas-de-Calais, Pays-de-la-Loire, Picardie, Poitou-Charentes, Provence-Alpes-Côte d'Azur, Rhône-Alpes, Ile de France
Germany	Arnsberg, Berlin, Brandenburg, Braunschweig, Bremen, Chemnitz, Darmstadt, Detmold, Dresden, Dusseldorf, Freiburg, Giessen, Hamburg, Hannover, Karlsruhe, Kassel, Koblenz, Koln, Leipzig, Lüneburg, Mecklenburg-Vorpommern, Mittelfranken, Munster, Niederbayern, Oberbayern, Oberfranken, Oberpfalz, Rheinhessen-Pfalz, Saarland, Sachsen-Anhalt, Schleswig-Holstein, Schwaben, Stuttgart, Thûringen, Trier, Tûbingen, Unterfranken, Weser-Ems
Greece	Anatoliki Makedonia. Thraki, Attiki, Dytiki Ellada, Dytiki Makedonia, Ionia Nisia, Ipeiros, Kentriki Makedonia, Kriti, Notio Aigaio, Peloponnisos, Sterea Ellada, Thessalia, Voreio Aigaio
Hungary	Dél-Alföld, Dél-Dunantul, Közép-Dunantul, Közép-Magyarorszag, Nyugat-Dunanntul, Eszak-Alföld, Eszak-Magyarorszag
Ireland	Eastern and Midland, Northern and Western, Southern
Italy	Abruzzo, Basilicata, Calabria, Campania, Emilia-Romagna, Friuli-Venezia Giulia, Lazio, Liguria, Lombardia, Marche, Molise, Piemonte, Provincia Autonoma di Bolzano, Provincia Autonoma di Trento, Puglia, Sardegna, Sicilia, Toscana, Umbria, Valle d'Aosta, Veneto

Table B.5: NUTS-2 Regions in our Panel (continued)

Country	Regions
Latvia	Latvija
Lithuania	Lietuva
Luxembourg	Luxembourg
Malta	Malta
Netherlands	Drenthe, Flevoland, Friesland, Gelderland, Groningen, Limburg, Noord-Brabant, Noord-Holland, Overijssel, Utrecht, Zeeland, Zuid-Holland
North Macedonia	Severna Makedonija
Norway	Agder og Rogaland, Hedmark og Oppland, Nord-Norge, Oslo og Akershus, Sor-Ostlandet, Trondelag, Vestlandet
Poland	Dolnoslaskie, Kujawsko-Pomorskie, Lubelskie, Lubuskie, Lödzkie, Malopolskie, Mazowiecki regionalny, Opolskie, Podkarpackie, Podlaskie, Pomorskie, Slaskie, Swietokrzyskie, Warminsko-Mazurskie, Warszawski stoleczny, Wielkopolskie, Zachodniopomorskie
Portugal	Alentejo, Algarve, Centro, Norte, Regiao Autonoma da Madeira, Regiao Autonoma dos Acores, Area Metropolitana de Lisboa
Romania	Bucuresti - Ilfov, Centru, Nord-Est, Nord-Vest, Sud - Muntenia, Sud-Est, Sud-Vest Oltenia, Vest
Slovakia	Bratislavsky Kraj, Stredno Slovensko, Vychodné Slovensko, Zapadné Slovensko
Slovenia	Vzhodna Slovenija, Zahodna Slovenija
Spain	Andalucia, Aragon, Canarias, Cantabria, Castilla y Leon, Castilla-la Mancha, Catalunia, Ciudad Autonoma de Ceuta, Ciudad Autonoma de Melilla, Comunidad Foral de Navarra, Comunidad Valenciana, Comunidad de Madrid, Extremadura, Galicia, Illes Balears, La Rioja, Pais Vasco, Principado de Asturias, Region de Murcia
Sweden	Mellersta Norrland, Norra Mellansverige, Smaland med oarna, Stockholm, Sydsverige, Västsverige, Ostra Mellansverige, Ovre Norrland
United Kingdom	Bedfordshire and Hertfordshire, Berkshire. Buckinghamshire and Oxfordshire, Cheshire, Cornwall and Isles of Scilly, Cumbria, Derbyshire and Nottinghamshire, Devon, Dorset and Somerset, East Anglia, East Wales, East Yorkshire and Northern Lincolnshire, Eastern Scotland, Essex, Gloucestershire. Wiltshire and Bristol/Bath area, Greater Manchester, Hampshire and Isle of Wight, Herefordshire. Worcestershire and Warwickshire, Highlands and Islands, Inner London, Kent, Lancashire, Leicestershire. Rutland and Northamptonshire, Lincolnshire, Merseyside, North Eastern Scotland, North Yorkshire, Northern Ireland, Northumberland and Tyne and Wear, Outer London, Shropshire and Staffordshire, South Yorkshire, Southern Scotland, Surrey. East and West Sussex, Tees Valley and Durham, West Central, Scotland, West Midlands, West Wales and The Valleys, West Yorkshire

Table B.6: Description of variables

Variable name	Data-Level	Detailed description	Source
Hourly Wage	Regional (NUTS-2)	Compensation of employees divided by the number of hours worked (employed persons), in thousand euros (all economic activities included, NACE Rev. 2).	Authors' calculations from Eurostat data
Growth of Hourly Wage	Regional (NUTS-2)	Annual variation of wage per hour worked, in % (computed from variable annual wage per hour worked).	Authors' calculations from Eurostat data
Unemployment Rate	Regional (NUTS-2)	Total unemployment rate, considering the labor force from 15 to 74 years old, in %.	Eurostat
Unemployment Gap	Regional (NUTS-2)	Unemployment rate - Mean of unemployment rate (calculated over the available time span). We consider the Mean of Unemployment rate a proxy for structural unemployment rate.	Authors' calculations from Eurostat data
Employment Rate	Regional (NUTS-2)	Total employment rate, considering people 15-64 years old, in %.	Eurostat
Employment Gap	Regional (NUTS-2)	Mean of Employment rate - Employment rate (calculated over the entire available time span).	Authors' calculations from Eurostat data
Growth of Annual GVA	Regional (NUTS-2)	Annual variation of gross value added, in % (all economic activities included, NACE Rev. 2).	Authors' calculations from Eurostat data
Share of Industry GVA in Total GVA	Regional (NUTS-2)	Industry GVA/Total GVA. Total GVA corresponds to gross value added, all economic activities included, NACE Rev. 2.	Authors' calculations from Eurostat data
Share of Construction GVA in Total GVA	Regional (NUTS-2)	Construction GVA/Total GVA. Total GVA corresponds to gross value added, all economic activities included, NACE Rev. 2.	Authors' calculations from Eurostat data
Share of Agriculture GVA in Total GVA	Regional (NUTS-2)	Agriculture GVA/Total GVA. Total GVA corresponds to gross value added, all economic activities included, NACE Rev. 2.	Authors' calculations from Eurostat data
Long-term Unemployment Rate	Regional (NUTS-2)	Long-term unemployment (12 months or more) in % of total unemployed	Authors' calculations from Eurostat data
Share of Low-Educated Population	Regional (NUTS-2)	Share of 25-64 year olds who achieved a low level of education, i.e., either early childhood education, or primary education, or lower secondary education (following the International Standard Classification of Education, 2011).	Eurostat
Share of Medium-Educated Population	Regional (NUTS-2)	Share of 25-64 year olds who achieved a medium-level of education, i.e., either upper secondary education, or post-secondary non tertiary-education (following the International Standard Classification of Education, 2011).	Eurostat
Net Migration	Regional (NUTS-2)	Net Migration to regions, in number of people	Authors' calculations from Eurostat data
Predominant level of wage bargaining (LEVEL)	National (Country)	The predominant level at which wage bargaining takes place in terms of coverage. A level is "predominant" if it accounts for at least two-thirds of the total bargaining coverage rate in a given year. 4 = bargaining predominantly takes place at cross-sectoral level, with possible alternation with sectoral bargaining; 3 = bargaining predominantly takes place at the sector level; 2 = intermediate or alternating between sector and company bargaining; 1 = bargaining predominantly takes place at the local or company level.	ICTWSS
Centralization of wage bargaining (BARGCENT)	National (Country)	The centralization of wage bargaining is a composite variable taking into account the predominant level of wage bargaining and the flexibility for firm-level bargaining. This flexibility captures the incidence of additional enterprise bargaining, weighted by the control of unions that signed "higher order" agreements, the "hierarchical ordering" of agreements, the tightness of wage norms in central and sectoral agreements, and the incidence of general and temporary opening clauses. A higher value of this indicator means more flexibility for firm bargaining.	ICTWSS
Bargaining Coverage (ADJCOV)	National (Country)	Employees covered by valid collective (wage) bargaining agreements as a proportion of all wage and salary earners in employment with the right to bargaining, in %.	ICTWSS

Appendix B.2. Robustness

Table B.7: Robustness results

	(1)		(2)		(3)		(4)	
	Additional controls		No lag restrictions		After 2008		Coverage	
	Coef.	SE	Coef.	SE	Coef.	SE	Coef.	SE
Unemployment Gap	-0.297***	[0.086]	-0.281***	[0.081]	-0.226**	[0.108]	-0.238**	[0.108]
Centralization of Wage Bargaining	0.472***	[0.138]	0.401***	[0.126]	0.578***	[0.182]		
Interacted with Unemployment Gap	0.118***	[0.038]	0.101***	[0.036]	0.107**	[0.054]		
Coverage of Collective Agreements							0.002	[0.004]
Interacted with Unemployment Gap							0.003*	[0.002]
Other Control Variables	YES		YES		YES		YES	
Intercept	2.203	[1.334]	2.124	[1.318]	-1.882*	[1.027]	0.000	[0.000]
Observations	3 199		3 585		2 082		3 469	
R-squared	0.585		0.589		0.472		0.585	
Year FE	YES		YES		YES		YES	
Region FE	YES		YES		YES		YES	
Number of Regions	224		228		228		228	
Number of Instruments	246		731		227		244	
AR(1) (p-value)	0.000		0.000		0.000		0.000	
AR(2) (p-value)	0.193		0.223		0.120		0.213	
Hansen test (p-value)	0.305		1.000		0.161		0.225	

Notes: Dependent variable is growth of hourly wage (in %). Coefficients of control variables are not reported. All columns report coefficients from system GMM estimation, with Lagged Wage Inflation, Unemployment Gap and Growth of Annual GVA considered predetermined. Robust standard errors are in brackets. Statistical significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Appendix B.3. Testing for threshold effects

Here, we deepen the analysis of the role of collective bargaining in the slope of the wage PC by investigating the existence of a threshold of the level of centralization at which the slope would become flat.

We follow the approach of Kremer et al. (2013). In their approach, they combine the panel threshold model of Hansen (1999) and the instrumental variable estimation of the cross-sectional model introduced by Caner and Hansen (2004) thanks to the application of the forward orthogonal deviations transformation suggested by Arellano and Bover (1995). This approach has several advantages. First, we can estimate threshold values rather than impose them as underlined by Hansen (1999). Second, we can use a dynamic panel data model where endogeneity of important control variables is no longer an issue.

Thus, we follow Kremer et al. (2013) to investigate the possibility of threshold effects in the relationship between the unemployment gap and nominal wage growth. To this aim, we consider the following panel threshold model:

$$\begin{aligned}\Pi^W_{i,c,t} = \mu_i + \chi\Pi^W_{i,c,t-1} + \beta_1 Ugap_{i,c,t} I(Cent_{c,t} \leq \gamma) \\ + \beta_2 Ugap_{i,c,t} I(Cent_{c,t} > \gamma) + \alpha_1 X_{i,c,t} + \varepsilon_{i,c,t}\end{aligned} \tag{B.1}$$

where subscripts $i = 1, ..., n$ represent the region and $t = 1, ..., T$ index the time. μ_i is the region-specific fixed effect, and the error term is ε_{it}. $\Pi^W_{i,c,t}$ is the annual wage growth and $I(.)$ is an indicator function indicating the regime defined by the threshold variable, $Cent_{c,t}$, which is the bargaining centralization (BARGCENT).[10] The independent regime control variables, $X_{i,c,t}$, include those described in Section 3.1, and a dummy representing eurozone membership (1 if the region belongs to eurozone, and 0 otherwise).

The dynamic version of the model in Eq. (B.1) is estimated in three steps:

1. In the first step, we estimate a reduced form of the endogenous variable, $\Pi^W_{i,c,t-1}$, as a function of the instruments on a set of regressors restricted to 1 lag because instruments[11] can overfit instrumented variables as shown by Roodman (2009*b*). The endogenous variable, $\Pi^W_{i,c,t-1}$, is then replaced in the structural equation by the predicted values, $\widehat{\Pi}^W_{i,c,t-1}$.

2. In the second step, Eq. (B.1) is estimated through least squares for a fixed threshold γ where Π^W is replaced by its predicted values from the first-step regression. We can denote the resulting sum of squares as $S(\gamma)$. This step is repeated for a strict subset of the support of the threshold variable, $Cent$.

3. In the third step, the estimator of threshold value is selected as the one with the smallest sum of squared residuals, namely, $\hat{\gamma} = \underset{\gamma}{\operatorname{argmin}}\, S_n(\gamma)$. In accordance with Hansen (1999) and

[10] The threshold variable must be continuous. Therefore, we cannot use LEVEL as in Section 3.

[11] Which can be $\Pi^W_{i,c,t-2}$ to $\Pi^W_{i,c,t-P}$ with $p = T - 1$.

Table B.8: Dynamic threshold panel regression estimation

	(1) BARGCENT		(2) BARGCENT (after 2008)	
Estimated Threshold	2.2		2.1	
95% Confidence Interval	[2.2; 2.4]		[1.2; 2.6]	
Impact of Unemployment Gap				
Below Threshold (β_1)	-0.567***	[0.083]	-0.753***	[0.109]
Above Threshold (β_2)	-0.255**	[0.113]	-0.315*	[0.182]
Other Control Variables	YES		YES	
Year FE	YES		YES	
Region FE	YES		YES	
AR(1) (p-value)	0.000		0.000	
AR(2) (p-value)	0.672		0.086	
Observations	3 660		2 948	
Observations above threshold	1435		1 184	
Number of Regions	249		249	
Number of Instruments	176		96	

Notes: Dependent variable is growth of hourly wage (in %). The coefficients for control variables are not reported. Robust standard errors are in brackets. Statistical significance levels are * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Caner and Hansen (2004), the critical values for determining the 95% confidence interval of the threshold value is given by

$$\Gamma = \{\gamma \,:\, LR(\gamma) \geq C(\alpha)\}$$

where $C(\alpha)$ is the 95^{th} percentile of the asymptotic distribution of the likelihood ratio statistic $LR(\gamma)$. Once $\hat{\gamma}$ is determined, the slope of the coefficients can be estimated by the GMM for the previously used instruments and the previously estimated threshold $\hat{\gamma}$.

As reported in Table B.8, we identify a threshold of 2.2 when considering the bargaining centralization (BARGCENT). Below this threshold, the wage PC is negatively sloped as expected. After this threshold, the wage PC is significantly more flat. The wage PC is twice as flat for observations (region and year) with a rather centralized system of collective bargaining (values of BARGCENT above 2.2). We may infer that when the collective bargaining is more centralized, DWR is stronger. Interestingly, after the beginning of the Great Recession in 2008, the wage PC is steeper for low values of BARGCENT (inferior to 2.2), as we can see in column 2 of Table B.8.