Adjustments along the intensive margin and wages: Evidence from the euro area and the US *

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Abstract

Firms in the euro area (EA) have higher propensity to adjust the labour input along the intensive margin (hours per worker) relative to the US. We show that this different behavior has consequences for wage dynamics and for the estimation of the Wage Phillips curve, i.e. the relationship between (nominal) wage growth and unemployment. First, we present a partial equilibrium model in which matching frictions allow for equilibrium unemployment and hour adjustments are costly for both firms and workers. The relative cost of each type of adjustment and households' disutility for work determine whether firms prefer to adjust the extensive vs the intensive margin and the reaction of wages. The model delivers a wage equation which allows us to study the sign of the relationship between wages and the intensive margin of labour utilization. By calibrating the model on euro area data, we show that this relationship is likely to be positive and significant. A relatively lower cost of adjusting head-employment, as in the US, weakens such relationship. Lastly, we test the predictions of the model by estimating a wide set of Phillips curves for the US and the euro area. Consistently with the theory we find that in the EA changes in the intensive margin are positively correlated with wage growth. This relationship is instead weaker in the US.

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1 Introduction

Empirical models for wage growth relate the latter to some measure of labour market slack, generated by firms adjusting their labour input in response to shocks. However, most measures of slack, both conventional as the ILO unemployment rate, and unconventional, are expressed in heads and capture what is commonly referred to as the extensive margin of labour under-utilization. Under-utilization, however, can also take the form of insufficient numbers of hours of work demanded by firms. Thus, the following question arises: do changes in the intensive margin affect wage growth?

In practice, the choice to adjust the extensive or the intensive margin depends on several factors. Among them, the relative cost of adjustment along the two margins and workers' preferences about working time play a relevant role. For instance, in an expansionary phase, firms can respond to increasing demand by hiring more workers. The cost of this option is related to the time and resources devoted to the hiring process as well as to the expected cost of workers' dismissal. In the case of a negative shock firms have to consider also the possible loss of specific human capital associated to firing.

Alternatively, in upturns, firms could ask for extra hours to those who are already employed, and reduce their working time during downturns. Increasing the amount of per capita hours worked is also costly, however, as workers could require higher compensation for working extra-time. Similarly, reducing hours can also be costly if workers with some bargaining power can oppose to avoid a proportional drop in earnings. In general, ceteris paribus adjustments along the intensive margin are then more likely in labour markets where its cost is partly subsidized, as in many euro area (EA) countries like Germany and Italy.

Even if these mechanisms are rather intuitive, it is not clear however if they can influence wage growth. In this paper we try to fill this gap by providing a theoretical framework used to compare US and the EA. It is well known, indeed, that the EA and the US firms differ greatly in their propensity to adjust the intensive or the extensive margin. On the one hand, the US economy is characterized by low firing restrictions[1] and high speed of filling job positions. On the other hand many European countries subsidize reductions in per capita hours worked to help firms coping with temporary shortfalls in production.[2] For example during the Great Recession that started in 2008 the unemployment rate increased by 3.5 and 2 percentage points in the US and EA respectively, whereas the intensive margin declined by 1.5 percent in the former and by 2.2 per cent in the latter. This evidence led Paul Krugman to write in October 2009[3] that the US policy makers should learn from the EA (and from Germany in particular) and design policy instruments which increase the convenience to adjust the intensive margin

[1] The Employment Protection Legislation index computed by the OECD is almost 10 times higher in the four main European countries than in the US.

[2] Examples of such institutions are *Cassa Integrazione Guadagni* in Italy and *Kurzarbeit* in Germany.

[3] New York Times, 13th November 2009.

of labour utilization (see e.g. Burda and Hunt 2011 and Ohanian and Raffo 2012 for a general overview of hours adjustment in OECD countries). Less is known, however, about the impact of changes in the intensive margin on wage growth. Indeed the related existing literature has developed along two lines of research. One line motivated by the recent subdued dynamics of inflation, core inflation and especially wage inflation in most advanced economies has found renewed interest in the wage Phillips curve (WPC henceforth), its microfoundation (Gali 2011) and its stability over time (for instance see Gali and Gambetti 2018 and Blanchard 2016, among others). The significant scars inflicted to labour markets by the Great Recession in advanced economies and the inability of standard models to predict the observed low and persistent inflation has pushed the other line of research, more focused on the limits of traditional measures of slack and on the development of broader measures of unemployment (see e.g. ECB 2019 for a detailed review).

Within this second line of research Bell and Blanchflower (2013) have been among the first to propose new measures of labour market slack that account for variations in the number of hours worked relative to the desired amount of hours by labour market participants. While these measures suggest that labour underutilization is currently considerably higher than what traditional measures indicate, a thorough examination of the information content of the intensive margin of labour utilization for wage growth is still lacking. Also from a theoretical perspective a deeper understanding of the conditions under which firms adjust along the intensive margin and its implications for wage growth is needed. Thus, we present a partial equilibrium model that features costly adjustments in both the extensive margin through the Diamond-Mortensen-Pissarides search and matching framework and the intensive margin, along the lines suggested by Trigari (2009).

The novelty of the model is an explicit role for the intensive margin of labour utilization for wage determination. Indeed, we assume that each firm pairs with a worker and bargains over the amount of hours of work and the hourly wage by maximizing the Nash surplus. We obtain a model-based WPC that allows to study analytically the interaction among the hourly wage rate, hours of work per worker and the unemployment rate. The model predicts that the hourly wage rate depends on both unemployment (whose dynamics is determined by changes in the extensive margin) and hours per worker (intensive margin). Interestingly, the sign of the coefficient of the intensive margin is ambiguous. Intuitively, increasing hours per worker is costly both for the firm and for the worker, with the first effect calling for a reduction in the wage rate and the second one for an increase. Hence, the elasticity of wages to the intensive margin depends in a non-trivial way on households' preferences for leisure and firms' adjustment costs. Heterogeneity in these parameters can thus be responsible for the different response to shocks observed in the euro area and the US.

Calibrating the model on EA data indicates that the coefficient of the intensive margin on wage growth is positive. As the relative cost of adjusting the intensive margin with respect to the extensive one increases, the elasticity of the hourly wage rate to hours per worker diminishes. We interpret this case as closer to the US, where firms can adjust employment relatively less costly as they face a higher labour market matching efficiency and lower firing costs. We also generate simulated data for the two economies and run WPC regressions with and without the intensive margin among regressors. We find that the inclusion of the intensive margin improves the fit of the Phillips curve for the EA, whereas it has a negligible effect on estimates for the US.

Then, the information content of the intensive margin of labour utilization for wage growth is empirically evaluated on US and euro area observed data. First, we describe the evolution of both margins and the different contribution of hours per worker on total hours cyclicality in both countries. We find confirmation of our initial intuition. In the period 2000-2018 the contribution of the intensive margin to total hours cyclicality is higher in the EA than in the US. As a second step, we estimate on observed data two different types of WPC: a standard one, where labour market slack is proxied by the unemployment rate, and an augmented version, where we introduce the intensive margin among the regressors, as done for simulated data. To check whether our results are generally valid or influenced by the PC specification (see e.g. Gordon 2011), for both the standard and the augmented Phillips curve we estimate a large set of equations, changing the number of lags and using different proxies for inflation expectations and labour market slack. In line with the model insights, we find that in most cases changes along the intensive margin affect positively wages in the EA while the effect is more muted and less precisely estimated on US data. In the euro area the inclusion of the intensive margin also considerably increases the fit of the models.

Our paper relates to some of the most recent contributions originated by the historically strong increases in unemployment in most advanced economies during the Great Recession and the stubbornly stagnant dynamics of prices and wages in its aftermath. The diverging trends observed since the Great Recession in head-count employment and average amount of hours per worker have sparked interest in broader measures of labour market slack. Among the many analysed, measures of (under-) utilization along the intensive margin have been suggested by Bell and Blanchflower (2011) initially for the UK and more recently for many advanced economies (Bell and Blanchflower 2019). In the latter contribution the authors provide evidence for the UK, the US as well as other advanced economies that a measure of underemployment expressed in hours helps explaining lower wages in the years after the Great Recession better than the standard unemployment rate. In a similar vein, Hong et al. (2018) provide empirical evidence that historically high levels of involuntary part-time workers exerted significant downward pressures on nominal wage growth beyond the negative effect due to traditional measures of unemployment. In Phillips curve framework applied to italian data Conti and Gigante (2018) also use broader measures of labour market slack, showing that they are informative about the evolution of core inflation. In a previous work (Bulligan, Guglielminetti, and Viviano 2017) we have investigated the information content of the intensive margin of labour utilization for wage dynamics in the euro area and its main economies. The results of that analysis suggested a significant role for the intensive margin in explaining wage dynamics at the euro area aggregate level both directly and indirectly by interacting with the traditional measure of labour market slack along the extensive margin. Compared to that analysis, here we present a theoretical model that justifies our earlier intuition. Furthermore we conduct a more robust empirical analysis of the relationship between wage dynamics and hours worked.

From the theoretical perspective, our paper is similar in spirit to Walsh (2005), and especially to Trigari (2006) and Trigari (2009). In particular Trigari (2009) integrates a model of involuntary unemployment *à la* Mortensen and Pissarides into a standard NK model in which labour can be adjusted both along the intensive and extensive margin. Within this framework, the interactions between wage, employment and hours depend on the way firms and workers bargain over the surplus of the match. In our model they further relate to the relative cost of adjusting one margin with respect to the other. This assumption allows us to interpret the different cyclicality of the intensive margin in the EA with respect to the US.

Other papers have investigated the role of the intensive margin for business cycle fluctuations in a search and matching framework. Recent contributions are Fang and Rogerson (2009), Trapeznikova (2017) and Kudoh, Miyamoto, and Sasaki (2018).[4] Our paper instead explicitly deals with the estimation of a Phillips curve, consistent with the model's finding. Within a different setup, Conti, Guglielminetti, and Riggi (2019) also study the implications of adjusting the extensive or the intensive margin of labour for wage growth. Consistently with our findings, they show that in the euro area the intensive margin of labour utilization is an important driver of wage growth. However they focus on the cyclical response of the labour market over different time periods rather than on the structural factors behind this relationship.

The paper is organized as follows. In Section 2 we illustrate the model and present analytical insights on the impact of the intensive margin on wage growth. We calibrate the model on euro area and US data to show the different implications for WPC estimates. In Section 3 we present evidence about the adjustment of the intensive margin in the EA and in the US and we compare the magnitude of these adjustments. In Section 4 we describe our exercises aimed at comparing a set of estimates of the standard WPC and its augmented version in the two areas. Last, Section 5 briefly concludes.

[4] Cooper, Haltiwanger, and Willis (2007) also introduce hours per worker in a search model but they assume that workers are paid at their reservation wage.

2 The model

In this Section we build a partial equilibrium model to illustrate why both the extensive (which affects the unemployment rate) and the intensive margin (hours) of labour utilization should be taken into account to explain wage dynamics. A natural candidate to analyze wage movements in light of labor market developments is the search and matching framework *à la* Diamond-Mortensen-Pissarides, which has become standard in the literature. In this type of models involuntary unemployment arises naturally as employment adjusts slowly over time, driven by the costly and time-consuming hiring process and by exogenous separation shocks that in each period destroy some of the existing firm-worker matches. Hence, for a given number of vacancies the level of unemployment represents an indicator of labour market slack. Cyclical fluctuations in the unemployment rate are thus associated with wage changes, as the number of workers who compete for a job changes too. This leads to a negative relationship between wage growth and unemployment, the traditional measure of labor market slack usually employed in the standard specification of the WPC. Firms, however, can vary the labor input also along the intensive margin (hours worked per worker). We thus modify the standard setup to take that into account, by letting both households' utility and firms' adjustment costs to depend on hours per worker. We will see that this modification has non-trivial implications for the hourly wage rate process.

After having sketched the main ideas, let us present the model in detail. The model dynamics are governed by two aggregate shocks, technology and demand, which realize at the beginning of the period. The first ones are the standard source of macroeconomic variation in the backbone search and matching model and follow an AR(1) process. We add demand shocks in a reduced form way to provide a role for prices and obtain a model-based WPC close to the empirical specification. Given the level of production Y_t and the demand shock ε_t^d, the price P_t adjusts to clear the market, such that the following equilibrium condition holds:

$$\log(Y_t) - \log(\bar{Y}) = -\beta^y p_t + \nu_t^d \tag{1}$$

where ν_t^d follows an exogenous AR(1) stochastic process, $p_t = \log(P_t)$ and $\bar{Y}$ is the steady state level of output. In other words, in steady state the price level which equalizes supply and demand is equal to 1 and $p_t = 0$. A positive demand shock determines an increase in both output and prices because consumers are willing to consume more at a higher price.

Output is produced by firm-worker matches. Each firm pairs with a worker and produces output using only the intensive margin of labour: aggregate output is thus proportional to the number of workers employed and their average hours of work. Hence variations in the extensive margin occur through job creation fostered by firm's entry. In this way we conveniently separate the decision on the extensive margin - to create a job or not - to the one on the intensive margin, which is taken afterwards inside the match.[5]

At the beginning of the period a fraction δ of the employed workers in the previous period lose their job and enter the unemployment pool: we assume that they cannot find another job within the same period. At the same time a number v_t of firms post vacancies to pair with workers and start production. This is job creation through the extensive margin. The number of matches is determined by an aggregate Cobb-Douglas matching function, which takes as input vacancies and job seekers, namely those who remained unemployed in the previous period: $m(v_t, u_{t-1}) = m_{0t} v_t^{\eta} u_{t-1}^{1-\eta}$. We can define the labor market tightness as the ratio between vacancies and job seekers ($\theta_t = v_t/u_{t-1}$), which determines the job filling rate ($q(\theta_t) = \frac{m_t}{v_t} = m_{0t}(\theta_t)^{\eta-1}$) and the job finding probability ($f(\theta_t) = \frac{m_t}{u_{t-1}} = \theta_t q(\theta_t)$). The law of motion of employment follows:

$$n_t = (1-\delta)n_{t-1} + f(\theta_t)u_{t-1} \tag{2}$$

By normalizing labor force to 1, unemployment is simply $u_t = 1 - n_t$.

Hours worked and the hourly wage are then bargained within each match. Each firm-worker pair produces output y_t, which depends on the level of technology and hours worked; aggregate production is the sum of individual productions along the extensive margin of labour: $Y_t = \int_0^{n_t} y(A_t, h_t)di = n_t y_i(A_t, h_{it})$. In our partial equilibrium setup firms take both the good price and labor market tightness as given.

2.1 Firm optimization problem

A firm produces output y_t taking its price P_t as given. Out of her revenues she pays some fixed costs of production Q, the wage and the costs of adjusting hours per worker ($c(h)$). In the next period, the match is destroyed with probability δ. We can then write the value of a productive match for the firm:

$$J_t = P_t y_t - Q - w_t h_t - c_t(h_t) + \beta \mathbb{E}_t \left[(1-\delta_{t+1})J_{t+1} + \delta_{t+1} J_{t+1}^v \right] \tag{3}$$

where w_t is the nominal hourly wage and h_t is hours per worker. All costs are expressed in nominal terms.

J_t^v represents the value of a vacancy in period t, that is the value of creating a new job and searching for a worker to fill the position. In order to post a vacancy, a firm needs to pay a monetary cost κ, which represents the resources devoted to the hiring process. Hence the

[5] An alternative would have been to consider a large firm which takes decisions on both the extensive and the intensive margin simultaneously. However this framework yields additional consequences on wage dynamics stemming from the effects of the size of the firm on the average wage (see Smith (1999)) that are beyond the scope of this paper.

value of a vacancy is:

$$J_t^v = -\kappa + q(\theta_t)J_t + (1 - q(\theta_t))\beta \mathbb{E}_t J_{t+1}^v \tag{4}$$

The vacancy is filled with probability $q(\theta_t)$, which depends on aggregate labor market conditions taken as given by the firm. If the firm is not matched in the current period the vacancy stays in place also for the next one. Firms keep creating jobs until the value of the vacancy is driven to zero by the increasing labor market tightness which reduces the hiring probability. Hence, in equilibrium the free-entry condition ($J_t^v = 0, \ \forall \ t$) holds and eq. (3) can be rewritten as

$$\frac{\kappa}{q(\theta_t)} = P_t y_t - Q - w_t h_t - c_t(h_t) + \beta(1-\delta)\mathbb{E}_t \left[\frac{\kappa}{q(\theta_{t+1})}\right] \tag{5}$$

Equation (5) is the job creating condition, which governs the dynamics of the extensive margin. In equilibrium the real cost of posting a vacancy ($\frac{\kappa}{q(\theta_t)}$) is equal to the value of the match (the r.h.s). The cost of adjusting the extensive margin is thus represented by $\frac{\kappa}{q(\theta_t)}$, that is the monetary cost of creating a new job divided by the probability of filling it. Hence economies characterized by an efficient matching process face relatively lower costs of expanding heads employment. The firm's surplus, defined by the difference between the value of a productive match and the value of a vacancy, coincides with the first one because of the free-entry condition: $S_t^f = J_t$.

2.2 Worker optimization problem

When paired with a firm the worker receives a salary and suffers from disutility of working; the disutility is increasing in hours and is denoted by the function $g(h_t)$. With a probability δ the next period the worker becomes unemployed. The value function of a productive worker thus reads as follows:

$$W_t = w_t h_t - P_t g_t(h_t) + \beta \mathbb{E}_t \left[(1-\delta)W_{t+1} + \delta U_{t+1}\right] \tag{6}$$

The disutility of working is multiplied by the price to express it in units of consumption. When unemployed the job seeker enjoys utility from leisure (and/or unemployment benefits) b. By assumption she can look for a job only in the next period and she finds it with expected probability $f(\theta_{t+1})$. Her utility is

$$U_t = b + \beta \mathbb{E}_t \left[f(\theta_{t+1})W_{t+1} + (1 - f(\theta_{t+1}))U_{t+1}\right] \tag{7}$$

The worker's surplus is defined as the difference between the value in employment and the utility enjoyed when unemployed: $S_t^w = W_t - U_t$.

2.3 Wage and hours setting

In perfect competition the wage clears the market by equating the worker's marginal rate of substitution and the firm's marginal productivity. Conversely, in this class of models the productive match generates a positive surplus because the matching frictions prevent the market from clearing. The wage is thus a way to split the surplus between the firm and the worker. As in Fang and Rogerson (2009) we assume that both wages and hours are Nash bargained. Wages and hours thus maximize the Nash product:

$$\max_{h_t, w_t} \left[S^w\left(h_t, w_t\right)\right]^\gamma \left[S^f\left(h_t, w_t\right)\right]^{1-\gamma}$$

where γ is the worker's bargaining power, such that the higher is γ the larger is the share of the surplus that goes to the worker.

By maximizing with respect to hours we obtain:

$$P_t mph_t = c_t'(h_t) + P_t g_t'(h_t) \tag{8}$$

where $mph_t = \frac{\partial y_t(a_t, h_t)}{\partial h_t}$ denotes the marginal productivity of hours. Equation (8) indicates that the optimal level of hours is such that the value of the additional output produced by marginally augmenting the intensive margin (the l.h.s. of eq. (8)) compensates the increase in firms' adjustment costs and worker's disutility (the r.h.s). After some computations we obtain the wage equation:

$$w_t h_t = (1-\gamma)\left(P_t g_t(h_t) + b\right) + \gamma\left[P_t y_t(A_t, h_t) - c_t(h_t) + \beta\kappa \mathbb{E}_t \theta_{t+1}\right] \tag{9}$$

Equation (9) implies that the wage per person is a weighted combination of the cost of the match for the worker (the first term on the r.h.s) and its value for the firm (the second term on the r.h.s). Moreover, the hourly wage depends on both the extensive and the intensive margin in a non trivial way. On the one side, the hourly wage depends negatively on unemployment through labor market tightness. A high level of unemployment indicates a high degree of slack in the labor market, one in which it is easy to find workers. For this reason the firm's value of an existing match is low, as well as the wage she is willing to pay. On the other side, the wage bill depends on working hours through three channels: i) the disutility of working ($g_t(h_t)$); ii) the production function (y_t) and iii) the cost of adjusting hours per worker ($c_t(h_t)$). Depending on the functional forms and the parameters' value, the relationship between hourly wages and working hours can thus be positive or negative. To shed light on this relationship we can linearize eq. (9) around the deterministic steady state. By denoting with $\hat{x}$ the log deviation of variable x from its steady state $\bar{x}$ we can write[6]:

$$\hat{w}_t = \beta_1^w a_t + \beta_2^w p_t + \beta_3^w \hat{h}_t + \beta_4^w \left[\mathbb{E}_t \hat{v}_{t+1} - \hat{u}_t\right] \tag{10}$$

where $\beta_1^w = \frac{\gamma}{\bar{w}\bar{h}} \frac{\partial y}{\partial A}|_{\bar{A},\bar{h}}$, $\beta_2^w = \frac{1}{\bar{w}\bar{h}} \left[\gamma \bar{y} + (1-\gamma) g(\bar{h})\right]$, $\beta_3^w = \frac{1}{\bar{w}} \left[(1-\gamma) g'(\bar{h}) + \gamma \left(\bar{mph} - c'(\bar{h})\right) - \bar{w}\right]$ and $\beta_4^w = \frac{\gamma}{\bar{w}\bar{h}} \beta \kappa \bar{\theta}$ are convolutions of structural parameters. Equation (10) is the model-based wage Phillips curve, which corresponds to the empirical one estimated in Section 4. We can notice that the coefficients β_1^w, β_2^w and β_4^w are always positive, implying that the wage is positively related to productivity (through technology), prices and vacancies and negatively related to unemployment. As previously mentioned, the head count unemployment is the traditional measure of labor market slack, with higher unemployment rates associated to lower wage pressures. However, there is another measure of labour market slack which appears in the model-based WPC, namely hours worked. The sign of relationship between the wage and the intensive margin β_3^w is ambiguous, though. Wages depend positively on the intensive margin if

$$\beta_3^w > 0 \qquad \text{if} \qquad (1-\gamma) g_t'(\bar{h}) + \gamma \left(\bar{mph} - c'(\bar{h})\right) - \bar{w} > 0$$

By taking into account the FOC on hours worked (eq. (8)), the previous condition reduces to:

$$\beta_3^w > 0 \qquad \text{if} \qquad g_t'(\bar{h}) > \bar{w} \tag{11}$$

Equation (11) indicates that the hourly wage increases with the intensive margin if the marginal disutility of labour is higher than the equilibrium wage rate. To gain intuition, assume that we observe a unit increase in hours per worker. This is costly both for the firm, which has to pay the worker an additional hour of salary, and for the worker, whose marginal disutility increases. Since the split of the match surplus should be kept constant, the first effect would call for a reduction in the wage rate, while the second one for an increase. The net effect will depend on the relative strength of these two forces: as indicated by eq. (11), the upward pressure prevails when households' marginal disutility of labour exceeds the equilibrium level of wage $\bar{w}$.

In general β_3^w is a complicated function of all model parameters, as they determine the level

[6] To derive eq. (10) we assume that the steady state levels of technology and price are both equal to 1 ($\bar{A} = 1$, $\bar{P} = 1$). As a consequence, the log-deviation from their respective steady state level is equal to their log, here expressed with lower case letters: $\hat{A}_t = \log(A_t) = a_t$ and $\hat{P}_t = \log(P_t) = p_t$.

of hours per worker and the hourly wage. Here we focus on the relative adjustment costs of hours, that may differ between countries for institutional reasons, for instance because they are partly subsidized by the central government like in some European countries. Assume that the production function features non-increasing marginal returns to labor - so that mph_t is non-increasing in h_t - and that disutility and adjustment costs are both positive and convex in h_t. These are standard assumptions that will be satisfied in the calibration exercise. If these conditions hold, as the marginal cost of adjusting hours gets higher, the optimal amount of hours falls (see eq. 8), entailing a lower marginal disutility for the worker.[7]

2.4 Functional forms and calibration

In order to simulate the model we adopt the following functional forms:

$$
\begin{aligned}
y_t &= A_t h_t \\
m_t &= m_0 v_t^{\eta} u_{t-1}^{1-\eta} \\
g_t(h_t) &= g_0 \frac{h_t^{1+\phi}}{1+\phi} \\
c_t(h_t) &= \frac{c_0 \bar{h}}{2} \left(\frac{h_t}{\bar{h}} \right)^2
\end{aligned}
$$

The production function is linear in hours, the matching functions is Cobb-Douglas and the disutility of working is similar to Trigari (2009). The adjustment cost of hours depends on the deviation of hours from their steady state level according to the parameter c_0.[8]

We calibrate the model partly by taking standard values in the literature and partly by matching some steady state targets on euro area data. The period is a month. The standard parameters are summarized in the upper part of Table 1. The discount rate β is set to 0.996, so that the annual interest rate is approximately 4%. The elasticity of good demand to its own price is equal to 6, as in Christiano, Eichenbaum, and Evans (2005). Both the elasticity of the matching function η and the workers' bargaining power are equal to 0.5. We follow Trigari (2009) and set the parameter which governs the disutility of labour ϕ to 10. The fixed cost amounts to 10% of production, an assumption which drives firm's profit close to zero, as in Christiano, Eichenbaum, and Evans (2005). The other targets are summarized in the middle part of Table 1. We target an unemployment rate of 9.6%, the average value in the euro area between 1999 and 2016. Following Elsby, Hobijn, and Sahin (2013) we target a job

[7] Higher adjustment costs also reduce the steady state wage but in general this effect is second-order compared to the impact on the level of hours.

[8] We further multiply c_0 by the steady state level of hours $\bar{h}$ to conveniently obtain $c'(\bar{h}) = c_0$.

finding rate of 0.18.[9] Steady state hours per worker are normalized to 1. The cost of posting a vacancy is set to 4.5% of the wage, close to the one estimated by Kramarz and Michaud (2010) for France. The replacement rate for unemployment benefits is 40%, the average value in Germany, France, Italy and Spain as reported by the OECD. The fixed costs of production are set to 10% of output.

To shed light on the different wage dynamics that emerge when the relative cost of adjusting the extensive and the intensive margin change, we further calibrate the model on US data. The US economy is characterized by: (i) lower unemployment benefits replacement rate (25%), (ii) lower unemployment rate (6.1% over the period 1968-2016) and (iii) much higher job finding rate (0.58 in Elsby, Hobijn, and Sahin (2013)'s estimates) compared to the euro area. This indicates a lower real costs of adjusting the extensive margin, since firms can quickly fill vacancies. However the lack of specific institutions designed to allow variations in the intensive margin can be taken into account by considering positive costs in changing hours per worker. We thus calibrate US adjustment costs of hours so that the total costs of changing the extensive and the intensive margin in the two economies are equal.[10] In this way, the US economy features higher costs of adjusting the intensive margin relative to the extensive one. However higher adjustment costs would imply a lower level of hours per worker in steady state, which is counterfactual since US workers usually work more hours than European ones. Hence, for simplicity, we assume that the disutility of labour is lower in the US, such that in steady state hours per worker are 10% higher than in the euro area. The log-linearized model and the computation of the steady state are described in Appendixes A.1 and A.2, respectively.

2.5 Results

We present the results obtained by simulating the theoretical model. In a comparative statics exercise we first study how the elasticity of wages to the intensive margin varies with the disutility of labour and the adjustment costs of hours. Recall from eq. (10) that the relationship between the hourly wage and hours per worker is summarized by the coefficient $\beta_3^w = \frac{1}{\bar{w}}\left[g'(\bar{g}_0, \bar{h}) - \bar{w}\right]$. The disutility of labour, captured by the parameter g_0, affects directly the elasticity β_3^w, pushing up the wage asked by the worker for additional hours. This relationship is represented in the left panel of Figure 1 for different levels of adjustment costs. β_3^w slightly increases with the disutility of labour, whereas the position of the curve is determined by the level of the adjustment costs. The elasticity is always positive in the euro area, where hour adjustment costs are set to zero, and negative in the US, which feature relatively higher costs of varying the intensive margin.

The adjustment cost c_0 affects both the optimal choice of hours and the steady state wage

[9] We take the average value in Germany, France, Italy and Spain.

[10] Formally, we impose: $\frac{(\kappa/\bar{q}^{US}+c_0^{US})}{y^{US}} = \frac{(\kappa/\bar{q}^{EA})}{y^{EA}}$.

(see eq. (A.2.4) in Appendix A.2), so that β_3^w may vary in non-trivial ways. To study how β_3^w varies when the cost of adjusting the intensive margin increases relative to the cost of creating new jobs we run the same exercise as for the calibration of the US economy. As c_0 increases we reduce the real cost of posting vacancies to keep constant the total costs of changing the labor input. Figure 1 panel (b) plots β_3^w against the adjustment costs of hours computed in this way. We further consider two different scenarios: one in which g_0 is set at the euro area level and hours fall with the increase in adjustment costs (blue solid line) and one in which hours are kept fixed by reducing g_0 (red dashed line). In both cases, as adjustment costs increase the marginal disutility of labour $g'(\cdot)$ decreases below the steady state wage $\bar{w}$. In other words, as adjustment costs get higher an increase in hours worked becomes more costly for the firm than for the worker. Since the share of the matching surplus which accrues to the two parties has to remain constant the firm asks for a wage reduction. On the contrary if adjustment costs are low an increase in hours generate a higher loss for the worker which needs to be compensated by a wage increase. In summary we have shown that sign of the response of wages to hours per worker is ambiguous and depends on the relative costs of adjusting the intensive margin relative to the extensive one.

We can now use simulated data to verify whether a regression analysis can correctly identify this relationship. We simulate data from the model by imposing random technology and demands shocks and extract series of 150 periods length.[11] Then we estimate the WPC on simulated data and present median results over 100 simulations. In the standard specification we regress the wage onto unemployment, productivity and prices[12]; in the augmented version we further include hours worked. The calibration for the euro area implies $\beta_w^3 = 0.17$: we thus expect to find a positive and significant coefficient on the intensive margin. Table 2 presents the results. In the standard WPC estimates the wage depends negatively on unemployment and positively on productivity, as the theory predicts. Interestingly, the coefficient on prices is instead negative. This happens because technology shocks determine a negative co-movement between wages and prices, that shows up in the regression if we do not include additional controls, like hours worked. In fact this coefficient turns positive in the augmented version. By including the intensive margin, the coefficient on unemployment is still negative and significant but its magnitude is much smaller; as expected the relationship between the hourly wage rate and hours worked per worker is positive and significant. Importantly the fit of the WPC improves substantially, with the adjusted R^2 increasing from 0.72 to 1. Table 3 reports the same analysis for the US economy, where the relatively higher cost of adjusting the intensive margin should make the wage rate less responsive to hours per worker. Indeed the model fit is already very high (0.96) in the standard specification and accounting for the intensive margin can do little to improve it. The coefficient on hours is three times smaller than the

[11] Technology and demand shocks both follow an AR(1) process with persistence equal to 0.9 and volatility equal to 0.1.

[12] In order to avoid collinearity, we assume that productivity is observed with a measurement error.

one obtained for the euro area simulation. To conclude, this analysis shows that the behaviour of the intensive margin is relevant in explaining wage dynamics in those economies where its relative adjustment costs are low, like in the euro area.

3 Evidence on EA and US

This section presents some stylized facts on hours worked per employee in the euro area and the US, both from a structural and a business cycle perspective. First, we look at the aggregate time series of hours worked per employee in the EA and US, from 2000 to 2018 (private sector only). Figure 2 shows that weekly hours per worker are on a declining trend in both the US and EA; hours per worker are remarkably higher in the US than in the EA and this difference has further widened in recent years.

The figure also shows the presence of some cyclicality in hours per worker. They declined consideraly in the aftermath of the Great Recession in 2008. This phenomenon was accompaied by a sharp increase in part time positions, mainly unvoluntary in both the EA and the US. Immediately after the Great Recession, hours slightly recovered, but in the EA they collapsed again during the Sovereign debt crisis and rised again in the following years, albeit they remained at very low levels with respect to the pre-crisis period (and conversely, unvoluntary part time remained high). In the US after the Great Recession hours per workers fluctuated remarkably less. Differences in hours worked cannot be easily explained by differences in the sectoral composition of the two economies. The manufacturing sector, where hours per worker are typically higher than in services, is more developed in the EA than in the US. Differences remain wide also by workers' socio-demographic characteristics, like gender and age. This feature can be appreciated by looking at Figure 3, based on MTUS microdata and plotting the average time spent working per week in the US and two large euro area countries, Germany and Italy (the only countries for which comparable data are available). The data refer to prime-age workers i.e. those aged between 25 and 45. In the US hours per worker are higher than in Germany and Italy for all age brackets as well as for both men and women.

Since Prescott (2004) differences in hours worked between US and Europe have been imputed to differences in the tax system. In particular Prescott (2004) shows that under reasonable assumptions about labour supply elasticities, all of the gap can be explained by differences in the marginal tax rates, higher in Europe than in the US.[13] In our framework differences in the tax system are captured by differences in the disutility of work, and their effects are documented in the previous section.

To prepare the ground for the subsequent empirical investigation we then focus on the

[13]Other factors, such as cultural ones may also play some role. On a different side Alesina, Glaeser, and Sacerdote (2007) impute these differences to regulation and labour market institutions but their results are not conclusive.

reduced-form correlations in order to get a first quantitative assessment of the role played by the intensive margin in the adjustment of total labour input. In particular we focus on the following filtered variables[14]: total hours worked by employees (TH), average number of hours worked per employees (AH) and the number of employees (N). The first represents the overall labour input used to produce output and can be decomposed into the product of the second variable (which proxies for the intensive margin of labour utilization) and the third (which proxies for the extensive margin). Table 4 reports the variability (standard deviations on the first row) and cross-correlations among these variables in the two economies. Total hours worked fluctuate significantly over the business cycle (with deviations from trend comprised between -2 and 4 per cent in the EA and -5 and 4 per cent in the US). They strongly co-move with the number of employees (extensive margin). The correlation with the average number of hours worked per employee (intensive margin) is slightly milder, albeit significant, in both areas. Finally the correlation between the two margins is also non-negligible (0.8 in the EA and 0.6 in US), suggesting that two margins are mainly moved in the same direction.

To take into account the fact that hours per worker are on a declining trend in both the US and the EA, Figure 4 shows the cyclical components of total hours of work, of the extensive margin and of the intensive margin. It can be appreciated how adjustments in total hours worked are mainly obtained by variations along the extensive margin. Changes along the intensive margin are quantitatively more muted but non-negligible in the euro area; they are instead marginal in the US. Following Kudoh, Miyamoto, and Sasaki (2018) a straightforward way to measure the relative importance of the intensive and extensive margins in adjusting the total labour input is by recalling the following identity:

$$th = ah + n \tag{12}$$

where the log of total labour input (th) is expressed as the sum of the log of the average number of hours worked per employees (intensive margin (ah)) and (the log of) the number of employees (extensive margin (n)). It follows that:

$$Var(th) = Var(ah) + Var(n) + 2Cov(ah, n) = Cov(th, ah) + Cov(th, n) \tag{13}$$

The term $Cov(th, ah)$ gives the amount of variation in total hours worked derived from variation in the intensive margin directly and through its co-movements with the extensive margin n. Similarly, $Cov(th, n)$ gives the amount of variation in total hours (th) derived from the extensive margin (n) directly and through its co-movements with the intensive margin (ah). Dividing both sides by $Var(th)$ we obtain:

[14] All variables are HP filtered, with smoothing parameter equal to 1600.

$$1 = \frac{Cov(th, ah)}{Var(th)} + \frac{Cov(th, n)}{Var(th)} = \beta^{ah} + \beta^{n} \tag{14}$$

where β^{ah} and β^{n} are the relative contribution to variation in total hours worked from variations in the intensive margin and the extensive margin respectively. For the euro area we find $\beta^{ah} = 0.31$ and $\beta^{n} = 0.69$ meaning that 69 per cent of fluctuations in the total labour input are due to the extensive margin and 31 per cent to the intensive margin. For the US, an economy where labour protection legislation is minimal and adjusting the extensive margin is relatively easy $\beta^{ah} = 0.17$, i.e. the contribution of the intensive margin is just 17 per cent (See Figure 5). Overall, this evidence is fully consistent with the model implications presented in Section 2.5.

4 Estimates of the wage Phillips curve: standard and augmented

In this section we evaluate the information content of the intensive margin of labour utilization with respect to wage growth for the euro area and the US economies with quarterly data over the period 2000q1-2018q2, to test the implications of the model. The information content of the intensive margin is evaluated and quantified by measuring by how much the in-sample-fit of the WPC is increased by introducing the intensive margin as an additional regressor. As the empirical literature on the Phillips curve shows no consensus on one exact specification (e.g. Gordon (2011)), we conduct a thick modelling exercise (Granger and Jeon 2004) considering several specifications that differ in terms of measure of labour market slack, proxies for inflation expectations, and in terms of lead-lag relationship with wage dynamics. More formally, the standard Wage Phillips Curve (SWPC) can be expressed as follows:

$$\pi^{w} = c + \rho\pi^{w}_{t-1} + \beta_1 U_{t-p} + \beta_2 prod_t + \beta_3 \pi^{e}_{t-h;t-h+k} + \epsilon_t \tag{15}$$

where π^{w} is hourly wage inflation, U is a measure of labour market slack along the extensive margin, $prod$ is a measure of hourly labour productivity and $\pi^{e}_{t-h;t-h+k}$ is a measure of k-period ahead inflation expectations sampled at time $t - h$. Labor market slack along the extensive margin is measured either by the official ILO unemployment rate or by an estimate of the unemployment gap. Labour productivity is measured as value added per hours worked. Finally, several proxies of inflation expectations are used such as i) quantitative surveys among professional forecasters, namely the ECB-FED Surveys of Professional Forecasters and Consensus Economics forecasts (Consensus Economics) from which we exploit the agents' point forecast at medium-term horizon (2-year ahead for SPF, 6-quarter ahead and 1-year ahead for Consensus), ii) qualitative surveys conducted among households (EC survey for the euro area and University of Michigan survey for the US) which focus on inflation expectations at a shorter horizon (1 year), and iii) past realized inflation either measured by the average HICP inflation rate recorded in the previous 4 quarters or by the household consumption deflator. Such wide range of proxies allows us to control for both the forward- and backward looking behavior of economic agents.

The lag of the dependent variable is kept fixed to 1. This lag is aimed at capturing serial correlation, which however is quite low since we consider quarter-on-quarter percentage changes. We capture past slack and shocks with the lags of the slack indicator (p) and of the inflation expectation indicator (l), which are allowed to vary between 1 and 4. Contemporaneous shocks are captured by contemporaneous productivity changes.[15] Table 5 summarizes the main characteristics of the estimation exercises as far as the choice of the explanatory variables and their lag structure.

Overall, we consider 193 different specifications of the SWPC. In Table 6 we report the median and the 10th and 90th percentiles of the empirical distribution of the estimated coefficients.[16] Both in euro area and US traditional labour market slack variables, as proxied by the unemployment rate or an estimate of the unemployment gap [17], affect negatively future wage dynamics. On the contrary, productivity and inflation expectations, whether forward or backward looking, affect wages positively albeit in the case of the US the estimated coefficients are not statistically different from zero.

Figure 6 shows the empirical distribution of the point estimates. The support of the distributions of point estimates for the traditional labour market slack variables marginally includes the zero suggesting overall statistically significant estimates. Table 6 reports the median estimates and the 10th and 90th percentiles in squared brackets. In terms of adjusted R^2, the SWPC accounts for 31 percent of the variability of wages in the euro area and for 53 percent in the US.

We can now turn to the estimation of the Augmented Wage PhiIlips Curve (AWPC) which takes the following form.

$$\pi^w = c + \rho\pi^w_{t-1} + \beta_1 U_{t-p} + \alpha AH_{t-q} + \beta_2 prod_t + \beta_3 \pi^e_{t-h;t-h+k} + \epsilon_t \tag{16}$$

Compared to the SWPC we include as an additional regressor the intensive margin of labour utilization (AH) measured by the cyclical component of the average number of hours worked

[15] Other lags for productivity are not significant and do not affect the other estimated coefficients.

[16] The empirical distribution accounts for both model and parameter uncertainty by bootstrapping the residual of each of the 193 model.

[17] For this exercise all gap estimates are obtained by the use of a HP filter. The results, however, are robust to alternative filters and are available upon request.

per worker. As for the other regressors we consider a range of lags (q) between 1 and 4, estimating overall 769 different specifications.

Similarly to Table 6, Table 7 reports the median, the 10th and 90th percentiles of the estimated coefficients, and Figure 7 plots the entire empirical distributions. For the euro area the intensive margin of labour utilization (AH) affects wages positively and the estimated coefficient is statistically different from zero. We notice that the coefficient of the unemployment rate remains negative albeit its magnitude and statistical significance diminish slightly, in line with the simulated results. This is due to the fact that the two margins tend to co-move over the business cycle and therefore part of the variability of wages due to the extensive margin is now correctly attributed to the intensive one. The coefficients on productivity and inflation expectations are very similar to those under the SWPC. Finally the explanatory power of the AWPC increases from 31 percent to 50 percent.

The comparison with the US unveils some interesting results. In the US, the median estimated coefficient for the intensive margin is positive but considerably smaller than in the EA and not statistically significant. Furthermore the estimates of the other coefficients do not change much, similar to what we observed with simulated data. More importantly, the adjusted R^2 does not improve by adding the intensive margin of labour utilization among the regressors. Overall we interpret these results as in line with the insights from the theoretical model.

5 Conclusions

In this paper we try to rationalize why in some countries firms adjust labour input mainly along the extensive margin and in others mainly along the intensive margin and what are the consequences of this different behaviour for the estimation of the relation between nominal wage growth and labour market slack, a crucial question for monetary policy. In particular we look at differences between the US, where firms tend to adjust more frequently the extensive margin, and the euro area, where several institutions tend to increase the costs of job termination and favour adjustments along the intensive margin.

A simple partial equilibrium search model is used to illustrate why both the extensive (which affects the unemployment rate) and the intensive margin (hours per worker) of labour utilization should be taken into account to explain wage dynamics. Each firm pairs with a worker and produces output using the extensive and the intensive margin of labour, within a matching framework *à la* la Diamond-Mortensen-Pissarides. The relative adjustment cost of the intensive vs. the extensive margin determines the amount of hours demanded. Households supply hours given their disutility of work. Households and firm choices combine into a wage Phillips curve which depends not only on unemployment but also by the number of hours worked by each worker.

According to our model the differences between US and the euro area adjustments depend then not only on workers' preferences for leisure, but also on differences in the adjustments costs, which allow for higher volatility along the extensive margin in the US and of the intensive margin in the euro area (in relative terms). We then check empirically for the validity of our results.

For both the US and the euro area we estimate two types of Phillips curve: a standard one and an augmented one which includes also a detrended measure of the intensive margin (which mimics the unemployment gap typically used in standard empirical literature on the Phillips curve). In order to hedge against model uncertainty, a large set of models are estimated using several proxies for labour market slack along the extensive margin, inflation expectations and lag structures. Median results over the whole range of the augmented WPC that we estimate clearly show that in the euro area accounting for variation in the intensive margin leads to i) a strongly positive estimated coefficient for the intensive margin, ii) a non-negligible increase in the explanatory power of the WPC as indicated by the adjusted R^2. Consistently with the model predictions, in the US, where adjustments of the intensive margin are less frequent, this variable does not substantially contribute to explain wage growth.

Overall, our results lead us to conclude that aggregate wage growth and, consequently, the empirical specification of the Phillips wage curve, should take into account all costs of using labour inputs and how they interact with labour market institutions. This also implies that, when it comes to the empirical specification of the Phillips curve, it is probably true that 'one size does not fit all' and, in the presence of differences in the way firms adjust the labour input, these differences should be reflected in the empirical specifications of the Phillips curve.

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Tables and figures

Table 1: Calibration

		Value	Source
Calibrated parameters			
Discount rate	β	0.996	$\simeq$ 4% annual interest rate
Elasticity of good demand w.r.t. price	β^y	6	Christiano, Eichenbaum, and Evans (2005)
Elasticity of matching function	η	0.5	
Workers' bargaining power	γ	0.5	
Disutility of labour parameter	ϕ	10	Trigari (2009)
Targets Euro area			
Unemployment rate	$\bar{u}$	9.6%	avg. unemployment rate (1999–2016)
Job finding rate	$f(\bar{\theta})$	0.18	Elsby, Hobijn, and Sahin (2013)[a]
Replacement rate UB	$b/\bar{w}\bar{h}$	40%	OECD[a]
Working time	$\bar{h}$	1	
Vacancy cost as % of wage	$\kappa/\bar{w}\bar{h}$	4.5%	Kramarz and Michaud (2010)
Fixed cost as % of production	Q/y	10%	
Cost intensive margin	c_0	0	
Targets US			
Unemployment rate	$\bar{u}$	6.1%	avg. unemployment rate (1968-2016)
Job finding rate	$f(\bar{\theta})$	0.58	Elsby, Hobijn, and Sahin (2013)
Working time	$\bar{h}$	1.1	
Replacement rate UB	$b/\bar{w}\bar{h}$	25%	OECD
Cost intensive margin	c_0	0.92	Total costs equal to EA

[a] Average of Germany, France, Italy and Spain.

Table 2: WPC estimates on simulated data (EA calibration)

	Standard WPC	Augmented WPC
Unemployment	-1.1048 (0.0000)	-0.0016 (0.0000)
Productivity	0.0074 (0.2296)	0.0000 (0.9209)
Price index	-0.7032 (0.0007)	0.9432 (0.0000)
Hours worked	-	0.0937 (0.0000)
$\bar{R}^2$	0.72	1.00

Notes: P-values in parenthesis. The Table reports median coefficients estimated on 100 simulations of 150 periods length.

Table 3: WPC estimates on simulated data (US calibration)

	Standard WPC	Augmented WPC
Unemployment	-1.1786 (0.0000)	-0.0061 (0.0000)
Productivity	0.0009 (0.8412)	0.0000 (0.7792)
Price index	-0.1833 (0.0612)	0.2064 (0.0000)
Hours worked	-	0.0315 (0.0000)
$\bar{R}^2$	0.96	1.00

Notes: P-values in parenthesis. The Table reports median coefficients estimated on 100 simulations of 150 periods length.

Table 4: Correlations among labour market variables over the business cycle

	Euro area			US		
	TH	AH	N	TH	AH	N
	0.013	*0.004*	*0.009*	*0.017*	*0.004*	*0.015*
TH	1			1		
AH	0.890	1		0.75	1	
N	0.974	0.7636	1	0.98	0.62	1

Notes: Sample 1995q1-2018q2. H-P filtered data. Standard deviations in *italics*. Correlations at lag 0.

Table 5: Variables used in the estimation exercise

Explanatory variable	**Proxy**	**Lag structure**
Slack along the extensive margin	Unemployment rate Unemployment gap	1 to 4
Productivity	Value added per hour worked	0
Inflation expectation	SPF 2 year ahead Consensus 6 quarter ahead Consumer survey Past HICP inflation Past Consumption deflator inflation	1 to 4
Slack along the intensive margin	Average number of hours per employee gap	1 to 4

Table 6: Standard WPC: median estimates

	EA	US
U	-0.32	-0.21
	[-0.54, -0.03]	*[-0.34, -0.07]*
PROD	0.22	0.03
	[0.12, 0.32]	*[-0.01, 0.06]*
INFL	0.43	0.07
	[0.15, 0.63]	*[-0.06, 0.21]*
Adjusted-R2	0.31	0.53

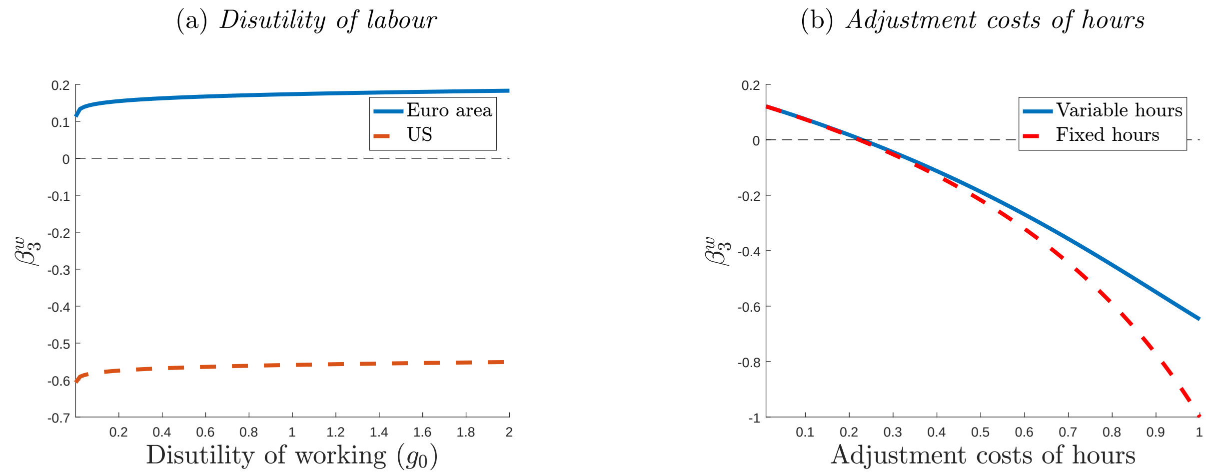
Notes: Sample 2000q1-2018q2. Median estimates. 10th and 90th percentiles in square brackets and in *italics*. U: labour market slack along extensive margin. PROD: hourly productivity. INFL: inflation expectations.

Table 7: Augmented WPC: median estimates

	EA	US
AH	0.58	0.08
	[0.37, 0.77]	*[-0.06, 0.21]*
PROD	0.33	0.05
	[0.24, 0.41]	*[0.01, 0.08]*
U	-0.21	-0.22
	[-0.40, -0.03]	*[-0.35, -0.09]*
INFL	0.31	0.05
	[0.12, 0.49]	*[-0.10, 0.18]*
Adjusted-R2	0.50	0.55

Notes: Sample 2000q1-2018q2. Median estimates. 10th and 90th percentiles in square brackets and *italics*.AH: labour market slack along intensive margin. U: labour market slack along extensive margin. PROD: hourly productivity. INFL: inflation expectations.

Figure 1: Elasticity of wages to hours worked

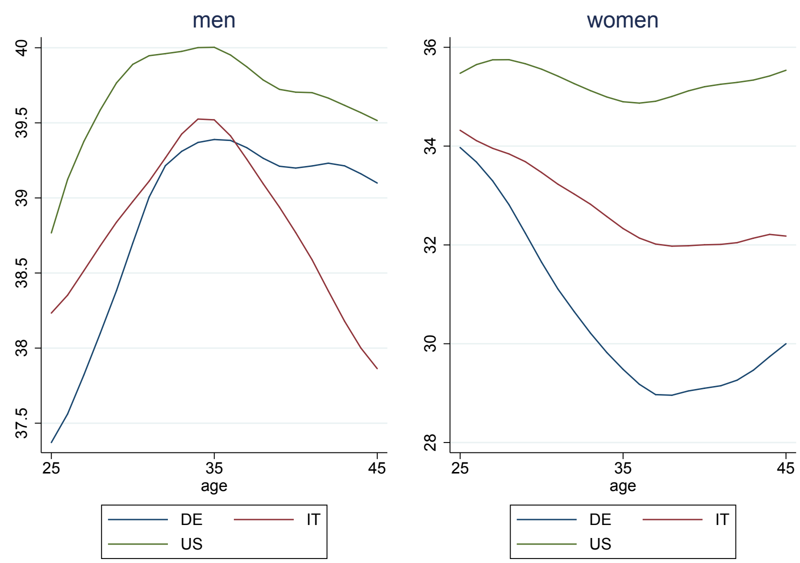


Notes: The figure plots the elasticity of wages to hours worked (β_3^w). In panel (a) the x-axis represents the disutility of working (g_0). Different lines correspond to different calibrations of the adjustment costs of hours ($c(h) = 0$ in the euro area and $c(h) = 0.8$ in the US). In panel (b) the x-axis represents the adjustment costs of hours ($c(h)$), keeping constant the overall costs paid by the firm and setting all the other parameters at the level of the euro area. In other words, in the right panel the cost of varying the extensive margin (κ/q) is adjusted so that the following condition holds: $(\kappa/q + c(h))/y = const.$ For the blue solid line g_0 remains constant at the level calibrated for the euro area, so that hours worked fall with c_0. For the red dashed line, g_0 decreases so to keep hours worked constant.

Figure 2: Average hours worked by employees in US and EA

Notes: The figure plots the number of weekly hours per worker in the EA and US, (National account data and FRED Database, respectively). Seasonally adjusted.

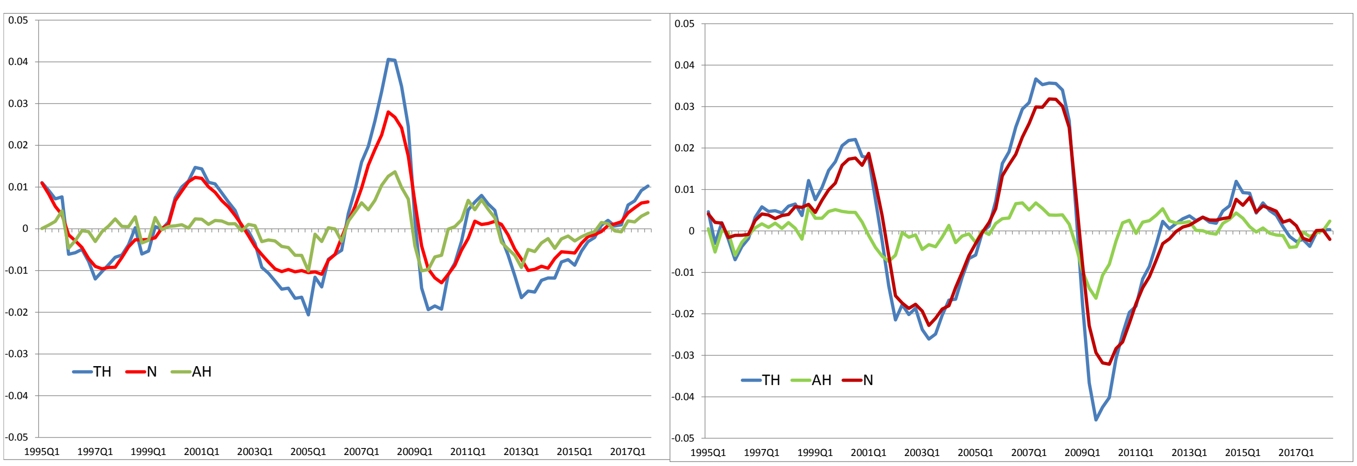
Figure 3: Average hours worked in US and selected EA countries, by age and gender



Notes: The figure plots the number of weekly hours per worker in the Germany, Italy and US. Prime age individuals (25-45 years old). Eaw data are drawn from MTUS (Multinational Time Use Survey) and are smoothed by the use of a lowess estimator.

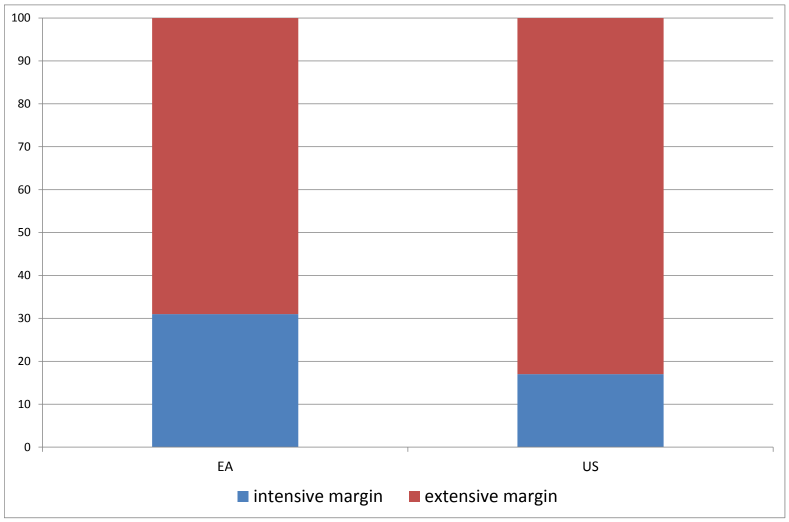
Figure 4: Cyclical variation in the extensive and the intensive margins

(a) *Euro area* (b) *US*



Notes: The figure plots the H-P filtered series of total hours worked (TH), head employment (N) and hours worked per worker (AH).

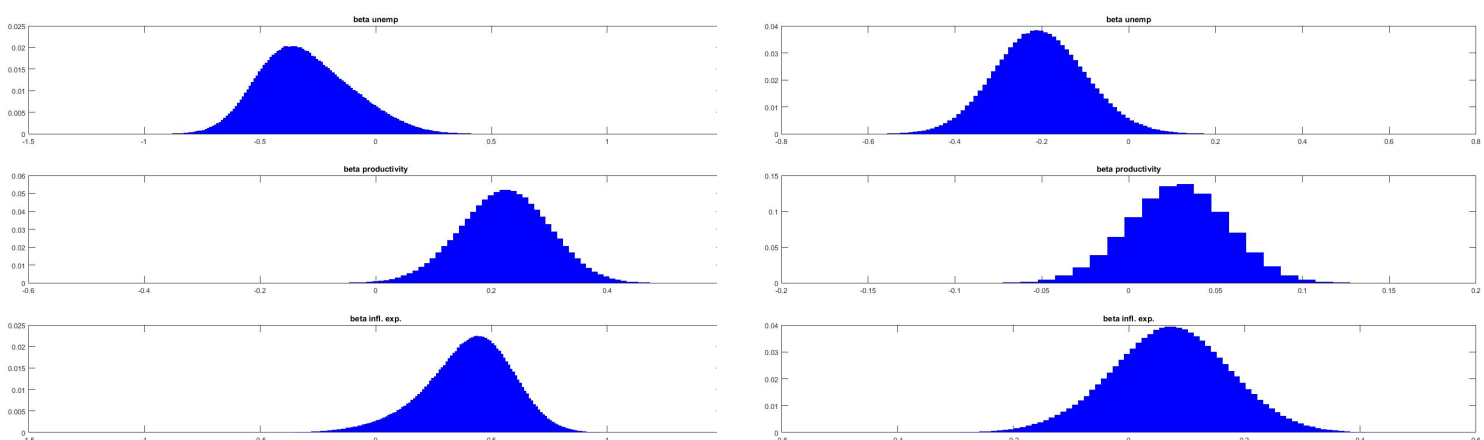
Figure 5: Contribution of the intensive and extensive margin to adjustment of the labour input over the business cycle: 1995-2018



Notes: Percentage points. On H-P-filtered data.

Figure 6: Distribution of the estimated coefficients in the standard wage Phillips curve

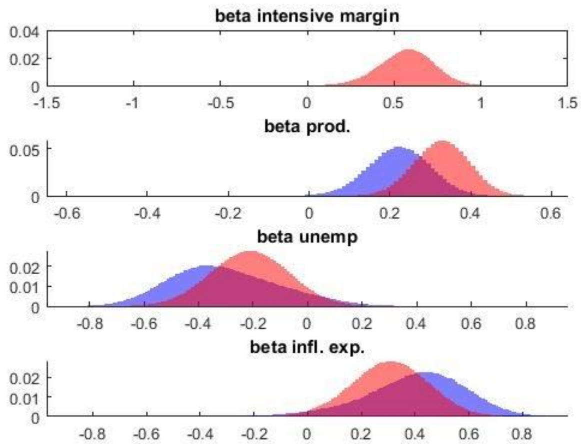
(a) *Euro area* (b) *US*



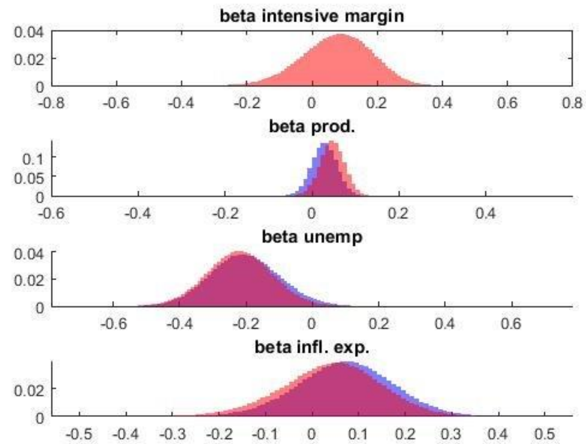
Notes: The distributions are obtained by bootstrapping (with replacement) 10000 times the residuals of each model.

Figure 7: Distribution of the estimated coefficients in the augmented wage Phillips curve

(a) *Euro area*



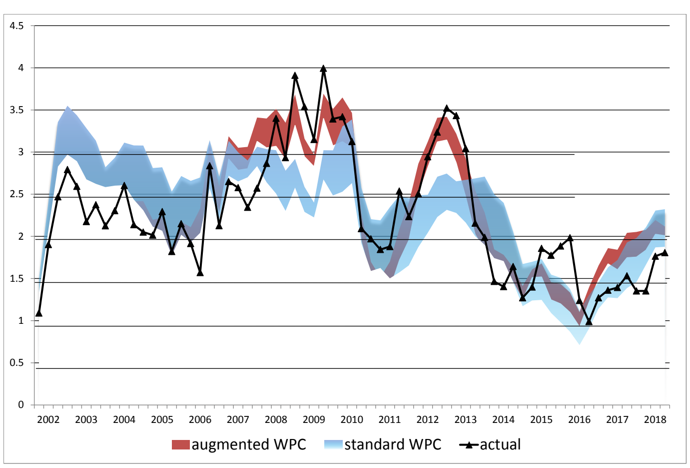
(b) *US*



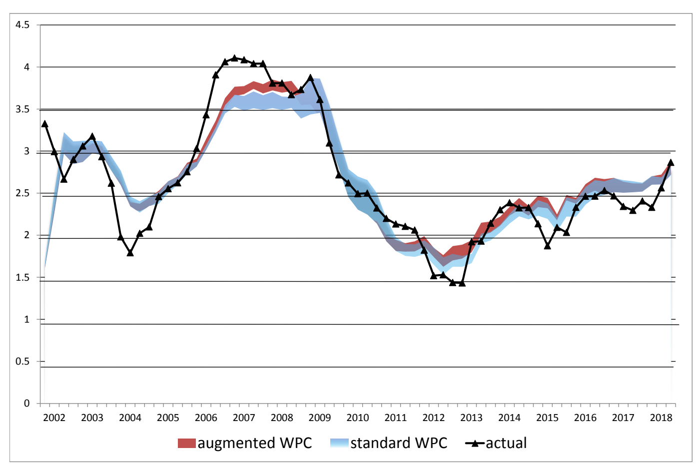
Notes: The distributions are obtained by bootstrapping (with replacement) 10000 times the residuals of each model. The blue areas are the distributions of the estimated parameters under the standard WPC. The red areas are the distributions of the estimated parameters under the augmented WPC.

Figure 8: In-sample fit: standard vs augmented wage Phillips curve

(a) *Euro area*



(b) *US*



Notes: The plots show the range of in-sample predictions of the 10 models with highest adjusted-R2 under the standard WPC (light blue area) and under the augmented WPC (red area) along with actual data (black line). Data are transformed into year-on-year percentage changes.

A Theoretical model

A.1 Log-linearized model

We report here the log-linearization of the theoretical model presented in Section 2.

Individual production function: $\hat{y}_t = a_t + \hat{h}_t$.

Marginal productivity of hours: $\hat{mph}_t = a_t$.

Aggregate production: $\hat{Y}_t = \hat{n}_t + \hat{y}_t$.

Labor market tightness: $\hat{\theta}_t = \hat{v}_t - \hat{u}_{t-1}$.

Job finding rate: $\hat{f}(\cdot)_t = \hat{m}_{0t} + \eta\hat{\theta}_t$.

Job filling rate: $\hat{q}(\cdot)_t = \hat{m}_{0t} - (1-\eta)\hat{\theta}_t$.

Disutility of labour: $\hat{g}_t(\cdot) = (1+\phi)\hat{h}_t$.

Marginal disutility of labour: $\hat{g}'_t(\cdot) = \phi\hat{h}_t$.

Adjustment costs of hours: $\hat{c}_t(\cdot) = \frac{c_0}{\bar{c}}\bar{h}\hat{h}_t$.

Law of motion of employment (eq. 2):

$$\hat{n}_t = \bar{\delta}\left(\hat{f}_t + \hat{u}_{t-1}\right) + (1-\bar{\delta})\hat{n}_{t-1} \tag{A.1.1}$$

Demand for goods (eq. (1)):

$$\log(Y_t) - \log(\bar{Y}) = -\beta^y p_t + \nu_t^d \tag{A.1.2}$$

Job creating condition (eq. (5)):

$$\hat{\theta}_t = \frac{(1-\gamma)\bar{q}}{(1-\eta)\kappa}\left[(\bar{y} - g(\bar{h}))p_t + \bar{y}a_t\right] + \beta\left[1 - \delta - \frac{\gamma\bar{q}\bar{\theta}}{1-\eta}\mathbb{E}\hat{\theta}_{t+1}\right] \tag{A.1.3}$$

FOC on hours (eq. (8)):

$$\hat{mph}_t = \frac{1}{\bar{mph}}\left[g'(\bar{h})\left(p_t + \phi\hat{h}_t\right) + c'(\bar{h})\hat{h}_t\right] \tag{A.1.4}$$

Wage Phillips curve (eq. (9)):

$$\hat{w}_t = \frac{\gamma}{\bar{w}} a_t + \frac{1}{\bar{w}\bar{h}} \left[\gamma \bar{y} + (1-\gamma) g(\bar{h})\right] p_t + \frac{1}{\bar{w}} \left[(1-\gamma) g'(\bar{h}) + \gamma \left(\bar{mph} - c'(\bar{h})\right) - \bar{w}\right] \hat{h}_t + \frac{\gamma}{\bar{w}\bar{h}} \beta \kappa \bar{\theta} \left[\mathbb{E}_t \hat{v}_{t+1} - \hat{u}_t\right] \tag{A.1.5}$$

Shock processes:

$$a_t = \rho^a a_{t-1} + \varepsilon_t^a \qquad \text{(technology)}$$
$$\nu_t^d = \rho^d \nu_{t-1}^d + \varepsilon_t^d \qquad \text{(demand)}$$

A.2 Steady states

Denote with a superscript T the variables which are taken as target from the data. The unemployment rate is one of those, and its steady state level is such that $\bar{u} = u^T$. The steady state employment rate immediately follows: $\bar{n} = 1 - \bar{u}$. By taking as a target the job finding rate ($\bar{f}(\cdot) = f^T$), we get the separation rate from eq. (2):

$$\bar{\delta} = \frac{\bar{f}(\cdot)\bar{u}}{\bar{n}} \tag{A.2.1}$$

Let us normalize to 1 the steady state level of technology and the price. Given the target for working hours ($\bar{h} = h^T$), we can derive the individual and the aggregate output and the marginal productivity of hours: $\bar{y} = \bar{h}$, $\bar{Y} = \bar{n}\bar{y}$, $\bar{mph} = 1$. The fixed cost of production Q is a fraction of y. In the euro area we assume no adjustment costs of hours: $c(h) = 0$.

From the FOC on working hours (eq. (8)) we can derive $\bar{g}_0$:

$$\bar{g}_0 = \frac{\bar{mph}}{\bar{h}^\phi} \tag{A.2.2}$$

where we have used: $c'(\bar{h}) = 0$ (in the euro area calibration).

We find the steady state values of labor market tightness and the wage by solving the system of the job creating condition and the wage setting equation, namely equations (5) and (9). We obtain:

$$\bar{\theta} = \frac{\bar{f}(\cdot)}{r_\kappa} \left[\frac{(\bar{y} - Q)(1-\gamma)(1-r_b) - (1-\gamma)\bar{g}(\cdot)}{(1-\gamma)\bar{g}(\cdot)\left(1-\beta(1-\bar{\delta})\right) + \gamma(\bar{y} - Q)\left(1 - \beta\left(1 - \bar{f}(\cdot) - \delta\right)\right)} \right] \tag{A.2.3}$$

$$\bar{w} = \frac{1}{\bar{h}} \left[\frac{\bar{f}(\cdot)(\bar{y} - Q)}{\bar{f}(\cdot) + r_\kappa \bar{\theta}(1-\beta(1-\bar{\delta}))} \right] \tag{A.2.4}$$

where we have used the relationship $\bar{q}(\cdot) = \bar{f}(\cdot)/\bar{\theta}$ and we have defined $r_\kappa = \frac{\kappa}{\bar{w}\bar{h}}$ and $r_b = \frac{b}{\bar{w}\bar{h}}$ as the ratios between the vacancy posting cost and the wage and between the value of leisure and the wage, respectively. Finally, we get $\bar{m}_0$ from the definition of job finding rate: $\bar{m}_0 = \frac{\bar{f}(\cdot)}{\bar{\theta}^\eta}$.

B Data definitions and sources

B.1 Euro area

- Hourly wages: euro area 19 (fixed composition), ratio of total wages to employee and hours worked by all employees in the private sector excluding agriculture and energy. Source: Eurostat. Seasonally adjusted, working day adjusted.
- Unemployment rate: euro area 19 (fixed composition) - Standardized (ILO) unemployment, Rate, Total (all ages), Total (male and female); percentage of civilian labor force . Source: Eurostat. Seasonally adjusted, not working day adjusted.
- Unemployment gap: own estimate on unemployment rate data.
- Average number of hours worked: ratio of total hours worked and number of workers in the private sector excluding agriculture and energy. Source: Eurostat. Seasonally adjusted, working day adjusted.
- Hourly gap: own estimate on average number of hours worked
- Productivity: ratio of Real value added and total hours worked in the private sector excluding agriculture and energy. Source: Eurostat. Seasonally adjusted, working day adjusted.
- Consumer survey: euro area 19 (fixed composition) Price trends over next 12 months. Source: EU Commission, DG-ECFIN (Eurostat). Seasonally adjusted, not working day adjusted.
- SPF 2-year ahead Inflation expectations. Source: Survey of Professional Forecasters (ECB).
- Consensus 1 year-ahead Inflation expectations. Source: Consensus Economics.
- Consensus 6 quarter-ahead Inflation expectations. Source: Consensus Economics.
- Past HICP inflation : 4 quarters moving average of (YoY) inflation rates (HICP), lagged 1 quarter. Source: Eurostat.
- Past Consumption Deflator inflation: annualized 4 quarters moving average of (QoQ) inflation rates (private consumption deflator), lagged 1 quarter. Source: Eurostat.

B.2 United States

- Hourly wage: Average Hourly Earnings of Production and Nonsupervisory Employees: Total Private. Dollars per hour. Source: FRED Database. Seasonally adjusted.

- Unemployment rate: Civilian unemployment, Rate, Total (all ages), Total (male and female); percentage of civilian labor force . Source: FRED Database. Seasonally adjusted, not working day adjusted.
- Unemployment gap: own estimate on unemployment rate data.
- Average number of hours worked: Nonfarm Business Sector. Average Weekly Hours (Index 2012=100). Source: FRED Database. Seasonally adjusted.
- Hourly gap: own estimate on average number of hours worked.
- Productivity: Nonfarm Business Sector. Real Output Per Hour of All Persons (Index 2012=100). Source: FRED Database. Seasonally adjusted.
- Consumer survey: University of Michigan: expected change in prices during the next year. Source: FRED Database. Seasonally adjusted.
- SPF 2-year ahead Inflation expectations. Source: Survey of Professional Forecasters (Federal Reserve Bank of Philadelphia).
- Consensus 6 quarter-ahead Inflation expectations. Source: Consensus Economics.
- Past HICP inflation : 4 quarters moving average of (YoY) inflation rates (HICP), lagged 1 quarter. Source: Fred Database.
- Past Consumption Deflator inflation: annualized 4 quarters moving average of (QoQ) inflation rates (private consumption deflator), lagged 1 quarter. Source: FRED Database.