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

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Abstract

Compared to the US in the Euro area firms have higher propensity to adjust along the intensive margin of labour utilization (hours per worker) in case of shocks. In this paper we check whether this different behaviour has consequences on wage growth. First, we present a partial equilibrium job search model in which frictions allow for equilibrium unemployment. The standard search and matching setup is however modified by introducing costly hour adjustments for both firms and workers. We then derive a wage equation which depends on firms' adjustments costs both along the extensive margin (i.e. the unemployment rate) and the intensive margin and households' preferences for leisure. The model, calibrated for the Euro area, is then used to analyse the conditions under which wages react to the extensive and/or the intensive margin and the sign of this relationship, *a priori* undetermined. Last, we empirically estimate different Phillips curves in the US and the Euro area. Consistently with the model predictions, we find that in an economy where it is relatively easier to adjust the intensive margin (as in the Euro area), this margin highly influences wage growth. In a Phillips curve which controls not only for standard variables but also for the intensive margin the relationship between this measure of slack and wages is positive. For the Euro area its inclusion considerably improves the model fit.

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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 questions arise: do changes in the intensive margin affect wage growth? And how?

In practice, the choice to adjust the extensive and/or the intensive margin depends on several factors among which the relative cost of adjustment along the two margins play a relevant role. For instance, in an expansionary phase, firms can respond to increasing demand by hiring more workers or asking extra hours to existing ones. The cost of the first option is related to the time and resources devoted to the hiring process as well as to the expected cost of workers' dismissal. Increasing the amount of hours worked by each existing worker is also costly as workers could require higher compensation for working extra-time. Conversely, during a downturn, firms could chose to hoard labour and reduce the amount of hours worked per worker. Reducing hours can however be costly. For instance, during a downturn workers with some bargaining power could oppose to a reduction of hours worked to avoid a drop in earnings; as a result despite the reduction in the total wage bill, the hourly wage rate could actually increase. Alternatively the firm could reduce its workforce incurring the cost related to the firing process, to the loss of human capital as well as to the expected hiring process. 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 where during a downturn the subsidy reduces the adjustment cost of the intensive margin relative to that of the extensive margin.

It is well known, indeed, that the EA and the US firms differ greatly in their propensity to adjust the intensive and or the extensive margin. For example during the Great recession 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[1] 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 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 seems to have developed along two lines of research. One line motivated by the recent subdued dynamics of

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

inflation, core inflation and especially wage inflation in most advanced economies has found renewed interest in the wage Phillips curve, its microfoundation (**Gali˙2010**) and its stability over time (**Gali˙Gambetti˙2018** and **Blanchard˙2016**). The other line of research initially motivated by the significant scars inflicted by the financial crisis to labour markets in advanced economies and more recently further pushed by the inability of standard models to predict the observed low and persistent inflation has focused on the limits of traditional measures of slack and has developed broader measures (see e.g. **ECB˙2019**).

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 theorethical perspective a deeper understanding of the conditions under which firms adjust along the intensive margin, its implications for wage growth and head-count employment is needed. In this paper we try to fill these gaps. After reviewing the related literature (Section **??**), in Section 3 along the line suggested by Trigari (2009) we present a partial equilibrium model of labour demand that features the Diamond-Mortensen-Pissarides search and matching framework in order to introduce involuntary unemployment.

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 wage Phillips curve 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 on hours per worker (intensive margin). Interestingly the sign of the coefficient of the intensive margin is ambiguous, as it depends in non-trivial ways on households preferences for leisure and firms adjustment costs. Thus, differences in these two parameters determine 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 wrt the extensive one increases, the elasticity of hourly wage rate to hours per worker diminishes. We interpret this case as closer to the US case, where as firms face a higher labour market matching efficiency and lower firing costs, they can relatively less costly adjusting employment.

In Section 4 the information content of the intensive margin of labour utilization for wage growth is empirically evaluated on US and Euro area data. Two types of the WPC are estimated: a standard WPC where labour market slack is proxied by the extensive margin of labour utilization and an augmented WPC where the intensive margin is introduced among the regressors. To check whether our results are generally valid or specific to the PC specification, for each type of WPC we estimate a large set of equations, changing the number of lags and different proxies for inflation expectations and unemployment. 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 effects 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. Last, Section 6 briefly concludes.

2 Literature review

As anticipated in the introduction, the renewed interest on the wage Phillips curve is explained by the historically strong increases in unemployment in most advanced economies during the financial crisis and the stubbornly stagnant dynamics of prices and wages in its aftermath. Standard New Kenesian general equilibrium models are unable to explain the large fluctuations observed in the unemployment rate as they assume a frictionless perfectly competitive labor market in which individuals vary the hours that they work, but the number of people working never changes.

Gali' (2010) is among the first to derive a wage phillips curve within a standard new keynesian model by relating the wage mark-up to the prevailing unemployment rate. An alternative framework to explain involuntary unemployment rate is the searching and matching one proposed by Diamond Mortensen and Pissarides. Here an inverted relationship between wage growth and labour market slack arise because the labour market is not competitive and firms and workers bargain over the resulting surplus of the "match" and the bargaining position of the worker weakens as the unemployment rate increases.

Walsh (2003) is the first to introduce such labour market structure into a monetary NK model. In both class of models however the worker can only be employed or unemployed. Similarly firms, can only adjust the labour input by hiring or firing. Therefore wage growth con only depend on labour market slack along the extensive margin. This representation of the choices of workers and firms is however at odds with the emprircal evidence where the average amount of hours worked by each worker - a proxy of the intensive margin of labour utilization - varies significantly (see Hall et al. 2000).

The diverging trends observed since the great financial crisis 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 (2018). The authors provide evidence (see Bell and Blanchfloewer 2018) for the UK, the US as well as other advanced economies that a measure of underemployment expressed in hours helps explaining lowers pay 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. From a theorethical perspective, when labour adjustment can occur both along the extensive and the intensive margin, the interaction between wages, employment and hours is non-trivial.

Few theorethical models have been developed to explain it. Similarly to Walsh (2003), Trigari (2006) and (2009) integrates a model of involuntary unemployment a-la Mortensen and Pissarides (1994) into a standard NK model allowing however for labour to be adjusted both along the intensive and extensive margin. While the implications for the interaction between wage, employment and hours are not explored in full, the models include a wage phillips curve where the wage is a function of both the thightness of the labour market and the level of hours worked per worker. Furthrmore the author shows that the interaction between wage, hours and employment depends also on the way firms and workers bargain over the surplus of the "match".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).[2] Differently from them, we introduce hours adjustment costs and focus on the relationship between the relative cost of the intensive margin wrt the cost of the extensive margin for the wage dynamics.

3 The model

In this Section we build a partial equilibrium model of labour demand 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. Higher values of the unemployment rate are thus associated with lower wage pressures, as more workers compete for a job. This leads to a negative relationship between wage growth

[2] 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.

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 and 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 ε_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 - create a job or not - to the one on the intensive margin, which is taken afterwards inside the match.[3]

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 ($q(\theta_t) =$

[3]An alternative would have been to consider a large firm which take 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.

$\frac{m_t}{v_t} = m_{0t}(\theta_t)^{\eta-1}$) 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.

3.1 Value functions

Here we describe the agents' 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:

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

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

J^v_t represents the value of a vacancy in period t, that is the value of creating a new job and searching for 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 value of a vacancy is:

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

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 ($J^v_t = 0, \ \forall \ t$) holds and eq. (3) can be rewritten as

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

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: $S_t^f = J_t$.

Let now consider the worker's problem. When paired with a firm the worker receives a salary and suffers from disutility of working increasing in hours 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: $S_t^w = W_t - U_t$.

3.2 Wage and hours setting

In perfect competition the wage clears the market by equating to 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:

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

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 slack 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 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[4]:

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

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 5. 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

[4]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 $\hat{P}_t = \log(P_t) = p_t$.

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 in steady state the marginal disutility of labour is higher than the wage. To gain intuition, assume that we observe a one unit increase in hours per worker. This is costly both for the firm, which has to pay a 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, while the second one for an increase. The net effect will depend on the relative strength of these two forces.

In general β_3^w is a complicated function of all model parameters, as they determine the level 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. 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.[5]

3.3 Functional forms and calibration

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

[5] 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.

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

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.[6]

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 finding rate of 0.18.[7] 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%. 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 lower unemployment benefits replacement rate (25%), lower unemployment rate (6.1% over the period 1968-2016), compared to the euro area much higher job finding rate (0.58 in Elsby, Hobijn, and Sahin (2013)'s estimates). 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

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

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

margin in the two economies are equal.[8] 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 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.

3.4 Results

In this Section we present the results obtained by simulating the theoretical model. In a comparative statics exercise we first study how the elasticity of 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 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 (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 are allowed to reduce with the increase in adjustment costs (blue solid line) and one in which hours are kept fixed by varying 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 rather 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 am-

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

biguous and depends on the relative costs of adjusting the intensive margin with respect 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.[9] 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[10]; 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 wages depend 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. Tables 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 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.

4 Evidence on EA and US

As shown in the theorethical model both the extensive and the intensive margin of labor utilization play an important role in explaining wage growth. This section presents some stylized facts on the euro area and the US labour markets over the business cycle.[11] To prepare the ground for the subsequent empirical investigation here we focus on reduced-form correlations among labour market variables in order to get a first quantitative assessment of the role played by the intensive margin in the adjustment of the labour input. In particular we focus on the following variables: total hours worked by employees (TH), average number of hours worked per employees (AH) and the number of employees (N). The former represents

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

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

[11] For this descriptive analysis all variable are HP filtered, with smoothing parameter equal to 1600.

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 comprised between 4 and -5 per cent. They strongly co-moves with the number of employee (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 directions and substitutions between the two is overall limited.

Figure 2 shows the cyclical components of total hours of work, of the extensive margin and of the intensive margin. It can be appreciated how adjustment 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, which we have found to be non-negligible. 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:

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

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. In other words, in the euro area the intensive margin plays a significant role in labour adjustment over the business cycle albeit not the prevailing one. For the US, an economy where labour protection legislation is minimal and adjusting the extensive margin is relatively easy $\beta^{ah} = 0.17$, the contribution of the intensive margin is just 17 per cent (See Figure 3).

5 Estimates of the 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. The conceptual framework is that of the Wage Phillips Curve (WPC) by which wage dynamics is modelled as a function of labour market slack, productivity and inflation expectations. 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 additional regressor. As the empirical literature on the Phillips curve shows no consensus on one exact specification, we conduct a thick modelling exercise (Granger and Jeon 2004) considering several specifications that differ in terms of measure of labour market slack and in terms of of inflation expectations used as well as in terms of lead-lag relationship with wage dynamics. In more formal and general terms, the standard Wage Philips Curve (SWPC) can be expressed as follows:

$$\pi^w = c + \rho\pi^w_{t-1} + \beta U_{t-p} + \gamma prod_t + \pi^e_{t-h;t-h+k} + \epsilon_t \tag{15}$$

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 (UR) or by an estimate of the unemployment gap (UG). 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 (ECB-FED survey 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 Univeristy 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 quarter 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.

In terms of lag relationship we keep fixed respectively equal to 1 and 0 the lag of the dependent variable and that on productivity but allow those of the slack indicator (p) and of the inflation expectation indicator (l) to vary between 1 and 4. We do not consider contemporaneous effect for two reasons: i) the use of contemporaneous variables increase the likelihood of incurring in some sort of endogeneity/reverse causality bias and ii) economies are characterized by some degree of labour market rigidities which significantly affect the timing of transmission of shocks from quantities to prices. Table 5 summarizes the main characteristics of the estimation exercises as far as the choice of the explanatory variables and their lag structure is concerned.

Overall we consider 193 different specifications of the SWPC. In Table 2 we report the median and the 10th and 90th percentiles of the empirical distribution of the estimated coefficients.[12] Both in Euro area and US traditional labour market slack variables, as proxied by the unemployment rate or the unemployment gap, 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 4 shows the empirical distribution of the point estimates. It can be appreciated how 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-R2, 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.

$$\pi^w = c + \rho\pi^w_{t-1} + \beta U_{t-p} + \alpha H_{t-q} + \gamma prod_t + \pi^e_{t-h;t-h+k} + \epsilon_t \tag{16}$$

Compared to the SWPC we include as additional regressor the intensive margin of labour utilization (AH) measured by the cyclical component of the average number of hours worked per worker. As for the other regressors we consider a range of lags (q) between 1 and 4 estimating overall 769 different specifications.

As before Table 7 reports the median, the 10th and 90th percentiles of the estimated coefficients, while Figure 5 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

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

the business cycle and therefore part of the variability of wages due to the extensive margin is now captured by that of 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 with what we observed with simulated data. More importantly, the adjusted R-squared 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.

6 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 bwtween 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 model of labour demand is used 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. Each firm pairs with a worker and produces output using only both the extensive and the intensive margin of labour. In order to introduce involuntary unemployment we adopt the search and matching framework la Diamond-Mortensen-Pissarides, where 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.

At the beginning of each period, firms post vacancies up to the point where the hiring cost equate the expected profitability of a productive match with a worker. Hours worked and the hourly wage are then bargained within each match by maximizing the Nash surplus, with fixed bargaining powers for the worker and the firm. Under the hypothesis that working longer hours generates a disutility to the worker, and in the presence of adjustments costs for firms, which depend on the specific margin used, the optimal level of hours is such that the marginal product is equal to the marginal disutility. By solving the wage setting problem the model generates 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 adjustments costs, which allow for a smoother adjustment along the extensive margin in the US and of the intensive marginn in teh 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 (more than 400) are estimated using several proxies for labour market slack along the extensive margin, inflation expectations (forward- and backward-looking) and lag structures (from 1 to 4). Median results over the whole range of models considered for the augmented WPC clearly show that in the Euro area accounting for variation in the intensive margin of labour utilization 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 R2. 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.

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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

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	1 to 4

Table 6: Standard WPC: median estimates

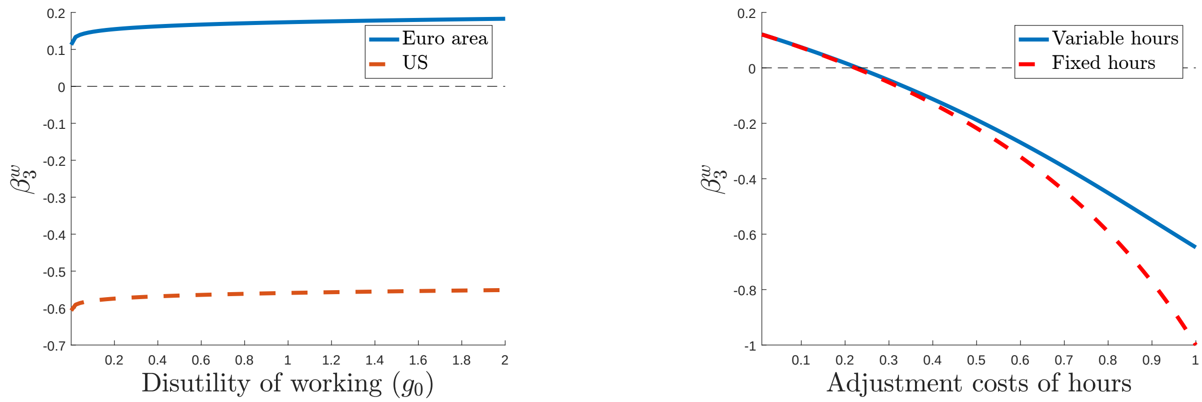
	EA	US
U	-0.32	-0.21
	[-0.54, -0.03]	*[-0.34, -0.07]*
prod	0.22	0.03
	[0.12, 0.32]	*[-0.01, 0.06]*
infl	0.43	0.07
	[0.15, 0.63]	*[-0.06, 0.21]*
Adjusted R2	0.31	0.53

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

Figure 1: Elasticity of wages to hours worked

(a) *Disutility of labour* (b) *Adjustment costs of hours*



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 reduce with c_0. For the red dashed line, g_0 decreases so to keep hours worked constant.

Figure 2: Cyclical variation in the intensive margin

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

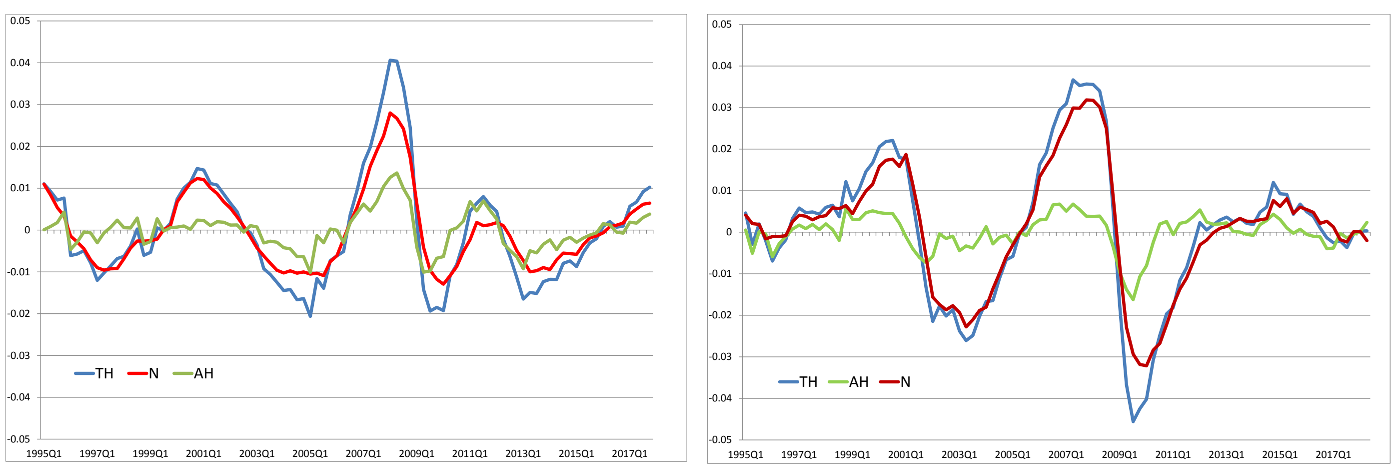


Figure 3: Contribution of the intensive and extensive margin to adjustment of the labour input over the business cycle: 1995-2018

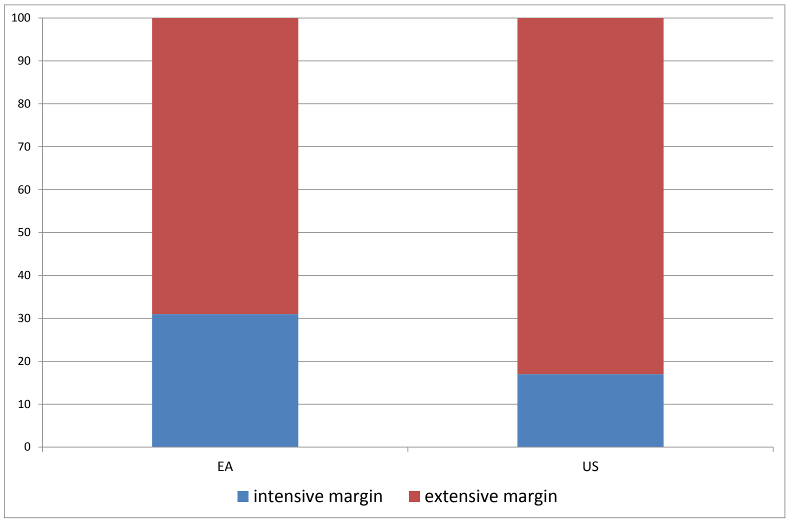
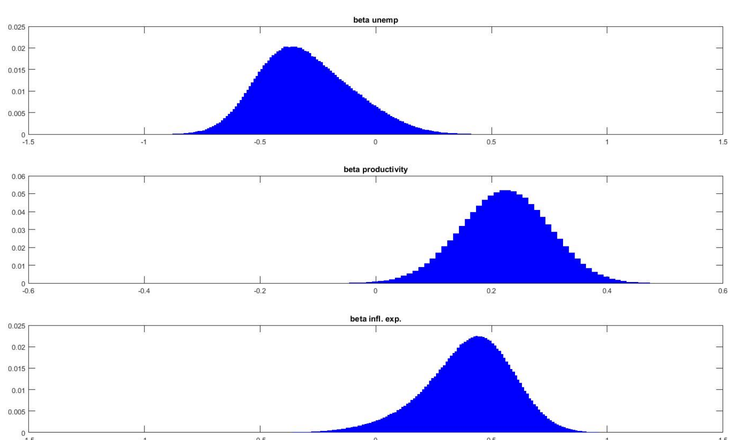


Figure 4: Distribution of the estimated coefficients in the standard Phillips curve

(a) *Euro area*



(b) *US*

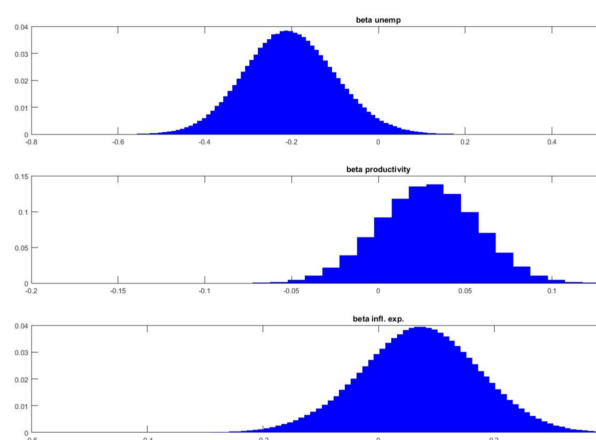


Figure 5: Distribution of the estimated coefficients in the augmented Phillips curve

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

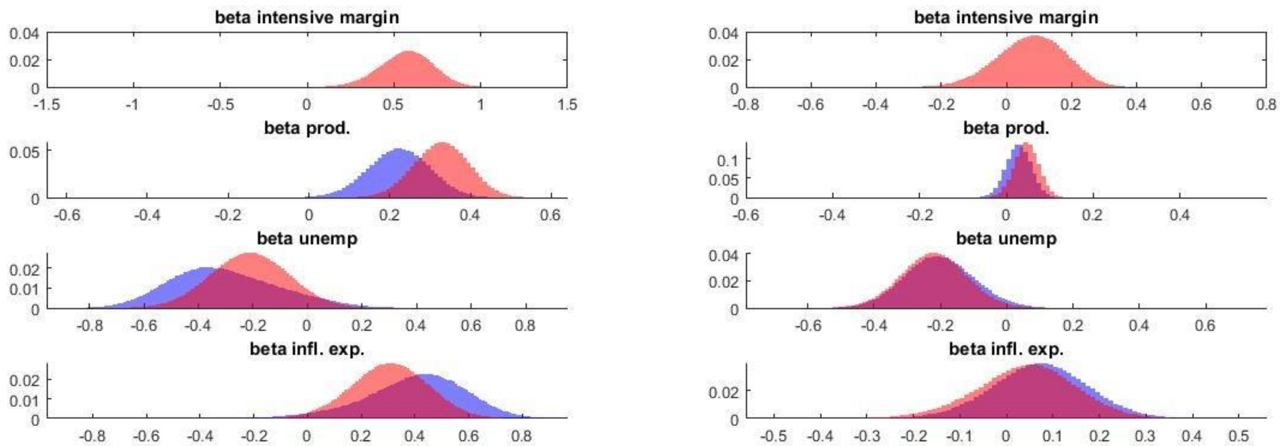
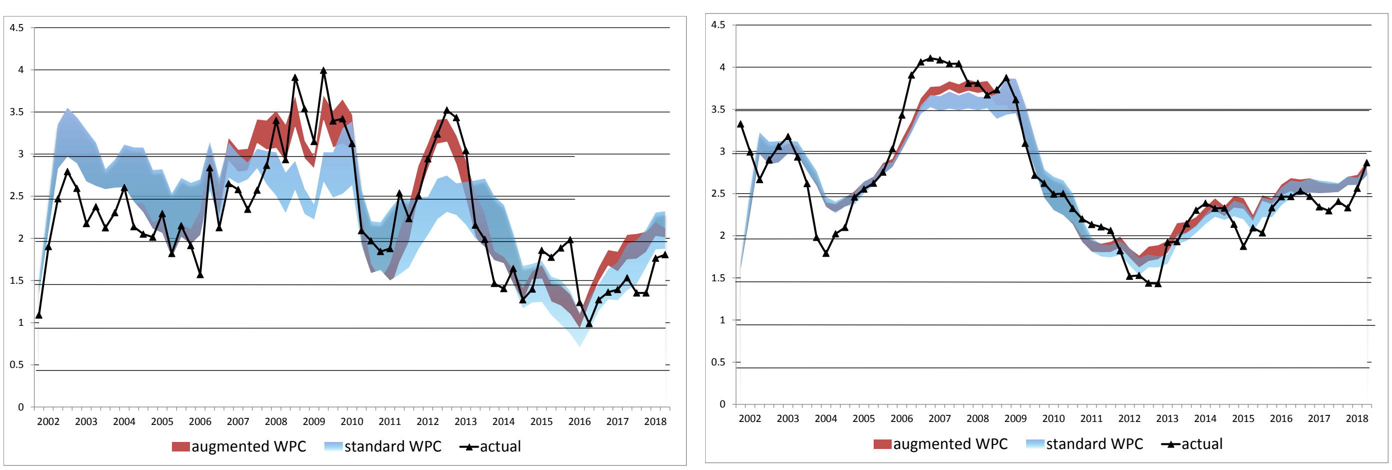


Figure 6: In-sample prediction: standard vs augmented PC

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



A Theoretical model

A.1 Log-linearized model

We report here the log-linearization of the theoretical model presented in Section 3.

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.