Labor Productivity and Inflation Dynamics: the Euro Area versus the US*

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Abstract

We document that labor productivity is significantly more procyclical and inflation is less volatile in the Euro Area compared to the US. To explain these differences jointly, we estimate a New Keynesian model with search frictions in the labor market. In addition to employment and hours we include variable effort as a third adjustment margin. Our estimates show that the effort margin is much more important in the Euro Area than in the US. Variable labor utilization generates procyclical productivity, which dampens the volatility of real marginal cost and inflation. Moreover, we show that variable labor utilization is more important than variable capital utilization in explaining the business cycle facts.

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1 Introduction

We document two differences between the Euro Area and US business cycles. First, labor productivity is procyclical in the Euro Area, while it is acyclical in the US. Second, Euro Area inflation is less volatile than US inflation. The hypothesis we test in this paper is that procyclical labor productivity and the low inflation volatility in the Euro Area are caused jointly by highly variable labor utilization. Although both business cycle facts have been documented separately in ECB (2011) and Fahr et al. (2011), to the best of our knowledge, we are the first to conjecture that there is a close link between the two, because both result from labor market differences between the Euro Area and the US.

Variable labor utilization or effort – as featured in e.g. Bils and Cho (1994) – has received renewed interest in the more recent literature for explaining the decrease in the procyclicality of US labor productivity.[1] If labor market frictions are reduced, firms rely less on the effort margin. As a result labor productivity becomes less procyclical. Barnichon (2010) uses this mechanism to explain the switch from a negative to a positive correlation between US productivity and unemployment in the mid-1980s. Galí and van Rens (2017) argue that a decline in US labor market turnover has reduced hiring frictions so that variable effort has become a less important adjustment margin. The implied reduction in the procyclicality of labor productivity has according to their model reduced the volatility of output. Fernald and Wang (2016) show that empirically reduced variation in factor utilization – the workweek of capital and labor effort – is indeed the main driver for the change in the cyclicality of US labor productivity.

While these papers analyse the role of effort for changes in the cyclicality of US labor productivity, we study its role for differences between the US and the Euro Area. We do not restrict the analysis to differences in the cyclicality of labor productivity, but also analyse the

[1] The related concept of labor hoarding goes back even further, see Oi (1962), Rotemberg and Summers (1990) and Burnside et al. (1993).

implied difference in inflation volatility. To do so, we derive a New Keynesian model with labor search frictions, variable labor effort and price and wage rigidities. We estimate the model using Bayesian estimation for the US and the Euro Area with quarterly data from 1999 onwards. The estimates show that the effort margin is more important for the Euro Area than for the US. It leads to procyclical labor productivity and lowers inflation volatility via the following mechanism: effort leads to increasing returns to hours in production which makes labor productivity procyclical and puts downward pressure on real marginal costs in response to a demand expansion, thereby dampening inflation fluctuations. Using counterfactual simulations, we show that this channel is quantitatively important for the Euro Area. It can explain why labor productivity is procyclical in the Euro Area, but acyclical in the US and why inflation volatility is higher in the Euro Area compared to the US.

The larger role of effort in the Euro Area might be related to the fact that Europe has greater institutional frictions in labor market adjustment, which explains why Euro Area labor flows are smaller than in the US (Nunziata, 2003; Gnocchi et al., 2015; Dossche et al., 2018, among others). Hence, firms might be reluctant to lay off workers during a downturn and turn to variable labor utilization – the effort margin – instead. Besides the importance of labor effort, we also find a larger degree of wage rigidities in the Euro Area compared to the US, which might reflect more general institutional frictions in labor market adjustment in the Euro Area. In the literature there is, however, mixed evidence on the importance of labor market frictions for productivity, real marginal costs and inflation dynamics. Thomas and Zanetti (2009) and Krause et al. (2008) report in New Keynesian models, for the Euro Area and the US respectively, that the contribution of hiring costs to real marginal costs and inflation is small. In Christoffel and Linzert (2010), wage rigidities are a more important determinant of inflation than other labor market frictions. Importantly, those models do not feature endogenous effort.

It is important to note that the effort margin only generates procyclical labor productivity, if effort is procyclical. From a theoretical perspective it is not clear a priori whether this is the case. For example, the shirking model within efficiency wage theory would instead point to countercyclical effort: workers work harder in a downturn, when the probability and costs of getting fired are higher. Empirically, however, various studies find that labor effort is procyclical. Based on data from the American Time Use Survey 2003-2012, Burda et al. (2017) find that time at work spent on non-work activities conditional on any positive amount rises with unemployment, while the fraction of workers reporting positive values declines. Since the former effect dominates, there is a positive relationship between non-work and the unemployment rate, i.e. effort is procyclical. Evidence from health economics shows that sick leave, workplace accidents and mortality rates are all procyclical.[2] One possible explanation is job-related stress and hazardous working conditions, consistent with the idea that labor is used more intensively in boom periods, implying procyclical effort. There is less evidence in support of countercyclical effort. Based on a direct measure of productivity in a single US firm, Lazear et al. (2016) find that effort was countercyclical between 2006 and 2010.

We conduct a number of robustness checks with regard to alternative model specifications. Using a likelihood test, we show that in both economies the model featuring labor effort is strongly preferred by the data compared to a model without labor effort. Variable capital utilization, another common explanation for procyclical productivity, is shown to be far less important for the overall model fit. Finally, we replace the standard efficient bargaining mechanism with right-to-manage bargaining as in Trigari (2006) and Christoffel et al. (2009). While the baseline model can explain the lower inflation volatility in the Euro Area compared to the US, the right-to-manage specification can additionally partially explain low inflation rates in recent years. Hence, variable labor utilization is a potentially important piece in the debate on

[2]Ruhm (2000) shows that people are healthier in recessions. For evidence on procyclical accident rates, see Kossoris (1938), Fairris (1998), and Boone and van Ours (2002). Procyclical sick leave is documented in Taylor (1979), Leigh (1985), Arai and Thoursie (2005), Askildsen et al. (2005) and Schön (2015).

the missing inflation puzzle (see, e.g., Ciccarelli and Osbat, 2017, for an overview).

The remainder of the paper is structured as follows. Section 2 reports business cycle statistics for the US and the Euro Area. Section 3 outlines the New Keynesian model. In Section 4, we estimate the model using Bayesian techniques. In Section 5, we show the dynamic adjustment of the economy to shocks, given our estimated parameter values for the US and the Euro Area, and we conduct counterfactual exercises. Section 6 estimates the importance of the effort margin vs variable capital utilization for fitting the data. Section 7 concludes. Technical details and robustness checks are appended to the paper.

2 Business Cycle Evidence

Table 1 shows HP-filtered data on standard deviations and output correlations of different labor market measures, inflation and the policy interest rate. The sample runs from 1999Q1 to 2016Q4, starting with the beginning of the single monetary policy regime in the Euro Area.

Table 1: US and Euro Area business cycle statistics

Variable	Output correlations			Relative standard deviations		
	Euro Area	US	Diff.	Euro Area	US	Ratio
Real output				1.29	1.19	1.08
Total hours	0.85***	0.86***	-0.02	0.64	1.13	0.56***
Employment	0.76***	0.78***	-0.02	0.55	0.84	0.65***
Unemployment	-0.84***	-0.85***	0.01	0.43	0.68	0.64**
Productivity	0.85***	0.04	0.80***	1.42	1.22	1.16
Inflation	0.45***	0.55***	-0.11	0.27	0.40	0.68**
Policy interest rate	0.50***	0.62***	-0.12	0.32	0.45	0.71**

Notes: Data sources and transformations are provided in the online appendix. Sample: 1999Q1-2016Q4. Data have been HP-filtered, except for the policy interest rate. Standard deviations are computed relative to output. Inflation is measured as year-on-year percentage changes in the GDP deflator. *,**,*** denote significance at the 0.1, 0.05, 0.01 level, respectively. The significance with respect to the deviation of the difference of correlations from zero and the deviation of the ratio of standard deviations from one are based on a block bootstrap with 100,000 draws.

The table documents three striking differences in unconditional business cycle moments between the Euro Area and the US.[3] First, total hours and employment are much less volatile in the Euro Area than in the US. Different labor market legislation might explain why the observed labor adjustment in the Euro Area is subdued. In particular, the strict employment protection legislation (EPL) in Europe, compared to the US, discourages firms from using hiring and firing policies as an adjustment margin (see data from OECD, 2013). An alternative tool that allows employers to adjust hours worked are working time accounts, largely used in Germany in the 2008-9 recession (see Burda and Hunt, 2011). In the European Union, short-time work can be used once other options such as balancing working time accounts or granting leave days have been exhausted. The short-time work schemes have been widely used in some Euro Area countries – mainly Belgium, Germany and Italy – to deal with the worsening labor market conditions in the aftermath of the financial crisis. At the same time, the high level of EPL in Euro Area countries gives rise to an institutional set-up which favors endogenous effort (ECB, 2003).

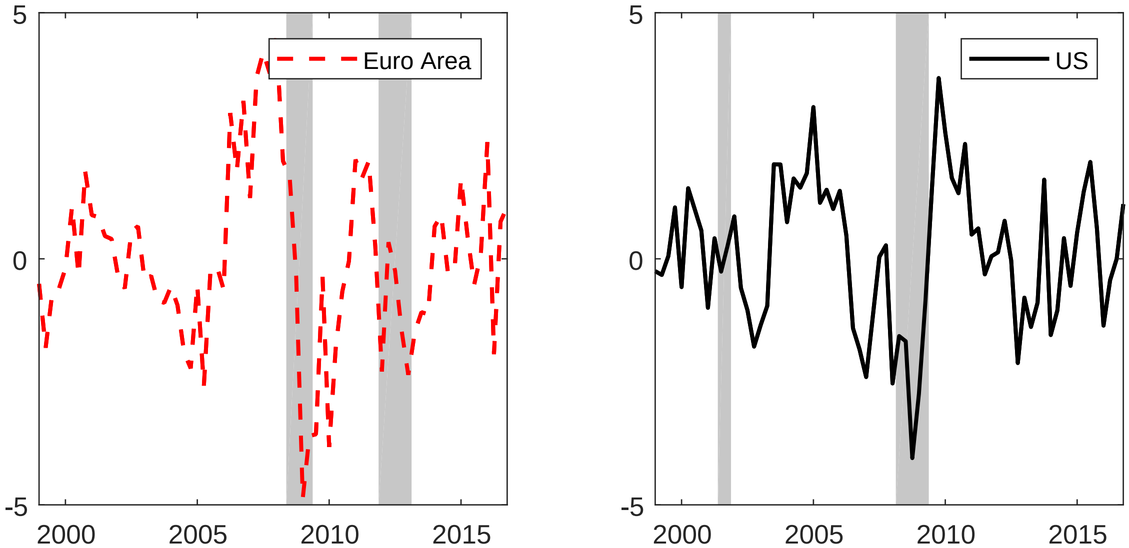
Second, labor productivity is procyclical in the Euro Area and acyclical in the US. In Figure 1, the procyclical behavior of labor productivity in the Euro Area is visible in the large increase during the boom period before the financial crisis, the fall in productivity during the Great Recession of 2008/2009 and the sovereign debt crisis in 2012/2013, and the rebound in the recoveries afterwards. There is no such systematic link between labor productivity and the business cycle in the US.

Third, inflation volatility is lower in the Euro Area than in the US. This result is robust to using the CPI. The policy interest rate in the Euro Area varies less than in the US.

Is the cyclicality of labor productivity linked to the variability of inflation? The remainder of the paper attempts to answer to this fundamental question in the context of a general

[3]Our three observations are robust to using the band-pass filter as well as the fourth-difference filter. We also computed the same statistics using the projection method proposed by Hamilton (2018). The differences between the Euro Area and the US are slightly less clear-cut in this case, but the data still support the three main observations. Details are reported in the online appendix.

Figure 1: Labor productivity (cyclical component) in Euro Area and US.



Notes: Cyclical component extracted with HP-filter. Shaded areas show CEPR recessions for Euro Area and NBER recessions for US.

equilibrium model.

3 Model

The procyclicality of labor productivity observed in the data indicates that total hours respond less to shocks than output. Standard business cycle models cannot replicate this pattern. What is needed are increasing returns to hours in production. This can be accomplished by introducing variable labor effort into the model, providing an additional margin through which an extra unit of output can be produced without the need for adjusting employment (or hours). In the following, we outline a labor search and matching model of the business cycle, which allows for labor adjustment along three margins: employment, hours and effort. Furthermore, it features a host of nominal and real frictions (price and wage adjustment costs, investment adjustment costs, variable capital utilization, consumption habit formation).

This section outlines the optimization problem of each agent in the model and derives important equilibrium conditions. The full model derivation can be found in the online appendix.

3.1 Households

There exists a unit mass of households. A fraction n_t of workers in a household are employed in the market economy and receive the nominal wage W_{it} from firm $i \in (0,1)$ for providing hours h_{it} and effort e_{it}. The remaining $1 - n_t$ workers are unemployed. The representative household has expected lifetime utility given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[U(C_t) - Z_t^{\ell} n_t \int_0^1 g\left(h_{it}, e_{it}\right) di \right], \tag{1}$$

where $\beta \in (0,1)$ is the subjective discount factor, C_t is consumption, Z_t^{ℓ} is a labor supply shock, and $g\left(h_{it}, e_{it}\right)$ denotes individual labor disutility of providing hours and effort to firm i to those n_t household members that are employed. Each employed household member works for all firms on the unit interval; therefore, we sum labor disutility across all firms. Consumption utility is further specified as $U(C_t) = \ln(C_t - \lambda_c C_{t-1})$, where $0 \leq \lambda_c < 1$ is the degree of habit persistence. There exists an insurance technology guaranteeing complete consumption risk sharing between household members, such that C_t denotes individual as well as household consumption.

The household owns the capital stock K_t and finances investment I_t. It maximizes utility (1) subject to a sequence of budget constraints,

$$C_t + \frac{B_{t+1}}{Z_t^r R_t P_t} + I_t + a(u_t^k) K_t = n_t \int_0^1 \frac{W_{it}}{P_t} di + r_t^k u_t^k K_t + \frac{B_t}{P_t} + (1 - n_t) b + D_t + T_t. \tag{2}$$

Consumption expenditure, bond purchases B_{t+1}, investment and capital utilization costs $a(u_t^k)K_t$ are financed through wage income by employed members, rental income on capital holdings, income on bond holdings, the leisure value b enjoyed by the unemployed members, real profits D_t, and lump sum government transfers T_t.[4] One-period bonds pay a nominal return R_t, which is subject to a risk premium shock Z_t^r; u_t^k is the rate of utilization of the capital stock, and r_t^k repre-

[4]Leisure value can represent unemployment benefits or home production.

sents the rental rate on capital. Capital utilization costs are $a(u_t^k) = (1-\kappa_u)(u_t^k-1)+\frac{\kappa_u}{2}(u_t^k-1)^2$, with $\kappa_u \in [0,1]$.[5] Normalizing the steady state utilization rate to unity, $u^k = 1$, it follows that the elasticity of the utilization rate to changes in the marginal utilization cost, defined as $\sigma_u \equiv \frac{a'(u^k)}{a''(u^k)u^k}$, equals $\frac{1-\kappa_u}{\kappa_u}$. Letting Z_t^I denote a shock to investment-specific technology, the aggregate capital stock evolves according to the law of motion $K_{t+1} = (1-\delta)K_t + F(I_t, I_{t-1})\, Z_t^I$, with $F(I_t, I_{t-1}) = [1-\frac{\kappa_I}{2}(I_t/I_{t-1}-1)^2]I_t$ representing flow adjustment costs to investment. The parameter $\kappa_I > 0$ measures the size of these adjustment costs.

The optimization problem consists in maximizing utility (1), subject to the household budget constraint (2) and capital accumulation. Letting Λ_t denote the Lagrange multiplier on (2), the optimality conditions for bonds, investment, capital holdings and capital utilization are, respectively,

$$1 = Z_t^r R_t E_t\{\beta_{t,t+1}/\Pi_{t+1}\}, \tag{3}$$

$$1 = p_t^k Z_t^I F_{1t} + E_t\{\beta_{t,t+1} p_{t+1}^k Z_{t+1}^I F_{2t+1}\}, \tag{4}$$

$$p_t^k = E_t\{\beta_{t,t+1}[r_{t+1}^k u_{t+1}^k - a(u_{t+1}^k) + (1-\delta)p_{t+1}^k]\}, \tag{5}$$

$$r_t^k = a'(u_t^k), \tag{6}$$

where F_{it} is the derivative of the function $F(.)$ with respect to its i^{th} argument, $\beta_{t-1,t} \equiv \beta\frac{\Lambda_t}{\Lambda_{t-1}}$ is the stochastic discount factor or the growth of the marginal utility of consumption between $t-1$ and t, $\Pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate between $t-1$ and t, and p_t^k denotes the household's shadow price of physical capital. So far, we have described the representative household. Given that all households are identical in equilibrium and the mass of households is normalized to unity, C_t is household consumption as well as economy-wide consumption.

[5]See Zubairy (2014) and Melina and Villa (2018), among others. Following Smets and Wouters (2007), we estimate κ_u.

3.2 Final Goods

Final output Y_t is an aggregate of intermediate goods Y_{it} bundled according to the function $Y_t = (\int_0^1 Y_{it}^{\frac{\varepsilon_t - 1}{\varepsilon_t}} di)^{\frac{\varepsilon_t}{\varepsilon_t - 1}}$, where ε_t, the elasticity of substitution between the individual varieties, varies exogenously. Given a price P_{it} for each variety i, perfectly competitive final goods firms choose optimally the inputs Y_{it} to minimize total expenditure $\int_0^1 P_{it} Y_{it} di$ subject to the aggregator function given above. This yields the demand functions $Y_{it}^d = (P_{it}/P_t)^{-\varepsilon_t} Y_t$, where the price of the final good P_t can be interpreted as the consumer price index.

3.3 Labor Market Search and Matching Frictions

Firms post vacancies and unemployed workers search for jobs. Let M_t denote the number of successful matches in the labor market. The matching technology is a Cobb-Douglas function of the unemployment rate $u_t = 1 - n_t$ and the aggregate number of vacancies $v_t = \int_0^1 v_{it} di$, $M_t = M_0 u_t^{\eta} v_t^{1-\eta}$, where $\eta \in (0, 1)$ is the elasticity of matches to the unemployment rate and M_0 scales the matching technology. The probability of a vacancy being filled next period q_t equals the number of matches divided by the number of vacancies posted, $q_t = M_t/v_t = M_0 \theta_t^{-\eta}$, where the ratio of vacancies to unemployed workers, $\theta_t \equiv v_t/u_t$, is a measure of labor market tightness. The job finding rate equals the number of matches divided by the number of unemployed, $p_t = M_t/u_t = q_t \theta_t$. An alternative expression for the job finding rate is the probability of filling a vacancy multiplied by the degree of labor market tightness. Defining the aggregate labor force as $n_t = \int_0^1 n_{it} di$, we can write the law of motion for employment as $n_{t+1} = (1 - \lambda) n_t + q_t v_t$. A fraction $\lambda \in (0, 1)$ of matches are destroyed each period.

3.4 Intermediate Goods

Intermediate firms produce differentiated goods under monopolistic competition. Firm i produces output according to the following technology $Y_{it} = Z_t^A (l_{it}^s)^{1-\alpha} (k_{it}^s)^{\alpha}$, where Z_t^A is an exogenous technology index common to all firms, l_{it}^s are labor services, k_{it}^s are capital services, and α is the weight on capital services in production. Labor services are the product of employment, hours per worker and effort per hour; capital services are given by the capital stock multiplied by the capital utilization rate,

$$l_{it}^s = e_{it} h_{it} n_{it}, \tag{7}$$

$$k_{it}^s = u_t^k K_{it}. \tag{8}$$

Since both capital and employment are predetermined, a firm cannot raise output on impact by increasing k_{it} or n_{it}. Instead, the firm adjusts capital and labor *services*, by varying utilization, hours or effort, to satisfy demand in the short run.

Labor Effort. Following Bils and Cho (1994), labor disutility is given by

$$g\left(h_{it}, e_{it}\right) = \frac{\lambda_h h_{it}^{1+\sigma_h}}{1+\sigma_h} + h_{it} \frac{\lambda_e e_{it}^{1+\sigma_e}}{1+\sigma_e}, \tag{9}$$

where $\lambda_h \left(\lambda_e\right) > 0$ is the weight on hours (effort) in labor disutility and $\sigma_h \left(\sigma_e\right) \geq 0$ determines the degree of increasing marginal disutility of hours (effort). The first term in (9) captures disutility from spending h_{it} hours at work, rather than some best alternative, even when exerting no productive effort. The second term reflects disutility from exerting effort.

Every period, firms and workers choose jointly the combination of hours and effort to minimize labor disutility (9) subject to the production function, yielding the following optimality condition:

$$e_{it} = e_0 h_{it}^{\frac{\sigma_h}{1+\sigma_e}}, \tag{10}$$

where $e_0 = \left(\frac{1+\sigma_e}{\sigma_e} \frac{\lambda_h}{\lambda_e}\right)^{\frac{1}{1+\sigma_e}}$. Equilibrium effort is therefore an increasing and convex function of hours worked.

Returns to Hours in Production. Using the optimal effort choice (10), we can replace labor services in the production function,

$$Y_{it} = y_0 Z_t^A (n_{it} h_{it}^{\phi})^{1-\alpha} (k_{it}^s)^{\alpha}, \tag{11}$$

with $y_0 = e_0^{1-\alpha}$ and $\phi = 1 + \frac{\sigma_h}{1+\sigma_e}$. The elasticity of output to hours worked is thus $\phi(1-\alpha)$. The production function displays short-run increasing returns to hours if $\phi(1-\alpha) > 1$. In response to an expansionary demand shock, firms increase both hours and effort, such that measured productivity (output per hour) increases. To obtain a procyclical response of labor productivity to demand shocks, we need that either the marginal product of hours and effort $(1-\alpha)$, or the effort elasticity to hours, $\sigma_h/(1+\sigma_e)$, is sufficiently high.

Firm Value, Capital Services and Price Setting. The value of firm i in period t is

$$V_{it}^f = \frac{P_{it}}{P_t} Y_{it}^d - w_{it} n_{it} - r_t^k k_{it}^s - c v_{it} - \Phi n_{it} - \Psi_{it}^w - \Psi_{it}^p + E_t\{\beta_{t,t+1} V_{it+1}^f\}, \tag{12}$$

where $w_{it} \equiv W_{it}/P_t$ is the firm-level real wage; $c > 0$ is the cost of posting a vacancy, common to all firms and expressed in terms of the final good, v_{it} is the number of vacancies posted by the i^{th} firm, and Φ denotes job-related overhead costs independent of the number of hours per worker.[6] As originally proposed by Rotemberg (1982) and applied to wages by, inter alia, Arseneau and Chugh (2008) and Furlanetto and Groshenny (2016), Ψ_{it}^w and Ψ_{it}^p are quadratic wage and price adjustment costs given by

$$\Psi_{it}^w = \frac{\kappa_w}{2} (\Omega_{it}^w - 1)^2 n_{it}, \tag{13}$$

$$\Psi_{it}^p = \frac{\kappa_p}{2} (\Omega_{it}^p - 1)^2 Y_{it}, \tag{14}$$

[6] Overhead costs in production facilitate the calibration of the model as shown in Christoffel et al. (2009).

where $\Omega^w_{it} = \frac{w_{it}}{w_{it-1}}\frac{\Pi_t}{\Pi}\left(\frac{\Pi_{t-1}}{\Pi}\right)^{-\lambda_w}$, $\Omega^p_{it} = \frac{\Pi_{it}}{\Pi}\left(\frac{\Pi_{t-1}}{\Pi}\right)^{-\lambda_p}$ and $\Pi_{it} \equiv P_{it}/P_{it-1}$ is firm-level price inflation. The parameters $\kappa_w \geq 0$ and $\kappa_p \geq 0$ capture, respectively, the size of wage and price adjustment costs. Firm i chooses capital services, k^s_{it}, and a price P_{it}, so as to maximize its value V^f_{it}, subject to the law of motion for its workforce, and the demand constraint,

$$n_{it+1} = (1-\lambda)n_{it} + q_t v_{it}, \tag{15}$$

$$(P_{it}/P_t)^{-\varepsilon_t} Y_t = y_0 Z^A_t (n_{it} h^{\phi}_{it})^{1-\alpha} \left(k^s_{it}\right)^{\alpha}. \tag{16}$$

Denoting by s_{it} the Lagrange multiplier on (16), the demand for capital services satisfies $r^k_t = s_{it}\alpha\frac{Y_{it}}{k^s_{it}}$, such that the real marginal cost equals the rental rate of capital divided by the marginal product of capital. In a symmetric equilibrium, the optimal pricing decision leads to the New Keynesian Phillips Curve,

$$\kappa_p \Omega^p_t(\Omega^p_t - 1) = \varepsilon_t s_t - (\varepsilon_t - 1) + \kappa_p E_t\{\beta_{t,t+1}\Omega^p_{t+1}(\Omega^p_{t+1} - 1)Y_{t+1}/Y_t\}. \tag{17}$$

where $\Omega^p_t = \frac{\Pi_t}{\Pi}(\frac{\Pi_{t-1}}{\Pi})^{-\lambda_p}$. We now derive the firm's and worker's match surplus.

Firm's Match Surplus and Vacancy Posting. The surplus from employing a marginal worker, defined as $S^f_{it} \equiv \frac{\partial V^f_{it}}{\partial n_{it}}$, is given by

$$S^f_{it} = s_{it}(mpn_{it}) - w_{it} - \Phi - \Psi^{w'}_{it} + (1-\lambda)\, E_t\{\beta_{t,t+1} S^f_{it+1}\}, \tag{18}$$

where mpn_{it} is the marginal product of employment and $\Psi^{w'}_{it}$ is the derivative of the wage adjustment cost to the number of employees. A vacancy is filled with probability q_t and remains open otherwise. The value of posting a vacancy, in terms of the final good, is

$$V^v_{it} = -c + E_t\{\beta_{t,t+1}[q_t S^f_{it+1} + (1-q_t)\, V^v_{it+1}]\}. \tag{19}$$

The firm posts vacancies as long as the value of a vacancy is greater than zero. In equilibrium, $V_{it}^{v}=0$ and so the vacancy posting condition is $c/q_t = E_t\{\beta_{t,t+1}S_{it+1}^{f}\}$, or using (18):

$$c/q_t = E_t\{\beta_{t,t+1}[s_{it+1}(mpn_{it+1}) - w_{it+1} - \Phi - \Psi_{it+1}^{w'} + (1-\lambda)c/q_{t+1}]\}. \tag{20}$$

A firm posts vacancies until the cost of hiring a worker equals the expected discounted future benefits from an extra worker. The costs of hiring a worker are given by the vacancy posting costs divided by the probability of filling a vacancy, equivalent to vacancy posting costs multiplied by the average duration of a vacancy, $1/q_t$.

Worker's Surplus. Denote the value of being employed by the i^{th} firm $\mathcal{W}_{it}$ and the value of being unemployed $\mathcal{U}_t$. In period t, an employed worker receives the real wage w_{it} and suffers the disutility $g\left(h_{it}\right)$ given by (9). In the next period, he is either still employed by firm i with probability $1-\lambda$, or the employment relation is dissolved with probability λ. The worker's asset value of being matched to firm i is therefore

$$\mathcal{W}_{it} = w_{it} - mrs_{it} + E_t\{\beta_{t,t+1}[(1-\lambda)\mathcal{W}_{it+1} + \lambda\mathcal{U}_{t+1}]\}, \tag{21}$$

where $mrs_{it} \equiv Z_t^{\ell}\frac{g(h_{it})}{\Lambda_t}$ denotes the marginal rate of substitution between hours and consumption. We divide labor disutility $g(h_{it})$ by the marginal utility of consumption Λ_t to convert utils into consumption units. The value of being unemployed is in turn given by

$$\mathcal{U}_t = b + E_t\left\{\beta_{t,t+1}\left[\int_0^1 \frac{v_{jt}}{u_t} q_t W_{jt+1} dj + \left(1-p_t\right)\mathcal{U}_{t+1}\right]\right\}. \tag{22}$$

An unemployed worker receives or produces b units of market consumption goods in period t. In the next period, he faces a probability $\frac{v_{jt}}{u_t}q_t$ of finding a new job with firm j and a probability

$1-p_t$ of remaining unemployed. Defining the worker's surplus as $S^w_{it} \equiv \mathcal{W}_{it} - \mathcal{U}_t$, we can write

$$S^w_{it} = w_{it} - mrs_{it} - b + E_t \left\{ \beta_{t,t+1} \left[(1-\lambda) S^w_{it+1} - p_t \int_0^1 \frac{v_{jt}}{v_t} S^w_{jt+1} dj \right] \right\}. \tag{23}$$

Hours worked. In the efficient bargaining (EB) model, following Thomas (2008) and Cantore et al. (2014) among many others, hours are determined jointly by the firm and the worker to maximize the sum of the firm's surplus, S^f_{it}, and the worker's surplus, S^w_{it}. The first order condition for hours worked implies that the firm's real marginal cost is,

$$s_{it} = \frac{1}{\phi(1-\alpha)^2} \frac{mrs_{it}}{\mathcal{P}_{it}}, \tag{24}$$

where $\mathcal{P}_{it} \equiv \frac{Y_{it}}{n_{it}h_{it}}$ is firm-level labor productivity, or firm output divided by total hours. Equation (24) shows that movements in real marginal costs are driven by variations in the marginal rate of substitution between hours and consumption, adjusted for labor productivity.

Trigari (2006) puts forward the Right-to-Manage model as an alternative way to determine hours. In that setup, firms choose hours unilaterally after the wage has been bargained. In equation (24), mrs_{it} is replaced with w_{it}, such that real marginal costs are affected by the real wage. We explore this alternative model in Section 6.

Wage bargaining. Workers and firms bargain bilaterally over the nominal wage W_{it} and split the surplus according to their respective bargaining weight given by Z^B_t and $(1-Z^B_t)$, respectively. Similarly to Cacciatore et al. (2017), the workers' bargaining power is exogenous and follows an AR(1) process.[7] Under Nash bargaining, the wage is chosen to maximize the joint match surplus, $(S^w_{it})^{Z^B_t}(S^f_{it})^{1-Z^B_t}$. The first order condition implies the following sharing

[7] This shock can be interpreted as the counterpart of the wage markup shock in standard New Keynesian models featuring competitive labor markets.

rule $S^w_{it} = \Upsilon_t S^f_{it}$, where Υ_t is the workers' effective bargaining power defined as

$$\Upsilon_t \equiv \frac{Z^B_t}{1 - Z^B_t} \frac{\delta^w_{it}}{-\delta^f_{it}}. \tag{25}$$

In (25), $\delta^w_{it} \equiv \frac{\partial S^w_{it}}{\partial W_{it}}$ and $\delta^f_{it} \equiv \frac{\partial S^f_{it}}{\partial W_{it}}$ are the changes to the worker's and firm's surplus, respectively, that result from a marginal increase in the nominal wage. Without wage adjustment costs, $\kappa_w = 0$, the effective bargaining power reduces to $\Upsilon_t = \frac{Z^B_t}{1-Z^B_t}$. Taking wage adjustment costs into account, the effective bargaining power can be written as

$$\frac{Z^B_t}{1 - Z^B_t} \frac{1}{\Upsilon_t} w_{it} h_{it} = w_{it} h_{it} + \kappa_w (\Omega_{it} - 1)\Omega_{it} + (1 - \lambda) E_t\{\beta_{t,t+1} \kappa_w (\Omega_{it+1} - 1)\Omega_{it+1}\}. \tag{26}$$

Substituting the definitions of the worker's and the firm's surplus, using the sharing rule and the vacancy-posting rule, yields the following equation for the equilibrium real wage

$$\begin{aligned} w_{it} h_{it} \; = \; & \frac{\Upsilon_t}{1 + \Upsilon_t} [s_{it}(mpn_{it}) - \Psi^{w'}_{it} + (1 - \lambda) c/q_t] \\ & + \frac{1}{1 + \Upsilon_t} [mrs_{it} + b - E_t\{\Upsilon_{t+1}(1 - \lambda - p_t) c/q_t\}]. \end{aligned} \tag{27}$$

The real wage is a convex combination of two terms. The first term on the right hand side of (27) reflects the surplus to the firm of hiring a new worker: the marginal product of this worker, less wage adjustment costs per worker, plus the continuation value of the match. The second term on the right hand side of (27) reflects the required compensation to the worker of forming a match: the marginal rate of substitution – at the household level – of one more worker in employment and consumption, plus the leisure value, b, less the worker's continuation value of forming a match.

3.5 Closing the Model

The government budget constraint equates current income (bond issues) with current expenditure (government spending, unemployment benefits, lump-sum transfers, and maturing government bonds),

$$B_{t-1}/P_t = Z_t^G + (1 - n_t)b - T_t + R_t B_t/P_t. \tag{28}$$

Combining the household budget constraint (2), aggregated over households, with the government budget constraint (28), we obtain the aggregate accounting identity,

$$Y_t = C_t + Z_t^G + I_t + a\left(u_t^k\right) K_t + cv_t - \Phi n_t + \Psi_t^w + \Psi_t^p. \tag{29}$$

The central bank follows an interest rate rule given by

$$\ln(R_t/R) = \tau_R \ln(R_{t-1}/R) + (1 - \tau_R)[\tau_\Pi \ln(\Pi_t/\Pi) + \tau_y \ln(Y_t/Y_t^n)] + Z_t^R, \tag{30}$$

where Y_t^n is the level of output under flexible prices and wages in the absence of price mark-up and bargaining power shocks; and Z_t^R is a shock to monetary policy.

The model is closed by a set of AR(1) shock processes,

$$\ln\left(Z_t^x/Z^x\right) = \varrho_x \ln\left(Z_{t-1}^x/Z^x\right) + \epsilon_t^x \quad \text{with} \quad \epsilon_t^x \sim N\left(0, \varsigma_x\right), \tag{31}$$

where $x = \{r, \ell, A, B, I, G, R, \epsilon\}$, $Z_t^\varepsilon = \varepsilon_t$, ϱ_x and ς_x denote the persistence and standard deviation of innovation ϵ_{xt}, respectively.

4 Calibration and Prior Distributions

The model is estimated on quarterly data for the period 1999Q1-2016Q4. The eight observable variables are real GDP, real investment, real private consumption, wages per hour, total hours worked, inflation, unemployment and the nominal interest rate. The Appendix reports data sources and definitions. All variables are expressed in logarithms, except the nominal interest rate and the unemployment rate. The inflation rate is measured as the first difference of the log GDP deflator. To be consistent with the empirical evidence reported in Section 2, all variables are detrended using the Hodrick-Prescott filter.[8]

Table 2 reports the calibration of the parameters which are related to great ratios or long-run averages, and for which not enough information is contained in the dataset. The time period in the model corresponds to one quarter. Steady state gross inflation Π is set to one. The discount factor, β, is set equal to 0.99, implying a yearly real interest rate of 4%. The depreciation rate of capital, δ_K, is equal to 0.025, such that 10% of the capital stock is written off each year. The capital share of income, α, is set to the conventional value of 0.3. In line with the literature, we set the elasticity of substitution between the individual varieties of goods, ε, to 11 in order to target a steady-state gross price mark-up equal to 1.10.

We normalize the weights on hours and effort in labor disutility, λ_h and λ_e, to unity. The parameter that is key to our mechanism linking variable labor utilization and productivity is the degree of short-run returns to hours in labor services, ϕ. It is a function of the curvature of labor disutility with respect to hours worked, σ_h, and with respect to effort, σ_e. We set σ_h to unity and estimate the composite parameter ϕ. Our calibration for σ_h lies between the values favored by the macro literature, which are typically greater than 1, and estimates elasticitues, which tend to be smaller than 1. See Keane and Rogerson (2012) for a survey. Given our estimate of ϕ, we can back out the value the deep parameter σ_e consistent with this value.

The workers' bargaining weight is calibrated at 0.5 as in Cantore et al. (2014). The elasticity of matches to the unemployment rate, η, is set to 0.65, which is in the middle of the range of values estimated in a number of studies on Euro Area countries and the US (Burda and Wyplosz, 1994; Christoffel et al., 2009; Lubik, 2009; Justiniano and Michelacci, 2011; Barnichon and Figura, 2015), similarly to the calibration strategy adopted by Furlanetto and Groshenny (2016). The parameter c is set to target total hiring costs equal to 1% of output, a value that

[8]For DSGE models with search and matching frictions estimated with HP-detrended data, see Christoffel et al. (2009) among others. We investigate the sensitivity of our results to an alternative filtering technique proposed by Hamilton (2018) in the online appendix.

Table 2: Calibrated parameters

Parameter		Value	Target/Reference
Discount factor	β	0.99	4% risk-free rate p.a.
Capital depreciation rate	δ	0.025	10% depreciation rate p.a.
Production function parameter	α	0.3	SW (2003)
Elasticity of substitution in goods	ε	11	10% price markup
Weight on hours in labor disutility	λ_h	1	Normalization
Weight on effort in labor disutility	λ_e	1	Normalization
Returns to hours in labor disutility	σ_h	1	Keane and Rogerson (2012)
Workers' bargaining weight	Z^B	0.5	Cantore et al. (2014)
Match elasticity	η	0.65	various studies
Cost of posting a vacancy	c	$cv/Y = 1\%$	GT (2009), BG (2010)
Replacement rate	$b/(wh)$	0.40	Shimer (2005), CK (2009)
Steady state unemployment rate	u	9.6% EA; 6.1% US	Data
Steady state job finding rate	p	0.30	Christoffel et al. (2009)
Steady state vacancy filling rate	q	0.70	Christoffel et al. (2009)
Government spending share	Z^G/Y	0.20	Data

Notes: SW (2003): Smets and Wouters (2003), CK (2009): Christoffel and Kuester (2009), GT (2009): Gertler and Trigari (2009), BG (2010): Blanchard and Galí (2010).

is consistent with Gertler and Trigari (2009) and Blanchard and Galí (2010). Steady state output is normalized to unity. Following Shimer (2005) and Christoffel and Kuester (2009), the replacement rate, b/wh, equals 0.40. As explained in the online appendix, we derive the steady state employment rate n, the separation rate λ, and the number of matches M, as a function of the job finding rate, p, set equal to 0.30 (as in Christoffel et al., 2009), and the unemployment rate u, calibrated to the average values in the dataset, 9.6% in the Euro Area and 6.1% in the US. The implied separation rate is 3% in the Euro Area – in line with the evidence on Euro Area data proposed by Christoffel et al. (2009) – and 2% in the US. Using a calibrated value of 0.70 for the vacancy filling rate, q, as in Christoffel et al. (2009) and Cantore et al. (2014), we then calculate the number of vacancies v and the degree of labor market tightness θ. The government share in output, Z^G/Y, is equal to 20%. Section 7.3 in the online appendix provides details on the calibration strategy.

All the remaining parameters are estimated, as shown in Table 3. The locations of the prior means correspond to a great extent to those in Smets and Wouters (2007). The prior mean of the Rotemberg parameter for price stickiness corresponds to a Calvo contract average duration of around 3 quarters, with a loose standard deviation, as in Di Pace and Villa (2016). The prior mean of the parameter measuring short-run returns to hours in labor services, ϕ, is set to 1 with a loose standard deviation so that the prior distribution encompasses a broad range of values around 1. In this way, we allow for both decreasing and increasing returns to hours in production. In setting the prior mean for the cost-adjustment parameter for wage stickiness, κ_w, we choose the value 10 proposed by Arseneau and Chugh (2008), which corresponds to nominal wages being sticky for four quarters on average.

5 Results

We first discuss the parameter estimates, highlighting any important differences between the Euro Area and the US, and we report the model-implied business cycle statistics. Second, we show the model dynamics via impulse response functions. Finally, we run counterfactual exercises where we isolate the role of effort in affecting inflation dynamics.

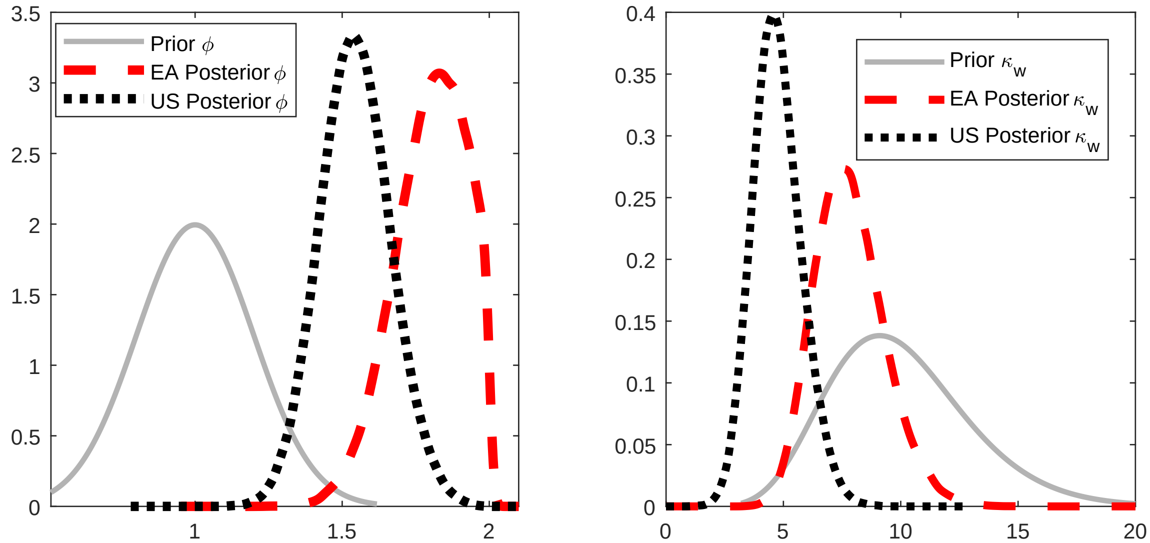
5.1 Parameter Estimates

The posterior distributions of most parameters are in line with the literature. Some parameters are rather different between the EA and the US, in particular the labor market parameters.[9] The median estimate of the returns to hours ϕ is higher in the Euro Area compared to the US, equal to 1.80 and 1.54, respectively. Wage stickiness is also higher in the Euro Area, with its mean estimate outside the probability band for the US.[10] The fact that nominal wage contracts

[9] We consider two parameters different if the mean estimate of a parameter in one economy does not fall in the 90% HPD intervals for the same parameter of the other economy (as in Smets and Wouters, 2005).

[10] Note that in the presence of Nash bargaining under search and matching frictions there is no 'wage Phillips curve', hence it is not possible to make a precise mapping from the duration of wage-stickiness to the cost-adjustment parameter κ_w.

Figure 2: Prior and posterior densities of returns to hours ϕ and wage stickiness κ_w.



are set for longer periods in the Euro Area compared to the US points to greater labor market flexibility in the latter economy. The mean of the parameter measuring the elasticity of the capital utilization function is quite large in both economies, even higher in the US, indicating a limited role for this margin of adjustment (see Section 6 on this). Price stickiness differs between the two economies: in the EA prices are sticky for three quarters and half while in the US they are sticky for slightly more than a year.[11] As far as the shock processes are concerned, they are generally more volatile in the US than in the Euro Area.

Figure 2 shows the prior and posterior densities of two labor market parameters, short-run returns to hours in production, ϕ, and wage stickiness, κ_w. Both are well identified by the data, exhibiting a probability density tightly gathered around the posterior mean, despite the loose prior. The posterior probability densities for the two economies overlap to a minor extent only.[12]

[11]For the algebraic relationship between the Rotemberg and the Calvo parameter see Cantore et al. (2014). Queijo von Heideken (2009) and Villa (2016) also find price stickiness higher in the US compared to the EA.

[12]These results hold also when the observable variables are filtered with the method proposed by Hamilton (2018), as shown in the online appendix. Hence the difference in the labor market of the two economies is confirmed under an alternative filtering of the data.

Table 3: Parameter estimates: baseline model.

Parameter		Prior			Posterior Mean	
		Distrib.	Mean	Std/df	Euro Area	United States
Structural						
Returns to hours	ϕ	Normal	1.00	0.20	1.80 [1.63;2.00]	1.54 [1.35;1.74]
Habits in consumption	λ_c	Beta	0.50	0.15	0.29 [0.17;0.40]	0.31 [0.21;0.41]
Capital utilization	κ_u	Beta	0.50	0.15	0.79 [0.68;0.90]	0.94 [0.90;0.98]
Investment adjust. costs	κ_I	Gamma	4.00	1.50	1.84 [1.02;2.63]	2.16 [1.19;3.11]
Price stickiness	κ_p	Gamma	60.0	20.00	77.40 [57.34;97.20]	148.74 [113.24;186.11]
Price indexation	λ_p	Beta	0.50	0.15	0.15 [0.05;0.25]	0.31 [0.11;0.49]
Wage stickiness	κ_w	Gamma	10.0	3.00	7.80 [5.38;10.14]	4.72 [3.00;6.38]
Wage indexation	λ_w	Beta	0.50	0.15	0.45 [0.23;0.67]	0.53 [0.29;0.77]
Inflation -Taylor rule	τ_Π	Normal	1.70	0.20	1.73 [1.42;2.03]	1.79 [1.50;2.09]
Output gap -Taylor rule	τ_y	Normal	0.12	0.03	0.12 [0.04;0.19]	0.12 [0.04;0.19]
Interest rate smoothing	τ_R	Beta	0.75	0.10	0.77 [0.72;0.83]	0.83 [0.79;0.87]
Exogenous processes						
Technology	ρ_A	Beta	0.50	0.15	0.50 [0.37;0.64]	0.69 [0.60;0.79]
	σ_A	IG	0.10	2.0	0.63 [0.54;0.73]	0.58 [0.49;0.67]
Price mark-up	ρ_P	Beta	0.50	0.15	0.67 [0.56;0.79]	0.48 [0.27;0.67]
	σ_P	IG	0.10	2.0	8.52 [5.81;11.17]	27.59 [18.49;36.51]
Bargaining power	ρ_{γ^B}	Beta	0.50	0.15	0.61 [0.48;0.72]	0.14 [0.04;0.23]
	σ_{γ^B}	IG	0.10	2.0	2.21 [1.58;2.84]	5.08 [3.72;6.41]
Labor supply	ρ_ℓ	Beta	0.50	0.15	0.62 [0.50;0.74]	0.71 [0.61;0.81]
	σ_ℓ	IG	0.10	2.0	0.96 [0.78;1.14]	2.42 [1.98;36.51]
Government spending	ρ_G	Beta	0.50	0.15	0.70 [0.60;0.80]	0.72 [0.62;0.81]
	σ_G	IG	0.10	2.0	1.46 [1.25;1.67]	2.14 [1.85;2.43]
Monetary policy	ρ_R	Beta	0.50	0.15	0.28 [0.15;0.40]	0.31 [0.20;0.42]
	σ_R	IG	0.10	2.0	0.10 [0.09;0.12]	0.10 [0.08;0.11]
Investment-specific	ρ_I	Beta	0.50	0.15	0.27 [0.14;0.39]	0.50 [0.35;0.66]
	σ_I	IG	0.10	2.0	1.60 [0.87;2.32]	1.73 [1.00;2.48]
Risk premium	ρ_r	Beta	0.50	0.15	0.61 [0.46;0.76]	0.79 [0.71;0.87]
	σ_r	IG	0.10	2.0	0.31 [0.16;0.46]	0.25 [0.16;0.33]
Marginal log-likelihood					-171.538	-390.407

Notes: Table shows prior and posterior distributions of estimated parameters; 90% HPD intervals in square brackets. Posterior mean computed with two chains of the Metropolis-Hastings algorithm on sample of 350,000 draws.

The curvature of the effort disutility function, σ_e, is equal to 0.25 in the Euro Area and 0.84 in the US. A lower σ_e implies a greater use of effort. Thus, in line with our conjecture, the effort margin plays a more important role in the Euro Area.

Table 4 shows the correlations with output and the relative volatilities of labor market

Table 4: US and Euro Area business cycle statistics: model vs. data.

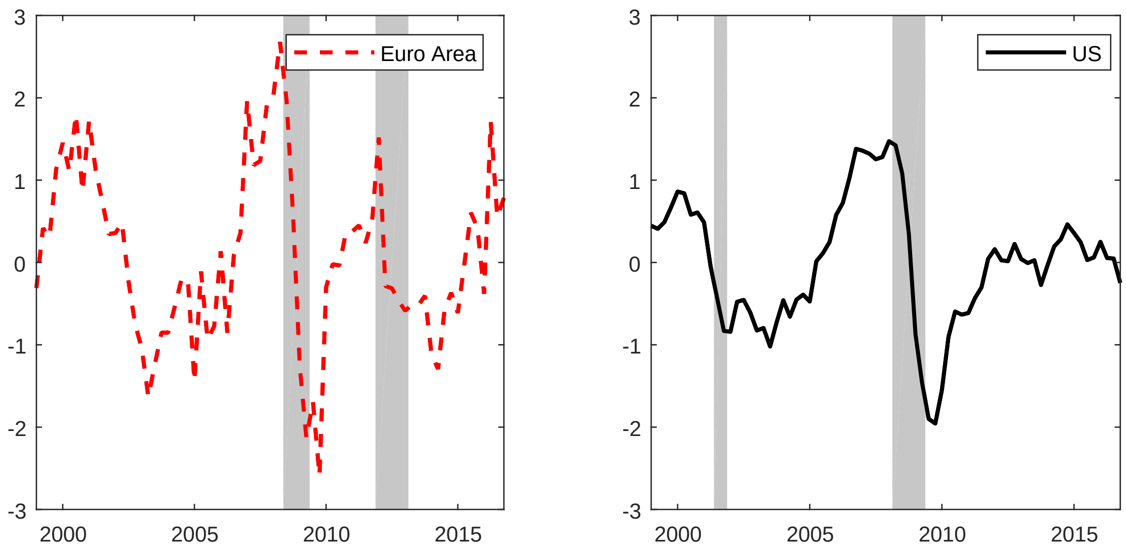
Variable	Output correlations						Relative standard deviations					
	Euro Area		US		Diff.		Euro Area		US		Ratio	
	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data
Real output							1.26	1.29	1.19	1.19	1.05	1.08
Total hours	0.85	0.85	0.86	0.86	-0.02	-0.02	0.28	0.64	0.73	1.13	0.38	0.56
Employment	0.84	0.76	0.85	0.78	-0.01	-0.02	0.04	0.55	0.04	0.84	1.03	0.65
Hours per worker	0.84	0.50	0.87	0.80	-0.02	-0.30	0.30	0.36	0.75	0.46	0.39	0.78
Unemployment	-0.84	-0.84	-0.85	-0.85	0.01	0.01	0.04	0.43	0.04	0.68	1.03	0.64
Productivity	0.79	0.85	0.05	0.04	0.74	0.80	1.31	1.42	0.88	1.22	1.49	1.16
Inflation	0.43	0.45	0.57	0.55	-0.14	-0.11	0.29	0.27	0.40	0.40	0.73	0.68
Policy interest rate	0.80	0.50	0.76	0.62	0.04	-0.12	0.16	0.32	0.24	0.45	0.69	0.71
Effort	0.84	–	0.87	–	-0.02	–	0.85	–	0.64	–	1.31	–

measures, inflation and the policy interest rate implied by the estimated models. As the table indicates, the models replicate reasonably well both the sign and the magnitude of the output correlations in the data. In particular, labor productivity is strongly procyclical in the Euro Area and acyclical in the US, with output correlations of 0.79 and 0.05, respectively. As far as the volatilities are concerned, the model replicates the higher standard deviation (relative to output) of year-on-year inflation in the Euro Area compared to the US, and the model-implied ratio of standard deviations is equal to 0.73 in the model and 0.68 in the data. In addition, the model-generated data display ratios of volatilites of hours and the policy interest rate in line with the data. However, the model is not able to replicate the high volatility of unemployment.[13]

Table 4 reports in the last row the implied series for effort. It is procyclical both in the Euro Area and in the US, in line with the evidence provided by Burda et al. (2017) for the US economy. Figure 3 confirms that during recessions, labor has been used less intensively both

[13] This is the so-called unemployment volatility puzzle (Shimer, 2005), i.e. the inability of the search and matching model to generate the observed fluctuations in unemployment in response to shocks of a plausible magnitude. The literature offers alternative explanations based on endogenous and exogenous mechanisms of amplification: factor complementarity, deep habits and unemployment benefits; and price-elasticity shocks, investment-specific shocks, matching efficiency as exogenous sources of amplification (see Rotemberg, 2008; Hagedorn and Manovskii, 2008; Christoffel et al., 2009; Di Pace and Faccini, 2012; Di Pace and Villa, 2016, among many others).

Figure 3: Model-implied labor effort in Euro Area and US.



Notes: Shaded areas show CEPR recessions for Euro Area and NBER recessions for US.

in the US and in the Euro Area. Also, effort is more volatile in the Euro Area than in the US, revealing a greater utilization of this labor margin in the former economy, in line with our conjecture.[14]

Table 5 shows the unconditional (long-run) variance decomposition. Price mark-up and labor supply shocks are the most important supply-side innovations explaining fluctuations in output, while the risk premium shock is the corresponding most important demand-side exogenous innovation. Technology shocks play a minor role, in line with Hornstein (1993) who shows that the introduction of increasing returns to scale reduces the contribution of productivity changes to aggregate fluctuations. The important role played by labor supply shocks is con-

[14] US data on capacity utilization, provided by the Federal Reserve Board, constructs estimates of capacity utilization for industries in manufacturing, mining, and electric and gas utilities. For a given industry, the capacity utilization rate is equal to an output index divided by a capacity index. The capacity indexes attempt to capture the concept of sustainable maximum output - the greatest level of output a plant can maintain within the framework of a realistic work schedule, after factoring in normal downtime and assuming sufficient availability of inputs to operate the capital in place. A rough measure of capacity index in the model could be constructed as the sum of input shares times their utilization rates, i.e. $\alpha u_t^k + (1-\alpha)\, e_t$. Given the value of the capital share and the estimated paths of effort and capital utilization in the US economy, the correlation between the US model-implied capacity utilization and the corresponding HP-detrended data on capacity utilization is 0.82.

Table 5: Variance decomposition: baseline model.

Variable		Structural shocks							
		Techno-logy	Price mark-up	Barg. power	Labor supply	Risk premium	Investment specific	Monetary policy	Fiscal policy
Output	EA	10.90	33.55	0.01	19.82	13.33	7.21	7.27	7.92
	US	8.38	16.77	0.00	48.46	9.98	6.21	4.67	5.53
Inflation	EA	15.56	14.95	0.00	16.14	26.54	0.84	25.51	0.47
	US	4.87	22.68	0.00	25.04	28.21	1.33	17.27	0.60
Productivity	EA	72.03	10.79	0.05	4.68	4.12	4.51	2.20	1.62
	US	72.78	3.56	0.01	13.11	1.20	8.29	0.67	0.38
Wages	EA	10.89	62.89	6.62	3.26	7.32	2.47	6.39	0.15
	US	7.29	33.52	29.27	13.26	8.99	2.64	4.89	0.15
Employment	EA	8.58	46.38	15.48	12.67	8.07	1.05	7.55	0.21
	US	6.31	31.43	5.83	33.55	13.89	1.34	7.51	0.14
Hours	EA	19.24	26.81	0.07	20.68	11.83	6.52	6.28	8.58
	US	6.53	16.51	0.01	49.81	10.58	5.16	4.85	6.55

firmed by other studies (Blanchard and Diamond, 1989; Shapiro and Watson, 1988; Chang and Schorfheide, 2003; Foroni et al., 2018). There are some differences between the EA and the US. In particular, labor supply shocks are more important in the US compared to the EA, in line with the results in Smets and Wouters (2005).[15] Inflation is mainly driven by risk premium and price mark-up shocks. Monetary policy shocks play a non-negligible role, explaining about 26% and 17% of inflation variation in the Euro Area and US, respectively. Labor productivity and wages are mainly driven by supply-side shocks. In particular, technology shocks are the main driver of productivity in both economies, while wages are mainly explained by price mark-up shocks and bargaining power shocks in the US in the same order of magnitude of Furlanetto and Robstad (2017). There are some notable differences in the unconditional variance decomposition between the two economies as far as labor market variables are concerned. Price mark-up shocks explain about 63% of real wage fluctuations in the Euro Area and 34% in the US. Hours are driven mainly by supply shocks in the Euro Area (technology, price markup, as well as labor supply shocks) and by labor supply shocks in the US.

[15] In the short run demand shocks (mainly risk premium and government spending shocks) play a more important role in accounting for output fluctuations in line with the findings by Foroni et al. (2018).

5.2 Model Dynamics

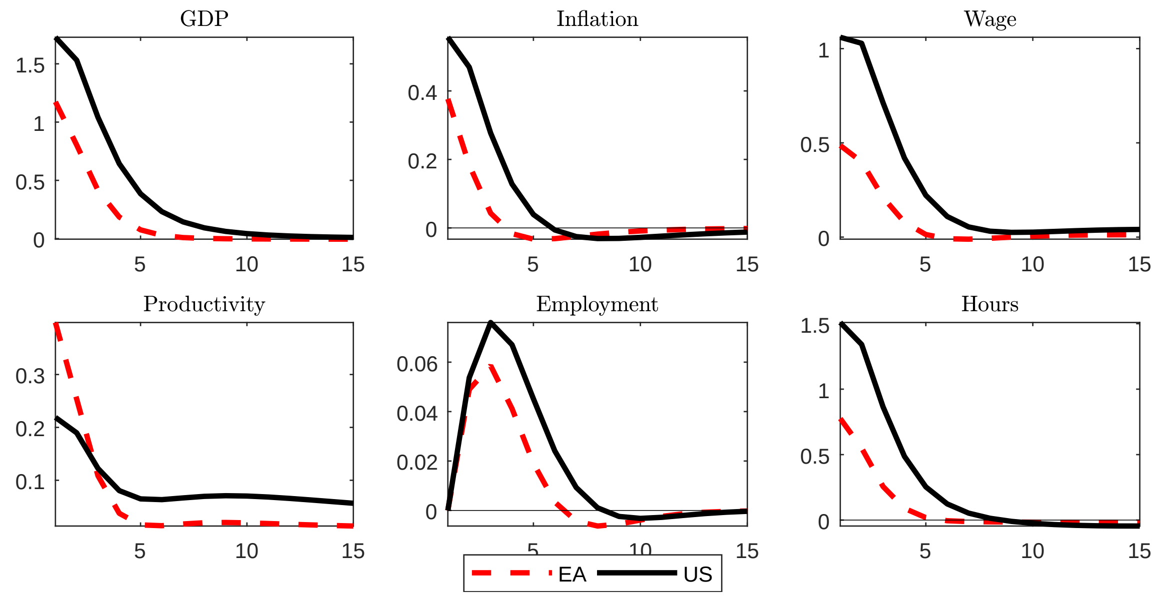
Figure 4 shows the estimated mean impulse response functions of selected variables in the Euro Area and the US to a risk premium shock, which is the most important demand-side shock for business cycle fluctuations.[16] The size of the shock is normalized to one in both economies.

As explained by Smets and Wouters (2007), an expansionary *risk premium shock* increases the wedge between the interest rate controlled by the central bank and the return on assets held by the households. The risk premium shock lowers the nominal interest rate faced by households, affecting the consumption-saving decision. As a result, consumption and output increase, which in turn raises the demand for investment and the price of capital (see also Fisher, 2015). The upward shift in the aggregate demand curve causes an increase in inflation, as shown in Figure 4. Producing more output requires more factors for production, capital and labor. Both the intensive and extensive margins of labor rise. Since employment can adjust only slowly, its response is hump-shaped; hours worked increase on impact. The procyclical response of productivity is stronger in the Euro Area compared to that in the US, reflecting the greater returns to hours in production. The higher degree of wage stickiness in the Euro Area explains the smaller increase in the real wage. This, in turn, affects the response of marginal costs; procyclical labor productivity together with a modest increase in wages dampens the rise in marginal costs in the Euro Area. As a result, inflation rises less in the Euro Area than in the US. The online appendix shows similar dynamics in response to a monetary policy shock.

In the following, we disentangle the relative importance of increasing return to hours in explaining the transmission mechanism. Figure 5 shows responses to a risk premium shock in two different scenarios: (1) the estimated responses for the Euro Area; and (2) a counterfactual model where all parameters are set to their estimated values for the Euro Area, except the

[16] In the interest of clarity, we report only the mean impulse response function, without probability bands. Impulse response functions for the monetary policy shock and supply shocks are provided in the online appendix.

Figure 4: Impulse responses to risk premium shock: baseline model.

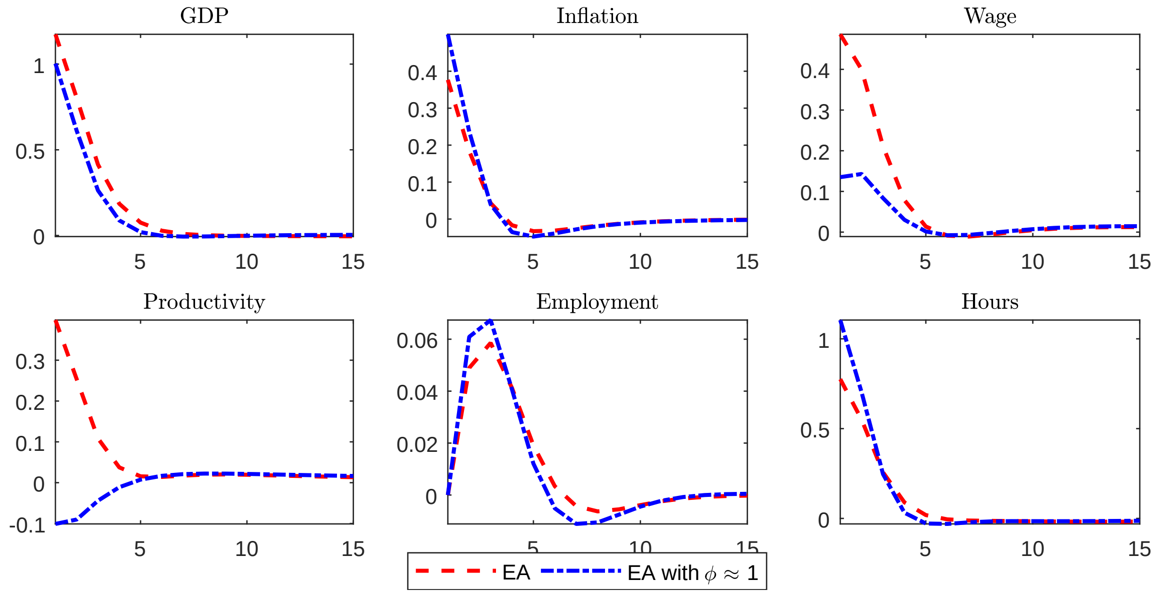


Notes: Figure shows estimated mean responses. Y-axes show percent deviations from steady state. Time horizon on X-axes measured in quarters. Shock size normalized to one for both countries.

parameter measuring the returns to hours, ϕ, which is set close to one. The second scenario implies constant returns to hours in the production function, i.e. the effort margin is not used. The counterfactual model shows that the other two margins of labor, hours and employment, are exploited more when the effort margin is shut off. It is also evident that in the presence of constant returns to hours, labor productivity becomes countercyclical. Therefore, parameter ϕ clearly governs the sign of the response of productivity. In particular, in the presence of effort hours worked are more productive, the extensive margin can decrease and this helps explain the procyclicality of productivity. The real wage rises by more in the presence of increasing returns to hours because workers are more productive. Finally, the procyclicality of labor productivity dampens the rise in inflation. Similar results hold for the monetary policy shock, shown in the online appendix.

Figure 6 shows the Euro Area smoothed inflation series and the counterfactual simulation for this variable when the parameter measuring the returns to hours, ϕ, which is set close to

Figure 5: Impulse responses to risk premium shock: counterfactual varying ϕ.



Notes: Figure shows estimated mean and counterfactual responses. Parameter ϕ measures returns to hours in production. Y-axes show percent deviations from steady state. Time horizon on X-axes measured in quarters. Shock size normalized to one for both countries.

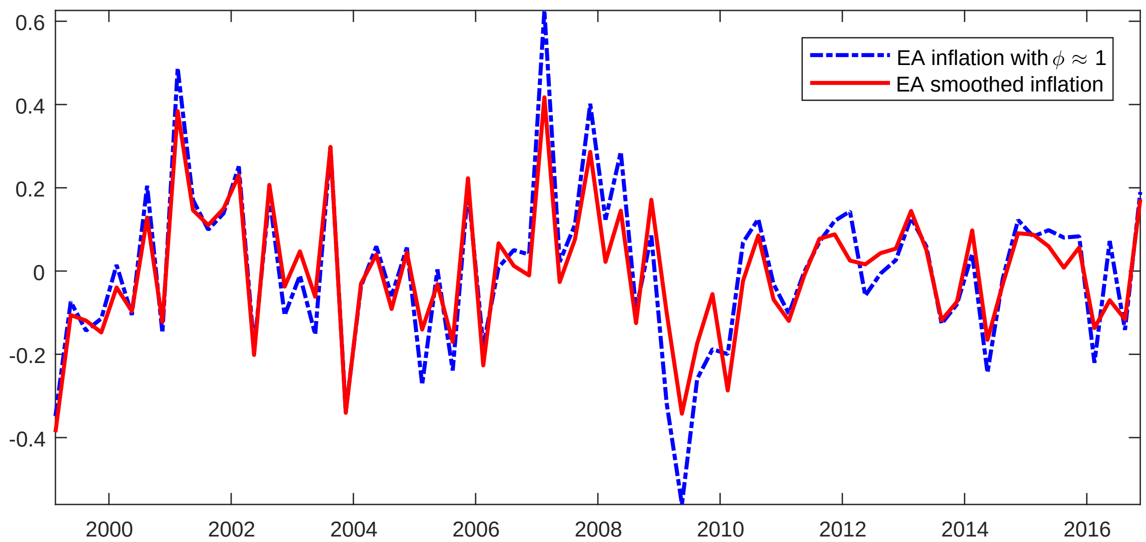
one. This exercise illustrates the role of effort in reducing inflation volatility.

6 Alternative Model Specifications

Our business cycle model is able to account for procyclical productivity dynamics and inflation volatility. But what is the relative importance of labor versus capital utilization in accounting for the observed dynamics of labor productivity and inflation? And could alternative wage bargaining schemes affect the baseline results? This section assesses the relative importance of alternative model specifications: (1) a 'standard' model with no effort; (2) a model with no variable capital utilization; and (3) a model with right-to-manage for the specification of the bargaining process. In particular, we estimate the above-mentioned models. This exercise allows us to see to what extent the transmission mechanisms and the model fit are driven by either labor or capital utilization and the type of bargaining process.

This section disentangles the role of variable labor utilization versus variable capital utiliza-

Figure 6: Euro area (smoothed) inflation series with and without effort.



tion in fitting the data and in affecting the cyclicality of labor productivity.

We first analyse the role of variable labor utilization on the model fit and dynamics. We therefore change the baseline model by setting ϕ close to 1, which requires that $\sigma_e \to \infty$, in order to investigate the role of variable labor utilization. This implies that increasing effort leads to a prohibitively large rise in disutility, hence effort does not vary in equilibrium.

Table 6 reports the Bayes factor (BF) and the statistics by Kass and Raftery (1995) (KR), computed as twice the log of the BF, between the baseline model and the no-effort model.[17] With a BF well above 100, we find 'decisive evidence' in favor of our baseline model featuring effort. The KR statistics points to 'very strong' evidence in favor of the unconstrained baseline model versus the restricted model without effort.

[17] Let m_i be a given model, with $m_i \in M$, and $L(Y|m_i)$ be the marginal data density of model i for the common dataset Y, then the BF between model i and model j is computed as:

$$BF_{i/j} = \frac{L(Y|m_i)}{L(Y|m_j)} = \frac{exp(LL(Y|m_i))}{exp(LL(Y|m_j))}$$

where LL stands for log-likelihood. According to Jeffreys (1998), a BF of $3-10$ provides 'slight' evidence in favor of model i relative to model j; a BF in the range $[10-100]$ provides 'strong to very strong' evidence; and a BF greater than 100 provides 'decisive evidence'. Values of the KR statistic above 10 can be considered 'very strong' evidence in favor of model i relative to model j; between 6 and 10 represent 'strong' evidence; between 2 and 6 'positive' evidence; while values below 2 are 'not worth more than a bare mention'.

Table 6: Marginal log-likelihood comparison: baseline vs. alternative models.

	Euro Area		United States	
	Baseline	Alternative	Baseline	Alternative
No effort				
Geweke (1999) marginal log-likelihood	−171.538	−187.746	−390.407	−401.880
Bayes factor	1.09×10^7		9.61×10^4	
Kass-Raftery statistic	32.42		22.95	
No variable capital utilization				
Geweke (1999) marginal log-likelihood	−171.538	−167.418	−390.407	−378.513
Bayes factor	61.59		1.46×10^5	
Kass-Raftery statistic	8.24		23.79	
Right-to-Manage bargaining				
Geweke (1999) marginal log-likelihood	−171.538	−225.861	−390.407	−421.954
Bayes factor	3.91×10^{23}		5.02×10^{13}	
Kass-Raftery statistic	108.65		63.09	

The online appendix reports the estimated parameters of the restricted model. The comparison between the estimates of the model with and with no effort shows a significant difference between parameter estimates. In the Euro Area, two additional mechanisms replace the role played by labor effort: (1) an endogenous mechanism represented by variable capital utilization, whose estimate is lower than the baseline model, revealing a magnified role of this margin of factor utilization; and (2) and exogenous mechanism since the no-effort model features a more persistent technology shock, with an autoregressive coefficient equal to 0.68 (compared to the baseline value of 0.50). Thus, the model relies more on exogenous sources of persistence in the absence of the endogenous labor effort. The estimated wage stickiness in the Euro Area is lowered to 4.82 in the no-effort model compared to the baseline value 7.80.

In the US, the estimates of parameters related to price dynamics are affected. In the no-effort model, prices are more flexible – requiring a stronger response to inflation in the Taylor rule – and the autoregressive parameter for the price mark-up shock is higher, equal to 0.66 compared to 0.48 in the baseline.

The variance decomposition of the no effort model, shown in the online appendix, shows that productivity shocks are more important in accounting for business cycle fluctuations in the no-effort model with compared to their role in the model with effort. This result is in line with Hornstein (1993), who shows that the introduction of increasing returns to hours (and noncompetitive markets) reduces the contribution of productivity changes to aggregate fluctuations. The role of labor supply shocks is also limited in the model without an effort margin.

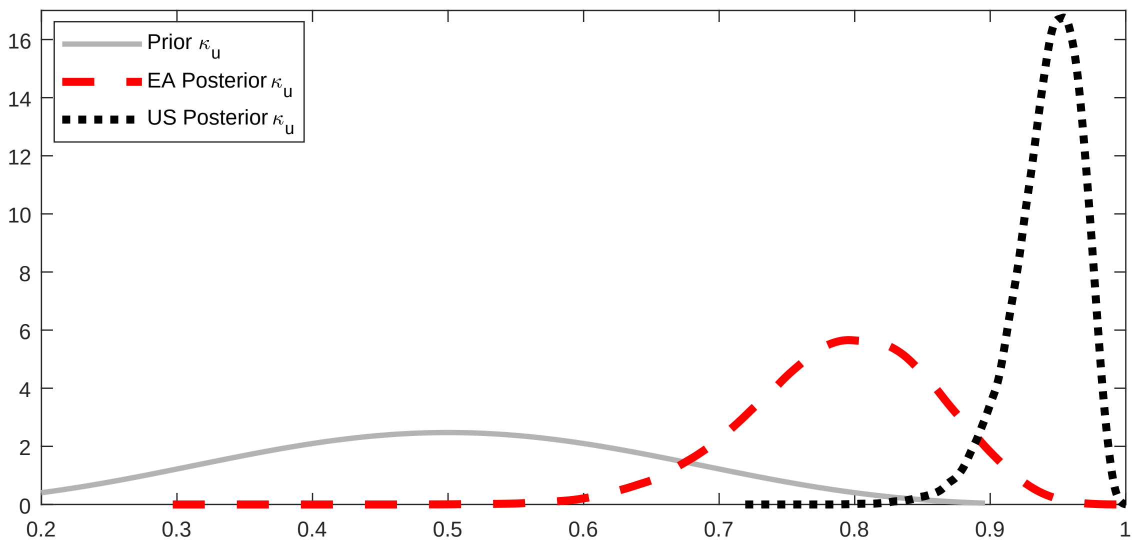
Christiano et al. (2005) point to wage staggering and variable capital utilization (VCU) as key features that can account for the observed inflation inertia. Their proposed model indeed matches very well the response of inflation. However, the response of productivity is more procyclical in the data than it is in their model.[18] And if the model is missing important frictions that would capture better the observed productivity response, these frictions will very likely also influence the implied inflation dynamics, and hence might affect any inference one draws regarding the relative importance of various real rigidities in generating realistic impulse response functions to a monetary shock. Since in their model variable capital utilization appears to be unable to generate sufficiently procyclical labor productivity, we investigate whether this is the case also in our model.

Our specification of the elasticity of the capital utilization adjustment cost function implies that if κ_u is close to 1, the elasticity is zero, i.e. variation in capital utilization is costly and, thus, capital utilization is virtually constant. In contrast, if κ_u is close to 0, the elasticity tends to infinity, meaning that variable capital utilization is a very important margin for amplifying business cycle fluctuations (see also Villa, 2012).

Figure 7 shows the posterior distributions of the elasticity of the capital utilization adjustment cost function for the Euro Area and the US. This parameter is well identified in both

[18] In fact, the model response is outside the probability bands of the corresponding empirical impulse response, indicating a poor fit in that dimension.

Figure 7: Prior and posterior densities of capital utilization elasticity κ_u: baseline model.



economies, with a fairly tight posterior distribution. In both cases, the posterior distribution is located to the right of the parameter range, revealing high capital utilization costs and, hence, a limited role for this margin of input adjustment. In the US, the parameter is higher and estimated with more accuracy. Since the median estimate in the US does not fall in the probability band of the Euro Area, the estimates of this parameter differ significantly between the two countries.

We investigate the role of this margin of adjustment by estimating a model in which we calibrate the elasticity of capital utilization adjustment costs close to 1, as in Smets and Wouters (2007). Table 6 shows that the model without VCU is strongly preferred by the data. This margin of adjustment does not play an important role in affecting the dynamics of the model, pointing to the limited role of this endogenous margin of amplification.

Parameter estimates (not reported in the interest of brevity) are similar under the two models specifications (VCU and no-VCU) both in the Euro Area and in the US. The only notable difference is the estimate of the degree of returns to hours in the Euro Area, whose mean value is $1.88[1.75; 2.00]$ in the no-VCU model versus $1.80[1.63; 2.00]$ in the baseline model.

VCU represents an additional endogenous mechanism which might contribute in explaining the procyclicality of labor productivity in the Euro Area. Therefore, when this margin is removed, the other margin, i.e. variable labor utilization, becomes more relevant and the estimate of ϕ increases. The estimate of the degree of returns to hours in the US is 1.55 [1.36;1.75] in the no-VCU model, very similar to estimate in the baseline model and this can be explained by the acyclicality of labor productivity in the US.

As shown in Trigari (2006), the specification of the bargaining process has a considerable impact on the dynamics of marginal costs and, hence, on inflation dynamics. In our baseline specification, we follow the standard approach that hours are determined jointly by the firm and the worker as a part of the same Nash bargain that determines the wage. Under this specification, referred to as efficient bargaining, marginal costs are determined by the worker's marginal disutility from supplying hours of work and the wage does not affectr hours worked.

Trigari (2006) proposes an alternative bargaining process, the Right-to-Manage framework (RtM, henceforth), where firms retain the right to set hours after wages have been bargained. In that case, marginal costs are determined by the real wage and any factor influencing the outcome of the wage bargaining process or the degree of wage rigidity will have a direct effect on marginal costs and inflation. We investigate how this alternative specification of the bargaining process affects inflation dynamics in our model.

As a first step, we estimate the model under RtM. We set the prior mean of the parameter measuring short-run returns to hours in production, ϕ, to 1.30, because there exists a lower bound for ϕ for the marginal rate of substitution to be positive, see Section 7.3 of the online appendix. The prior distributions of the remaining parameters are as in the baseline model. Determinacy issues reduces the range of values that the estimated degree of returns to hours can take in both economies if we specify the steady state as in the efficient bargaining model for comparability.[19] This endogenous constraint limits the range of values for this parameter. Notwithstanding this, the estimated degree of return to hours is lower under the RtM model and the estimates are statistically different between the Euro Area and the US. Wage stickiness is lower in the US compared to the Euro Area. Table 6 shows that our baseline model (efficient bargaining) is favored by the data compared to the Right-to-Manage. A possible explanation is that the determinacy issue – that limits the interval of values for the degree of increasing returns to hours – accounts for the worse fit of the latter model. Impulse response analysis, shown in the online appendix, shows that the effect of effort on the dynamics of productivity and inflation is similar to that in the efficient bargaining model.

Figure 8 shows the Euro Area smoothed inflation series and a counterfactual simulation for which we set $\phi = 1.05$ the lowest value for which determinacy holds, i.e. we reduce the effort margin as much as possible. This exercise illustrates the role of effort in reducing inflation volatility even more clearly compared to the efficient bargaining baseline specification. Further, according to this alternative specification, the effort margin has reduced the level of inflation by on average by about 0.2 percentage points since 2012. Hence, the effort margin is a potential piece in the missing inflation puzzle debate (see Ciccarelli and Osbat, 2017, for other factors that can explain low inflation rates in recent years).

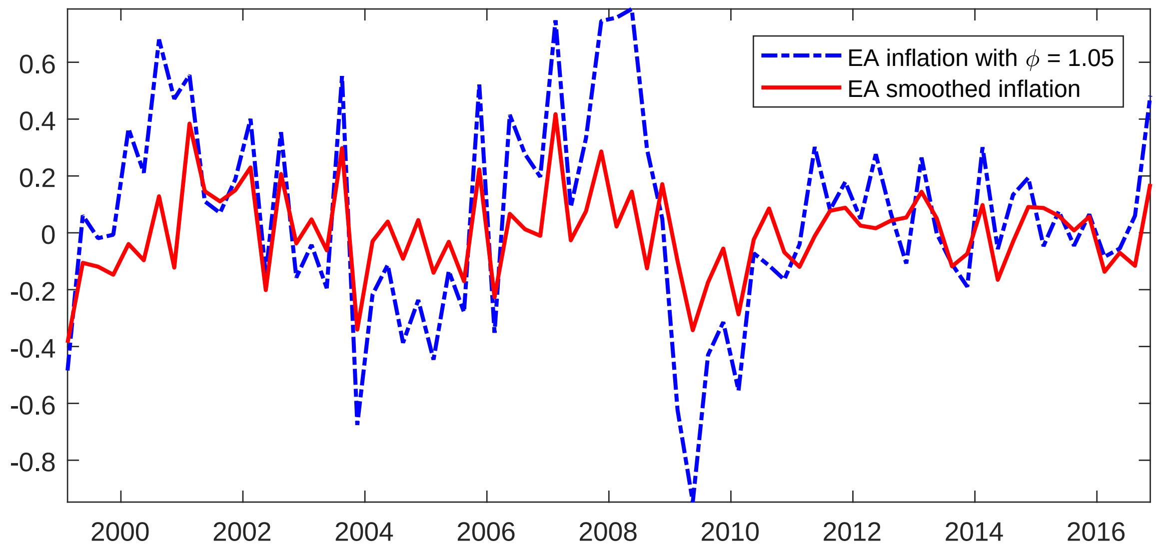
7 Conclusion

In this paper, we investigate to what extent differences in labor market adjustment can explain the more procyclical movements in labor productivity, measured as output per hour worked, and the lower inflation volatility in the Euro Area compared to the US.

The current vintage of business cycle models do not provide an explanation for the observed

[19] See Lewis and Villa (2018) for an analysis on the role of hours and effort in affecting the existence and uniqueness of the equilibrium solution in a standard labor search and matching model.

Figure 8: Euro area (smoothed) inflation series with/without effort (right-to-manage model).



cyclicality of labor productivity and inflation dynamics. Our proposed model features increasing returns to hours through variable labor effort. The estimation of the model with Bayesian techniques reveals that the parameter measuring returns to hours in production is greater than unity and significantly higher in the Euro Area than in the US. This explains the difference cyclicality of labor productivity in the two economies. In addition, we find evidence that the effort margin affects the dynamics of inflation as the procyclicality of labor productivity dampens real marginal costs. We allow for variable capital utilization as well, and show that the data prefer the labor utilization margin over the capital utilization margin.

Our model with endogenous effort is useful as a way to generating increasing returns to hours in production. But the fact that effort is not observed makes the underlying preference assumptions hard to test empirically. Future research might therefore focus on finding ways to capture increasing returns to hours which are consistent with microeconomic models of the labor market.

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