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

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Abstract

Labor productivity is more procyclical and inflation is less volatile in the Euro Area compared to the US. To explain these differences, we estimate a business cycle model with search frictions, employment, hours worked and two alternative wage bargaining setups. In addition, we include variable labor effort. Two results emerge. First, wages are more rigid and effort is more important in the Euro Area, generating procyclical productivity. Second, variable effort does not affect inflation fluctuations under efficient wage bargaining. However, under right-to-manage bargaining, procyclical labor productivity combined with higher wage rigidity in the Euro Area reduces inflation volatility via the wage channel.

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1 Introduction

We document two differences between the Euro Area and US business cycles. First, labor productivity is more procyclical in the Euro Area than in the US. Second, Euro Area inflation is less volatile than US inflation. The hypothesis we test in this paper is that variable labor utilization in Europe, resulting from institutional frictions in labor market adjustment, contributes to more procyclical labor productivity and lower inflation volatility as compared with the US. 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 the two facts are related to each other and result from differences in labor market features.

Labor markets in the Euro Area are a lot more rigid than in the US, as shown by Gnocchi et al. (2015). In a study of 20 OECD countries over the period 1975-1997 Nunziata (2003) concludes that stricter employment protection and looser working time regulations are associated with a lower variability of employment over the cycle. Jung and Kuhn (2014) show that the mean hiring rate in Germany is a quarter of that in the US, suggesting that hiring costs are larger in Germany. Dossche et al. (2018) report that in Germany, France and Italy, around half of the cyclical adjustment of hours worked is in terms of hours per person, while in the US most of this adjustment takes place along the employment margin (see also Abraham and Houseman, 1995). This slow and limited adjustment of Euro Area employment might suggest that other margins of labor, more specifically hours and effort, are more relevant there than in the US.

Variable labor utilization, sometimes also referred to as endogenous effort, is an old concept in macroeconomics, going back to Oi (1962), Rotemberg and Summers (1990), Burnside et al. (1993), and Bils and Cho (1994). It has received renewed interest in the more recent literature, for instance Barnichon (2010) and Galí and van Rens (2017). The former study proposes a

New-Keynesian model with variable labor effort and technology versus non-technology shocks to explain the change in the correlation between unemployment and productivity in the US. In the model Barnichon (2010) argues that a weaker procyclicality of productivity is the result of a more flexible labor market with lower hiring frictions as firms rely less on the effort margin when the other labor margins, hours and employment, become cheaper. Galí and van Rens (2017) develop a business cycle model with hiring frictions and variable effort to explain the vanishing procyclicality of labor productivity, the rise in the relative volatility of employment, and the rise in real wage volatility in the US.

In the presence of variable labor utilization, during a downturn a firm might be reluctant to lay off workers and instead choose to use labor less intensively, such that labor productivity – output per hour – decreases. The most likely reason behind this phenomenon is that firing workers and hiring new workers once demand picks up again entails considerable costs such as search and training costs. Institutional frictions in labor market adjustment, such as employment protection laws, might reinforce this mechanism of endogenous effort. During cyclical recoveries, output can be increased by correcting this underutilization of labor, so that labor productivity increases. Similar to variable capital utilization, variable labor utilization makes productivity procyclical.

In the literature there is mixed evidence on the importance of such labor market frictions for productivity, real marginal costs and inflation dynamics. Using a panel of 19 OECD countries, Gnocchi et al. (2015) find that labor market institutions matter for business cycle fluctuations. In particular, they find that reforms reducing replacement rates, defined as unemployment benefits as a percentage of average earnings before tax, make labor productivity more procyclical. This evidence suggests that workers, faced with a higher probability of not receiving benefits upon entering an unemployment spell, have an incentive to vary effort over the cycle to a greater extent, making productivity more procyclical.

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.

In this paper, we propose two features which in combination can explain the difference in the cyclicality of labor productivity and inflation dynamics between the US and Euro Area: increasing returns to hours in production – which makes labor productivity procyclical – and a different degree of wage stickiness – which in turn affects price dynamics. We develop and estimate with Bayesian methods a dynamic stochastic general equilibrium (DSGE) model with three elements: variable labor effort, price and wage rigidities, and labor search and matching frictions with alternative wage bargaining setups.

Our contribution to the literature is twofold. First, we find greater wage rigidity and a more important role for variable labor effort in the Euro Area compared to the US. 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.

Second, while increasing returns to hours can explain the (more) procyclical labor productivity observed in the Euro Area, this procyclicality does not result in a dampening of inflation under efficient bargaining. As in Trigari (2006) and Christoffel et al. (2009), we introduce a 'wage channel' through right-to-manage bargaining and show that this alternative setup helps explain the lower inflation volatility in response to demand shocks in the Euro Area.

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

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
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 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 blocks of four observations and 100000 bootstraps.

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. Section 6 estimates the model under alternative specifications: right-to-manage bargaining, no effort and no variable capital utilization. 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.[1] The sample runs from 1999Q1 to 2016Q4, starting with the beginning of the single monetary policy regime in the Euro Area.

The table documents three striking differences in unconditional business cycle moments between the Euro Area and the US. First, hours and employment are much less volatile in the Euro Area than in the US. Different labor market legislation might explain why the observed

[1] 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 Appendix.

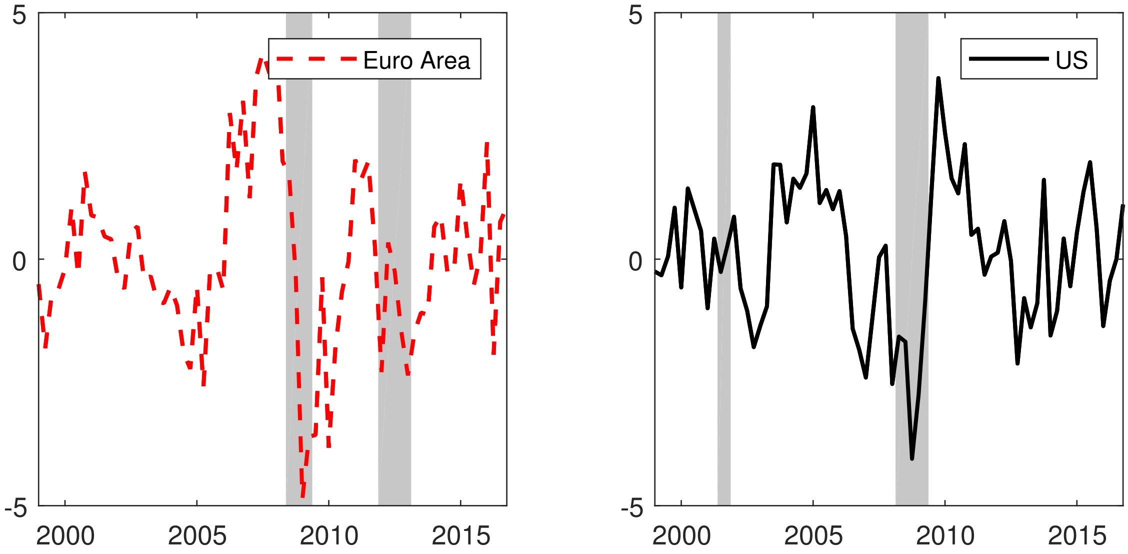
labor adjustment in the Euro Area is subdued. In particular, the strict employment protection legislation (EPL) in Europe, compared to the US, discourages firms from using hiring and firing policies as an adjustment margin (see data from OECD, 2013). An alternative tool that allows employers to adjust 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. Since the introduction of the single currency, Euro Area inflation is less variable than in the US. The results for inflation are robust to using the CPI. Despite the fact that interest rates in the Euro Area are less volatile than in the US, Euro Area inflation is more stable.

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 equilibrium model.

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.

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 model which allows for labor adjustment along three margins: employment, hours and effort. Our model 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.[2] 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-

[2]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 $\kappa_u \in [0,1]$.[3] 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.

[3] 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^s_{it} are labor services, k^s_{it} 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,

$$l^s_{it} = e_{it} h_{it} n_{it}, \tag{7}$$

$$k^s_{it} = u^k_t K_{it}. \tag{8}$$

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.[4] 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

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

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

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

where $\Omega_{it}^{w} = \frac{w_{it}}{w_{it-1}} \frac{\Pi_t}{\Pi} (\frac{\Pi_{t-1}}{\Pi})^{-\lambda_w}$, $\Omega_{it}^{p} = \frac{\Pi_{it}}{\Pi} (\frac{\Pi_{t-1}}{\Pi})^{-\lambda_p}$ 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_{it}^{s}, and a price P_{it}, so as to maximize its value V_{it}^{f}, subject to the law of motion for its workforce, and the demand constraint,

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

$$(P_{it}/P_t)^{-\varepsilon_t} Y_t = y_0 Z_t^A (n_{it} h_{it}^{\phi})^{1-\alpha} (k_{it}^{s})^{\alpha}. \tag{16}$$

Denoting by s_{it} the Lagrange multiplier on (16), the demand for capital services satisfies $r_t^k = s_{it} \alpha \frac{Y_{it}}{k_{it}^{s}}$, 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,

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

where $\Omega_t^p = \frac{\Pi_t}{\Pi} (\frac{\Pi_{t-1}}{\Pi})^{-\lambda_p}$. 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 $S_{it}^{f} \equiv \frac{\partial V_{it}^{f}}{\partial n_{it}}$, is given by

$$S_{it}^{f} = s_{it}(mpn_{it}) - w_{it} - \Phi - \Psi_{it}^{w'} + (1-\lambda) E_t\{\beta_{t,t+1} S_{it+1}^{f}\}, \tag{18}$$

where mpn_{it} is the marginal product of employment and $\Psi_{it}^{w'}$ 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

$$V_{it}^{v} = -c + E_t\{\beta_{t,t+1}[q_t S_{it+1}^{f} + (1-q_t) V_{it+1}^{v}]\}. \tag{19}$$

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):

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

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 $g(h_{it})$ 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

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

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

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

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. In the Right-to-Manage model described in Section 6.1, we will see that real marginal costs are instead affected by fluctuations in the real wage.

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

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

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

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 $\Upsilon_t = \frac{Z^B_t}{1-Z^B_t}$. However, 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 worker's and 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),

$$B_{t-1}/P_t = Z^G_t + (1-n_t)b - T_t + R_tB_t/P_t. \tag{28}$$

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

4 Calibration and Prior Distributions

The model is estimated on quarterly data for the period 1999Q1-2016Q4, characterized by a single monetary policy regime in the Euro Area. 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.[6]

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 in the data. 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 of 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 the 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. Given our estimate of ϕ, we can back out the value the deep parameter σ_e consistent with this estimate.

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 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

[6]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 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	**XXX**
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	**XXX**
Workers' bargaining weight	Z^B	0.5	Cantore et al. (2014)
Match elasticity	η	0.65	various studies
Cost of posting a vacancy	c	$cv/Y = 0.01$	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: CK (2009)=Christoffel and Kuester (2009), GT (2009)=Gertler and Trigari (2009), BG (2010)=Blanchard and Galí (2010).

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. Second, we show the transmission of demand shocks via impulse response analysis. Finally, we run counterfactual exercises where we transplant some structural labor market features of the Euro Area to the US and consider the implied change in the dynamic response to different shocks.

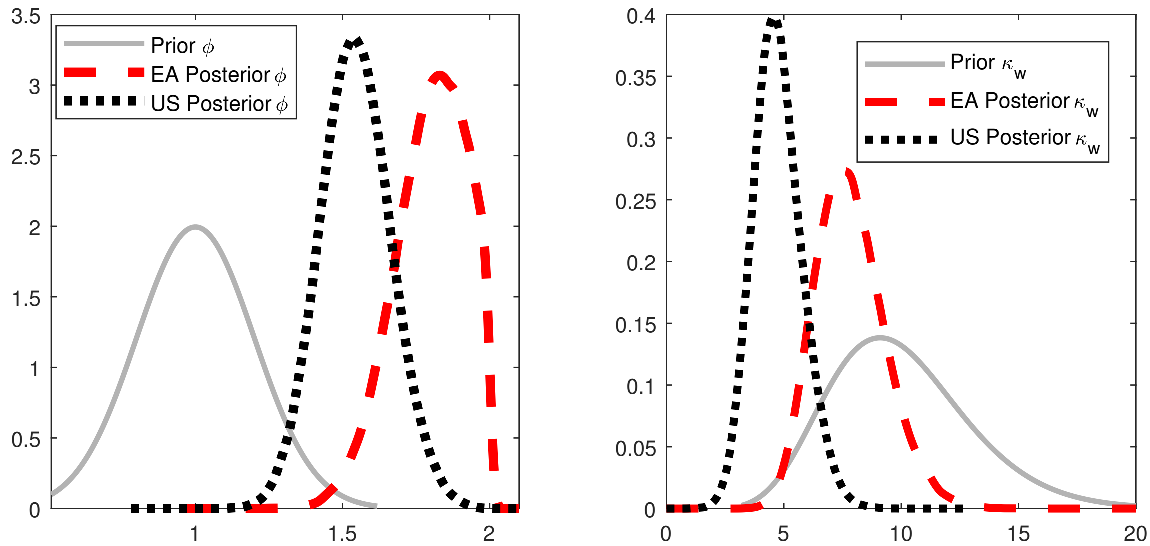
5.1 Parameter Estimates

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.[7] 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 estimated probability band for the US.[8] The fact that nominal wage contracts are set for longer periods in the Euro Area compared to the US points to greater labor

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

[8]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.



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, pointing to the limited role for this margin of adjustment (see Section **??** 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.[9] 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.[10]

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

[9] 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.

[10] These results hold also when the observable variables are filtered with the method proposed by Hamilton (2018), as shown in Table **??**. 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	$\rho_{\gamma B}$	Beta	0.50	0.15	0.61 [0.48;0.72]	0.14 [0.04;0.23]
	$\sigma_{\gamma B}$	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.

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 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

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

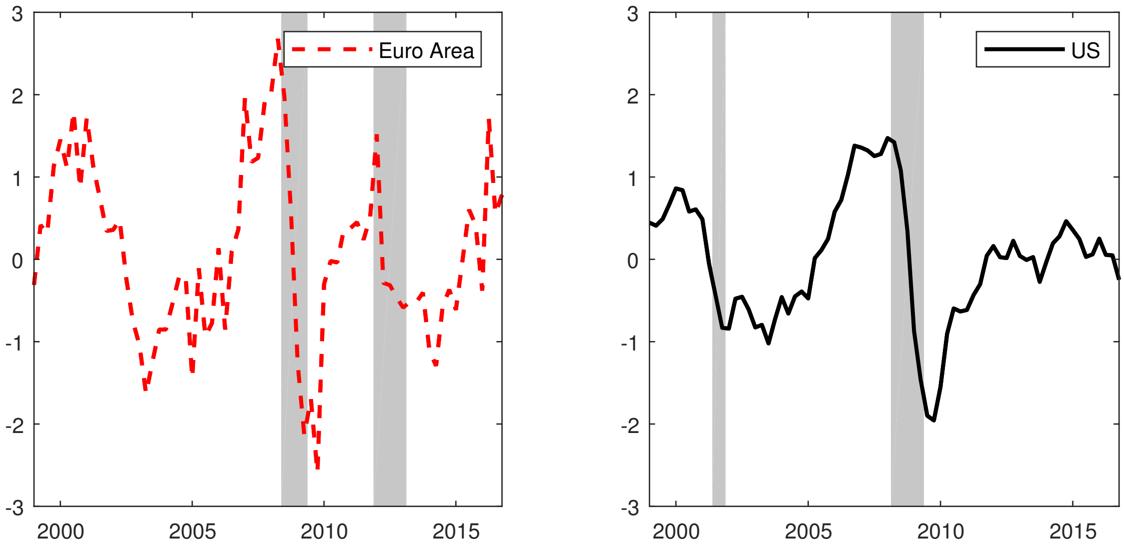
Variable	Output correlations						Relative standard deviations					
	Euro Area		US		Diff.		Euro Area		US		Ratio	
	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data	Model	Data
Real output							1.26	1.29	1.19	1.19	1.05	1.08
Total hours	0.85	0.85	0.86	0.86	-0.02	-0.02	0.28	0.64	0.73	1.13	0.38	0.56
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	–

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.[11]

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 Shea (1990) and Burda et al. (2017) for the US economy. Figure 3 confirms that during recessions, labor has been used less intensively both 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

[11] This is the so-called unemployment volatility puzzle (Shimer, 2005), i.e. the inability of 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.

line with our conjecture.

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 confirmed 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).[12] Inflation is mainly driven by risk premium and price mark-up shocks. Monetary policy shocks play a non-negligible role, explaining about 26%

[12]It is worth noting that 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).

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

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.

5.2 Model Dynamics

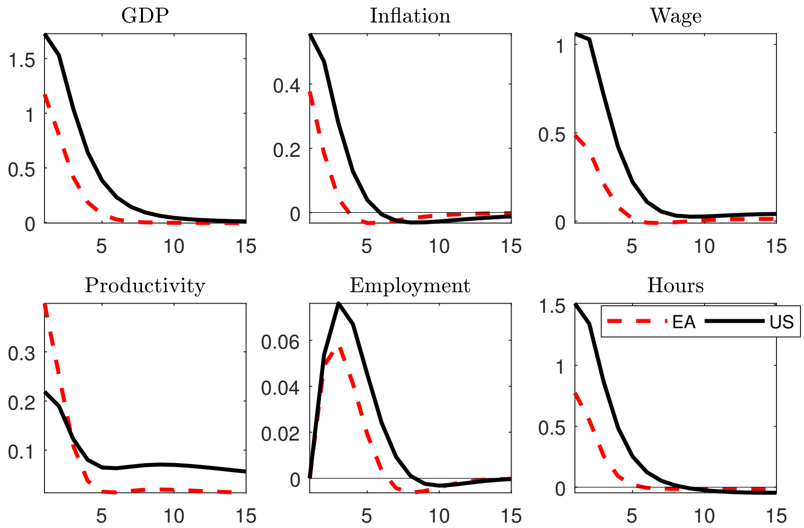
Figures 4 show the estimated mean impulse response functions of selected variables to the risk premium shock, which is the demand-side innovation most important for business cycle fluctuations.[13]

[13] 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 Appendix.

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 margin of labor services 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 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 the 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 the estimated value for the EA, except the 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 clearly more used when the effort margin is constant. 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

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

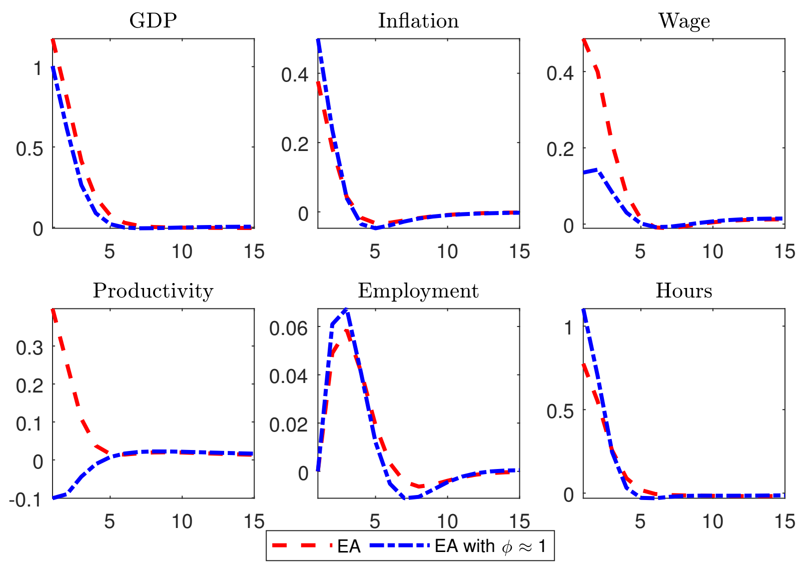


Notes: Figure shows estimated mean responses. Y-axes show percent deviations from steady state. Time horizon on X-axes measured in quarters. Shock size normalized to one for both countries.

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 acts in the direction of dampening the rise of inflation. It should be noted that a European-style use of the intensive labor margin would not dramatically change inflation in the baseline model with efficient bargaining. Similar results hold for the monetary policy shock, shown in the Appendix.

In Section 6.1, we investigate whether a different wage bargaining setup, Right-to-Manage (RtM), alters this transmission mechanism. Under RtM, firms choose hours unilaterally after the wage has been set through bargaining. Trigari (2006) shows that RtM generates a wage channel, by which wage changes are transmitted to inflation. The wage channel is not present under efficient bargaining, where the two parties bargain over wages and hours simultaneously.

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.

6 Alternative Model Specifications

Our business cycle model is able to account for procyclical productivity dynamics. But can other model features also account for the observed dynamics of labor productivity and inflation? This section assesses the relative importance of alternative model specifications: (1) a model with right-to-manage for the specification of the bargaining process; (2) a 'standard' model with no effort; (3) a model with no variable capital utilization. In particular, we estimate the above-mentioned models. We then provide a comparison between their marginal log-likelihood. 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.

6.1 Right-to-Manage Bargaining

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.

From a modelling point of view, in the RtM model of Trigari (2006), firms set hours worked to maximize their match surplus (18). They do this after the wage bargaining process, taking the equilibrium wage rate as given. The first order condition to this problem is

$$s_{it} = \frac{1}{\phi\left(1-\alpha\right)^2}\frac{w_{it}}{\mathcal{P}_{it}}. \tag{32}$$

Thus, in the right-to-manage model, the wage is allocational. Equation (32) shows that movements in real marginal costs, which in turn determine inflation volatility, are driven by variations in the real wage, w_{it}, relative to variations in labor productivity, $\mathcal{P}_{it}$. In particular, any procyclicality in the real wage results in procyclical real marginal costs, which increases inflation volatility. To the extent that fluctuations in productivity are also procyclical, this will (partially) offset the procyclicality in real marginal costs, thereby dampening inflation volatility.

Workers and firms bargain bilaterally over the nominal wage W_{it} as in the baseline model with efficient bargaining, and the equilibrium real wage is still given by (27). However, the new equilibrium condition for hours– which determines marginal costs – is given by (32) and the effective bargaining power (25) is replaced with

$$\frac{Z_t^B}{1-Z_t^B}\frac{1+\sigma_h}{\Upsilon_t}mrs_{it} = w_{it}h_{it} + \kappa_w(\Omega_{it}^w - 1)\Omega_{it}^w + (1-\lambda)E_t\left\{\beta_{t,t+1}\kappa_w(\Omega_{it+1}^w - 1)\Omega_{it+1}^w\right\}. \quad (33)$$

All other equations are the same as in the baseline model. This modification exerts a considerable impact both on the dynamics of the model.[14]

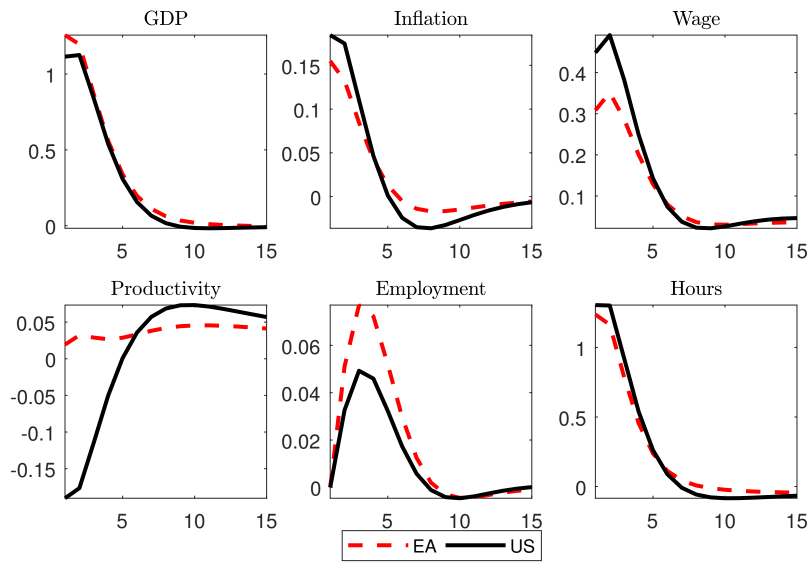
As a first step, we estimate the model under RtM. We set the prior mean of the parameter measuring short-run returns to hours in production, ϕ, to 1.30, because there exists a lower bound for ϕ for the marginal rate of substitution to be positive, see Section 7.3 of the online appendix. The prior distributions of the remaining parameters as in the baseline model. There are some notable differences between the estimates of the baseline model and the RtM model, shown in the Appendix. Determinacy issues reduces the range of values that the estimated degree of returns to hours can take in both economies.[15] 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. Also related to this channel is the reduced estimate of the persistence of the price mark-up shock in the US, equal to 0.20 versus 0.48 in the baseline model, and of the volatility of the bargaining power shock, equal to 1.13 versus 5.08 in the baseline model.

Figure 6 shows the impulse responses to a risk premium shock in the RtM model. Hours worked in the Euro Area increase less than output, while the opposite is true for the US. As a result, productivity increases in the former economy and decreases in the latter. The estimated degree of wage stickiness is much lower in the US economy compared to the Euro Area. The increase in wages and thus marginal costs after the shock is much larger in the US compared to

[14]The steady state changes as well. For details, see the online appendix.

[15]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 6: Impulse responses to risk premium shock: Right-to-Manage model.

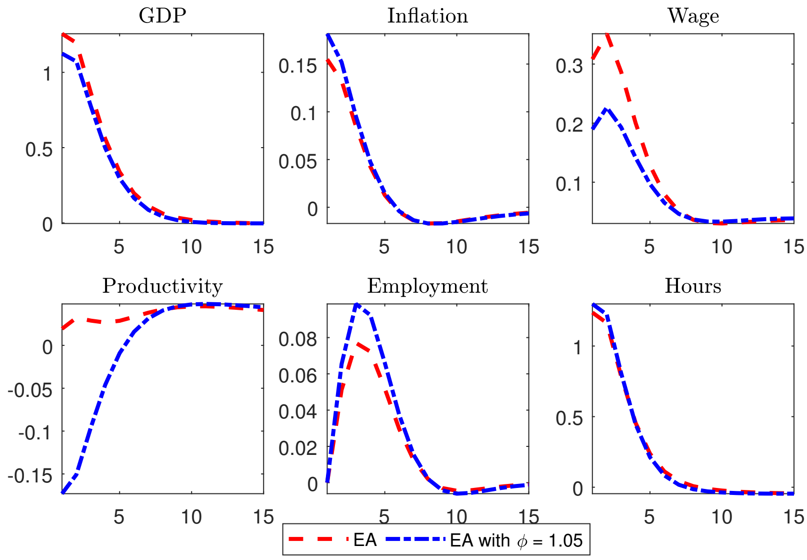


Notes: Figure shows estimated mean responses. Y-axes show percent deviations from steady state. Time horizon on X-axes measured in quarters.

the Euro Area. This in turn affects inflation, which rises by more in the US than in the Euro Area. This mechanism is even stronger in the case of the monetary policy shock shown in the Appendix.

Figures 7 disentangles the role of increasing returns to hours in affecting the dynamics of productivity and inflation presenting the model estimated for the Euro Area and a counterfactual model where all parameters are set to the estimated value for the Euro Area, except the parameter measuring the returns to hours, ϕ, which is set to the lowest value needed to ensure determinacy in the model. A very low degree of returns to hours makes labor productivity counter-cyclical in response to the shock. The extremely reduced role of the effort margin makes the response of the extensive margin more volatile. Workers are less productive in the counterfactual scenario, hence their wage falls. Therefore, there are two contrasting effects of effort on inflation: (1) procyclical labor productivity; and (2) stronger increase in wage. The first effect dampens the increase in real marginal costs, as shown by equation (32), hence the increase in inflation should be mitigated. At the same time the productivity of the workers in

Figure 7: Impulse responses to risk premium shock in RtM model: 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.

the presence of effort is higher, hence the increase in the wage is more pronounced compared to the case where this labor margin is barely used. The stronger increase in the real wage lead to a stronger rise in real marginal costs, equation (32), hence in inflation. Overall, the first effect dominates and the increase in inflation in response to the demand shock is mitigated under effort.

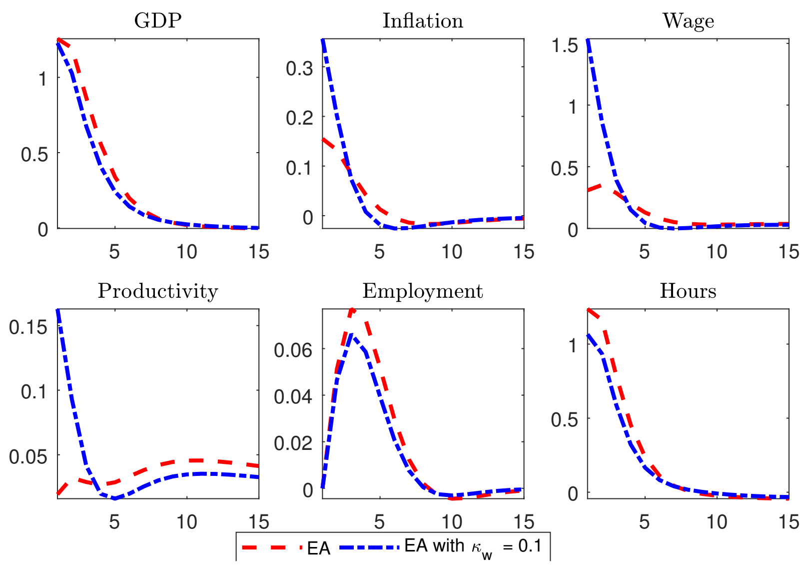
The wage channel in the RtM model makes marginal costs and inflation sensitive to the degree of wage rigidity, as shown in Figure 8. Lower wage stickiness reduces the volatility of the real wage and attenuates the increase in inflation. Counterfactual exercises for the monetary policy shock, shown in the Appendix, confirm these results.

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 RtM model and the baseline model with effort.[16] Our baseline model – efficient bargaining – is favored by the data.

The variance decomposition under RtM, reported in the Appendix, differs from that of

[16]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

Figure 8: Impulse responses to risk premium shock in RtM model: counterfactual varying κ_w.



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

the baseline model. Labor supply shocks are the most important shocks in driving output fluctuations in both economies and play a major role also for movements in productivity, wages, employment and hours. Price mark-up shocks explain the bulk of inflation movements in the Euro Area. Overall, the importance of demand shocks in the RtM model is smaller compared to the baseline model.

6.2 Variable Labor Utilization versus Variable Capital Utilization

This section disentangles the role of variable labor utilization versus variable capital utilization in fitting the data and in affecting the cyclicality of labor productivity.

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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
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	
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	

We first 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 and the Kass and Raftery (1995) statistic in comparing the baseline model and the no-effort model. The Appendix reports the estimated parameters of the restricted model. 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.

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.

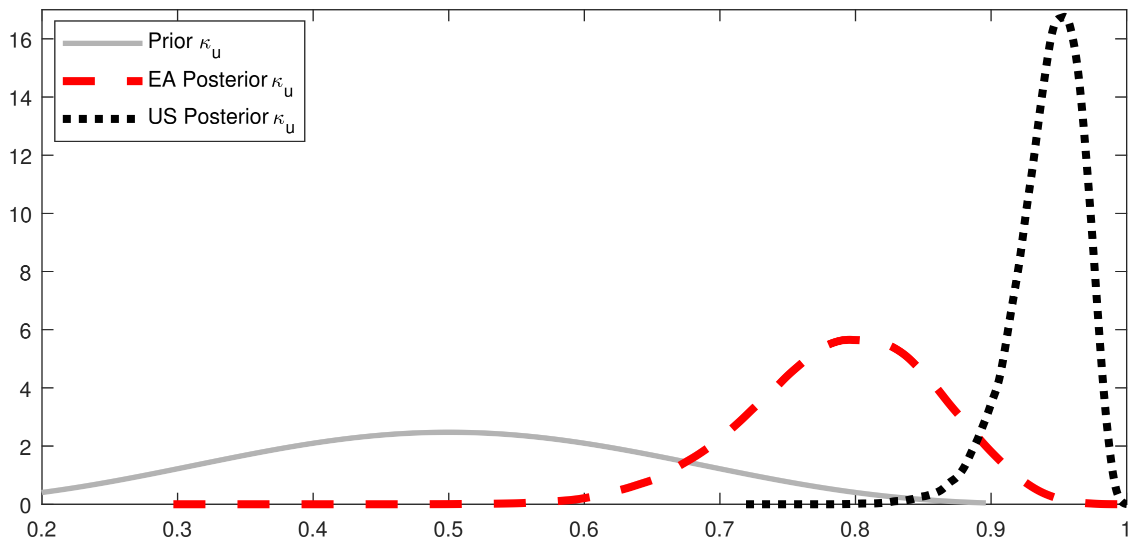
The variance decomposition of the no effort model, shown in the Appendix, shows that productivity shocks are more important in accounting for business cycle fluctuations in the no-effort model with compared to their role in the model with effort. This result is in line with Hornstein (1993), who shows 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 mode 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.[17] 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

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

Figure 9: Prior and posterior densities of capital utilization elasticity κ_u: baseline model.



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 9 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 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.

7 Conclusion

In this paper, we investigate whether differences in labor market adjustment as a way of explaining 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 falls short in accounting for the procyclicality of labor productivity. Our proposed model features increasing returns to hours through variable labor effort. The estimation of the model with Bayesian techniques reveals that two labor market parameters differ significantly between the Euro Area and the US: the degree of wage rigidity and the returns to hours in production. The latter parameter is higher in the Euro Area, providing evidence for increasing returns to hours. We allow for variable capital utilization as well, and show that the data prefer the labor utilization margin over the capital utilization margin. The baseline specification featuring efficient wage bargaining is not able to replicate the different inflation dynamics observed in the data. However, under Right-to-Manage bargaining, the presence of more rigid wages in the Euro Area helps explain the lower volatility of inflation due to the wage channel.

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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