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LABOR PRODUCTIVITY, EFFORT AND THE EURO-AREA BUSINESS CYCLE

by Vivien Lewis* and Stefania Villa**

Abstract

Labor productivity is highly procyclical in the euro area. We investigate the sources of this procyclicality in an estimated New Keynesian business cycle model with labor search frictions and variable factor utilization in both capital and labor. Labor input can vary along three margins: employment, hours, and effort (or utilization). We find evidence for a significant use of the effort margin in labor adjustment. Moreover, a model that uses effort outperforms one with variable capital utilization or dominant technology shocks. Finally, the effort margin dampens inflation volatility.

JEL Classification: E24, E31, E32.

Keywords: capital utilization, effort, labor productivity, inflation.

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1 Introduction[1]

The Euro Area business cycle is characterized by strongly procyclical labor productivity, measured as output per hour worked. Over the period 1999Q1-2019Q4, the correlation between the cyclical components of labor productivity and output is equal to 0.76.[2] We consider three candidate explanations for this observation: variable capital utilization, variable effort (or labor utilization) and dominant technology shocks. In an estimated general equilibrium model with frictional labor markets, we disentangle these three mechanisms. The effort margin plays a significant role in the Euro Area business cycle. Furthermore, we find that a model with effort outperforms one with variable capital utilization in terms of overall fit.

The observed procyclicality of labor productivity indicates that total hours respond less to shocks than output. Standard business cycle models cannot replicate this pattern if non-technology shocks are an important source of fluctuations. For instance, the Great Recession is believed to have been demand-driven rather than the result of adverse technology shocks (Christiano et al., 2015). With constant technology, more factor input is required to expand production. To obtain a rise in labor productivity, what is needed are increasing returns to hours. This can be accomplished by introducing variable factor utilization 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 response to a demand expansion, productivity rises through an increase in utilization. These considerations lead us to include both capital and labor utilization in our business cycle model.

Another distinct feature of European economies is that employment flows are rather small, reflecting institutional frictions in labor market adjustment (Gnocchi et al., 2015, among others). Firms rely more on changes in hours per worker to adjust their labor input (Dossche et al., 2019). This evidence suggests that we need labor market frictions and variable hours per worker for our model to be able to describe Euro Area labor markets adequately.

We thus derive a New Keynesian model with labor search frictions and variable factor utilization in addition to the nominal and real rigidities found in Christiano et al. (2005). Using Bayesian methods à la Smets and Wouters (2007), we estimate the model on Euro

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[2] This correlation is based on HP-filtered data, see Hodrick and Prescott (1997). The procyclicality of labor productivity is preserved under alternative filtering methods such as the band pass filter and the filter by Hamilton (2018), see the online appendix, Table B.2.

Area quarterly data from 1999Q1 to 2019Q4. The estimates show that the effort margin is quantitatively important. Using a likelihood test, we show that the model featuring labor effort is overwhelmingly preferred by the data compared to a standard model with constant effort. Two other common explanations for procyclical productivity, variable capital utilization and a dominance of technology shocks in driving business cycles, are shown to be far less successful at generating a good model fit. Counterfactual simulations of our model show that effort reduces inflation variability and makes output more volatile. In terms of policy implications, our results suggest that the labor effort margin dampens inflation fluctuations, which is desirable for a central bank.

What is crucial for variable labor effort to have the desired effects in our model is the combination of two features as in Barnichon (2010). First, monopolistic competition in product markets and sticky prices imply that output is demand-determined in the short run. Second, employment is predetermined; of the three labor input margins, only hours and effort can change on impact in response to shocks. Given that the capital stock is fixed initially, and abstracting from variable capital utilization, these two assumptions imply that effective hours per worker are essentially determined residually as the firm needs to satisfy demand for its good at the prevailing price. This is how the goods market structure is critical in determining the labor market responses to shocks, in particular the timing and speed of the responses in the different labor input margins: extensive (employment) versus intensive (effective hours).

Now, we allow for another input margin, the capital utilization rate, to vary in order to produce the amount of output demanded. We model capital utilization as is commonly done in much of the business cycle literature. The household holds the capital stock and chooses both investment in new capital and the utilization rate of existing capital. Our main contribution is to investigate which margin, labor or capital utilization, is used more in the short run as the economy adjusts to shocks. While Christiano et al. (2005) emphasize the importance of variable capital utilization in replicating the empirical responses to a monetary policy shock, we also allow for labor effort to vary. Moreover, we evaluate the model fit using full-information estimation techniques when a range of shocks is active in the model, as pioneered by Smets and Wouters (2003).

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. The shirking model by Shapiro and Stiglitz (1984) instead implies countercyclical effort: people work harder in a downturn, when the job finding probability is low and so the 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. (2020) 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. This is consistent with procyclical effort. Lewis and van Dijcke (2019)

consider cross-country survey data and find that self-reported effort is procyclical. Evidence from health economics shows that sick leave, workplace accidents and mortality rates are all procyclical.[3] 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 (Lazear et al., 2016).

This paper is related to a long literature on the concept of labor hoarding, going back to Oi (1962), Okun (1963), Rotemberg and Summers (1990) and Burnside et al. (1993), among many other contributions. It is also related to more recent studies that seek to explain the drop in the cyclicality of US labor productivity since the mid-1980s. Several explanations have been put forward. Barnichon (2010) and Galí and van Rens (2020) argue that a decline in hiring frictions has reduced the importance of effort as a labor adjustment margin. Fernald and Wang (2016) show empirically that lower variation in factor utilization – the workweek of capital and labor effort – is the main factor. Our contribution adds weight to this explanation by showing the importance of labor effort in the Euro Area, where the cyclicality of labor productivity has not fallen. Moreover, we show that variable utilization is more important for the factor labor than it is for capital. Our main finding thus calls for the inclusion of labor utilization in business cycles models designed for policy analysis.

Only a limited number of studies allow for both capital and labor utilization to vary independently. Barnichon (2010) abstracts from physical capital entirely. Bils and Cho (1994) do have capital utilization in their model, however, they assume that the utilization rate is mechanically linked to hours and effort. The assumption is that, when workers work longer hours or exert more effort, they tend to use the available capital more intensively. Then hours/effort and capital utilization are complements rather than substitutes. Shapiro (1986) allows the firm to vary both capital and labor utilization; however, varying labor essentially means having employees work overtime, so there is no third labor margin beyond employment and hours per worker. Baxter and Farr (2001)'s model also allows for both types of factor utilization to vary independently; however, they abstract from price stickiness, which plays an important role in our setting. Moreover, their main focus is on international factor comovement, which we do not consider. Basu et al. (2006) argue that the short-run fall in input use observed in response to technology improvements is consistent with a model featuring sticky prices and variable factor utilization. However, they do not study the relative importance of capital versus labor utilization, as we do here.

The remainder of the paper is structured as follows. We discuss the key stylized facts of the Euro Area business cycle in Section 2. Section 3 outlines our model. In Section 4, we estimate the model using Bayesian techniques. Section 5 gauges the importance of the effort margin versus variable capital utilization and dominant technology shocks for

[3] 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 (2006). Procyclical sick leave is documented in Taylor (1979), Leigh (1985), Arai and Thoursie (2005), Askildsen et al. (2005) and Schön (2015).

fitting the data. In Section 6, we discuss the role of effort in the dynamic adjustment of the economy to shocks, we analyze how effort interacts with frictions, and we conduct counterfactual simulations. Section 7 concludes. The full model derivation, technical details and robustness checks are provided in the online appendix.

2 Data and institutional context

Table 1 shows selected business cycle statistics for the Euro Area and four other advanced economies prior to the Covid-19 pandemic. Our sample period starts in 1999 with the introduction of the euro. The Euro Area business cycle is characterized by a high correlation of productivity and output, and comparatively low inflation volatility.[4] These features are robust to using alternative filtering techniques, see Table B.2 in the online appendix.

Table 1: Business cycle statistics: Euro Area and beyond

	Output correlations				Relative standard deviations			
	EA	Canada	UK	US	EA	Canada	UK	US
Total hours	0.89	0.81	0.74	0.87	0.76	0.81	0.72	1.28
Hours per worker	0.69	0.66	0.51	0.81	0.42	0.43	0.40	0.39
Unemployment	-0.46	-0.61	-0.43	-0.55	1.11	0.66	1.16	1.64
Employment	0.73	0.68	0.75	0.80	0.52	0.52	0.46	1.01
Productivity	0.76	0.54	0.68	-0.19	0.42	0.60	0.70	0.62
Inflation	0.36	0.07	0.12	0.37	0.17	0.77	0.44	0.21

Notes: Data sources are provided in Table B.3 of the online appendix. Sample: 1999Q1-2019Q4. Output is real GDP per capita. Inflation is measured as quarter-on-quarter percentage changes in the GDP deflator. Data for output, total hours, hours per worker, employment, productivity have been logged and HP-filtered. Standard deviations are computed relative to output.

Looking more closely at the labor market variables in Table 1, we see that total hours are less volatile than output in the Euro Area (as well as in Canada and the UK), but more volatile in the US. This difference is driven mainly by the extensive margin; employment is twice as volatile in the US as it is in the Euro Area, while hours per worker have roughly the same variability in the two economies.

Institutional frictions in Euro Area labor market adjustment may explain why employment flows are relatively small there (Gnocchi et al. 2015, among others). European countries have stricter employment protection legislation, such as e.g. dismissal restrictions, than the UK or the US, see OECD (2020). If it is costly to fire workers, employers will be more cautious in hiring workers in the first place. In a study of 20 OECD countries over the period 1975-1997, Nunziata (2003) concludes that stricter employment protection and

[4] Including the Covid-19 period does not fundamentally alter this conclusion, see Table B.1 in the online appendix.

looser working time regulations are associated with a lower variability of employment over the cycle. Recent evidence points to high levels of labor hoarding, measured as the share of firms that do not reduce their workforce despite a deterioration in their firm-specific outlook, see European Commission (2023), Botelho (2024) and Carmine et al. (2024).

In a downturn, firms that are reluctant to lay off workers may adjust labor input along the intensive margin – hours per worker and effort per hour – instead. Dossche et al. (2019) 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). Short-time-work (STW) schemes, i.e. subsidized reductions in working hours, are very prominent in the Euro Area (Balleer et al., 2016; Giupponi and Landais, 2022). STW and the use of working time accounts encourage firms to adjust labor along the hours margin while keeping the size of the workforce stable (Burda and Hunt, 2011). In brief, labor market regulations and policies in Europe tend to discourage employment adjustment and encourage hours adjustment. It is clear, therefore, that our business cycle model needs, firstly, a frictional labor market. Secondly, it needs to have both an employment margin and an hours margin of labor adjustment.

In our baseline model, we propose adding a third labor input margin to the firm's factor mix, effort per hour, as in Bils and Cho (1994). Why is effort needed? Variable labor effort combined with labor market frictions can explain the observation that stable employment and labor productivity procyclicality go hand-in-hand, as documented in a cross-country analysis by Dossche et al. (2023). In turn, a higher procyclicality of labor productivity has the effect of dampening fluctuations in real marginal costs, and this dampens inflation fluctuations. Thus, variable labor effort might help explain the relative stability of inflation in the Euro Area documented in Table 1, in addition to producing procyclical productivity in an economy with moderate employment fluctuations. We show below that the effort margin included in our model is indeed successful in generating procyclicality of labor productivity, consistent with the data.

We do not consider an efficiency wage framework such as Akerlof (1982), where firms set wages unilaterally in order to get workers to exert effort, as appropriate for the Euro Area. As documented by Jäger et al. (2024), collective bargaining is still the dominant mode of wage setting in Europe; workers have some bargaining power.

3 Model

This section presents a labor search-and-matching model of the business cycle, which allows for labor adjustment along three margins: employment, hours and effort. Leaving out hours per worker, as in Bils et al. (2022), could bias upwards the importance of the effort margin. Moreover, changes in hours per worker account for around half of the variation in total

hours in the Euro Area, see Dossche et al. (2019). Furthermore, the model features a host of nominal and real frictions (price adjustment costs, investment adjustment costs, variable capital utilization, consumption habit formation).

Next, we outline the optimization problem of each agent in the model and derive the most important equilibrium conditions.

3.1 Households

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

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

where $\beta \in (0,1)$ is the subjective discount factor, C_t is consumption, Z_t^{ℓ} is a labor supply shock, and $g(h_{it}, e_{it})$ denotes individual labor disutility of providing hours and exerting effort at work. Labor disutility to the household is the sum of disutilities to employed members from providing hours and effort. 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, introduced in order to capture the empirical persistence in the consumption process. 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 faces a sequence of budget constraints,

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

Consumption expenditure, bond purchases B_{t+1}, investment, capital utilization costs $a(u_t^k)K_t$ and lump-sum taxes are financed through employed members' wage income, rental income on capital holdings, income on bond holdings, the leisure value b enjoyed by the unemployed members, and real profits D_t. The leisure value b may represent unemployment benefits or home production. One-period bonds pay a gross nominal return R_t, which is subject to a risk premium shock Z_t^r, and P_t is the price index.

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 variable u_t^k is the rate of utilization of the capital stock, and r_t^k represents the rental rate on capital. Capital utilization costs are $a(u_t^k) = \gamma_1(u_t^k - 1) + \frac{\gamma_2}{2}(u_t^k - 1)^2$, with

$\gamma_1, \gamma_2 > 0$.[5] In assuming a constant capital depreciation rate $\delta \in (0,1)$, combined with variable capital utilization, we follow Christiano et al. (2005). An alternative approach for modeling endogenous capital utilization would be to stipulate a capital depreciation function that depends positively on the utilization rate of the capital stock, as in Greenwood et al. (1988). The optimality conditions for bonds, investment, capital holdings and capital utilization are reported in the online appendix.

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.

3.2 Firms

Intermediate firms produce differentiated goods under monopolistic competition. Firm i produces output according to the following technology $Y_{it} = A_t(l^s_{it})^{1-\alpha}(k^s_{it})^{\alpha}$, where A_t is an exogenous technology index common to all firms, l^s_{it} are labor services, k^s_{it} are capital services, and $\alpha \in [0,1)$ 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,

$$l^s_{it} = e_{it} h_{it} n_{it}, \tag{3}$$

$$k^s_{it} = u^k_t K_{it}. \tag{4}$$

Since the capital stock 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

$$g(h_{it}, e_{it}) = \frac{h_{it}^{1+\sigma_h}}{1+\sigma_h} + h_{it}\frac{e_{it}^{1+\sigma_e}}{1+\sigma_e}, \tag{5}$$

where $\sigma_h(\sigma_e) \geq 0$ determines the degree of increasing marginal disutility of hours (effort). The first term in (5) 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 negotiate over hours and effort to minimize labor disutility (5) subject to the production technology. The optimization problem is

$$\min_{h_{it}, e_{it}} \frac{h_{it}^{1+\sigma_h}}{1+\sigma_h} + h_{it}\frac{e_{it}^{1+\sigma_e}}{1+\sigma_e} - \varphi_{yt}[Y_{it} - A_t(n_{it}h_{it}e_{it})^{1-\alpha}(k^s_{it})^{\alpha}],$$

[5] See Zubairy (2014) and Melina and Villa (2018), among others.

where φ_{yt} is the Lagrange multiplier on the production technology constraint. Combining the first order conditions for h_{it} and e_{it} yields the following optimality condition:

$$e_{it} = e_0 h_{it}^{\frac{\sigma_h}{1+\sigma_e}}, \tag{6}$$

where $e_0 = (\frac{1+\sigma_e}{\sigma_e})^{\frac{1}{1+\sigma_e}}$. Equilibrium effort is an increasing function of hours worked, and will therefore largely inherit the dynamics of hours worked.

We might compare the effort-hours-choice to the optimal choice of two goods that are substitutes in consumption. Assuming both goods are normal goods, utility is greatest if we consume some of both, rather than a lot of one good and (almost) nothing of the other good. We smooth consumption over the two varieties, just as we seek to smooth consumption over time. One can make a similar argument for effort and hours, both of which are 'bads' and lead to disutility. In such a situation, it is optimal to smooth labor input across the two bads and provide a combination of both hours and effort, rather than e.g. work long hours without raising effort at all.

Intuitively, labor disutility rises with hours worked, and it does so at an increasing rate: the longer hours you have worked already on any given day, the more unpleasant each additional hour becomes, and the more willing you are to work harder in order to finish the task at hand sooner. This willingness to exert more effort is captured by (the inverse of) σ_e. A convex labor disutility function and a finite value for σ_e are prerequisites for there to be some substitution away from hours and toward a higher effort per hour.

Another way to rationalize the effort function in (6) is to think of fixed costs of working, which relate to getting set up for a job. Fixed costs imply that labor services are (initially) convex in hours worked, which helps explain why part-time workers tend to be paid a lower wage per hour than full-time workers, see Rogerson and Wallenius (2009) and the references therein.

Returns to hours in production. Using the optimal effort choice (6), we can replace labor services in the production function,

$$Y_{it} = y_0 A_t (n_{it} h_{it}^{\phi})^{1-\alpha} (k_{it}^s)^{\alpha}, \tag{7}$$

with $y_0 = e_0^{1-\alpha}$ and

$$\phi = 1 + \frac{\sigma_h}{1+\sigma_e}. \tag{8}$$

The elasticity of output to hours worked is thus $\phi(1-\alpha)$. The production function displays short-run increasing returns to hours if $\phi(1-\alpha) > 1$, which we show below is true in our estimation. 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.[6]

It is worth emphasizing that these are short-run increasing returns to *measured* (rather than *effective*) hours worked. The observation of short-run increasing returns to labor (SRIRL) stems from our inability to observe effort, i.e. from mismeasurement. The production function is still Cobb-Douglas in labor and capital services, and thus exhibits constant returns to scale. Burnside et al. (1995) measure capital utilization using energy use. They conclude that SRIRL is an artifact of the failure to accurately measure capital utilization rates and find no evidence against the hypothesis of constant returns to scale.

Firm value, capital services and price setting. The value of firm i in period t is

$$V_{it}^f = \frac{P_{it}}{P_t} Y_{it}^d - w_{it} h_{it} n_{it} - r_t^k k_{it}^s - c v_{it} + n_{it}\Phi - \Psi_{it}^w - \Psi_{it}^p + E_t\{\beta_{t,t+1} V_{it+1}^f\}, \tag{9}$$

where Y_{it}^d is demand, $w_{it} \equiv W_{it}/P_t$ 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 ith firm, $\beta_{t-1,t} \equiv \beta \frac{U'(C_t)}{U'(C_{t-1})}$ is the stochastic discount factor or the growth of the marginal utility of consumption between $t-1$ and t, and Φ denotes a per-period employment subsidy independent of the number of hours per worker.[7] As originally proposed by Rotemberg (1982) and applied to wages by 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

$$\Psi_{it}^w = \frac{\kappa_w}{2}(\Omega_{it}^w - 1)^2 n_{it}, \tag{10}$$

$$\Psi_{it}^p = \frac{\kappa_p}{2}(\Omega_{it}^p - 1)^2 Y_{it}, \tag{11}$$

where $\Omega_{it}^w \equiv \frac{w_{it}}{w_{it-1}} \frac{\Pi_t}{\Pi} (\frac{\Pi_{t-1}}{\Pi})^{-\lambda_w}$, $\Omega_{it}^p \equiv \frac{\Pi_{it}}{\Pi} (\frac{\Pi_{t-1}}{\Pi})^{-\lambda_p}$, $\Pi_t \equiv P_t/P_{t-1}$ is the gross inflation rate between $t-1$ and t, and $\Pi_{it} \equiv P_{it}/P_{it-1}$ is firm-level 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,

$$n_{it+1} = (1-\lambda) n_{it} + q_t v_{it}, \tag{12}$$

$$(P_{it}/P_t)^{-\varepsilon_t} Y_t = y_0 A_t (n_{it} h_{it}^{\phi})^{1-\alpha} (k_{it}^s)^{\alpha}, \tag{13}$$

where q_t is the probability of filling vacancy and a fraction $\lambda \in (0,1)$ of job matches are destroyed each period. Denoting by s_{it} the Lagrange multiplier on (13), the demand for

[6] It should be noted that Krause and Lubik (2010) show the indeterminacy dynamics of the standard search-and-matching model and that, in general, a model with increasing returns may feature equilibrium indeterminacy. However, Hertweck et al. (2021) find that indeterminacy arises in the canonical labor search model only under a large deviation from the Hosios condition (Hosios, 1990).

[7] The employment subsidy Φ facilitates the calibration of the model. Christoffel et al. (2009) assume overhead costs in production, which serves the same purpose.

capital services satisfies $r_t^k = s_{it}\alpha\frac{Y_{it}}{k_{it}^s}$, such that rental rate of capital equals the real marginal cost s_{it} multiplied by the marginal product of capital services. In a symmetric equilibrium, the optimal pricing decision leads to the New Keynesian Phillips Curve,

$$\kappa_p\Omega_t^p(\Omega_t^p - 1) = \varepsilon_t s_t - (\varepsilon_t - 1) + \kappa_p E_t\{\beta_{t,t+1}\Omega_{t+1}^p(\Omega_{t+1}^p - 1)Y_{t+1}/Y_t\}, \tag{14}$$

where $\Omega_t^p \equiv \frac{\Pi_t}{\Pi}(\frac{\Pi_{t-1}}{\Pi})^{-\lambda_p}$ and ε_t is the elasticity of substitution between the individual varieties, which varies exogenously over time. We now turn to the modeling of the labor market.

3.3 Labor market search and matching

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 $v_t = \int_0^1 v_{it}di$, $M_t = M_0 u_t^{\xi} v_t^{1-\xi}$, where $\xi \in (0, 1)$ 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, $q_t = M_t/v_t = M_0\theta_t^{-\xi}$, 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 workers, $p_t = M_t/u_t = q_t\theta_t$. An alternative expression for the job finding rate is the probability of filling a vacancy multiplied by the degree of labor market tightness.

Defining aggregate employment as $n_t = \int_0^1 n_{it}di$, we can write the law of motion for employment as $n_{t+1} = (1 - \lambda)n_t + q_t v_t$. The job destruction rate $\lambda \in (0, 1)$ is constant in our model, as is the depreciation rate of capital. By treating capital and labor depreciation symmetrically, we aim at giving both the capital and labor utilization margins the same ex ante chances in the 'horse race' below.

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

$$S_{it}^f = s_{it}mpn_{it} - w_{it}h_{it} + \Phi - \Psi_{it}^w/n_{it} + (1 - \lambda)E_t\{\beta_{t,t+1}S_{it+1}^f\}, \tag{15}$$

where $mpn_{it} = \partial Y_{it}/\partial n_{it}$ is the marginal product of employment. 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

$$V_{it}^v = -c + E_t\{\beta_{t,t+1}[q_t S_{it+1}^f + (1 - q_t)V_{it+1}^v]\}. \tag{16}$$

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 the firm's match surplus (15),

$$c/q_t = E_t\{\beta_{t,t+1}[s_{it+1} mpn_{it+1} - w_{it+1} h_{it+1} + \Phi - \Psi_{it+1}^w / n_{it+1} + (1-\lambda) c/q_{t+1}]\}. \tag{17}$$

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, which is 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 at the ith 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 $g(h_{it})$, which is given by (5) with equilibrium effort substituted out. In the next period, she is either still employed at 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

$$\mathcal{W}_{it} = w_{it} h_{it} - mrs_{it} + E_t\{\beta_{t,t+1}[(1-\lambda)\mathcal{W}_{it+1} + \lambda \mathcal{U}_{t+1}]\}, \tag{18}$$

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

$$\mathcal{U}_t = b + E_t\left\{\beta_{t,t+1}\left[\int_0^1 \frac{v_{jt}}{u_t} q_t (w_{jt+1} h_{jt+1} - mrs_{jt}) dj + (1-p_t)\mathcal{U}_{t+1}\right]\right\}. \tag{19}$$

An unemployed worker receives b units of market consumption goods in period t. In the next period, she 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 $S_{it}^w \equiv \mathcal{W}_{it} - \mathcal{U}_t$, we can write

$$S_{it}^w = w_{it} h_{it} - mrs_{it} - b + E_t\left\{\beta_{t,t+1}\left[(1-\lambda) S_{it+1}^w - p_t \int_0^1 \frac{v_{jt}}{v_t} S_{jt+1}^w dj\right]\right\}. \tag{20}$$

Hours worked. Following Trigari (2006), Thomas (2008) and Cantore et al. (2014) among others, hours are determined jointly by the firm and the worker to maximize the sum of the firm's and worker's surpluses,

$$\max_{h_{it}} \ \frac{W_{it}}{P_t} h_{it} - Z_t^\ell \frac{g(h_{it})}{\Lambda_t} - b + E_t\left\{\beta_{t,t+1}\left[(1-\lambda) S_{it+1}^w - \int_0^1 \frac{v_{jt}}{v_t} p_t S_{jt+1}^w dj\right]\right\}$$
$$+ s_{it} mpn_{it} - \frac{W_{it}}{P_t} h_{it} + \Phi - \frac{\Psi_{it}^w}{n_{it}} + (1-\lambda) E_t\{\beta_{t,t+1} S_{it+1}^f\}.$$

The first order condition for hours worked is

$$s_{it}\frac{\partial mpn_{it}}{\partial h_{it}} = Z_t^{\ell}\frac{g'(h_{it})}{\Lambda_t}.$$

Substituting the term $\frac{\partial mpn_{it}}{\partial h_{it}}$, using $\frac{\partial mpn_{it}}{\partial Y_{it}} = \frac{1-\alpha}{n_{it}}$ and $\frac{\partial Y_{it}}{\partial h_{it}} = \phi(1-\alpha)\frac{Y_{it}}{h_{it}}$, and rearranging, we find that the firm's real marginal cost is

$$s_{it} = \frac{1}{\phi(1-\alpha)^2}\frac{mrs_{it}}{\mathcal{P}_{it}}, \tag{21}$$

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 (21) 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.

Monopolistic competition in product markets and sticky prices imply that output is demand-determined in the short run. Given that the stocks of capital and employment are predetermined on impact, the initial burden of adjustment falls entirely on the intensive labor margin, i.e. hours per worker and effort per hour. With effort per hour determined by (6) and with workers and firms continuously renegotiating over hours to maximize joint surplus, the equilibrium studied here is isomorphic – in terms of allocation and surplus – to one where the worker offers a bundle of labor of services, $l_{it} = e_{it}h_{it}$, and the worker and the firm contract on that.

Wage bargaining. Workers and firms bargain bilaterally over the nominal wage W_{it} and split the surplus according to their respective bargaining weights given by $\eta_t \in (0,1)$ and $(1-\eta_t)$. Similarly to Gertler et al. (2008), the workers' bargaining power is time-varying. It is specified as $\eta_t = \eta Z_t^B$, where the exogenous shock Z_t^B follows an AR(1) process (in logs). Under Nash bargaining, the wage is chosen to maximize the joint match surplus, $(S_{it}^w)^{\eta_t}(S_{it}^f)^{1-\eta_t}$. The first order condition implies the following sharing rule that determines the real wage,

$$\Upsilon_{it}\left[s_{it}mpn_{it} + \Phi - w_{it}h_{it} - \frac{\Psi_{it}^w}{n_{it}} + (1-\lambda)\frac{c}{q_t}\right] = w_{it}h_{it} - mrs_{it} - b + E_t\left\{\Upsilon_{it+1}(1-\lambda-p_t)\frac{c}{q_t}\right\}, \tag{22}$$

with Υ_{it} capturing the worker's effective bargaining power. The term in square brackets reflects the firm's return to reaching an agreement, which is the value that the new worker brings to the firm (marginal product and hiring subsidy), less the cost (wage payments and wage adjustment costs), plus the firm's continuation value of the match. The term on the right hand side of (22) reflects the worker's return to reaching an agreement: wage income adjusted for labor disutility, less the leisure value, plus the worker's continuation value of the match.

3.4 Closing the model

The government budget constraint equates current income (bond issues and tax revenue) with current expenditure (government spending, unemployment benefits, employment subsidies, and maturing government bonds),

$$\frac{B_{t+1}}{Z_t^r R_t P_t} + T_t = G_t + (1 - n_t)b + n_t\Phi + \frac{B_t}{P_t}. \tag{23}$$

Combining the household budget constraint (2), summed over households, with the government budget constraint (23), we obtain the aggregate accounting identity,

$$Y_t = C_t + G_t + I_t + a(u_t^k)K_t + cv_t + \Psi_t^w + \Psi_t^p. \tag{24}$$

The central bank follows an interest rate rule given by

$$\ln(R_t/R) = \tau_R \ln(R_{t-1}/R) + (1 - \tau_R)[\tau_\Pi \ln(\Pi_t/\Pi) + \tau_y \ln(Y_t/Y_t^n)] + \ln Z_t^R, \tag{25}$$

where $\tau_\Pi > 0$ and $\tau_y > 0$ capture the responsiveness of the policy rate to inflation deviations and to the output gap, respectively, and $\tau_R \in (0, 1)$ measures interest rate smoothing. The term 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 first order autoregressive shock processes (in logs) for the eight shocks A_t, G_t, ε_t, Z_t^ℓ, Z_t^r, Z_t^I, Z_t^B and Z_t^R, that have innovations $\epsilon_t^x \sim N(0, \sigma_x)$ with $x = \{A, G, \varepsilon, \ell, r, I, B, R\}$. The parameters ρ_x and σ_x denote the persistence and standard deviation of innovation ϵ_t^x, respectively.

4 Bayesian estimation

The model is estimated on quarterly Euro Area data for the period 1999Q1-2019Q4. The eight observable variables are (log) real GDP, real investment, real private consumption, real wage per person, total hours worked, the unemployment rate, inflation and the nominal interest rate.[8] The online appendix reports data sources and definitions as well as robustness exercises. The inflation rate is measured as the first difference of the log GDP deflator; the nominal interest rate is in percentage points. All other variables are expressed in growth rates following Smets and Wouters (2007).[9]

[8] Data are taken from the Area Wide Model database (see Fagan et al., 2005, for details). Real data are computed aggregating Euro Area countries but Ireland, whose series are extremely volatile. Data on total hours come from Ohanian and Raffo (2012) and are a weighted average of the following available Euro Area countries: Austria, Finland, France, Germany, Ireland, Italy, and Spain.

[9] In the online appendix, we show that estimation results are similar under alternative filtering techniques, more specifically HP-filtering (Hodrick and Prescott, 1997) and the method proposed by Hamilton (2018), Tables C.6 and C.7, respectively.

4.1 Calibration and prior distributions

Table 2 reports the calibration of the parameters that are related to great ratios or long-run averages, and which cannot be identified given the data set. The time period in the model corresponds to one quarter.

Table 2: Calibrated parameters

Parameter	Value	Target / Reference
Discount factor	$\beta = 0.99$	4% risk-free rate p.a.
Capital depreciation rate	$\delta = 0.025$	10% depreciation rate p.a.
Production function parameter	$\alpha = 0.3$	Smets and Wouters (2003)
Elasticity of substitution in goods	$\varepsilon = 11$	10% price markup
Returns to hours in labor disutility	$\sigma_h = 1$	Keane and Rogerson (2012)
Workers' bargaining weight	$\eta = 0.5$	Cahuc and Le Barbanchon (2010), Mengano (2023)
Match elasticity	$\xi = 0.65$	Various studies (see main text)
Cost of posting a vacancy	$\frac{cv}{Y} = 1\%$	Gertler and Trigari (2009), Blanchard and Galí (2010)
Steady state unemployment rate	$u = 9.6\%$	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	$\frac{G}{Y} = 0.20$	Data

The discount factor, β, is set equal to the standard value of 0.99. The depreciation rate of capital, δ, 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, $\varepsilon > 1$, to 11 in order to target a steady-state gross price mark-up equal to 1.10.

The parameter that is key to our mechanism linking variable labor utilization and productivity is the degree of short-run returns to hours, ϕ. It is a function of the curvatures of labor disutility with respect to hours worked, σ_h, and with respect to effort, σ_e, as is clear from equation (8). The two parameters σ_h and σ_e are only jointly identified. Moreover, the value of the elasticity of labor supply, $1/\sigma_h$, is a source of controversy in the literature. 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 (e.g. Chetty et al., 2011; Di Pace and Villa, 2016), and microeconometric estimates, 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 of σ_e consistent with this calibration choice. Section 4.3 reports robustness exercises for the calibration of σ_h.

The workers' bargaining weight is calibrated at 0.5 as in Cahuc and Le Barbanchon (2010), which is at the high end of the range of estimates reported in Mengano (2023) for France. The elasticity of matches to the unemployment rate, ξ, 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 (Burda

and Wyplosz, 1994; Christoffel et al., 2009; Lubik, 2009; Justiniano and Michelacci, 2012; Barnichon and Figura, 2015), similarly to the calibration strategy adopted by Furlanetto and Groshenny (2016). The cost of posting a vacancy, c, is set to target total hiring costs equal to 1% of output, a value that is consistent with Gertler and Trigari (2009), Blanchard and Galí (2010) and Nucci and Riggi (2018). Steady state output is normalized to unity. 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 value in the dataset, 9.6%. The implied separation rate is 3% in the Euro Area, in line with the data (Christoffel et al., 2009). 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, G/Y, is equal to 20%.

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 price adjustment cost parameter corresponds to a Calvo (1983) contract average duration of around three 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, 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. We choose a loose prior for the replacement rate, $b/(wh)$, with a prior mean of 0.50 and a prior standard deviation of 0.20 to account for the range of values observed in the data (Shimer, 2005; Christoffel et al., 2009). In setting the prior mean for the wage adjustment cost parameter, κ_w, we choose the value 20 close to that proposed by Arseneau and Chugh (2008). The prior mean of the constant in the measurement equations, $\bar{\gamma}$, is equal to the corresponding average value in the data set.

4.2 Estimation results

In the following, we discuss the parameter estimates that are the most relevant for our research question. We then examine the relative importance of different shocks in driving business cycle fluctuations, and we compare the model-implied utilization series with suitable proxies.

Parameter estimates: labor and capital utilization. Recall that the effort elasticity is backed out as $\sigma_e = \sigma_h/(\phi - 1) - 1$. In the standard model, varying effort is extremely costly, $\sigma_e \to \infty$, and hence effort is constant. A lower σ_e implies a greater use of the effort margin. The estimation results in Table 3 show that effort plays an important role in the Euro Area business cycle; the median estimate of the returns to hours ϕ is equal to 1.80. Given this estimate and the calibrated value of σ_h, the curvature of the effort disutility function, σ_e, is equal to 0.25.

Table 3: Parameter estimates: baseline model

Parameter		Prior			Posterior
		Distrib.	Mean	Std/df	Mean
Structural					
Returns to hours	ϕ	Normal	1.00	0.15	1.80 [1.68;1.95]
Income replacement ratio	b/wh	Beta	0.50	0.20	0.49 [0.42;0.57]
Habits in consumption	λ_c	Beta	0.50	0.15	0.34 [0.24;0.43]
Capital utilization elasticity	σ_u	Gamma	2.50	1.50	0.20 [0.03;0.35]
Investment adjust. costs	κ_I	Gamma	4.00	1.50	5.70 [3.40;7.91]
Price stickiness	κ_p	Gamma	60.0	20.0	66.40 [40.40;91.40]
Price indexation	λ_p	Beta	0.50	0.15	0.43 [0.23;0.64]
Wage stickiness	κ_w	Gamma	20.0	10.0	15.17 [8.82;21.26]
Wage indexation	λ_w	Beta	0.50	0.15	0.60 [0.40;0.79]
Inflation -Taylor rule	τ_Π	Normal	1.70	0.20	2.35 [2.07;2.62]
Output gap -Taylor rule	τ_y	Normal	0.12	0.05	0.12 [0.04;0.21]
Interest rate smoothing	τ_R	Beta	0.75	0.10	0.61 [0.49;0.73]
Average					
Trend growth rate	$\bar{\gamma}$	Normal	0.35	0.1	0.15 [0.13;0.16]
Exogenous processes					
Technology	ρ_A	Beta	0.50	0.15	0.94 [0.92;0.97]
	σ_A	IG	0.10	2.00	0.73 [0.63;0.82]
Price mark-up	ρ_P	Beta	0.50	0.15	0.91 [0.88;0.95]
	σ_P	IG	0.10	2.00	10.31 [8.10;12.36]
Bargaining power	ρ_B	Beta	0.50	0.15	0.57 [0.43;0.71]
	σ_B	IG	0.10	2.00	2.05 [1.48;2.61]
Labor supply	ρ_ℓ	Beta	0.50	0.15	0.93 [0.90;0.97]
	σ_ℓ	IG	0.10	2.00	0.98 [0.81;1.14]
Government spending	ρ_G	Beta	0.50	0.15	0.80 [0.73;0.87]
	σ_G	IG	0.10	2.00	1.97 [1.70;2.22]
Interest rate	ρ_R	Beta	0.50	0.15	0.70 [0.60;0.79]
	σ_R	IG	0.10	2.00	0.35 [0.26;0.43]
Investment-specific	ρ_I	Beta	0.50	0.15	0.31 [0.17;0.44]
	σ_I	IG	0.10	2.00	5.78 [3.18;8.29]
Risk premium	ρ_r	Beta	0.50	0.15	0.97 [0.95;0.99]
	σ_r	IG	0.10	2.00	0.13 [0.10;0.16]
Marginal log likelihood					–444.032

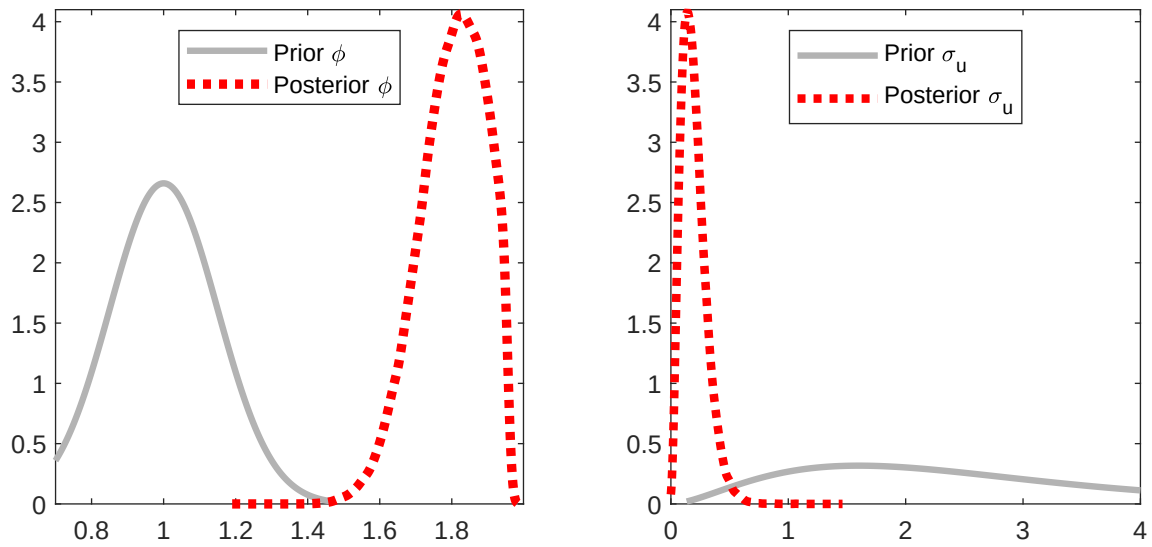
Notes: Table shows prior and posterior distributions of estimated parameters; 90% HPD intervals in square brackets. Posterior mean computed with two chains of the Metropolis-Hastings algorithm on sample of 400,000 draws.

The household's linearized optimality condition with respect to capital utilization is given by $\hat{u}_t^k = \sigma_u \hat{r}_t^k$, where a hat indicates the log-deviation of a variable from its steady-state value. If $\sigma_u = 0$, utilization is inelastic, i.e. it is extremely costly to change the utilization of capital, and thus u_t^k remains constant. Instead, if $\sigma_u \to \infty$, the capital utilization rate

is very responsive to the rental rate and the utilization margin becomes relevant for the dynamics of the model. Our posterior mean estimate for the capital utilization elasticity is low at $\sigma_u = 0.20$, see Table 3.

Figure 1 shows the prior and posterior densities of the two parameters measuring the degree of factor utilization: short-run returns to hours in production, ϕ, and the elasticity of the capital utilization adjustment cost function, σ_u.

Figure 1: Prior and posterior densities of returns to hours ϕ and capital utilization σ_u



Both parameters, ϕ and σ_u, are well identified by the data, exhibiting a probability density tightly gathered around the posterior mean, despite the loose prior. The posterior distribution of ϕ is located to the right of the prior, which is symmetric around 1. Thus the data are highly informative, providing evidence for increasing returns to hours. The posterior distribution of σ_u is located to the left of the prior parameter range, revealing high capital utilization costs and, hence, confirming the limited role for this margin of input adjustment.

The posterior distributions of the remaining parameters are in line with the literature.

Variance decomposition. Table 4 shows the unconditional (long-run) variance decomposition in the baseline model.

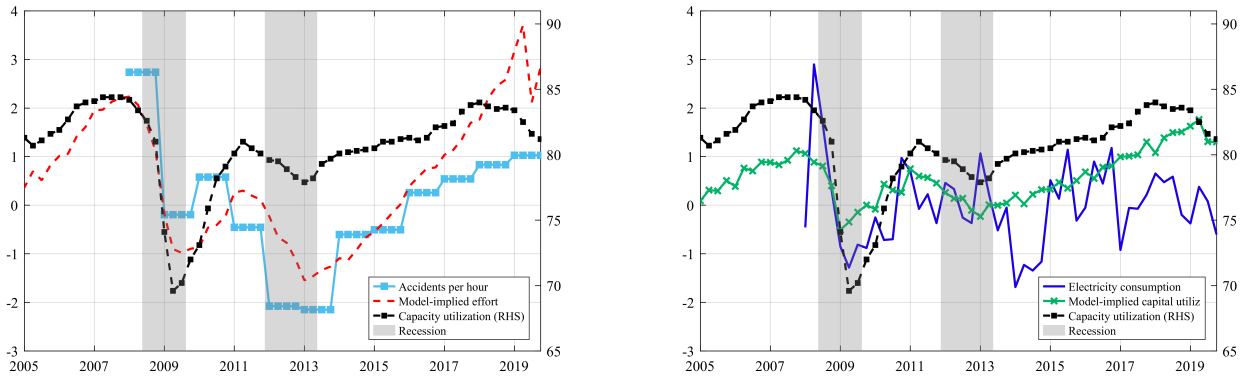
In the baseline model, supply shocks – technology and price mark-up – are the most important innovations explaining fluctuations in output. Inflation is mainly driven by demand shocks, contrary to labor productivity and wages. In particular, technology shocks are the main driver of productivity, while wages are explained by technology and price mark-up shocks. The role of bargaining power shocks is limited, in line with the results by Furlanetto and Robstad (2019) for the Norwegian economy. In contrast, Foroni et al. (2018) report that bargaining power shocks matter for output and unemployment fluctuations in the US. Labor market variables, employment and hours, are mainly explained by supply shocks.

Table 4: Variance decomposition of the baseline model

	Structural shock							
Variable	Techno-logy	Price mark-up	Bargaining power	Labor supply	Risk premium	Investment specific	Monetary policy	Fiscal policy
Output growth	20.6	23.7	0.0	14.0	1.8	5.6	19.4	15.0
Inflation	1.6	1.8	0.0	1.3	32.8	0.3	62.1	0.1
Wage	56.0	38.5	0.9	2.6	0.0	1.3	0.5	0.1
Productivity	80.1	10.2	0.0	7.5	0.0	1.6	0.4	0.2
Employment	25.3	54.3	2.4	13.6	0.3	0.3	3.8	0.1
Hours	5.2	43.3	0.0	40.9	0.3	2.8	3.9	3.7

Model-implied labor effort. In Figure 2, the plot on the left shows effort together with capacity utilization and workplace accidents (per hour). The plot on the right shows model-implied capital utilization together with capacity utilization and electricity consumption. The figure allows us to compare our effort measure with other utilization proxies that have been put forward in the literature.

Figure 2: Model-implied utilization measures and empirical utilization proxies (Euro Area)



Notes: Shaded areas show recessions as identified by the Centre for Economic Policy Research (CEPR). Accidents and electricity consumption have been linearly detrended. Data sources: workplace accidents: Eurostat, `https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Accidents_at_work_statistics`, capacity utilization: OECD series BSCURT02EZQ160S, retrieved from `https://fred.stlouisfed.org/series/BSCURT02EZQ160S`, electricity: Eurostat, series nrg_cb_em__custom_12803655.

First, accidents per hour worked can be regarded as a proxy for labor effort (Fairris, 1998; Boone and van Ours, 2006; Galí and van Rens, 2020). Figure 2 shows that model-implied effort lines up reasonably well with accidents, both series are procyclical and their correlation is 0.74.

Second, the figure displays a survey-based measure of capacity utilization, i.e. the ratio of actual to full-capacity output. Comin et al. (2025) suggest that this measure provides a good proxy for unobserved changes in worker effort. We would argue that capacity utilization

captures elements of both capital and labor utilization. Figure 2 shows that effort fell more steeply than capacity utilization during the sovereign debt crisis of 2011-2012, and rose more steeply in the expansion that followed. Indeed, during that period capacity utilization moved very much in parallel with our measure of capital utilization, see the right hand side of Figure 2. During the financial crisis and the Great Recession of 2007-2008, however, capital utilization fell by less, and rose by less afterward, than did capacity utilization. Over the whole sample, capacity utilization is as highly correlated with capital utilization as it is with effort; the correlation coefficients are 0.71 and 0.70, respectively.

Third, we consider electricity consumption as a proxy for capital utilization, following Burnside et al. (1995). The cyclical pattern of electricity consumption resembles the one of capacity utilization during and just after the Great Recession. However, after 2011 electricity consumption is rather volatile and not highly correlated with either capital or capacity utilization. Within our sample, the correlation coefficients are 0.29 and 0.41, respectively.

Finally, two observations from Figure 2 are worth noting. First, comparing our model-based utilization measures, we see that effort is more volatile and exhibits larger swings than capital utilization. Second, the pronounced drop of capacity utilization and electricity consumption in 2008 aligns well with the narrative that the collapse in investment spending and capital usage during the Great Recession was to some extent a correction of an unsustainable construction boom, see Rognlie et al. (2018).

4.3 Robustness

We now show that our main result, the importance of the effort margin in Euro Area business cycle fluctuations, stands up to a number of robustness exercises. Changing the sample of euro countries and using alternative filtering techniques do not change our main results, as reported in the online appendix, Sections C.4 and C.5.

Instantaneous hiring. Given the comparatively stringent employment protection legislation and the low volatility of employment in many Euro Area countries (as documented in Dossche et al., 2019), we regard a model with predetermined employment as appropriate for the Euro Area. Moreover, Dossche et al. (2023) show that countries with more stable employment tend to have more procyclical labor productivity. Notwithstanding this, we investigate whether the importance of the effort margin is robust to the timing of employment. More specifically, we estimate a model where employment is allowed to adjust contemporaneously, $n_t = (1-\lambda)n_{t-1} + q_t v_t$.[10] The idea behind this exercise is that the effort margin likely compensates for the lack of flexibility in employment as a way of adjusting labor input.

Parameter estimates for this alternative model, reported in the online appendix Table

[10] Several other model equations are affected by this change in timing. See the online appendix for details.

C.1, are remarkably similar to the baseline model. The median estimate of the returns to hours, ϕ, is equal to 1.70. It is lower than the baseline value of 1.80, but within its credible interval. Therefore, this exercise shows that labor effort is an important labor adjustment margin even in the presence of instantaneous hiring.

Labor income taxes. In the baseline model, government spending is financed with lump-sum taxes. Using instead distortionary labor income taxes makes working less attractive, prompting individuals to allocate their time away from labor (e.g. Shi and Wen, 1999). This shift increases the reservation wage. Consequently, the higher equilibrium wage diminishes firms' profitability, reducing their incentive to hire and ultimately leading to a decline in equilibrium employment. In a robustness exercise with a model featuring labor income taxes, our main results are confirmed.[11] In particular, the estimates of ϕ and σ_u in the modified model fall in the credible interval of the baseline estimates. At the steady state, hours fall relative to the baseline model, in line with the results in Fang and Rogerson (2009).

The role of the hours elasticity. The value of the Frisch elasticity of labor supply is much debated. Microeconomic estimates point to values in the interval $[0, 1]$, see Keane and Rogerson (2012), while macroeconomists generally work with higher values. In our model, the elasticity $1/\sigma_h$ refers specifically to the intensive labor margin (hours worked). We set this elasticity equal to 1 in our baseline calibration. Here, we provide two robustness exercises. First, we calibrate this elasticity to 0.5, in line with Christoffel et al. (2009), assuming that hours are rather inelastic. Second, we estimate the parameter σ_h in the model with constant effort. We do this because imposing that the effort margin is not used might affect the estimated responsiveness of the intensive labor margin. Estimation tables are provided in the online appendix, Tables C.3 and C.4.

First, when σ_h is set equal to 2, we still find evidence for the use of the labor effort margin. The comparison of the marginal log-likelihood reveals that the model with $\sigma_h = 1$ is strongly preferred by the data compared to the model with $\sigma_h = 2$.

Second, in the constant-effort model in which the parameter σ_h is estimated, we find a posterior mean of 0.22. This points to a high responsiveness of hours worked once the effort margin is shut off. The marginal log-likelihood is lower than that in the baseline model. Therefore, we conclude that a model with variable effort is strongly preferred by the data compared to a model with constant effort, even in the case in which hours are more responsive to business cycle fluctuations.

[11] Table C.2 in the online appendix reports parameter estimates of this alternative specification.

5 Alternative explanations for procyclical labor productivity

What is the importance of effort relative to other competing mechanisms in accounting for the observed procyclicality of labor productivity? We consider two prominent candidate explanations: variable capital utilization and dominant technology shocks.

First, Christiano et al. (2005) point to wage staggering and variable capital utilization as key features that can account for the observed macroeconomic inertia. Their proposed model indeed matches very well the response of output and inflation to a monetary policy shock. However, the response of productivity is more procyclical in the data than it is in their model. If the model is missing important features that would capture better the observed productivity response, these features will likely also influence the implied output and inflation dynamics, and hence might affect any inference one draws regarding the relative importance of various real rigidities in generating realistic impulse response functions. 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.

Second, procyclical productivity could simply be explained by technology shocks being the dominant source of Euro Area business cycle fluctuations. In that case, the introduction of variable labor effort would be an unnecessary complication of the model.

Inspecting the mechanism. To build intuition, we first focus on the relevant linearized equilibrium conditions of the model to illustrate the alternative sources of labor productivity procyclicality. Replacing the labor and capital services in the production function yields

$$\hat{Y}_t = \hat{A}_t + (1-\alpha)(\hat{n}_{t-1} + \phi\hat{h}_t) + \alpha(\hat{u}_t^k + \hat{K}_{t-1}). \tag{26}$$

Replacing output in the definition of labor productivity, $\hat{\mathcal{P}}_t \equiv \hat{Y}_t - (\hat{n}_{t-1} + \hat{h}_t)$, using (26) yields

$$\hat{\mathcal{P}}_t = \hat{A}_t + \alpha\hat{u}_t^k + [\phi(1-\alpha) - 1]\,\hat{h}_t. \tag{27}$$

Equation (27) shows that three variables affect labor productivity in the short-run when employment and the capital stock are fixed: (i) technology shocks; (ii) capital utilization; and (iii) hours worked. Technology shocks affect productivity one-for-one, while the effect of capital utilization is scaled by the capital share α. The effect of hours on labor productivity depends on the size of the effort margin. Under constant effort ($\phi = 1$), hours affect productivity negatively with a coefficient equal to $-\alpha$. Under increasing returns to hours and with $\phi > 1/(1-\alpha)$, productivity instead depends positively on hours. According to our estimates, $\phi - 1/(1-\alpha) = 0.25$. The presence of variable labor effort thus inverts the usual link between hours and labor productivity.

Which utilization margin is more effective at generating procyclical labor productivity?

To answer this question, we need to understand how variable capital utilization (VCU) and variable labor effort alter the short-run response of output (the numerator of labor productivity) and total hours (the denominator of labor productivity) to various shocks. And since employment is predetermined, the short-run response of total hours is given by the response of hours per worker.

Variable capital utilization boosts the responsiveness of output to shocks. Utilization increases output by the factor $\alpha \in (0, 1)$, see (26). At the same time, we can show that VCU has little effect on the short-run hours response.[12] Through short-run increasing returns to hours in the presence of variable labor effort, an increase in hours gives rise to a disproportionate expansion in output. This expansionary output effect coming from labor effort is greater than the same effect coming from capital utilization: in (26), $\hat{h}_t$ is multiplied by $(1 - \alpha)\phi$ with $\phi > 1$, while $\hat{u}_t^k$ is multiplied only by $\alpha < 0.5$. In addition, the short-run hours response is dampened when effort is allowed to adjust, as the intensive labor margin adjusts more through effort per hour and less through hours per worker.[13] In sum, it is the combination of a stronger expansion of output and a stronger dampening of hours per worker that allows the effort margin to generate more procyclical labor productivity compared to the capital utilization margin.

Note that the effect of labor effort on generating procyclical labor productivity does not hinge on the search-and-matching framework. It is preserved in a simple real business cycle model with employment adjustment costs instead of labor search, see Dossche et al. (2023).

5.1 Estimating restricted versions of the model

In the following, we re-estimate the model, imposing either constant capital utilization or constant labor effort. Then in the next subsection, we carry out various counterfactual exercises, keeping the model parameters fixed at their baseline values, and compute the implied second moments of selected variables.

Labor or capital utilization? A comparison of model fit. We first analyse to what extent the goodness of fit can be attributed to either labor or capital utilization. To this end, we estimate two alternative model specifications: (1) a 'standard' model with constant labor effort; and (2) a model with constant capital utilization. In the first model, we set ϕ close to 1, thus we let $\sigma_e \to \infty$.[14] In other words, we impose that increasing effort leads to a prohibitively large rise in disutility, hence effort does not vary in equilibrium. In the second model, we impose that σ_u is close to 0, such that variation in capital utilization is

[12] The impulse responses of hours in the baseline model and in a counterfactual model with constant capital utilization virtually coincide, see Figures D.1 to D.3 in the online appendix.

[13] Figures 3 to 5 below illustrate how the effort margin dampens the short-run response of hours to monetary policy shocks, labor supply shocks and technology shocks.

[14] Notice that σ_e is not defined for $\phi = 1$, given the definition $\sigma_e = \sigma_h/(\phi - 1) - 1$.

costly and, thus, capital utilization is virtually constant.[15]

In this exercise, the marginal log-likelihood is computed as in Geweke (1999). Let m_i be a given model within a set of model $\mathcal{M}$, with $m_i \in \mathcal{M}$, and $L(Y|m_i)$ be the marginal data density of model i for the common data set Y, then the Bayes factor (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 to 10 provides 'slight' evidence in favor of model i relative to model j; a BF in the range 10 to 100 provides 'strong to very strong' evidence; and a BF greater than 100 provides 'decisive evidence'. The statistic proposed by Kass and Raftery (1995) (KR) is computed as twice the log of the BF. 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 5: Marginal log-likelihood comparison baseline vs. alternative models

	Baseline model		Constant labor effort
Marginal log-likelihood	−444.032		−470.806
Bayes factor		4.24×10^{11}	
Kass-Raftery statistic		53.55	
	Constant capital utilization		Baseline model
Marginal log-likelihood	−437.369		−444.032
Bayes factor		7.83×10^{2}	
Kass-Raftery statistic		13.33	
	Constant capital utilization		Constant labor effort
Marginal log-likelihood	−437.369		−470.806
Bayes factor		3.32×10^{14}	
Kass-Raftery statistic		66.87	

Table 5 reports the Bayes factor and the Kass-Raftery statistic between the baseline model and the alternative models (constant effort and constant capital utilization). Three main results emerge. First, with a BF well above 100, we find 'decisive evidence' in favor of our baseline model featuring effort. The KR statistic supports this finding, pointing to a 'very strong' evidence in favor of the unconstrained baseline model versus the restricted model with constant effort. Second, variable capital utilization is not a modelling feature that is favored by the data. Our likelihood comparison indicates that the restricted model with constant capital utilization has a better fit than the baseline model. Third, what is

[15] In contrast, if the elasticity σ_u is large, variable capital utilization is a very important margin for amplifying business cycle fluctuations as shown in a calibrated model by Villa (2012).

most interesting for our research question is the comparison between the constant-effort versus the constant-capital-utilization model. Table 5 reveals that the latter is strongly preferred by the data. Therefore, the constant-effort model comes out last in our likelihood race, underscoring the empirical relevance of the effort margin of labor adjustment.

Tables D.1 and D.2 in the online appendix report the estimated parameters of the two restricted models. In the constant-effort model, σ_u is estimated to be higher than in the baseline model, revealing a greater role for capital utilization. However, the difference is not statistically significant.[16] Indeed, parameter estimates are similar under the two model specifications, baseline and constant capital utilization.

Given the similarity of the parameter estimates, it is not surprising that the variance decomposition of the constant capital utilization model is not noticeably different from that of the baseline model, see Table 6. In particular, the contributions of the various shocks to output and productivity fluctuations are of a comparable order of magnitude. This suggests that the drivers of business cycle fluctuations, as inferred from our estimation exercise, are not altered by the inclusion of variable capital utilization once we account for variable labor effort.

Table 6: Variance decomposition of the restricted models

	Structural shock							
	Techno-logy	Price mark-up	Bargaining power	Labor supply	Risk premium	Investment specific	Monetary policy	Fiscal policy
Variable				*Constant labor effort*				
Output growth	28.3	13.8	2.1	4.9	25.6	16.5	0.1	8.7
Inflation	2.0	0.4	30.5	0.7	64.9	0.8	0.0	0.7
Wage	58.0	31.7	0.0	2.1	0.0	0.5	1.7	5.9
Productivity	92.2	2.9	0.0	2.3	0.0	0.2	0.0	2.4
Employment	31.1	54.9	0.1	0.3	2.4	0.0	2.4	8.7
Hours	4.7	33.3	0.4	3.3	5.9	5.3	0.1	47.0
Variable				*Constant capital utilization*				
Output growth	21.9	21.2	0.0	15.6	1.5	6.0	16.4	17.4
Inflation	1.4	1.8	0.0	1.3	32.7	0.3	62.5	0.2
Wage	58.4	35.4	0.9	3.1	0.0	1.6	0.4	0.2
Productivity	82.0	7.9	0.0	7.8	0.0	2.0	0.2	0.1
Employment	5.0	41.1	0.0	42.7	0.3	2.9	3.7	4.3
Hours	26.3	52.1	2.6	14.5	0.3	0.4	3.7	0.1

The role of technology shocks. The variance decomposition in Table 6 shows that technology shocks are more important in accounting for output and productivity fluctuations in the constant-effort model compared to the baseline model. This result is in line with Hornstein (1993), who shows that the introduction of increasing returns in production

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

(and imperfectly competitive markets) reduces the contribution of exogenous productivity changes to aggregate fluctuations.[17] In our estimation results, the autoregressive coefficient of the technology shock is similar in the constant-effort model compared with the baseline model. Indeed, technology shocks are larger in the baseline model, yet their contribution to fluctuations is lower. This finding suggests that the differences in the variance decomposition between the baseline model and the constant-effort model are driven by the model's endogenous propagation mechanism and not by differences in the exogenous technology process.

5.2 Counterfactual exercises in the baseline model

We further investigate the role of the three alternative explanations for procyclical productivity by running counterfactual exercises in the spirit of Andrade et al. (2019), among others. Specifically, for total hours, unemployment, labor productivity and inflation, we compute the correlation with output and the standard deviation relative to output in a number of simulated models. These models have the same parameter values as the baseline estimated model but differ in one of the following three features: (a) constant effort, $\phi \approx 1$; (b) constant capital utilization, $\sigma_u \approx 0$; and (c) a much smaller technology shock, with $\sigma_A = 0.073$, which is a tenth of the estimate in the baseline model.

Table 7: Euro Area data and model-implied moments

	Output correlations					Relative standard deviations				
Variable	Data	Base-line	Const. labor effort	Const. capital utilizat.	Small tech. shocks	Data	Base-line	Const. labor effort	Const. capital utilizat.	Small tech. shocks
Total hours	0.89	0.79	0.63	0.76	0.99	0.76	0.79	1.00	0.75	0.76
Unemployment	-0.46	-0.66	-0.62	-0.64	-0.64	1.11	0.97	1.67	1.02	1.04
Productivity	0.76	0.79	0.41	0.66	0.93	0.42	0.62	0.85	0.64	0.27
Inflation	0.36	0.21	0.25	0.21	0.29	0.17	0.29	0.41	0.33	0.33

Notes: Data sources and transformations are provided in the online appendix. Sample: 1999Q1-2019Q4. Data series for total hours and productivity have been logged and HP-filtered.

The baseline model generates a correlation between output and productivity equal to 0.79, rather close to the empirical value of 0.76 shown in Table 7. In the counterfactual model simulated under constant effort, the correlation with productivity drops to 0.41. This statistic is equal to 0.66 in the counterfactual model with constant capital utilization. Therefore, the effort margin is more successful than variable capital utilization in generating procyclicality of labor productivity – in line with the data. When we reduce the volatility of the technology shock to one tenth of its estimated value, the productivity-output correlation

[17] Notice that Hornstein's setup differs from ours with respect to the modeling of increasing returns. He directly imposes a scale parameter that leads to a declining marginal cost curve, as well as a fixed cost parameter, while in our setup increasing returns to hours are generated endogenously through variable effort.

is equal to 0.93, much higher than in the data. This is because the other two supply shocks that generate procyclical productivity in the presence of effort, price mark-up and labor supply shocks, now become more important in accounting for fluctuations in labor productivity compared to the baseline model. This is reported in Table D.3 in the online appendix. The baseline model and the two restricted models perform similarly in that they overpredict the countercyclicality of unemployment.

In terms of volatilities, the model with variable labor effort is more in line with the data compared to the constant-effort model. More specifically, we see that the effort margin reduces the volatility of all reported variables. In contrast, the impact of capital utilization on the relative standard deviations is relatively minor. When technology shocks are small, labor productivity becomes too stable compared to the data.

Can variable capital utilization do it alone? We conduct an exercise to make the capital utilization mechanism much more powerful while shutting off the effort margin. This requires a sufficiently high elasticity of capital utilization σ_u. In the online appendix, Section D.2, we show that such a model can generate procyclical labor productivity only at the cost of making counterfactual predictions regarding the labor market variables. In particular, unemployment is more countercyclical and more volatile than in the data and in the baseline model.

6 Labor effort and macroeconomic dynamics

This section examines, first, how variable labor effort affects the conditional dynamics of the model, second, how effort interacts with adjustment frictions in determining unconditional moments, and finally, how effort affects movements in output and inflation.

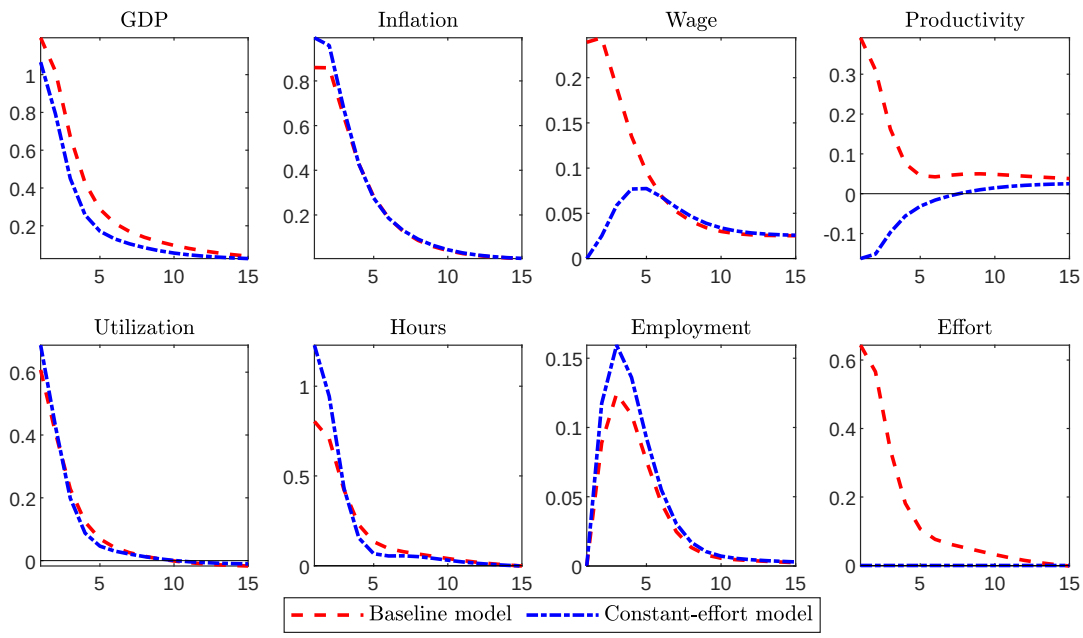
6.1 How does effort affect the dynamic responses to shocks?

We start by considering the transmission of shocks to macroeconomic aggregates. Figures 3 to 5 show impulse response functions to monetary policy, labor supply and technology shocks.[18] Those three shocks are the most important source of fluctuations in output, inflation and productivity, our main variables of interest. Risk premium shocks also matter; however, since they are qualitatively very similar to monetary policy shocks, we do not discuss them separately here. The responses to the other shocks are reported in Section E in the online appendix. Two different scenarios are depicted: (1) the estimated responses in the baseline model; and (2) a counterfactual constant-effort model, where again all parameters are set to the estimated values from the baseline model, except the parameter measuring the returns to hours, ϕ, which is set close to unity.

[18] In the interest of clarity, we report only the mean impulse response function, without probability bands.

Monetary policy shock. An expansionary monetary policy shock, modeled as an exogenous fall in the nominal interest rate, is depicted in Figure 3. It raises output by boosting investment and bringing consumption forward. Demand pressures feed through to inflation through the New Keynesian Phillips Curve (14) by opening up an output gap.

Figure 3: Impulse responses to a monetary policy shock



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

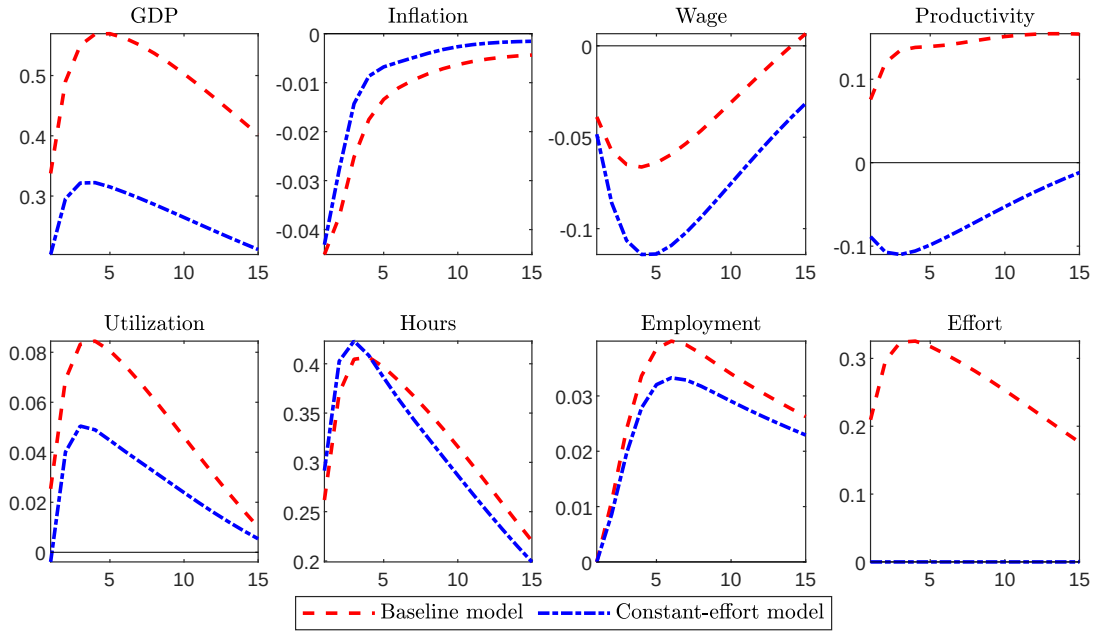
Producing more output requires more factors of production. Since employment and the capital stock are state variables, the need for more input leads to an immediate increase in hours and the utilization rate. In the baseline model, the response of productivity is procyclical, reflecting increasing returns to hours in production. The counterfactual model shows that the two input margins, hours and – to a minor extent – capital utilization, are exploited more when effort is kept constant. Under constant returns to hours, labor productivity becomes countercyclical in response to a demand shock. Thus, the parameter ϕ governs the sign of the response of productivity. The real wage is unchanged on impact and then gradually increases under constant returns to hours; this reflects the fact that workers are not working any harder, and therefore are less productive than in the baseline model. Recall that wage setting is efficient in our setup. Finally, the procyclicality of labor productivity dampens the rise in inflation.

Figure 3 demonstrates that the response of productivity to monetary policy shocks is very sensitive to the presence or absence of labor effort. In a vector autoregression (VAR) estimated on US data, Christiano et al. (2005) show that labor productivity rises in response to an expansionary monetary policy shock. That finding is confirmed by van Zandweghe (2015). We also find a procyclical response, confirming earlier results in Peersman and Smets

(2003), in Euro Area data. For details, see Appendix B.3. Our baseline model with labor effort can generate this procyclical response, while the constant-effort model cannot.[19]

Labor supply shock. Figure 4 shows impulse response functions to an expansionary labor supply shock. As the disutility of providing hours of work falls and the labor supply schedule (21) shifts out, hours rise and the wage falls. Labor effort rises along with hours, which increases productivity. The qualitative effects of this shock on output, inflation, and the interest rate are similar to those of a productivity shock, as explained by Smets and Wouters (2003).

Figure 4: Impulse responses to a labor supply shock



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

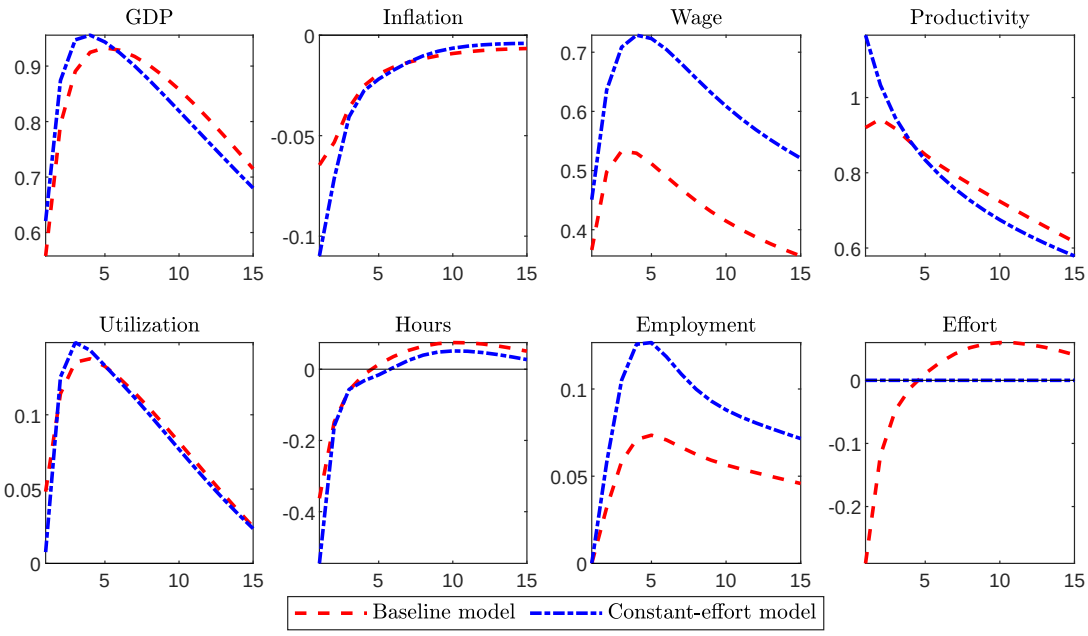
In the absence of an effort margin, there is no such boost to productivity. As we illustrated with equation (27), productivity is now inversely related to hours worked, and so the increase in GDP is less than proportional to the increase in hours. The fall in the real wage is stronger than in the baseline, because workers are now less productive. In the baseline model, the rise in labor effort leads to a reduction in marginal costs and hence to a greater fall in inflation.

Technology shock. Figure 5 shows the impulse responses to an exogenous improvement in the firms' production technology, who react by expanding production. Higher productivity

[19] Indeed, the failure of Christiano et al. (2005)'s model to generate a sufficiently strong rise in labor productivity is perhaps its only major shortcoming as this is the only instance where the model response is outside the confidence bands of the VAR response for a number of quarters after the shock.

allows firms to reduce their other adjustable labor input margin downward: effort and hours per worker fall on impact. Employment increases over time; hiring becomes more attractive as the marginal worker becomes more productive and therefore more valuable.

Figure 5: Impulse responses to a technology shock



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

Labor productivity increases by less in our baseline model than it does when effort is constant; this is explained by the endogenous fall in effort. Consequently, output expands less on impact in the baseline model than in the counterfactual model. The real wage rises by less in the baseline model, reflecting the smaller rise in productivity. The effort margin dampens the inflation response to technology shocks. Moreover, it dampens the response of employment to technology shocks as the fall in effort reduces the value of a marginal worker.

6.2 How does effort interact with adjustment frictions?

We now analyze how the main adjustment frictions of the model and their interaction with labor effort influence the procyclicality of productivity, as well as the volatility of inflation and labor inputs. The frictions we consider are investment adjustment costs and sticky prices and wages. Table 8 shows the model-implied business cycle statistics of three alternative model specifications, shutting off one friction at a time. We compare the statistics in the variable-effort model to those in the model with constant labor effort.

Investment adjustment costs capture the sluggish response of investment to economic shocks; in doing so, this friction greatly improves the empirical fit of New Keynesian models

Table 8: The role of frictions: model-implied moments

Variable	Data	Base-line	Endogenous labor effort			Constant labor effort		
			Flexible invest.	Flexible prices	Flexible wages	Flexible invest.	Flexible prices	Flexible wages
			Output correlations					
Total hours	0.89	0.79	1.00	0.77	0.79	1.00	0.58	0.63
Unemployment	-0.46	-0.66	-0.17	-0.66	-0.65	-0.20	-0.62	-0.60
Productivity	0.76	0.79	0.98	0.75	0.72	-0.93	0.54	0.41
Inflation	0.36	0.21	0.92	-0.07	0.21	0.96	-0.06	0.25
			Relative standard deviations					
Total hours	0.76	0.79	0.73	0.76	0.75	1.29	1.28	1.26
Unemployment	1.11	0.97	0.09	1.04	0.95	0.26	2.13	1.74
Productivity	0.42	0.62	0.25	0.26	0.27	0.30	0.36	0.33
Inflation	0.17	0.29	0.05	0.59	0.33	0.15	0.97	0.55

(Adolfson et al., 2007; Smets and Wouters, 2007). Table 8 shows that, in the counterfactual model with frictionless investment, productivity displays an almost perfect positive correlation with output. Strikingly, if we then, in addition, keep labor effort constant, the output correlation of productivity flips, becoming equal to -0.93. This reflects the interaction of two forces. First, investment-specific technology shocks become the most important sources of business cycle fluctuations when investment is frictionless. Second, with constant effort, labor productivity is countercyclical in response to these shocks.[20] A closer look at the constant-effort model with frictionless investment reveals that total hours respond very strongly to shocks, displaying a volatility far beyond what is observed in the data. This is not true for the model with variable effort, however, where hours are as volatile as in the data, both in the baseline and with fully flexible investment. This is because the presence of an extra margin to adjust labor dampens the volatility of total hours worked. Finally, investment adjustment costs are needed in the variable-effort model to generate empirical plausible unemployment volatility. Assuming frictionless investment makes unemployment much too stable relative to the data.

Nominal frictions are also found to be empirically relevant in the literature (e.g. Adolfson et al., 2007). In our model with sticky prices, output is demand-determined in the short run. Combined with labor market frictions and predetermined capital, this shifts the burden of adjustment onto hours and effort. As already noted in the introduction, this leads to an important role of effort in determining the cyclicality of labor productivity. Table 8 confirms that imposing flexible prices or wages drives down the output correlation of productivity in the constant-effort model but not in the variable-effort model. Moreover, total hours and unemployment become excessively volatile in the constant-effort model, but remain close to their empirical counterparts in the variable-effort model, when one of the two nominal

[20] In the absence of investment adjustment costs, investment-specific technology shocks explain more about 70 per cent of movements in productivity, as reported in Table D.4 of the online appendix. Figure E.2 in the online appendix shows the responses to investment-specific technology shocks in the baseline model and in the constant-effort model.

frictions is removed.

Thomas and Zanetti (2009) and Krause et al. (2008) report that the contribution of hiring costs to real marginal cost and inflation dynamics is small in New Keynesian models with constant labor effort. In our framework, however, employment adjustment frictions encourage the use of labor effort as an adjustment margin. The effort margin, in turn, dampens fluctuations in real marginal costs and inflation. We see from Table 8 that allowing for price (or wage) flexibility makes inflation more volatile, worsening the model fit in this dimension. This counterfactual increase in inflation volatility is much more pronounced in the constant-effort model than it is in the variable-effort model. In Christoffel and Linzert (2010)'s model featuring labor market frictions and constant labor effort, wage rigidities are an important determinant of inflation persistence. We add to this the insight that labor effort increases the importance of nominal rigidities for inflation dynamics. Qualitatively, price and wage stickiness have similar effects on the model-implied moments. However, the impact of price stickiness on the volatility of inflation and unemployment is noticeably larger than that of wage stickiness.

6.3 How does effort affect movements in output and inflation?

We conduct counterfactual simulations of inflation and output in the model with and without effort. We have seen that increasing returns to hours make labor productivity procyclical in response to demand shocks. According to the variance decomposition in Table 4, demand shocks explain a substantial part of both output and inflation variability. Therefore, we conjecture that the effort margin: (a) makes output more volatile and (b) reduces inflation volatility by dampening fluctuations in real marginal costs (Trigari, 2006; Gertler et al., 2008). Hence, given horizontal shifts in aggregate demand, a flatter aggregate supply curve makes the movements in output bigger and the movements in prices smaller.

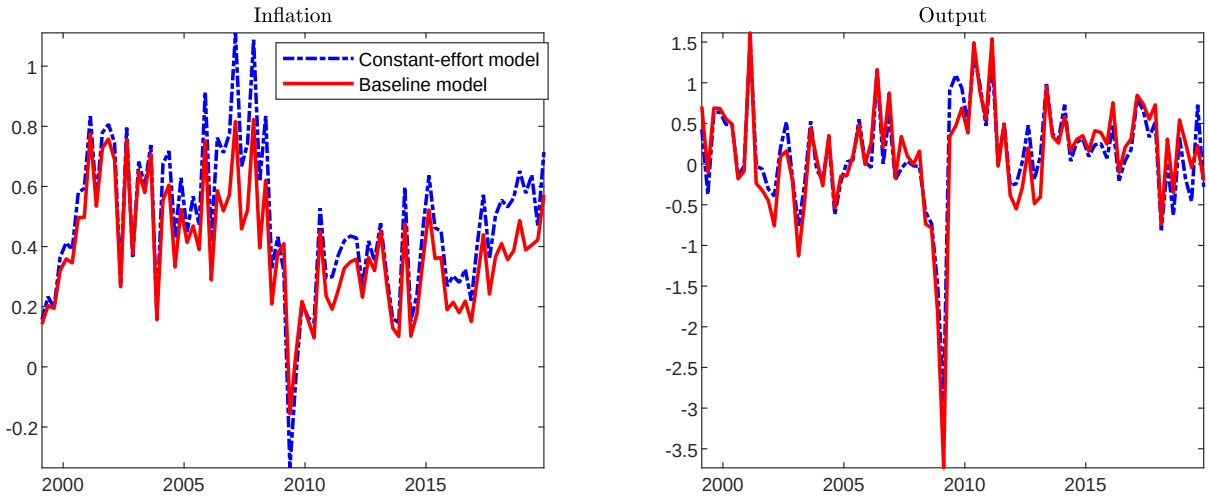
This intuition is confirmed in Figure 6, which shows – for inflation and output – the smoothed series and the counterfactual simulation when the returns to hours parameter, ϕ, is set to 1. The counterfactual model without effort indeed features less volatile output and more volatile inflation.

Finally, we highlight the greater importance of real shocks in driving inflation when effort is allowed to vary. Recall that monetary policy shocks dominate inflation volatility in the baseline model (Table 4). In the constant effort model, instead, risk premium and bargaining power shocks are the main source of inflation fluctuations, see Table 6.[21]

To summarize, accounting for the effort margin in a sticky-price business cycle model has two implications for our understanding of inflation dynamics. First, effort reduces model-predicted inflation volatility: firms can partially absorb demand fluctuations by adjusting effort, which dampens the response of marginal costs (and thus inflation) to shocks. Second,

[21] As reported in Appendix E, inflation responds more strongly to those two types of shocks in the constant-effort model than in the baseline.

Figure 6: Counterfactual simulations of inflation and output



Notes: The figure reports the smoothed series of the observable variables for inflation and output, i.e. the best guess for the variable given all observations derived from the Kalman smoother at the posterior mean.

allowing for variable labor effort alters our assessment of inflation drivers, increasing the influence of monetary shocks while reducing the role of real shocks.

7 Conclusion

We investigate the role of labor effort in explaining the procyclical movements in labor productivity in the Euro Area. Such movements are puzzling when they are observed concurrently with demand shocks. Indeed, a decline in labor productivity has been observed during the Great Recession, widely thought of as the result of a negative demand shock. The macroeconomic literature is divided on the driving forces of the cyclicality of labor productivity. We disentangle the three most common ones: variable capital utilization, variable labor utilization and dominant technology shocks. More specifically, 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 substantially greater than one, evidence in support of our specification. Our work has three main messages. First, we show that, while both margins of utilization give rise to procyclical labor productivity, the data prefer the labor utilization margin over the capital utilization margin to explain Euro Area business cycle fluctuations. The reason is that the model with effort exhibits low (un)employment volatility, which is a key feature of labor markets in the Euro Area. Second, the procyclicality of productivity does not seem to be driven by a dominance of technology shocks over other types of shocks. Third, we note that effort reduces the volatility of inflation as procyclical movements in labor productivity dampen real marginal costs. To a central bank wishing to dampen inflation fluctuations, the effort margin of labor adjustment could lend a helping hand in achieving its goal. Char-

acterizing optimal monetary policy in a model with variable effort is left for future research.

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