Employment, Hours, and Optimal Monetary Policy*

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Abstract

We document that in countries where labor productivity is more procyclical, both unemployment and inflation are more stable. A sticky-price model with search frictions and increasing returns to hours through variable labor effort can explain these stylized facts. Firms face a trade-off between the intensive labor margin (hours and effort) and extensive one (employment). If the workers’ bargaining weight is low, raising employment and instead reducing hours of existing workers allows for large wage cuts. Then firms use the extensive margin excessively and the intensive margin is underused, especially if effort is very elastic. Inflation serves as an instrument to affect the real wage and the aforementioned trade-off. The Ramsey policy deviates from price stability so as to dampen inefficient unemployment fluctuations.

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1 Introduction

The Great Recession has contributed to a renewed interest in the role of labor productivity in explaining business cycle fluctuations.\(^1\) In this respect, Figure 1 documents two observations. OECD countries with more procyclical labor productivity have a less variable unemployment rate and more stable inflation. The first observation is consistent with the evidence in Ohanian and Raffo (2012).

This picture raises the issue about the interaction between the cyclicality of labor productivity and the volatility of unemployment and inflation. We adopt a New Keynesian (NK) business cycle model with frictional labor markets where \textit{variable labor effort} allows us to explain the patterns observed above. Our aim is then to analyze the distortions generated by the presence of variable labor effort and to characterize optimal monetary policy. Several features might explain the procyclicality of labor productivity. The real business cycle (RBC) literature has interpreted technology shocks as the major source of business cycles, generating naturally procyclical productivity. Alternative explanations are increasing returns to scale and measurement error in inputs (see Basu, 1996). For instance, King and Rebelo (1999) emphasize the importance of variable capital utilization to improve the ability of the RBC model to match key business cycle facts.\(^2\) As argued by Oi (1962) and Solow (1964), unobserved variations in factor utilization – such as work intensity, or effort – may explain the procyclicality of labor productivity. Variations in work intensity can also be interpreted as reflecting schemes such as ‘short-time work’, widely used in Germany during the Great Recession, see Cahuc and Carcillo (2011).

Our model features increasing returns to hours through variable labor effort, building on Barnichon (2010, 2012). Procyclical variations in effort allow for output to rise more than hours in a boom, such that labor productivity becomes procyclical. As a result, real marginal costs and hence inflation are more stable than in the no-effort case. Since employment is predetermined, a firm adjusts the intensive labor input margin (hours and effort) rather than the extensive one (the number of workers) to meet fluctuations in demand in the short run. The availability of the intensive margin implies more stable unemployment over the cycle.

\(^1\)See e.g. Garin et al. (2011), Schaal (2011) and McGrattan and Prescott (2012). The latter authors emphasize the importance of intangible capital. Garin et al. (2011) focus on the size of aggregate shocks relative to shocks on labor reallocation. Schaal (2011) argues that idiosyncratic volatility shocks drive unproductive firms out of the market, which affects productivity.

\(^2\)Variable capital utilization might also explain the link between productivity and inflation volatility. However, it is unlikely that this could at the same time explain the cross-country differences in the volatility of unemployment. Using multi-year multi-country data, Nunziata (2003) shows that stricter employment protection and looser working time regulations are associated with a lower variability of employment.
We estimate key parameters of our business cycle model by matching impulse responses from a bivariate vector autoregression (VAR) model with labor productivity (measured in terms of hours) and unemployment for the Euro Area over the post-1984 period. The model is able to match the procyclical response of labor productivity to a non-technology shock, while the standard model without effort is not. This supports our hypothesis of increasing returns to hours.

The contribution of this paper is to stress that variable labor effort has important implications from a normative perspective. Our main results are twofold. First, we emphasize the steady-state distortions resulting from the interaction of labor search and matching, variable labor effort and monopolistic competition, which are all located in the same sector, i.e. affecting the same firms. We argue that these distortions are driven by the trade-off between the intensive labor margin (hours and effort) and the extensive one (employment). Second, we show that, if workers have low bargaining power, the optimal monetary policy deviates from price stability to dampen inefficient unemployment fluctuations.

Regarding the first main result, we highlight three steady-state distortions present in our model. First, monopolistic competition in goods markets gives rise to a price markup, leading to a suboptimally low level of production. In the standard NK model where wages are set by firms, a revenue subsidy equal to the markup removes this distortion by raising production to its efficient level. In our model with bilateral wage bargaining, the optimal revenue subsidy instead equals the markup adjusted for the firm’s bargaining share. This is because pricing power by monopolistically competitive firms and wage bargaining are located in the same sector. Through the bargaining process, firms and workers share the surplus generated by a match. The lower the firm’s bargaining power, the smaller its share of the surplus and the lower is the required revenue subsidy. When workers and firms have similar bargaining weights, we obtain an optimal revenue tax rather than a subsidy.

Second, the choice of hours is distorted in the case where firms and workers have similar bargaining power. Since hours have a positive effect on both wages and effort, a firm that expands production by increasing hours faces two opposing effects. On the one hand, if it demands more hours per worker, wages rise and this increases the firm’s wage bill. The higher the workers’ bargaining power, the smaller this effect. This is because the steady state wage is higher when workers have more bargaining power, and therefore a given absolute wage increase is lower in percentage terms. On the other hand, more hours worked imply higher effort per hour, and thus higher labor productivity. This effect is stronger, the more important is the effort margin, i.e. the lower is the marginal disutility of effort and the greater the degree of increasing returns to hours. This means that a small rise in hours results in a lot of additional output. For an efficient level of hours, the two effects must just
offset each other. This is the case for a particular value of the worker’s bargaining weight, which is greater than the typical calibration. If the worker’s bargaining weight is lower than this optimal value, then wages rise strongly with hours, and the firm chooses to exploit the extensive margin more than is efficient. As a result, steady-state hours and production are too low.

Third, equality between the weight of unemployment in the matching function and the workers’ bargaining weight is needed in order to obtain efficient variations in hiring. This is the well-known Hosios condition (Hosios, 1990).

Out of steady state, there is a fourth distortion due to price adjustment costs. Inflation stabilization is no longer optimal when steady-state distortions in labor inputs lead to inefficient fluctuations in response to shocks. Since we want to focus on the importance of the effort margin for optimal policy, we isolate the hours distortion and remove the other two steady-state distortions. We do this by setting an optimal revenue tax and assuming that the Hosios condition holds.

We now turn to the second main result: stabilization policy faces an inflation-unemployment trade-off. This trade-off results from the effect of wage bargaining on the choice between expanding the extensive rather than intensive labor input margin in response to demand shocks. The policy maker can use inflation to affect the real wage response in such a way as to make hours a more attractive adjustment margin, thereby limiting the reduction in unemployment after a government spending shock. We derive the optimal Ramsey policy under commitment and determine the inflation and unemployment volatility under that policy, for different values of the bargaining parameter. We find that when the worker’s bargaining power is lower than its optimal value, it is optimal to allow for some inflation variability to stabilize inefficient unemployment fluctuations.

Several authors have analyzed the implications of labor search frictions and sticky prices for optimal policy. In Faia (2009), deviations from the Hosios condition imply that optimal monetary policy does not fully stabilize prices. Thomas (2008) shows that imperfect wage adjustment creates inefficient hiring and leads to optimal deviations from price stability. Blanchard and Galí (2010) study the effect of real wage rigidities on the inflation-unemployment trade-off. Ravenna and Walsh (2012) characterize optimal tax policies in a model where price rigidities and labor search frictions affect different sectors. Our contribution compared to the latter papers is to stress how policy recommendations are influenced by the existence of an effort margin and the fact that two frictions are located in the same sector. Bils and Chang (2003) investigate how nominal wage rigidities affect welfare in the presence of variable labor effort. They argue that effort allows to reduce inefficient fluctuations in hours which reduces the welfare cost of wage stickiness. Compared to these authors, we show that
variable labor effort has normative implications, even in the absence of wage rigidities. The remainder of the paper is structured as follows. Section 2 presents the model. Section 3 describes the estimation procedure and the results. In Section 4, we analyze optimal policy. Section 5 concludes.

2 A Model with Variable Labor Effort

Our model features search and matching frictions in the labor market, variable labor effort as in Bils and Cho (1994), and sticky prices à la Rotemberg (1982). The idea of attributing the observed procyclicality of labor productivity to variable labor utilization goes back at least to Oi (1962) and Solow (1964). In combining endogenous effort and labor market frictions we follow Barnichon (2010, 2012).\(^3\) Labor input can be adjusted along two margins, the extensive margin (number of workers) and the intensive one (hours and effort). The optimal effort level is chosen to minimize labor disutility subject to the firm’s production technology. Wages are set through bilateral bargaining. In equilibrium, effort and wages are increasing functions of the number of hours worked. Employment is predetermined and hours are residually determined to meet demand in the short run.

Many New Keynesian models with labor market search, e.g. Faia (2009) and Ravenna and Walsh (2012), separate search frictions and price rigidities. In this model, these two features are instead located in the same sector, as in Barnichon (2010), Kuester (2010) and Thomas (2011). By setting its profit-maximizing price, the firm chooses a point on the demand curve. Since employment is predetermined, the price setting decision determines the number of hours worked needed to satisfy demand. In turn, hours worked affect wages and effort. The assumption that the price (and thus firm revenue) is given at the time of the hiring decision implies that the contribution of a marginal worker to the firm’s profits is not given by his marginal productivity but instead by the marginal reduction in the wage bill. The latter is the result of a reduction in hours worked due to the hiring of an additional worker, which reduces the wage payments to all existing workers.

2.1 Production and Preferences

**Setup** We assume that firms indexed by \(i \in (0, 1)\) use labor to produce intermediate goods under monopolistic competition. Output of an individual firm \(Y_{it}\) is produced according to

\(^3\)An alternative framework is Galí and van Rens (2010), who present a model with variable labor effort and a hiring cost function instead of search and matching frictions.
the following production function,

\[ Y_{it} = A_t n_{it} (h_{it} e_{it})^\alpha, \]  

(1)

where \( A_t \) is a technology index common to all firms, \( n_{it} \) is employment and \( 0 < \alpha < 1 \) measures the returns to effective labor in production. Effective labor is the product of hours worked \( h_{it} \) and effort per hour \( e_{it} \).

In the representative family, a fraction \( n_t \) of household members are employed in the market economy and receive the real wage \( w_{it} \) from each firm \( i \) for providing hours \( h_{it} \) and effort \( e_{it} \) per hour. Each employed family member works for all firms on the unit interval. The remaining \( 1 - n_t \) family members are unemployed; they are instead engaged in home production with productivity \( b_t \). The family maximizes lifetime utility

\[
E_0 \sum_{t=0}^{\infty} \beta^t \left[ \ln C_t + n_t \int_0^1 g(h_{it}, e_{it}) \, di \right],
\]  

(2)

where \( \beta \in (0, 1) \) is the discount factor and \( C_t \) denotes consumption. There exists an insurance technology guaranteeing complete consumption risk sharing between family members, such that \( C_t \) denotes consumption enjoyed by a member as well as overall family consumption.\(^4\) The function \( g(h_{it}, e_{it}) \) captures individual labor disutility to a worker of providing hours and effort to firm \( i \). Following Bils and Cho (1994), labor disutility is

\[
g(h_{it}, e_{it}) = \frac{\lambda_h h_{it}^{1+\sigma_h}}{1 + \sigma_h} + h_{it} \frac{\lambda_e e_{it}^{1+\sigma_e}}{1 + \sigma_e},
\]  

(3)

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

### Hours and Effort

Every period, firms and workers agree on the combination of hours and effort that minimizes labor disutility (3), subject to the production technology given by (1). At the optimum, effort per hour is a positive function of hours per worker,

\[
e_{it} = e_0 \frac{h_{it}^{\sigma_h}}{h_{it}^{\sigma_e}}, \quad \text{where} \quad e_0 = \left( \frac{1 + \sigma_e}{\sigma_e \lambda_h - \lambda_e} \right)^{\frac{1}{1+\sigma_e}}.
\]  

(4)

\(^4\)This modelling device goes back to Andolfatto (1996) and Merz (1995).
The elasticity of effort to hours $\frac{\sigma_\varepsilon}{1+\sigma_\varepsilon}$ is large if workers are more willing to increase effort rather than hours, i.e. if $\sigma_\varepsilon$ is small relative to $\sigma_h$. Using the optimal effort choice (4), we can rewrite the production function (1) as

$$Y_{it} = y_0 A_t n_i h_{it}^\varphi,$$

where $y_0 \equiv e_0^a$ and the returns to hours in production, $\varphi$, are given by

$$\varphi = \alpha \left(1 + \frac{\sigma_h}{1+\sigma_\varepsilon}\right).$$

Production displays short-run increasing returns to hours if $\varphi > 1$. In response to an expansionary demand shock, firms increase both hours and effort; measured productivity (output per hour) increases. This condition requires either that the marginal product of hours and effort, $\alpha$, be sufficiently high or that effort be sufficiently elastic to hours (high $\frac{\sigma_\varepsilon}{1+\sigma_\varepsilon}$). More specifically, the condition for increasing returns to hours is $\frac{\sigma_h}{1+\sigma_\varepsilon} > \frac{1-\alpha}{\alpha}$. We impose that effort increases with hours at a decreasing rate, such that $0 \leq \frac{\sigma_h}{1+\sigma_\varepsilon} \leq 1$. The calibration $\sigma_h \leq 1 + \sigma_\varepsilon$ puts an upper bound on the returns to hours, $\varphi_{max} \equiv 2\alpha$. If the effort margin plays no role ($\sigma_h = 0$ or $\sigma_\varepsilon \to \infty$, such that effort is inelastic to hours), we obtain a search and matching model with constant effort. This limiting case provides a lower bound on the returns to hours, $\varphi_{min} \equiv \alpha$.

**Intertemporal Optimization** The family maximizes lifetime utility (2) subject to the sequence of budget constraints

$$C_t^m + \frac{B_t}{R_t P_t} + \frac{M_t}{P_t} = n_t \int_0^1 w_i d_i + \frac{B_{t-1} + M_{t-1}}{P_t} + D_t + T_t.$$

As in Ravenna and Walsh (2012), we assume that consumption consists of final goods sold in the market and home-produced goods, i.e $C_t = C_t^m + (1 - n_t) b_t$. Let $B_t$ denote one-period nominal bonds that cost $R_t^{-1}$ units of currency in $t$ and pay a safe return of one currency unit in period $t+1$, $M_t$ denotes money holdings and $P_t$ is the price level. Consumption expenditure, bond purchases, and money holdings are financed through wage income by employed members, interest income on bond holdings, money left over from the previous period, real dividends $D_t$, and lump sum transfers $T_t$. In addition, we stipulate that agents need cash in order to purchase goods in the market,

$$M_t = P_t C_t^m.$$
The first order conditions for consumption and bonds imply $1 = R_t E_t \{\beta_{t,t+1}/\Pi_{t+1}\}$, where $\beta_{t-1,t} = \beta \frac{C_{t-1}}{C_t}$ is the stochastic discount factor and $\Pi_t = P_t/P_{t-1}$ is the gross inflation rate.

**Final Good** Final output $Y_t$ is an aggregate of intermediate goods $Y_{it}$ bundled according to the function $Y_t = (\int_0^1 Y_{it} e^{-\varepsilon i} di)^{1-\varepsilon}$, where $\varepsilon$ is the elasticity of substitution between the individual varieties. Given a price $P_{it}$ for each variety $i$, the corresponding demand function is given by $Y_{it}' = (P_{it}/P_t)^{-\varepsilon} Y_t$.

### 2.2 Firms and Workers

**Labor Market Search and Matching** Firms post vacancies and unemployed workers search for jobs. Let $M_t = M_0 u_t^{\eta} v_t^{1-\eta}$ denote the number of successful matches. The matching technology is a Cobb-Douglas function of the unemployment rate $u_t = 1 - n_t$ and the aggregate number of vacancies $v_t = \int_0^1 v_{it} di$, where $\eta \in (0, 1)$ is the elasticity of the number of matches to unemployment and $M_0 > 0$ is a scale parameter. The probability of a vacancy being filled next period is $q_t = M_t/v_t = M_0 \theta t^{-\eta}$, where the ratio of vacancies to unemployed workers $\theta_t = v_t/u_t$ is a measure of labor market tightness. The job finding rate is $p_t = M_t/u_t = q_t \theta_t$. A constant fraction $\lambda$ of matches are destroyed each period, such that employment at firm $i$ evolves as $n_{it+1} = (1 - \lambda) n_{it} + q_t v_{it}$.

**Nash Bargaining over Wages** Workers and firms bargain bilaterally over the real wage $w_{it}$ and split the joint surplus according to their respective bargaining weights $\gamma$ and $(1 - \gamma)$. It can be shown that the bargaining wage satisfies

$$w_{it} = \gamma \left( \frac{h_{it}}{\varphi} \frac{\partial w_{it}}{\varphi} + \kappa_{it} \theta_t \right) + (1 - \gamma) \left( \frac{g(h_{it})}{\Lambda_t} + b_t \right),$$

where $\kappa_{it}$ is the per-period cost to the firm of posting a vacancy. The firm’s surplus from employing a marginal worker equals the latter’s contribution to profits. As in Barnichon (2010, 2012) and Thomas (2011), a firm sets its price prior to hiring and wage bargaining. Once it has set a price, it adjusts hours to satisfy demand at that price, taking into account the optimal effort response embodied in (5).\(^5\) Therefore, firm revenues are independent of $n_{it}$ and the contribution of the marginal worker to firm profits is the marginal reduction in the wage bill, $h_{it} \frac{\partial w_{it}}{\varphi} \frac{\partial h_{it}}{\varphi}$, and not his marginal revenue product as in the standard search and matching model. An employed worker suffers the disutility $g(h_{it})$ from working, which we divide by $\Lambda_t = 1/C_t$, the Lagrange multiplier on (7), to convert utils into consumption goods.

\(^5\)Unlike Thomas (2011), we do not assume that hours are determined through bargaining between the firm and the worker.
His outside option is represented by home production of $b_t$ units of market consumption goods. By the method of undetermined coefficients, we find the following solution to (9),

$$w_{it} = \gamma \kappa_{it} \theta_t + (1 - \gamma) b_t + (1 - \gamma) \frac{h_{it}^{1+\sigma_h}}{\Lambda_t}, \quad (10)$$

where $\gamma = \lambda_h^{1+\sigma_h+\sigma_e} (1 - \gamma) (1+\sigma_h) \varphi^{-1}$. For the model to be well-behaved, we impose $\gamma > 1$. This implies that $\gamma > 0$, such that the bargaining wage is an increasing function of hours worked.

**Shadow Value of Marginal Worker**  The shadow value of a marginal worker is defined as the total reduction in the wage bill induced by an additional hire,

$$\chi_{it} = -\frac{\partial (w_{it} n_{it})}{\partial n_{it}} = -w_{it} + \frac{h_{it} \partial w_{it}}{\varphi \partial h_{it}}. \quad (11)$$

Hiring an additional worker costs the firm $w_{it}$. However, it also allows the firm to reduce the number of hours of, and through (10) the wage payments to, all other workers. Since effort is an increasing function of hours (see (4)), a reduction of hours brings about a reduction in effort. The firm effectively reduces the intensive margin and raises the extensive margin of production. In our model, the shadow value is

$$\chi_{it} = -\gamma \kappa_{it} \theta_t + (1 - \gamma) b_t + (1 - \gamma) \left( \frac{1+\sigma_h}{\varphi} - 1 \right) \frac{h_{it}^{1+\sigma_h}}{\Lambda_t}, \quad (12)$$

where, using the terminology of Monacelli et al. (2010), the last term $\omega_{nit}$ can be regarded as the marginal value of employment. Provided that $\frac{1+\sigma_h}{\varphi} > 1$ and $\gamma > 0$, the marginal value of employment increases with the number of hours per worker.

As noticed by Barnichon (2012), two parameters affect the trade-off between the intensive and the extensive labor margin as embodied in $\omega_{nit}$. First, the marginal value of employment is decreasing in the worker’s bargaining power, $\gamma$. If the worker has a lot of bargaining power, i.e. $\gamma$ is large, hiring an additional worker and reducing the hours worked of existing employees reduces the firm’s wage bill only by a small amount. Then the marginal value of employment is low and the firm prefers to expand the intensive labor margin rather than the extensive one. As a result, employment responds less to shocks.

Second, the marginal value of employment is a negative function of the degree of increasing returns to hours in production $\varphi$, for a given utility cost of increasing hours, $\sigma_h$. The firm benefits more from using the intensive rather than from the extensive labor margin when the
returns to hours, $\varphi$, are large. This happens if workers do not suffer much disutility from exerting more effort, i.e. $\sigma_e$ is low.\(^6\) Thus, higher returns to hours in production make employment respond less to shocks.

To conclude, a greater bargaining weight $\gamma$ and higher returns to hours $\varphi$ dampen the volatility of employment by tilting the trade-off between the two labor input margins away from hiring and towards the use of hours. As we show below, these two parameters are also crucial for the normative predictions of the model.

**Real Marginal Costs**  
Firm $i$’s real marginal costs, i.e. the change in the wage bill for a unit increase in output, are given by

\[
s_{it} = (1 - \gamma) \times \frac{1 + \sigma_h h_{it}^{1 + \sigma_h - \varphi}}{\varphi y_0 A_t \Lambda_t},
\]

(13)

Real marginal costs are more volatile, the greater is the bargaining power of workers $\gamma$. The degree of increasing returns to hours $\varphi$ has two opposing effects on the volatility of $s_{it}$. As argued above, a large bargaining power $\gamma$ or high returns to hours in production $\varphi$ boost incentives for firms to expand hours instead of employment in response to a positive demand shock. In that case, hours and therefore real marginal costs rise by a lot. However, equation (13) also shows that, if we consider a given increase in hours $h_{it}$, real marginal costs rise less, the greater are the returns to hours in production $\varphi$. This is because productivity responds positively to a demand shock in the presence of the effort margin, raising the amount of output that can be produced with a given number of worker hours.

Alternatively, we can express real marginal costs in terms of the worker’s shadow value,

\[
s_{it} = \frac{w_{it}}{y_0 h_{it}^\varphi} + \frac{X_{it}}{y_0 h_{it}^\varphi}.
\]

(14)

In the standard New Keynesian model with a linear technology and competitive labor markets, real marginal costs are given by the real wage divided by labor productivity. In the standard search and matching framework with exogenous separations, real marginal costs have an additional component: today’s hiring costs less the saving of tomorrow’s expected hiring costs in case the employment relationship continues, again divided by labor productivity. Under the assumption of instantaneous hiring, this term represents the current shadow value of a worker. See Krause and Lubik (2007) and Faia (2009). In the no-effort model, labor productivity is *exogenous*. In the present model, both the wage and the shadow value are

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\(^6\)Recall that the constant effort model is obtained by letting the marginal disutility of effort go to infinity, $\sigma_e \to \infty$.  

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divided by endogenous labor productivity, i.e. the marginal product of employment (output per worker), \( \partial Y_{it}/\partial n_{it} = y_0 h^e_{it} \).

**Prices and Vacancies** Firms maximize the present discounted stream of future profits,

\[
E_0 \sum_{t=0}^{\infty} \beta_{0,t} \left[ \tau^f \frac{P_t}{P_{t-1}} n_{it} - w_{it} \epsilon_{it} - \kappa_{it} v_{it} - \frac{\kappa_p}{2} \left( \frac{P_t}{P_{t-1}} \Pi_{t-1} - 1 \right)^2 y_t \right],
\]

(15)

where \( \tau^f \) is a gross subsidy on firm revenues and \( \beta_{0,t} = \beta_{0,1} \beta_{1,2} \cdots \beta_{t-1,t} \). Firm \( i \) chooses a price \( P_{it} \), vacancies \( v_{it} \), and next period’s employment \( n_{it+1} \) to maximize (15) subject to the law of motion for employment \( n_{it+1} = (1 - \lambda) n_{it} + g_t v_{it} \), the demand function \( Y_{it} = (P_{it}/P_t)^{-\varepsilon} Y_t \), and the equilibrium wage (10).

Following Rotemberg (1982), price changes are subject to quadratic adjustment costs scaled by the parameter \( \kappa_p \geq 0 \). We allow for price adjustment costs to vary with the deviation of firm-level inflation from past aggregate inflation weighted by \( \lambda_p \). The specification mimics indexation of non-adjusted prices in the Calvo setup. The first order condition for prices is

\[
\frac{P_{it}}{P_t} = \frac{\varepsilon s_{it}}{\tau^f (\varepsilon - 1)} + \frac{\kappa_p \gamma_{it}}{(P_{it}/P_t)^{1-\varepsilon}},
\]

(16)

where \( \gamma_{it} = \Pi_{t-1} \Pi_{it} \Pi_{it} \Pi_{it+1}(\Pi_{it+1} - 1) - E_t \{ \beta_{t,t+1} \Pi_{t} (\Pi_{it+1} - 1)^2 \frac{\Pi_{it+1} \Pi_{it+1}}{Y_t} \} \) and \( \Pi_{it} = P_{it}/P_{it-1} \) is firm-level inflation. Our specification of price rigidities differs from Barnichon (2010), Kuester (2010) and Thomas (2011), who adopt Calvo (1983) price staggering. The price set by a firm determines the shadow value of the marginal worker, and thus its hiring decision. In the Calvo setup, sticky-price firms choose a different employment level than flexible-price firms. This firm-specificity of labor alters the slope of the New Keynesian Phillips Curve. For simplicity, we opt for the Rotemberg scheme, which delivers the standard New Keynesian Phillips Curve slope.\(^7\)

The first order conditions for vacancies and next period’s employment together imply

\[
\frac{\kappa_{it}}{q_{it}} = E_t \left\{ \beta_{t,t+1} \left[ \lambda_{it+1} + (1 - \lambda) \frac{\kappa_{it+1}}{q_{it+1}} \right] \right\}.
\]

(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

\(^7\)In addition, the Rotemberg price setting scheme allows us to write down the model in non-linear form, which we need to derive the Ramsey first order conditions in the normative part of the paper.
costs divided by the probability of filling a vacancy, equivalent to vacancy posting costs multiplied by the average duration of a vacancy, \(1 / q_t\). The benefits of hiring a worker are his shadow value plus the vacancy posting costs saved in case the employment relationship continues.

### 2.3 Equilibrium

The government budget constraint equates current income (bond issues and seigniorage revenues) with current expenditure (government consumption, lump-sum transfers, maturing government bonds and revenue subsidies to firms),

\[
\frac{B_t}{R_t P_t} + \frac{M_t - M_{t-1}}{P_t} = G_t + T_t + \frac{B_{t-1}}{P_t} + (\tau^f - 1) \int_0^1 \frac{P_t y^d_k}{P_t} \, dt. \tag{18}
\]

We consider a symmetric equilibrium and drop the \(i\)-subscript. Combining the aggregated household budget constraint with the government budget constraint (18), we obtain the aggregate accounting identity,

\[
Y_t + (1 - n_t) b_t = C_t + G_t + \kappa v_t + \frac{K^p}{2} \left( \Pi_{t-1}^{-\lambda} \Pi_t - 1 \right)^2 Y_t. \tag{19}
\]

The growth rate of technology \(\Delta a_t = \ln(A_t/A_{t-1})\) and the logarithm of government spending \(\hat{g}_t = \ln \left( \frac{G_t}{G/A} \right)\) follow autoregressive processes,

\[
\Delta a_t = \rho_a \Delta a_{t-1} + \varepsilon^a_t, \quad \varepsilon^a_t \sim N(0, \sigma_a), \tag{20}
\]

\[
\hat{g}_t = (1 - \rho_g) \ln (G/A) + \rho_g \hat{g}_{t-1} + \varepsilon^g_t, \quad \varepsilon^g_t \sim N(0, \sigma_g). \tag{21}
\]

We specify monetary policy as a money growth rule reacting to current and lagged technology shocks,

\[
\Delta m_t = (1 - \rho_m) \ln (\Pi) + \rho_m \Delta m_{t-1} + \tau_a \varepsilon^a_t + \tau_a \varepsilon^a_{t-1}, \tag{22}
\]

where \(\Delta m_t \equiv \ln (M_t/M_{t-1})\). We linearize the model around its zero-inflation (\(\Pi = 1\)) balanced growth path, where we divide all trending variables by technology \(A_t\).\(^8\) Home production and vacancy posting costs grow with technology.

---

\(^8\)See the online appendix for a derivation of the balanced growth path.
3 Empirical Evidence

This section estimates the model’s key parameters for the Euro Area after 1984. In particular, we are interested in the degree of increasing returns to hours in production, $\varphi$. With this exercise, we aim to gauge the importance of variable labor effort in explaining the dynamics of labor productivity. We disentangle the effects of technology and non-technology shocks on labor productivity and unemployment through a vector autoregression (VAR) identified with long run restrictions. We then estimate our business cycle model by matching the empirical responses to both shocks.

A conditional analysis using a VAR model is necessary as it allows us to quantify the importance of non-technology shocks in explaining the observed fluctuations in labor productivity. The standard real business cycle (RBC) model predicts a procyclical productivity response to technology shocks. If business cycle fluctuations were entirely driven by technology as in the RBC paradigm, we would not need endogenous effort to explain the observed dynamics.

3.1 VAR Impulse Response Matching

In a first step, a bivariate quarterly VAR model for the Euro Area is estimated to analyze the response of labor productivity to technology and non-technology shocks. It contains the log of labor productivity (in first differences) and the unemployment rate. The former is constructed as the difference between log real GDP and log hours worked.\footnote{Real GDP and unemployment are obtained from the Area-Wide Model (AWM) database. The total hours series is the one used in Christiano et al (2012).} We choose unemployment as our preferred labor market variable in our baseline VAR.\footnote{The results are robust to using hours worked as a measure of labor input. See online appendix.} The estimation covers the sample 1984Q1-2011Q1. Even though in the Euro Area monetary policy was formally unified only in 1999, we believe that by the mid-1980s monetary policy was already sufficiently homogeneous, with a dominant role for the Bundesbank, to justify an estimation analysis starting in 1984. All variables are demeaned and the lag length is set to 4. Using the technique pioneered by Blanchard and Quah (1989), the technology shock is identified with long-run restrictions. More specifically, we assume that this is the only shock that has a permanent effect on labor productivity, as in Galí (1999).

In a second step, the model parameters are partitioned into two groups. Let $\psi^c$ denote the vector of calibrated parameters as reported at the top of Table 1.

\begin{center}
[ insert Table 1 here ]
\end{center}

The subjective discount factor is set to $\beta = 0.99$, implying a steady-state annualized real
interest rate of 4%. We assume a markup of 10 percent in the intermediate sector (i.e., \( \varepsilon = 11 \)). The returns to effective hours in production, \( \alpha \), is set to 0.65, as in Bils and Cho (1994). We assume that prices are fully indexed to past inflation (\( \lambda_p = 1 \)), given that this parameter was driven to its upper bounds in preliminary exercises. The degree of increasing marginal disutility of hours, \( \sigma_h \), is set to 2, as in Bils and Cho (1994). Following Gertler et al. (2008), we set the matching elasticity to unemployment, \( \eta \), to 0.5, which is in line with Petrongolo and Pissarides’ (2001) findings. The Hosios (1990) condition is satisfied such that the bargaining weight of workers equals the matching function coefficient on unemployment, \( \gamma = \eta \). The share of vacancy posting costs in GDP, \( C_v \equiv \kappa_v v/y \), is set to 0.01, as in Blanchard and Galí (2010). We choose a steady-state vacancy filling rate, \( q \), of 0.7, which corresponds to an average vacancy duration of one and a half quarters in the Euro Area. This value is in line with Christoﬀel et al. (2009). We set the steady-state unemployment rate, \( u \), to 9.1%, corresponding to the average value over our sample. Following Christoﬀel et al. (2009), the steady-state job finding rate, \( p \), is set to 0.30. For estimation purposes, we consider the model without revenue taxes, \( \tau_f = 1 \). Without loss of generality, we normalize steady-state hours and effort to unity, which allows us to solve for the steady state recursively. The remaining parameters are deduced from the steady-state relations. The implied steady-state ratio of home production to market output equals 10.4%. The implied job separation rate, \( \lambda \), equals 3%.

The second set of model parameters is estimated by matching the empirical responses of labor productivity and unemployment to technology shocks (\( \varepsilon^a_t \)) and non-technology shocks (\( \varepsilon^b_t \)). Estimated parameters are chosen to drive the theoretical impulse response functions (IRFs) as close as possible to their empirical counterparts. More precisely, parameter estimates \( \hat{\psi}_T \) fulfil

\[
\hat{\psi}_T = \arg \min_{\psi \in \Psi} \mathcal{J}(\psi), \quad \text{where} \quad \mathcal{J}(\psi) = [\Phi^m(\psi^c, \psi) - \hat{\Phi}_T]' \hat{W} [\Phi^m(\psi^c, \psi) - \hat{\Phi}_T], \tag{23}
\]

where \( \hat{\Phi}_T \) is the vector stacking all empirical IRFs, \( \Phi^m(\psi^c, \psi) \) is its theoretical counterpart and \( \hat{W} \) is diagonal matrix with the inverse of the asymptotic variances of each element of \( \hat{\Phi}_T \) along the diagonal. We generate 200 bootstrap replications of the VAR and re-estimate the parameters to compute the distribution of the minimum distance \( \mathcal{J}(\psi_i) \). The \( p \)-value at the bottom of Table 1 indicates that the null hypothesis \( H_0: \mathcal{J}(\psi_i) = 0 \) cannot be rejected, suggesting that the model is not rejected by the data.
3.2 Estimation Results

Figure 2 plots the theoretical and the empirical IRFs to a technology and a non-technology shock, as well as the 95% confidence intervals.

We observe from the empirical IRFs that labor productivity is procyclical in response to both technology and non-technology shocks. Labor productivity rises gradually to a higher steady-state level after a positive technology shock. The unemployment rate increases in response to such a shock, consistent with Blanchard and Quah (1989) and Canova et al. (2007). Our model is able to replicate this feature. The technological improvement lowers the number of hours needed to produce a given amount of output; this reduces the shadow value, see (12). Firms post fewer vacancies and so unemployment rises.

An expansionary non-technology shock (i.e., a disturbance that has no effect on productivity in the long run and that lowers unemployment) generates a procyclical response of labor productivity in the Euro Area. This is in contrast with Barnichon’s (2010) post-1984 US results, where labor productivity does not react significantly. In our model, hours immediately increase to accommodate the rise in demand. The rise in hours brings about a rise in the shadow value, which encourages hiring by firms and lowers the unemployment rate in the following period.

The model reproduces the size of the unemployment response to both shocks. This is in contrast with the so-called ‘Shimer puzzle’ (Shimer, 2005), which states that search and matching models generate too little (un-)employment volatility over the business cycle. As argued above and shown analytically by Barnichon (2012), the variable labor effort model generates high employment volatility for low values of the worker’s bargaining power $\gamma$ and the degree of returns to hours $\varphi$. In the online appendix, we show that a model with constant effort fails to replicate the magnitude of the unemployment response to both shocks.

The estimated parameters are provided in Table 1. We focus our discussion on the returns to effort in labor disutility, $\sigma_e$, which determines the degree of increasing returns to hours $\varphi$ for a given value of $\sigma_h$, the returns to hours in labor disutility. We find that $\sigma_e$ is significantly estimated at 2.00, suggesting that the Euro Area exhibits increasing returns to hours in production, $\varphi = 1.08$. Thus, the effort margin appears to be an important feature to replicate the dynamics of labor productivity in the Euro Area. We confirm this finding by estimating a model without effort, where $\sigma_e$ is set to a large value ($\sigma_e = 1000$). We find that the no-effort model is rejected by the data.\textsuperscript{11}

\textsuperscript{11}See online appendix.
The other estimates are in line with the literature. The estimated degree of nominal rigidities $\kappa_p$ is 11. Krause et al. (2008) estimate a model with matching frictions by Bayesian techniques and report an interval of values of [5.27; 12.73]. Our estimate lies in the middle of this range. The money growth rule features a high degree of inertia with $\rho_m = 0.90$. In addition, the policy response to current technology shocks is positive ($\tau_a = 0.04$) while money growth responds negatively to lagged technology shocks ($\tau_{a,1} = -0.07$). Regarding the estimates of the two shocks, we observe that the technology shock is small since our estimate of its standard deviation $\sigma_a$ is 2%. This result is consistent with Altig and al. (2011) who estimate an NK model by minimum distance techniques on US data. The autocorrelation parameter of the growth rate of the technology shock, $\rho_a$, is estimated at 0.68, a value larger than Altig et al. (2011) for the US.

4 Optimal Policy

In this section, we analyze the implications of endogenous effort from a normative perspective. We first establish that the two labor input margins, the choice of hours and the vacancy posting decision, are distorted in the competitive equilibrium. In response to shocks, these distortions vary together with real marginal costs. Thus, around an efficient steady state, the optimal policy stabilizes real marginal costs over the cycle, i.e. inflation targeting is optimal. Second, we derive the conditions under which the competitive steady state is efficient. Finally, we characterize the optimal Ramsey policy under price stickiness when the steady state is distorted.

4.1 Efficient Allocation

The social planner problem is to maximize household utility subject to the aggregate employment dynamics, which we regard as a technological constraint, and the resource constraint. As a benchmark, we consider the planner problem of choosing consumption, employment, vacancies and hours in the absence of price setting frictions. For simplicity, we assume that effort has already been chosen optimally, such that the optimal choice of the intensive labor margin coincides with the choice of hours. The optimization problem reads

$$
\max_{\{c_t, n_{t+1}, v_t, h_t}\} E_0 \sum_{t=0}^{\infty} \beta^t \left[ (\ln c_t + a_t) + n_t \lambda h_t \frac{1 + \sigma_h + \sigma_e}{(1 + \sigma_h) \sigma_e} h_t^{1+\sigma_h} \right],
$$

(24)
where $c_t = C_t/A_t$ and $a_t = \ln A_t$, subject to

$$n_{t+1} = (1 - \lambda) n_t + M_0 (1 - n_t)^{\eta} v_t^{1-\eta}, \quad (25)$$

$$y_0 n_t h_t^\varphi + (1 - n_t) b = c_t + g_t + \kappa_v v_t. \quad (26)$$

Notice that the resource constraint has been divided by the technology index $A_t$, and we define $b = b_t/A_t$, $g_t = G_t/A_t$ and $\kappa_v = \kappa_{v,t}/A_t$.

The efficient allocation is characterized by two first order conditions related to the choice hours and employment. First, it can be shown that the efficient hours choice satisfies

$$-\lambda h \frac{1 + \sigma_h + \sigma_k h_t^{1+\sigma_h-\varphi} c_t}{\varphi\sigma_k h_t^{1+\sigma_h \varphi} y_0} = 1. \quad (27)$$

The left hand side of (27) corresponds to the hours wedge, $\omega_{ht}$, defined as the ratio of the household’s marginal rate of substitution between hours and consumption to the marginal product of hours, $\omega_{ht} \equiv \frac{\sigma_h (h_t)}{\sigma_h (h_t) + h_t}$. Equation (27) thus implies that the efficient hours wedge equals unity, $\omega_{ht}^* = 1$. Second, the planner’s choice of employment implies that the efficient marginal value of employment is given by

$$\omega_{nt}^* = (1 - \eta) \left( 1 - \frac{\varphi}{1 + \sigma_h} \right) y_0 h_t^\varphi. \quad (28)$$

### 4.2 Conditions for Steady State Efficiency

The hours wedge and the marginal value of employment in the competitive equilibrium are as follows,

$$\omega_{ht} = \frac{\gamma^{1+\sigma_h} - 1}{1 - \gamma} s_t, \quad (29)$$

$$\omega_{nt} = \left( 1 - \frac{\varphi}{1 + \sigma_h} \right) y_0 h_t^\varphi s_t. \quad (30)$$

Expressions (29) and (30) relative to their efficient counterparts embody the two distortions that arise in the absence of corrective fiscal and monetary policies.

$$\frac{\omega_{ht}}{\omega_{ht}^*} = \frac{\gamma^{1+\sigma_h} - 1}{1 - \gamma} s_t, \quad \text{and} \quad \frac{\omega_{nt}}{\omega_{nt}^*} = \frac{1}{1 - \eta} s_t. \quad (31)$$

Real marginal costs introduce a time-varying distortion in the choice of hours worked and in vacancy posting. We can see directly that *cyclical* distortions can be removed by fully sta-
bilizing real marginal costs. Since inflation varies only through fluctuations in real marginal costs, we conclude that, *around an efficient steady state*, strict inflation targeting is optimal. Next, we characterize the steady-state distortions.

A first steady-state distortion is related to the presence of monopolistic competition and wage bargaining in the same sector. At the steady state, real marginal costs are equal to the revenue subsidy over the markup, \( s_t = \tau^f / \mu \). Under the Hosios (1990) condition where \( \eta = \gamma \), eliminating the employment distortion requires a gross revenue subsidy equal to the markup multiplied by the firm’s bargaining power,

\[
\tau^f_{\text{opt}} = (1 - \gamma) \mu > 0.
\]  

Equation (32) shows that if \( \gamma > \frac{\mu - 1}{\mu} \), firm revenues are *taxed* at the optimum, \( \tau^f_{\text{opt}} < 1 \). This is the case in a typical calibration, e.g. suppose the net price markup is 10%, such that \( \mu = 1.1 \), and the workers have half the bargaining weight, \( \gamma = 0.5 \).

If the firm has all the bargaining power, i.e. \( \gamma = 0 \), we have the standard result from the New Keynesian model prescribing an optimal revenue *subsidy* equal to the gross markup. It is a well-known result that monopolistic competition leads to an inefficient price markup, which can be removed with a constant revenue subsidy. In contrast with other studies that assume price setting frictions and labor market frictions located in different sectors of the economy (see e.g. Ravenna and Walsh, 2012), we locate these two frictions within the same sector. The presence of wage bargaining implies that workers are able to appropriate part of the markup in the form of higher wages. This affects the size of the optimal revenue tax/subsidy. In particular, the share of revenues that the firm should be able to appropriate equals the gross markup adjusted for the firm’s bargaining share. Suppose that firm revenues are neither taxed nor subsidized, \( \tau^f = 1 \). Then steady-state hours and production are suboptimally high. The wage rate, the shadow value and real marginal costs, being a positive function of the number of hours, are also too high. In the rest of our analysis, we assume that the Hosios condition holds, such that \( \eta = \gamma \), and set the revenue tax \( \tau^f \) to its optimal value in order to isolate the effects of the second distortion that we describe next.

The second steady-state distortion is related to the trade-off between the two labor input margins, hours/effort vs. employment. Setting \( s_t = \tau^f / \mu \), we see that the steady-state hours distortion is eliminated if the worker bargaining weight satisfies

\[
\gamma_{\text{opt}} = \frac{\varphi}{1 + \sigma_h}.
\]  

18
The worker’s bargaining power has to equal twice the relative benefit of using hours.\textsuperscript{12} The optimal $\gamma$ thus depends on the two parameters affecting the trade-off between the intensive and the extensive labor margin.

To illustrate the importance of the hours distortion, Figure 3 displays welfare, output, hours and consumption in deviation from their efficient values, for different values of the bargaining parameter $\gamma$. Recall that there is a minimum value $\gamma_{\text{min}} = \frac{\varphi}{1 + \sigma_h}$, for the model to be well-behaved. In order to isolate the distortion in the choice of hours, we assume in the competitive equilibrium that $\tau^f = (1 - \gamma)\mu$ and $\eta = \gamma$, which removes the vacancy-posting distortion. The circle illustrates the calibration where $\gamma = \gamma^{\text{opt}}$, i.e. the efficiency condition (33) is satisfied.

\[ \text{[ insert Figure 3 here ]} \]

If the worker’s bargaining power is too low, $\gamma < 2\frac{\varphi}{1 + \sigma_h}$, the hours wedge (29) in steady state is smaller than unity. This implies that the marginal rate of substitution between consumption and labor is below the marginal product of hours. So, increasing hours a little raises output and adds consumption utility with only a small disutility cost. However, recall that a low bargaining power of workers implies that firms are reluctant to use the intensive labor margin. Therefore, hours and effort are suboptimally low, as is the level of production.

We now analyze the effect of these steady-state distortions on the model’s dynamics. Figure 4 compares the impulse responses of output, hours and unemployment in response to technology and government spending shocks in the competitive flexible-price equilibrium and in the efficient allocation. The parameters are set to their calibrated/estimated values as summarized in Table 1, except that we set $\kappa_p = 0.0001$, to remove the sticky-price distortion, as well as an optimal revenue tax, $\tau^f = (1 - \gamma)\mu$ and the Hosios condition $\eta = \gamma$, to remove the hiring distortion.

\[ \text{[ insert Figure 4 here ]} \]

The competitive equilibrium is characterized by a bargaining power parameter that is lower than its optimal value, $\gamma < 2\varphi/(1 + \sigma_h)$. As argued earlier, a too low bargaining power of workers implies that firms are reluctant to use the intensive margin. The shadow value is too sensitive to hours worked, such that firms post too many vacancies and employment rises too much in response to a given expansionary shock. Consequently, the extensive margin (unemployment) is too volatile compared to the efficient allocation. This distortion can be corrected by increasing the worker’s bargaining power which stabilizes employment fluctuations by making firms more willing to adjust hours instead of the number of workers.

\textsuperscript{12}One can show that an efficient choice of hours can be implemented in the competitive equilibrium by imposing a consumption subsidy, coupled with a lump sum transfer to the unemployed.
4.3 Optimal Monetary Policy

In the following, we investigate how the steady-state hours distortion, given by a violation of condition (33), affects optimal monetary policy. We compute the paths the Ramsey policymaker should choose for the model variables to maximize household utility. To this end, we condense the optimality conditions of households and firms into three implementability conditions determining real marginal costs (13), vacancy posting (17) and price setting (16). These three equations are constraints for the Ramsey planner in addition to the evolution of employment (25) and the resource constraint, which now includes price adjustment costs,

\[
\left(1 - \frac{k_p}{2}(\Pi_t - \lambda_t^* \Pi_t - 1)^2\right) y_0 n_t h_t^\phi + (1 - n_t) b = c_t + g_t + \kappa_v v_t. \tag{34}
\]

**Definition:** For given stochastic processes \(\{a_t, g_t\}_{t=0}^{\infty}\) and for a given initial employment level \(n_0\), the Ramsey optimal policy under sticky prices is a set of plans for the control variables \(\{c_t, n_t, v_t, h_t, s_t, \Pi_t\}_{t=0}^{\infty}\) that maximize the utility of the representative household (24) subject to the five constraints named above.

Here again, we focus only on the role of distortions related to an inefficient choice of hours. Thus, we impose \(\tau^f = (1 - \gamma)\mu\) and \(\eta = \gamma\) in order to remove the vacancy-posting distortion. We investigate how the Ramsey policy is affected by deviations of the bargaining power \(\gamma\) from its optimal value in (33). First, we study the optimal dynamics for the case where worker’s bargaining power is lower than is optimal, \(\gamma < 2\varphi/(1 + \sigma_h)\). More precisely, in our calibration \(\gamma^{opt} = 0.72\) and we set \(\gamma = 0.5\). Second, we simulate the model under the Ramsey policy and compute volatility of inflation and unemployment as a function of the bargaining parameter, \(\gamma\).

The impulse response function of inflation, output, hours and unemployment, under the optimal policy and in the efficient allocation, are shown in Figure 5.

![Figure 5](insert Figure 5 here)

The left hand panel of Figure 5 shows the optimal responses of unemployment, hours and inflation after a **technology shock**, while the right hand column displays the Ramsey responses to a spending shock. Figure 5 shows that price stability is not optimal if the bargaining share deviates from the value given by (33). When \(\gamma < 2\varphi/(1 + \sigma_h)\), the worker’s bargaining power is low and so the firm benefits from a large cut in the real wage when it increases employment and decreases hours. In this situation, lower inflation mimics a higher bargaining power \(\gamma\) since it mitigates the fall in the real wage due to the switch from the intensive to the extensive labor margin.
In order to investigate how optimal volatilities vary with the hours distortion, Figure 6 depicts inflation and unemployment volatility in the Ramsey allocation as a function of $\gamma$. The horizontal axis plots the bargaining parameter $\gamma$ over the unit interval. On the vertical axis, we plot the standard deviation of inflation and unemployment divided by the standard deviation of output.

Figure 6 confirms that the optimal inflation volatility is nil when the steady state is efficient, i.e., when $\gamma = 2\phi/(1 + \sigma_h)$, and increases with the deviation of $\gamma$ from (33). As explained above, when the workers’ bargaining power is lower than $\gamma^{opt}$, firms are reluctant to use the intensive labor input margin by expanding hours; after an expansionary spending shock, hours rise too little and unemployment falls too much in the competitive equilibrium. By influencing the real wage, inflation can be used to tilt the trade-off between the two labor margins towards the efficient allocation.

To conclude, when the extensive labor margin is used excessively as a shock absorber due to a low bargaining power of workers, the Ramsey policy allows for some inflation variability in order to dampen fluctuations in unemployment.

5 Conclusion

We have documented that in countries with more procyclical labor productivity, unemployment is less volatile and inflation tends to be more stable. These phenomena can be captured in a dynamic stochastic equilibrium model with three key features: search and matching in the labor market, price rigidities and variable labor effort. We estimate the model on Euro Area data by matching the impulse responses of a vector autoregression in labor productivity and unemployment, identified with long run restrictions. The VAR results show that in the Euro Area, labor productivity is procyclical in response to non-technology shocks. We estimate the returns to hours in production and find a value significantly above unity, thus supporting our hypothesis that the effort margin plays a role in the adjustment to shocks.

We analyze how optimal monetary policy is affected by the existence of variable labor effort. The competitive allocation is characterized by distortions in the two labor inputs, hours and employment. In response to shocks, these wedges vary only with real marginal costs. Therefore, given an efficient steady state, policy can remove the cyclical distortions by keeping real marginal costs constant, which can be implemented through a policy of strict inflation targeting.

The steady state is characterized by three distortions, which interact due to the presence of
labor search, wage bargaining and pricing power in the same sector. We show how a revenue tax and the Hosios condition, i.e. the equality of the matching coefficient on unemployment and the worker’s bargaining power, are needed to ensure efficient vacancy posting. In equilibrium, hours are too low if the worker’s bargaining power is lower than a certain threshold. Then the firm has an incentive to post more vacancies than is optimal, because hiring an additional worker allows it to reduce the hours worked by all existing employees. Through wage bargaining, workers that enjoy a reduction in hours must accept a lower real wage in return. And that wage cut is greater, the lower is their bargaining power. So, in response to a positive demand shock, the firm expands the extensive margin (employment) too much relative to the intensive one (hours and effort). This is particularly detrimental to welfare if variable labor effort is an important adjustment margin and, consequently, production displays increasing returns to hours. If workers do not suffer much disutility from exerting more effort, it is welfare-improving to stabilize employment and to rely more on the intensive labor margin.

In response to spending shocks, inflation can be used to affect the real wage set through bargaining and thus the benefit of hiring new workers relative to expanding hours of existing workers. A fall in prices, by limiting the real wage cut resulting from a new hire and a corresponding fall in hours worked, makes the extensive margin less attractive for firms relative to the intensive one. Vacancy posting is discouraged and this stabilizes unemployment. Under the typical assumption of equal bargaining weights of firms and workers, it is optimal to allow for a some inflation volatility so as to reduce unemployment fluctuations.

References


Table 1. Parameters

<table>
<thead>
<tr>
<th>Calibrated Parameters</th>
<th>Value</th>
</tr>
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<tbody>
<tr>
<td>$\beta$ Discount factor</td>
<td>0.99</td>
</tr>
<tr>
<td>$\varepsilon$ Substitution elasticity between varieties</td>
<td>11.00</td>
</tr>
<tr>
<td>$\alpha$ Returns to effective hours in production</td>
<td>0.65</td>
</tr>
<tr>
<td>$\lambda_p$ Degree of price indexation</td>
<td>1.00</td>
</tr>
<tr>
<td>$\sigma_h$ Returns to hours in labor disutility</td>
<td>2.00</td>
</tr>
<tr>
<td>$\eta$ Matching function elasticity to unemployment</td>
<td>0.50</td>
</tr>
<tr>
<td>$\gamma$ Worker’s bargaining weight</td>
<td>0.50</td>
</tr>
<tr>
<td>$C_v$ Total vacancy posting costs over GDP</td>
<td>0.01</td>
</tr>
<tr>
<td>$C_g$ Government spending share</td>
<td>0.2</td>
</tr>
<tr>
<td>$q$ Steady state vacancy filling rate</td>
<td>0.70</td>
</tr>
<tr>
<td>$u$ Steady state unemployment rate</td>
<td>0.091</td>
</tr>
<tr>
<td>$p$ Steady state job finding rate</td>
<td>0.30</td>
</tr>
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<table>
<thead>
<tr>
<th>Estimated Parameters</th>
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<tbody>
<tr>
<td>$\sigma_e$ Returns to effort in labor disutility</td>
<td>2.001 (0.198)</td>
</tr>
<tr>
<td>$\kappa_p$ Rotemberg price adjustment cost parameter</td>
<td>11.125 (4.870)</td>
</tr>
<tr>
<td>$\rho_m$ Smoothing parameter of money growth</td>
<td>0.900 (0.365)</td>
</tr>
<tr>
<td>$\tau_a$ Policy response to technology shocks</td>
<td>0.037 (0.044)</td>
</tr>
<tr>
<td>$\tau_{a1}$ Policy response to lagged technology shocks</td>
<td>-0.066 (0.031)</td>
</tr>
<tr>
<td>$\rho_g$ Persistence non-technology shock</td>
<td>0.875 (0.025)</td>
</tr>
<tr>
<td>$\sigma_g$ Standard deviation non-technology shock</td>
<td>0.326 (0.085)</td>
</tr>
<tr>
<td>$\rho_a$ Persistence technology shock</td>
<td>0.676 (0.078)</td>
</tr>
<tr>
<td>$\sigma_a$ Standard deviation technology shock</td>
<td>0.002 (0.000)</td>
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</table>

<table>
<thead>
<tr>
<th>Implied Parameters</th>
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<tbody>
<tr>
<td>$\varphi$ Returns to hours in production</td>
<td>1.083 (0.014)</td>
</tr>
<tr>
<td>$\lambda$ Job separation rate</td>
<td>0.030</td>
</tr>
<tr>
<td>$\left(1-n\right)_h$ Ratio of home production to market output</td>
<td>0.104</td>
</tr>
</tbody>
</table>

$\mathcal{J}(\psi)$ 41.89 (0.09)
Labor productivity is measured as GDP divided by total employment and has been HP-filtered. The correlation with output is computed as the correlation of HP-filtered labor productivity with HP-filtered output. The standard deviation of inflation and unemployment are both divided by the standard deviation of output, to adjust for overall macroeconomic volatility.
Figure 2: Impulse Responses to Technology and Non-Technology Shocks

The figure displays the impulse response functions (IRFs) to a technology shock (first row) and to a non-technology shock (second row). The solid lines are the VAR-based IRFs. The lines with markers are the model-based IRFs. The shaded area is the 95% confidence interval.
The figure shows the deviation between the competitive steady state, which is subject to a distortion in hours, $\gamma < 2 \frac{\bar{\sigma}_h}{1 + \bar{\sigma}_h}$, and the efficient one. Notice that the competitive steady state is derived under the assumption of an optimal revenue tax, $\tau = (1 - \gamma)\mu$, and the Hosios condition, $\eta = \gamma$, which removes the hiring distortion. Notice that $\kappa_p = 0.0001$. The circles correspond to the case where the efficiency condition for hours is satisfied in the competitive allocation, i.e. $\gamma = 2 \frac{\bar{\sigma}}{1 + \bar{\sigma}_h}$. 

Figure 3: Effect of Hours Distortion on Steady State
The figure shows the impulse response functions (IRFs) to a one-standard-deviation technology shock (first column) and to a one-standard-deviation spending shock (second column). The solid lines represent the IRFs in the efficient allocation. The dashed lines show the IRFs under a steady-state distortion in hours, \( \gamma < 2 \frac{\kappa_p}{1 + \kappa_p} \). Notice that the dashed IRFs are derived under the assumption of flexible prices, \( \kappa_p = 0.0001 \), which removes the sticky-price distortion, as well as an optimal revenue tax, \( \tau^f = (1 - \gamma)\mu \), and the Hosios condition, \( \eta = \gamma \), which removes the hiring distortion.
The figure shows the impulse response functions (IRFs) to a one-standard-deviation technology shock (first column) and to a one-standard-deviation spending shock (second column). The solid lines represent the IRFs in the efficient allocation. The dashed lines represent the optimal responses under a steady-state distortion in hours, $\gamma < 2 \frac{\bar{\epsilon}}{1 + \sigma_h}$. The optimal responses are the solution to the linearized Ramsey first order conditions imposing an optimal revenue tax, $\tau^f = (1 - \gamma)\mu$ and the Hosios condition, $\eta = \gamma$. Inflation is expressed in annualized percentage terms.
Figure 6: Optimal Volatility of Inflation and Unemployment

Volatilities are computed by conducting 50 simulations of length 500 of the Ramsey allocation under an optimal revenue tax, $\tau^f = (1 - \gamma)\mu$, for a given value of $\varphi$. All standard deviations are normalized by the standard deviation of output.