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by Kai Christoffel, Keith Kuester and Tobias Linzert

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Keywords: Labor Market, wage rigidity, bargaining, Bayesian estimation

JEL Codes: E32,E52,J64,C11

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1 Introduction

Euro area labor markets are characterized by a long duration of individual unemployment spells and inflexible wages. The relationships between rigid labor markets and labor market outcomes, such as, for example, unemployment durations, have received great attention in both the academic literature and the political debate.[1] In contrast, little work is available on the link between structural features of the labor market and inflation, and particularly on the relevance of these features for monetary policy. This is the more astonishing as central bank practice puts considerable emphasis on monitoring the labor market, justified on two grounds: first, the structure of labor markets affects the transmission of shocks to marginal costs and inflation, and it affects the transmission of monetary policy to the economy; second, the labor market is itself an important source of business cycle fluctuations, and thereby has a significant impact on real activity and inflation.

The contribution of this paper is to examine the role of rigid labor markets for monetary policy in the euro area along these two dimensions. We first analyze to what extent the business cycle and monetary policy transmission are affected by changes in the underlying institutions governing the labor market. We specifically look at labor market structures that differ from the baseline setting with respect to the replacement rate, the bargaining power of workers, the costs of posting vacancies and the degree of wage rigidity. For the model simulations, we employ a genuine euro area calibration. Second, we analyze whether, given the current state of labor market institutions, the labor market itself is an important source of business cycle shocks. Toward this aim, we estimate the model on euro area data, investigating specifically the impact of three labor market shocks (shocks to bargaining power, shocks to job destruction and shocks to hiring impediments) on business cycle fluctuations.

We build a New Keynesian model with a non-Walrasian labor market along the lines of Trigari (2006). Calibrating this model to the euro area, we quantitatively assess how the specific institutional aspects of the labor market affect the transmission of business cycle shocks and, most prominently, the transmission of a monetary policy shock. Rigidities and frictions in the

[1] The political efforts for making the EU more dynamic and competitive as established by the Lisbon Agenda set out by the European Council in March 2000 bear witness to that debate. In light of this, assessing the role that changes in labor markets have for monetary policy will become increasingly important as the Lisbon Agenda is being implemented in the member states.

labor market may affect inflation dynamics - and hence are of relevance for the transmission of monetary policy - in various ways. First, sluggishness in wages directly affects firms' marginal costs and their price setting and hence ultimately feeds through to the dynamics in inflation, particularly its persistence. Second, rigidities in the labor market may affect the fluctuations in hours worked which may affect inflation dynamics via their effect on firm's marginal costs through changes in the marginal product of labor. The institutional features that we consider in this paper will affect inflation through one or a combination of these two channels.

We find that a labor market characterized by a lower degree of wage rigidity significantly changes the transmission of shocks in our model economy. For example, monetary policy becomes more effective, i.e., a monetary policy shock transmits faster to inflation, and inflation becomes less persistent. In contrast, altering other labor market characteristics, such as lowering firms' overhead labor costs, reducing the net replacement rate of unemployment insurance or reducing the costs of posting a vacancy, would have an effect on the steady state of the economy but would have little effect on the fluctuations around the steady state beyond the transition phase.

Estimating the same model using Bayesian techniques and allowing labor market shocks to affect the economy (in the analysis these are shocks to the costs of posting a vacancy, to the rate of separation, and to the bargaining power of workers), we find that shocks to the costs of posting a vacancy and to the separation rate seem to be less important for euro area business cycle fluctuations. In contrast, shocks to the bargaining power of workers explain a considerable share of the fluctuations in inflation and output. Therefore, while monetary policy may not need to react to the former shocks, closely monitoring the wage process and wage-bargaining disturbances appears to provide valuable information for monetary stabilization policy.

We use a New Keynesian DSGE model with Mortensen and Pissarides (1994) type search and matching frictions. Key to our model is the channel from wages to inflation, which crucially hinges on Trigari's (2006) right-to-manage (RTM) framework. Under RTM workers and firms bargain only about the hourly wage rate and the firm chooses employment along the intensive (i.e., the hours worked) margin in a second step. One can show that in this case a direct channel from wages to inflation exists, so that the level of hourly wages and their stickiness play a direct role for inflation dynamics; see, e.g., Trigari (2006) and Christoffel and Linzert (2005). Allowing for the existence of such a wage channel is in line with much of the New Keynesian modeling tradition, e.g. Christiano, Eichenbaum, and Evans (2005) and Smets and Wouters (2003).[2]

We complement Trigari's (2006) right-to-manage model with Calvo type wage rigidities. These shift the labor market adjustment from prices to quantities and affect the degree of inflation persistence in our model.[3] Moreover, we follow Christoffel and Kuester (2008) and account for fixed costs associated with maintaining a job. These fixed costs allow calibrating the model so as to endogenously account for the size of unemployment fluctuations over the cycle. We use the model to assess the importance of various forms of labor market rigidities for business cycle fluctuations, and their relevance for monetary policy. Unlike Trigari, we explicitly first calibrate and then estimate the model using euro area data. Given the limited coverage of the euro area in the previous literature, we devote considerable effort to calibrate the model in a reasonable way, particularly in terms of the replacement rate, the job filling rate and the separation rate.

A growing literature incorporates more complex and more realistic labor markets into monetary business cycle models. Walsh (2005) focuses on the real effects of monetary policy shocks. Krause and Lubik (2007) analyze the role of wage rigidities in a model with efficient Nash bargaining. Zanetti (2007) is concerned with the business cycle when the labor market itself is frictionless but atomistic unions set the wage above the market-clearing level. Zanetti calibrates his model to the euro area, but employment is the only labor market variable in his model. In our paper, instead, we focus on search and matching frictions rather than unionization, which necessitates a much wider set of labor market parameters to be calibrated for the euro area.

The remainder of the paper is structured as follows. We present a New Keynesian model with equilibrium unemployment in Section 2. We calibrate the model to the euro area in Section 3. Section 4 shows how different labor market settings affect the business cycle and, in particular, monetary policy transmission. Section 5 estimates the model by Bayesian techniques, thereby identifying labor market shocks. We subsequently analyze whether these shocks are important determinants of business cycle fluctuations of output and inflation. A final section concludes. The Appendix presents the steady state, the linearized version of the model, and background

[2] This direct channel would be missing when applying the efficient bargaining assumption, which is the workhorse in the literature; see Krause and Lubik (2007). Under both bargaining regimes, however, there is also an indirect channel from wages to inflation *via* employment, hours worked and their impact on marginal costs.

[3] We are not the first to introduce staggered wage setting into models with matching frictions. Our motivation follows Gertler and Trigari (2006), who combine staggered wage setting with Nash efficient bargaining in a real business cycle framework.

information on the calibration of the replacement rate and the separation rate. Furthermore, the Appendix provides information with regard to the fit of the calibrated and the estimated version of the model.

2 The Model

We build a closed-economy, single-country New Keynesian model for the euro area, which is augmented by Mortensen and Pissarides (1994) type matching frictions. Our model incorporates the following features. First, we build on Trigari's (2006) right-to-manage framework to allow for a direct channel from wages to inflation. Second, once a firm and a worker have met, they bargain over the hourly wage rate only infrequently, where the staggering of the wage-setting process is modeled following Calvo (1983). And third, we follow Christoffel and Kuester (2008) in accounting for job-related fixed costs.

2.1 Preferences and Consumers' Constraints

Consumers have time-additive expected utility preferences. Preferences of consumer i can be represented by

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \mathtt{u} \left(c_{i,t}, c_{t-1}, h_{i,t} \right) \right\}, \tag{1}$$

where E_0 marks expectations conditional on period 0 information. $\mathtt{u}(c_{i,t}, c_{t-1}, h_{i,t})$ is a standard period utility function of the form

$$\mathtt{u}(c_{i,t}, c_{t-1}, h_{i,t}) = \frac{(c_{i,t} - \varrho c_{t-1})^{1-\sigma}}{1-\sigma} - \kappa^L \frac{(h_{i,t})^{1+\varphi}}{1+\varphi},\ \sigma > 0,\ \varphi > 0. \tag{2}$$

Here, $c_{i,t}$ denotes consumption of consumer i, c_{t-1} denotes aggregate consumption last period and $h_{i,t}$ are hours worked by consumer i. κ^L is a positive scaling parameter of disutility of work and $\varrho \in [0, 1)$ indicates an external habit motive.

Consumers Live in Large Families

There is a large number of identical families in the economy with unit measure. Each family consists of a measure of $n_t = 1 - u_t$ employed members and u_t unemployed members, both with above preferences. The representative family pools the income of its working members, unemployment benefits of the unemployed members and financial income from assets that family members hold via a mutual fund. Its budget constraint is given by

$$c_t + t_t + \kappa_t v_t = \int_0^{1-u_t} w_{i,t} h_{i,t} \mathrm{d}i + u_t b + \frac{D_{t-1}}{P_t} R_{t-1} \epsilon_{t-1}^b - \frac{D_t}{P_t} + \Psi_t + n_t \Phi^K, \tag{3}$$

where c_t is a choice variable of the family. t_t are lump-sum taxes per capita payable by the family. $\kappa_t v_t$ are vacancy posting costs multiplied by the number of posted vacancies. $w_{i,t} h_{i,t}$ is the wage per hour times hours worked by individual household member i. b are real unemployment benefits paid to an unemployed family member. The family holds D_t units of a risk-free one-period nominal bond (government debt) with gross nominal return $R_t \epsilon_t^b$ in $t+1$. ϵ_t^b denotes a serially correlated shock to the risk premium, where

$$\log(\epsilon_t^b) = \rho_b \log(\epsilon_{t-1}^b) + e_t^b, \quad \rho_b \in [0,1), \text{ with } e_t^b \overset{iid}{\sim} N(0, \sigma_b^2).$$

This shock drives a wedge between the return on assets held by households and the interest rate controlled by the central bank; see Smets and Wouters (2007). The household also owns representative shares of all firms in the economy. Ψ_t denotes real dividend income per member of the family arising from these firms' profits in period t. Since our model does not explicitly account for capital income, we assume that the family also receives a fixed share $n_t \Phi^K, \Phi^K \geq 0$, out of current revenue of labor firms as "capital income." Dividend income *ex* capital income-payment by firms splits into

$$\Psi_t = \Psi_t^C + \int_0^{1-u_t} \Psi_{i,t}^L \mathrm{d}i, \tag{4}$$

where Ψ_t^C and $\int_0^{1-u_t} \Psi_{i,t}^L \mathrm{d}i$ are the profits arising in the differentiating industry and in the labor good industry, respectively; these terms are described in Sections 2.2 and 2.3.

The family maximizes the sum of unweighted expected utilities of its individual members,

$$\int_0^1 E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \mathrm{u}\left(c_{i,t}, c_{t-1}, h_{i,t}\right) \right\} \mathrm{d}i, \tag{5}$$

by taking consumption, saving, vacancy posting and labor supply decisions on their behalf. The corresponding Euler equation for the consumption-saving decision is given by

$$1 = E_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \frac{R_t \epsilon_t^b}{\Pi_{t+1}} \right\}, \tag{6}$$

where marginal utility of consumption is $\lambda_t = (c_t - \varrho c_{t-1})^{-\sigma}$.[4] The optimal consumption plan satisfies the transversality condition

$$\lim_{j\to\infty} E_t \left\{ \beta^j \frac{\lambda_{t+j}}{\lambda_t} \frac{D_{t+j}}{P_{t+j}} \right\} = 0, \ \forall t.$$

The vacancy posting and labor supply decisions are discussed in Section 2.3.

2.2 Firms

There are three sectors of production. Firms in the first sector produce a homogeneous intermediate good, labeled the "labor good." Firms in this sector need to find exactly one worker in order to produce. Labor goods are sold to a wholesale sector in a perfectly competitive market. Firms in the wholesale sector take the intermediate labor good as their sole input and produce differentiated goods by using a constant-returns-to-scale production technology. Subject to price-setting impediments, which are modeled following Calvo (1983), they sell to a final retail sector under monopolistic competition.[5]

Retailers bundle differentiated goods into a homogeneous consumption/investment basket, y_t. They sell this final good to consumers and to the government at price P_t.

Retail Firms

The retail sector operates in perfectly competitive factor markets. It takes wholesale goods of type $j \in [0,1]$, labeled $y_{j,t}$, and aggregates these varieties into the final good, y_t, according to

$$y_t = \left(\int_0^1 y_{j,t}^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}j \right)^{\frac{\epsilon}{\epsilon-1}}, \epsilon > 1. \tag{7}$$

The cost-minimizing expenditure, P_t, needed to produce one unit of the final good is given by

$$P_t = \left(\int_0^1 P_{j,t}^{1-\epsilon} \mathrm{d}j \right)^{\frac{1}{1-\epsilon}}, \tag{8}$$

[4] Due to additive separability of preferences of each family member in consumption and leisure, the family optimally allocates the same consumption stream to each member, $c_{i,t} = c_t$, whether employed or unemployed.

[5] Following the literature (see, e.g., Trigari, 2006) we separate the markup pricing decision from the labor demand decision. For an application that operates with temporarily firm-specific labor and a matching market in the price-setting sector, see Kuester (2007).

where $P_{j,t}$ marks the price of good $y_{j,t}$. P_t coincides with the consumer/GDP price index. The demand function for each single good $y_{j,t}$ is given by

$$y_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} y_t, \tag{9}$$

where $\epsilon > 1$ is the own-price elasticity of demand.

Wholesale Firms

Firms in the wholesale sector have unit mass and are indexed by $j \in [0, 1]$. Firm j produces variety j of a differentiated good according to

$$y_{j,t} = l^d_{j,t}. \tag{10}$$

Here $l^d_{j,t}$ denotes its demand for the intermediate labor good, which a wholesale firm j can acquire in a perfectly competitive market at real price x^L_t. Real period profits of firm j, $\Psi^C_{j,t}$, are given by

$$\Psi^C_{j,t} = \frac{P_{j,t}}{P_t} y_{j,t} - e^C_t l^d_{j,t} x^L_t.$$

The first term gives wholesale firm revenues, and the second term marks real payments for the labor good. e^C_t is an i.i.d. wholesale sector "cost-push" shock with $\log(e^C_t) \overset{iid}{\sim} N(0, \sigma^2_C)$.[6]

We assume that in each period a random fraction $\omega \in [0, 1)$ of firms cannot re-optimize their price. As in Smets and Wouters (2003) these firms partially index their price to last period's inflation rate, Π_{t-1}, and partially to the steady state inflation rate, Π. The indexation factor is $\Pi^{\xi_p}_{t-1}\Pi^{1-\xi_p}$ with the degree of indexation to past inflation given by $\xi_p \in [0, 1]$. Those firms that re-optimize their price in period t face the problem of maximizing the value of their enterprise by choosing their sales price, $P_{j,t}$, taking into account the pricing frictions, demand function (9) and production function (10). Realizing that for any given demand the optimal factor input choice leads to marginal costs that are independent of the production level, the price-setting

[6] There are alternative ways of introducing shocks to the Phillips curve in the literature. Other papers, Smets and Wouters (2003), for example, model the elasticity of demand, ϵ, as time-varying. This leads to fluctuations in firms' markups. These shocks appear in the Phillips curve exactly the way that our cost-push shocks do. Up to a first-order approximation, both formulations yield identical results for model dynamics. The reader can therefore interpret the cost-push shocks as well as the "price markup shocks."

problem for a firm that can re-optimize its price in period t simplifies to

$$\max_{P_{j,t}} E_t \left\{ \sum_{s=0}^{\infty} \omega^s \beta_{t,t+s} \left[\frac{P_{j,t} \left(\Pi_{t-1,t-1+s}^{\xi_p} \left(\Pi^{1-\xi_p} \right)^s \right)}{P_{t+s}} - mc_{t+s} \right] y_{j,t+s} \right\}. \tag{11}$$

The term in brackets in the numerator above represents the partial indexation mechanism, with $\Pi_{t-1,t-1+s} = \frac{P_{t-1+s}}{P_{t-1}}$. Above, mc_t are real marginal costs, with $mc_t = e_t^C x_t^L$, and $\beta_{t,t+s} := \beta^s \frac{\lambda_{t+s}}{\lambda_t}$ is the equilibrium stochastic discount factor. The typical re-optimizing wholesale firm's first-order condition for price-setting is:

$$E_t \left\{ \sum_{s=0}^{\infty} \omega^s \beta_{t,t+s} \left[\frac{P_t^* \left(\Pi_{t-1,t-1+s}^{\xi_p} \left(\Pi^{1-\xi_p} \right)^s \right)}{P_{t+s}} - \frac{\epsilon}{\epsilon - 1} mc_{t+s} \right] y_{j,t+s} \right\} = 0, \tag{12}$$

where P_t^* marks the optimal price set in period t. Linearizing this first-order condition around steady state leads to the standard New Keynesian Phillips curve with a backward-looking element. Total real profits of the wholesale (Calvo) sector are $\Psi_t^C = \int_0^1 \Psi_{j,t}^C \mathrm{d}j$, where

$$\Psi_{j,t}^C = \left\{ \frac{P_{j,t}}{P_t} - mc_t \right\} y_{j,t} \tag{13}$$

denotes the period profits of firm j. These profits accrue to the representative family, cp. equations (3) and (4).

Labor Good Firms

The labor good is homogeneous. Firms in this sector need to find exactly one worker in order to produce. In period t there is thus a mass of $(1 - u_t)$ operative labor firms. Match i can produce amount $l_{i,t}$ of the labor good using hours worked according to

$$l_{i,t} = z_t h_{i,t}^{\alpha}, \ \alpha \in (0, 1). \tag{14}$$

Labor-augmenting productivity z_t is identical over the different matches and follows

$$\log(z_t) = (1 - \rho_z) \log(z) + \rho_z \log(z_{t-1}) + e_t^z, \quad \rho_z \in [0, 1), \text{ where } e_t^z \overset{iid}{\sim} N(0, \sigma_z^2).$$

2.3 Labor Market

We now turn to the specification of the labor market in our model. We first describe the matching technology and then focus on the bargaining and vacancy posting decisions.

Matching Firms and Workers

The matching process is governed by a standard Cobb-Douglas aggregate matching technology

$$m_t = \sigma_m (u_t)^{\xi} (v_t)^{1-\xi}, \xi \in (0,1). \tag{15}$$

Here $\sigma_m > 0$ is a parameter governing the matching efficiency, m_t is the number of new matches between workers and firms, and v_t is the number of economy-wide job vacancies. We define aggregate labor market tightness as

$$\theta_t := \frac{v_t}{u_t}. \tag{16}$$

The probability that a particular vacancy of a firm will be filled is

$$q_t := \frac{m_t}{v_t} = \sigma_m \theta_t^{-\xi}. \tag{17}$$

The probability of finding a worker when a vacancy has been opened is falling in market tightness, and thus in the number of vacancies other firms post, showing the congestion externality of new vacancies. The probability that an individual unemployed worker finds a job,

$$s_t := \frac{m_t}{u_t} = \sigma_m \theta_t^{1-\xi}, \tag{18}$$

in turn is increasing in aggregate market tightness. Each new unemployed worker decreases the tightness of the labor market and therefore means a negative labor market tightness externality to other workers searching for employment. Separations occur with an exogenous probability $\vartheta_t \in (0,1)$ in each period. The separation rate evolves as follows

$$\log(\vartheta_t) = (1-\rho_\vartheta)\log(\vartheta) + \rho_\vartheta \log(\vartheta_{t-1}) + e_t^\vartheta, \quad \rho_\vartheta \in [0,1), \text{ where } e_t^\vartheta \overset{iid}{\sim} N(0, \sigma_\vartheta^2).$$

New matches in t, m_t, become productive for the first time in $t+1$. The employment rate

$n_t := 1 - u_t$ evolves according to

$$n_t = (1 - \vartheta_t) n_{t-1} + m_{t-1}. \tag{19}$$

Bargaining under Wage Rigidities

Due to the matching frictions and decreasing returns to scale at the individual labor firm level, formed matches *ex post* entail economic rents. Firms and workers bargain about their share of the overall match surplus. We follow den Haan, Ramey, and Watson (2000) in assuming that the family takes the labor supply decision for its workers.

The value (to the family) of a worker who is employed and receives nominal wage $W_{i,t}$ is

$$\begin{aligned} V_t^E\left(W_{i,t}\right) \;=\; & \tfrac{W_{i,t}}{P_t} h_{i,t} - \kappa^L \tfrac{h_{i,t}^{1+\varphi}}{(1+\varphi)\lambda_t} \\ & + E_t\left\{\beta_{t,t+1}(1-\vartheta_{t+1})\left[\gamma V_{t+1}^E\left(W_{i,t}\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right) + (1-\gamma) V_{t+1}^E\left(W_{t+1}^*\right)\right]\right\} \\ & + E_t\left\{\beta_{t,t+1}\vartheta_{t+1} U_{t+1}\right\}. \end{aligned} \tag{20}$$

The value of a worker in employment depends on his wage income, which is determined by the product of the nominal wage rate, $W_{i,t}$, and the hours worked, $h_{i,t}$. The final term in the first row pertains to the utility loss from working. In the next period, an employed worker retains his job with probability $1 - \vartheta_{t+1}$. If he stays employed in $t+1$, with probability γ he will not be able to re-bargain the nominal wage. In case the worker cannot renegotiate his wage, the nominal wage is partially indexed to inflation by $\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]$, $\xi_w \in [0,1]$, as in Smets and Wouters (2003), in which case his value to the family is $V_{t+1}^E\left(W_{i,t}\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right)$. Or he is able to re-bargain, in which case his value reflects the optimal re-bargained wage rate in $t+1$: $V_{t+1}^E(W_{t+1}^*)$. With probability ϑ_{t+1} he will be unemployed next period. The value to the family of having a worker who is unemployed is given by

$$\begin{aligned} U_t \;=\; b \; & + E_t\left\{\beta_{t,t+1} s_t \left[\gamma V_{t+1}^E\left(W_t\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right) + (1-\gamma) V_{t+1}^E\left(W_{t+1}^*\right)\right]\right\} \\ & + E_t\left\{\beta_{t,t+1}(1-s_t) U_{t+1}\right\}. \end{aligned} \tag{21}$$

Here b is the value of real unemployment benefits. A worker who is unemployed in t has a chance of s_t of finding a new job that is productive from $t+1$ onward. This newly hired worker enters the same Calvo scheme as the average currently employed worker. With probability $(1-\gamma)$ the family can bargain the wage in $t+1$ on his behalf, with probability γ he will start working at the average nominal hourly wage rate of existing contracts in t partially indexed to inflation, $W_t\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]$. This implies stickiness of hourly wage rates also for new matches. The rationale is that actual firms in the economy have many jobs, i.e., firm-worker matches. These jobs may be filled at different moments of time, while the firm itself adjusts its entire wage structure only infrequently. As a result, the individual worker who joins a firm between two adjustment points receives the prevailing wage rate at that multi-worker firm. A similar assumption is made by Gertler and Trigari (2006).[7]

Let $\Delta_t(W_{i,t}) := V_t^E(W_{i,t}) - U_t$ denote the family's surplus from having a worker in employment at wage $W_{i,t}$ rather than having him unemployed. One can show that

$$\begin{aligned}\Delta_t(W_{i,t}) \quad = \quad & \tfrac{W_{i,t}}{P_t}h_{i,t} - b - \kappa^L\tfrac{(h_{i,t})^{1+\varphi}}{(1+\varphi)\lambda_t} \\ & +E_t\left\{\beta_{t,t+1}(1-\vartheta_{t+1})\gamma\left[V_{t+1}^E\left(W_{i,t}\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right) - V_{t+1}^E\left(W_{t+1}^*\right)\right]\right\} \\ & -E_t\left\{\beta_{t,t+1}s_t\gamma\left[V_{t+1}^E\left(W_t\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right) - V_{t+1}^E\left(W_{t+1}^*\right)\right]\right\} \\ & +E_t\left\{\beta_{t,t+1}(1-\vartheta_{t+1}-s_t)\Delta_{t+1}(W_{t+1}^*)\right\}.\end{aligned} \tag{22}$$

Due to free entry in the vacancy posting market, in equilibrium firms are economically worthless when they are separated from a worker. The market value, $J_t(W_{i,t})$, of a labor firm matched to a worker who receives nominal wage $W_{i,t}$ therefore is given by

$$\begin{aligned}J_t(W_{i,t}) \quad = \quad & \Psi_t^L(W_{i,t}) \\ & +E_t\left\{\beta_{t,t+1}(1-\vartheta_{t+1})\left[\gamma J_{t+1}\left(W_{i,t}\left[\Pi_t^{\xi_w}\left(\Pi^{1-\xi_w}\right)\right]\right) + (1-\gamma)J_{t+1}\left(W_{t+1}^*\right)\right]\right\}.\end{aligned} \tag{23}$$

Here

$$\Psi_t^L(W_{i,t}) = x_t^L z_t h_{i,t}^{\alpha} - \frac{W_{i,t}}{P_t}h_{i,t} - \Phi \tag{24}$$

denotes real per-period profits of the firm when the nominal wage rate is $W_{i,t}$. $h_{i,t}$ is the firm's labor input. x_t^L is the competitive price for the labor good in real terms, $\Phi \geq 0$ denotes a per-

[7] Christoffel and Kuester (2008) show that the existence of a wage channel under RTM does not depend on sticky entry wages. Similarly, the existence of sticky entry wages is not crucial for unemployment fluctuations when RTM bargaining is used; see Christoffel *et al.* (2008). The latter is in contrast to EB.

period fixed cost of production. For calibration purposes, this fixed cost is split into a putative cost of capital, which accrues to the owners of the firm, $\Phi^K \geq 0$, and a fixed overhead cost of production, which is pure waste, $\Phi^L \geq 0$, so $\Phi = \Phi^K + \Phi^L$.[8]

With right-to-manage wage bargaining, facing a certain hourly wage rate firms decide unilaterally about their demand for hours worked. Each labor firm i optimally demands labor at the intensive margin until the marginal value product of every labor firm i, $x_t^L mpl_{i,t}$, equals the real hourly wage rate at that firm:

$$x_t^L mpl_{i,t} = \frac{W_{i,t}}{P_t}, \text{ where } mpl_{i,t} := z_t \alpha h_{i,t}^{\alpha-1}. \tag{25}$$

For those firms that bargain in a given period, nominal wages are determined by means of Nash bargaining over the match surplus:

$$\arg\max_{W_{i,t}} \left[\Delta_t(W_{i,t})\right]^{\eta_t} \left[J_t(W_{i,t})\right]^{1-\eta_t} \quad \Rightarrow W_t^* \tag{26}$$

where $\eta_t \in (0,1)$ denotes the possibly time-varying bargaining power of the workers or, respectively, of their families:

$$\log(\eta_t) = (1-\rho_\eta)\log(\eta) + \rho_\eta \log(\eta_{t-1}) + e_t^\eta, \quad \rho_\eta \in [0,1), \text{ and } e_t^\eta \overset{iid}{\sim} N(0, \sigma_\eta^2).$$

The optimization in (26) takes into account that each firm sets hours worked optimally according to (25) in each period.[9]

[8] Job-related fixed costs are costs that are independent of the actual hours worked per employee (but not of the number of employees). In our model they make a firm's surplus (and thus its hiring incentives) more responsive to economic shocks. In practice such job-related fixed costs arise both on the labor and the capital side. On the labor side most prominently some employer benefits are not linked to the actual input of hours worked (and current earnings). An example of this is a fixed entitlement of paid leave per quarter. As Table 5 shows, in our calibration this share is reasonably small, less than a percent of output. On the capital side, too, and even more so some expenditure seems relatively inelastic to the actual hours worked per employee, a prime example being rental costs for office space, or other longer-term financial liabilities. This cost, Φ^K, consequently is larger in our calibration.

[9] The corresponding first-order condition for the wage is $\eta_t J_t(W_t^*)\delta_t^W = (1-\eta_t)\Delta_t(W_t^*)\delta_t^F$. Here δ_t^W is the marginal gain in surplus of the worker when increasing the wage rate, δ_t^F the marginal loss of the firm. The resulting expressions for δ_t^W and δ_t^F are complicated and add little to the economic intuition. See Appendix A.2 for linearized versions. See Trigari (2006) for the wage equation under RTM in the absence of wage stickiness.

Vacancy Posting

Free entry into the vacancy posting market drives the *ex ante* value of a vacancy to zero. In equilibrium, real vacancy posting costs, κ_t, equal the expected value of a labor firm properly discounted to t, so

$$\kappa_t = q_t E_t \left\{ \beta_{t,t+1} \left[\gamma J_{t+1} \left(W_t \left[\Pi_t^{\xi_w} \left(\Pi^{1-\xi_w} \right) \right] \right) + (1-\gamma) J_{t+1}(W_{t+1}^*) \right] \right\}. \tag{27}$$

The term in square brackets reflects our assumption that newly started jobs face the same Calvo rigidities as incumbent jobs. This is motivated by the existence of wage structures in multi-worker firms (these firms being the collection of many jobs) that are adjusted only infrequently. With probability $(1-\gamma)$ the firm-worker pair can reset its wage. With the remaining probability, the wage is set to the average wage rate that prevailed in the previous period. κ_t evolves according to

$$\log(\kappa_t) = (1-\rho_\kappa)\log(\kappa) + \rho_\kappa \log(\kappa_{t-1}) + e_t^\kappa, \quad \rho_\kappa \in [0,1), \text{ and } e_t^\kappa \overset{iid}{\sim} N(0, \sigma_\kappa^2).$$

2.4 Monetary Policy and Fiscal Policy

The monetary authority controls the risk-free wholesale interest rate on nominal bonds, R_t. The empirical literature (see, e.g., Clarida, Gali, and Gertler, 1998, Smets and Wouters, 2005) finds that simple generalized Taylor-type rules of the form

$$\begin{aligned} \log(R_t) \quad = \quad & (1-\gamma_R)\log\left(\frac{\overline{\Pi}}{\beta}\right) + \gamma_R \log(R_{t-1}) + \gamma_{\Delta y}\log\left(\frac{y_t}{y_{t-1}}\right) \\ & +(1-\gamma_R)\left[\frac{\gamma_\pi}{4}\log\left(\frac{\Pi_t^{\text{yoy}}}{\overline{\Pi}^4}\right) + \frac{\gamma_y}{4}\log\left(\frac{y_t}{y_t{}^{\text{flex}}}\right)\right] + \log(e_t^{money}), \end{aligned} \tag{28}$$

once linearized are a good representation of monetary policy in recent decades in a number of countries. Here $\overline{\Pi}$ is the inflation target, and $y_t{}^{\text{flex}}$ is the flexible price/flexible wage output level in the economy. This is the hypothetical level of output in the absence of nominal rigidities taking the states in the actual economy as given. $\log(e_t^{money}) \overset{iid}{\sim} N\left(0, \sigma_{\text{money}}^2\right)$ is a shock to monetary policy.

Government spending, g_t, is exogenous and follows

$$\log(g_t) = (1-\rho_g)\overline{g} + \rho_g \log(g_{t-1}) + e_t^g, \text{ where } \rho_g \in [0,1), \text{ and } e_t^g \overset{iid}{\sim} N(0,\sigma_g^2),$$

and $\overline{g}$ is the long-run target level of government spending. The government budget constraint is given by

$$t_t + \frac{D_t}{P_t} + (e_t^C - 1)x_t^L = u_t b + \frac{D_{t-1}}{P_t} R_{t-1}\epsilon_{t-1}^b + g_t. \tag{29}$$

The government generates revenue from lump-sum taxes, t_t. It also earns income through new debt issues, $\frac{D_t}{P_t}$ (left-hand side). The last term on the left-hand side clarifies the nature of our modeling of the cost-push shock, e_t^C. The shock is modeled as a lump-sum tax so that it does not enter the economy's resource constraint. Up to first-order, this modeling delivers the same results as when shocks to the price markup existed; cf., for example, Smets and Wouters (2003). On the expenditure-side appear unemployment benefits (the term involving b), debt repayment and coupon as well as government spending. We assume that fiscal policy is debt-stabilizing.

2.5 Market Clearing

Retail output is used for private and government consumption and for vacancy posting activity and the fixed overhead costs of producing labor goods. Total demand is thus given by

$$y_t^d = c_t + g_t + \kappa_t v_t + n_t \Phi^L. \tag{30}$$

Market clearing in the retail market requires that the demand for retail goods equal total supply, which is given by $y_t = \left[\int_0^1 \left(y_{j,t}^d\right)^{\frac{\epsilon-1}{\epsilon}} \mathrm{d}j\right]^{\frac{\epsilon}{\epsilon-1}}$. For each firm j in the wholesale sector, its supply $y_{j,t} = l_{j,t}^d$, must be matched by the corresponding demand $y_{j,t}^d = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} y_t$ in order to clear the wholesale market. The total demand for the labor good is given by $l_t^d = \int_0^1 l_{j,t}^d \mathrm{d}j$, where $l_{j,t}^d$ marks demand for the labor good by individual wholesale firm j. Market clearing requires that total demand for the labor good equal the supply of the labor good, which is given by $l_t^d = z_t \int_0^{1-u_t} h_{i,t}^\alpha \mathrm{d}i$.

3 Euro Area Data and a Calibrated Version of the Model

We calibrate the model to the euro area as of the end of 2006.[10] For individual euro area countries it is well documented that aggregate macroeconomic time series have become less volatile starting from the 1980s; see Stock and Watson (2005). Hence, we employ only quarterly data from 1984Q1 to 2006Q4 for the calibration. All euro area-wide data are taken from the Area-Wide-Model database.[11]

The AWM data set does not include two of the central labor market series for estimating the model: hours worked per employee and vacancies, both of which are not readily available for the euro area. Instead we resort to proxies. First, we entertain a euro area proxy, in which a quarterly series for total hours worked is obtained from the annual euro area figures from the EU KLEMS database interpolated with euro area GDP. An index of vacancies is constructed based on individual euro area country vacancy data following ECB (2002), covering around 60% of the euro area.[12] Second, as an alternative, we use German data to proxy for euro area vacancies and hours, thus assuming implicitly that business cycles in the euro area and Germany are fully synchronized. The vacancy series corresponds to "Offene Stellen" from the German Federal Employment Agency. The German series for quarterly hours worked is taken from the ESA quarterly national accounts.

The rows in brackets in Table 1 present the second moments of the data. All data are in logs, hp(1,600) filtered and multiplied by 100 thereafter in order to obtain percentage fluctuations. The first column gives the notation of the variable in our model. The third column shows the standard deviation of the series and the fifths column displays the standard deviation of the respective series relative to that of output. The last column reports the serial correlation of the

[10] The euro area at that point comprised Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain.

[11] We use the unemployment rate and the 3-month short-term nominal interest rate. Output is measured by nominal GDP divided by the GDP deflator. Similarly, government spending is deflated by the GDP deflator. Inflation is measured by year-on-year GDP inflation. Total real wages are computed by dividing compensation to employees by the GDP deflator. The real wage per employee is obtained by dividing this series by the number of employees.

[12] ECB (2002) describes the data available for measuring vacancies in the euro area. We use OECD data for Austria, Belgium, Germany, Spain, Finland, Luxembourg, and Portugal and BIS data for the Netherlands, from which we construct a population-weighted euro area vacancy measure. Vacancy data correspond to vacancies posted at public employment agencies and do not take into account other sources of offers, such as newspapers, the Internet and private agencies.

respective series. It is worthwhile to mention that the second moments of the euro area data do not display pronounced differences to the respective U.S. series.

Euro Area Calibration

The calibration of the model for the euro area is summarized in Table 5, in Appendix B. Note that this calibration also forms the basis for the priors in the Bayesian estimation exercise in Section 5. The time-discount factor, β, is chosen to match an average annual real rate of 3.3%. The value of the curvature of disutility of work, $\varphi = 2$, follows the estimates of Smets and Wouters (2003).[13] The value of the risk aversion coefficient is set to $\sigma = 1.5$ and habit persistence, $\varrho = 0.6$, in line with the estimates by Smets and Wouters (2003). κ^L targets hours per worker, $h = 1/3$.

Turning to the labor good sector and the labor markets, we set parameter α to the conventional value of $\alpha = 0.66$, targeting a labor share of 60%. On monthly data ranging to the early 1990s, Burda and Wyplosz (1994) estimate an elasticity of matches with respect to unemployment of $\xi = 0.7$ for France, Germany and Spain. Petrongolo and Pissarides (2001) survey estimates of the matching function for European countries and for the U.S. and conclude that a range from $\xi = 0.5$ to $\xi = 0.7$ is most reasonable.[14] We select the midpoint, setting $\xi = 0.6$. We set the quarterly job separation rate, ϑ, to 3% following the evidence for the euro area collected in Appendix C.2. This squares well with indirect evidence for OECD countries presented by Hobijn and Sahin (2007). The bargaining power of the worker is set to a conventional value of $\eta = 0.5$. We target a probability of finding a worker when having opened a vacancy of $q = 0.7$, in line with the evidence reported in ECB (2002) and Weber (2000).[15] We further target an unemployment rate in steady state of $u = 9.1\%$, which is the average unemployment rate in our sample. In order to match these two targets, the efficiency of the matching process is set to

[13] The elasticity of inter-temporal substitution of labor, $1/\varphi$, is small in most microeconomic studies (between 0 and 0.5) for the euro area; for details, see Evers, Mooij, and Vuuren (2005), who report statistics based on a meta sample as well as estimates based on Dutch data.

[14] The estimates Petrongolo and Pissarides (2001) summarize show more variability than suggested by this range, and several papers estimate a lower value of ξ. Our calibration is in line though with more recent evidence for Germany based on data for different industries and educational groups; see Fahr and Sunde (2004).

[15] ECB (2002) reports the proportion of hard-to-fill vacancies, i.e., vacancies that have a duration of six months and longer for some euro area countries. This proportion is roughly 10%, squaring with the probability of finding a worker within a quarter's time of $q = 70\%$. Moreover, Weber (2000), using Dutch data, reports that after 4 months, 74% of the vacancies in her sample were filled.

$\sigma_m = 0.42$, and vacancy posting costs are set to $\kappa = 0.058$. The level of technology $z = 2.27$ ensures that output, y, equals unity in steady state. We assume that 1/3 of a firm's revenue flows to "capital," $\Phi^K = 1/3$.[16] We calibrate the period fixed cost associated with overhead labor costs to 0.69% of revenue, which means $\Phi^L = 0.0069$. In choosing this number, we seek to replicate the degree of fluctuations in unemployment that the model implies. We set real unemployment benefits, b, by targeting a replacement rate of $\frac{b}{wh} = 0.65$ in steady state, which Appendix C.1 argues is a reasonable choice.

In the wholesale sector, we calibrate the markup to a conventional value of 10% implying an elasticity of demand of $\epsilon = 11$. For the average contract duration of prices we use the results of the Eurosystem Inflation Persistence Network and set the corresponding Calvo parameter to $\omega = 0.75$, which amounts to an average price duration of 4 quarters, see Alvarez et al. (2006).[17] Mermet (2001) reports that wages in euro area countries are typically renegotiated every 1 to 2 years. Following this we set the degree of nominal wage rigidity to $\gamma = 0.83$, which implies an average wage duration of 6 quarters.[18]

We set the share of government spending in GDP to 20%, which corresponds to the average government consumption to GDP ratio from 1984Q1 to 2006Q4. Monetary policy follows a standard Taylor rule with a long-run response to inflation of $\gamma_\pi = 1.5$, with a long-run response to the output gap of $\gamma_y = 0.5$, and no response to output growth $\gamma_{\Delta y} = 0$. The rule is augmented by interest rate smoothing, with the coefficient on the lagged interest rate being set to $\gamma_R = 0.85$. These values are roughly in line with Smets and Wouters (2003). In Appendix B we provide information on the calibration of the shock processes and the steady state in the calibrated model.

Second Moments in the Calibrated Model

[16] It is understood that with capital being endogenous and mobile, a capital share of 1/3 would not necessarily be counted as a fixed cost. The size of job-related fixed costs matters for the size of the unemployment fluctuations in the model. If unemployment fluctuations are to be large enough, in the absence of labor market shocks the fixed costs must make up a large enough share of a firm's revenue once variable costs have been deducted. Yet an extended model with RTM bargaining, which would allow for endogenous capital accumulation, could also be calibrated to match the unemployment fluctuations.

[17] According to the evidence in Álvarez et al. (2006), the average price duration in the euro area based on data for Austria, Belgium, Finland, France, Germany, Italy, Luxembourg, the Netherlands, Portugal and Spain is 13 months.

[18] This is also in line with more recent evidence collected by the Eurosystem Wage Dynamics Network. This reports average wage contract durations for various euro area countries between one and three years; see du Caju *et al.* (2008).

Table 1: Second Moments of the model compared to euro area data

Variable	std to std(y)		corr with y		AR(1)	
	model	data	model	data	model	data
$\widehat{y}_t$	1.00	[1.00]	1.00	[1.00]	.93	[.87]
$\widehat{R}_t$	.21	[.24]	-.06	[.65]	.84	[.88]
$\widehat{\Pi}_t^{yoy}$	.37	[.59]	.68	[.43]	.89	[.82]
$\widehat{w}_t + \widehat{h}_t + \widehat{n}_t$	1.37	[1.32]	.85	[.77]	.80	[.93]
$\widehat{w}_t + \widehat{h}_t$	1.00	[.67]	.67	[.36]	.63	[.77]
$\widehat{u}_t$	5.36	[5.36]	-.91	[-.85]	.94	[.96]
Euro area proxies for total hours worked and vacancies						
$\widehat{h}_t + \widehat{n}_t$	1.45	[.85]	.80	[.76]	.80	[.96]
$\widehat{h}_t$	1.10	[.52]	.60	[.39]	.66	[.91]
$\widehat{w}_t$	.24	[.64]	.04	[.56]	.93	[.75]
$\widehat{v}_t$	15.94	[14.28]	.75	[.71]	.63	[.95]

Notes: The table reports summary statistics of the calibrated model and compares those to the data (values in brackets). The model was calibrated so as to replicate the standard deviation of hp-filtered output and unemployment in the data. The first column reports the standard deviation of the respective series relative to the standard deviation of output. The second column shows the cross-correlation with output. The final column reports the serial correlation of the respective series. All model moments are unconditional moments. The computations for the data were performed on the sample 1984Q1 to 2006Q4.

Table 1 shows the implied second moments in the calibrated model along with the serial correlation coefficients. For comparison, the moments in the data are given in square brackets. The model captures both the standard deviations and the co-movement in the data fairly well. Due to the decreasing returns to scale in the production function, hours worked being the only factor of production and due to the calibrated series of shocks not being very persistent, the total hours worked are too volatile relative to the data and similarly is the compensation per employee.[19] Most important, however, the model reproduces the substantial fluctuations in unemployment and vacancies over the business cycle that are present in the euro area data. See Appendix D for further evidence on the fit of the calibrated model in dimensions that were not targeted. Refer to Appendix E for comparisons of the calibrated model and the version of the model that we estimate in Section 5.

[19] As a point of reference, Trigari (2006) analyzes the use of the intensive (hours worked) and the extensive (employment) margin and the forces that drive the use of these margins in a model with efficient bargaining. Much of her analysis carries over to our model, the exception being that the replacement rate, $b/(wh)$, does not have a strong bearing on the relative use of the two margins with RTM.

4 The Role of Labor Market Rigidities for Monetary Policy

In this section, we use the calibrated version of the model for counterfactual analysis. To identify the effect of changes in the structural parameters of the model we let both the steady state be affected by parameter changes as well as the model's dynamics. While the same exercise could in principle have been conducted with the estimated version of the model, the calibrated version has a number of advantages. First, all parameters are chosen to strictly comply with microeconomic estimates. The parameters also form the basis of the priors in the estimated model, but the estimation trades off this evidence against the time-series fit of the model. In addition, parameter estimates will typically not be independent. Since the counterfactuals involve changing one parameter at a time, we prefer to conduct this exercise using the calibrated model. Second, the calibrated model is more parsimoniously parameterized which makes it easier to explain the changes in dynamics brought about by the counterfactuals.

We first look at the transmission of monetary policy in this calibrated baseline that is characterized by rather rigid labor markets, labeled case a). We compare this to the transmission if the euro area were characterized by more flexible labor markets. Thereafter, we assess the effect on the business cycle more generally. As in the ongoing policy discussion, the term "flexible labor markets" here is encompassing: We look at proxies that capture many of the different dimensions in which labor market institutions and labor laws in the euro area could be reformed. In particular, these more flexible labor markets are characterized by b) a lower degree of nominal wage rigidity (read: more frequent wage negotiations or, more generally, a more flexible firm-worker bargaining), or by c) lower hiring costs/lower costs of posting vacancies, which capture impediments to hiring as well as – to a certain extent – lay-off costs.[20] We further examine the behavior of the economy when d) unemployment benefits are lower, which would make labor supply more responsive to economic conditions, and when e) the bargaining power of workers is below the *status quo*. This is a proxy for lower union bargaining power or for less "worker-friendly" labor legislation. In addition, we look at the economy when f) there are fewer job-related fixed costs, so that average labor costs are more responsive to actual hours worked (or more broadly interpreted: to economic conditions and effort).

[20] Since separations are exogenous in our model, costs of hiring and costs of separation have the same economic effects. This would cease to be the case once the separation margin was endogenized.

Before describing the impact of these counterfactuals quantitatively, we give a brief overview of what drives marginal costs in the model, and thus inflation dynamics. This helps to gauge how the labor market-related rigidities and the specific modeling affect the marginal costs.

i) The Wage Channel and the Intensive Margin

Under right-to-manage, there is a direct channel from the hourly wage rate to the marginal costs of price-setting firms and thus to inflation; see Trigari (2006) and Christoffel and Linzert (2005). In the model, marginal costs of price-setting firms – once linearized around steady state – are given by

$$\begin{aligned} \widehat{mc}_t &= \widehat{e}_t^C + \widehat{x}_t^L = \widehat{e}_t^C + \widehat{w}_t - \widehat{mpl}_t \\ &= \widehat{e}_t^C + \widehat{w}_t + (1-\alpha)\widehat{h}_t, \ \alpha \in (0,1). \end{aligned} \tag{31}$$

Hats denote percent deviations from steady state. As apparent from Equation (31), factors affecting the wage dynamics, such as shocks to the bargaining power of workers, the outside option of the worker or changes in market tightness, or factors affecting the degree of wage stickiness, will have a direct effect on marginal costs.[21] Therefore wages directly feed into the dynamics of inflation via the Phillips curve. This differentiates a setup with RTM from models with efficient wage bargaining (EB). In the latter, in equilibrium, wages also matter for inflation dynamics, yet this effect is less direct, and works only *via* the effect of wages on hiring incentives on the extensive margin. In particular, wage stickiness in existing matches alone does not have any effect on inflation dynamics with efficient bargaining (all that matters is the stickiness of wages of prospective new hires), while it does affect inflation dynamics under RTM; see Christoffel *et al.* (2008) for an extensive discussion. Under EB more rigid wage rates do not directly induce a smoother response of inflation to a monetary shock.[22] Allowing the firm to

[21] The wage equation in the absence of wage stickiness ($\gamma = 0$) helps to build intuition. Up to a first-order approximation, it takes the form:

$$w_t h_t = \frac{1}{1+\chi_t}\left\{\frac{x_t\, mpl_t\, h_t}{\alpha} - \Phi\right\} + \frac{\chi_t}{1+\chi_t}\left\{b + \frac{mrs_t h_t}{1+\varphi}\right\} + \frac{1}{1+\chi_t}\frac{\kappa}{q_t}\left\{(1-\vartheta_{t+1}) - E_t\left[\frac{\chi_t}{\chi_{t+1}}(1-\vartheta_{t+1}-s_t)\right]\right\},$$

where $\chi_t := 1/\left(\frac{\eta_t}{1-\eta_t}\frac{1}{\alpha-1}\left[\alpha - \frac{mrs_t}{w_t}\right]\right)$. mrs_t marks the family's marginal rate of substitution between consumption and leisure. Though the details differ from wage equations with efficient bargaining (Trigari, 2006, provides a comparison), wages are driven by the same forces. Wages are the higher the larger the marginal revenue product of labor and the lower fixed costs are, the higher benefits and the higher the marginal rate of substitution between consumption and leisure, and the tighter the labor market.

[22] In the presence of an intensive margin, marginal costs are given by the marginal cost of an hour worked. With

choose hours worked on the intensive margin for a given wage rate is crucial for the existence of the direct wage channel. We view this assumption as particularly realistic for the euro area, where restrictions on the hiring and separation margin might make firms more likely to cover temporary fluctuations in demand by means of an adjustment in hours worked per employee.

As shown in Equation (31), in addition to the direct effect of wages on inflation there is another effect via the marginal product of labor, which would also be present in the efficient bargaining environment. In both approaches the relative use of the extensive margin (number of employees) *vs.* the intensive margin (hours per worker) affects inflation dynamics. The more of an increase in labor input falls on the intensive margin, the more does the marginal product of labor, $\widehat{mpl}_t = (\alpha - 1)\widehat{h}_t$, fall, and the more does the price of the labor good rise, and thus the more do marginal costs for price-setting firms increase. The wage, too, is affected by changes in the composition of total hours worked in the intensive and the extensive margin, both through changes in the marginal product of labor and the marginal rate of substitution between consumption and leisure and through changes in market tightness; cf. Footnote 21. Many of the counterfactuals that we discuss have implications for the relative use of the extensive margin.

ii) The Role of Job-Related Fixed Costs for Unemployment and Inflation

For the relative use of the two margins, the fixed costs are essential. Under RTM, in equilibrium employees receive a constant share α of a firm's revenue, $x_t^L z_t h_{i,t}^{\alpha}$. Absent fixed costs, Φ, the same would hold true for profits. However, combining period profits of a labor firm (24) and the firm's first-order condition for the demand of hours worked (25) yields that

$$\Psi_t^L(W_{i,t}) = \frac{1-\alpha}{\alpha}\frac{W_{i,t}}{P_t}h_{i,t} - \Phi. \tag{32}$$

Period-by-period job-related fixed costs break the one-to-one link between profits, $\Psi_{i,t}^L$, and wages per employee, $\frac{W_{i,t}}{P_t}h_{i,t}$. For any given fluctuation in wages higher fixed costs mean that profits fluctuate by more (in percentage terms), which can be seen from the linearized version of (32): $\widehat{\Psi}_{i,t}^L = A(\widehat{w}_{i,t} + \widehat{h}_{i,t})$, where $A = \frac{\frac{1-\alpha}{\alpha}wh}{\frac{1-\alpha}{\alpha}wh - \Phi} \geq 1$. The increased fluctuation of profits in

EB, in our model marginal costs would be given by $mc_t = e_t^C \frac{mrs_t}{mpl_t}$, where the marginal rate of substitution of the worker between leisure and consumption, mrs_t, replaces the wage rate. In Krause and Lubik (2007), the contemporaneous employment adjustment margin instead is to lay off fewer workers. Marginal costs are therefore more complicated and include the behavior of the (shadow) cost of posting a vacancy.

percentage terms in turn translates into more co-variation of the hiring behavior of firms with the business cycle; see Christoffel and Kuester (2008). For this reason, the size of the fixed costs in the labor good sector also has a bearing on the response of inflation to shocks. The higher the fixed costs for given calibration targets in the labor market, the more of any adjustment in labor input falls on the extensive (hiring) margin of employment and the less is the marginal product of labor affected.[23]

4.1 Monetary Transmission in Rigid and More Flexible Labor Markets

In the figures that follow we analyze how an unanticipated monetary policy shock works its way to output and inflation in each scenario. The baseline response is always shown as a black solid line. The interest rate is denoted in quarterly terms and is not annualized, similarly for inflation.

a) Rigid Labor Markets - the Baseline Response

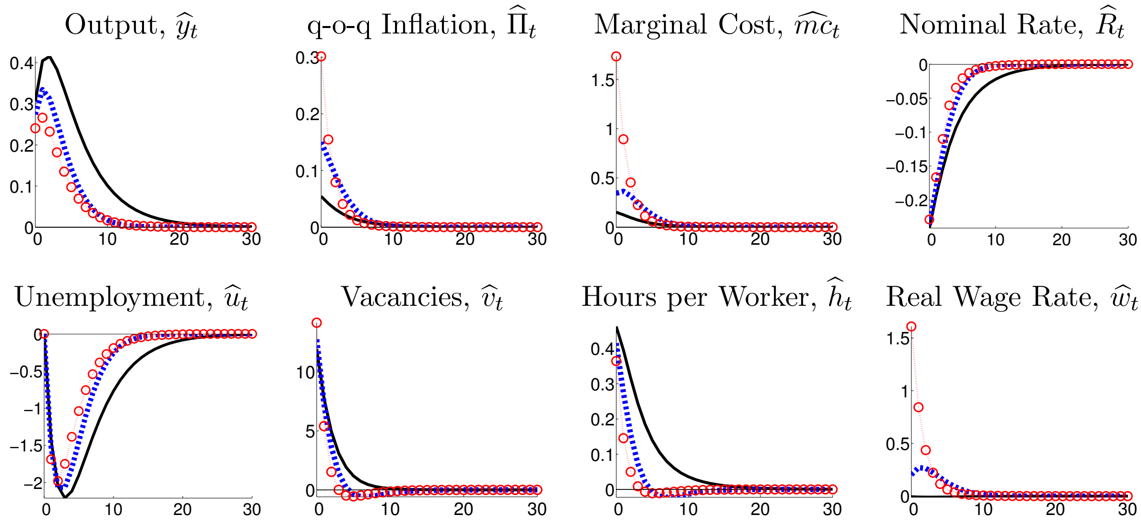
A lower interest rate in the presence of nominal rigidities induces a lower real interest rate, which leads households to increase consumption. Output reacts accordingly; cp. Figure 1. Increased production in turn requires additional labor input. Due to the one-period lag between matching and employment, the number of employed workers cannot increase instantly. Hence labor adjustment is initially fully implemented by an increase of hours worked per employee (the intensive margin), $\widehat{h}_t$. But the rise in demand also stimulates expected profits in the labor sector. This leads to more vacancy posting activity. As a consequence, there is more hiring (the extensive margin), so unemployment falls. In anticipation of a tighter labor market and higher profits, the value of an existing match increases and workers who renegotiate their contracts aspire to gain higher wages.[24] In the baseline, the changes in wages and the marginal product of labor taken together imply a rise in inflation following a monetary easing (see the black solid line in Figure 1).[25]

[23] Related to the former, Hall (2005) and Shimer (2004) demonstrate that under efficient wage bargaining, the smoother the wage is, the more will percentage profits fluctuate. As a result, under EB the smoother the wage is, the greater will be the fluctuations in hiring activity. Under RTM in contrast, in equilibrium the revenue of labor firms fluctuates (in percentage terms) as much as wages per employee. Absent fixed costs, profits would also fluctuate (in percentage terms) as much as wages per employee.

[24] With wages as rigid as in the baseline, newly negotiated nominal and real wages rise but average real wages fall (since in the short-run the nominal wage rate of most employees is fixed and inflation increases).

[25] Equation (31) suggests that the smaller the curvature of the production function, α, the larger the effect of

Figure 1: Impulse responses to 25bps monetary policy shock: nominal wage rigidity



Notes: The panels show percentage responses (1 in the plots corresponds to 1%) to a $\frac{1}{4}$% monetary policy easing for varying degrees of nominal wage rigidity. The **black solid line** marks the calibrated model. For this, the average real wage rate falls mildly below steady state, which is hard to see due to the scaling of the charts (lower right panel). The **blue dashed line** corresponds to an intermediate degree of wage rigidity ($\gamma = 0.5$). The **red dotted line marked by circles** shows the case of no wage rigidity ($\gamma = 0$). An increase in unemployment of 1 means that the unemployment rate increases by 1% above steady state, say ,from 9.1% to 9.19%, not by one percentage point.

b) Lower Degree of Nominal Wage Rigidity

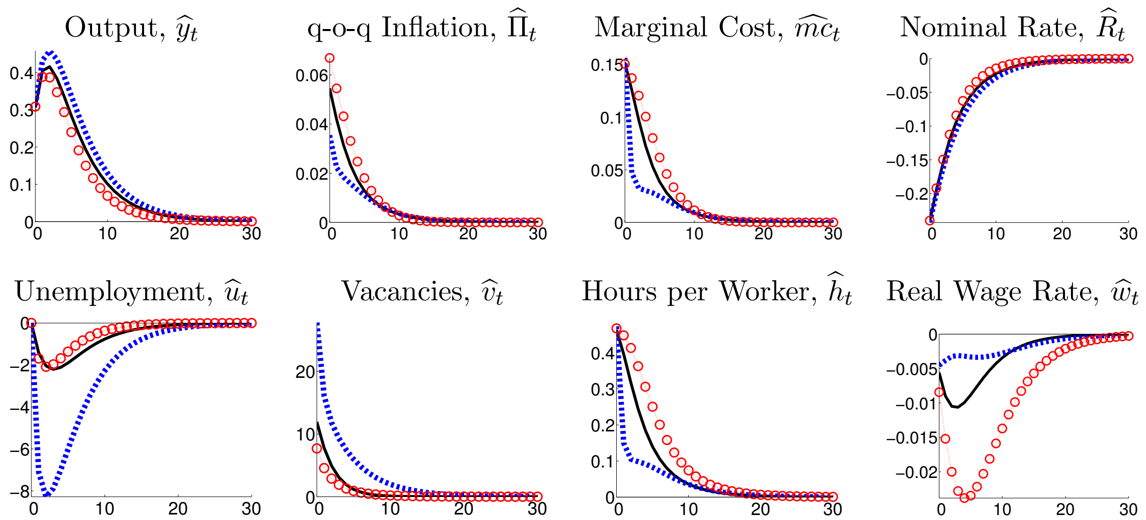
The blue dashed line in Figure 1 shows the response of the economy to a monetary easing when wages are negotiated on average twice a year ($\gamma = 0.5$) instead of only every six quarters. The case of fully flexible wages ($\gamma = 0$) is shown as a red dotted line marked by circles. All other parameters remain at the values in the baseline. Real wage rates rise more profoundly when nominal wages are more flexible, which implies a steeper increase in marginal costs. In turn, this causes the initial inflation response to be greater, and the response of output to be weaker. Therefore, the more flexible the wages are, the stronger is the lever that monetary policy has on inflation. In addition, less sticky wages also mean less persistent inflation.

a monetary shock on inflation. As in Trigari (2006), in our model also habit persistence bears on the use of the extensive relative to the intensive margin, since habits smooth out and prolong the effects of any shock on profits and thus affect hiring. With different choices for these parameters, however, the most material change in business cycle behavior arises when wage rigidity is affected, while the effect on the business cycle is considerably less pronounced for the other flexible labor market scenarios.

c) Lower Hiring Costs/Lower Costs of Posting Vacancies

We next analyze a scenario that can be interpreted literally as reduced costs to firms associated with hiring but also as reduced costs to firms of separation. The blue dashed line in Figure 2 shows the effect of a monetary easing when steady state vacancy posting costs, κ, are only 1/16 of their value in the baseline. Vacancy posting costs do not have a direct impact on the marginal

Figure 2: Impulse responses to 25bps monetary policy shock: flexible labor market



Notes: The panels show percentage responses (1 in the plots corresponds to 1%) of endogenous variables to a $\frac{1}{4}$% monetary policy shock. The **black solid line** marks the calibrated model. The **blue dashed line** shows the case when vacancy posting costs, κ, are 1/16 of their size in the baseline. All other parameters are as in the baseline. The steady state features $s = .65$, $u = .045$, $y = 1.04$, $h = 0.3296$ and $A = 544.5$. The **red dotted line marked by circles** corresponds to a scenario with a lower replacement rate, mirroring the U.S. level, $\frac{b}{wh} = 40\%$. All parameters apart from b are left at their baseline values. The steady state features $s = .55$, $u = .052$, $y = 1.058$, $h = 0.34$, $A = 43.6$. An increase in unemployment of 1 in the plot means that the unemployment rate increases by 1% above steady state, say, from 9.1% to 9.19%.

costs, and thus inflation, because they are treated as sunk costs in the production phase. In equilibrium, however, they still matter for inflation as they affect the steady state employment and market tightness, and thereby the use of the intensive margin. On the one hand, in- and out-of steady state, firms will use the hiring margin more intensively. This reduces both the level and the response of hours per employee and thus reduces the percentage response of the marginal product of labor and of the worker's disutility of work to shocks. This line of argument suggests that the inflationary response would be reduced; compare equation (31). On the other hand, and countervailing, with lower vacancy costs, the labor market is also considerably tighter for firms. This by itself would mean that wages are more responsive to shocks.

While the latter effect is visible in the wage response, for inflation the former effect prevails. On average more vacancies are opened. This results in a steady state job-finding rate of $s = 65\%$ per quarter, so unemployed workers find a job as quickly as in the U.S.; compare Table 7 in the Appendix. The steady state unemployment rate drops to $u = 4.5\%$. Ex-post labor revenues per firm are lower than in the baseline steady state. Not least since job-related fixed costs remain constant at the same time, labor profits and employment on the extensive margin react more strongly (in percentage terms) to the monetary policy shock. Therefore the additional output is produced with less recourse to the intensive margin, $\widehat{h}_t$, with a dampening effect on inflation. As a result, despite real wage rates being slightly more responsive (falling by less), marginal costs and inflation rise by less than in the baseline.[26]

d) Lower Unemployment Benefits

A reduction in unemployment benefits, b, reduces the outside option of the worker. This means that – all else equal – wages are lower in the new steady state, which reduces equilibrium unemployment. For a given level of output, firms need to make less use of the intensive margin, with the dampening effect on inflation that we already described in c). On the other hand, there are now two countervailing effects: First, lower wages, all else equal, also mean that the firm will demand more labor at the intensive margin; cp. equation (25). This means that the sign of any change in the steady state level of hours is ambiguous, and similarly for the hourly wage rate. Also, output increases. Second, and as for vacancy posting costs, any expansion may require more of a recourse to hours per worker since the pool of unemployed workers who could satisfy additional demand for labor is smaller after the reform. This would lead to a stronger response of marginal costs and inflation to shocks.

To assess the effect quantitatively, we considerably reduce the replacement rate to $\frac{b}{wh} = 40\%$, so as to mimic the average replacement rate in the U.S.; cp. Engen and Gruber (2001) and Table

[26] In our baseline calibration unemployment features a semi-elasticity of unemployment with respect to benefits of 1.7, very close to the value of 2 favored by Costain and Reiter (2008). Fixed costs are essential in generating this reasonable elasticity of unemployment with respect to benefits. In a similar vein, the results of paragraphs c) and d) also depend on the presence of fixed costs of production. Absent fixed costs, unemployment would be hardly more responsive to changes of economic conditions when benefits or vacancy costs change, and the dynamics of inflation would thus be little affected.

7 in the Appendix. All parameters apart from b are left at the same values as in the baseline. The steady state features a level of output that exceeds the baseline by almost 6% and the pool of unemployed workers shrinks to $u = 5.2\%$. Because of the latter, even though the percent response of unemployment (see the red dotted line marked by circles in Figure 2) is similar to the baseline, the percent response of the number of employees is smaller. Therefore, eventually, more of the additional demand has to be satisfied out of hours worked per employee. This reduces the marginal product of labor – but also the real hourly wage – by slightly more than in the baseline. Overall, marginal costs and therefore inflation rise by more than in the baseline. Quantitatively, however, the transmission of monetary policy to inflation still remains close to the baseline. This is the case despite the paradigm shift that the reduction in the replacement rate means for the economy's potential output. Also the response of output, in percentage terms, resembles closely the response in the baseline economy.

e) Bargaining Power of Workers Below the Status Quo

The theoretical implications of a change in bargaining power are comparable to changes in the replacement rate. However, changes in the replacement rate affect the level of the total surplus, while changes in bargaining power affect primarily the distribution of the joint surplus of firms and workers. We therefore also examined how a lower bargaining power of workers would affect the transmission of a monetary easing.[27] We found that hours worked would respond similarly to the previous scenarios, the effect on the marginal product of labor being cushioned by a slightly stronger fall in the real wage. As a result, in an economy with a lower bargaining power of workers, the effect of a monetary policy impulse on marginal costs, inflation and output would be very similar to the response in the baseline economy, again, despite noticeable differences in the implied steady state. We do not display these responses.

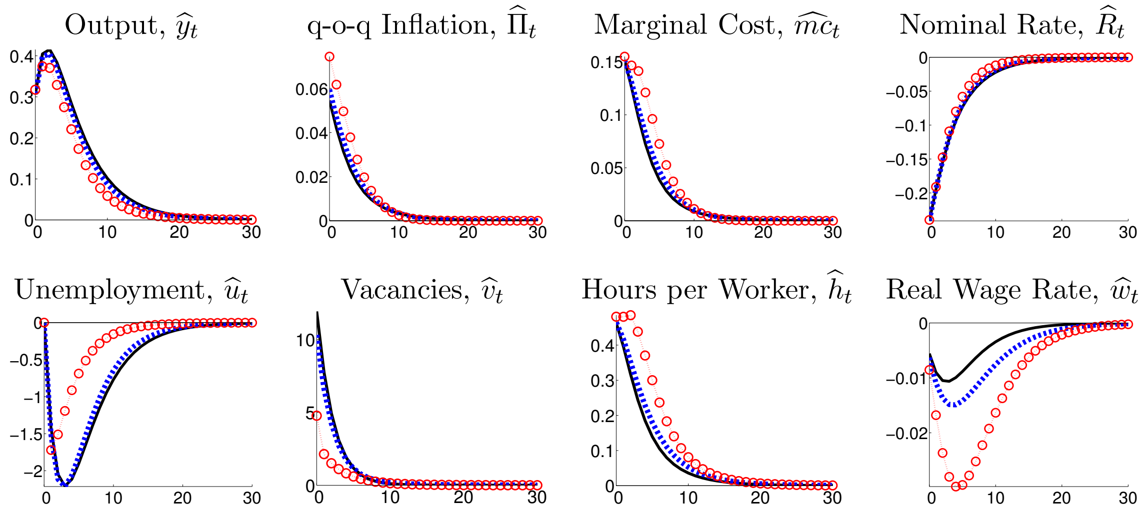
f) Lower Amount of Job-related Fixed Costs

Figure 3 depicts the effect of a monetary easing when changes in institutions induced smaller job-related fixed costs. *Ex ante* lower fixed costs increase firms' hiring incentives and thus reduce equilibrium unemployment. Similar to the previous discussions, on the one hand this reduces the

[27] We reduced the workers' bargaining power from $\eta = .5$ to $\eta = .2$. All other parameters were as in the baseline. The resulting steady state featured the following values: $s = .37$, $u = .074$, $y = 1.02$ and $A = 77.2$.

responses of inflation, since firms are more likely to hire in an upturn; on the other hand it also strongly increases steady state labor market tightness, leading firms to make more recourse to the intensive margin; cp. the discussion of equation (32). The latter dominates in the numerical examples. The blue dashed line assumes that the overhead component of fixed costs, Φ^L, is

Figure 3: Impulse responses to 25bps monetary policy shock: job-related fixed costs



Notes: The panels show percentage responses (1 in the plots corresponds to 1%) of endogenous variables to a $\frac{1}{4}$% monetary policy shock for varying sizes of job-related fixed costs. The **black solid line** marks the calibrated model. The **blue dashed line** sets the overhead component of fixed costs to $\Phi^L = 0$. All other parameters remain at their values in the baseline calibration. The associated steady state features $y = 1.0007$, $s = .37$, $q = .51$, $h = .325$, $u = .075$, $A = 77.36$. The **red dotted line marked by circles** shows the case where in addition the capital component of fixed costs is reduced by 10%, $\Phi^K = .30$, $\Phi^L = 0$. All other parameters remain at their baseline values. This implies a steady state with $y = 0.992$, $s = .90$, $q = .13$, $h = .29$, $u = .0322$, $A = 19.06$.

reduced to zero. All other parameters remain at their baseline values. This seemingly small change induces a fall in the steady state unemployment rate to $u = 7.5\%$. Since fixed costs are lower, percentage labor profits react by less than in the baseline model, and so do hiring and unemployment. More of the required adjustment of employment is borne by hours worked per employee. Consequently, the marginal product of labor falls by more than in the baseline. Therefore marginal costs and inflation rise by slightly more, with the increase in marginal costs being somewhat cushioned by a stronger fall in real hourly wages. Further to this, the red dotted line marked by circles shows the economy's response to the monetary easing when, in addition, fixed costs associated with capital are reduced (by 10% in the example, so $\Phi^K = 0.3,\ \Phi^L = 0$). This change means that steady state unemployment rates are lower still, at $u = 3.2\%$. Labor adjustment in response to the monetary easing shifts further to the intensive margin with a smaller and less protracted response (in percent deviation from steady state) in unemployment and a more pronounced rise in marginal costs and inflation. Still, despite the sizable effect that lower fixed costs have on the steady state of the economy, quantitatively the transmission of the monetary impulse to output and inflation appears to be little affected.

4.2 The Business Cycle when Labor Markets Are More Flexible

So far we have exclusively reported on the role of the labor market for the transmission of monetary policy shocks. But for the other business cycle shocks in the calibrated model, reducing wage rigidity as well is the one change in labor market structure that quantitatively most significantly affects their transmission – and thus overall business cycle fluctuations. This is shown in Table 2, which reports the standard deviations for selected variables under the different scenarios presented above. A lower degree of nominal wage rigidity reduces the volatility of

Table 2: More flexible labor markets and business cycle fluctuations

		More flexible labor market through *lower* ...				
Standard deviation of	Base-line	Wage rigidity	Vacancy costs	Replace-ment rate	Bargaining power	Fixed costs
$\widehat{y}_t$	.85	.60	.96	.76	.85	.73
$\widehat{R}_t$	.18	.21	.18	.19	.18	.19
$\widehat{\Pi}_t^{yoy}$	.31	.71	.25	.38	.31	.41
$\widehat{h}_t$	.94	.78	.79	1.08	1.00	1.17
$\widehat{w}_t$	.20	.49	.20	.21	.21	.20
change of std. dev. of $\widehat{\Pi}_t^{yoy}$		+ 129%	- 19%	+22%	$\approx$ 0%	+32%

Notes: The table reports standard deviations of variables in the baseline model to the implied standard deviations under scenarios with more flexible labor markets. All model moments are unconditional moments. From top to bottom: output, $\widehat{y}_t$, the nominal rate, $\widehat{R}_t$, year-on-year inflation, $\widehat{\Pi}_t^{yoy}$, average hours per employee, $\widehat{h}_t$, and average real hourly wage, $\widehat{w}_t$. From left to right: baseline, lower wage rigidity ($\gamma = .5$), lower vacancy posting costs ($\kappa = .058/16$), lower replacement rate $\left(\frac{b}{wh} = 40\%\right)$, lower bargaining power of workers ($\eta = .2$), lower job-related fixed costs $\left(\Phi^L = 0, \Phi^K = .3\right)$. The previous figures and the main text contain more details about the scenarios. The final line of the table reports the percentage change in the standard deviation of inflation in the respective scenarios relative to baseline.

output and hours per employee and induces notably more pronounced fluctuations of inflation over the business cycle. Table 2 suggests that the standard deviation of inflation would increase by 65% if the average duration of wage contracts were cut to one-third of the baseline duration, i.e., to an average duration of half a year. In contrast, the other structural changes that would make the labor market more flexible but which would not directly touch on wage rigidity do not have as much of an impact on the business cycle. Lowering the replacement rate to the level witnessed in the U.S. would raise the standard deviation of inflation but by less, namely, by 23%. Lowering fixed costs associated with jobs increases inflation volatility by 26%. As the previous discussion would have suggested, lowering the bargaining power hardly has any effect on inflation volatility. And a reduction in vacancy posting costs would (through a more intense use of the extensive margin) reduce inflation volatility by about 19%.[28]

5 The Role of Labor Market Shocks - A Bayesian Estimation

So far, we analyzed to which extent the business cycle and monetary transmission would be affected by permanent changes in the underlying institutions governing the labor market. In this section, we analyze whether – given the current state of labor market institutions – shocks originating in the labor market are an important source of fluctuations in production and prices. This would likely render these shocks valuable information for monetary policy. To identify the labor market shocks, we estimate the model economy using Bayesian techniques.[29] This allows us to assess the contribution of specific shocks to the fluctuations of the endogenous variables. In addition to this, the method allows us to capture the uncertainty surrounding the estimates of the contributions in light of the cross-correlation of parameter estimates.[30]

We make use of standard macroeconomic variables as well as of variables characterizing the labor market. We employ as observable variables the series for output, year-on-year inflation,

[28] We have analyzed the sensitivity of the above results with respect to different values of the labor supply elasticity φ. The main result, that removing wage rigidity has a bigger impact on monetary transmission and inflation volatility than the other scenarios, is robust, and the difference becomes the more pronounced, the less elastic the labor supply (the larger φ).

[29] The Bayesian estimation strategy allows us to use as many shocks as observable variables and to choose the shocks according to their economic meaning and to evaluate the choice along econometric criteria. As described in Section 3 the choice of shocks in the calibration approach is restricted by the property that the shocks must be easily identifiable. In the calibrated model we therefore abstained from shocks like the price mark-up shock.

[30] The cross-correlation of parameter estimates also implies that the calibrated model is the preferable tool for conducting the counterfactual analysis of Section 4. However, the quantitative results of Section 4 are robust to using the estimated model instead.

the nominal interest rate, wages per employee, unemployment, total hours worked and vacancies. We are aware of the measurement problems of the latter two series as described in Section 3. Nonetheless these series appear to be at the core of the search and matching literature and are crucial for the identification of parameters.[31] We also include government spending in our set of observable time series in order to identify the government spending shock. Besides the four shocks already embedded in the calibrated version, the estimated model allows for a non-zero cost-push shock, and three labor market shocks: a shock to the bargaining power of workers, η_t, a shock to the separation rate, ϑ_t, and a shock to vacancy posting costs, κ_t. The rationale for the choice of these three labor market shocks is as follows. We abstract from an endogenous separation decision of firms. At the same time some observers of the business cycle point to fluctuations in separations as important driving forces of employment fluctuations, with potential implications for inflation and output. To account for variations along the separation margin we thus include a stochastic element in the form of a shock to the separation rate.[32] Similarly, our model abstracts from many of the details that affect the bargaining process between firms and (often-times unionized) workers, and their relative bargaining positions. The shock to the bargaining power captures exogenous variations that drive the outcome of the bargaining process. Finally, the shock to the vacancy posting costs captures variations in institutional features and other factors that have a bearing on the incentives to hire over and above fluctuations in wages, and which are not fully captured in the theoretical model.[33]

Our paper is placed within a growing literature that estimates dynamic stochastic general equilibrium (DSGE) models by means of Bayesian techniques; see e.g. Schorfheide (2000) and Smets

[31] We conducted an extensive sensitivity analysis with respect to using the German set of proxies for euro area hours worked and vacancies, and with respect to estimating different sets of parameters. The results are robust to these changes. The corresponding tables are available upon request.

[32] In our model, shocks to the separation rate lead to both higher unemployment and more vacancy posting. Separation shocks therefore weaken the Beveridge curve in the model; yet they do not destroy it altogether: In the estimated version of the model reported below, unemployment and vacancies are negatively correlated, but weaker so than in the data. A graph is available upon request. Mortensen and Nagypal (2007) stress that the outside option in the bargaining matters for the sign of the correlations conditional on the separation shock.

[33] Our paper treats all the available labor market series as observable, which allows us to identify these three labor market shocks. In contrast, Gertler, Sala, and Trigari (2008) estimate their New Keynesian model with labor market frictions by using only the variables that Smets and Wouters (2007) also use. In particular, they do not allow for a difference in hours worked at the intensive and extensive margin, which may be due to their focus on the U.S. Similarly they do not include vacancies as an observable series. This means that they identify only one labor market shock, the bargaining power shock.

and Wouters (2003, 2007). Model estimates provide a complete characterization of the data-generating process. For this paper, that means that the estimation will in particular inform on the relative importance of shocks in the labor market. In a Bayesian framework prior information (derived from earlier studies, outside evidence or informed judgement) can be brought to bear on the estimation process in a consistent and transparent manner. The following section discusses the priors we use in our application.

5.1 Fixed Parameters and Priors

It is standard practice to estimate certain parameters while keeping others fixed at their calibrated values; cp., e.g., Smets and Wouters (2003). In particular, there are a number of parameters which are well-identified on the basis of long-run averages and great ratios but for which little information is contained in the HP-filtered data we use in the estimation. This is the case for the following parameters: β is identified by the average real interest rate. α is identified by the labor share. ϑ is identified by the micro-level separation rate and Φ^K by the capital share. $\overline{g}$ is the mean share of government spending in GDP. In the estimation process these parameters therefore remain fixed at their values given in Table 5 in the appendix. Also the replacement rate, $\frac{b}{wh}$, is well-identified on the basis of outside evidence which was used for the calibrated model, as discussed in Section 3. We further retain the convention that κ^L targets hours worked per employee, $h = \frac{1}{3}$, and that steady state vacancy posting costs, κ, and the efficiency of matching, σ_m, continue to target mean job-filling rates, which are identified by outside data as discussed in Section 3, and mean unemployment. Further, in the linearized model the elasticity of demand, ϵ, multiplies only the cost-push shock. The demand elasticity is thus not empirically distinguishable from the standard deviation of the shock. We therefore fix it at the calibrated value of $\epsilon = 11$. Similarly, we initially fix the bargaining power of workers, η, at the value used in the calibrated model, since it is not well identified by the model's dynamics.[34] In addition, we initially keep parameter A fixed, which links wage and profit fluctuations, reflecting our prior that the model should be enabled to endogenously explain a significant share of the

[34] η could be conjectured to have a significant impact on the steady state and thereby on economic dynamics. In our estimation procedure we target a number of steady state variables, in particular steady state unemployment and the replacement rate. Therefore "slack parameters" like κ, κ^L, and σ_m partly undo the effect of changes in η on the dynamics of the economy. The main impact of a change in η in the linearized dynamic system is to scale the impact of a shock to the bargaining power, meaning that the standard deviation of a bargaining power shock cannot easily be discerned from the level of the bargaining power parameter η.

fluctuations in unemployment through endogenous transmission of business cycle shocks. None of the results reported here changes qualitatively when η and A are estimated alongside the other parameters.

This still leaves us with 26 parameters to estimate. There are four parameters related to monetary policy in the Taylor rule: the interest rate smoothing coefficient, γ_R, and the response parameters to inflation, the output gap and output growth, γ_π, γ_y and $\gamma_{\Delta y}$. Three parameters relate to preferences, namely, the curvature of the disutility of work, φ, risk aversion, σ, and habit persistence, ϱ. Three parameters relate to the labor market, namely, the probability that wage contracts are not updated, γ, the degree of wage indexation, ξ_w, and the elasticity of matches with respect to unemployment, ξ. Finally, two parameters relate to the wholesale sector: the probability that prices are not updated, ω, and the degree of price indexation, ξ_p. The remaining 14 parameters refer to the stochastic structure of the model.

The first three columns of Table 3 report our priors for these parameters. The center of the prior distribution for each parameter is in line with the discussion of parameters in the calibrated version of the model (see Section 3), and with the literature, e.g., Smets and Wouters (2003). Overall, priors for the estimated parameters are fairly wide, leaving space for the data to inform about the parameters. Tighter priors are further chosen for parameters for which there is strong outside evidence, as most notably is the case for the Calvo probabilities of not re-setting wages and prices, γ and ω, or for parameters for which there is previous estimation evidence.

5.2 Estimation Results

The final five columns of Table 3 report information on the posterior distribution of the parameters. For most of the parameters, the data are informative, meaning prior and posterior mean do not coincide and the posterior standard deviation is tighter than for the prior distribution, albeit to a different degree. Economically, the parameter estimates appear to be reasonable. The estimates for the monetary policy reaction function are within the standard range of values found in the literature. In terms of preferences, values for the labor supply elasticity and the risk-aversion parameter remain close to their priors, while the degree of habit persistence that we estimate has a posterior mean value of $\varrho = 0.22$, which is at the low end of values considered in the literature.

Turning to the labor market parameters, the estimates suggest less wage rigidity than incorpo-

Table 3: Parameter estimates

	prior			posterior		posterior		
	mean	std	distr.	mean	std	2.5%	median	97.5%
Monetary policy								
γ_R	.85	.1	beta	.80	.03	.74	.80	.86
γ_π	1.5	.2	gamma	1.62	.19	1.25	1.61	1.99
γ_y	.5	.2	gamma	.43	.15	.17	.42	.73
$\gamma_{\Delta y}$	0	.2	normal	.12	.04	.05	.11	.19
Preferences								
φ	2	.5	gamma	1.63	.44	1.01	1.54	2.50
σ	1.5	.2	gamma	1.44	.20	1.06	1.43	1.82
ϱ	.7	.1	beta	.22	.05	.13	.22	.32
Labor market								
γ	.83	.05	beta	.68	.05	.59	.68	.77
ξ_w	.5	.25	uniform	.44	.20	.06	.42	.82
ξ	.6	.05	beta	.68	.03	.61	.67	.74
Wholesale/price-setting firms								
ω	.75	.05	beta	.69	.03	.63	.69	.75
ξ_p	.5	.25	uniform	.17	.09	.01	.17	.34
Serial correlation of shocks								
ρ_b	.5	.2	beta	.79	.04	.69	.79	.87
ρ_g	.5	.2	beta	.73	.06	.62	.73	.84
ρ_z	.5	.2	beta	.60	.07	.48	.61	.74
ρ_η	.5	.2	beta	.09	.05	.01	.08	.18
ρ_κ	.5	.2	beta	.78	.06	.65	.79	.91
ρ_ϑ	.5	.2	beta	.51	.08	.37	.51	.66
Standard deviation of innovations								
σ_b	50	28.67	uniform	.26	.08	.14	.25	.42
σ_C	50	28.67	uniform	1.94	.39	1.28	1.89	2.72
σ_g	50	28.67	uniform	.48	.04	.41	.48	.55
σ_{money}	50	28.67	uniform	.12	.01	.10	.12	.14
σ_z	50	28.67	uniform	.39	.03	.33	.39	.45
σ_η	50	28.67	uniform	43.48	18.4	16.4	38.9	84.0
σ_κ	50	28.67	uniform	7.62	.87	6.04	7.53	9.40
σ_ϑ	50	28.67	uniform	3.47	.26	2.97	3.46	3.98

Notes: Parameter estimates in the baseline model. The estimation sample is 1984Q1 to 2006Q4. Data from 1980Q1 to 1983Q4 are used in addition, in order to initialize the Kalman filter. Second column: prior mean, third column: prior standard deviation. Fourth column: prior distribution of parameters. The final columns show the posterior mean, the posterior standard deviation and the posterior median bracketed by a 95% coverage interval. The posterior estimates are based on 500,000 draws.

rated into the priors; namely, the median wage duration suggested by the median estimate of $\gamma = 0.68$ is just above three quarters, possibly reflecting that employer-union bargaining intervals fix only the pay scale while employers retain some flexibility of allocating workers along the pay scale over the cycle, and some flexibility of adjusting performance pay components. The degree of wage indexation, ξ_w, is below the prior mean but still points to considerable indexation. The elasticity of matches with respect to unemployment is estimated to have a mean of $\xi = 0.68$, which is within the bounds provided by Petrongolo and Pissarides (2001), if at the upper end. Price stickiness, ω, is relatively mild in our estimates, amounting to a median duration of prices of somewhat more than three quarters. There is only mild evidence for price indexation, with mean $\xi_p = 0.17$. Turning to the shock processes, despite starting from identical priors, estimates of serial correlation coefficients and the standard deviation of the innovations differ considerably. The estimates point toward the risk-premium shock and the vacancy posting shock as the most persistent shocks in the model economy.[35] At the other end of the spectrum, the shock to the workers' bargaining power is estimated to be almost white noise. Appendix E provides measures of fit for the estimated and the calibrated model and compares their implications.[36]

5.3 The Importance of Labor Market Shocks

Closely monitoring labor market developments can be important for monetary policy makers if these developments ultimately have a non-negligible effect on inflation and output. Using the posterior distribution of parameters, we can assess the importance of the respective labor market shocks in determining fluctuations of specific variables in the estimated model. Toward this end, Table 4 reports the median contribution of labor market shocks to the forecast error variance of selected variables along with 95% confidence intervals. Shown are two different forecast horizons (Table 11 in Appendix E reports the forecast error variance decomposition for all shocks and variables and also for the long term).

As shown in Table 4, labor market shocks such as the shock to the cost of posting a vacancy

[35] The estimation uses HP-filtered data. As a result, in our estimated model there is no shock with a permanent effect on output.

[36] Figure 5 in the Appendix compares the impulse responses in both model versions. The estimation is informative. The estimated model shows less persistence than the calibrated model. Wages in the estimated model are just as sticky as prices. As a result, real wages rise upon a monetary easing while they fall in the baseline, which in part explains the somewhat stronger response of inflation in the estimated model.

as well as a shock to the job separation rate contribute substantially to the fluctuations in unemployment and vacancies in the short as well as in the medium run. However, these shocks

Table 4: Contribution of labor market shocks to forecast error variance

	bargaining power		vacancy cost		separation rate		all labor shocks	
Horizon 2								
$\widehat{y}_t$	8.0	3.6; 15.5	.3	.07 ; .9	.1	.02; .7	8.5	3.9; 16.4
$\widehat{\Pi}_t^{yoy}$	12.0	7.5; 19.2	.3	.1; .7	.6	.2; 1.3	13.1	8.5; 20.3
$\widehat{u}_t$	.8	.1; 2.4	16.5	9.9; 24.5	64.3	48.8; 78.9	82.3	70.9; 90.8
$\widehat{v}_t$	3.5	.9; 9.2	46.5	34.3; 57.6	6.2	3.7; 10.7	56.2	43.4; 68.5
$\widehat{w}_t$	67.4	53.8; 78.3	.1	.05; .3	.04	.0007; .3	67.7	54.1; 78.5
Horizon 10								
$\widehat{y}_t$	16.7	8.7; 29.8	1.7	.4; 6.6	.6	.1; 2.6	19.8	9.9; 34.3
$\widehat{\Pi}_t^{yoy}$	11.9	6.4; 22.7	1.2	.4; 3.1	.7	.2; 1.8	14.1	8.1; 25.5
$\widehat{u}_t$	6.0	2.4; 14.0	43.4	26.2; 63.8	24.2	13.0; 43.2	76.6	56.1; 89.7
$\widehat{v}_t$	5.4	2.1; 12.5	47.3	33.3; 64.6	6.7	3.5; 13.0	60.7	45.8; 75.4
$\widehat{w}_t$	59.5	43.3; 73.4	.8	.1; 3.1	.1	.01; .7	60.8	44.6; 74.3

Notes: Contribution of labor market shocks to the forecast error variance for two different forecast horizons (in percent). Shown are median values and 95% confidence intervals. From top to bottom: output, annual inflation, unemployment, vacancies and the real wage rate. From left to right: bargaining power shock, vacancy posting cost shock and shock to the separation rate. The final column reports the median value and confidence bands of the joint contribution of all three shocks. Note: entries in the final column do not need to be the sum of entries in previous columns. Entries are based on 10,000 draws from the posterior distribution. The variance decomposition into all shocks is reported in Table 10 in Appendix E.

seem to be of only minor importance for fluctuations in output and inflation. This can be explained as follows. On the one hand, shocks to the vacancy posting costs and separation rate are neither large nor very persistent. Stickiness in wages and prices further reduce the impact of current shocks on average wages and inflation. Besides, at the parameter estimates, the presence of the intensive margin to some extent isolates wages from these shocks, leaving only the effect through the marginal product of labor on inflation. Yet while these shocks make a sizable contribution to employment dynamics, fluctuations in employment on the extensive margin empirically may not be large enough to have much of an effect on the intensive margin and inflation, that is, relative to other sources of fluctuations in inflation in the estimated model.[37] The shock to the bargaining power of workers, in contrast, does explain a significant share of the

[37] In the model, employment is predetermined and firms can demand hours worked per employee flexibly along their labor demand curve. In particular, adjustment along the intensive margin does not require any further outlays by the firm. The intensive margin is therefore too volatile in the model relative to the data; cp. Tables 1 and 9. Non-labor-market shocks explain most of the variation on the intensive margin.

fluctuations not only of wages but also of output and inflation. The effect on output fluctuations is 8% in the short run, and in the medium run fluctuations in the bargaining power explain about 16%. Similarly, the shock to the bargaining power of workers accounts for about 12% of the forecast error variance of inflation in the short and medium run. In terms of unemployment and vacancies, the shock to the bargaining power of workers accounts for about 6% of the forecast error variance of each in the medium run.[38] The bargaining power shock affects wages and thus marginal costs directly. There are no countervailing effects on wages: A positive shock makes wages rise unambiguously – and notably so on average, since the estimated shocks are quite large. Shocks to the bargaining power therefore feed through to wages and inflation despite sticky prices and wages.

In sum, it appears that disturbances to the bargaining power of workers contain valuable information for the central bank for evaluating the evolution of inflation and output. In contrast, shocks to the costs of hiring or shocks to the job separation rate matter much more for the evolution of labor market variables than they would for explaining output and inflation.

6 Conclusions

In this paper, we employed a New Keynesian model with a non-Walrasian labor market to investigate the role of rigid labor markets for euro area monetary policy along two dimensions. First, we analyzed to which extent a more flexible labor market would alter the business cycle and in particular the transmission of monetary policy. We investigated the relevance of a higher degree of flexibility of wages, of lower overhead labor costs, of a lower bargaining power of workers, of lower vacancy posting costs and of a lower level of unemployment benefits for monetary policy. Second, we investigated to which extent labor market shocks, such as disturbances in the vacancy posting process, shocks to the separation rate, and disturbances in wage-bargaining, are important determinants of business cycle fluctuations and hence contain valuable information for the monetary policy maker.

[38] To square this result with Section 4.1. it is important to note that impulse response functions to other shocks may not vary much with the calibrated size of the bargaining power, while the direct impact of a bargaining power shock on observed variable fluctuations can matter. Using the Kalman smoother and the median parameter estimates, we find that shocks to the bargaining power are indeed close to white noise but shocks can be sizable. Wage and price indexation, as well as other rigidities and persistent monetary policy, can mean that even shocks with little serial correlation can have a lasting and important impact on the economy.

First, we find that the importance of labor market rigidities for the business cycle in general and for the transmission of monetary policy in particular crucially depends on the nature of the labor market rigidity. A more flexible labor market environment that is characterized by a lower degree of wage rigidity makes monetary policy more effective; i.e., a monetary policy easing feeds faster into inflation. In contrast, altering other labor market characteristics, such as lowering overhead labor costs of firms, reducing the net replacement rate of unemployment insurance or lowering the cost of hiring, does not have as significant an impact on the transmission of shocks in our model. This is so although these changes to the underlying structure of the labor market imply substantial changes in the steady state of the economy.

Second, we find that shocks to the bargaining power of workers, in particular, contain valuable information for the central bank for evaluating inflation and output dynamics. In contrast, shocks to the costs of posting a vacancy or to the job separation rate do not appear to be of importance in explaining dynamics in output and inflation. We, therefore, conclude that while the labor market matters for monetary policy, some labor market features are of more importance for the monetary policy maker than others. For example, while monetary policy may not need to react to hiring and separation shocks, closely monitoring the wage process and wage-bargaining disturbances is likely to provide valuable information for monetary stabilization policy.

In total, the labor market may be crucial for monetary policy in two dimensions, namely, in altering the transmission of shocks through the economy – and thus altering the business cycle – and in affecting the evolution of the economy itself through labor market shocks. In both dimensions we find that the labor market is of key importance insofar as wage-setting is concerned. The paper thus lends some support to central bank practice in the euro area that closely monitors wage developments but assigns less weight to other labor market information.

For future research it would be interesting to further study the interaction of the labor market with other markets in the economy in the framework of a DSGE model, and it would be interesting to conduct optimal policy exercises so as to study further the implications of labor market rigidities for monetary policy-making from a normative point of view.

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A Appendix

A.1 Steady State of the Model Economy

Nominal rate:	$R = \frac{1}{\beta}$.
Marginal utility of consumption:	$\lambda = (c - \varrho c)^{-\sigma}$.
Marginal cost and price of labor good:	$mc = x^L = \frac{\epsilon - 1}{\epsilon}$.
Matches:	$m = \sigma_m u^{\xi} v^{1-\xi}$.
Employment:	$\vartheta n = m$.
Unemployment	$u = 1 - n$.
Probability of finding a worker:	$q = \frac{m}{v}$.
Probability of finding a job:	$s = \frac{m}{u}$.
Wage bargaining FOC:	$\eta J \delta^W = (1-\eta)\Delta\delta^F$.
	$\delta^F = \frac{1}{1-\beta(1-\vartheta)\gamma} wh$.
	$\delta^W = \frac{1}{1-\beta(1-\vartheta)\gamma} h \left[\frac{-\alpha}{1-\alpha} w - \frac{-1}{1-\alpha} mrs\right]$.
Definition marginal rate of substitution:	$mrs = \frac{\kappa^L h^{\varphi}}{\lambda}$.
Value of labor firm:	$J = \frac{1}{1-\beta(1-\vartheta)} \Psi^L$.
Period profit of a labor firm:	$\Psi^L = x^L z h^{\alpha} - wh - \Phi$.
Surplus of representative family:	$\Delta = \frac{1}{1-\beta(1-\vartheta-s)} \left[wh - mrs\, h \frac{1}{1+\varphi} - b\right]$.
Hours FOC:	$w = x^L z \alpha h^{\alpha-1}$.
Vacancy posting - zero profit condition:	$\kappa = q\beta J$.
Resource constraint:	$y = c + g + \kappa v + n\Phi^L$.
Production:	$y = nzh^{\alpha}$.
Period profit of a goods differentiation firm:	$\Psi^C = (1 - mc)y$.

A.2 Linearized Model Economy

Consumption Euler equation:	$\widehat{\lambda}_t = E_t\left\{\widehat{\lambda}_{t+1} + \widehat{R}_t + \widehat{\epsilon}^b_t - \widehat{\Pi}_{t+1}\right\}$,
	where $\widehat{\lambda}_t = -\frac{\sigma}{1-\varrho}\left(\widehat{c}_t - \varrho\widehat{c}_{t-1}\right)$.
New Keynesian Phillips curve:	$\widehat{\Pi}_t = \frac{\xi_p}{1+\beta\xi_p}\widehat{\Pi}_{t-1} + \frac{\beta}{1+\beta\xi_p} E_t\left\{\widehat{\Pi}_{t+1}\right\} + \frac{1}{1+\beta\xi_p}\frac{(1-\omega)(1-\omega\beta)}{\omega}\widehat{mc}_t$,
	where $\widehat{mc}_t = \widehat{e}^C_t + \widehat{x}^L_t$.
Matching:	$\widehat{m}_t = \xi\widehat{u}_t + (1-\xi)\widehat{v}_t$.
Employment stock:	$\widehat{n}_t = (1-\vartheta)\widehat{n}_{t-1} + \frac{m}{n}\widehat{m}_{t-1} - \vartheta\widehat{\vartheta}_t$.

Link employment to unemployment: $\widehat{n}_t = -\frac{u}{1-u}\widehat{u}_t$.

Probability of finding a worker: $\widehat{q}_t = \widehat{m}_t - \widehat{v}_t$.

Probability of finding a job: $\widehat{s}_t = \widehat{m}_t - \widehat{u}_t$.

Bargaining FOC: $\widehat{J}_t^* + \widehat{\delta}_t^W = \widehat{\Delta}_t^* + \widehat{\delta}_t^F - \frac{1}{1-\eta}\widehat{\eta}_t$.

Aggregate hours index: $\widehat{x}_t^L + \widehat{z}_t + (\alpha-1)\widehat{h}_t = \widehat{w}_t$.

Evolution of aggregate real wage: $\widehat{w}_t = \gamma\left[\widehat{w}_{t-1} - \widehat{\Pi}_t + \xi_w\widehat{\Pi}_{t-1}\right] + (1-\gamma)\widehat{w}_t^*$.

Law of motion of $\widehat{\delta}_t^F$:

$$\begin{aligned}\widehat{\delta}_t^F \quad = \quad & [1-\beta(1-\vartheta)\gamma]\left[\tfrac{-\alpha}{1-\alpha}\widehat{w}_t^* + \tfrac{1}{1-\alpha}\left(\widehat{x}_t^L + \widehat{z}_t\right)\right] \\ & + \beta(1-\vartheta)\gamma E_t\left\{\tfrac{-\alpha}{1-\alpha}\left[\widehat{w}_t^* - \widehat{\Pi}_{t+1} + \xi_w\widehat{\Pi}_t - \widehat{w}_{t+1}^*\right] + \widehat{\delta}_{t+1}^F + \widehat{\lambda}_{t+1} - \widehat{\lambda}_t - \tfrac{\vartheta}{1-\vartheta}\widehat{\vartheta}_{t+1}\right\}.\end{aligned}$$

Law of motion of $\widehat{\delta}_t^W$:

$$\begin{aligned}\delta^W\widehat{\delta}_t^W \quad = \quad & \tfrac{-\alpha}{1-\alpha}wh\left[\tfrac{-\alpha}{1-\alpha}\widehat{w}_t^* + \tfrac{1}{1-\alpha}\left(\widehat{x}_t^L + \widehat{z}_t\right)\right] \\ & + \tfrac{1}{1-\alpha}mrsh\left[\tfrac{(-1)(1+\varphi)}{1-\alpha}\widehat{w}_t^* - \widehat{\lambda}_t + \tfrac{1+\varphi}{1-\alpha}\left(\widehat{x}_t^L + \widehat{z}_t\right)\right] \\ & + \tfrac{\beta(1-\vartheta)\gamma}{1-\beta(1-\vartheta)\gamma}\left[\left(\tfrac{\alpha}{1-\alpha}\right)^2 wh - \tfrac{1+\varphi}{(1-\alpha)^2}mrs\,h\right]E_t\left\{\widehat{w}_t^* - \widehat{\Pi}_{t+1} + \xi_w\widehat{\Pi}_t - \widehat{w}_{t+1}^*\right\} \\ & + \beta(1-\vartheta)\gamma\delta^W E_t\left\{\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{\delta}_{t+1}^W - \tfrac{\vartheta}{1-\vartheta}\widehat{\vartheta}_{t+1}\right\}.\end{aligned}$$

Vacancy posting equation:

$$\begin{aligned}\tfrac{\kappa}{q}\left[\widehat{\kappa}_t - \widehat{q}_t\right] \quad = \quad & \tfrac{\beta\gamma}{1-\beta(1-\vartheta)\gamma}whE_t\left\{\widehat{w}_{t+1}^* + \widehat{\Pi}_{t+1} - \widehat{w}_t - \xi_w\widehat{\Pi}_t\right\} \\ & + \beta JE_t\left\{\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{J}_{t+1}^*\right\}\end{aligned}$$

Evolution of $\widehat{J}_t^*$:

$$\begin{aligned}J\widehat{J}_t^* \quad = \quad & \tfrac{wh}{\alpha}\left[-\alpha\widehat{w}_t^* + \widehat{x}_t^L + \widehat{z}_t\right] \\ & + \tfrac{\beta(1-\vartheta)\gamma}{1-\beta(1-\vartheta)\gamma}whE_t\left\{\widehat{w}_{t+1}^* + \widehat{\Pi}_{t+1} - \widehat{w}_t^* - \xi_w\widehat{\Pi}_t\right\} \\ & + \beta(1-\vartheta)JE_t\left\{\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{J}_{t+1}^* - \tfrac{\vartheta}{1-\vartheta}\widehat{\vartheta}_{t+1}\right\}.\end{aligned}$$

Evolution of $\widehat{\Delta}_t^*$:

$$\begin{aligned}
\Delta\widehat{\Delta}_t^* \quad = \quad & wh\tfrac{1}{1-\alpha}\left[-\alpha\widehat{w}_t^* + \widehat{x}_t^L + \widehat{z}_t\right] \\
& -\tfrac{1}{1+\varphi}mrsh\left[\tfrac{1+\varphi}{1-\alpha}\left((-1)\widehat{w}_t^* + \widehat{x}_t^L + \widehat{z}_t\right) - \widehat{\lambda}_t\right] \\
& +\tfrac{\beta(1-\vartheta)\gamma}{1-\beta(1-\vartheta)\gamma}\left[\tfrac{\alpha}{1-\alpha}wh - \tfrac{1}{1-\alpha}mrsh\right]E_t\left\{\widehat{w}_{t+1}^* + \widehat{\Pi}_{t+1} - \widehat{w}_t^* - \xi_w\widehat{\Pi}_t\right\} \\
& -\tfrac{\beta\gamma s}{1-\beta(1-\vartheta)\gamma}\left[\tfrac{\alpha}{1-\alpha}wh - \tfrac{1}{1-\alpha}mrsh\right]E_t\left\{\widehat{w}_{t+1}^* + \widehat{\Pi}_{t+1} - \widehat{w}_t - \xi_w\widehat{\Pi}_t\right\} \\
& +(1-\vartheta-s)\beta\Delta E_t\left\{\widehat{\lambda}_{t+1} - \widehat{\lambda}_t + \widehat{\Delta}_{t+1}^*\right\} \\
& -\beta\Delta s\widehat{s}_t \\
& -\beta\Delta\vartheta E_t\left\{\widehat{\vartheta}_{t+1}\right\}.
\end{aligned}$$

Resource constraint:	$y\widehat{y}_t = c\widehat{c}_t + g\widehat{g}_t + \kappa v\left[\widehat{\kappa}_t + \widehat{v}_t\right] + \Phi^L n\widehat{n}_t.$
Aggregate production:	$\widehat{y}_t = \widehat{z}_t + \alpha\widehat{h}_t + \widehat{n}_t.$
Average profits labor firm:	$\widehat{\Psi}_t^L = A\left[\widehat{w}_t + \widehat{h}_t\right],\ A := \frac{\frac{1-\alpha}{\alpha}wh}{\frac{1-\alpha}{\alpha}wh-\Phi}.$
Average wholesale profits:	$\Psi^C\widehat{\Psi}_t^C = (1-mc)y\,\widehat{y}_t - y\,mc\,\widehat{mc}_t.$

Taylor rule:

$$\widehat{R}_t \quad = \quad \gamma_R\widehat{R}_{t-1} + (1-\gamma_R)\left[\tfrac{\gamma_\pi}{4}\widehat{\Pi}_t^{yoy} + \tfrac{\gamma_y}{4}(\widehat{y}_t - \widehat{y}_t^{\text{flex}})\right] + \gamma_{\Delta y}\left[\widehat{y}_t - \widehat{y}_{t-1}\right] + \widehat{e}_t^{money}.$$

Year-on-year inflation: $\quad \widehat{\Pi}_t^{yoy} = \widehat{\Pi}_t + \widehat{\Pi}_{t-1} + \widehat{\Pi}_{t-2} + \widehat{\Pi}_{t-3}.$

Flexible Price and Flexible Wage Economy

The monetary authority reacts to deviations of output from its putative value under flexible prices and flexible wages. In calculating this flex-price-flex-wage output in t, y_t^{flex}, we take the values of the states of the actual economy prevailing in period t, e.g., the habit level c_{t-1}, as the states prevailing in the flex-price-flex-wage economy, too. This is the same concept used to define the flex-price output in Smets and Wouters (2003). The flexible price, flexible wage economy duplicates the above system, setting price and wage rigidity to zero.

B Calibrated Version: Table of Parameters and Calibration of Shocks and Steady State

Table 5: Parameters and their calibrated values

Parameter	Value	Explanation; Target/Reference
Preferences		
β	.992	Time-discount factor; matches annual real rate of 3.3 percent.
φ	2	Labor supply elasticity of 0.5; close to mode in Smets and Wouters (2003).
σ	1.5	Risk aversion; mode of estimates in Smets and Wouters (2003)
ϱ	.6	External habit persistence; mode of estimates in Smets and Wouters (2003).
κ^L	94.7	Scaling factor to disutility of work; targets $h = 1/3$.
Bargaining and Labor Good		
α	.66	Labor elasticity of production; targets labor share of 60%.
ξ	.6	Elasticity of matches w.r.t. unemployment; Burda and Wyplosz (1994).
γ	.83	Avg. duration of wages contracts of 6 qtrs.; see e.g. Mermet (2001).
ϑ	.03	Quarterly separation rate; Hobijn and Sahin (2007) and Appendix C.2.
η	.5	Bargaining power of workers; conventional value.
σ_m	.42	Efficiency of matching; reconciles m with target $u = 0.09$ and $q = 0.7$.
κ	.058	Vacancy posting costs; reconciles m with target for u and q.
z	2.27	Technology; targets output $y = 1$.
Φ^K	.33	Imputed share of capital in revenue; capital income ratio.
Φ^L	.0069	Fixed cost associated with labor; targets $std(\widehat{u}_t)/std(\widehat{y}_t)$ in the data.
ξ_w	0	Wage indexation; no indexation in baseline model.
Wholesale Sector		
ϵ	11	Markup; conventional price-markup of 10%.
ω	.75	Calvo stickiness of prices; avg. duration of 4 qrts; Álvarez *et al.* (2006).
ξ_p	0	Price indexation; no indexation in baseline model.
Government		
γ_π	1.5	Response to inflation; conventional Taylor rule.
γ_y	.5	Response to output gap; conventional Taylor rule.
$\gamma_{\Delta y}$	0	Response to output growth; conventional Taylor rule.
γ_R	.85	Interest rate smoothing coefficient; conventional value.
$\overline{g}$	.2	Government spending; targets government spending-GDP ratio.
b	.429	Unemploym. benefits; targets replacement rate $\frac{b}{wh} = 0.65$, see Appendix C.1.
Correlation of Shocks and Size of Innovations		
ρ_g	.79	Autocorrelation of government spending; estimated, see text.
ρ_z	.64	Autocorrelation of technology shock; estimated, see text (identified using the model's resource constraint).
ρ_b	.85	Autocorrelation of premium shock; persistent demand shock.
σ_{money}	.1	Standard deviation of monetary policy shock; estimated, see text.
σ_g	.47	Standard deviation of innovation to government spending; estimated, see text.
σ_z	.39	Standard deviation of innovation to technology; estimated, see text.
σ_b	.19	Standard deviation of innovation to premium shock; targets $std(\widehat{y}_t)$.

Notes: The table reports calibrated parameter values. The model's implications, the level of inflation apart, are independent of the target level of inflation. Without loss of generality, we set $\overline{\Pi} = 1$. The model is calibrated to euro area data from 1984Q1 to 2006Q4. See the main text for details.

Table 5 presents the overview of the parameters in the calibrated model.

Shock processes of the Calibrated Model

This section discusses in detail how we parameterize the shock process in the calibrated version of the model. We parameterize four shock processes: the technology shock, z_t, the government spending shock, g_t, the monetary policy shock, e_t^{money}, and the risk-premium shock, ϵ_t^b. That is, the calibrated version of the model abstracts from labor market shocks as well as cost-push shocks. The first three of the above shocks are directly observable or identified by our model given our previous assumptions. The technology shock follows from the model's aggregate production function

$$\widehat{z}_t = \widehat{y}_t - \left(\alpha \widehat{h}_t + \widehat{n}_t\right).$$

A hat denotes the HP(1,600) filtered cyclical component of the corresponding series in logs. We model the technology shock as an AR(1) process, the parameters of which are obtained by estimating $\widehat{z}_t = \rho_z \widehat{z}_{t-1} + e_t^z$ by ordinary least squares. Also government spending is represented by an AR(1) process estimated on the HP(1,600) filtered government consumption data for the sample period. The shock to monetary policy can be inferred by inverting the Taylor rule[39]

$$\widehat{e}_t^{money} = \widehat{R}_t - \left\{\gamma_R \widehat{R}_{t-1} + (1-\gamma_R)\left[\frac{\gamma_\pi}{4}\widehat{\Pi}_t^{\text{yoy}} + \frac{\gamma_y}{4}\left(\widehat{y}_t - \widehat{y}_t^{\text{flex}}\right)\right] + \gamma_{\Delta y}\left(\widehat{y}_t - \widehat{y}_{t-1}\right)\right\}.$$

We then compute the standard deviation of the shock series $\widehat{e}_t^{money}$, which gives our calibration for σ_{money}. Finally, we model the risk-premium shock as an AR(1) process. The autocorrelation is set to $\rho_b = 0.85$. The standard deviation of the risk-premium shock is set such that the output series in our model matches the fluctuations of output in the data.

Steady State of the Calibrated Model

Table 6 reports the resulting steady state of the calibrated model. Output was normalized to unity, allowing us to interpret GDP components as shares of GDP. Consumption is 79% of GDP owing to our calibration of the government sector to 20% of GDP and the absence of investment and foreign trade. The remainder of output falls on vacancy costs and overhead labor costs.

[39] We proxy for the output gap by using the deviation of actual output from trend.

Table 6: Steady state

Variable	Value	Description
y	1	Output.
c	.79	Consumption.
whn/y	.6	Labor share in total output.
u	.091	Unemployment rate.
v	.039	Vacancies.
s	.3	Probability of finding a job within a quarter.
q	.7	Probability of finding a worker within a quarter.
$b/(wh)$	.65	Unemployment insurance replacement rate.
$\kappa v/y$	.0023	Share of output lost to vacancy posting.
$\Phi^K/(x^L zh^\alpha)$	.33	Share of a labor firm's revenue paid to capital.
$\Phi^L/(x^L zh^\alpha)$	.0069	Share of a labor firm's output lost to fixed costs.
Ψ^C/y	.091	Profit share (Calvo sector) in total output.
$\Psi^L n/y$	.0029	Profit share (labor sector) in total output.
J	.084	Value of a labor firm.
Δ	.07	Surplus of the worker from working.

Notes: Steady state implied by the calibration summarized in Table 5.

The labor share in output is $\frac{nwh}{nzh^\alpha} = \frac{w}{zh^{\alpha-1}} = x^L\alpha = 60\%$, in line with the recent figures for euro area countries reported by Lawless and Whelan (2007) and Eurostat's measure of the adjusted wage share.[40]

The steady state unemployment rate was targeted to be 9.1%, in line with the average of the euro area unemployment rate over the sample period. The calibration implies a probability of finding a job within a quarter's time, s, of around 30%, which is in line with the high incidence of long-term unemployment in the euro area; see also Table 7 in Appendix C.1. Roughly 0.23% of output is lost to vacancy posting costs each quarter. The steady state value of a worker to a firm is $J = 0.084$, meaning 8.4% of a quarter's value of its revenue, and the surplus to the family of having a worker employed is $\Delta = 0.070$, or 10.6% of a quarter's wage.

[40] Eurostat reports the adjusted wage share as the ratio of the compensation of employees and nominal GDP. This averages to around 60% over the period from 1984 to 2004. These numbers do not include imputed wage income of entrepreneurs. With the AWM data set used in this paper, the labor share averages to 56%.

C Further Background Information for the Calibration

This section gives details on the calibration of the euro area replacement and separation rates.

C.1 Replacement Rate

For the labor supply decision and the outside option of the worker the relevant replacement rate is the net replacement rate, *i.e.*, the replacement rate of after-tax (and after deduction of contributions to social security) income. We resort to the OECD's publication of net replacement rates in its "Benefits and Wages" publication. Since the net replacement income is not least shaped by the tax code, which differentiates tax liabilities by family types, the OECD distinguishes between different income characteristics and different family characteristics. We follow the OECD practice and take the simple average over the income categories of the replacement rates when pre-unemployment income was, respectively, 67% and 100% of the income of an average production worker. We furthermore take simple averages over the family characteristics. We use the latest vintage of the data available, which currently is 2004. Table 7 reports the effective net replacement rates by country thus computed for the euro area member states (excluding the new entrants in 2007).

Turning to the average replacement rate, which is used as a calibration target, both simple averages and population-weighted replacement rates give a similar picture: initial replacement rates averaging over all family characteristics are around 75% in the euro area (ranging from 59% in Ireland to 88% in Luxembourg). After 5 years of unemployment, the effective net replacement rate (including social assistance, family, housing and child-care benefits) is on average roughly 55% for the euro area.[41] With respect to the calibration target, we choose the average of the replacement rates for the different unemployment durations and set $\frac{b}{wh} = 65\%$.

The final four columns of Table 7 illustrate that longer-term unemployment is a common phenomenon in the euro area. On average about 45% of the unemployment spells last at least a year.

[41] This number already is strongly driven down by two outliers. Both Greece and Italy feature hardly any direct unemployment benefit or social assistance entitlement in the longer-term.

Table 7: Net replacement rates and unemployment duration as share of unemployed

Country	Net replacement rate (%)					Unemployment duration (months)			
	Initial		month 60		Avg. 5 yrs.	≤ 5	6 to 11	12 to 23	≥ 24
Euro area									
Austria	70	(65)	69	(73)	(67)	52	18	16	14
Belgium	72	(69)	67	(65)	(66)	29	14	18	39
Germany	77	(71)	70	(75)	(71)	29	15	19	36
Spain	78	(74)	44	(41)	(52)	48	18	15	19
Finland	78	(77)	69	(72)	(70)	48	19	16	17
France	82	(79)	60	(65)	(68)	38	18	20	23
Greece	65	(64)	17	(2)	(33)	29	16	21	34
Ireland	59	(55)	71	(71)	(62)	43	19	16	22
Italy	63	(55)	19	(0)	(6)	30	14	17	40
Luxembourg	88	(87)	69	(74)	(51)	50	22	18	11
Netherlands	82	(81)	68	(77)	(61)	35	19	21	24
Portugal	86	(84)	59	(61)	(61)	34	19	22	26
Euro area min	59	(55)	17	(2)	(6)	29	14	15	11
Euro area max	88	(87)	70	(77)	(71)	52	22	22	40
Euro area average	75	(71)	57	(56)	(56)	39	18	18	26
Pop.-weight avg.	75	(70)	52	(51)	(53)	35	17	18	30

Notes: Replacement rates and distribution of unemployment duration for the euro area by country. All entries are in percent. For each category, the table also reports the largest and smallest entry in the euro area, an unweighted average and a population-weighted average with 2004 population weights. Second to fourth columns: effective net replacement rates, source: OECD, "Benefits and Wages." Entries refer to an average over six family types (single adult, one-earner married couple, two-earner married couple with 2 children and without children) and over the level of pre-unemployment income of 67% of the average production worker wage (APW) and 100% of the average production worker wage (for married couples the percent of APW relates to one spouse only; the second spouse is assumed to be "inactive" with no earnings in a one-earner couple and to have full-time earnings equal to 67% of APW in a two-earner couple. Children are ages 4 and 6.). Entries in brackets refer to an average over four family types only (excluding the two-earner case). Second column: initial replacement rate. Third column: replacement rate of a long-term unemployed, measured by the replacement rate 5 years after the unemployment incidence. Column four: average net replacement rate over 60 months of unemployment, no data for two-earner couples provided by the OECD, the numbers are averages over replacement rates when the household receives social assistance and the case when it does not. Columns five to eight: decomposition of the unemployed population by duration of unemployment. Source for European countries: OECD "Labour Force Survey." Averages from 2001Q1 to 2006Q4. Column five, duration of at most five months, column six: unemployment duration of six to 11 months, column seven: share of the unemployed with an unemployment duration of 12 to 23 months, final column: share of the unemployed population with an unemployment duration of at least two years.

C.2 Separation Rates

We next turn to the calibration of the separation rate of firms and workers in the euro area. In our model worker flows and job flows coincide. Whenever a worker is separated from a firm/job, the firm/job ceases to exist. The same is not true for actual data in which worker flows typically exceed job flows by a factor of two to three; for the U.S., see for instance Davis, Faberman, and Haltiwanger (2006), for France see Blanchard (2005), Abowd *et al.* (1999), and for Portugal see Blanchard and Portugal (2001). In addition, Burda and Wyplosz (1994), Bachmann (2005) illustrate that there are substantial flows of workers from both employment and unemployment to out-of-the-labor-force for both France and Germany. Here we abstract from these flows. Since our model takes a simplifying view, we believe that the closest empirical proxy to the destruction rate in our model is the job destruction rate.

No comprehensive study of job flows and/or worker flows concerned with job flows at a monthly or at least quarterly frequency exists for the euro area as a whole.[42] We studied the available evidence on separation for euro area individual countries from the perspective of worker flows (which as argued provide an upper-bound on job flows), and some direct evidence on job flows.[43] Complementary evidence is provided in Hobijn and Sahin (2007), who report indirect estimates of separation rates for the full set of OECD countries. We take the evidence as suggestive of a euro-area wide job destruction rate of about 3% per quarter.

Complementary information from a worker flow perspective can be taken from Eurostat's EU Labour Force Survey, which collects quarterly information on the share of employed persons who started a job within the past three months for each country of the European Union, see Table 8.[44]

While the data presented in Table 8 cover only a relatively short time span (2004Q1 to 2006Q4), it is nevertheless suggestive of worker flows in the European Union. The evidence appears to

[42] The frequency of observation is important, since low frequencies can mask labor market flows between observation dates. For example, a worker who takes up employment in a different job in each of the quarters of a year will appear to have experienced just one job change in annual data; cp. Abowd, Corbel, and Kramarz (1999).

[43] See, e.g., Abowd, Corbel, and Kramarz (1999), Picart (2007), Burda and Wyplosz (1994) and Bachmann (2005), Bertola and Ichino (1995) on evidence concerning worker flows, and Abowd, Corbel, and Kramarz (1999), Picart (2007), Cahuc and Zylberberg (2004) and Blanchard and Portugal (2001) on respective evidence on job flows.

[44] The data are published in Table 12 of Eurostat's publication "Labour Market Latest Trends."

Table 8: Share of persons whose job started within the past 3 months

Country	Share	pop. weight	Country	Share	pop. weight
Austria	4.5	3%	Greece	2.2	4%
Belgium	3.7	3%	Ireland	4.7	1%
Germany	4.2	26%	Italy	3.7	19%
Spain	7.6	14%	Luxemburg	2.6	.2%
Finland	7.3	2%	Netherlands	1.3	5%
France	6.2	20%	Portugal	3.1	3%
Euro area min	1.3	0.2%			
Euro area max	7.6	26%			
Euro area average	4.3	–			
Pop.-weight avg.	4.8	–			

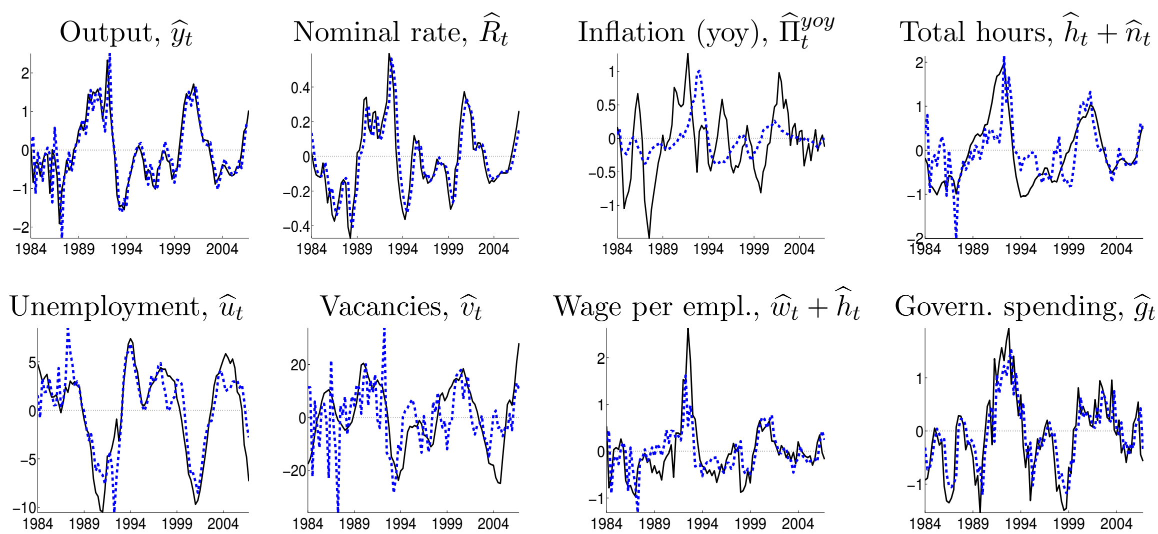
Notes: Estimate of share of currently employed persons who have started a new job in the last 3 months for European countries. Source: EU Labour Force Survey, Table 12 of Eurostat's publication "Labour Market Latest Trends." Data are available from 2004Q1 to 2006Q4 and are not seasonally adjusted. Column two presents averages over these observations. For some countries observations are not available for each quarter. This is the case for Germany (three quarters missing), Ireland (one quarter missing) and Luxembourg (7 quarters missing). The final column reports population weights for the euro area member states, which were used to compute the population-weighted average rate in the third to last row.

be roughly in line with that of our literature survey. Namely, Germany and Italy tend to have lower worker flow rates than Spain and France. From a worker flow perspective, these data for the recent three years point to separation rates of at most 4.8% per quarter (including job-to-job transitions). Taking into account that worker flow data typically overestimate job flows by a factor of two to three, we are led to a job destruction rate between 1.6% and 2.4% during the period of relatively weak growth that these data cover. Overall, weighing the evidence above, we opt for calibrating our model to a quarterly job destruction rate of 3% for the euro area as a whole.

D Fit of the Calibrated Model

This section evaluates the fit of the calibrated model beyond the standard deviations shown in Section 3. Further evidence is contained in Table 9 in Appendix E. Figure 4 presents a metric that can be used as a rough eyeball test to judge the calibrated model's fit. Each panel plots the one-step Kalman-filter forecast, once the calibrated model is used to generate the observation and the state equation (blue dotted line). The data shown are the same data we use in estimating the full model. The actual data are shown as black solid lines. The exercise is the following: output, $\widehat{y}_t$, interest rates, $\widehat{R}_t$, wages per employee, $\widehat{w}_t + \widehat{h}_t$, and government spending, $\widehat{g}_t$, are treated as observable data. We use these four series only, since the calibrated model with the four shocks would be stochastically singular when using more than four observable data series. The graphs thus reveal to which extent the model, absent the cost-push shock and the three labor market shocks, can explain the evolution of all series. In particular, the smaller the difference between the black solid line and the blue dotted line, the better the fit of the model in that particular dimension.

Figure 4: Fit: actual data vs. Kalman-filtered estimates using only four series



Notes: The figures compare Kalman-filtered one-step forecasts (for t given information up to $t-1$) using the calibrated model (blue dashed line) along with the actual data (black solid line). In each panel, a black solid line marks the corresponding HP-filtered series of actual data. The data used are the same as those used for the estimation exercise in Section 5: output, $\widehat{y}_t$, interest rates, $\widehat{R}_t$, the year-on-year inflation rate, $\widehat{\Pi}_t^{yoy}$, total hours worked, $\widehat{n}_t + \widehat{h}_t$, the unemployment rate, $\widehat{u}_t$, vacancies, $\widehat{v}_t$, the wage per employee, $\widehat{w}_t + \widehat{h}_t$, and government spending, $\widehat{g}_t$. The sample starts in 1980Q1 and ends in 2006Q4. The first four years are used to initialize the Kalman filter. Since the calibrated model features only four shocks, it is stochastically singular when using more than four observable data series. For the Kalman filtering underlying the above charts we use the following four data series: output, interest rates, the wage per employee, and government spending.

The calibrated model fits the evolution of output, total hours worked, nominal rates, unemployment and government spending. For hours and unemployment this is the case despite the fact that none of these series is treated as observable in the Kalman filtering. Also for vacancies the model infers the correct cyclical pattern, yet implies too much volatility at high frequencies. To a satisfactory but not full extent the model fits the evolution of wages per employee. Without a cost-push shock, the model captures part of the pattern in inflation, yet to a much lesser extent than for the other series. The importance of shocks to price (and wage) setting for the empirical performance of monetary business cycle models is well-documented in the literature. In Smets and Wouters (2003), for example, price-markup and wage-markup shocks, respectively, explain more than half of the share of the short-term forecast error variance of inflation and wages, respectively. Similar findings obtain in our estimation exercise reported in Section 5.

E Estimation: Fit, Variance Decomposition, Impulse Responses

As a measure of how well both the estimated and the calibrated model match the data, Table 9 reports in-sample one-step root mean-squared errors (RMSEs) for the observable data in the model (see the third column for the estimated model and the fourth column for the calibrated model) and compares these to the RMSE in an unrestricted VAR(1) estimated on the same data (see second column). The results indicate that the estimated model is competitive for output, interest rates and unemployment. In terms of RMSE it is significantly worse than the VAR, though, for hours worked and wages per employee, while it provides a better fit for inflation than the VAR. A comparison of the RMSEs for the estimated model and the RMSEs for the calibrated model (cp. third and fourth columns) shows that for most variables, the estimation improves upon the (in sample) fit of the model. The second set of results displayed in Table 9 concerns standard deviations in the model and in the data. Once we have accounted for both parameter and data uncertainty, the estimated model captures the standard deviations of output, interest rates, vacancies and unemployment at the 5% level, but implies too volatile series for hours worked and wages per employee. For completeness, accounting for data uncertainty, we also report the standard deviations implied by the calibrated version of the model used in Section 3. For comparing the implications of the calibrated and the estimated version of the model, Figure 5 shows the impulse responses to a monetary shock in the calibrated economy, overlayed by 95% coverage intervals for the impulse responses implied by the estimated version of the model.

Table 10 reports the full forecast error decompositions at three horizons for the baseline estimation. This complements the information in Table 4, which limited itself to a subset of variables,

Table 9: Root mean-squared error and standard deviation

Variable	RMSE			standard deviation		
	VAR	estimated	calibrated	data	estimated	calibrated
$\widehat{y}_t$	.39	.41 [.41, .42]	.44	.86	.76 [.56, 1.04]	0.78 [0.53, 1.11]
$\widehat{R}_t$	.08	.10 [.10, .11]	.10	.21	.22 [.15, .33]	0.17 [0.12, 0.24]
$\widehat{\Pi}_t^{yoy}$	.26	.21 [.20, .23]	.50	.51	.73 [.51, 1.05]	0.30 [0.22, 0.40]
$\widehat{h}_t+\widehat{n}_t$	.12	.24 [.20, .29]	.54	.74	1.14 [.88, 1.50]	1.16 [0.87, 1.56]
$\widehat{u}_t$	1.05	1.01 [1.00, 1.04]	2.32	4.59	3.79 [2.51, 5.84]	4.18 [2.76, 6.00]
$\widehat{v}_t$	3.44	5.63 [4.89, 6.78]	12.14	12.24	14.72 [11.41, 19.34]	13.26 [10.62, 16.37]
$\widehat{w}_t+\widehat{h}_t$	.29	.44 [.42, .49]	.45	.58	1.10 [.86, 1.40]	0.83 [0.66, 1.03]
$\widehat{g}_t$	.41	.47 [.46, .49]	.46	.77	.67 [.49, .97]	0.72 [0.54, 0.96]

Notes: The table compares root mean squared forecast errors (RMSEs) and standard deviations of variables in the estimated and the calibrated model to the data. Column "RMSE-VAR": RMSE in VAR(1), sample 1984:Q1 - 2006:Q4. Column "RMSE-estimated": median RMSE, in brackets 95% confidence interval; based on 10,000 draws from the posterior parameter distribution; for each draw the RMSE is computed using the actual data. The bounds therefore reflect parameter uncertainty but not data uncertainty. The table also reports the RMSEs for the calibrated model. Compare the notes to Figure 4 for computation details. Column "standard deviation-data": measured standard deviation in the data. Column "standard deviation-estimated": median standard deviations in estimated model, in brackets 95% confidence intervals; based on 10,000 random draws from the posterior parameter distribution. Standard deviations are computed by, for each draw, simulating time-series of the same length as in the data used to compute the standard deviations (an initial 200 observations are discarded so as to draw out of the stochastic steady state). The bounds reflect data and parameter uncertainty. Column "standard deviation-calibrated": median standard deviations and 95% bounds in the calibrated model of Section 3; based on 10,000 draws of time-series of the same length as in the data, keeping parameters fixed at the calibrated values. The calibration focused on matching unconditional moments in the model to second moments in the data; this is reported in Table 1. Here we take the sampling uncertainty of shocks into account, too.

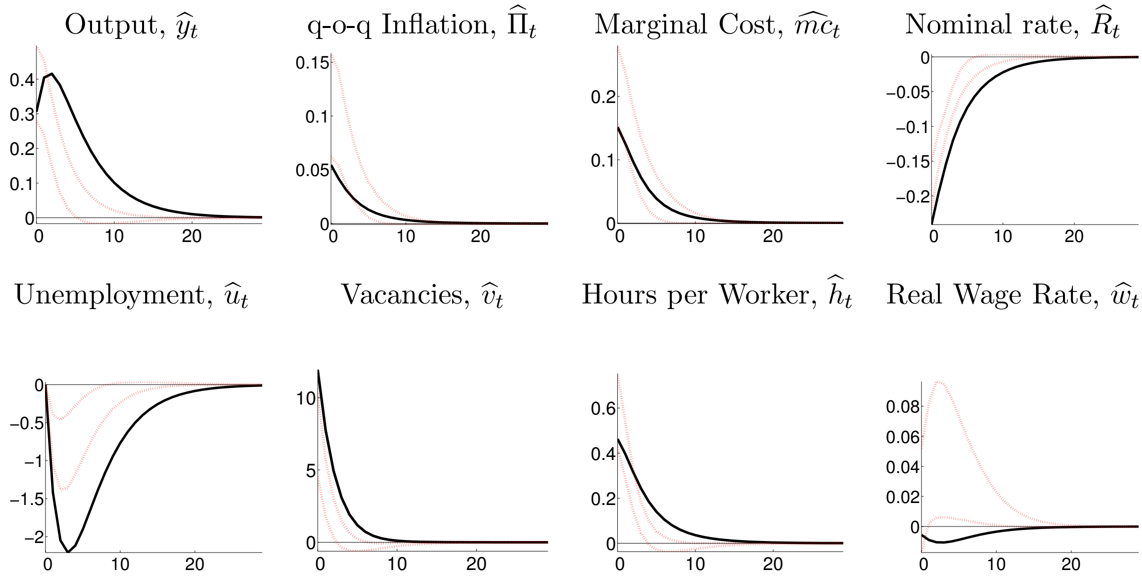
shocks and horizons.

Table 10: Forecast error variance decomposition estimated model – baseline version

	labor market shocks							
	bargain	vacancy	separation	premium	cost-push	monetary	governm.	technol.
Horizon 2								
$\widehat{y}_t$	8.0	.3	.1	60.5	6.9	14.8	2.6	4.9
$\widehat{R}_t$	5.4	.02	.02	32.2	2.5	56.5	.8	.6
$\widehat{\Pi}_t^{yoy}$	12.0	.3	.6	24.8	35.0	6.5	.2	18.2
$\widehat{h}_t+\widehat{n}_t$	6.3	.08	.2	47.9	5.3	11.7	2.1	24.8
$\widehat{u}_t$	.8	16.5	64.3	11.0	2.8	2.8	.2	.2
$\widehat{v}_t$	3.5	46.5	6.2	26.2	7.0	6.9	.4	1.7
$\widehat{w}_t+\widehat{h}_t$	1.9	.5	3.1	47.2	17.5	11.5	1.8	15.0
$\widehat{h}_t$	5.9	.6	3.5	44.6	4.5	10.9	2.0	26.1
$\widehat{w}_t$	67.4	.1	.04	.6	22.2	.2	.02	8.3
Horizon 10								
$\widehat{y}_t$	16.7	1.7	.6	48.2	6.3	12.1	2.0	9.2
$\widehat{R}_t$	11.3	.6	.4	46.5	4.7	28.1	.5	5.6
$\widehat{\Pi}_t^{yoy}$	11.9	1.2	.7	39.5	18.0	11.1	.2	13.9
$\widehat{h}_t+\widehat{n}_t$	14.7	.1	.2	45.1	5.5	11.2	1.9	19.1
$\widehat{u}_t$	6.0	43.4	24.2	12.3	3.2	3.4	.2	2.8
$\widehat{v}_t$	5.4	47.3	6.7	22.4	6.1	5.8	.4	2.8
$\widehat{w}_t+\widehat{h}_t$	2.8	3.0	3.4	45.8	16.9	11.3	1.6	13.4
$\widehat{h}_t$	11.0	4.6	4.0	40.3	4.3	9.9	1.8	21.6
$\widehat{w}_t$	59.5	.8	.1	2.6	19.3	.7	.03	14.6
Horizon ∞								
$\widehat{y}_t$	16.8	2.0	.6	47.9	6.3	12.0	2.0	9.1
$\widehat{R}_t$	11.2	.8	.4	47.7	4.6	27.1	0.5	5.4
$\widehat{\Pi}_t^{yoy}$	12.1	1.2	.7	39.4	17.8	11.1	0.2	14.0
$\widehat{h}_t+\widehat{n}_t$	14.7	.2	.2	45.0	5.5	11.2	1.9	19.1
$\widehat{u}_t$	6.1	45.1	23.0	11.8	3.1	3.2	0.2	2.6
$\widehat{v}_t$	5.4	47.4	6.7	22.4	6.0	5.8	0.4	2.8
$\widehat{w}_t+\widehat{h}_t$	2.8	3.2	3.4	45.7	16.9	11.3	1.6	13.4
$\widehat{h}_t$	11.0	5.0	4.0	40.1	4.3	9.9	1.8	21.5
$\widehat{w}_t$	59.3	1.0	0.1	2.6	19.2	0.6	0.03	14.7

Notes: Forecast error variance decomposition for three different forecast horizons using the baseline parameter estimates. All entries are in %. Shown are median values for each entry, so entries do not need to sum to exactly 100%. Entries are based on 10,000 draws from the posterior distribution. From top to bottom: output, nominal interest rate, annual inflation, total hours worked, unemployment, vacancies, wage per employee, hours worked per employee and the real wage rate. From left to right: bargaining power shock, vacancy posting cost shock, separation rate shock, risk premium shock, cost-push shock, monetary policy shock, government spending shock and technology shock.

Figure 5: Responses to a monetary shock – calibrated vs. estimated baseline



Notes: The panels show percentage responses (1 in the plots corresponds to 1%) to a $\frac{1}{4}$% monetary policy shock for varying degrees of wage rigidity. The black solid line marks the responses in the calibrated model. The red dotted lines bracket 95% confidence intervals. These were obtained using 10,000 draws from the posterior distribution of the estimated parameters, baseline version.