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Inflation dynamics with Search and Matching in the Labour Market: A Survey of Alternative Specifications

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Abstract

This paper reviews recent approaches to modeling the labour market, and assesses their implications for inflation dynamics through both their effect on marginal cost and on price-setting behavior. In a search and matching environment, we consider the following modeling setups: right-to-manage bargaining *vs.* efficient bargaining, wage stickiness in new and existing matches, interactions at the firm level between price and wage-setting, alternative forms of hiring frictions, search on-the-job and endogenous job separation. In particular, we look at the impact of these various modelling choices on the determinants of marginal cost and inflation dynamics, and provide the underlying intuition.

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1 Introduction and motivation

Central banks are typically charged with maintaining price stability, often defined by a target for inflation. But in order to achieve this, it is important to understand what the dynamics of inflation are: in particular, what are the nature of nominal and real frictions associated with the adjustments of prices in the economy and how do these frictions affect the response of inflation to shocks. The answer to this question will have an important bearing for the monetary transmission mechanism as well as what a central bank can and should seek to achieve.

A long tradition in monetary economics assigned labour market frictions and, in particular wage-setting frictions, a central role in inflation dynamics; see, *e.g.*, Ball and Romer (1990), Christiano *et al.* (2005). The rationale was that labour market frictions altered either aggregate marginal cost or the firms' price-setting behaviour for given marginal cost.[1] An active strand of research has recently set out to model the labour market more explicitly in a New Keynesian environment, most often opting for variants of the Mortensen and Pissarides (1994) model of search and matching frictions. The variety of implications is stunning. Some have, for example, argued that accounting for equilibrium unemployment increases the resilience of marginal cost, and hence inflation, to shocks by adding a pool of slack resources; see, *e.g.*, Trigari (2005) and Walsh (2005). Others, *e.g.*, Krause and Lubik (2007), conclude that contrary to received wisdom wage rigidity does not impact on inflation inertia.[2]

This paper surveys the existing modeling approaches. It explains their implications for the behavior of marginal cost and inflation, and highlights which of the particular features of each modeling approach drive the results. A key aim is to give a structure to the rich variety of existing literature, and to distill the policy-relevant features.[3]

Technically, we take a plain New Keynesian model with search and matching frictions as our starting point. As the baseline, we choose the efficient bargaining version of Trigari (2006). Building on this, we replace certain assumptions on the labor market structure by others, one at a time. We consider the following variants: right-to-manage (instead of efficient) bargaining (Trigari, 2006), stickiness of wages in these setups (Gertler and Trigari, 2006; Christoffel and Linzert, 2005) differentiating between stickiness in new

[1] Thus, the labour market was seen as a source of "real rigidities". For an overview of the extensive literature on real rigidities more generally, see Woodford (2003).

[2] Another strand of iterature has been concerned with normative implications, such as the design of optimal monetary policy; see, *e.g.*, Blanchard and Gali (2006), Faia (2008), Tang (2006).

[3] Other papers, largely sparked by Shimer's (2005) critique, seek to improve the modeling or calibration of the labour market *per se*, and are not necessarily concerned with nominal frictions, *e.g.*, Gertler and Trigari (2006), Fujita and Ramey (2005), Yashiv (2006). In this paper, we take up some of the suggestions made in these papers, as – through their implications for the behavior of wages and (un)employment – they also imply changes in the behavior of marginal cost.

matches and existing matches (Bodart *et al.*, 2005; Bodart *et al.*, 2006), interactions at the firm-level between price and wage-setting (Kuester, 2007; Sveen and Weinke, 2007; Thomas, 2008), alternative forms of vacancy posting costs (Yashiv, 2006) and the hiring process (Fujita and Ramey, 2005), search on-the-job (Krause and Lubik, 2006; van Zandweghe, 2006) and endogenous separation (den Haan *et al.*, 2000; Zanetti, 2007). In particular, we look at the impact of these variants on marginal cost and inflation. In each of the cases we provide intuition for the effect that a specific modification of the baseline model has on inflation dynamics.

In the New Keynesian model, the response of inflation to a given shock (such as a monetary policy shock) is determined both by the response of real marginal cost to that shock and by the reactions of firms to a given change in real marginal cost. Models that imply large and immediate responses of real (marginal) wages to shocks will not match the sluggish response of inflation observed in empirical research (see Appendix A for a summary) unless other real rigidities induce firms not to pass such changes in costs through to their customers, or unless real wages do not fully drive all of marginal cost. For this reason, throughout the paper, we trace the impact of the respective modeling approach on the form and behaviour of marginal cost and on the firms' price setting behaviour and analyse in which respect each approach improves upon the standard New Keynesian framework in accounting for a sluggish response of inflation to monetary shocks.

Our findings are as follows. We show, first, that the baseline model predicts a response of inflation that is too large relative to the data, as a result of the large and immediate response of real marginal cost. This would suggest either that the labour market is not an important source of real rigidities or that the specific way of modeling the labour market was not appropriate. Indeed, when combined with a 'right-to-manage' assumption for the determination of hours, staggered wages at the level of the match help to smooth the reaction of the marginal wage resulting in a smaller response to shocks of marginal cost and inflation. Inflation responds even less to shocks when accounting for the firm-specific nature of labour in the search and matching model. This, however, also had implications for the response of unemployment and vacancies that took it further away from the data in these dimentions. While variations of the hiring costs empirically only had a small impact on inflation dynamics, we found that both search on-the-job and endogenous separation reduce the response of inflation to shocks, though our results based on endogenous job destruction depended critically on the calibration of the model.

The rest of the paper is structured as follows. In section 2, we lay out the baseline model, which is Trigari's (2006) efficient bargaining setup. We highlight which are the features of the model that will be changed subsequently. In section 3, we calibrate the baseline model using euro area data and compare the responses of inflation (and wages and unemployment) to a monetary policy shock in the model with the responses to the same shock in euro area data. Subsequently, we assess to which extent this response is an artefact of the modeling approach, and assess whether other specifications reverse that finding. In section 4 we consider the effects of having 'right-to-manage' bargaining and section 5 adds nominal wage rigidities for new and existing jobs, exploring how these rigidities interact with the bargaining scheme. Section 6 considers what happens if wages and prices are set simultaneously in the presence of firm-specific labour. Section 7 allows for new hires being productive immediately and not only with a one-period delay. In section 8 we discuss the effects of varying the free-entry condition and vacancy costs. Sections 9 and 10 consider other margins along which adjustment can occur in the labour market: section 9 discussing on-the-job search and section 10 discussing endogenous job destruction. Section 11 concludes. An appendix presents empirical evidence on monetary transmission in the euro area.

2 The baseline model

In this section we lay out those aspects which we use as our baseline for the analysis. The baseline is a simplified version of Trigari's (2006) efficient bargaining setup. Some of these aspects will remain fixed throughout the analysis, while some will be replaced by other modeling assumptions. We point to the dimensions in which we vary the baseline as we proceed.

2.1 Households, consumption and saving

We assume that there is a continuum of workers indexed by j on the unit interval who supply a homogeneous type of labour. Only a proportion n_t of them are employed. We adopt a representative –or large– household interpretation so that the unemployment rate u_t is identical at the household or at the aggregate level. As shown by Merz (1995), the representative household assumption amounts to allowing for the existence of state contingent securities offering workers insurance against differences in their specific labour income. Household members (workers) share their labour income, *i.e.*, wage and unemployment benefits, before choosing per capita consumption and bond holdings.

The representative household's total real income is therefore equal to the aggregate income

$$\mathcal{Y}_t = n_t \cdot w_t \cdot h_t + (1 - n_t) \cdot b + \Psi_t \ . \tag{1}$$

Labour income is made of the sum of hourly wages and unemployment benefit b, weighted by total hours worked and unemployment, respectively.[4] As shareholders, households also receive the profits Ψ_t generated by the monopolistic competitive retail firms and the intermediate producers fo labor services.

Workers hold their financial wealth in the form of bonds B_t. Bonds are one-period securities with price $1/r_t$, where r_t is the nominal interest rate. The budget constraint faced by the representative household may be written as

$$\frac{B_t}{r_t \cdot p_t} + c_t + t_t = \frac{B_{t-1}}{p_t} + \mathcal{Y}_t \tag{2}$$

where c_t represents aggregate consumption, t_t are lump-sum taxes payable and p_t is the consumer price index.

We assume separability between leisure and consumption in the instantaneous utility function, implying that all workers share the same marginal utility of wealth and choose the same optimal consumption, be they employed or not. A worker's utility can be written as

$$\mathcal{U}\left(c_{jt}, h_{jt}\right) = \frac{c_{jt}^{1-\sigma_c}}{1-\sigma_c} - \chi \frac{h_{jt}^{1+\phi}}{1+\phi} \tag{3}$$

with $\sigma_c \geq 1, \chi > 0, \phi \geq 0$. Let $\mathcal{H}_t(j)$ be the value function of worker j. If we momentarily leave aside the labour supply decision, which is taken by the household as a whole, worker j's maximization program is

$$\begin{aligned} \mathcal{H}_t(j) \quad &= \max_{c_{jt}, B_{jt+1}} \left\{\mathcal{U}\left(c_{jt},\, h_{jt}\right) + \beta \cdot \mathrm{E}_t \mathcal{H}_{t+1}(j)\right\} \\ & \qquad st. \, (2) \end{aligned}$$

The worker's optimal and saving decision coincide with those of his peers and are derived from the following first order conditions:

$$\frac{\lambda_t}{p_t} = \beta \, r_t \cdot \mathrm{E}_t \left\{\frac{\lambda_{t+1}}{p_{t+1}}\right\} , \tag{4}$$

$$\lambda_t = c_t^{-\sigma_c} . \tag{5}$$

This block will not be altered in the variants that we present.

[4] b could alternatively be interpreted as the income generated by the domestic activities of an unemployed worker.

2.2 Firms

The baseline is a three sector economy. Firms in the final good sector, assumed to be a competitive market, produce a homogeneous final good used for consumption. The final homogeneous good is made from differentiated goods which are produced by monopolistic retailers. Retailers simply buy a homogeneous good from intermediate producers and transform them one for one into differentiated goods at no cost. Intermediate producers are perfectly competitive. They produce the intermediate homogeneous good with labour as the only input. They can hire at most one worker and in order to find him/her, they post vacancies.

Final good sector

We assume a continuum of differentiated goods indexed by i on the unit interval. Final good firms aggregate the differentiated goods $y_t^r(i)$ produced by the retailers using a Dixit-Stiglitz technology

$$y_t = \left[\int_0^1 [y_t^r(i)]^{\mu_p} \; di \right]^{1/\mu_p} \quad \text{with } \mu_p \in (0,1) \tag{6}$$

where $1/\mu_p$ represents the retailers' gross price mark-up while $1/(1-\mu_p)$ is the elasticity of substitution between intermediate differentiated goods. Each final good firm maximises profit, leading to the following demand for intermediate good i

$$y_t^r(i) = \left(\frac{p_t(i)}{p_t} \right)^{\frac{1}{\mu_p - 1}} y_t \tag{7}$$

where p_t is the final good price, obtained by aggregation of the retailers prices

$$p_t = \left[\int_0^1 [p_t(i)]^{\frac{\mu_p}{\mu_p - 1}} \; di \right]^{\frac{\mu_p - 1}{\mu_p}} . \tag{8}$$

The modeling of the final good sector will remain fixed throughout the paper.

Monopolistic retailers and price setting

Given the demand $y_t^r(i)$ retail firm i faces for its product, it buys a homogeneous intermediate labour good at nominal price $p_t x_t$ per unit and transforms it one for one into a differentiated product. Its real profit is

$$\Psi_t^r(i) = \frac{p_t(i) - p_t x_t}{p_t} \cdot y_t^r(i)$$

At each period, a fraction $1-\xi_p$ of retail firms sets a new price $p_t^*(i)$. This price prevails

j periods later with probability ξ_p^j. The price setting firms maximise the discounted flows of expected real profits using a discount rate consistent with the pricing kernel for nominal returns used by the shareholders-households. All the price setting firms face the same optimization problem, implying that they all choose the same new price p_t^*. Profit maximization results in the following first-order condition

$$\mathrm{E}_t \sum_{j=0}^{\infty} \left(\beta \xi_p\right)^j \cdot \frac{\lambda_{t+j}}{\lambda_t} \cdot \frac{y_{t+j}^r(i)}{p_{t+j}} \cdot \left(p_t^* - \frac{1}{\mu_p} p_{t+j} x_{t+j}\right) = 0 \tag{9}$$

Given the definition of the price index (8), its law of motion is

$$p_t^{\frac{\mu_p}{\mu_p - 1}} = \left(1 - \xi_p\right) \cdot \left(p_t^*\right)^{\frac{\mu_p}{\mu_p - 1}} + \xi_p \cdot p_{t-1}^{\frac{\mu_p}{\mu_p - 1}} \tag{10}$$

Combining (9) and (10) and log-linearising the resulting expressions around steady state enables us to derive the New Keynesian Phillips Curve

$$\hat{\pi}_t = \beta \mathrm{E}_t \hat{\pi}_{t+1} + \frac{\left(1 - \xi_p\right)\left(1 - \beta \xi_p\right)}{\xi_p} \hat{x}_t \ , \tag{11}$$

where $\pi_t = p_t / p_{t-1}$ is the inflation rate while hats denote percentage deviations from steady state. This expression makes clear that, for a given response of inflation to movements in real marginal cost – which will depend on ξ_p – the response of inflation to a given shock will depend on how real marginal cost responds to that shock. Within the period of the shock, output can only be increased by increasing the number of hours worked per worker; so the cost of increasing hours worked will determine the immediate response of inflation to shocks.

One-worker intermediate labor–services firms

In the baseline, we consider a continuum of intermediate producers uniformly distributed and selling their output in a competitive market. Their only factor of production is labour, and labour efficiency is decreasing with hours, so that h hours supplied by one worker produce only h^α units of efficient labour, $\alpha < 1$. Keeping the Mortensen and Pissarides (1999) assumption, intermediate producers can hire at most one worker so that their production is either zero or

$$y_t^l(o) = \left[h_t(o)\right]^\alpha \ \text{ with } \alpha < 1 \ ,$$

where o indicates match o. As will be clear later, as long as wages are flexible, every firm pays the same wage which implies the same working time. We defer the wage bargaining to the next section. In the baseline the labor-services sector and price-setting firms are linked through competive markets for the labor service. In section 6, we assess the implications for inflation dynamics once these two sectors are merged so that there are interactions between wage and price setting at the level of the individual firm.

2.3 The labour market

The labor market is organized such that it links the intermediate labor-services firm and the workers.

Labour market flows

Let n_t represent the total number of jobs. Normalising the total labour force to one yields the following accounting identity:

$$n_t + u_t = 1 \tag{12}$$

where u_t denotes the number of unemployed, all of which are job-seekers. Let m_t denote the number of new firm-worker matches. We assume that the number of matches is a function of the number of job vacancies v_t and effective job seekers u_t, and we consider the following linear homogeneous matching function:

$$m_t = \sigma_m \, u_t^{\vartheta} \, v_t^{1-\vartheta} \tag{13}$$

with $\sigma_m > 0$ and $\vartheta \in (0, 1)$. Models with search on-the-job (section 9) modify the matching function to depend also on the number of searchers on the job. In the baseline, the probability an unemployed worker finds a job is given by

$$s_t = \frac{m_t}{u_t} \tag{14}$$

while the probability that a firm fills a vacancy is given by

$$q_t = \frac{m_t}{v_t} \ . \tag{15}$$

An exogenous proportion ρ of firm-worker relationships ends each period, which implies the following employment dynamics:

$$n_t = (1 - \rho) \cdot n_{t-1} + m_{t-1} \ . \tag{16}$$

In the baseline therefore employment is predetermined, while hours per worker are free to adjust contemporaneously. This means that marginal costs are in the first period influenced exclusively by the marginal cost of an additional hour worked on the intensive margin. We ease this assumption in section 7, where we allow for contemporaneous hiring, and in section 10, which looks at endogenous separation.

Value of a job and of a vacancy for an intermediate labor-services producer
Throughout the paper, firms and workers engage in wage bargaining. This bargaining distributes the rents that arise once a match is formed to both the firm and the worker.We denote by J_t and V_t, respectively, the asset value of a job and of a vacancy at period t, dropping match index i for convenience:

$$J_t = y_t^l x_t - h_t w_t + \mathrm{E}_t \left\{ \beta(1-\rho) \frac{\lambda_{t+1}}{\lambda_t} J_{t+1} \right\} , \tag{17}$$

$$V_t = -k_t^v + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[q_t J_{t+1} + (1-q_t) V_{t+1} \right] \right\} , \tag{18}$$

where k_t^v represents the per-period hiring cost (in units of the consumption good).

Value of a job and value of unemployment for a household
For a worker's family, which bargains on his behalf, the value of a new job is given by

$$W_t = h_t w_t - \frac{\chi}{\lambda_t} \frac{h_t^{1+\phi}}{1+\phi} + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\rho)\, W_{t+1} + \rho\, U_{t+1} \right] \right\}, \tag{19}$$

where U_t represents the present value of being unemployed at period t. Formally,

$$U_t = b + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[s_t\, W_{t+1} + (1-s_t)\, U_{t+1} \right] \right\}. \tag{20}$$

2.4 Wage bargaining

In this section, we discuss the bargaining over wages and hours between workers and firms once a match has been formed. We will focus here on a bargaining scheme that is efficient, *i.e.,* in which the bargained wage maximizes the joint surplus of the firm and the worker. Also, in the baseline we abstract from any wage rigidity. We will look at a different, right-to-manage bargaining scheme in section 4, and will analyze in section 5 what real wage rigidity means for inflation and unemployment dynamics.

Baseline: efficient bargaining over wages and hours
Under efficient bargaining, hours and wages are bargained over simultaneously and firms and workers maximise the joint surplus of the firm-worker pair. As a result,

the decision for hours worked is independent of the wage actually set, as long as the wage is within the bargaining set, as stressed by Hall (2005). In our model, efficiency requires that the marginal gain to the labor firm of an additional hour worked (the firm's marginal value product of labour, $x_t mpl_t$) is the same as the marginal cost to the worker of that hour (his marginal rate of substitution between consumption and leisure, mrs_t). In other words, the firm will at the margin compensate the worker at his subjective price for work. This makes clear that this subjective price of work determines the marginal wage and is essential for the marginal costs of producing labor services, while the average wage rate, w_t, will be unrelated to that marginal wage and, thus, to real marginal cost.[5]

In particular, we assume that firms and workers use Nash bargaining to determine both wages and hours. The outcome of the bargaining process is obtained by maximization of the Nash product:

$$\max_{w_t, h_t} \ (W_t - U_t)^{\eta} \cdot (J_t - V_t)^{1-\eta} \, . \tag{21}$$

The first term of the Nash product is the surplus a worker obtains from a job, raised to the worker's relative bargaining power $\eta \in (0,1)$. The second term is the firm surplus, raised to the firm's relative bargaining power $1 - \eta$.

The first-order condition for wages is

$$\eta \cdot (J_t - V_t) \cdot \frac{dW_t}{dw_t} + (1-\eta) \cdot (W_t - U_t) \cdot \frac{dJ_t}{dw_t} = 0 \ . \tag{22}$$

The first-order condition for hours is

$$\eta \cdot (J_t - V_t) \cdot \frac{dW_t}{dh_t} + (1-\eta) \cdot (W_t - U_t) \cdot \frac{dJ_t}{dh_t} = 0 \ . \tag{23}$$

Combining these two optimality conditions, we get

$$\frac{dJ_t}{dh_t} \cdot \frac{dW_t}{dw_t} = \frac{dJ_t}{dw_t} \cdot \frac{dW_t}{dh_t} \tag{24}$$

Under efficient bargaining, the solution of (24) simplifies to

$$\frac{\chi}{\lambda_t} h_t^{\phi} = x_t \alpha h_t^{\alpha-1} = \alpha \frac{x_t y_t^l}{h_t}. \tag{25}$$

[5]Putting it differently, the average hourly wage in this bargaining setup is not a sufficient statistic for the marginal wage. Fixing the average hourly wage rate leaves the marginal wage schedule still indeterminate. This differs from a the right-to-manage bargaining setup that we introduce in section 4.

This shows that the individual matches' wage is not allocational for hours, that is $\partial h_t / \partial w_t = 0$. Note that x_t, the price of labor services, coincides with the marginal costs of price-setting firms. Rearranging above equation

$$x_t = \frac{\chi \frac{h_t^{\phi}}{\lambda_t}}{\alpha h_t^{\alpha-1}} := \frac{mrs_t}{mpl_t} \tag{26}$$

highlights the implications of efficient bargaining for marginal costs (and inflation). Real marginal cost will equal the worker's marginal rate of substitution between consumption and leisure (mrs_t) divided by the real marginal product of labour (mpl_t). Both of these will, in turn, depend on hours worked per employee. Again, the key point is that the cost of an extra hour's work will be given by the *marginal wage,* which coincides with mrs_t, and not the *average* real wage, measured by w_t.
This bargaining procedure is said to be 'efficient' because it results in hours that maximise the joint surplus of the match, that is $J_t + W_t - U_t - V_t$. Since the wage is not allocational for hours, the first-order condition (22) for the wage bargaining simplifies to

$$\eta \cdot (J_t - V_t) = (1 - \eta) \cdot (W_t - U_t) \tag{27}$$

which states that each of the contracting parties receives a share of the total surplus proportional to its relative bargaining power.

2.5 Vacancy posting

In order to find a worker, and so in order to produce, labor firms have to post a vacancy first. In the baseline we follow the most common assumptions in the literature, namely that vacancy posting costs are constant over the cycle in real terms and that these costs keep open a vacancy for just one period. Both of these assumptions will be relaxed individually in section 8.

Baseline: free entry condition and constant recurrent vacancy posting costs
In the baseline model, we assume free entry in the market for vacancies. This implies that in equilibrium the value of a vacancy is $V_t = 0$ in every period t. Furthermore, assuming that the vacancy posting cost k_t^v is constant over the cycle at value κ, as in the standard Mortensen and Pissarides (1999) framework, the equation for the asset value of a vacancy (18) can be recast as:

$$\kappa = q_t \, \mathrm{E}_t \left\{ \beta \, \frac{\lambda_{t+1}}{\lambda_t} \, J_{t+1} \right\} \; . \tag{28}$$

Total vacancy costs are given by κv_t, and the average cost per hiring is κ / q_t. Using this, the value of a job for a firm simplifies to

$$J_t = y_t^l \cdot x_t - h_t \cdot w_t + (1-\rho) \cdot \frac{\kappa}{q_t} \ . \tag{29}$$

From equations (28) and (29), one easily obtains the dynamic representation of the average cost per hire

$$\frac{\kappa}{q_t} = \mathrm{E}_t \left\{ \beta \, \frac{\lambda_{t+1}}{\lambda_t} \left[y_{t+1}^l \cdot x_{t+1} - h_{t+1} \cdot w_{t+1} + (1-\rho) \cdot \frac{\kappa}{q_{t+1}} \right] \right\} \tag{30}$$

which determines job creation in the model. Substituting (17), (19) and (20) into (27) while taking (28) into account, we obtain the following wage equation

$$h_t \cdot w_t \ = \eta \cdot y_t^l \cdot x_t + (1-\eta) \cdot \left(\frac{\chi}{\lambda_t} \cdot \frac{h_t^{1+\phi}}{1+\phi} + b + \frac{\eta \cdot \kappa}{1-\eta} \cdot \theta_t \right) \tag{31}$$

where $\theta_t = \frac{v_t}{u_t}$ represents labour market tightness. Intuitively, in these equations the wage is a weighted sum of a worker's value to the firm – *i.e.*, the value of his output – and the value of his outside option – consisting of the utility he gains from his leisure, his unemployment benefit and the present discounted value of his expected gains from search, which will be higher the easier it is to find a job (*i.e.*, the tighter is the labour market).[6]

2.6 Monetary policy, fiscal policy and market clearing

Throughout the paper we assume that monetary policy is conducted according to the following Taylor rule

$$\hat{r}_t = \rho_r \cdot \hat{r}_{t-1} + (1-\rho_r) \cdot \delta_\pi \cdot \hat{\pi}_{t-1} + \zeta_t^m \tag{33}$$

whith $\rho_r \geq 0$ and $\delta_\pi > 1$ and ζ_t^m is an i.i.d. normally distributed interest rate shock. Lump-sum taxes, t_t, are set so as to balance the budget period by period, there is no autonomous government spending.

[6] Alternatively, we can use the hours equation (25) to rewrite the wage equation in a form that is useful for eliminating hours and wages from (30):

$$h_t \cdot w_t \ = \eta \kappa \theta_t + (1-\eta) b + \left[\eta + \frac{\alpha\,(1-\eta)}{1+\phi} \right] x_t y_t^l \tag{32}$$

Equilibrium in the final goods market implies[7]

$$y_t = c_t \; . \tag{34}$$

2.7 Summary

To sum up, the baseline model consists of the following equations: (4), (5), (12), (13), (14), (15), (16), (9), (10), (33), (34), (25), (30) and (31).

3 Stylized facts and the baseline economy

The aim of this paper is to elicit the role of specific labor market frictions for the behaviour of marginal cost and inflation. In order to obtain a measure of the empirical relevance of the frictions, we compare the responses to a monetary policy easing in the respective model variant to stylized facts for the euro area. We start by discussing the calibration of the models. Thereafter we present stylized facts regarding the effects of monetary policy in the euro area (in section 3.2) and highlight the shortcomings of the baseline model in that regard (in section 3.3).

3.1 Calibration of the model economies

In order to put all approaches on the same footing, the calibration is harmonised as much as possible. The calibration matches salient features of the euro area between 1984 and 2006. See, *e.g.,* Christoffel et al. (2008) for a description of the underlying data, further references for the calibrated values, and a comparison of the euro area and the U.S. labour market. Table 1 presents the assigned common parameter values. The time-discount factor, β, is chosen to match an average annual real rate of 3.3%. We set ϕ to 10, implying an elasticity of substitution for labour of 0.1, in line with – but at the lower end of – microeconomic studies for the euro area.[8] The value of the risk aversion coefficient is set to $\sigma_c = 1.5$, following Smets and Wouters (2003).
Turning to the labour good sector and the labour markets, we set $\alpha = 0.99$, so there are almost constant-returns to hours per employee.[9] On monthly data ranging to

[7] We assume that vacancy posting costs are taxes which are rebated lump-sum to the consumers and which do not require real ressources.

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

[9] Our model does not contain capital. In some of the variants, there is thus a trade-off between obtaining a reasonable labour share (of around 60%) and small *ex post* profits associated with jobs.

	Value	Explanation
Preferences		
β	.992	Time-discount factor (matches annual real rate of 3.3 percent).
ϕ	10	Labor supply elasticity of 0.1.
σ_c	1.5	Risk aversion.
Bargaining, Intermediate Producers and Labor Market		
α	.99	Labor elasticity of production (close to constant-returns-to-scale).
ϑ	.6	Elasticity of matches with respect to unemployment.
η	.5	Bargaining power of workers
ξ_w	.83	Calvo stickiness wages (avg. wage duration 6 qtrs), where applicable.
Monopolistic Retail Sector and Price Setting		
λ_p	1.1	Price-markup of 10 percent.
ξ_p	.75	Calvo stickiness of prices (average duration of 4 qrts).
Monetary Policy		
γ_π	1.5	Response to inflation in Taylor rule.
γ_R	.85	Interest rate smoothing coefficient in Taylor rule.

Table 1: PARAMETERS AND THEIR CALIBRATED VALUES. The Table reports calibrated parameter values that are identical over the different modeling approaches. The model is calibrated to the euro area from 1984Q1 to 2006Q4.

the early 1990s, Burda and Wyplosz (1994) estimate an elasticity of matches with respect to unemployment of $\vartheta = 0.7$ 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 $\vartheta = 0.5$ to $\vartheta = 0.7$ is admissible. We select the midpoint, setting $\vartheta = 0.6$. The bargaining power of workers is set to a conventional value of $\eta = 0.5$.

For the variants that involve wage stickiness, we follow recent evidence collected by the Eurosystem Wage Dynamics Network,du Caju et al. (2008),.which reports average wage contract durations for various euro area countries between one and three years. Where applicable, we therefore set the degree of nominal wage rigidity to $\xi_w = 0.83$, which implies an average wage duration of 6 quarters.

In the price-setting sector, we calibrate the markup to a conventional value of 10%, so $\mu_p = 1/1.1$ (in the Dixit-Stiglitz setup this implies a price-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

We opt to fit the latter, and choose $\alpha = 0.99$ instead of a lower value.

to $\xi_p = 0.75$, see Alvarez et al. (2005), which amounts to an average price duration of 4 quarters. As is conventional, we set the response of monetary policy to inflation to $\gamma_\pi = 1.5$, and allow for interest rate smoothing by setting $\gamma_R = 0.85$.
In addition to these direct parameterizations, we chose to ensure that steady state values for certain endogenous variables coincide across the different setups. The target values for these variables, shown Table 2, thereby implicitly define the values of the remaining model parameters.

	Value	Explanation
u	9%	Unemployment rate
q	70%	Probability of finding a worker
h	1	Hours worked per employee.
$\frac{b}{wh}$	65%	Unemployment benefits replacement rate.
ρ	.06	Quarterly separation rate.

Table 2: CALIBRATION TARGETS. The table reports calibrated parameter values. The model is calibrated to the euro area from 1984Q1 to 2006Q4.

The steady state unemployment rate is targeted to be $u = 9\%$, in line with the average of the euro area unemployment rate over the sample 1984 to 2006. We target a probability of finding a worker when having opened a vacancy of $q = 0.7$, in line with the euro area evidence collected in Christoffel et al. (2008). Our target for steady state hours worked per employee is $h = 1$. We set the replacement income b so as to ensure that the replacement rate in steady state in each of the variants conforms with the net replacement rates published by the OECD in its set of "Benefits and Wages" data. This replacement rate is $\frac{b}{wh} = 65\%$. Finally, the evidence collected in Christoffel et al. (2008) and Hobijn and Sahin (2007) points.to quarterly separation rates, from a worker flow perspective, of $\rho = 6\%$.

3.2 Stylized facts – the transmission of monetary policy

In the following, we assess each of the different modeling variants against five sylized facts regarding the monetary transmission in the euro area. These facts are based on VAR evidence that we generated ourselves, and a survey of the literature,.see Appendix A for details. These facts are:

In response to a monetary shock that causes interest rates to fall by 100bps in annualized percentage terms,

Fact 1: output rises significantly above its steady state. Depending on the study the peak response varies between 0.3 and 0.7 percentage points.

Fact 2: inflation rises. The peak increase in year-on-year inflation lies between 0.2 and 0.3 percentage points.

Fact 3: wages per employee also rise but by less than output (in percentage terms).

Fact 4: employment rises significantly, and unemployment falls. Unemployment falls by 3% to 4.5% (number of heads), and the unemployment rate falls by 0.25 to 0.4 percentage points.

Fact 5: most of the adjustment in labour is borne by the number of employees rather than by hours worked per employee. Some uncertainty surrounds this statement, though, as the data for hours worked in the euro area are of relatively poor quality.[10]

Indeed, while significant differences exist in the microstructure of the economy, and the labor market in particular, between the euro area and the U.S. the above stylized facts happen to be consistent also with the evidence for the U.S., cp. *e.g.* Christiano et al. (2005), Angeloni et al. (2003) and Trigari (2005).

3.3 Effects of a monetary policy shock in the baseline

Figure 1 reports the response of the economy to a monetary easing, where the impulse is an exogenous one percentage point reduction in the nominal interest rate.

As can be seen from Figure 1, inflation responds far to strongly to the monetary easing while output effects are of the appropriate size. The strong response of inflation comes from the fact that real marginal cost are very volatile in this baseline. To see this, recall that real marginal cost for price setting firms here determined by the cost of increasing hours worked by each worker. Under efficient bargaining, these marginal costs were given by the marginal rate of substitution (divided by the marginal product of labor), so

$$x_t = \frac{\chi}{\lambda_t} \frac{h_t^{1+\phi}}{\alpha y_t^l} = \frac{\chi \frac{h_t^{\phi}}{\lambda_t}}{\alpha h_t^{\alpha-1}} := \frac{mrs_t}{mpl_t}. \quad (35)$$

[10] For example, no quarterly series for actual hours worked exists for the euro area, or individually for all its member states. The measured response of hours worked (and hours per worker) therefore naturally is based on proxy series, cp. Appendix A.

Note in particular, that the average wage rate w_t does not have a direct bearing on marginal cost. Given near constant returns to scale (α close to unity), the marginal product of labor, mpl_t, will be little effected. The percentage change in real marginal cost will therefore be driven by the response of the marginal rate of substitution, mrs_t. This in turn depends on the percentage change in the marginal utility of consumption and, fundamentally, on the response of hours per worker, where the latter is amplified ϕ times. Given our calibration, this implies a strong response of real marginal cost to an increase in hours worked and output. Therefore, inflation responds too much to the monetary easing.

So, in order to better match inflation dynamics relative to the benchmark model, we will need to alter features of the model that affect the response of real marginal cost to shocks, either by removing the link between the marginal rate of substitution and real marginal cost or by altering the model such the pass-through of marginal costs to price-setting is affected, [or by allowing for more margins of immediate adjustment than hours per employee]

Given the setup of the model, employment and unemployment can only respond to monetary policy shocks with a lag. Their eventual response will be determined by the job creation condition, (30). As illustrated in Figure 1, above, in the baseline model the real wage responds substantially to the monetary policy shock. The result of this is that the incentive for a firm to post a vacancy will not respond by much, and so employment and unemployment will not respond by much either, which is reminiscent of Shimer's (2005) puzzle that unemployment is not volatile enough an RBC version of this model relative to the data. Trigari (2006) highlights that solving the Shimer puzzle in the benchmark model also helps to reduce the response of inflation. At the moment that more of the labour adjustment needed to produce the additional output is provided through the extensive (number of employees) margin, also the intensive (hours per employee) margin reacts by less, which curbs the rise in the marginal rate of substitution and thus the rise in marginal costs. Indeed wage rigidity, the topic of section 5, helps in this respect for the same reason that Hall (2005) emphasizes in an RBC context.

4 Right-to-manage bargaining

In this section, we consider an alternative process for bargaining over wages and hours. In particular, we follow Trigari (2006) and use a 'right-to-manage' assumption for the bargaining process. In this setup, first the wage rate is agreed upon and then the firm

chooses hours worked at that going wage rate so as to maximise profits.[11] This setup is very much in tune with the standard New Keynesian practice, *e.g.* Christiano et al. (2005) and Smets and Wouters (2003), since as a result the average and marginal wage rate in the economy coincide. The measured average wage rate, w_t ,will now have a direct effect on marginal costs and inflation dynamics.
In the case of right-to-manage, the demand for labour is determined by the optimising condition that the cost of the marginal hour is equal to its benefits, *i.e.*, that the hourly wage is equal to the marginal value product of an hour worked:

$$x_t \alpha h_t^{\alpha-1} = w_t \Longleftrightarrow x_t = \frac{w_t h_t}{\alpha y_t^l} = \frac{w_t}{mpl_t}. \tag{36}$$

The right-to-manage assumption radically modifies the composition of real marginal cost. Under efficient bargaining, real marginal cost depend essentially on hours and the marginal utility of consumption. Under right-to-manage, the hourly wage becomes an essential element of real marginal cost, opening what is called the 'wage channel' in the literature (Christoffel *et al.,* 2008, Trigari, 2006). Therefore, the response of marginal cost and inflation to shocks will depend entirely upon the response of the bargained hourly wage to shocks.[12]

This notwithstanding, the effect of the right-to-manage assumption on the marginal cost and inflation in equilibrium is *a priori* unclear. The major difference to the efficient bargaining assumption is that the choice of hours depends directly on the average wage, and that $\partial h_t / \partial w_t < 0$. This affects the wage bargaining. Wage equation (22) becomes

$$\eta \cdot \Omega_t \cdot J_t = (1-\eta) \cdot (W_t - U_t) \tag{37}$$

with

$$\Omega_t = \frac{1}{1-\alpha} \left(\frac{mrs_t}{x_t \cdot mpl_t} - \alpha \right) = \frac{1}{1-\alpha} \left(\frac{\chi {h_t}^{1+\phi-\alpha}}{\alpha \lambda_t x_t} - \alpha \right) . \tag{38}$$

This means that the relative bargaining power of the workers in the wage negociation is modified by Ω_t: expressions (37) and (38) display that it increases with hours worked.[13]

[11] So the bargaining, contrary to (21), is conducted only over the wage, $[\max_w \ (W_t - U_t)^\eta \cdot (J_t - V_t)^{1-\eta}]$, anticipating the profit-maximizing choice of hours per worker by the firm at the later stage.

[12] In general equilibrium this does, of course, not mean that the marginal rate of substitution plays no role in inflation dynamics whatsoever under right-to-manage. There is still an indirect influence of the marginal rate of substitution on inflation through its effect on the wage rate and the wage bargaining.

[13] If we keep the free entry assumption and constant recurrent vacancy posting costs, equation (28) still holds. The value of a job for a firm (29) and the dynamic of the average cost per hiring (30) can be simplified by replacing $x_t y_t^l$ by $h_t w_t / \alpha$.

The more inelastic the labour supply at the intensive margin (the larger parameter ϕ), the stronger this effect. Indeed, if the disutility parameter ϕ is large enough, the average wage will tend to be more responsive under right-to-manage than under efficient bargaining because of the strong relative bargaining power effect. It is less clear, however, whether this also implies that the marginal cost are more responsive. In both cases, these are given by the *marginal* wage. Under right-to-manage this coincides with the average wage, w_t, which is more responsive than the average wage would be under efficient bargaining. Under efficient bargaining, however, the marginal wage, given by mrs_t, which there is already more responsive than the average wage (cp. black solid line in Figure 2).

Figure 2 compares the response of the economy to a monetary shock under both bargaining schemes. As above logic suggests, the average hourly wage rate, w_t, responds more strongly (and in fact much too strongly in view of the stylized facts) to a monetary easing under right-to-manage. Still, the marginal wage rates (which determine the marginal cost of firms) show a very similar movement under both bargaining schemes, as can be witnessed in the similar response of marginal cost under the two schemes, leaving the response of inflation to a monetary policy shock essentially, unchanged.

The different response in the average wage rate caused by the bargaining power effect does, however, imply differences in the response of unemployment. The average wage rate responds by more under right-to-manage and thus leaves relatively less of the increased revenue in the hand of the firms, thereby reduces hiring incentives. As a consequence, this leads to a smaller response of employment under right-to-manage than under efficient bargaining. [14]

We conclude that the bargaining scheme in itself has little implications for inflation dynamics. As the next section shows, however, different bargaining schemes can hold fundamentally different implications for the effect of *wage rigidity* on inflation dynamics.

[14] This in turn leads to slightly more recourse to the intensive margin under right-to-manage than under efficient bargaining, which reinforces the increase in the wage and thus marginal costs. As can be seen from Figure 2, however, quantitatively the effect on hours per employee is not large.

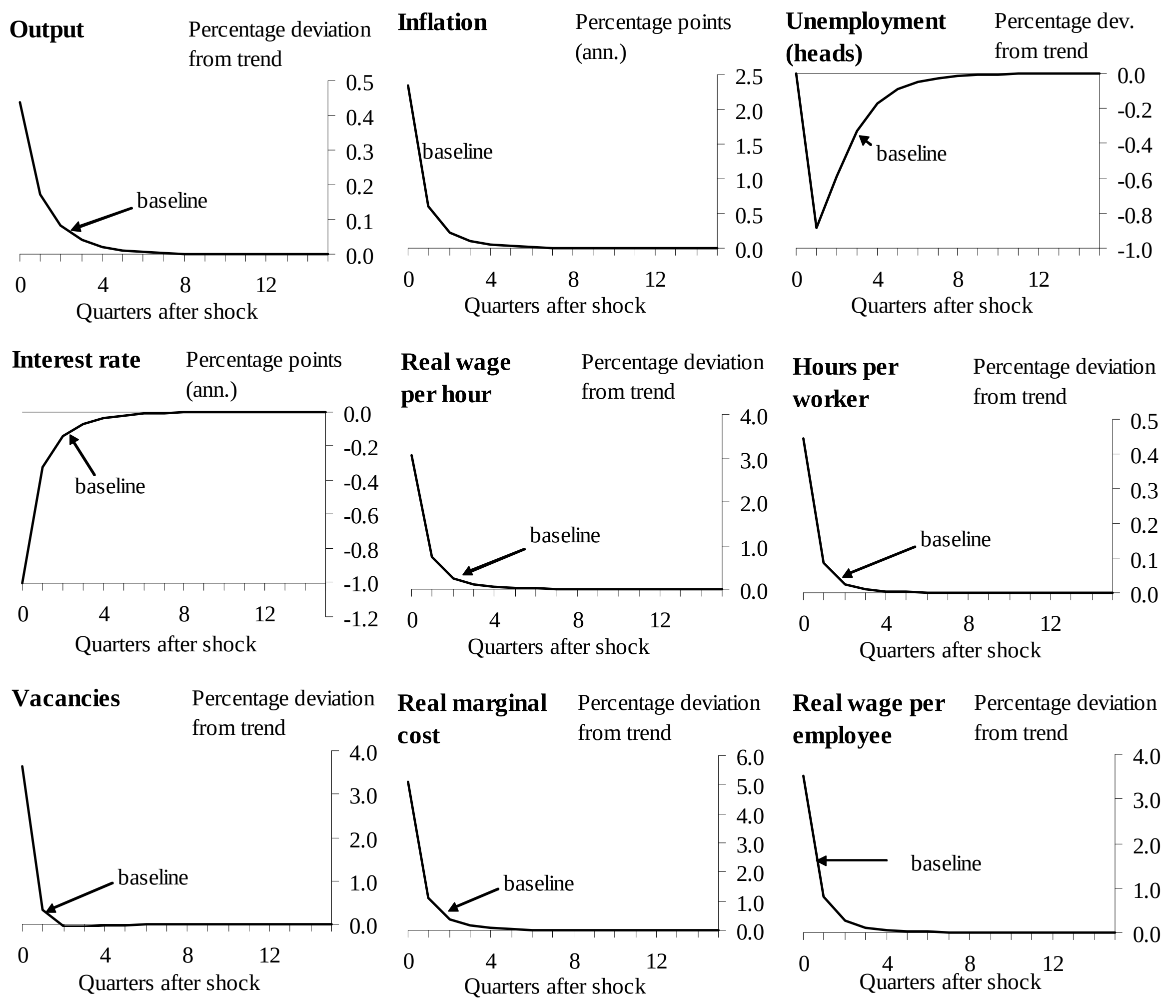

Figure 1: Impulse responses to a monetary easing in the baseline economy. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0 for the baseline economy (cp. section 2). All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms.

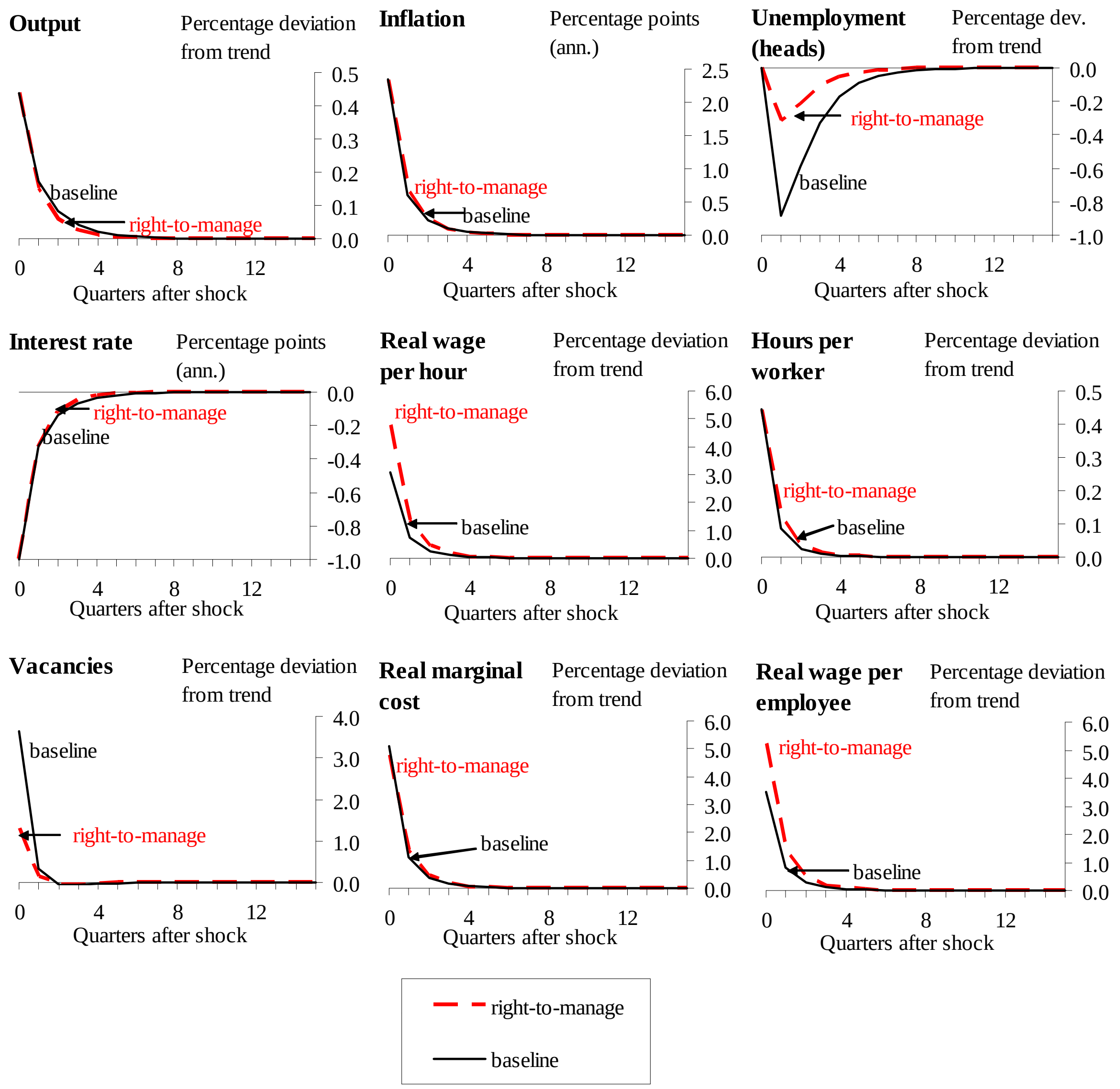

Figure 2: Impulse responses to a monetary easing – baseline vs. right-to-manage. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line marks the baseline response with efficient bargaining. The red dashed line shows the response under right-to-manage bargaining.

5 Wage rigidity

A cornerstone of the main-stream New Keynesian framework is that average wage rates and their stickiness are instrumental for inflation dynamics, see, *e.g.*, Christiano *et al.* (2005).[15] This section of the paper discusses the role of wage stickiness for inflation dynamics.

The question for this paper is whether or not, once the labour market is modeled explicitly, the insight that observed (average) wage rates and their stickiness matter for inflation dynamics may cease to be true, as has been argued by Krause and Lubik (2008). This section will find that the bargaining setup matters. The reason is that wage rigidity is typically formulated in terms of the average wage rate, and already the previous section argued that in the right-to-manage setup the (average) wage rate and the (marginal) wage rate coincide, while under efficient bargaining they do not. Much of the discussion is contained one way or another in the related New Keynesian literature such as Trigari (2006), Christoffel and Linzert (2005), Christoffel and Kuester (2008), and Krause and Lubik (2008).

In the following, we define wages stickiness loosely as hourly wage rates, which react less to the cyclical conditions than they would do absent wage stickiness. The role of wage stickiness for inflation dynamics depends on the type of wage bargaining along which the economy is organised (efficient vs. right-to-manage) as well as on the fact whether wage stickiness affects only existing matches or also new matches (and thus the hiring incentives of firms). It is less sensitive to whether wage rigidity affects nominal or real wages.

Wage rigidity may affect existing matches, new hires, or both

In this section we allow for nominal wage rigidities. We suppose that in each period only a fraction $(1-\xi_w^o)$ of all existing wage contracts is renegotiated. New hires are paid either the existing nominal contract wage from the previous period (with respective probabilities ξ_w^n)[16] or they freely negotiate the wage (with probability $1-\xi_w^n$). Full

[15] In the current context, wage rigidity has also been found to matter in a real business cycle context. In a model with efficient bargaining, Hall (2005) shows that the Shimer (2005) puzzle of too little adjustment on the extensive margin in the Mortensen and Pissarides framework can be circumvented by introducing wage rigidity. The reason is that rigid wages mean that increases in revenue to a large extent translate into increases in profits which increasing the cyclicality of hiring incentives over the cycle. Bodart, Pierrard and Sneessens (2005) and Gertler and Trigari (2006) show that in this context it is particularly important that wage rigidity holds for newly created jobs.

[16] These matches draw a wage from the previous period's wage distribution. The rationale for this assumption, following Gertler and Trigari (2006), lies in interpreting a match as one position in a multiworker firm. While every period there may be new hires for some positions, these firms may adjust they overall pay-scale only infrequently. There is currently a discussion whether there is evidence in the data that wages of new hires are sticky. Pissarides (2007) and Haefke, Sonntag, and van Rens (2007), for example, find little empirical support for wage stickiness for new hires.

nominal wage flexibility obtains for $\xi_w^o = \xi_w^n = 0$.
Even though the wage bargaining will be discussed in detail later, it is important at this stage to stress that all the 'firm-worker' pairs that are given the opportunity to (re)-negotiate their wage contract face the same problem and therefore set the same wage. Because wage negotiation is time-dependent, different workers may be paid different wages and can supply different hours, even though they are otherwise ex-ante identical. Let w_t^* represent the real value of the nominal wage negotiated at time t while w_t is the real value of the average hourly wage.

5.1 Efficient bargaining

Under efficient bargaining, as long as wage stickiness affects only existing matches, it does not have any bearing on real marginal cost, or for that matter on inflation. The reason is that the average wage rate is not allocative but rather splits the surplus of the match among the two parties. In particular, even when fixing the *average* hourly wage rate, this does not fix the hourly wage rate *schedule*! As part of an efficient bargaining agreement, the relevant section of marginal wages can be freely set in a state-contingent way even if average wage rates are fixed. In this case, as we showed earlier, real marginal cost will equal the workers' marginal rate of substitution divided by their marginal product and will be independent of the average wage rate. For that reason, wage rigidity, if it only affects existing matches, does not have a bearing on inflation dynamics if bargaining is efficient.
Matters change if wage stickiness affects the wages of prospective new hires. As the vacancy posting condition equation (30) makes clear, hiring incentives depend on the expected profits of firms. Wages are important in allocating the surplus of the match among firms and workers. As Hall (2005) notes, wage stickiness in new matches enhances the cyclicality of job creation by altering the share of revenue left to firms over the cycle.[17]
Since hiring incentives are affected, however, future marginal costs and, thus, inflation will be affected. The reason is that the hiring behaviour of firms influences the economy-wide relative use of the extensive margin and the intensive margin of employment and this will have a direct bearing on marginal costs, as a result of the decreasing returns to hours worked per employee, $\alpha \leq 1$, and the increasing marginal disutility of work $\phi > 0$. (See also Trigari (2006).) Wage stickiness, insofar as it affects new matches, makes hiring more responsive to a monetary easing. This means that the

[17] So as to justify stickiness of wages for new hires, Gertler and Trigari (2006), for example, assume that some of the new matches cannot bargain about their wage. Their rationale is that jobs are located within bigger (multi-worker) firms, which adjust their pay-scale only infrequently.

demand-driven increase in labour input is borne more by the number of employees rather than by hours worked. As a result, the average worker works fewer hours than in the absence of wage stickiness. This means that the marginal rate of substitution rises less strongly, and also that the marginal product of labour falls less strongly. So, wage stickiness for new hires, through its effect on employment, makes marginal costs (and thus inflation) less responsive to a monetary easing.

In the baseline setup, employment only reacts with a lag, cf. equation (16). The initial response of hours per employee to a monetary easing is therefore largely unmodified with respect to the baseline. The expected larger reaction of employment occurs with a delay of one period. This leads to a quicker drop of the hours response, lowering the persistence of the marginal cost and inflation reactions. While through the weaker response as of the time of the monetary easing of expected future marginal costs inflation reacts less than in the absence of wage rigidity, quantitatively the differences are tiny, as Figure 3 illustrates. Section 7 assesses the case when the baseline is modified to allow for contemporaneous hiring, so employment is jump variable.

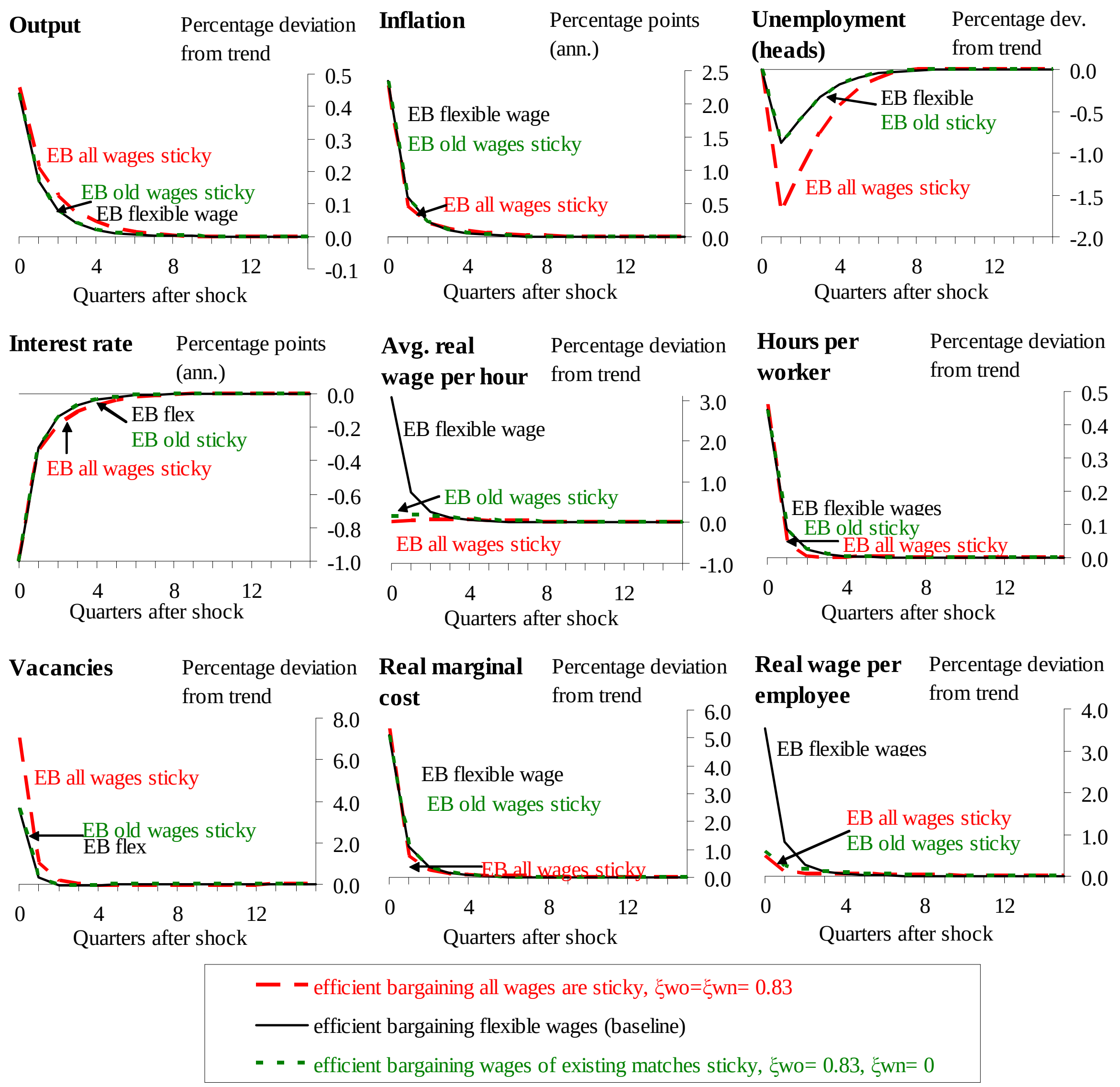

Figure 3: MONETARY EASING – EFFICIENT BARGAINING AND WAGE RIGIDITY OLD AND NEW HIRES. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line marks the baseline response. A red dashed line marks the response when both wages of new hires and of old matches are sticky. The green dotted line shows the response when only wages of old hires are sticky.

5.2 Right-to-manage bargaining

Section 4 already highlighted that right-to-manage it implies a close relationship between worked hours and wage. In particular, if the wage of a worker has been bargained i periods ago, he or she will work

$$h_t(w_{t-i}^*) = \left(\alpha \cdot \frac{x_t}{w_{t-i}^*} \cdot \frac{p_t}{p_{t-i}}\right)^{\frac{1}{1-\alpha}} = h_{t-i}(w_{t-i}^*) \cdot \left(\alpha \cdot \frac{x_t}{x_{t-i}} \cdot \frac{p_t}{p_{t-i}}\right)^{\frac{1}{1-\alpha}} \tag{39}$$

hours. Here $w_{t-i}^* = \frac{w_{t-i}^{n,*}}{p_t}$. $w_{t-i}^{n,*}$ is the nominal wage rate negotiated i periods ago, which for some matches will continue to prevail today.

The asset value of a job clearly depends on the bargained wage. Adopting the viewpoint of an intermediate producer, we denote $J_t(w_{t-j}^*)$ the asset value in period t of a job with a wage that was bargained i periods ago. *Ex ante*, the asset value of a new match for the firm can be written as

$$J_t = (1 - \xi_w^n)\ J_t(w_t^*) + \xi_w^n\ J_t(w_{t-1}) \tag{40}$$

and the asset value of a vacant job V_t is still given by equation (18), *i.e.*, the vacancy posting condition is not modified.

From the household point of view, the value of a job with a wage bargained i periods ago is $W_t(w_{t-i}^*) - U_t := \mathcal{W}_t(w_{t-i}^*)$. $\mathcal{W}_t(w_{t-i}^*)$ defines the household surplus in order to shorten notation.

All the (re-)negotiating firm-worker couples face the same problem and therefore choose the same wage w_t^* through the usual Nash bargaining procedure

$$\max_{w_t^*}\ [\mathcal{W}_t(w_t^*)]^{\eta} \cdot [J_t(w_t^*)]^{1-\eta}$$

The first-order condition is identical to (22), but the staggered wage setting complicates somewhat the total derivatives with respect to wage:

$$\frac{dX_t(w_t^*)}{dw_t^*} = \frac{\partial X_t(w_t^*)}{\partial w_t^*} + \mathrm{E}_t \sum_{i=0}^{\infty} \frac{\partial X_t(w_t^*)}{\partial h_{t+i}(w_t^*)} \frac{\partial h_{t+i}(w_t^*)}{\partial w_t^*}\ , \text{ for } X = \{J, \mathcal{W}\}\ .$$

Combining these expressions with (39), we may compute

$$\eta \cdot J(w_t^*) \cdot \Omega_t' = (1 - \eta) \cdot \mathcal{W}_t(w_t^*) \tag{41}$$

with

$$\Omega_t' = \frac{1}{1-\alpha}\left[\frac{\chi \cdot h_t(w_t^*)^{1+\phi-\alpha}}{\alpha\lambda_t x_t} \cdot \frac{\mathrm{E}_t \sum_{i=0}^{\infty}\left(\beta(1-\rho)\xi_w^o\right)^i \left[\frac{x_{t+i}}{x_t}\frac{p_{t+i}}{p_t}\right]^{\frac{1+\phi}{1-\alpha}}}{\mathrm{E}_t \sum_{i=0}^{\infty}\left(\beta(1-\rho)\xi_w^o\right)^i \left[\frac{x_{t+i}}{x_t}\left(\frac{p_{t+1}}{p_t}\right)^{\alpha}\right]^{\frac{1}{1-\alpha}}} - \alpha\right].$$

One easily verifies that for $\xi_w^o = 0$, Ω_t' is equal to Ω_t we obtained for right-to-manage in the case of wage flexibility (cf. equation (38)). Note that the Calvo structure of the wage negotiation strongly decreases the bargaining power of the workers. Indeed, if more working time is needed in the aggregate economy, the firms can get it cheaply from the workers who are prevented from bargaining over their wages.

Effects of a monetary policy shock

Figure 4 shows the response of a monetary easing in the right-to-manage model of the previous section (solid line) and two alternatives with nominal wage rigidities. The dashed line shows the case in which only wages in existing matches are sticky, $\xi_w^o = 0.83$ and $\xi_w^n = 0$, and the dotted line refers to the case in which wage rigidity also affects new matches, $\xi_w^o = \xi_w^n = 0.83$.

Three observations are in order. First and foremost, the combination of the right-to-manage bargaining with nominal wage stickiness produces much more sticky wages. These translate into a more reasonable response of inflation, and into inflation persistence. In other words, the combination of sticky wages with 'right-to-manage' bargaining is able to generate a magnitude of the response of inflation to a monetary policy shock that is in line with the stylized facts. This follows directly from the fact that in right-to-manage bargaining, there is a direct cost channel from wages to marginal cost to inflation. Second, the responses are very similar for the two cases of wage rigidity. Whether wage rigidity affects also new match does not matter much for inflation dynamics. For a similar point, see Christoffel and Kuester (2008). Third, unemployment reacts less to the shock than under the alternative of flexible wages.

The third observation contrasts sharply with results obtained by Hall (2005), Bodart, Pierrard and Sneessens (2005) or Gertler and Trigari (2006) in models with efficient bargaining. These authors show that wage stickiness for newly created jobs (ξ_w^n) increases strongly the volatility of the expected value of a new job to the firm and therefore *increases* the response of vacancies and employment.

On the one hand, equation (40) suggests that under right-to-manage the incentive to post vacancies will be affected by wage rigidity (when the $\xi_w^n > 0$) in the same way. By making the average wage rate less responsive to the cycle, the expected value of a new job for a firm will *a priori* be more sensitive to the cyclical conditions since the wage reacts less to the cyclical movement. The larger ξ_w^n, therefore, the more cyclical one would expect the firms' incentive to post vacancies to be. Yet, there is an opposing general equilibrium effect under right-to-manage. Wage stickiness for existing hires, $\xi_w^o > 0$, (and possibly also for new hires) works against more fluctuations of unemployment. The more sticky wages of existing matches are, the more willing will be existing firms to demand additional hours worked from their employees for any given price of the labor good. In equilibrium, this puts downward pressure on the price of the labor good, x_t,relative to a case without wage stickiness. This in turn reduces the prospective revenue associated with new hires and works to reduce hiring [18]

From the moment intermediate producers are given full flexibility to adjust hours, the expected value of a vacancy varies much less than if it wasn't the case: hours flexibility allows them to compensate for the wage stickiness. From the workers point of view, they anticipate that small wage adjustments will be compensated by huge (about $1/(1-\alpha)$ larger) hours adjustments in the opposite direction, and this effect is particularly strong with $\phi = 10$. These two forces combine to produce small wage adjustments through Nash bargaining and all the adjustment occurs on hours.

Several solutions can be considered for this shortcoming. Christoffel and Kuester (2007) introduce a fixed cost in the production function of the labour firm in order to amplify its profit fluctuations and make the asset value of a job much more procyclical. De Walque *et al.* (2008) analyse an economy where workers are endowed with positive bargaining power over hours (but not necessarily equal to that they have over wages). There is a range of value for the hours bargaining power such that it reduces strongly the flexibility along the intensive margin without affecting the wage channel.

[18] It should be stressed that this is an implication of right-to-manage and not of the existence of an intensive margin of adjustment. The same would not hold true under efficient bargaining, where wage stickiness in existing matches alone does not alter the incentives to demand hours per worker; again, this is due to the average (sticky) wage rate not being a sufficient statistic of the marginal wage rate under efficient bargaining.

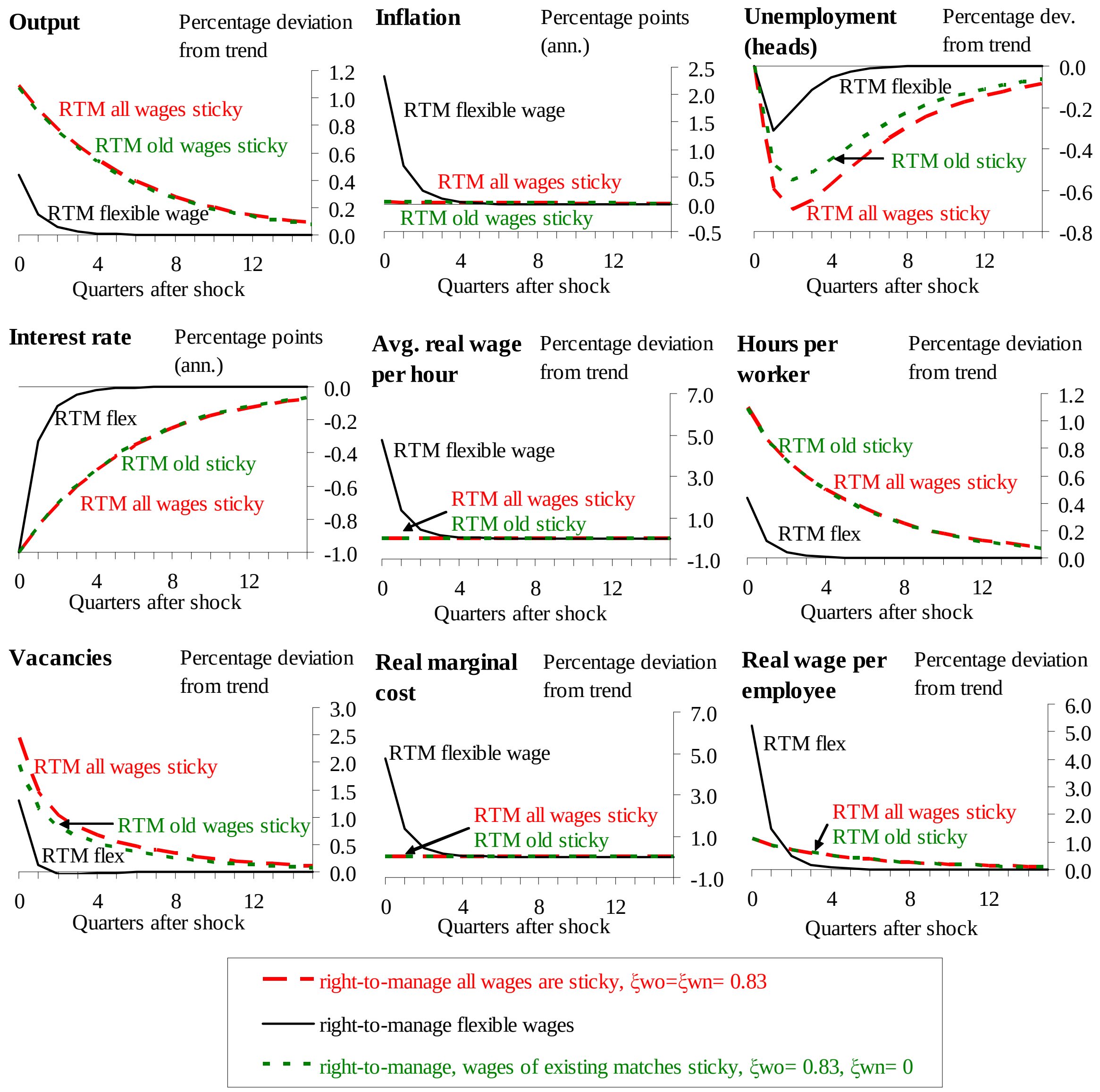

Figure 4: Impulse responses to a monetary easing right-to-manage with wage rigidity. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line shows the response in the right-to-manage model in the absence of wage rigidity. The red dashed line shows the response when all wages are sticky. The green dotted line shows the case in which wage rigidity affects only existing matches.

6 Real rigidities arising at the individual firm

The baseline model assumes that price-setting firms can buy labour goods, y_t^l, in a competitive factor market at cost x_t per unit. They then transform this into a differentiated product.[19] Due to this assumption, price-setting firms' marginal cost are independent of their own output level. In that setup only if aggregate marginal costs are more rigid will inflation be more rigid. Following Kuester (2007), this section instead emphasises real rigidities arising at the individual firm level over and above the real rigidities arising at the aggregate level. Related papers are Sveen and Weinke (2007) and Thomas (2008).

This section merges the intermediate labour good sector with the retail sector. Firms that set prices also engage directly in hiring and in wage negotiations. The presence of search and matching frictions in the labour market means that a worker in this economy temporarily constitutes a firm-specific factor of production to the firm at which he is employed.[20] This, in turn, means that a firm's price-setting has an effect not only on the demand that the firm faces but also on the wage demand of its worker, and thus on the firm's own marginal costs.

As a consequence, for any given behaviour of aggregate marginal costs, firms are induced to adjust prices by less. The mechanism at work is the following. Consider an aggregate shock that all else equal would imply an increase in the marginal cost of all firms. A firm that can re-optimise its price passes part of the cost increase on to consumers. The increase in its price causes a fall in demand. This fall in demand will be the stronger the more price-elastic is demand, *i.e.*, the larger is $\epsilon := \frac{\mu_p}{\mu_p - 1}$. In turn hours worked at the firm fall (they fall by more the more the production function exhibits decreasing returns to scale, *i.e.*, the smaller α). So, in sum, hours worked fall the more in response to a price increase, the larger ϵ and the smaller α.

If workers have an increasing marginal disutility of work, *i.e.*, $\phi > 0$, this fall in hours worked leads to a reduction in the worker's marginal disutility of work. Therefore, at the time of deciding on the price it sets, the firm anticipates that the price increase would induce an effect that balances the original increase of marginal costs: workers

[19] As in our baseline model, the majority of studies assumes that – explicitly or implicitly – wage negotiations are independent of the demand situation of individual price-setting firms. Trigari (2006), for example, entertains the two-sector structure. A working paper version of Krause and Lubik (2007) assumed that the disutility of work is linear, i.e. $\phi = 0$, so the worker did not demand a higher hourly wage rate when the work-load in terms of hours worked increases. This implicitly induces the same behavior of firms as in a two-sector structure. Their published version does not allow for an intensive margin.

[20] In the intermediate labor sector of the baseline model, workers also constituted a temporarily firmspecific production factor. By assumption, however, this sector operated under perfect competition and flexible prices.

take part of the original cost increase onto their books by accepting lower marginal wage rates. As a consequence, price setting firms decide to move their prices by less for any given behaviour of aggregate marginal costs than in the baseline model.[21] This effect on the price-setting behaviour of firms curbs inflation relative to the benchmark model. [22]

The Phillips curve

Technically, the analysis keeps with one-worker firms and assumes that each firm-worker pair produces one variety of the differentiated good. Workers and firms Nash-bargain about the wage rate and the price (which determines demand, hours worked and disutility of work).[23] In what follows, we consider the special case in which nominal wage rates are renegotiated whenever prices are. The economic mechanism underlying the increase in real rigidities however also obtains if wages are bargained on a period-by-period basis and when product variety is fixed, as Sveen and Weinke (2007) and Thomas (2008) show in setups with multi-worker firms. The Phillips curve in the modified model economy reads as follows:

$$\widehat{\pi}_t = \beta(1-\rho)E_t\left\{\widehat{\pi}_{t+1}\right\} + \frac{1-\xi_p}{\xi_p}\left[1-\beta(1-\rho)\xi_p\right]\underline{\left\{\frac{1}{1+\frac{\epsilon}{\alpha}[(1-\alpha)+\phi]}\right\}}\widehat{x}_t. \qquad (42)$$

As in the baseline Phillips curve, equation (11), the driving term $\widehat{x}_t = \widehat{mrs}_t - \widehat{mpl}_t$ represents average marginal cost in the economy. Yet, there is an additional term dampening the pass-through of marginal cost on inflation (underlined). As the above discussion suggested, the more price-elastic is demand (the larger is ϵ), the more curved the marginal disutility of labour is (the larger ϕ) and the faster the returns to hours per employee decrease at the firm level (the smaller α), the less will firms adjust prices to aggregate shocks, and the weaker will therefore be the response of inflation to its aggregate driving forces. [24]

[21] With decreasing returns to labor, a further factor works to directly curb the effect of shocks on marginal costs and thus inflation. As hours worked fall, the marginal product of labor rises – and it rises the more quickly the smaller is α. In our calibration, with α close to 1, this effect is small, however.

[22] It seems important to distinguish between real rigidities arising at the aggregate level and real rigidities arising at the individual firm level. For real rigidities arising at the aggregate level, as in Ball and Romer (1990), prices (and thus inflation) will respond the less to shocks the less (the aggregate component of) marginal cost responds to these shocks. For real rigidities arising at the individual firm level, prices will respond the less to shocks the more (the firm-specific component of) any firm's marginal cost rises with demand. For a further exposition, see also Woodford (2003, Chapter 3).

[23] The same allocation could be achieved by having firm and worker simultaneously bargain about the wage and hours worked as in the baseline, while imposing the constraint that the implied market clearing price exhibits nominal stickiness.

[24] This finding is robust. A further difference appears, which hinges on keeping the one worker

Response to a monetary policy easing

Figure 5 compares the impulse response to a monetary easing in the baseline model (blue solid line) to the model with firm-specific labour (dashed purple line). The additional factor pre-multiplying the aggregate driving forces of inflation in the Phillips curve (42) is equal to $\left\{\frac{1}{1+\frac{\epsilon}{\alpha}[(1-\alpha)+\phi]}\right\} = 0.009$. As a result, inflation reacts considerably less to the monetary shock when allowing for firm-specific labour, bringing the response more in line with the stylized facts. In turn, this implies that the monetary easing provides more stimulus, which translates into a response of output that is larger than in the baseline and closer to the sylized facts. Since the monetary easing is more expansionary under the firm-specific labour specification than in the baseline average marginal costs rise by more than in the baseline. Despite this rise in average marginal costs, however, the response of inflation to the monetary easing is much attenuated.

setup. In above Phillips curve price-setting firms discount the future more intensively than in (11), at rate $\beta(1-\rho)$. The reason is that hiring activity drives *ex-ante* profits to zero so any firm loosing its worker will cease to make pure profits. Consequently, future inflation receives less weight reflecting the possibility of separation from the worker. This result is specific to the assumption of one-worker firms as in Kuester (2007) and would not be present with multi-worker firms and fixed product variety as in Sveen and Weinke (2007) and Thomas (2008).

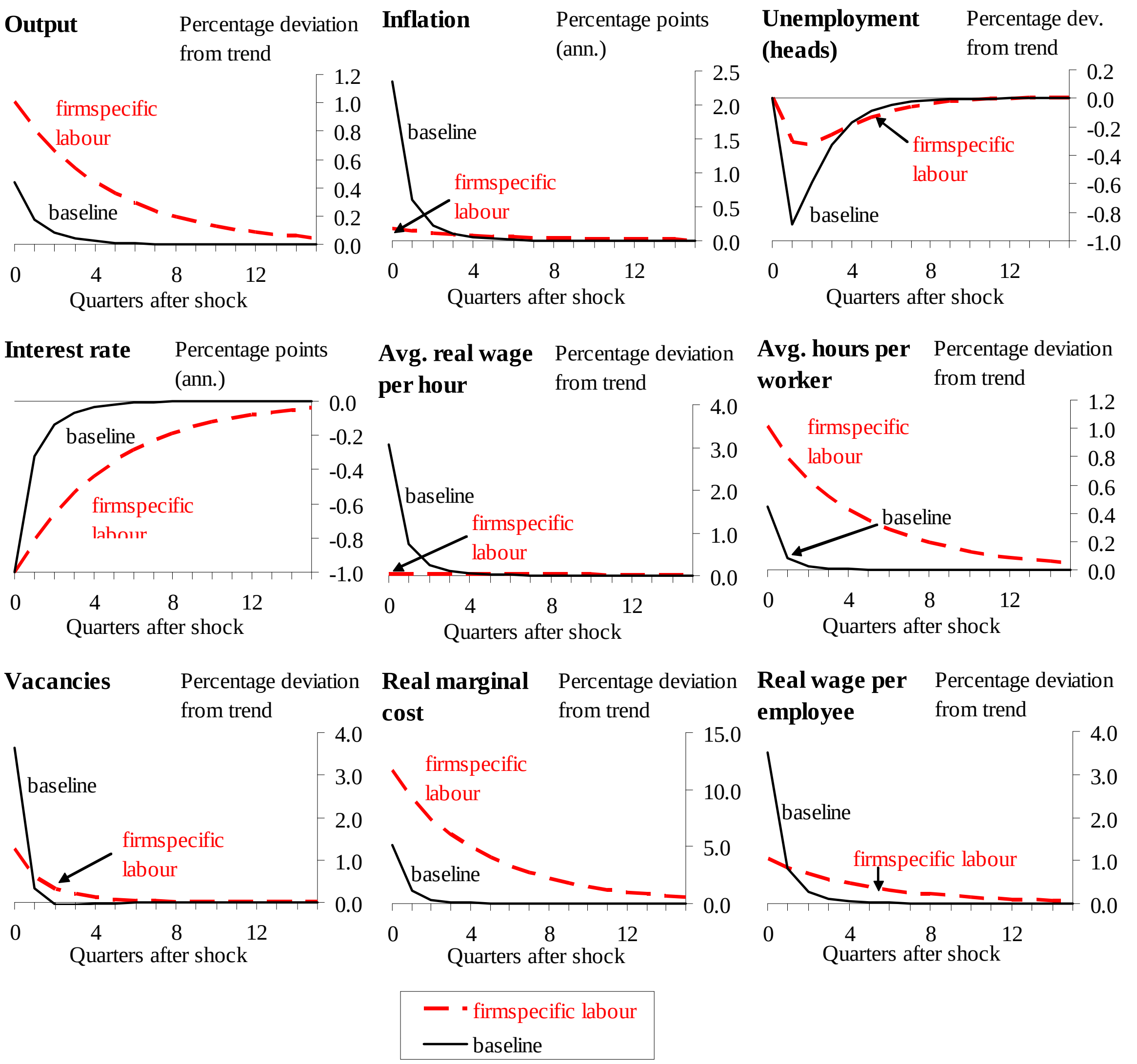

Figure 5: IMPULSE RESPONSES TO A MONETARY EASING – FIRMSPECIFIC LABOUR VS BASELINE. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line shows the response in the efficient bargaining baseline, which separates price setting and wage setting in two different sectors. The red dashed line shows the response of the economy when these two sectors are merged.

7 Contemporaneous Hiring

The variants of the search model discussed above assume that there is one period lag between the posting of a vacancy and the production of a successful match between firms and workers. Given that the time period is set to be one quarter it is useful to look at a variant allowing for contemporaneous hiring. Following Walsh and Ravenna we assume the following timing. At the beginning of each period firms and workers are hit by a separation shock. All firms that are not matched with a worker can then post vacancies where the successful matches become productive in the same period. This timing assumption implies the following flow values:

$$J_t = y_t^l x_t - h_t w_t + \mathrm{E}_t \left\{ \beta (1-\rho+\rho q_{t+1}) \frac{\lambda_{t+1}}{\lambda_t} J_{t+1} \right\} , \tag{43}$$

$$V_t = -k_t^v + q_t J_t + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[(1-q_t) V_{t+1} \right] \right\} , \tag{44}$$

The flow values of an existing job and the flow value of posting a vacncy are defined with respect to the situation after the realization of the separation shock and before the decision on the posting of vacancies.

$$W_t = h_t w_t - \frac{\chi}{\lambda_t} \frac{h_t^{1+\phi}}{1+\phi} + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[(1-\rho+\rho s_{t+1})\, W_{t+1} + \rho (1-s_{t+1})\, U_{t+1} \right] \right\}, \tag{45}$$

$$U_t = b + \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \left[s_{t+1}\, W_{t+1} + (1-s_{t+1})\, U_{t+1} \right] \right\} . \tag{46}$$

It is important to note that the flow value of being employed and the flow value of being unemployed are defined with respect to the end of the period after the formation of the current period matches.

The introduction of contemporaneous hiring has a direct impact on marginal costs.[25] First, the property that matches become productive in the period moves the labor adjustments from the intensive to the extensive margin. The reaction of employment is considerable more pronounced and the reaction of hours per worker is lower than in the baseline. Furthermore the more pronounced reaction of unemployment increases labor market tightness and puts upward pressure on wages. **[To be completed.]**

[25] Whether or not allowing for contemporaneous hiring quantitatively changes the behaviour of marginal costs in general equilibrium is not clear *ex ante*. Given the forward-looking nature of the Phillips Curve, inflation today will depend on current and expected future marginal cost. Current marginal cost change when allowing for contemporaneous hiring, while future marginal cost continue to depend on the ease with which firms can hire workers.

8 Variants of vacancy posting process

Vacancy creation in response to the business cycle is essential for determining the response of the intensive versus the extensive margin of labour adjustment. As discussed in section 3.3, this in turn has a bearing on the response of marginal wages, marginal cost and inflation over the business cycle. For example, if vacancies and hiring are more responsive in reaction to shocks, this means that in a boom an expansion of labour input is engineered more through a rise in employment than through a rise in hours per employee. As a result, the marginal wages do not rise as quickly and marginal cost and inflation react less than in the baseline.

This section studies the implications of two modifications of the vacancy posting process which have been introduced in the RBC literature on frictional unemployment with the aim to help the Mortensen and Pissarides model reproduce labour market stylised facts. The first modification, following Yashiv (2006), draws on the intuition that it is easier to incorporate a worker into a company when there already is ample employment. This modification therefore assumes that vacancy posting costs are not constant as in the baseline but that they are a decreasing function of the number of employees.[26] If, as in Gertler and Trigari (2006), we only retain this form of vacancy costs, the dynamics of hiring become independent of the labour market tightness $\frac{v_t}{u_t}$ and this helps to increase the volatility and persistence of employment dynamics. The second modification, following Fujita and Ramey (2005), concerns the free entry condition. Previously, paying the vacancy cost kept the vacancy open for just one period. One may reasonably assume that opening a vacancy for the first time is much more costly than keeping it open thereafter. The modification therefore assumes that vacancy costs are paid only once and that the vacancy then remains open indefinitely until filled. This generates a more persistent response of vacancies and hiring, and should therefore affect inflation persistence. Note that the two modifications of the vacancy costs that we consider have in common that they yield countercyclical costs per hire.

8.1 Employment adjustment costs convex in the hiring rate

In the first variant of the model, we keep the free entry condition for vacancies but drop the assumption of a fixed recurrent vacancy posting cost. Instead, we follow Gertler and Trigari (2006) and assume that total hiring costs are a quadratic function of the hiring rate. The idea is that hiring costs not only increase with the number of new

[26] The rationale mimicks that for investment adjustment costs in the related literature. The time cost of incorporating or training a new employee decreases with the existing labour force much the same way as the cost of installing an additional unit of fixed capital, due to disruptions in the production process, say, falls with the existing capital stock.

hires, but also with the proportion of new hires with respect to exisiting jobs. This represents the costs incurred in integrating the new workers into the existing labour force (*e.g.,* training costs).[27] Adopting these authors' formulation, we write

$$k_t^v \, v_t = \psi \left(\frac{m_t}{n_t} \right)^2 n_t \tag{47}$$

where we assume that the total hiring cost is shared equally among all the firms that posted a vacancy, be they filled or not. k_t^v is the cost per vacancy, v_t are the number of vacancies, m_t the newly formed matches and n_t is employment. $q_t = \frac{m_t}{v_t}$ is the probability to recruit once a vacancy is opened. Transforming (47), we have that $k_t^v / q_t = \psi \frac{m_t}{n_t}$. The cost per hiring (left-hand side) is therefore proportional to the hiring rate $\frac{m_t}{n_t}$, and is clearly decreasing with employment. This assumption is in sharp contrast to the baseline. Indeed, in the baseline case the cost per hiring is κ / q_t which typically increases with n_t due to the congestion effect which is associated with the search and matching process.
Using the free entry condition $V_t = 0$ and substituting for k_t^v, equations (28), (29) and (30) are left unmodified but for the substitution of κ / q_t by $\psi m_t / n_t$, so that the dynamics of the job creation condition will be determined by the hiring rate instead of the probability of filling a vacancy. This has the consequence that m_t is determined in the model independently of the matching equation (13). In this sense, the model is a model of hiring under convex adjustment cost, where the cost is independent of the labour market tightness. The only role of the matching function is to generate a series for vacancies which is consistent with the hiring rate. In other words, the dynamics of the model is simply disconnected from the matching equation (but for vacancies).[28]
How will this variable recurrent vacancy posting cost mechanism affect the model? As already argued, convex employment adjustment costs lead to a reduction of these costs as employment increase. If a shock positively affects employment, this mechanism will enhance the volatility of employment as well as its persistence compared to the baseline. In particular, job creation is not altered by the congestion effect typical of search and matching models.
What are the consequences of this for inflation? Under efficient bargaining, this change will not have any effect on the initial response of real marginal cost to shocks since it will be determined by the marginal rate of substitution for hours (unaffected by changes

[27] The rationale for this way of modeling again is in understanding a match as one job in large, multi-worker firms. In this case firms face costs to adjust their labor force in the same way they could face costs to adjust capital. The reason why costs per hiring decrease with the labour force is simply that more employment eases the integration of new hires.

[28] We are indebted to Thijs van Rens for this forceful remark.

in the costs of adjusting employment). But, since hiring is increased in this model relative to the benchmark, future real marginal costs should be reduced, lessening the effect of the shock on inflation. It could also be the case that the high and persistent increase in employment would help to rapidly decrease the initial strong demand for hours. The combination of these two effects would imply a less persistent reaction of marginal cost and, so, a smaller response of inflation.

Empirically, however, in our calibration the effect is limited. Figure 6 (below) suggests that the dynamics of marginal cost and inflation look very much alike the baseline. This suggests that the effect on current marginal cost greatly outweighs any effect on future marginal cost.

8.2 Vacancy as a sunk cost

In the second variant of the model, we abandon the free entry condition assumption, so that $V_t \neq 0$ and we drop the recurrent cost, so that $k_t^v = 0$. Instead, as in Fujita and Ramey (2005), firms pay a sunk cost K only once when they post a new vacancy. This has the effect to transform vacancies into a stock instead of a flow variable, and enhance its persistence. The initial goal of these authors was to reproduce the hump shaped response of vacancies. However, in our setting, one might expect that persistence in vacancies and employment will affect the profile of the hours response and therefore inflation dynamics via the marginal rate of substitution. It is actually difficult to assess a priori whether this should imply more or less inflation persistence with respect to the baseline since it will also depend on the effect on employment volatility.

The sunk cost may differ across firms. We assume K follows a continuous distribution of which $f(K)$ represents the density function and $F(K)$ the cumulative distribution. Every period, all the firms that have neither a worker nor vacancy draw a sunk cost out of the K distribution. Among these, all the firms endowed with a sunk cost lower than

$$\overline{SC}_t = \mathrm{E}_t \left\{ \beta \frac{\lambda_{t+1}}{\lambda_t} \cdot \left[q_t J_{t+1} + (1 - q_t) \overline{SC}_{t+1} \right] \right\}$$

will post a vacancy.

Denoting the newly posted vacancies by v_t^n, we obtain that

$$v_t^n = F(\overline{SC}_t)$$

and the law of motion of vacancies is:

$$v_t = (1 - q_{t-1})\, v_{t-1} + v_t^n \,. \tag{48}$$

Let us assume that the cumulative distribution is a linear function of the sunk cost

$$F(K) = \varkappa \cdot (K - \bar{k}) \ , \ \varkappa > 0$$

where $\bar{k} \geq 0$ is the lower sunk cost in the distribution while $\varkappa$ is a slope parameter. Of course, the lower (resp. higher) parameter $\bar{k}$ (resp. $\varkappa$) is, the higher the number of new vacancies and the more volatile employment. Finally, total vacancy posting costs are given by:

$$\varkappa \int_{\bar{k}}^{V_t} K \cdot dK \ = \varkappa \left(\frac{\overline{SC}_t^2 - \bar{k}^2}{2} \right) \tag{49}$$

Note that in this variant, no equation of the baseline model is modified but the vacancy posting cost. The corresponding wage equation is obtained by substituting (17), (19) and (20) into (27) and cannot be further simplified. However, adding (48) to the model clearly introduces sluggishness in the vacancy dynamics and will help produce the empirically observed hump in vacancies.

The dynamics implied by this variant of the baseline model are illustrated on Figure 6 (dotted black line). The simulation is build under the following calibration: $\bar{k} = 0.3$ anf $\varkappa = 1$. For this calibration, the variant leads to more persistence in vacancies and employment, at the cost of a reduction in volatility. Increasing $\varkappa$, employment gets more volatile but this also reduces strongly the persistence in the vacancies dynamics (this case is not displayed on Figure 6 for readability). There is, essentially, no effect on the dynamic response of inflation to the shock. Again, the intuition is that under efficient bargaining, this change will not have any effect on the initial response of real marginal cost to shocks since it will be determined by the marginal rate of substitution for hours, which will be unaffected by the introduction of sunk costs in vacancy posting. As for the previous variant, it seems that the effect on the current marginal cost dominates those on future marginal cost. This again indicates that the combination of efficient bargaining with the assumption of pre-determined employment in a model with hours prevents inflation dynamics to be affected by labour market evolutions. Interestingly, the cost per hiring is even more countercyclical than in the convex adjustment cost for employment variant. This is however not sufficient to produce an equivalent volatility and persistence to employment: the congestion effect plays an important role here, while we argued earlier that it is not the case for the variant with adjustment cost convex in the hiring rate.

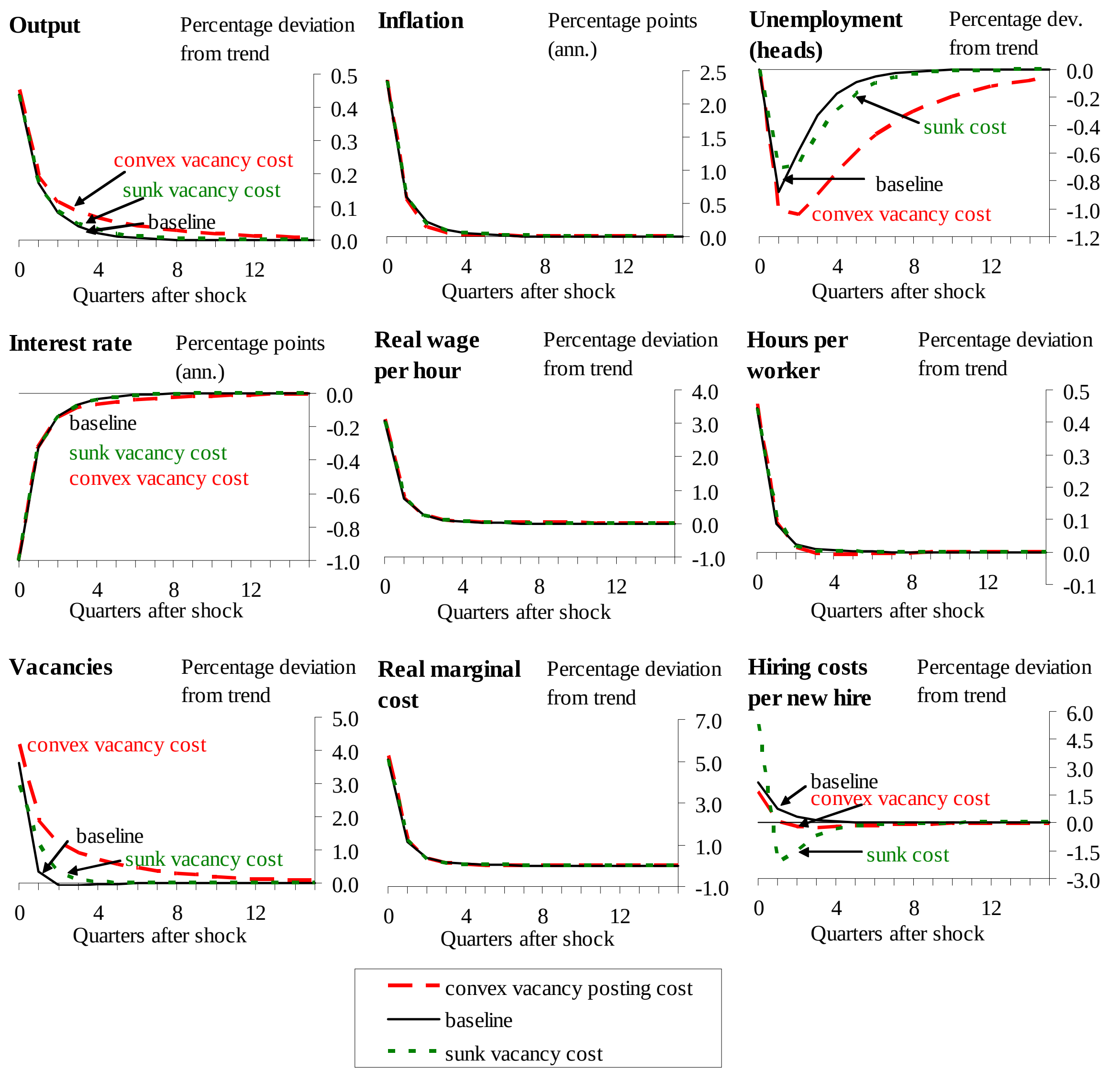

Figure 6: Impulse responses to a monetary easing when allowing for different vacancy posting costs than in the baseline and different vacancy creation technology. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The solid line shows the response in the baseline which features constant costs per vacancy over the cycle, and in which these costs keep open a vacancy for exactly one period. The red dashed line represent the response in the variant with adjustment costs convex in the hiring rate. The green dotted line is the response in the variant where vacany costs are sunk.

9 On-the-job search

Up to this point, we have assumed that only unemployed workers can search with the result that only they enter the matching function and can be matched up with vacancies. But, in reality, currently-employed workers spend at least some of their time looking around for alternative job opportunities. The result of this is that job-to-job movements form a large part of all job destruction and creation.[29]

The models of Krause and Lubik (2006) and van Zandweghe (2006) introduce these ideas in a simple way. In their models, jobs come in two types: 'good' jobs (that pay higher wages) and 'bad' jobs (that pay lower wages). Aggregate output is produced using workers employed in both types of job. The presence of these two types of job creates an incentive for workers employed in bad jobs to search for good jobs. So, good firms are able to recruit from a pool of workers that includes both those unemployed workers who are searching for good jobs, $u_{g,t}$, and those currently employed in bad jobs, $e_t = \zeta_t n_{b,t}$, where ζ_t is the search intensity of employed workers and $n_{b,t}$ is employment in the bad sector. Given this, the relevant measure of labour market tightness for the 'good' sector will be $\widetilde{\theta}_t = \frac{v_t}{u_{g,t}+e_t}$, where $u_{g,t}$ is unemployment of good sector workers. This measure of market tightness will likely be less volatile than the measure in the baseline model withhout search on-the-job, which was given by $\theta_t = \frac{v_t}{u_t}$. The reason is that e_t will be procyclical.

In a boom more new vacancies will be posted than if there were no on-the-job search; since employment in the 'bad' sector is procyclical, the number of searching workers will also be procyclical increasing the likelihood of filling a vacancy in a boom relative to the model with no on-the-job search. The first-order condition for employed search intensity will be given by:

$$\begin{aligned} \tau\gamma\zeta_t^{\tau-1} \quad = \quad & \frac{\eta}{1-\eta}\left(1-\rho\right)\sigma_{m,g}\left(\frac{v_{g,t}}{u_{g,t}+e_t}\right)^{1-\vartheta} \\ & * \left(\frac{\kappa_g}{\sigma_{m,g}}\left(\frac{v_{g,t}}{u_{g,t}+e_t}\right)^{\vartheta} - \frac{\kappa_b}{\sigma_{m,b}}\left(\frac{v_{b,t}}{u_{b,t}}\right)^{\vartheta}\right) \end{aligned} \tag{50}$$

where ζ_t^{τ} is the cost of searching with intensity ζ_t. As can be seen, as more vacancies are posted, employed workers to increase their search intensity which will lower expected hiring costs and increase the incentive to post vacancies even further. That is, the rising search activity of the employed in a boom forms an additional resource in the matching function that helps to keep hiring costs more stable. The model predicts that job-to-job flows rise in booms, in line with the data.

[29] In the United States and the United Kingdom, job-to-job flows account for around 50% of all job separations (Akerlof *et al.,* 1988; Gomes, 2007) although there is some evidence that the proportion is smaller than this in euro area countries, see Contini and Revelli (1997).

But what does all this imply for inflation dynamics? In the model with on-the-job search (and in the baseline model), the New Keynesian Phillips Curve will be given by (11). Given that final output is assumed to be a Cobb-Douglas function of output in each of the two sectors, real marginal cost will be given by:

$$x_t = \left(\frac{x_{g,t}}{1-\omega}\right)^{1-\omega}\left(\frac{x_{b,t}}{\omega}\right)^{\omega} \tag{51}$$

where ω denotes the share of the output of 'bad' jobs in final output. With efficient bargaining over hours, real marginal cost in each sector will again be equal to the marginal rate of substitution divided by the marginal product of labour in that sector:

$$x_{g,t} = \frac{\chi}{\lambda_t}\frac{h_{g,t}^{1+\phi}}{\alpha y_{g,t}^{l}} \tag{52}$$

and

$$x_{b,t} = \frac{\chi}{\lambda_t}\frac{h_{b,t}^{1+\phi}}{\alpha y_{b,t}^{l}} \tag{53}$$

So the response of real marginal cost to demand shocks will depend upon the response of hours to such shocks. For the same reasons as in the baseline model, we would expect the response of hours, hence real marginal cost, to be quite large. But, on-the-job search leads to a reduced response in hiring costs in response to shocks; this will reduce the response of future real marginal cost to shocks. Which of these effects dominates will be an empirical question.

Figure 7 shows the effects if a one percentage point cut in nominal interest rates in the on-the-job search model and compares these with the baseline model.[30] In the model with on-the-job search, this cut in interest rates leads to an immediate rise in output of about 0.5% and in inflation of about 2 percentage points. The response of inflation is clearly too great and too quick relative to the data and is only slightly smaller than the inflation response in the baseline model. In turn, this is because of the large and immediate 6% rise in real marginal cost in response to this shock, offset only slightly by the lower response of real marginal cost in future periods relative to the baseline. In other words, this mechanism has failed to dampen the response of marginal cost to the rise in output with the result that it fails to dampen the response of inflation to the shock. So, on-the-job search only slightly helps the model explain the response of inflation to demand shocks.

[30] We use the same parameters and steady state as for the baseline model.

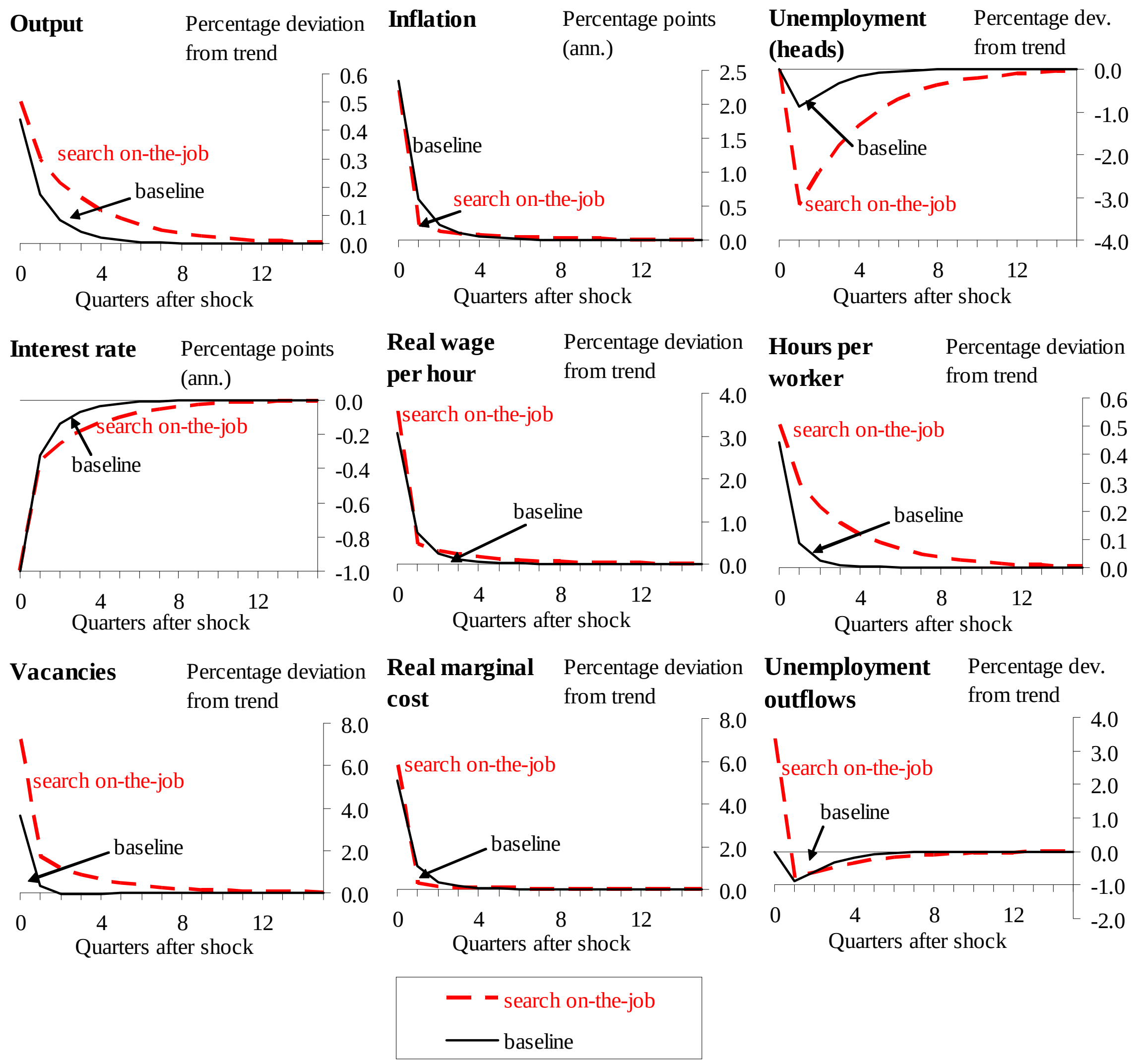

Figure 7: IMPULSE RESPONSES TO A MONETARY EASING WHEN ALLOWING FOR SEARCH ON-THE-JOB. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line shows the response in the baseline which features homogenous jobs, and in which workers are recruited only out of the unemployment pool. The red dashed line shows the response when allowing for search on-the-job.

10 Endogenous job destruction

So far we have treated job separation as an exogenous process occurring at a constant rate of 6% per quarter. In this we follow much of the literature on frictional labor markets, which assumes exogenous separation for several reasons: it makes the model easier to solve; it makes the model easier to calibrate; and it implies a robust negative correlation between unemployment and vacancies, whereas the Beveridge curve often disappears in models that endogenize separation.

However, it is disturbing to represent such an important economic decision by an exogenous constant, so in this section we incorporate an endogenous component into the separation process. The most obvious motive for endogenizing separation is that the separation rate rises in recessions (in spite of recent US evidence from Shimer (2005B) and Hall (2005B) that this countercyclicality is less pronounced than was previously believed). Sources of evidence for countercyclical separation in Europe include Burda and Wyplosz (1994); Garibaldi (1998), who shows a negative correlation between job creation and destruction; and Fredriksen (2003) and D'Addio and Rosholm (2005), who find a negative effect of GDP growth on individual separation rates. Moreover, endogenizing separation imposes an additional first-order condition related to the separation margin and thus further restricts the model's predicted dynamics. It may also help provide some of the missing variability in unemployment, as Costain and Jansen (2006) and Mortensen and Nagypal (2007) point out, especially if endogenous separation applies to newly formed jobs as well as to continuing jobs.[31] When endogenous separation is derived from idiosyncratic productivity shocks, it may also have interesting implications for productivity and wage dynamics, since it will give rise to a "cleansing effect" as low productivity matches are destroyed countercyclically.

As in Mortensen and Pissarides (1994), we endogenize separation by assuming that each match has an idiosyncratic productivity component which is uncorrelated with aggregate productivity. Thus, the income produced by a match is given by $x_t z_{it} \varepsilon_t^a h_{it}^\alpha$, where z_{it} is the match-specific productivity component and the rest of the notation follows that in Section 2.[32] We will assume z_{it} is normally distributed with distribution F, which has mean 1 and standard deviation σ_z. This distribution will allow us to nest the exogenous search model as a special case of our endogenous search model associated with $\sigma_z \longrightarrow 0$.[33] We will call the reservation productivity at which separation occurs

[31] Mortensen and Nagypal (2007) also discuss (exogenous) fluctuations in the job destruction rate as a possible driving force for unemployment fluctuations.

[32] Assuming the idiosyncratic and aggregate productivity components z_{it} and ε_t^a enter multiplicatively implies that they enter additively in logs, as in the calibration exercise in Sec. 5 of Mortensen and Pissarides (1994).

[33] We will choose parameters such that continuation is optimal for $z = 1$, implying a reservation

$\underline{z}_t$.

Following den Haan, Ramey, and Watson (2000), we assume z_{it} is *iid*. That is, z_{it} is uncorrelated with the aggregate shock x_t, it is uncorrelated across individual matches i, and most importantly it is uncorrelated over time. This matters because it simplifies the state space of the model: the equilibrium distribution of productivity is just a truncated version of the underlying exogenous distribution F. If instead z_{it} were correlated over time, high productivity matches would be more likely to survive than low productivity matches, and we would have to keep track of the endogenous evolution of the productivity distribution over time. This would require heterogeneous agent solution methods going far beyond the linear methodology employed elsewhere in the paper.

For continuity with the setup elsewhere in the paper, we still include an exogenous separation component: at the end of each period, existing matches separate for exogenous reasons with probability ρ^x. Allowing for productivity shocks with distribution F in all periods, and reservation productivity $\underline{z}_t$, the employment dynamics are:

$$n_t = \left(1 - F\left(\underline{z}_t\right)\right)\left[(1-\rho^x)n_{t-1} + m_{t-1}\right] \ . \tag{54}$$

The fraction of jobs surviving between periods $t-1$ and t is therefore $1-\rho_t \equiv \left(1 - F\left(\underline{z}_t\right)\right)(1-\rho^x)$. The total number of worker-firm pairs that meet at the end of $t-1$ is $m_{t-1} = \sigma_m \, v_{t-1}^{\vartheta} \, u_{t-1}^{1-\vartheta}$, where $u_{t-1} = 1 - n_{t-1}$ but the number that actually enter into production at the start of t is only $\left(1 - F\left(\underline{z}_t\right)\right) m_{t-1}$.

The rest of the model has the structure spelled out in Sections 2-3. In particular, we assume efficient bargaining, as in Sec. 3.1, which now implies that both wages and hours will depend on the match-specific productivity shock z_{it}. Thus in the analogue to equation (17), a matched firm's value function is a function of the shock, $J_t\left(z_{it}\right)$, and its flow of revenues is $x_t z_{it} \varepsilon_t^a h_t(z_{it})^{\alpha} - w_t(z_{it}) h_t(z_{it})$. A matched worker's value function $W_t\left(z_{it}\right)$ also depends on the shock; the worker's flow payoffs are $w_t(z_{it})h_t(z_{it}) - \lambda_t^{-1}\frac{\chi}{1+\phi}h_t(z_{it})^{1+\phi}$. On the right-hand side of all the Bellman equations there will therefore be expectations of future values with respect to z_{it+1}.

Efficient bargaining over hours gives a first-order condition which is equivalent to (26), except that it also takes into account the idiosyncratic productivity shock:

$$h_t\left(z\right) = \left(\alpha x_t \varepsilon_t^a \lambda_t / \chi\right)^{\frac{1}{1+\phi-\alpha}} z^{\frac{1}{1+\phi-\alpha}} \equiv H_t z^{\frac{1}{1+\phi-\alpha}} \tag{55}$$

productivity strictly less than one. In the limit as $\sigma_z \longrightarrow 0$, the fraction separating endogenously goes to zero and the mean of z for continuing matches goes to one. Therefore in this limit the additional first-order condition serves only to define the separation threshold, which has no effect on the remaining equations of the model.

Thus hours are proportional to $z^{\frac{1}{1+\phi-\alpha}}$ with the time-varying factor of proportionality H_t, which will help us aggregate hours and wages. As in Sec. 3.2, the first-order conditions from efficient bargaining can be manipulated to obtain a simplified wage equation like (32):

$$w_t(z)\,h_t(z) = \eta\kappa\theta_t + (1-\eta)\,b + \left[\eta + \frac{\alpha(1-\eta)}{1+\phi}\right] x_t z_{it}\varepsilon_t^a h_t(z_{it})^\alpha$$

If we make the substitution

$$\frac{c_t}{n_t} = \varepsilon_t^a \int_{\underline{z}_t}^{\infty} z h_t(z)\,dF(z)$$

then the expected labor income of an employed worker simplifies to

$$\left(1 - F\left(\underline{z}_t\right)\right)^{-1} \int_{\underline{z}_t}^{\infty} w_t(z)\,h_t(z)\,dF(z) = \eta\kappa\theta_t + (1-\eta)\,b + \left[\eta + \frac{\alpha(1-\eta)}{1+\phi}\right] \frac{x_t c_t}{\left(1 - F\left(\underline{z}_t\right)\right) n_t}$$

This substitution allows us to eliminate all integrals over z from the rest of the equilibrium conditions. In particular, the job creation Euler equation analogous to (30) becomes

$$\frac{\kappa}{q_t} = E_t\left\{\beta\frac{\lambda_{t+1}}{\lambda_t}\left[\begin{array}{l}\frac{(1-\eta)(1+\phi-\alpha)}{1+\phi}\frac{x_{t+1}c_{t+1}}{n_{t+1}} \\ -\left(1 - F\left(\underline{z}_{t+1}\right)\right)\left(\eta\kappa\theta_{t+1} + (1-\eta)\,b\right) \quad + \left(1 - \rho_{t+1}\right)\frac{\kappa}{q_{t+1}}\end{array}\right]\right\} \tag{56}$$

The reservation productivity $\underline{z}_t$ satisfies the job destruction equation $J_t\left(\underline{z}_t\right) = 0$. Eliminating the wage and expected future values from the Bellman equation for J, the job destruction equation can be written as

$$\frac{(1-\eta)(1+\phi-\alpha)}{1+\phi} x_t \varepsilon_t^a H_t^\alpha \underline{z}_t^{\frac{1+\phi}{1+\phi-\alpha}} - \eta\kappa\theta_t - (1-\eta)\,b + (1-\rho^x)\frac{\kappa}{q_t} = 0 \tag{57}$$

Calibrating this version of the model requires us to determine what fraction of separations are endogenous. Davis and Haltiwanger (1995) roughly calculated the fraction of endogenous separations in US data by comparing firm-level job destruction (which they argue should reflect changes in firms' labor demand, and therefore map into the model's endogenous component) with total worker separation flows (which are larger, and should include worker-initiated changes in employment status which they map into the model's exogenous component). They find that the endogenous component is roughly 40% of the total, which is the number we will use here. Then for any standard deviation σ_z of the idiosyncratic shock, we can calculate $\underline{z} = F^{-1}(0.4 * 0.06)$, assuming 6% total separation flows as before, and from $\underline{z}$ we can calculate all the integrals over

z that appear in the equations.

Next, we can back out the other parameters as before: the coefficient σ_m can be deduced from observed job flows; χ can be chosen so that the hours bargaining condition (55) is satisfied; κ is then chosen for consistency with the job creation equation (56). Finally, we can choose the unemployment income b so that the job destruction equation (57) holds. This makes the replacement ratio endogenous, so this calibration strategy will not automatically generate the same replacement rate used in previous sections of the paper. Therefore, we report a comparison between the endogenous search model and a simulation of the exogenous search model under the replacement ratio derived from the endogenous search calculation.

When we calibrate the model for endogenous search, assuming the standard deviation of the idiosyncratic shock is $\sigma_z = 0.1$, we obtain a replacement rate of 84.18%. Therefore Figure 8 compares these endogenous search results to the exogenous search model under a replacement rate of 84.18%. With endogenous search, a one-standard deviation decrease in interest rates causes the separation rate to fall by 15%. Thus, unemployment reacts immediately to a monetary shock, whereas it exhibits a one period lag in the case of exogenous search, and overall this leads to greater variation in unemployment over time in the case of endogenous search. On the other hand, the availability of the job destruction margin relaxes the vacancy margin so much that it goes in the wrong direction: a decrease in interest rates causes vacancies to fall in the endogenous search model. Also, the availability of the job destruction margin permits substitution away from the hours margin, so hours increase less than in the exogenous search case. With less need to increase hours and vacancies, the rise in wages is two orders of magnitude smaller than it is under exogenous search, and therefore real marginal cost and inflation are less volatile too. Higher unemployment volatility together with lower inflation volatility are both improvements in the model's fit to the data, but the fact that vacancies now go the wrong way relative to unemployment is a serious problem for this version of the model.

This simulation was based on an arbitrary value of the standard deviation of the idiosyncratic shock ($\sigma_z = 0.1$). To better determine σ_z, it would be natural to search for a value of σ_z that yields the same replacement ratio used in the baseline model. Interestingly, though, a search over σ_z reveals regions of qualitatively different behavior. A small increase in σ_z decreases the replacement ratio, bringing it closer to the 65% value in the baseline model, without qualitative changes in the impulse response functions. But as we raise σ_z to 0.4, we come to a region in which equilibrium is indeterminate (we will not attempt to characterize the model's behavior in this region). A further increase, to $\sigma_z = 0.5$, again results in a determinate equilibrium, but one which behaves very differently, as illustrated in Figure 9. In this case, a monetary stimulus causes labor to increase along all margins: separation falls, while vacancies and hours rise.

We again plot the endogenous search impulse responses together with those of the exogenous search model under the same replacement ratio. However, this is hard to see from the graphs, because the impulse responses from endogenous and exogenous search lie almost directly on top of each other. The reason is that the variation driven by vacancies is far more significant than that caused by changes in separation rates in this parameterization. Moreover, since the parameters of the exogenous and endogenous search cases have been chosen to give the same steady state unemployment rate and replacement ratio, they have the same surplus in steady state, so that productivity shocks cause nearly identical variation in vacancies in both cases.
A similar finding has been reported by Mortensen and Nagypal (2007). They show observational equivalence of appropriately parameterized endogenous and exogenous search models with respect to certain statistics (such as the relation between the volatility of tightness and that of aggregate productivity shocks). While their model has flexible prices instead of the New Keynesian features considered here, it assumes a very similar labor market structure, so the intuition for the result is similar: if we parameterize the steady states of the exogenous and endogenous search models so that the unemployment rate and replacement ratio are the same, then they will have the same surplus, and therefore similar hiring incentives.

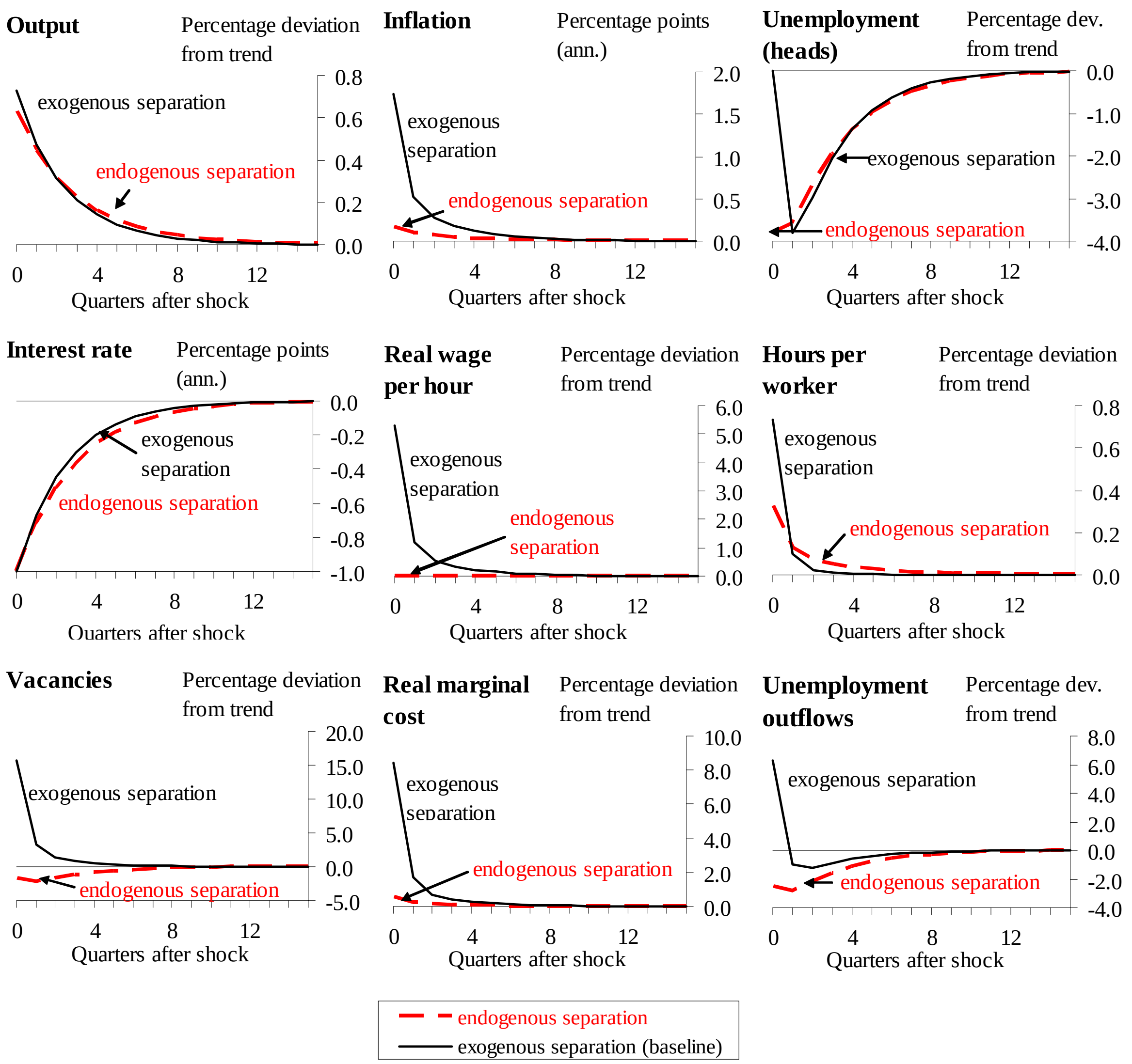

Figure 8: Impulse responses to a monetary easing, model with endogenous separation vs. model with exogenous separation. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line refers to the response in a model, which features only exogenous separation between firms and workers. Apart from slight differences in the calibration (described in the main text body) this resembles the baseline model. The red dashed line marks the responses when allowing for endogenous separation. Shown is the case with a low standard deviation of the idiosyncratic technology shock, $\sigma_z = 0.1$.

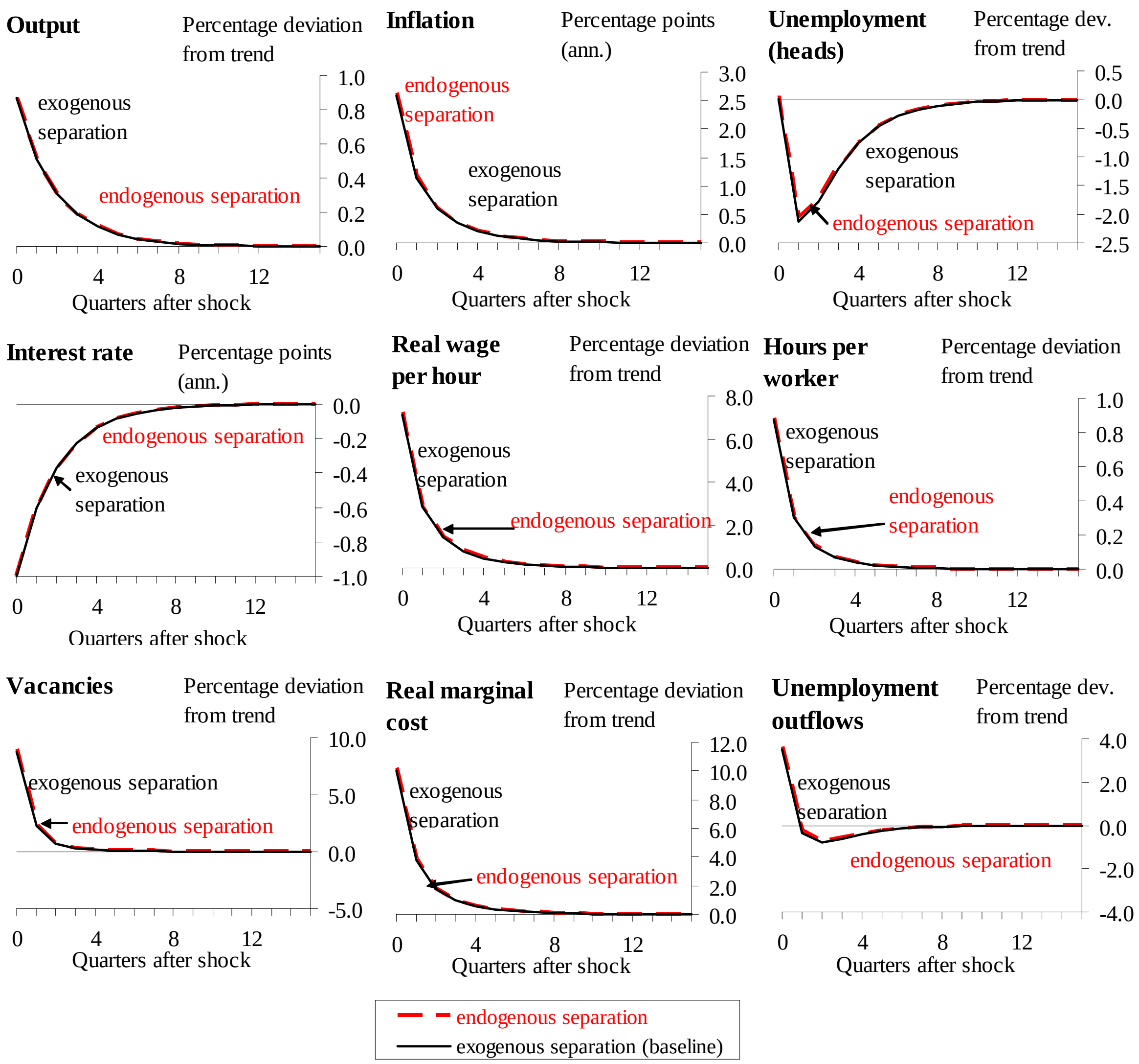

Figure 9: Impulse responses to a monetary easing, model with endogenous separation vs. model with exogenous separation, alternative calibration. Shown are impulse responses to an unanticipated 100 bps reduction in the quarterly nominal interest rate in quarter 0. All entries are in percentage deviations from steady state. Interest rates and inflation rates are reported in annualized terms. The black solid line refers to the response in a model, which features only exogenous separation between firms and workers. Apart from slight differences in the calibration (described in the main text body) this resembles the baseline model. The red dashed line marks the responses when allowing for endogenous separation. Shown is the case with a low standard deviation of the idiosyncratic technology shock, $\sigma_z = 0.5$.

11 Conclusions

In this paper, we have assessed the ability of a host of New Keynesian models with alternative labour market specifications to explain inflation dynamics. We first used a standard New Keynesian model with search and matching to show that such models typically generate a response of inflation to nominal shocks that is much too large relative to the data. We then considered some alternative specifications.

We first considered the addition of wage rigidity. Under efficient bargaining, wage stickiness in existing jobs has no effect since average wages are non-allocative in this set up. But, if the nominal wage of newly-created jobs is sticky, then there will be an effect. In this case, the existing wage rate will affect real marginal cost, since the wage paid to new hires affects hiring incentives. With real marginal cost sticky, inflation will respond less to nominal shocks. Perhaps more interestingly, we found that nominal wage rigidity can have a further role in a monetary model. Combined with a 'right-to-manage' assumption for the determination of hours (which implies a direct channel from wages to inflation), staggered wages at the level of the match will help to smooth the reaction of the aggregate wage resulting in a smaller response to shocks of marginal cost and inflation. When we then combined this nominal rigidity with the real rigidity of firm-specific labour, we found that prices respond less to shocks the more any firm's marginal costs respond to a change of the firm's price. Hence, the response of inflation to nominal shocks is reduced if the marginal disutility of work is increasing in hours worked and/or there are decreasing returns to labour; both these conditions hold in our calibrated model.

We then looked at variants of the model in which hiring costs were either proportional to the hiring rate or sunk (*i.e.*, unrelated to the number of vacancies opened). We found that neither of these modifications affected the response of inflation to nominal shocks, which was still too large. We then considered two other margins along which adjustment can occur in the labour market: on-the-job search and endogenous job destruction. We found that both features could help reduce the response of inflation to shocks, though our results based on endogenous job destruction depended critically on the calibration of the model.

In summary, we found that a model with sticky nominal wages when combined with right-to-manage bargaining was best able to capture unemployment volatility and the response of inflation to nominal shock. In that setup it was largely irrelevant whether wage stickiness affected only existing matches or also new matches. [**More nuanced here?**] The current paper therefore finds that if the labour market were to matter for inflation dynamics, it would most likely be the case for the above reasons. We have not been able to make a clear case, however, that the labour market would necessarily matter for inflation dynamics. The reason is the lack of micro-evidence to discern different modeling strategies.

For future work, it would therefore be interesting to put the mechanisms that we have explored to a test from micro-economic perspective. Work on wage stickiness for new hires that has recently been conducted, *e.g.,* by Haefke *et al.* (2007) is a first step in that direction. Micro-evidence on bargaining and contractual arrangements regarding state contingency of the wage, overtime payments and premia, overtime accounts and non-wage components of compensation would be a valuable further step towards discerning the different labour market setups.

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12 Appendix A: further evidence on monetary transmission in the euro area

In the paper, we benchmarked the different approaches to modelling the labor market against five stylized facts about the transmission of monetary policy in the euro area.

This section presents the background evidence from which we deduced these stylized facts.[34]

Figure 1 prints the impulse responses of euro area aggregates to a 100bps monetary shock (an easing) in McCallum and Smets (2008),[35] who estimate a Factor-Augmented VAR following the methodology of Bernanke et al. (2005). Also shown are the boundaries of bootstrapped 90% confidence intervals. According to this evidence, a monetary

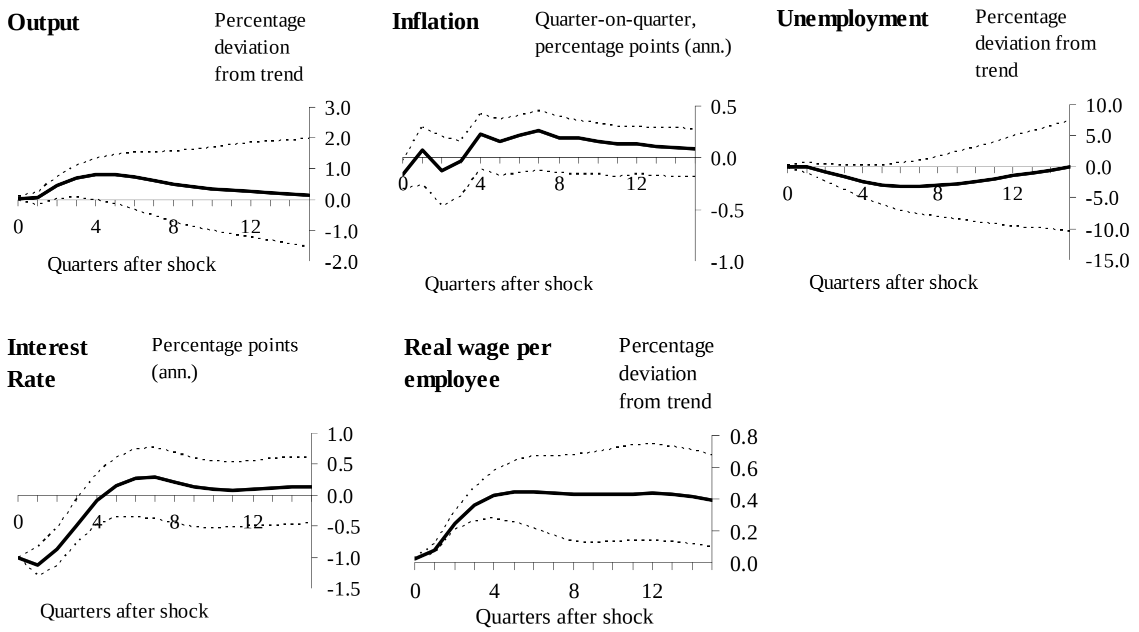

Figure 10: Impulse responses to an unanticipated monetary shock in the euro area, source: McCallum and Smets (2008). Depicted are responses to a 100 bps monetary easing (annualized nominal rates). Charts refer to the euro area. The sample is 1987Q1 to 2005Q4. Top row (from left to right): response of real GDP (in percentage deviation from trend), quarter-on-quarter GDP inflation (in annualized percentage points), unemployment (in percentage deviation from trend). Note: shown is the response of log unemployment (heads), log(ut). Bottom row: response of nominal interest rate (in annualized percentage points) and the real wage per employee (in percentage deviation from trend). Source: McCallum, Smets (2008), reprinted with the author's permission.

easing stimulates the economy. At its peak, output has risen by about 0.8% above steady state. Inflation increases, too, but in a muted manner. The peak increase in quarter-on-quarter GDP inflation is about 25bps (in annualized terms). As a conse-

[34] A number of studies have examined the response of real and nominal variables in the euro area to a monetary shock using alternative identification mechanisms. For early evidence on the euro area as a whole, see e.g. Peersman and Smets (2003) and Angeloni et al. (2003). More recent papers are McCallum and Smets (2008) and Peersman and Straub (2007). For evidence country by country see e.g. Mojon and Peersman (2003) and Normandin (2006).

[35] Their data comprise quarterly euro area aggregates and a number of euro-area country-specific series from 1987Q1 to 2005Q4, as well as foreign series.

quence of higher demand, the number unemployed people, *i.e.,* unemployment, falls by 3%.[36] The increase in economic activity also translates into an increase in the real wage per employee. That increase is about half the size of the increase in output, but is very persistent.

Complementing this evidence, Figure 11 reports our own estimates of the monetary transmission in the euro area. The sample starts in 1987Q1 as in McCallum and Smets (2008), and runs through 2006Q4. We estimated a standard VAR(4) in the variables shown in the graphs, and identified the monetary shock through the oft-used recursive ordering scheme. For details see the notes to Figure 11. According to these estimates, an unanticipated monetary easing induces a longer-lived deviation of nominal rates from the baseline than in McCallum and Smets (2008) and, as a result, most responses are more persistent. With regard to amplitudes, the evidence is robust, however. A monetary easing by 100bps causes a notable increase in output of about 0.8% at its peak, and an increase in real wages per employee of about half that size (which is, again, very persistent). Unemployment, according to our estimates, falls by 6% below steady state.[37] At the same time, the increase in inflation remains contained, with (GDP) inflation remaining below 0.4 percentage points in annualized terms.

In the above estimation, we resort to the same proxy for hours worked in the euro area as used by Christoffel et al. (2008).[38] When using this series to infer hourly wage rates and hours worked per employee, the results suggest that changes at the extensive margin are more relevant for labor adjustment than hours worked per employee. Hours worked per employee react very little throughout the period (and if anything, they fall), while the number of employees is more responsive. See the first two panels of Figure 12. As a result, the increase in wages per employee depicted in Figure 11 is mainly attributed to a slow but persistent increase in hourly wages instead of an increase in hours per worker, see Figure 12. Due to the limitations of the euro area data with respect to hours worked or hourly wages, however, the responses in Figure 12 – while indicative – should be taken with a relatively large grain of salt.

Table 3, finally, summarizes the impulse responses reported above, and augments these by evidence of three further studies. Angeloni et al. (2003) report impulse responses

[36] This refers to unemployment, not to unemployment rates in percentage points. The depicted fall in unemployment corresponds to a fall in unemployment rates of about .27 percentage points. Unemployment is calculated in a model-consistent from the response in employment, which McCallum and Smets report, by assuming that the labor force does not react to a monetary easing, and that average unemployment rates are 9%

[37] This translates into a reduction in unemployment rates of about .54 percentage points.

[38] Unfortunately, harmonized quarterly series for hours worked do not exist for the euro area. The proxy uses the quarterly real GDP series for the euro area to interpolate annual EU-Klems data on total hours worked in the euro area.

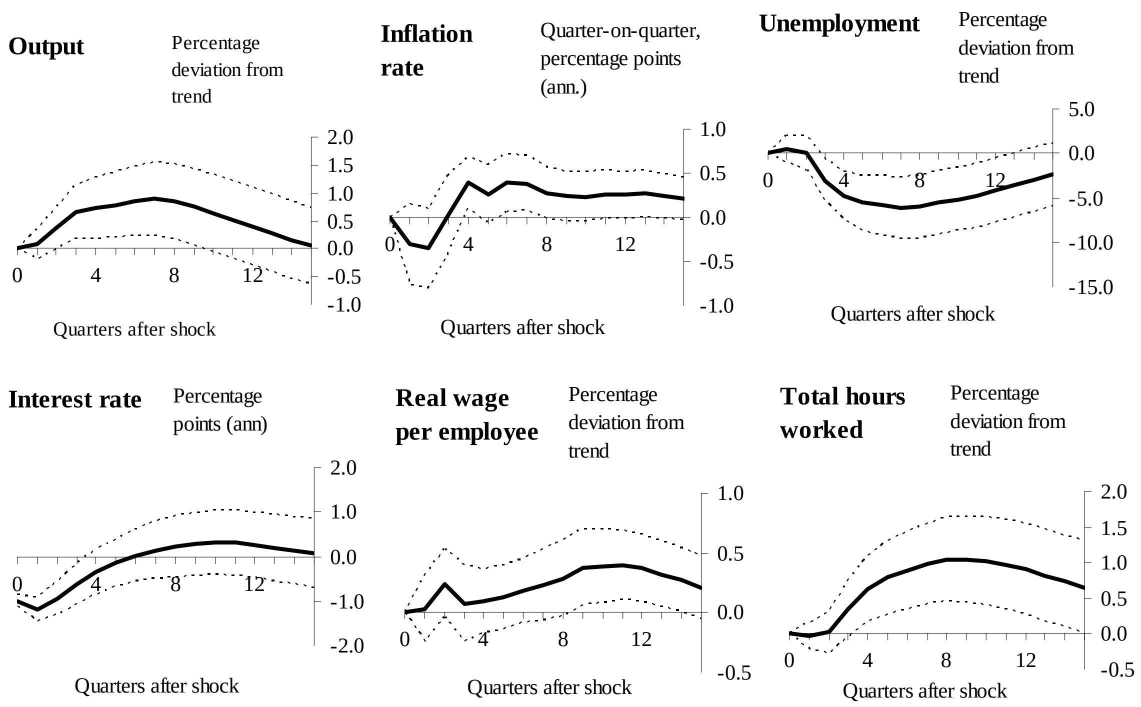

Figure 11: Impulse responses to an unanticipated monetary shock – own estimates. Underlying the results is a VAR(4) estimated on above data (taken from the AWM data set except four hours worked, which is taken from Christoffel et al., 2008). The sample is 1987Q1 to 2006Q4, identification relies on the usual Cholesky decomposition. The data was de-trended variable by variable prior to running the VAR. For real variables, we allow for a trend, and a break in the trend plus a level shift in 1991Q1 so as to accommodate German reunification. Inflation and mominal interest rates were regressed on a linear trend, which breaks after 1998Q4 in order to account for the disinflation in the euro area prior to the introduction of the common currency, and the constancy of the inflation objective thereafter. Dotted lines mark asymptotic 90% confidence intervals (5% and 95% bounds).

for the euro area based on various identification schemes for the monetary shock in a VAR. So do Peersman and Smets (2003). The Table, in addition, collects evidence of a recent study by Peersman and Straub (2007) who identify a monetary shock (and other shocks) based on sign restrictions, which were derived from a prototypical New Keynesian model. The Table summarizes the maximum amplitudes of the variables following the monetary shock. Most of the studies imply that after the initial shock, nominal rates fall somewhat further before being tightened. In order harmonize the studies, all responses have been normalized by the maximum easing of the nominal interest rate that these studies report.

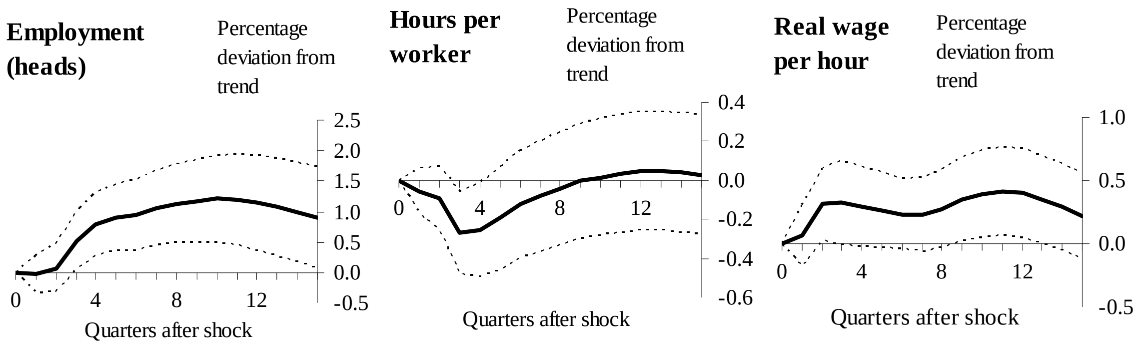

Figure 12: Impulse responses of hours and wages to a monetary shock – own estimates. Shown are the responses of employment, hours per employee and the real wage rate. The VAR is the same as in Figure 11, except that the a measure of hours per worker and of the real hour wage rate replaces the measures for total hours worked and the real wage per employee.

	Out-put	Infl.	Un-empl.	Empl.	Real wages per empl.	Real wage per hour	Total hours wor-ked	Hours per empl.
McCallum,Smets (1)	0.7	0.2	-2.9	0.3	0.4	–	–	–
Own VAR (2)	0.6	0.3	-4.5	0.4	0.3	0.4	0.9	0.04
Peersman,Straub (3)	0.3	0.2	-2.8	0.3	0.3	0.3	0.3	0
Angeloni et al. (4)	0.5	0.2	-3.3	0.3	–	–	–	–
Peersman,Smets (5)	0.5	0.2	-3.3	0.3	–	–	–	–

Table 3: Peak responses to a monetary easing in the literature. Most of the studies imply that after the initial easing, nominal rates fall somewhat further before they tighten. In order harmonize the studies, all responses have been normalized by the maximum easing of the nominal interest rate that these studies report (which in all studies occurs one quarter after the shock). Entries in small type refer to numbers that have been deduced indirectly as described below. (1): McCallum and Smets (2008) report the response of employment. The response for unemployment is inferred from the figure for employment assuming a constant labor force and an average unemployment rate of 9%. (2): Own VAR: hours worked data for the euro area is subject to measurement errors as stated in the main text. (3): Peersman and Straub (2007) only report the response of total hours worked, but state that responses are similar when employment is used. We thus report the same response of employment as for total hours worked. The response for unemployment is inferred as in (1). Similarly, hourly wage rates and hours per employee are inferred from this statement. (4): Peersman, Smets (2003): sample 1980-1998. Entries are based on their Fig. 2.1 and Fig. 2.8. The response for unemployment is inferred as in note (1). (5): Angeloni et al. (2003) report the response of the unemployment rate (see their Table 6). The response of unemployment reported here is obtained using an unemployment rate of 9%. Figures for employment were obtained accordingly. Results for the Angeloni et al. paper are averages over different specifications for the sample 1980-2001. Only the response of consumer prices is reported. Results were read-off the Figures and Tables in their paper.