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The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions ☆

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Abstract

We develop a New Keynesian model with search and matching frictions in the labor market. We show that the model generates counterfactual labor market dynamics. In particular, it fails to generate the negative correlation between vacancies and unemployment in the data, i.e., the Beveridge curve. Introducing real wage rigidity leads to a negative correlation, and increases the magnitude of labor market flows to more realistic values. However, inflation dynamics are only weakly affected by real wage rigidity. The reason is that labor market frictions give rise to long-run employment relationships. The measure of real marginal costs that is relevant for inflation in the Phillips curve contains a present value component that varies independently of the real wage.

JEL classification: E24; E32; J64

Keywords: Labor market; Real wage; Search and matching; New Keynesian model; Beveridge curve

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1. Introduction

It is widely recognized that the New Keynesian business cycle model cannot explain the dynamics of inflation and persistent effects of monetary shocks unless a sufficient degree of real marginal cost rigidity is present.[1] A potential source are rigid real wages. When firms set prices as a markup over marginal costs, the cyclicality of the real wage affects the dynamics of inflation. However, the standard New Keynesian model features a neoclassical labor market, which implies that the real wage is in fact strongly procyclical unless an implausibly high degree of individual labor supply elasticity is imposed. This suggests an important role of labor market imperfections in explaining the behavior of inflation. Of these, search and matching frictions along the lines of Mortensen and Pissarides (1994) figure prominently in current research.[2] This type of friction makes the search of workers and firms for a suitable match time consuming, which can serve as an internal propagation mechanism for business cycle shocks.

In this paper, we develop a New Keynesian model with sticky prices and employment adjustment in a frictional labor market with endogenous job destruction. We find that search and matching frictions per se do not improve the ability of the model to explain persistent effects of monetary shocks. Neither does the addition of a monetary side help explain labor market dynamics, such as the high volatility and the negative correlation of vacancies and unemployment. Fig. 1 shows the behavior of these variables in the U.S. over the period from 1951 to 2003.[3] The inverse relationship between vacancies and unemployment is referred to as the Beveridge curve. Moreover, both variables are several times more volatile than GDP (see Table 2). So is labor market tightness, as measured by the vacancy-unemployment ratio. It is these patterns that the baseline model fails to replicate.

Introducing real wage rigidity improves the behavior of the labor market, as the volatility of vacancies and unemployment is amplified and the Beveridge curve can be replicated. This confirms for the sticky price model the point made by Hall (2005) and Shimer (2005) in the context of real labor market models. However, we also show that real wage rigidity does not reduce the cyclicality of real marginal costs, and therefore cannot generally help explain persistent effects of monetary shocks. Real wage rigidity barely affects the dynamics of inflation, neither qualitatively nor quantitatively.

The explanation for this seemingly counterintuitive finding lies in the effect of real wage rigidity on the volatility of the costs of hiring and creating jobs. In the standard search and matching model, wages are perfectly flexible as they are set according to the Nash bargaining solution. Worker and firm share the surplus from their match; wages thus depend monotonically on the ratio of vacancies to unemployment. An increase in labor market tightness reduces the incentives for firms to post new vacancies because one component of costs, wages, rises. This keeps the overall response of vacancies and

[1]See, for example, Jeanne (1998), Galí and Gertler (1999) and Chari et al. (2000). The persistent effects of monetary shocks are documented in, amongst others, Rotemberg and Woodford (1997), Estrella and Fuhrer (2002), and Christiano et al. (2005).

[2]For early examples of real models including labor market frictions, see Merz (1995), Andolfatto (1996), and den Haan et al. (2000). An important aspect of the search and matching framework is that it gives rise to equilibrium unemployment, which is absent in the standard New Keynesian model.

[3]Unemployment and vacancy data are available from the website of the U.S. Bureau of Labor Statistics. Vacancies are constructed from the BLS index of help-wanted advertisements.

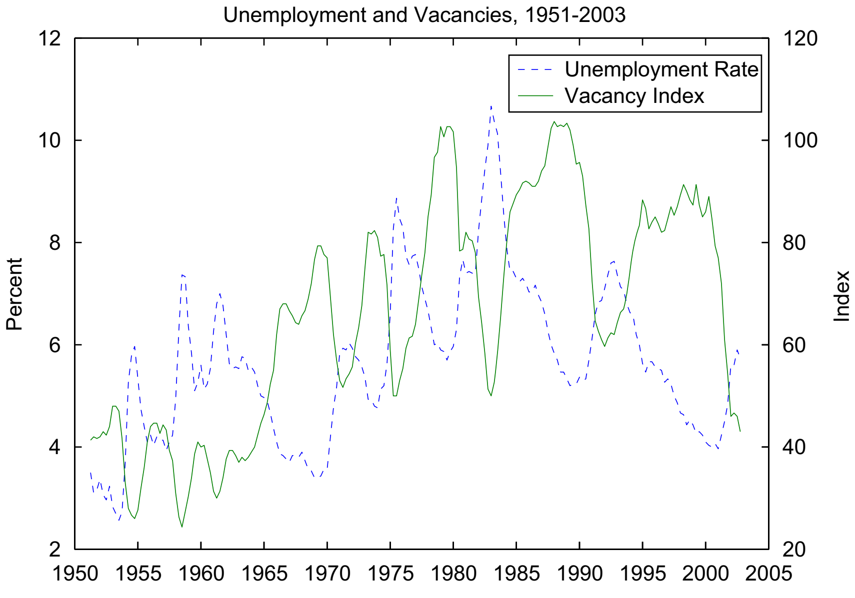

Fig. 1. The Beveridge curve.

unemployment muted. A rigid real wage, on the other hand, strongly increases the incentive to create jobs in a boom, since firms share less of the benefit with their workers. However, as vacancies rise and unemployment falls, there is a substantial increase in the cost of hiring workers which are a component of firms' real marginal costs. Thus, while one component becomes more rigid, the other becomes more volatile. For this reason, inflation dynamics are barely affected as the overall degree of real rigidity in the economy remains essentially unchanged.

Our model is largely standard in its description of product and labor markets with search frictions. A detail of interest is that we embed the price setting and employment adjustment decisions within a single, representative firm. This differs from the literature, which typically separates the economy into two sectors: a monopolistically competitive sector that produces differentiated goods; and an intermediate input sector that hires workers from the frictional labor market. Our unified approach makes the interaction between price setting and employment adjustment explicit. It also clarifies the nature of real marginal costs. They differ from the real wage because labor market frictions generate long-run attachments between workers and firms. The relevant marginal cost concept therefore includes the marginal contribution of a newly hired worker to the entire present value of the firm which need not move with the current real wage. Most importantly, even if real wages were entirely rigid, real marginal costs could vary substantially.[4] Therefore, using measures of labor costs such as the labor share can be a misleading shortcut in the estimation of the New Keynesian Phillips curve.

[4]Goodfriend and King (2001) discuss the role of long-run employment relationships in differentiating between real wages and 'effective' real marginal costs.

Two other recent papers incorporate search and matching frictions and endogenous job destruction into New Keynesian models. Walsh (2005) builds on den Haan et al. (2000) in his formulation of the labor market and focuses on how labor market frictions affect the response of the economy to monetary shocks. However, his macroeconomic structure features a cost channel of monetary policy transmission and habit formation which we abstract from to highlight the effects of real wage rigidity. Trigari (2004) follows Cooley and Quadrini (1999) in her description of the labor market, but focuses on the implications of labor market search for inflation and the ability to explain employment fluctuations at the intensive and extensive margins. Her model also differs from the baseline New Keynesian framework in that it assumes habit formation in consumption. Even though this improves the quantitative performance of the model, the precise role of frictions and real wage rigidity becomes difficult to assess.

The paper proceeds as follows. Section 2 develops the model, emphasizing the interaction between price setting and the frictional labor market. In Section 3, we describe the calibration of the model, while Section 4 reports and discusses the main findings of the baseline specification. In Section 5, we explore the role of real wage rigidity, while we show the robustness of the results to alternative calibrations in Section 6. Section 7 concludes.

2. The model

In this section, we present a New Keynesian business cycle model with labor market frictions.[5] Households maximize lifetime utility over consumption sequences of a CES aggregate of differentiated products and money holdings. Monopolistically competitive firms maximize profits by choosing prices and their workforce subject to price and employment adjustment costs. Separations of workers from firms are driven by job-specific productivity shocks. These shocks generate a flow of workers out of employment and into unemployment. At the same time, new workers are hired in a labor market subject to search frictions as represented by a matching function.

2.1. Households

Consider a discrete-time economy where households maximize lifetime utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \left[\frac{C_t^{1-\sigma} - 1}{1-\sigma} + \chi \log \frac{M_t}{P_t} \right], \tag{1}$$

choosing a consumption bundle C_t, nominal money holdings M_t, and bonds B_t subject to the budget constraint:

$$C_t + \frac{M_t}{P_t} + \frac{B_t}{P_t} = \mathscr{W}_t + \frac{M_{t-1}}{P_t} + R_{t-1}\frac{B_{t-1}}{P_t} + bu_t + \Pi_t + T_t. \tag{2}$$

$\mathscr{W}_t$ is labor income specified below, Π_t are aggregate profits, and T_t are transfers from the government. bu_t is income of unemployed household members u_t, which can be interpreted as total output of a home production sector with $b>0$. Bonds pay a gross interest rate R_t.

[5] The basic setup of the model follows Cooley and Quadrini (1999) and den Haan et al. (2000), who build on Mortensen and Pissarides (1994).

Labor is supplied inelastically, with the labor force normalized to one.[6] The composite consumption good is a CES aggregate of the differentiated products $C_t = \left(\int_0^1 C_{it}^{(\varepsilon-1)/\varepsilon}\,\mathrm{d}i\right)^{\varepsilon/(\varepsilon-1)}$, $\varepsilon > 1$, with price P_{it} for each good $i \in [0, 1]$, and the associated minimum expenditure price index $P_t = \left(\int_0^1 P_{it}^{1-\varepsilon}\,\mathrm{d}i\right)^{1/(1-\varepsilon)}$. This implies a demand function $C_{it} = (P_{it}/P_t)^{-\varepsilon} C_t$, which each monopolistically competitive firm faces when choosing the price of its differentiated product i. Intertemporal optimization by households implies the following first-order conditions:

$$C_t^{-\sigma} = \beta R_t E_t\left[\frac{P_t}{P_{t+1}} C_{t+1}^{-\sigma}\right], \tag{3}$$

$$\frac{M_t}{P_t} = \chi \frac{R_t}{R_t - 1} C_t^{\sigma}, \tag{4}$$

where the former is the consumption Euler equation that links present consumption with future consumption. The second condition is the standard money demand equation.

2.2. Firms and the labor market

Each differentiated good is produced by a monopolistically competitive firm using labor as the only input. There is a continuum of jobs within the firm, with each filled job j at firm i producing $A_t a_{ijt}$ units of output. Both jobs and firms are assumed to lie on the unit interval. Aggregate productivity A_t is common to all firms, while a specific job's productivity a_{ijt} is idiosyncratic. Every period, and before production commences, job-specific productivities are drawn from a time-invariant distribution with c.d.f. $F(a)$, with positive support and density $f(a)$.

Total output of firm i is determined by the measure n_{it} of jobs, aggregate productivity, and the aggregate over individual jobs:

$$y_{it} = A_t n_{it} \int_{\widetilde{a}_{it}}^{\infty} a \frac{f(a)}{1 - F(\widetilde{a}_{it})}\,\mathrm{d}a \equiv A_t n_{it} H(\widetilde{a}_{it}), \tag{5}$$

where we define $H(\widetilde{a}_{it})$ as the conditional expectation $\mathrm{E}[a \mid a \geqslant \widetilde{a}_{it}]$. $\widetilde{a}_{it}$ is an endogenously determined critical threshold below which jobs that draw $a_{ijt} < \widetilde{a}_{it}$ are not profitable. If this is the case, the job is destroyed, and the worker and the firm separate. This results in an endogenous job destruction rate $\rho_{it}^n = F(\widetilde{a}_{it})$. We also assume that there is a fraction ρ^x of jobs that are exogenously separated. Total separations at firm i are thus given by $\rho_{it} = \rho(\widetilde{a}_{it}) \equiv \rho^x + (1 - \rho^x)F(\widetilde{a}_{it})$.

Job creation, and thus hiring, is subject to matching frictions, determined by aggregate labor market conditions and a firm's recruitment effort. The aggregate flow of new matches in the next period is given by the matching function $m(u_t, v_t) = m u_t^{\mu} v_t^{1-\mu}$, $0 < \mu < 1$. It depends on the current period number of unemployed, i.e., searching workers u_t, and the total number of vacancies $v_t = \int_0^1 v_{it}\,\mathrm{d}i$, with v_{it} the number of vacancies posted by firm i. The probability of a vacancy being filled in the next period is $q(\theta_t) \equiv m(u_t, v_t)/v_t =$

[6]To avoid complications from heterogeneity, we follow Merz (1995) and Andolfatto (1996) in assuming a large number of members of families which perfectly insure each other against fluctuations in income. See also Nason and Slotsve (2004) for a more detailed treatment of this issue.

$m(u_t/v_t, 1)$, where $\theta_t = v_t/u_t$ is labor market tightness. For an individual firm, the inflow of new hires in $t+1$ is therefore $v_{it}q(\theta_t)$.

The inflow of new workers and the outflow of workers due to separations jointly determine the evolution of employment at firm i:

$$n_{it+1} = (1 - \rho_{it+1})(n_{it} + v_{it}q(\theta_t)). \tag{6}$$

There are two margins by which the firm can influence employment: the number of vacancies posted in the current period, and the fraction of jobs destroyed at the beginning of next period, determined by the threshold $\widetilde{a}_{it}$. Note that both new and old jobs are subject to idiosyncratic shocks.

The firm's optimization problem is to choose the price of its product, employment, the vacancy rate, and the job destruction threshold to maximize the present discounted value of real profits:

$$\Pi_{i0} = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left[\frac{P_{it}}{P_t} y_{it} - \mathscr{W}_{it} - cv_{it} - \frac{\psi}{2} \left(\frac{P_{it}}{P_{it-1}} - \pi \right)^2 Y_t \right], \tag{7}$$

subject to the demand function, the production function, and the employment evolution equation. The first and second terms in the profit function are, respectively, real revenues and the wage bill of the firm. If workers were paid identical wages, this would simply equal the wage times employment, $w_t n_{it}$. However, wages are not identical, but depend on the idiosyncratic productivities of the jobs. Therefore, the wage bill of firm i is given by the aggregate of individual wages:

$$\mathscr{W}_{it} = n_{it} \int_{\widetilde{a}_{it}}^{\infty} w_t(a) \frac{f(a)}{1 - F(\widetilde{a}_{it})} \, \mathrm{d}a. \tag{8}$$

The precise expression for the wage is derived below. The third term is the total cost of posted vacancies, with real cost per vacancy $c > 0$. Finally, price adjustment costs are assumed to be quadratic in the deviation of the firm's price change from steady-state inflation, with $\psi \geqslant 0$. The assumption of perfect capital markets implies that firms use the representative household's subjective discount factor.

The first-order necessary conditions are:

$$\partial n_{it} : \xi_t = \varphi_t A_t H(\widetilde{a}_t) - \frac{\partial \mathscr{W}_t}{\partial n_t} + E_t \beta_{t+1} (1 - \rho_{t+1}) \xi_{t+1}, \tag{9}$$

$$\partial v_{it} : \frac{c}{q(\theta_t)} = E_t \beta_{t+1} (1 - \rho_{t+1}) \xi_{t+1}, \tag{10}$$

$$\partial \widetilde{a}_{it} : \xi_t \frac{\partial \rho(\widetilde{a}_t)}{\partial \widetilde{a}_t} (n_{t-1} + v_{t-1} q(\theta_{t-1})) = \varphi_t A_t n_t \frac{\partial H(\widetilde{a}_t)}{\partial \widetilde{a}_t} - \frac{\partial \mathscr{W}_t}{\partial \widetilde{a}_t}, \tag{11}$$

$$\partial P_{it} : 1 - \psi(\pi_t - \pi)\pi_t + E_t \beta_{t+1} \left[\psi(\pi_{t+1} - \pi)\pi_{t+1} \frac{Y_{t+1}}{Y_t} \right] = \varepsilon(1 - \varphi_t), \tag{12}$$

where we define the stochastic discount factor $\beta_{t+1} = \beta(\lambda_{t+1}/\lambda_t)$. By symmetry, we drop subscripts i for individual firms. ξ_t and φ_t are the Lagrange multipliers on the employment and output constraints, respectively. The multiplier ξ_t gives the current period average value of workers across job-specific productivities a. The multiplier φ_t is the contribution of an additional unit of output to the firm's revenue and equal to the firm's real marginal cost. Note that firms take individual wages as given when choosing employment.

The second condition equalizes the cost of an open vacancy with the benefit of hiring a new worker. Substituting the second into the first condition yields a job creation condition which relates the cost of a vacancy (hiring cost c times the duration $1/q$) to its expected return:

$$\frac{c}{q(\theta_t)} = E_t\beta_{t+1}\left[(1-\rho_{t+1})\left(\varphi_{t+1}A_{t+1}H(\widetilde{a}_{t+1}) - \frac{\partial \mathscr{W}_{t+1}}{\partial n_{t+1}} + \frac{c}{q(\theta_{t+1})}\right)\right]. \tag{13}$$

When expected productivity rises, the right-hand side exceeds the left, so that firms have an incentive to post more vacancies. This increases v_t, and hence θ_t. With $q(\theta_t)$ decreasing in θ_t, the cost of a vacancy rises, until equality is restored.

The optimality condition for job destruction is such that the cost of shedding workers equals the benefit. Combining the first-order condition for the optimal threshold for a_t with the shadow value of employment ξ_t and the employment evolution equation yields as an intermediate step:

$$\left[\varphi_t A_t H(\widetilde{a}_t) - \frac{\partial \mathscr{W}_t}{\partial n_t} + \frac{c}{q(\theta_t)}\right]\frac{\partial\rho(\widetilde{a}_t)}{\partial\widetilde{a}_t}\,\frac{n_t}{1-\rho_t} = \varphi_t A_t n_t\,\frac{\partial H(\widetilde{a}_t)}{\partial\widetilde{a}_t} - \frac{\partial\mathscr{W}_t}{\partial\widetilde{a}_t}. \tag{14}$$

Intuitively, when job destruction increases due to a rise in $\widetilde{a}$, the firm loses current and expected profits it would have earned had it kept the laid-off workers; this is the left-hand side of the equation. At the same time, the firm benefits from job destruction, as unproductive jobs are removed and the distribution of productivities within the firm is improved. Further use of the derivatives of $H(\widetilde{a})$, $\rho(\widetilde{a})$, and the derivatives of the wage bill with respect to a and n gives

$$\varphi_t A_t\widetilde{a}_t - w_t(\widetilde{a}_t) + \frac{c}{q(\theta_t)} = 0. \tag{15}$$

This equation implicitly defines the critical threshold $\widetilde{a}_t$ below which jobs are destroyed. Once an expression for the wage is derived, the threshold can be solved for explicitly.

Finally, the fourth condition is standard for models with quadratic price adjustment. In its linearized form, it yields the New Keynesian Phillips curve.[7] It determines the dynamics of inflation as a function of real marginal cost φ. In steady state, when gross inflation is $\pi_t = \pi$, the condition collapses to $\varphi = (\varepsilon - 1)/\varepsilon$, the inverse of the markup.

2.3. Wage setting

The discussion so far has left the wage unspecified. In what follows, we derive a match-specific wage that depends on the idiosyncratic productivity of the job. The firm bargains with each worker individually; the bargaining solution then splits the surplus of their match in shares determined by an exogenous bargaining weight.[8] The joint surplus of a match over the firm's and the worker's outside options is $J_t + W_t - U_t$, where J_t is the marginal asset value of a filled job for the firm (or loss in case of a separation), W_t is the

[7]The dynamic properties of the linearized price setting equation are identical to those of the familiar price setting equation based on Calvo (1983). The only conceptual difference is that, here, all firms adjust their prices to some extent after a shock. In contrast, with the Calvo-assumption only a fraction of firms resets their price. It is the assumption of quadratic price adjustment, along with symmetry of firms, which makes it possible to integrate the price setting and employment decision of a representative firm.

[8]Like Cooley and Quadrini (1999), we assume surplus splitting, rather than Nash bargaining.

worker's asset value of being employed, and U_t is the asset value of being unemployed. The outside option for the firm is zero since without a worker the job has zero value. With $0<\eta<1$ being the share of the surplus going to the worker, the bargaining solution is given by $W(a_t) - U_t = (\eta/(1-\eta))J(a_t)$.

To derive expressions for the asset values, define the value of a job with idiosyncratic productivity draw a_t as $J_t(a_t) = \varphi_t A_t a_t - w_t(a_t) + c/q(\theta_t)$. Using the job creation condition (13), the equation for the asset value of a job can be written as

$$J_t(a_t) = \varphi_t A_t a_t - w_t(a_t) + E_t\beta_{t+1}\left[(1-\rho_{t+1})\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a)\,\frac{f(a)}{1-F(\widetilde{a}_{t+1})}\,\mathrm{d}a\right]. \tag{16}$$

The value of a job depends on real revenue minus the real wage, plus the discounted continuation value. With probability $1-\rho_{t+1}$, the job remains active and earns the expected value; the job is destroyed with probability ρ_{t+1} and thus has zero value. Correspondingly, the worker's asset value of being matched to a job with idiosyncratic productivity a_t is

$$\begin{aligned} W_t(a_t) = {} & w_t(a_t) + E_t\beta_{t+1}(1-\rho_{t+1})\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}(a)\,\frac{f(a)}{1-F(\widetilde{a}_{t+1})}\,\mathrm{d}a \\ & + E_t\beta_{t+1}\rho_{t+1}U_{t+1}, \end{aligned} \tag{17}$$

while the value of being unemployed is given by[9]

$$\begin{aligned} U_t = {} & b + E_t\beta_{t+1}\theta_t q(\theta_t)(1-\rho_{t+1})\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}\,\frac{f(a)}{1-F(\widetilde{a}_{t+1})}\,\mathrm{d}a \\ & + E_t\beta_{t+1}(1-\theta_t q(\theta_t)(1-\rho_{t+1}))U_{t+1}. \end{aligned} \tag{18}$$

An unemployed worker receives the value of home production b, the discounted continuation value and the option value of future employment (unless a successful match is destroyed before becoming productive).

Inserting the value functions in the bargaining rule yields the equation for the individual real wage:

$$w_t(a_t) = \eta(\varphi_t A_t a_t + c\theta_t) + (1-\eta)b. \tag{19}$$

The wage depends on aggregate conditions as well as firm-specific factors. It is increasing in labor market tightness, real marginal cost, aggregate and job-specific productivity. The aggregate real wage is the average of the individual wages paid, weighted according to the distribution of idiosyncratic productivities:

$$w_t = \int_{\tilde{a}_t}^{\infty} w_t(a)\frac{f(a)}{1-F(\widetilde{a}_t)}\,\mathrm{d}a = \eta\varphi_t A_t\int_{\tilde{a}_t}^{\infty} a\,\frac{f(a)}{1-F(\widetilde{a}_t)}\,\mathrm{d}a + \eta c\theta_t + (1-\eta)b. \tag{20}$$

Jobs are endogenously destroyed whenever $J(a)\leqslant 0$ (which is equivalent to $W(a)-U\leqslant 0$). Therefore, the critical value of a below which separation takes place is given by $J(\widetilde{a}_t)=0$. Using the individual real wage, the job destruction threshold from above can now be explicitly calculated as

$$\widetilde{a}_t = \frac{1}{\varphi_t A_t}\left[b + \frac{1}{1-\eta}\left(\eta c\theta_t - \frac{c}{q(\theta_t)}\right)\right]. \tag{21}$$

[9]Note that W is the asset value of being matched, not the wage bill $\mathcal{W}$.

The threshold is inversely related to the job's real marginal cost φ_t and aggregate productivity. Other things being equal, higher aggregate productivity or higher real marginal cost make production more profitable, thus allowing less productive matches to survive. The overall effect of labor market tightness is a priori ambiguous, as it depends on the relative magnitude of two effects. On the one hand, a higher θ_t increases the wage, and thus makes marginal jobs less productive. On the other hand, a tighter labor market increases hiring costs $c/q(\theta_t)$, which creates incentives to preserve matches in order to avoid costly rehiring.

2.4. The New Keynesian Phillips curve and labor market frictions

The presence of labor market frictions introduces a wedge between the real wage and the relevant real marginal cost that firms face, which in turn determine inflation dynamics. Consider the log-linearized version of the price-setting condition. Assuming zero net inflation in steady state, the New Keynesian Phillips curve is

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} + \kappa \widehat{\varphi}_t, \tag{22}$$

where $\kappa = (\varepsilon - 1)/\psi$.[10] The key difference between the Phillips curve in our model and in models with a neoclassical labor market is the behavior of the real marginal cost term. In a competitive labor market, φ_t is given by

$$\varphi_t = \frac{w_t}{A_t}. \tag{23}$$

That is, the real marginal cost of labor equals the real wage divided by marginal productivity.

In our model with search and matching frictions, we can rewrite the first-order condition for employment (9) to get

$$\varphi_t = \frac{\partial \mathscr{W}_t / \partial n_t}{A_t H(\widetilde{a}_t)} + \frac{\xi_t - c/q(\theta_t)}{A_t H(\widetilde{a}_t)}. \tag{24}$$

The first term on the right-hand side is the real marginal wage bill divided by the marginal product of labor. The second term arises from the presence of labor market frictions. It depends on the difference between the current value of the average worker ξ_t and the cost of posting a new vacancy. Recall that the latter term is equal to the expected discounted benefit of a worker producing in the next period. The cyclical behavior of this term can differ substantially from that of real wages in a frictional labor market. Note further that in steady state, $\xi > c/q(\theta)$. The fact that firms cannot instantaneously hire workers increases their marginal cost. To gain some intuition, suppose that ξ_t is constant, but productivity A_{t+1} is expected to rise. The job creation condition implies a higher $c/q(\theta_t)$, which reduces φ_t. As firms will want to raise employment next period, they anticipate the need to reduce prices. With quadratic price adjustment costs, there is an incentive to smooth these price cuts over time. Inflation would fall, even if the current marginal product and wage bill were constant.

[10] Recall that the parameter ψ stems from the quadratic adjustment cost function. In models where price setting is constrained following Calvo (1983), κ depends on the parameter that governs the frequency of price adjustment.

The expression for φ_t makes explicit the difference between the real wage and 'effective' real marginal cost that arises in the presence of frictions. Hiring frictions generate a surplus for existing matches which gives rise to long-term employment relationships. These, in turn, reduce the allocative role of current real wages. As a consequence, the effective real marginal cost can change even if the wage does not change, which has been stressed by Goodfriend and King (2001). Typically, attempts to estimate the New Keynesian Phillips curve use a proxy for (23), for example, the labor share.[11] However, this would no longer be appropriate in the presence of frictions. Further investigation of this issue is left to future research.

2.5. Closing the model

The final step is to find the aggregate quantities. The behavior of the labor market follows from symmetry in equilibrium, so that total employment evolves according to

$$n_{t+1} = (1 - \rho_{t+1})(n_t + v_t q(\theta_t)). \tag{25}$$

Note that searching workers u_t are equal to the currently unemployed $1 - n_t$. Gross job destruction in period t is equal to $\rho_t n_{t-1} - \rho^x n_{t-1}$. The second term is subtracted because it represents exogenous worker turnover, not gross destruction of employment opportunities. Gross job creation is $(1 - \rho_t)v_{t-1}q(\theta_{t-1}) - \rho^x n_{t-1}$, where, again, creation due to worker turnover is netted out. To obtain the corresponding rates, divide by n_{t-1}.

Aggregate income flowing to households is found by integrating over the outputs of all jobs:

$$Y_t = \mathscr{W}_t + \Pi_t = A_t n_t \int_{\tilde{a}_t}^{\infty} a \frac{f(a)}{1 - F(\tilde{a}_t)} \, \mathrm{d}a, \tag{26}$$

where the costs of vacancy posting are assumed to be distributed to the aggregate household. All output is consumed in equilibrium so that $C_t = Y_t$.

The government budget constraint is given by

$$\frac{M_t - M_{t-1}}{P_t} + \frac{B_t}{P_t} - \frac{R_{t-1}B_{t-1}}{P_t} + T_t = 0, \tag{27}$$

so that any seigniorage revenue is rebated to the household. We assume that monetary policy follows a simple money growth rule:

$$\ln(M_t/M_{t-1}) = \rho_m \ln(M_{t-1}/M_{t-2}) + \varepsilon_{m,t}, \tag{28}$$

where $0 < \rho_m < 1$, and $\varepsilon_{m,t} \sim N(0, \sigma_m^2)$.[12]

[11] Examples include Galí and Gertler (1999) and Sbordone (2002). An alternative promising avenue is to include measures of hiring costs or of the asset values of workers. See Merz and Yashiv (2004) for an attempt to estimate hiring and investment costs from the asset value of firms.

[12] Alternatively, we could have modeled the money supply process by using an interest-rate rule as in Trigari (2004) and Walsh (2005). Since equilibrium money balances and the nominal rate are linked via the money demand Eq. (4), these two approaches are conceptually virtually identical. Our focus, however, is on labor market dynamics over the post-war period during which the conduct of monetary policy changed several times. Moreover, calibrating the shock process in the interest rate rule is not straightforward due to identification problems. For these reasons we introduce monetary shocks as money growth innovations.

Table 1
Calibration

Parameter	Value	Parameter	Value
ε	11	$\overline{\rho}$	0.10
ψ	40	$\overline{q}$	0.7
σ	2	$\overline{u}$	0.12
β	0.99	μ_{LN}	0
η	0.5	σ_{LN}	0.12
μ	0.4	ρ_m	0.49
ρ^x	0.068	σ_m	0.0623
π	1	ρ_A	0.95
		σ_A	0.0049

3. Model solution and calibration

We log-linearize the equation system describing the model dynamics around its steady state. The resulting linear rational expectations model is solved using the method described in Sims (2002). We now describe our benchmark calibration, which is summarized in Table 1.

We set the steady-state separation rate $\overline{\rho} = 0.10$. This is based on evidence provided by Hall (1995) and Davis et al. (1996) for the U.S. quarterly worker separation rate. This number is at the midpoint of values used in the literature, which range from 0.07 (Merz, 1995) to 0.15 (Andolfatto, 1996). Following the argument in den Haan et al. (2000), we choose an exogenous job destruction rate of $\rho^x = 0.068$. Consequently, the endogenous separation rate can be computed as $\rho^n = (\rho - \rho^x)/(1 - \rho^x) = 0.034$. The implied steady-state threshold for idiosyncratic productivity is $\widetilde{a} = F^{-1}(\rho^n)$. We assume that idiosyncratic productivity a_t is i.i.d. lognormally distributed with c.d.f. $F(\cdot)$. In order to calibrate the parameters μ_{LN} and σ_{LN} of the lognormal distribution, we normalize $\mu_{\mathrm{LN}} = \mathrm{E}[\ln a] = 0$. We choose σ_{LN} to replicate the observed volatility of the job destruction rate. Cooley and Quadrini (1999) report that job destruction in U.S. data is almost seven times as volatile as employment. We thus find $\sigma_{\mathrm{LN}} = 0.12$. This is consistent with the values in den Haan et al. (2000) and Walsh (2005) who use 0.10 and 0.13, respectively.

The unemployment rate is set to $\overline{u} = 0.12$. This is higher than observed unemployment in order to allow for potential participants in the matching market such as discouraged workers and workers loosely attached to the labor force.[13] As in den Haan et al. (2000) we impose a steady-state firm matching rate of $\overline{q} = 0.7$. For the matching function $m(u_t, v_t) = m u_t^{\mu} v_t^{1-\mu}$, the match elasticity μ is calibrated at 0.4 based on the empirical estimates in Blanchard and Diamond (1989). The level parameter m is computed using the observation that the steady-state number of matches is $\rho/(1-\rho)(1-u)$. In the absence of direct evidence on the worker's share parameter η we follow the literature and set $\eta = 0.5$. The vacancy posting cost c and the outside option of the worker b are then computed, respectively, from the steady-state job creation and job destruction conditions.

[13] A similar assumption is, for example, made by Cole and Rogerson (1999), based on the evidence in Blanchard and Diamond (1989). Many papers with search and matching in business cycle models feature vastly higher unemployment rates. Examples are Andolfatto (1996) with $\overline{u} = 0.58$, and Trigari (2004) with $\overline{u} = 0.25$.

The parameters describing the household are standard. We choose a coefficient of relative risk aversion $\sigma = 2$; the discount factor at a time period of one quarter is $\beta = 0.99$. The elasticity parameter in the consumption aggregator is $\varepsilon = 11$, which implies a steady-state mark-up of 10%. We pick a value for the price adjustment cost parameter ψ based on following considerations. The linearized Phillips curve is observationally equivalent to the one derived under Calvo type contracts of random duration. Assuming an average contract length of four quarters as in Taylor (1999), we could choose ψ such that the Phillips curve coefficient $\kappa = (\varepsilon - 1)/\psi$ is equal to the one under Calvo-pricing. This implies $\psi = 105$. Alternatively, structural estimates of New Keynesian models find values of the coefficient κ around 0.5 (Lubik and Schorfheide, 2004), implying $\psi = 20$. We choose an intermediate value that allows us to reasonably match the behavior of inflation. We thus set our baseline stickiness parameter at $\psi = 40$. Steady state inflation is assumed to be $\pi = 1$.

Finally, we need to calibrate the shock processes. The logarithm of the money growth rate follows an AR(1) process. We use the same values as reported in Cooley and Quadrini (1999) and set $\rho_m = 0.49$ and the standard deviation of the innovation $\sigma_m = 0.0623$. The (logarithm of the) aggregate productivity shock is assumed to follow an AR(1) process with coefficient $\rho_A = 0.95$. As is common in the literature we choose an innovation variance such that the baseline model's predictions match the standard deviation of U.S. GDP, which is 1.62%. While this is not a robust procedure, it is not essential for our approach since we do not evaluate the model along this dimension. The standard deviation of technology is consequently set to $\sigma_A = 0.0049$.

4. Baseline results

This section presents the main findings of our baseline model with flexible real wages. First, we discuss impulse responses for monetary and technology shocks. Then, business cycle statistics from the data are compared with the corresponding statistics from the simulated model. The consequences of rigid real wages and robustness issues are discussed in subsequent sections. The behavior of the baseline model in response to money and technology shocks documents two results: first, the model with search frictions is not able to capture the dynamics of the labor market correctly, and second, these frictions do not add much in terms of persistence of the effects of monetary shocks.

Consider first the effects of a one percent increase in money growth. The impulse response functions of selected variables are depicted in Fig. 2. Panel (a) shows that output rises in line with inflation. As firms increase production to meet aggregate demand, the labor market tightens which puts pressure on real marginal costs. In a competitive labor market this would be solely due to a rise in real wages. In the frictional labor market, real marginal costs partly rise because real wages respond to the higher labor market tightness. But almost as much of the rise follows from more costly hiring and job creation. This can be seen in panel (b) which shows a jump in real marginal costs more than twice as large than that of real wages.

However, the increase in labor market tightness is not due to more vacancies posted and unemployment falling; it arises from vacancies falling by less than unemployment. This finding clearly contradicts the facts. It is caused by a strong drop in separations reflected in the behavior of job destruction in panel (c). As firms can instantaneously adjust the separation margin (see Eq. (21)), they increase employment by keeping more workers, even

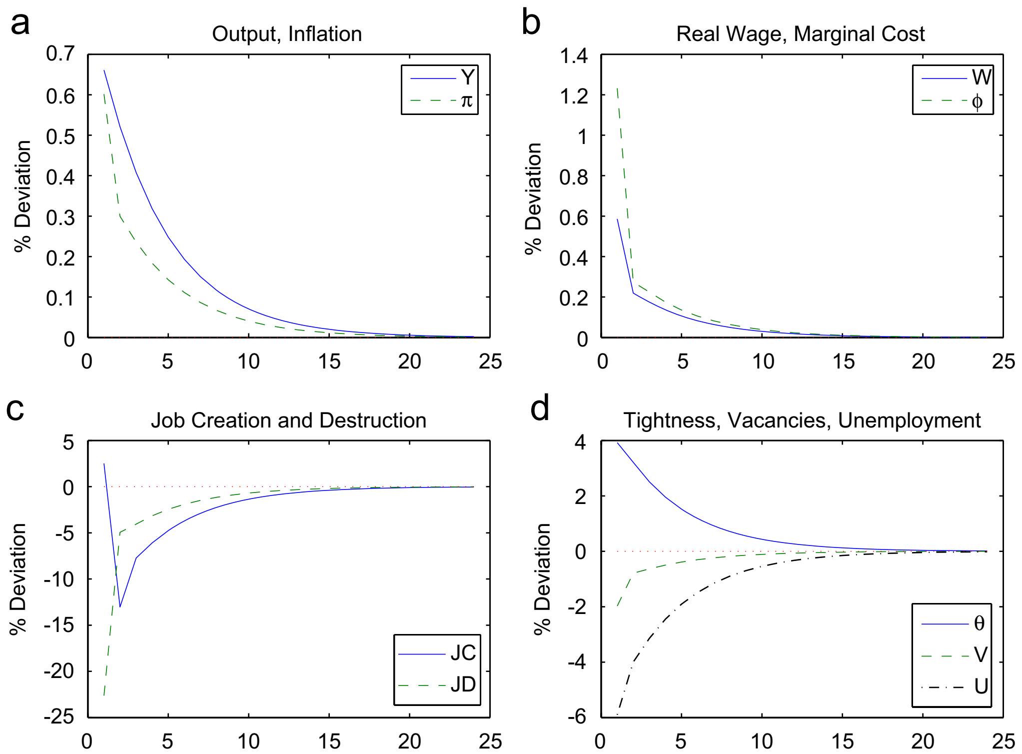

Fig. 2. Impulse responses to a money growth shock: baseline model.

less productive ones, rather than waiting for new workers to arrive from the matching market. The concomitant fall in unemployment reduces the likelihood of filling a vacancies, which consequently decline in line with job creation as seen in panels (c) and (d). The business cycle statistics in Table 2 (column 3) confirm these results. The correlation between vacancies and unemployment is almost one. There is no Beveridge curve. The same is true for the correlation between job creation and job destruction rates. The volatility of labor market tightness is far lower than in the data, and lower than that of unemployment.

The model's response to a technology shock is depicted in Fig. 3. Inflation declines, output rises on impact followed by a pronounced hump-shaped adjustment path. Even though the real wage increases, higher productivity leads to a strong reduction in real marginal costs. The labor market responds in a similar manner as before. Tightness rises, but this time, vacancies actually increase as the likelihood of finding workers drops less sharply than after a monetary shock. Therefore, unemployment falls only slowly. This is mirrored by the weaker fall in job destruction and a job creation rate that is higher than job destruction up until the sixth quarter. Only then does unemployment start to rise again. However, as the business cycle statistics show, a Beveridge curve still does not obtain after a technology shock. The long period over which vacancies are below steady state outweighs the initial negative comovement with unemployment. Similarly, the overall correlation between job creation and destruction remains positive, in contrast to the data.

Table 2
Business cycle properties of U.S. economy and model economy

	U.S.	Baseline model			Rigid wage model		
	economy	M & R	Money	Real	M & R	Money	Real
Standard deviations							
Output	1.62	1.80	0.65	1.62	4.33	1.00	4.30
Inflation	1.11	0.43	0.73	0.38	0.25	0.33	0.24
Real wage	0.69	0.36	0.65	0.30	–	–	–
Unemployment	6.90	4.98	8.20	4.36	6.73	8.06	6.66
Vacancies	8.27	1.46	2.23	1.34	1.57	0.62	1.59
Tightness	14.96	4.47	6.07	4.19	7.85	8.11	7.84
JCR	2.55	9.44	17.17	7.87	8.78	12.78	8.51
JDR	3.73	11.02	22.94	8.00	8.98	17.86	8.19
Correlations							
U, V	−0.95	0.48	0.97	0.28	−0.63	−0.04	−0.66
JCR, JDR	−0.36	0.34	0.18	0.49	0.76	0.28	0.88
Y, inflation	0.39	0.12	0.97	−0.11	−0.03	0.90	−0.09
Autocorrelation							
Output	0.87	0.95	0.78	0.98	0.98	0.89	0.99
Inflation	0.56	0.61	0.60	0.60	0.73	0.56	0.77

Notes: Statistics for the U.S. economy are computed using quarterly HP-filtered data from 1964:1 to 2002:3. Statistics for the model economies are computed by simulating the model 100 times for 200 periods. The statistics are averages over the HP-filtered simulations. The standard deviations of all variables are relative to output.

Simulation of the model with both money and technology shocks shows the same general patterns. The behavior is dominated by technology shocks, which generate a standard deviation of output that is about three times as large as that caused by money shocks. Thus, even though money shocks generate a negative correlation of output and inflation, in the overall simulation it is positive. We can also see clearly that the model fails along the labor market dimensions: labor market tightness is much less volatile than in the data, and vacancies and unemployment are positively correlated.

The simulations also reveal a lack of endogenous persistence that is characteristic of the standard New Keynesian framework. Since the internal propagation mechanism is weak, persistence of the technology shock carries over to the model's endogenous variables. Inflation persistence as measured by the first-order autocorrelation coefficient is in line with the evidence, but is generated almost entirely by the autocorrelation in the exogenous shocks. The impulse responses to money shocks, in fact, are similar to those in the New Keynesian model with competitive labor markets (for example, Galí, 2003).

We can draw the following conclusions at this point. The standard New Keynesian model with labor market frictions and endogenous job destruction can explain neither salient labor market facts nor the dynamics of inflation. Contrary to what might have been expected, search and matching frictions do not introduce sufficient real rigidity to add to the model's internal propagation mechanism. One factor is the role of job destruction as the endogenous margin of employment adjustment, which removes much of the

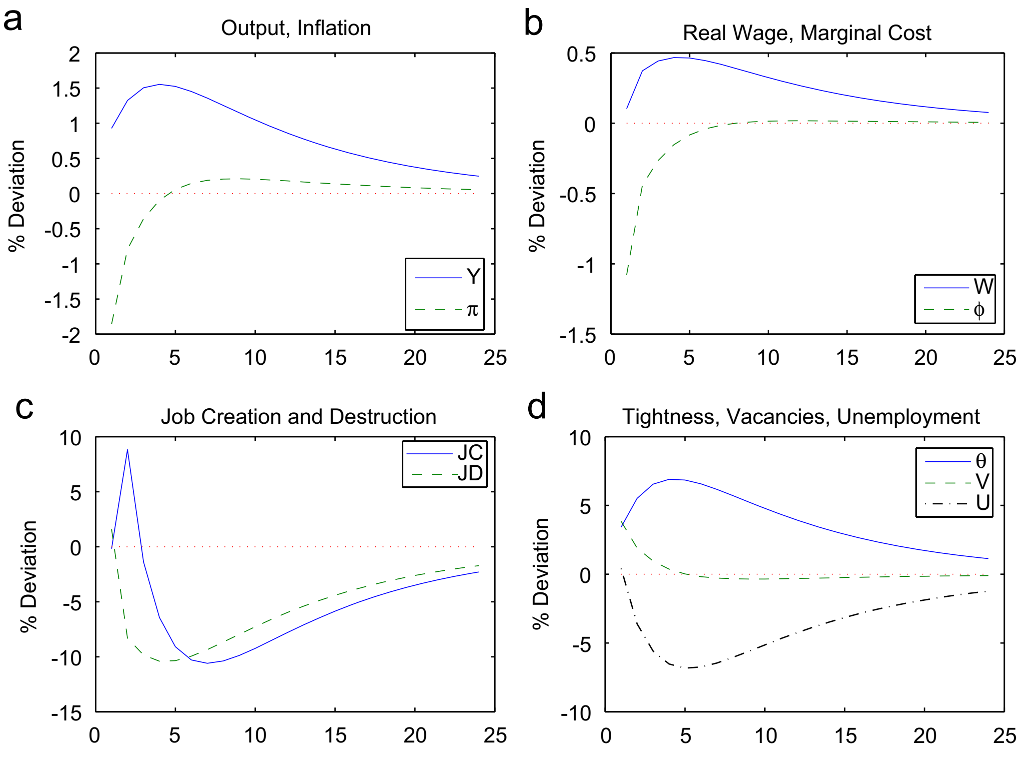

Fig. 3. Impulse responses to a productivity shock: baseline model.

sluggishness arising from matching frictions. The need for an additional source of real rigidity remains.

5. Real wage rigidity

Real wage rigidity has been seen as a central source of real rigidity at least since Ball and Romer (1990). In the simplest, static version of the New Keynesian sticky price model, prices are set as a mark-up over real wages. Without sticky wages, only a substantial and implausible degree of nominal price rigidity can suppress the strong incentives to adjust prices after monetary shocks. This intuition carries over to full-fledged dynamic models, as Jeanne (1998) and Chari et al. (2000) have demonstrated.

Furthermore, Hall (2005) and Shimer (2005) have argued that real wage rigidity is central to explaining the cyclical behavior of unemployment and vacancies. In a search and matching model, wages are typically set according to the Nash bargaining solution. This results in a wage that is proportional to labor market tightness and therefore excessively volatile. As a consequence, wage increases depress vacancy creation during a cyclical upswing, and unemployment does not fall by enough. Excessively high volatility of productivity shocks could in principle generate an empirically consistent amount of vacancy creation. However, real wage rigidity has the virtue of keeping incentives for vacancy creation high, thereby amplifying the response of the labor market to productivity shocks of plausible magnitudes.

5.1. Introducing real wage rigidity

We employ a version of Hall's (2005) notion of a wage norm to introduce real wage rigidity. A wage norm may arise from social convention that constrains wage adjustment for existing and newly hired workers. A straightforward way to model this is to assume that the real wage paid in job i is the weighted average of a notional wage w^n and a wage norm $\overline{w}$: $w_{it} = \gamma w_{it}^n + (1-\gamma)\overline{w}_t$, with $0 \leqslant \gamma \leqslant 1$. We assume that the notional wage is equal to the bargaining solution of our baseline model, whereas the wage norm is set independently of idiosyncratic conditions. Naturally, this form of wage determination is ad hoc; but it can be thought of as a reduced-form representation of a more elaborate bargaining setup.

Introduction of such a wage rule modifies the model as follows. The individual real wage, as a function of idiosyncratic productivity, is written as

$$w_t(a_t) = \gamma[\eta(\varphi_t A_t a_t + c\theta_t) + (1-\eta)b] + (1-\gamma)\overline{w}_t. \tag{29}$$

The separation condition can be calculated in the same way as before:

$$\widetilde{a}_t = \frac{1}{\varphi_t A_t}\left[\frac{\gamma(1-\eta)}{1-\gamma\eta} b + \frac{\gamma\eta c}{1-\gamma\eta}\,\theta_t + \frac{1-\gamma}{1-\gamma\eta}\overline{w}_t - \frac{c}{q(\theta_t)}\right]. \tag{30}$$

If $\gamma = 1$, the equation reduces to the condition without wage norm. In the other extreme, $\gamma = 0$, we have

$$\widetilde{a}_t = \frac{1}{\varphi_t A_t}\left[\overline{w}_t - \frac{c}{q(\theta_t)}\right]. \tag{31}$$

In this case, the separation threshold changes only with aggregate factors, namely marginal cost, aggregate productivity, labor market tightness, or movements in the wage norm.

To develop some intuition on the effects of wage rigidity, suppose that $\overline{w}_t = w, \forall t$, where w is simply the wage in the steady state of the baseline model. As before, higher A_t and φ_t lead to a lower threshold. θ_t now has an unambiguously negative effect on the threshold, as it represents the value of opening a vacancy. An increase thus indicates that matches have a higher value in the future by virtue of the job creation condition (13). Thus, less productive matches are worth preserving, and the threshold falls. If $\gamma > 0$, these effects are muted. More tightness in the labor market improves workers' outside options and therefore increases the real wage. This has a countervailing effect on $\widetilde{a}$, as workers share some of the benefits of improved aggregate conditions. Wage rigidity leads to more jobs surviving, while in a recession more jobs are destroyed than would be under flexible wages.[14] Since the wage norm shuts down the effect of labor market tightness on the wage, the job destruction threshold is likely to become more volatile and to comove more strongly with job creation.

[14]Note that separations may be inefficient. Wage flexibility would allow workers in jobs with low productivity to stay employed by accepting wage cuts, as long as there is joint match value to be preserved, and vice versa for firms. Therefore, even though the total surplus of a match is positive it may be that in booms: $\mathcal{W} - U < 0$ and $J > 0$, while in recessions $J < 0$ and $\mathcal{W} - U > 0$. Hall (2005) provides further discussion of this point.

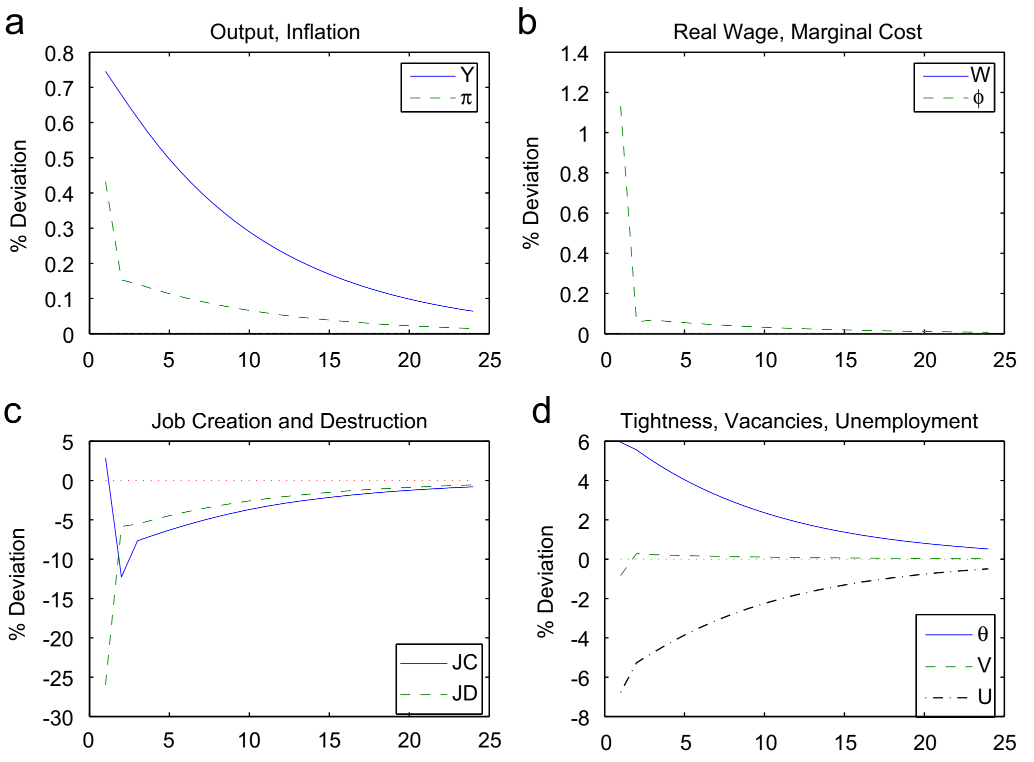

Fig. 4. Impulse responses to a money growth shock: rigid wage model.

5.2. Results

The effects of real wage rigidity on labor market variables and inflation dynamics can be most clearly demonstrated by shutting down the wage adjustment entirely, i.e. by setting $\gamma = 0$ and $\overline{w}_t = w$. The impulse response functions to monetary and technology shocks are depicted in Figs. 4 and 5, respectively. The results are striking. Despite perfectly rigid wages, real marginal costs change due to the amplified response of labor market tightness. In fact, marginal costs change by virtually the same amount as under flexible wages. This generates inflation dynamics which are very close to the baseline specification. Wage rigidity has therefore no impact on inflation dynamics as the other marginal cost component compensates by becoming more volatile.

The joint behavior of unemployment and vacancies, however, changes noticeably. Money and technology shocks both generate opposite movements in unemployment and vacancies over the adjustment path, although the impact behavior differs. Why does this happen? Under perfect wage rigidity workers receive a constant wage irrespective of economic conditions. This raises the surpluses for firms which would otherwise have accrued to workers under surplus sharing, stimulating vacancy creation. This is evident from comparing panels (c) of Figs. 4 and 5 with the corresponding panels in the baseline case. The increase in job creation is just strong enough to lead to above steady-state

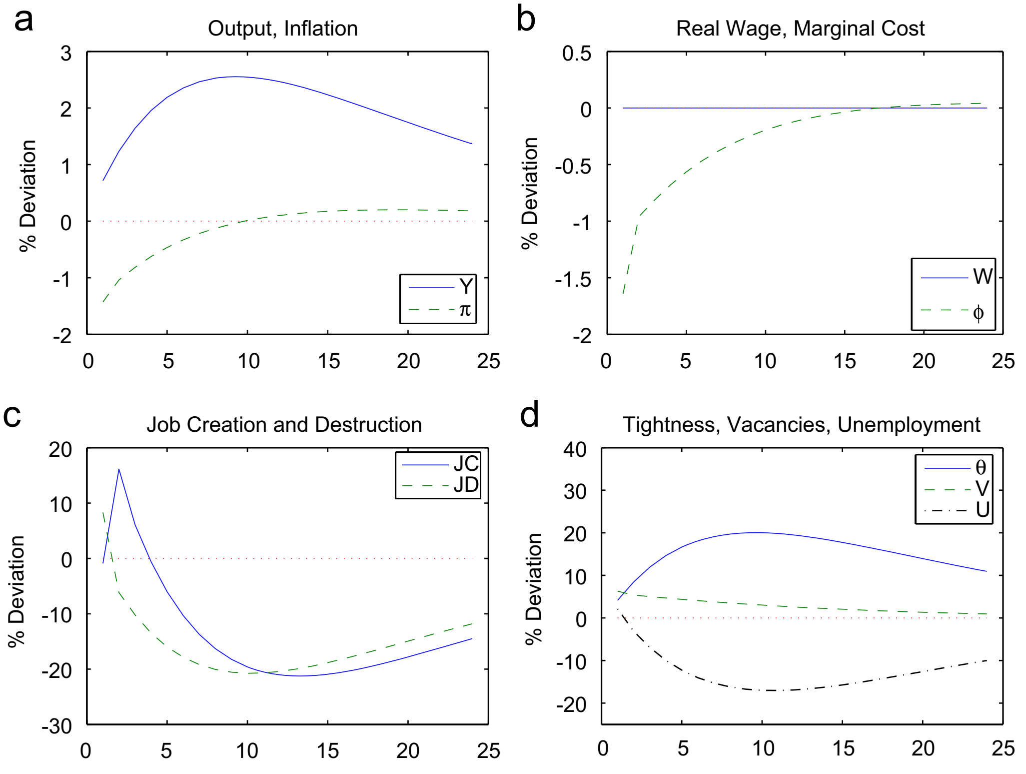

Fig. 5. Impulse responses to a productivity shock: rigid wage model.

adjustment of vacancies in the case of monetary shocks and more persistent adjustment in the case of productivity shocks. Note, however, that while this level effect results in a Beveridge curve, the volatility of job creation does not change substantially: it is still much higher than that found in the data. As in the baseline specification, the sticky wage model cannot replicate the observed patterns of job creation and job destruction. In all simulations their correlation is positive. As before, firms mainly adjust via their job destruction margin since it is less costly even compared to the higher return from job creation.

Depending on the degree of wage flexibility γ, the real wage responds to both idiosyncratic and aggregate labor market conditions. By varying γ we found that a fairly high degree of rigidity is needed to replicate the Beveridge curve, whereas the model requires a high degree of flexibility ($\gamma \to 1$) to explain the relative standard deviation of the real wage in the data of 0.69. Intermediate levels of rigidity are inconsistent with both the Beveridge curve, wage volatility, and the negative comovement of job creation and destruction.[15]

[15]Incidentally, the form of wage rigidity suggested by Jeanne (1998) delivers the same predictions as our wage rule. He assumes that the real wage is exogenously determined by aggregate conditions alone and independent of match-specific outcomes. We find that his specification produces the same results as our rigid wage model when γ is small.

We also consider a wage norm that equals last period's average wage $\overline{w}_t = w_{t-1}$. In this case, the wage is not just driven by current aggregate conditions, but exhibits dynamics of its own. When $\gamma = 0$, i.e. fully backward-looking wage-setting, the simulation results are similar to the model with a fully rigid wage. Firms cannot adjust wages contemporaneously to shocks. Since they anticipate wage increases in the future, the present value of a job rises. Firms take advantage of this by increasing employment, the separation rate falls, as does job destruction. As before, unemployment and vacancies move in the opposite direction, and the Beveridge curve obtains ($corr(u_t, v_t) = -0.68$). The crucial shortcoming of this specification is again the lack of negative correlation between job creation and destruction. The reason is that firms almost exclusively adjust via the endogenous separation rate, while job creation does not play a quantitatively significant role. Moreover, no degree of wage rigidity brings the model closer to the positive correlation between output and inflation.

We have shown in this section that the Shimer–Hall argument that real wage rigidity is important for the dynamics of the labor market carries over to a sticky-price model. Rigid wages allow firms to keep most of the increasing match surplus in a cyclical upswing. This stimulates vacancy creation and leads to the negative comovement with unemployment. However, this necessitates strongly positive comovement in job creation and destruction which is inconsistent with the empirical evidence. At the same time, the model's inflation dynamics are not much affected by real wage rigidity. There is virtually a disconnect between real wages and inflation dynamics, with sluggishness in the former being unable to explain persistence in the latter. In fact, as real wages become more rigid, labor market tightness, and with it the costs of creating jobs, becomes more cyclical.

6. Robustness issues

Calibrating a search and matching model is problematic as independent information on many parameters is hard to obtain. Indirect evidence is often derived from conflicting sources. Consequently, the literature abounds with a wide variation in parameterizations.[16] We therefore check the robustness of our results with respect to a few key parameters. Selected results are reported in Table 3.

A crucial parameter in the calibration is the unemployment rate. As discussed, we set $\overline{u} = 0.12$ following the reasoning by Cole and Rogerson (1999) and others, that the pool of effective searchers is larger than the measured unemployment rate. This, however, works against us in that it reduces the volatility of vacancies, unemployment, and labor market tightness induced by real wage rigidity. For instance, Hall (2005) obtains his results for an unemployment rate of $\overline{u} = 0.06$ which strongly amplifies the dynamics of the labor market in response to shocks. Using this value we obtain a standard deviation of 16.01 in the rigid wage case ($\gamma = 0$). We choose the more conservative calibration, in line with den Haan et al. (2000). All of our qualitative conclusions are unaffected by this choice.

It is standard to set the worker's share η to 0.5. Decreasing this parameter increases the volatility of unemployment which has been noted before by Cooley and Quadrini (1999). The model dynamics are largely unaffected with the exception of the real wage. For small enough η the real wage actually falls and remains negative for both types of expansionary

[16]An exception is Trigari (2004) who estimates the labor market parameters by impulse response function matching. However, she only considers responses to monetary policy shocks and calibrates many of the other structural parameters. Interestingly, she finds that the bargaining share is small, but very imprecisely estimated.

Table 3
Robustness and alternative calibrations

	$corr(u_t, v_t)$	$corr(jcr_t, jdr_t)$
Lagged wage norm: $\gamma = 0$	−0.68	0.34
Low worker's share: $\eta = 0.01$	0.74	0.94
Low match elasticity: $\mu = 0.1$	−0.20	−0.23
Exogenous job destruction: $\rho^x = 0.1$	−0.45	0.12

shocks. This pattern is, however, inconsistent with the observed comovement in the data. Noticeably, job destruction responses are muted for small η. When workers' bargaining power is small, each matched worker–job pair is more valuable to a firm which reduces the incentive to destroy existing matches. This effect is not strong enough to lead to negative comovement in job creation and destruction, nor to a Beveridge curve. Alternative choices of the bargaining share do not affect our conclusions.

The labor market aspects of our model are improved when we allow for a low match elasticity μ. For $\mu = 0.1$ we obtain $corr(u_t, v_t) = -0.20$ and $corr(jcr_t, jdr_t) = -0.23$. This is due to a more persistent response of job creation. Contrary to the baseline specification job creation remains positive for a longer time which results in prolonged vacancy postings. Under a less elastic response of the probability of filling a vacancy $q(\theta) = m\theta^{-\mu}$ firms react by posting more job openings. However, this finding has to be seen in the context of substantial empirical evidence that the match elasticity μ is around 0.4 (see Petrongolo and Pissarides, 2001).[17] We regard this an open issue subject to further research. However, our key result still goes through as marginal cost dynamics are unaffected by changes in η or μ.

We also highlight the dependence of the Beveridge relationship on the assumption of exogenous job destruction. As the separation rate ρ^x moves closer from its benchmark value 0.068 to the (calibrated) steady-state separation rate $\rho = 0.1$, the Beveridge-curve obtains. For instance, $\rho_x = 0.10$ results in $corr(u_t, v_t) = -0.41$. If additionally η declines, the correlation falls further, but does not reach the observed value of −0.95. However, exogenous job destruction does not resolve the counterfactual finding that job creation and destruction comove positively. Our model with endogenous job destruction proves to have counterfactual implications as long as it is less costly for firms to adjust employment along this margin.[18]

7. Conclusion

In a baseline New Keynesian model, labor market frictions render real wage rigidity potentially irrelevant for the dynamics of inflation. The reason is the importance of wage

[17] Cooley and Quadrini (1999) use a low μ to suppress the responsiveness of the match probability to falling unemployment. They see this as key to the inability of the model to account for the joint behavior of job creation and destruction. A similar mechanism is also at play in Trigari (2004) who obtains a very large unemployment rate in her estimation. This keeps the worker finding rate for firms relatively stable, and thus keeps the incentives for vacancy creation high.

[18] When we additionally allow for an exogenous wage rule and vary the flexibility parameter γ, we can in principle match the Beveridge curve for a proper choice of η. However, we need a fairly high degree of rigidity in combination with a large share parameter. Wage rigidity and the bargaining power of workers are thus important factors in deriving a Beveridge curve, even with endogenous job destruction.

rigidity for the dynamics of the labor market. A rigid real wage generates a Beveridge curve and cyclicality of vacancies and unemployment that is consistent with the data. But the resulting volatility of labor market tightness affects real marginal costs and thus inflation dynamics through the New Keynesian Phillips curve. As one component of real marginal costs, wages, becomes less volatile, the other component, hiring and job creation costs, becomes more volatile. The mechanism emphasized by Hall (2005) and Shimer (2005) that helps the search and matching model fit the facts, appears to have a neutralizing effect in sticky price models.

One of the insights of this paper is that in the presence of labor market frictions the relevant measure of marginal cost is explicitly *dynamic*. It represents the marginal contribution of an additional unit of labor to the present discounted value of profits which is distinctly different from current real wages. This suggests that empirical studies of the Phillips curve that use simple marginal cost measures or the labor share are misspecified. An alternative approach would either use system-based methods along the lines of Lubik and Schorfheide (2004), or use direct measures of workers' and firms' match asset values as suggested by Merz and Yashiv (2004). A second research direction should attempt to derive wage rigidity endogenously. A step in this direction is Krause and Lubik (2004) who introduce on-the-job search in an otherwise standard business cycle model with search and matching features. They show that this results in much less volatile wages compared to the standard model since the relevant measure of labor market tightness includes employed searchers as well as the unemployed. Other things being equal, on-the-job search increases competition for open vacancies to the effect that wages are kept lower and less volatile as the outside option of each worker declines.

While wage rigidity does help generate a Beveridge curve, a shortcoming remains. Job creation and destruction in our model are positively correlated. This is due to the excess sensitivity of job destruction to desired changes in employment. There are two factors at work. One is that job destruction is costless, while job creation is not. The other is that vacancy creation only leads to an inflow of new workers one period hence, while job destruction is instantaneous. This suggests introducing a mechanism that makes job destruction a costly margin relative to job creation, either directly in terms of firing costs, or indirectly via some form of heterogeneity. As an example for the latter, new and old jobs could be different, in which case it is beneficial to increase employment by hiring new workers on new jobs, rather than preserving more of the unproductive, old jobs. Introducing heterogeneity potentially generates more sluggish employment adjustment and hence contributes to the persistence of output and inflation. We leave this to future research.

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