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ABSTRACT

The Role of Real Wage Rigidity and Labor Market Frictions for Unemployment and Inflation Dynamics*

In this paper we incorporate a labor market with matching frictions and wage rigidities into the New Keynesian business cycle model. In particular, we analyze the effect of a monetary policy shock and investigate how labor market frictions affect the transmission process of monetary policy. The model allows real wage rigidities to interact with adjustments in employment and hours affecting inflation dynamics via marginal costs. We find that the response of unemployment and inflation to an interest rate innovation depends on the degree of wage rigidity. Generally, more rigid wages translate into more persistent movements of aggregate inflation. Moreover, the impact of a monetary policy shock on unemployment and inflation depends also on labor market fundamentals such as bargaining power and the flows in and out of employment.

JEL Classification: E52, J64, E32, E31

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1 Introduction

Europe's labor markets are rigid in many respects. High firing costs, generous unemployment benefits and strong unions are perceived to contribute to sluggish labor market adjustments. Moreover, the collective wage bargaining process is seen to prevent wages from adjusting instantaneously, introducing a substantial degree of wage rigidity. Therefore, rigidities and frictions in the labor market might be crucial for understanding sluggishness in firms' marginal cost and their price setting behavior.

In this paper, we stress the role of the labor market in determining firms' marginal cost and link labor market adjustments directly to the dynamics of inflation. For that reason, we introduce a Mortensen and Pissarides (1994) labor market model with matching frictions into the New Keynesian business cycle framework, see also Walsh (2003) and Trigari (2003). We particularly extend the Trigari (2003) model with right-to-manage wage bargaining to incorporate a real wage rigidity in form of a Hall (2005) type wage norm. In contrast to the traditional Nash efficient bargaining, the right-to-manage bargaining constitutes a channel through which wages affect the marginal costs of firms. Since marginal costs feed into the determination of prices through the New Keynesian Phillips curve, we establish a direct channel of real wage rigidities to translate into aggregate inflation.

We specifically explore the question whether the underlying labor market regime contributes to explaining inflation persistence. In particular, we analyze how different degrees of real wage rigidity affect the reaction of unemployment and inflation to a shock in monetary policy under different wage bargaining regimes. Moreover, we study the impact of a monetary policy shock on unemployment and inflation conditional on labor market fundamentals such as bargaining power of the workers and the flows in and out of employment.

The lack of inflation persistence implied by the standard New Keynesian model has triggered a line of research focusing on firms' price setting process. Generally, this approach accounts for the observed persistence only if a substantial backward-looking component is included into the Phillips curve relation, see Fuhrer and Moore (1995), Gali and Gertler (1999) and Christiano, Eichenbaum, and Evans (2005). A second line of research focuses on inflation persistence stemming from inertia in the underlying process of marginal costs. Erceg, Henderson, and Levin (2000) introduce Calvo type nominal wage rigidities to generate marginal cost sluggishness. Indeed, Gali, Gertler, and Lopez-Salido (2001) find that wage rigidities are a significant factor driving the persistent movement in marginal cost for both the euro area and the U.S..[1]

Yet, the mere modelling of wage rigidities might not suffice to fully understand the factors behind sluggish marginal cost. Adjustments in the labor market take place on the hours of work as well as the employment margin. Besides, in light of high levels of unemployment in Europe and generally rigid labor markets a cleared labor market neglecting unemployment might be a misleading assumption. In contrast, our model incorporates matching frictions that generate equilibrium unemployment. Moreover, workers and firms bargain over wages in a collective wage bargaining manner. In addition to adjustments in hours of work per worker, the model provides an additional adjustment channel via the employment margin. Consequently, we employ a model with nominal price rigidities that incorporates both real wage rigidities and matching frictions in the labor market. This model framework will allow us to analyze how labor market dynamics and particularly the adjustment of wages translate into marginal cost and inflation dynamics.

Our main results can be summarized as follows. Our model features a "labor market channel" in the monetary transmission mechanism. We can show that the interaction of the specific wage setting process, i.e. the right-to-manage bargaining with real wage rigidities establish a direct channel on aggregate inflation dynamics. In particular, assuming a high degree of wage rigidity induces marginal cost to adjust slowly which translates into more persistent inflation dynamics. In contrast, using an efficient bargaining framework, in which marginal cost are mainly determined by hours worked not wages, the wage rigidity does not lead to higher inflation persistence, see also Krause and Lubik (2003). Moreover, our calibration shows that unemployment and inflation dynamics depend also on the parameters that determine employment protection and bargaining power of workers. And finally, the model is able to describe both the effect of a monetary policy shock on unemployment and on inflation. An adverse monetary policy shock in our model leads to a negative response of unemployment and inflation, displaying the traditional Phillips curve trade-off.

The understanding of labor markets for the transmission process might be of crucial

[1] See Christiano, Eichenbaum, and Evans (2005) and Edge, Laubach, and Williams (2003) who also stress the importance of wage rigidities contributing critically to explain inflation and output dynamics.

importance for a central bank. First, inflation dynamics and hence inflationary pressures might depend on the flexibility of wages and labor flows. Second, countries that differ with respect to their labor market regime might respond quite differently to a monetary policy shock. In general, understanding labor market adjustments and how they are related to the monetary transmission process may reduce the uncertainty associated with the reaction of inflation to a monetary policy action.

The remainder of the paper is structured as follows. Section 3 introduces the business cycle model featuring nominal price and real wage rigidities. In Section 4 we analyze the role of wage rigidities for inflation dynamics in our simulated model framework. Section 5 assesses the impact of labor market fundamentals on inflation dynamics. Section 6 offers some conclusions and provides an outlook for further research.

2 Price and Wage Rigidities

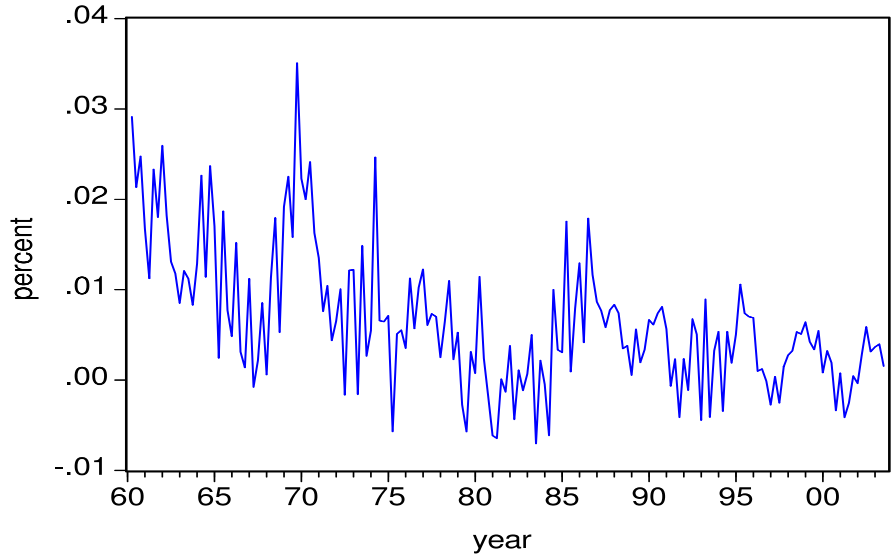
The New Keynesian business cycle paradigm is based on the notion that prices are sticky and are adjusted only infrequently. In particular, the impact of various kinds of economic shocks on the evolution of output and inflation depends heavily on the degree of stickiness in prices. There are a number of theoretical microeconomic models of price setting that introduce price stickiness into the macroeconomic business cycle model framework.

While it is almost an undisputed belief that price rigidities exist, empirical evidence on price rigidities has been rather scarce. A few pioneering studies starting with Carlton (1986) for the U.S. give evidence for sluggish price adjustments.[2] Only recently, a number of studies document firms price setting behavior in Europe.[3] Generally, the empirical evidence supports the incorporation of sluggish price adjustments into macroeconomic models of the business cycle. A weakness of most models of price setting behavior is, however, the inability to replicate the degree of inflation persistence observed in the data. Gadzinski and Orlandi (2003), Hondroyiannis and Lazaretou

[2] See also the evidence provided by Blinder (1994) and Blinder, Canetti, Lebow, and Rudd (1996) and Taylor (1999).

[3] See Aucremanne and Dhyne (2004), Baudry, Bihan, Sevestre, and Tarrieu (2004), Dias, Dias, and Neves (2004) and Fabiani, Gattulli, and Sabbatini (2004) for details on price setting behavior in the euro area. Specifically, the median duration of European consumer price contracts lies in the range of 8 months to 13 months. There is of course quite some heterogeneity in price changes depending on the particular sector. Prices change much more frequently in the energy and unprocessed food sector.

Figure 1: Quarterly Real Wage Growth from 1960 to 2003 in Germany



Notes: Wages correspond to hourly earning in manufacturing. Source: OECD

(2004) and Marques (2004) provide evidence that euro area inflation rates are fairly persistent.[4]

The failure of the New Keynesian model to generate the appropriate degree of inflation persistence can be caused by several reasons. First, the model of price setting itself might be an inappropriate description of the actual price setting process. Some studies augment the standard Calvo model with a proportion of backward-looking price setters or the assumption of inflation indexing to introduce an autoregressive term into the aggregate inflation process, see e.g. Gali and Gertler (1999). Second, the lack of persistence might result from far too variable marginal costs. If firms' marginal costs are sluggish, then firms have little incentives to change prices, hence introducing persistence to the inflation process.

It is uncontroversial to assume that labor costs are one of the key determinants of firms' marginal costs. Therefore, any determinant of firms' labor costs, i.e. wages, hiring and firing costs, etc. automatically translate into firms' marginal costs. Firms' marginal costs, in turn, determine firms' price setting and thus the evolution of inflation. Indeed,

[4] Notice that we define persistence throughout the paper as the sum of the coefficients of the lagged dependent variable of an univariate time series equation. As shown e.g. in Gadzinski and Orlandi (2003) the results on inflation persistence do not depend on the specific definition. The results remain valid if other measures like the half life indicator, etc. would be used.

the variance decomposition of inflation from a simple VAR reveals that real wages seem to be a major component in the forecast variance of inflation, see Figure 4 in the Appendix. This clearly indicates a close relationship between the formation of wages and inflation. We, therefore, ask the question how labor market dynamics and particularly the adjustment of wages translates into marginal cost and inflation dynamics.

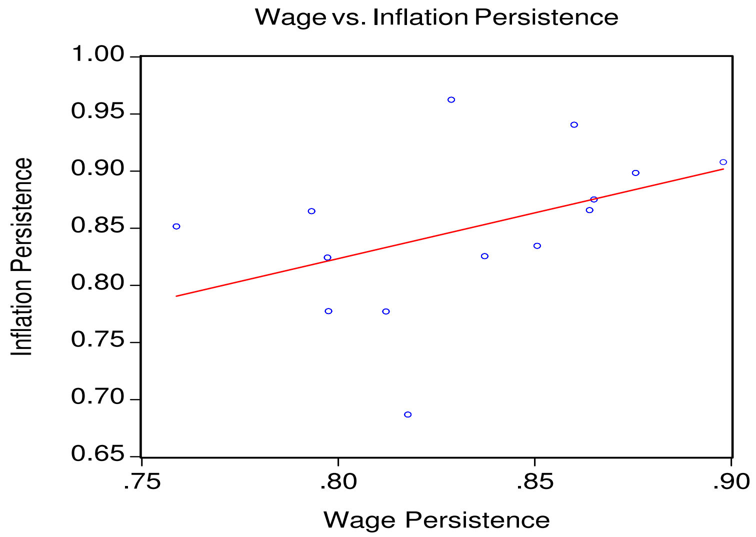
It is often argued that labor markets in Europe are rigid in many respects. High firing costs, unemployment benefits and strong unions are perceived to contribute to high unemployment and slow labor adjustments. Most importantly, the collective wage bargaining process is seen as a mechanism which prevents wages from adjusting instantaneously, hence introducing a substantial degree of wage rigidity.[5] In fact, recent studies on wage rigidity in Europe reveal that there is nominal as well real wage rigidity in micro wage data, see e.g. Smith (2000), Bauer, Bonin, and Sunde (2003), Knoppik and Beissinger (2003) and Dessy (2004). Moreover, as is apparent from individual wage growth distributions, the bulk of real wage changes lie in the interval from -5 to +5 percent. The macroeconometric evidence seems to be consistent with the numbers found in micro studies. For German data, aggregate quarterly real wage changes exceed 3% per quarter only in a few cases, see Figure 1.

If one constitutes a channel from wage to inflation dynamics (through firms' marginal costs), then clearly slow adjustment in wages will translate into more persistent movements in inflation. The empirical relationship between real wage persistence and inflation persistence is documented in Figure 2. The cross country evidence shows that wage and inflation persistence are positively related, i.e. the higher the real wage persistence in a country, the more persistent inflation tends to be. Moreover, labor market fundamentals as summarized by the average unemployment rate display a positive relation with inflation persistence, see Figure 3.[6] Consequently there is reason to believe that labor market dynamics affect inflation dynamics and hence the transmission process of monetary policy.

[5] We do not attempt to explain wage rigidity but the explanations put forward in the literature are manyfold. Wages might be rigid due efficient wage contracts, loss aversion, union power or fairness considerations, see Bewley (1999) for a survey.

[6] It seems that if unemployment is high, the labor market cannot exert enough pressure on wages and hence prices making inflation more persistent. This is in line with Driscoll and Holden (2004) who show based on U.S. data that inflation is more persistent when unemployment is high. See Linzert (2005) for similar evidence for euro area countries.

Figure 2: Inflation vs. Real Wage Persistence: Cross Country Evidence



Notes: OECD country data. Real wage and inflation persistence is calculated according to: $w_t = c + \varsigma w_{t-1} + \sum_{i=1}^{4} \psi_i \Delta w_{t-i} + \varepsilon_t$. where ς corresponds to the sum of the AR coefficients of the lagged dependent variable.

3 The Business Cycle Model with Labor Market Matching

Following Trigari (2003), we introduce a New Keynesian style business cycle model incorporating labor market frictions. These labor market frictions are twofold. First, we use the standard Mortensen-Pissarides model to account for equilibrium unemployment. This imposes a real rigidity on the adjustment of the factors of production to aggregate shocks. Second, we follow Hall (2005) and Krause and Lubik (2003) by including real wage rigidity in form of a wage norm. In that sense we extend the model by Trigari (2003) to allow for rigidities in wage contracts.

The model structure is characterized by a separation between firms in the wholesale and retail market. The intermediate goods are produced by competitive firms in the wholesale sector employing labor as the only input to production. The retail sector firms buy wholesale goods at marginal cost, transform them into differentiated goods and sell them with a mark-up over marginal cost in a monopolistic competitive environment, see Walsh (2003).[7]

[7] The two market structure of wholesale and retail sector simplifies the structure of the model. Notice that Krause and Lubik (2003) embed the two sector structure into a single integrated firm employing labor to produce intermediate and final good.

Figure 3: Inflation Persistence vs. Natural Unemployment: Cross Country Evidence

Notes: OECD country data. Wage and inflation persistence is calculated according to: $w_t = c + \varsigma w_{t-1} + \sum_{i=1}^{4} \psi_i \Delta w_{t-i} + \varepsilon_t$. where ς corresponds to the sum of the AR coefficients of the lagged dependent variable.

3.1 Household Problem

There is a continuum of households on the interval $[0, 1]$. The representative household chooses $\{c_t, h_t\}_{t=1}^{\infty}$ to maximize its utility given by:

$$\max \mathrm{E}_t \sum_{t=0}^{\infty} \beta^t \left[\frac{c_t^{1-\sigma}}{1-\sigma} - \kappa_h \frac{h_t^{1+\phi}}{1+\phi} \right] \tag{1}$$

where the first term is the utility from consuming c_t of the final good while the second part represents the disutility from work by supplying h_t units of hours. The degree of risk aversion is given by σ and ϕ denotes the inverse of the intertemporal elasticity of substitution of labor. κ_h accounts for the relative importance of disutility of work and utility from consumption in total utility.

Households maximize consumption subject to the following budget constraint:

$$c_t + \frac{B_t}{p_t r_t^n} = d_t + \frac{B_{t-1}}{p_t} \tag{2}$$

where p_t is the aggregate price level, B_t is per capita holdings of one period risk free bond, r_t^n is the gross nominal interest rate on this bond and d_t denotes the per capita income of the household in period t.

Household members can be employed or unemployed. When employed they receive the wage payments $w_t h_t$, when unemployed they engage in home production of a non-tradable goods or receive unemployment benefits which are evaluated in consumption units, b_t. In the absence of perfect income insurance an individual's savings decision would depend on its employment history and prospects. To avoid any distributional issues that may arise from this instance, we follow Merz (1995) and Andolfatto (1996) in assuming that households pool their income and consumption. Conditional on this assumption households optimality conditions can be given by the usual intra- and intertemporal relation.

3.2 Job Matching

In the following section we lay out the search and matching model of Mortensen-Pissarides that is incorporated into a New Keynesian style business cycle model to explicitly model labor market frictions in the form of equilibrium unemployment, see Mortensen and Pissarides (1994), Mortensen and Pissarides (1999), Pissarides (2000).

Trade in the labor market is an uncoordinated, time consuming, and costly activity that introduces frictions which lead to imperfect outcomes in the labor market. Jobs are constantly created and destroyed and unemployed workers look for new jobs generating unemployment in equilibrium. The process through which workers and firms find each other is represented by a matching function accounting for the imperfections and transaction cost in the labor market.[8] This function summarizes the entire search process in a single relation where the number of matches is a function of the number of unemployed persons, u_t, and the number of vacant jobs, v_t, in the labor market:

$$m_t = m(u_t, v_t) = \varrho_m u_t^{\varrho} v_t^{1-\varrho} \tag{3}$$

with ϱ being the elasticity of the matching with respect to the stock of unemployed persons. The parameter ϱ_m captures all factors that influence the efficiency of matching. The function is assumed to have constant returns to scale.

[8] Frictions usually derive from a complex set of factors such as imperfect information, heterogeneity, absence of perfect insurance, etc. The matching function incorporates the equilibrium outcome of such frictions without the explicit reference to the above sources of frictions.

The probability that a vacant job is matched with a worker is:

$$q_t = \frac{m_t}{v_t} = \varrho_m \theta_t^{-\varrho} \tag{4}$$

where $\theta_t = \frac{v_t}{u_t}$ defines an indicator for the tightness in the labor market. An increase in the number of vacancies relative to unemployment, θ_t, reduces the probability that a vacancy will be filled. This in turn means that additional vacancies per unemployed worker imply an increase of the probability that the unemployed person finds a job. Accordingly, the corresponding probability for an unemployed worker to find a job is given by:

$$s_t = m_t/u_t = \varrho_m \theta_t^{1-\varrho} \tag{5}$$

where the exit rate from unemployment is an increasing function of the labor market tightness. For a given number of unemployed persons in the market, the probability of finding a job increases when the number of vacancies rise.

The probabilities of filling a job and finding a job show that the matching model introduces two kinds of externalities responsible for determining equilibrium unemployment in the model: the congestion and the labor market tightness externality. Each firm posting a vacancy creates a negative congestion externality for other firms since an additional vacancy decreases the chance for other firms to fill their vacancies. Conversely, the labor market tightness describes the effect that each additional job searcher creates a negative search externality for other searchers. Thus, there will be a stochastic rationing in the labor market which cannot be solved by the usual price mechanism. The variable, θ_t, defined to capture both externalities, plays a crucial role in determining the degree of rationing and hence the equilibrium unemployment in the labor market.

Once a worker and a firm are matched, they produce output according to the production function:

$$f(h_t) = z_t h_t^{\alpha} \tag{6}$$

where labor, i.e. the number of hours, h_t, is the only input to production and z_t represents technological progress.

It is assumed that firms produce the output necessary to provide the aggregate household demand.

$$c_t = (1-\rho) n_t z_t h_t^{\alpha} \tag{7}$$

3.2.1 Job Destruction

Unemployment rises after an adverse shock. According to Hall (2004) employed workers do not loose jobs more frequently in a recession than in other times, i.e. job destruction remains rather constant over time. On the other hand, employers are far more reluctant to create jobs in a recession. Hence, unemployment rises because the exit rate of unemployment is lower, and not because the entrance rate is higher.

Therefore, without loss of plausibility, we can assume that job destruction occurs exogenously at the rate ρ. The rate ρ indicates the proportion of existing matches that disappear at the beginning of each period, i.e. become unproductive for unspecified reasons resulting in firms terminating the job.

The number of employed workers at the beginning of each period (n_t) evolves as follows:

$$n_t \quad = \quad (1-\rho)n_{t-1} + m_{t-1} \tag{8}$$

where the first part of the right hand side represents the matches that survived the job destruction process in the previous period and the second part being the matches formed in the previous period which become productive in the current period. It is important to note the n_t gives the number of employed workers at the beginning of period t. The number of productive workers in period t is therefore given by $(1-\rho)n_t$.

The number of searching workers is given accordingly as (where total labor force is normalized to one):[9]

$$u_t \quad = \quad 1-(1-\rho)n_t \tag{9}$$

3.2.2 Job Creation

Firms create a job vacancy when the expected gains from an employment relation exceed the cost of vacancy posting. Until the value of a new job is equal to the cost of creating a job new firms will enter the market to create vacancies. For simplicity it is assumed that each firm has one job so vacancy posting and hence the number of jobs created is a matter of how many firms are in the market.

[9] Note that u_t gives the number of searching workers, while the number of unemployed workers at the beginning of each period is given by $1-n_t$.

The value of a job for a firm is given by the contemporaneous payoff and the discounted future value of the job at the end of the period.

$$J_t = x_t f(h_t) - w_t h_t + \mathrm{E}_t\, \beta_{t+1}(1-\rho)J_{t+1} \tag{10}$$

where x_t is the relative price of the intermediate good and w_t is the wage the firm has to pay for an hour of work. Since all the intermediate good producers act in a competitive environment the relative price is given by marginal cost in relation to the price of the consumption good. The discount factor is constructed in terms of relative marginal utility ($\lambda_t = \frac{\partial U_t}{\partial c_t}$) from consumption, such that $\beta_{t+s} = \frac{\beta^s \lambda_{t+s}}{\lambda_t}$.

The value of an open vacancy to a firm is given by:

$$V_t = -\frac{\kappa}{\lambda_t} + \mathrm{E}_t\, \beta_{t+1}\left[q_t(1-\rho)J_{t+1} + (1-q_t)V_{t+1}\right] \tag{11}$$

with κ being the utility cost of vacancy posting.[10] When a job is vacant, the profit is zero. Hence the value of a vacancy is determined by the current cost of holding a vacancy open and the expected utility arising from future matches. As long as the value of a vacancy is greater than zero vacancies are created until $V_t = 0$.

Taking the difference between the two equations J_t and V_t yields the surplus, $J_t - V_t$, to the firm of filling a vacancy. It can be seen from the equations for J_t and V_t that the value of a firm from a filled vacancy increases in the search cost, the separation rate, the discount rate and the expected length of search.

Turning to the problem of the worker, we assume that a worker can either be employed or unemployed. The value of being employed is given by:[11]

$$W_t = w_t h_t - \frac{g(h_t)}{\lambda_t} + \mathrm{E}_t\, \beta_{t+1}\left[(1-\rho)W_{t+1} + \rho U_{t+1}\right] \tag{12}$$

The first term in the equation is the worker's wage income. The second term represents the disutility of work and the last term reflects the future utility of an employment relation. With a probability ρ the job is destroyed and the worker receives the utility of being unemployed while the value of being employed is realized if the job remains productive.

In the same way we can express the value of being unemployed:

$$U_t = b + \mathrm{E}_t\, \beta_{t+1}\left[s_t(1-\rho)W_{t+1} + (1 - s_t + s_t\rho)U_{t+1}\right] \tag{13}$$

[10] Notice that the vacancy costs cannot just be seen as the pure costs of hiring but also costs for machines and other capital that will be idle while the vacancy is not filled.

[11] Where $g(h_t) = \kappa_h \frac{h_t^{1+\phi}}{1+\phi}$ denotes the disutility from supplying labor.

The value of being unemployed is determined by the value of home production or unemployment benefits, b, and the probability of finding a job in period t and not loosing the job at beginning of period $t+1$ given by $s_t(1-\rho)$. With probability $1-s_t(1-\rho)$ unemployed workers remain in the unemployment pool, either by being not matched at all or being matched and separated immediately at the beginning of the next period.

Taking the difference between the two equations W_t and U_t yields the surplus, $W_t - U_t$, to the worker of staying employed. The surplus depends crucially on the level of unemployment benefits and the tightness in the labor market.

3.3 Wage Setting

In a frictionless Walrasian labor market, hours are chosen to equate the marginal rate of substitution between leisure and consumption with the marginal product of labor. The resulting wage rate equals the marginal product of labor. In a labor market with matching frictions and equilibrium unemployment, however, the worker and the firm bargain over wages. In general, wages will be bargained to split the positive rent or match surplus arising from a successful match between the worker and the firm.[12] There are several versions of noncooperative bargaining games that are able to solve the surplus sharing problem. In the following section we will consider the efficient Nash bargaining to contrast it with the right-to-manage bargaining.

3.3.1 Efficient Nash Bargaining

A plausible way to split the rent between workers and employers is through efficient Nash bargaining. MacDonald and Solow (1981) proposed a bargaining game in which bargaining takes place over employment and wages at the same time. In this case, wages and the number of hours worked are chosen to maximize the joint surplus:

$$\max_{w,h} \left[W_t - U_t\right]^{\eta} \left[J_t - V_t\right]^{1-\eta} \tag{14}$$

subject to equations (10) to (13).

[12] The rent is generated since it is costly to both workers and employers not to agree over employment. The worker remains unemployed and has to look for another job and similarly the firm faces search costs to find another worker.

This implies the following optimality condition:

$$\eta J_t = (1-\eta)(W_t - U_t) \tag{15}$$

The wage in this model can be interpreted as a weighted average of the two "threat" points of employers and employees, i.e. the marginal product and the reservation wage, respectively. The stronger the bargaining power of the worker, the closer the wage is to the marginal product and vice versa. Therefore, the wage has only a distributive role of the rent from the foregone expected search costs.

The wage relation following from (15) can be written as:

$$w_t = \eta\left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa\theta_t}{\lambda_t h_t}\right) + (1-\eta)\left(\frac{mrs_t}{1+\phi_t} + \frac{b}{h_t}\right) \tag{16}$$

Notice that in this formulation the wage does not only depend on the marginal rate of substitution (mrs) as in the frictionless Walrasian market but also on the state of the labor market, i.e. the value of household production or level of unemployment benefits (b), the labor market tightness (θ), etc. In the theoretical model an increased tightness of the labor market or higher unemployment benefits implies higher negotiated wages.

In the bargaining process wages and hours are determined simultaneously. This implies that hours are chosen in an efficient way according to the following optimality condition:

$$mpl_t x_t = mrs_t \tag{17}$$

Under efficient bargaining the outcome lies on the contract curve, i.e. the locus of tangency points of the isoprofit curve of the firm and worker's indifference curves. Any change in hours will be accompanied by a change in the wage as well so that any renegotiation of hours and wages will yield an agreement on the contract curve. Thus, the correct measure of firms marginal cost is the worker's marginal rate of substitution of consumption and leisure rather than the wage.

3.3.2 Right-To-Manage Bargaining

In contrast to efficient Nash bargaining the right-to-manage model proposes that unions and firms only bargain over wages and that firms subsequently choose the level of employment, see Nickell and Andrews (1983) and Trigari (2003). The reasoning to negotiate wages and the employment level separately is that firms want to adapt their labor demand if product demand changes. In practise employers are always able to adjust employment by changing work hours or the workforce. In this view, the efficient bargaining solution by which every adjustment in working hours is accompanied by a renegotiation of wages seems too restrictive. Besides, a large proportion of wages in Europe are covered by collective bargaining agreements at the sectoral level, leaving the individual firm with the optimal decision on the demand for hours only. Therefore, the right-to-manage model seems to characterize the institutional setup in Europe better than the efficient bargaining model.

The product of the weighted economic rents of the negotiating parties, i.e. workers and employers is maximized with respect to w_t:

$$\eta\delta_t^w J_t = (1-\eta)\delta_t^f (W_t - U_t) \tag{18}$$

where $\delta_t^w = \frac{\partial W_t}{\partial w_t}$ is the marginal contribution of wages to the value of a job to the worker and $\delta_t^f = \frac{\partial J_t}{\partial w_t}$ is the marginal contribution of the wage to the value of a job to the firm. Using the relations in equations (10)-(13) yield the following wage equation:

$$w_t h_t = \chi_t(x_t z h_t + f_t^F) + (1-\chi_t)\left(\frac{\kappa_h \frac{h_t^{1+\phi}}{1+\phi}}{\lambda_t} + b - f^W\right) \tag{19}$$

where f_t^F and f_t^W are the future net present values from employment for the firm and the worker, respectively and

$$\chi_t = \frac{\eta\delta_t^n}{\eta\delta_t^w + (1-\eta)\delta_t^f}$$

We can rewrite the wage as:

$$\begin{aligned} w_t = {} & \chi_t\left(\frac{x_t mpl_t}{\alpha} + \frac{\kappa\theta_t}{\lambda_t h_t}\right) + (1-\chi_t)\left(\frac{mrs}{1+\phi_t} + \frac{b}{h_t}\right) \\ & +\chi_t(1-s_t)\frac{\kappa}{\lambda_t q_t}\left(1 - \frac{1-\chi_t}{\chi_t}\frac{\chi_{t+1}}{1-\chi_{t+1}}\right) \end{aligned} \tag{20}$$

As in the efficient bargaining case, the wage differs from the competitive wage. The wage depends on the respective bargaining power of the negotiating parties, the reservation wage and the general tightness of the labor market. In that sense, the institutional framework of the labor market is crucial for the wage setting process.

Once the wage is determined, firms will choose hours to satisfy the relation:

$$x_t mpl_t = w_t \tag{21}$$

Wages are set through the bargaining process and are taken as given by the firms when choosing their level of employment. For every additional hour of work the firm must pay the previously bargained wage. Therefore, in contrast to the efficient bargaining case, the wage is now a direct determinant of the firm's marginal cost. The mechanism through which wages feed into marginal costs is crucial to our model since it constitutes a direct channel of wages on inflation dynamics via the New Keynesian Phillips curve.

3.3.3 Introducing Wage Rigidity

Aggregate wages are characterized by a high degree of persistence. Especially in Europe, sudden and significant shifts in the aggregate wage level are not observed. Due to collective wage bargaining agreements, wage changes only take place on a quite infrequent basis. Therefore, a wage that can be freely adjusted each period assumes a degree of wage flexibility that is hardly consistent with actual practises.

Erceg, Henderson, and Levin (2000) and Christiano, Eichenbaum, and Evans (2005) introduce wage rigidity into the New Keynesian business cycle model by a Calvo type wage setting scheme. As in final good price setting, firms are randomly chosen to change their wages while the remaining firms keep wages unchanged. In Europe, however, most wages are bargained on a sector wide level, are not allowed to fluctuate freely and once settled remain unchanged for a given period. More importantly, the Calvo wage rigidity modelling strategy neglects the crucial interdependence of the wage bargaining process with other labor market issues, like the flows in and out of employment or the level of unemployment. For that reason we opt for introducing a wage rigidity into the labor market setting presented in the previous sections.[13]

Following Hall (2005), we introduce wage rigidity into the model in the form of a backward looking social norm.[14] The possible outcome of the wage bargain lies within

[13] Throughout this paper we are using the term wage rigidity to refer to the general property that real wages are not adjusting immediately to the desired level. In contrast to this usage Trigari (2003) is using the term wage rigidity for the right-to-manage bargaining approach where wages are allocative but free to adjust immediately (compare Section 3.3.2).

[14] The wage norm has originally been introduced into the matching model to improve the model's performance in replicating labor market fluctuations. In particular, the model cannot explain well the magnitude of the cyclical behavior of unemployment and vacancies, see e.g. Hall (2005) and Shimer (2005). A wage norm limits the adjustment capabilities of wages and hence increases the adjustments on the labor quantity side. This channel substantially increases the business cycle fluctuations of unemployment and vacancies.

a bargaining set. The bargaining set is bounded by an upper limit denoting the wage rate ($w_t^{(u)}$) for which the firms's surplus from the employment relation is zero. The wage level for which the worker is indifferent between working and being unemployed determines the lower wage bound ($w_t^{(l)}$).[15] All wage levels in this bargaining set are possible solutions of the wage bargain and can be written as a convex combination of upper and lower bound:

$$w_t^\star \quad = \quad \Gamma_t w_t^{(u)} + (1 - \Gamma_t) w_t^{(l)} \tag{22}$$

where Γ_t is a function of the specific bargaining regime governed by η.

According to Hall (2005) a wage norm or social consensus can be perceived as a rule to select an equilibrium within the bargaining set. Without going into the details of the sources of this wage norm, we assume that the actual wage level is given by a weighted average of past wage level and the equilibrium wage level defined in Equation (22):[16]

$$w_t \quad = \quad (1 - \delta) w_t^\star + \delta \widehat{w} \tag{23}$$

where $\widehat{w} = w_{t-1}$ and δ denoting the respective weight. The wage norm used in this framework can be seen as encompassing various sources of wage rigidities.[17] While being a short cut to a micro founded wage rigidity, the aggregate wage norm used in this paper constitutes a plausible starting point for analyzing the impact of wage rigidities on the monetary transmission process, see also Krause and Lubik (2003), Uhlig (2004) and Blanchard and Gali (2005), which take a similar approach.

In contrast to the efficient bargaining model, the right-to-manage model of the previous section establishes a link between the wage setting and firms' marginal cost. In fact, in our model the wage rigidity will directly influence the marginal cost process.[18] In a New Keynesian model with a Walrasian labor market an adverse shock to production usually leads to large declines in real wages. Marginal costs of firms fall accordingly

[15] The upper and the lower limit of the wage bargaining set are derived from the value functions defined in equations (10) and (11) respectively (12) and (13).

[16] The wage norm can be rationalized, for example, in terms of an aggregation of individual wage decisions, each subject to idiosyncratic productivity shocks disturbing the wage outcome. Only those wages that fall out of the boundaries of the wage bargaining set are reset to the nearest boundary. In general, the average wage in a period becomes the norm for next period, see Hall (2003) for details.

[17] See for example Boeri and Burda (2003) or Danthine and Kurmann (2004) for possible microfoundations.

[18] Notice that the wage rigidity in this model does not affect the formation of a match itself. However, a wage rigidity influences the vacancy posting of employers as slow moving wages affect the profit condition and hence the amount of open vacancies posted by firms.

and the incentive for price adjustments is high. This is, however, in contrast to the empirical evidence that commonly demonstrates fluctuations of prices and wages to be rather small. Hence, the departure from the Walrasian labor market with wage rigidities may improve the model generated dynamics of output and inflation. More specifically, the introduction of the wage norm depresses marginal cost fluctuations and helps to generate more persistent inflation dynamics via the New Keynesian Phillips curve.

3.4 Final Good Firms and Price Setting

The final good firms aggregate the intermediate goods into the final consumption good.[19] The output index is assembled using the standard aggregation technology.

$$y_t = \left[\int_0^1 y_{it}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{24}$$

with y_t, y_{it} and ϵ being aggregate output, the individual firm's output and the firm's own price elasticity, respectively. The final good is sold at its unit price defined as

$$p_t = \left[\int_0^1 p_{it}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \tag{25}$$

The resulting demand for each aggregator depends on the relative price and aggregate demand.

$$y_{it} \quad = \quad \left(\frac{p_{it}}{p_t} \right)^{-\epsilon} y_t \tag{26}$$

Following the specification introduced by Calvo (1989) we can write the Dixit-Stiglitz price index as

$$p_t \quad = \quad \left[(1-\varphi) p_t^{\star 1-\epsilon} + \varphi p_{t-1}^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \tag{27}$$

where $(1-\varphi)$ denotes the per period probability that a firm is able to reset its price to the optimal price $p_t^\star$. The remaining fraction φ of firms keep their prices at the levels prevailed in the previous period. The optimal price $p_t^\star$ is chosen to maximize profits over the expected time span until the firm can re-optimize the price.

$$\mathrm{E}_t \sum_{s=0}^{\infty} \varphi^s \beta_{t+s} \left[\frac{p_{it}^\star}{p_{t+s}} - x_{t+s} \right] y_{i,t+s} \tag{28}$$

[19] This section follows the standard setting described in Rotemberg and Woodford (1998).

The solution to this problem is given by

$$p_{it} \quad = \quad \frac{\epsilon}{\epsilon - 1} \mathrm{E}_t \sum_{s=0}^{\infty} \omega_{t,t+s} p_{t+s} x_{t+s} \tag{29}$$

The weights $\omega_{t,t+s}$ are given by

$$\omega_{t,t+s} \quad = \quad \frac{\varphi^s \beta_{t+s} R_{it,t+s}}{\mathrm{E}_t \sum_{k=0}^{\infty} \varphi^k \beta_{t+k} R_{it,t+k}} \tag{30}$$

with R_{it} denoting the real interest rate.

3.5 Monetary Policy

The central bank's monetary policy is modelled via a Taylor-type interest rate rule according to which the nominal interest rate evolves as:

$$r_t^n = (r_{t-1}^n)^{\rho^m} E_t(p_{t+1}/p_t)^{\gamma_\pi (1-\rho^m)} (y_t)^{\gamma_y (1-\rho^m)} e^{\epsilon_t^m} \tag{31}$$

4 Impact of Real Wage Rigidity

To solve the model described in the previous section the equations are linearized around the model's steady state. The resulting linearized system is solved using AIM.[20] In order to analyze the dynamics of our model we calibrate the model choosing parameter values that are generally used in the literature. The benchmark parameter choices are displayed in Table 2.

In this section we analyze the model's dynamics to a unit shock in monetary policy, i.e. an increase in the nominal interest rate. We are particularly interested in how monetary policy is propagated in the presence of a non-Walrasian labor market with equilibrium unemployment and real wage rigidity. Towards that aim, we will compare the outcome of the model under the two bargaining schemes introduced in the previous sections, i.e. the efficient Nash bargaining and the right-to-manage bargaining. This allows the analysis of the transmission process of monetary policy when labor markets differ with respect to the bargaining regime as well as to the degree of wage rigidity. The results regarding the impact of wage rigidity on the variables of interest crucially depend on the prevailing bargaining regime.

[20] See Anderson and Moore (1985) for details on the solution method.

4.1 Efficient Bargaining Setup

As a first step, we analyze the impact of wage rigidity when combined with an efficient Nash bargaining setup. The corresponding impulse-response functions are displayed in Figure 5. An adverse interest rate shock initially leads to a fall in private demand. In order to adjust to private demand, intermediate good producers reduce production, implying a fall in employment and working hours. A dampened demand decreases expected profits and hence induces firms to post less vacancies. Vacancies fall and unemployment increases accordingly. Since working hours must fall to meet the reduced demand, firms pay lower wages to reduce worker's labor supply.

The drop in consumption implies an increase in the current period's marginal utility of consumption. The marginal rate of substitution between leisure and consumption falls accordingly. In Section 3.3.1 it was highlighted that the marginal rate of substitution is an important determinant of firms' marginal costs. As can be seen in Figure 5, a drop in the marginal rate of substitution is translated into a fall of marginal costs. Additionally, inflation falls also since marginal costs subsequently affect inflation via the New Keynesian Phillips curve.

The introduction of real wage rigidity in the efficient bargaining model increases the adjustment via the employment margin. Under rigid wages, changes in demand conditions have a stronger impact on the profits of the firm. If wages cannot decrease sufficiently, firms are paying excessive wage compensation. This implies a negative impact on firms' profits, a reduced number of posted vacancies and an additional reduction in employment. The path of hours, however, is not significantly affected, which implies that inflation dynamics are not strongly influenced by the introduction of wage rigidity.[21]

4.2 Right-to-Manage Bargaining Setup

As a second step, we analyze how the model dynamics change when workers and firms bargain according to a right-to-manage (RTM) bargaining regime. We are particularly interested in the responses of the variables when a wage rigidity is introduced into the RTM model. For that reason we compare the response functions of a RTM model without wage rigidity with a calibration using a high degree of wage stickiness. The

[21] This result is consistent with the findings of Krause and Lubik (2003).

corresponding impulse-response functions are shown in Figure 6.

The initial reactions to a monetary policy shock without a wage norm are quite similar to the responses in the efficient bargaining model. A noteworthy difference is that wages react much stronger in the RTM model and labor flows are much less pronounced than in the efficient bargaining version. The increased volatility of wages can be explained by a steeper labor demand function in the right-to-manage setup.

The introduction of wage rigidity in the RTM model has an important implication for the dynamics of inflation in the model, see Figure 6. Indeed, the introduction of wage rigidities reduce the volatility and increase the persistence of wages. Accordingly, as it is apparent from the figure, marginal costs and inflation also show a more persistent response to a monetary policy shock. Therefore, we can show that for a reasonable degree of wage rigidity the model improves significantly along the inflation persistence margin.

In our model, rigid wages feed into marginal costs and hence have a direct impact on inflation dynamics through the New Keynesian Phillips curve. The mechanism of wage rigidities in the right-to-manage framework can be best seen in the linearized version of the wage and inflation equation:[22]

$$\begin{aligned} w_t &= (1-\delta)(\gamma_1 mrs_t + \gamma_2(v_t - u_t - h_t - \lambda_t)) \\ &\quad -(1-\delta)(\gamma_3 h_t - \zeta_1 \chi_t + \zeta_2 \,\mathrm{E}(\chi_{t+1})) + \delta w_{t-1} \qquad (32) \\ \pi_t &= \frac{(1-\beta\varphi)(1-\varphi)}{\varphi}\,(w_t - (\alpha-1)h_t) + \beta\,\mathrm{E}(\pi_{t+1}) \qquad (33) \end{aligned}$$

It is obvious from Equation (32) that the inclusion of wage rigidities smooth the path of wages. Wages in turn determine firms' marginal costs and thus directly feed into the path of inflation, see Equation (33). Therefore, the wage rigidity smoothes marginal costs and increases inflation persistence. Moreover, since in our model not only hours but also employment adjusts to economic shocks, the fluctuations of hours can be smaller than in a model without the employment margin. This implies that marginal costs may be further smoothed by a less variable hours component. Therefore, the modelling of flows in and out of employment in our model can have further implications

[22] Where $\chi_t = \frac{\eta\widehat{\delta}_w(1-\widehat{\chi})}{\eta\widehat{\chi}\widehat{\delta}^w+(1-\eta)\widehat{\chi}\widehat{h}}\delta_t^w - \frac{(1-\eta)\widehat{\chi}\widehat{h}}{(\eta\widehat{\chi}\widehat{\delta}^w+(1-\eta)\widehat{\chi}\widehat{h})}\delta_t^f$, variables with a hat denote the steady state values and the parameters are given by the following relations: $\gamma_1 = \frac{\frac{1-\eta}{(1+\phi)}+\frac{\eta}{\alpha}}{1-\frac{\eta}{\alpha}}$, $\gamma_2 = \frac{\frac{(\eta\kappa)}{\hat{w}\hat{q}\hat{\lambda}\hat{h}}}{1-\frac{\eta}{\alpha}}$, $\gamma_3 = \frac{\frac{(\eta\kappa)}{\hat{w}\hat{q}\hat{\lambda}\hat{h}}+\frac{(1-\eta)b}{\hat{w}\hat{h}}}{1-\frac{\eta}{\alpha}}$, $\zeta_1 = \frac{\frac{\eta(1-\alpha)}{(1-\eta)\alpha}+\frac{\kappa}{\hat{q}\hat{w}\lambda\hat{h}}}{1-\frac{\eta}{\alpha}}$ and $\zeta_2 = \frac{\eta}{1-\eta}(1-\hat{s})\frac{\frac{\kappa}{\hat{q}\hat{w}\hat{\lambda}\hat{h}}}{1-\frac{\eta}{\alpha}}$.

for the dynamics of marginal costs and hence inflation.

Table 1 displays the inflation and wage persistence from model simulations when labor markets differ with respect to the bargaining regime as well as the degree of wage rigidity. The four columns show the persistence in wages and inflation from the model simulated series. Persistence is measured as the sum of the AR coefficients of the respective lagged dependent variable from a univariate autoregressive process, see Andrews and Chen (1994).[23]

The upper panel in Table 1 shows the model series persistence within a RTM bargaining framework and the lower panel the efficient bargaining counterparts. It is apparent from the table that the greater the exogenously imposed wage rigidity, the higher is inflation persistence in the RTM model. For wage norms consistent with aggregate wage data (e.g. an AR coefficient of 0.9) the RTM model generates substantial inflation persistence compared to model variants with no wage norm. In contrast, inflation persistence under the efficient bargaining framework is not affected significantly when the degree of wage rigidity increases. In the efficient bargaining model there is no direct channel from wages to firms' marginal costs. Obviously, this prevents wages from affecting inflation in a significant way.

To sum up, the introduction of RTM bargaining with real wage rigidities has important implications for the transmission of monetary policy in the traditional New Keynesian model. A non-clearing labor market together with wage rigidities help to explain a more persistent response of inflation to a shock in interest rates.

5 The Impact of Labor Market Fundamentals

European labor markets are governed by labor market institutions such as collective wage bargaining, employment protection legislation and unemployment insurance. These institutions may be seen to influence the bargaining power of workers which in

[23] The most common approach to determine a variable's persistence is to estimate a univariate AR equation of the following form:

$$w_t = c + \varsigma w_{t-1} + \sum_{i=1}^{4} \psi_i \Delta w_{t-i} + \varepsilon_t$$

where ς corresponds to the sum of the AR coefficients of the lagged dependent variables. See e.g. Gadzinski and Orlandi (2003) for further evidence and alternative measures on inflation persistence in the euro area.

Table 1: Estimated Persistence ς in Wages and Inflation

Bargaining Regime	Persistence ς in	Model $\delta = 0$	Model $\delta = 0.90$	Model $\delta = 0.95$	Model $\delta = 0.97$	German data	U.S. data
Right to Manage	Wages	0.36	0.81	0.88	0.92	0.86	0.81
	Inflation	0.38	0.71	0.77	0.78	0.87	0.78
Efficient Bargaining	Wages	0.52	0.92	0.95	0.97	0.86	0.81
	Inflation	0.17	0.18	0.19	0.16	0.87	0.78

Notes: Data Source: OECD MEI. δ is the coefficient of lagged wages in right-to-manage wage equation. Wage and inflation persistence is calculated according to:

$$w_t = c + \varsigma w_{t-1} + \sum_{i=1}^{4} \psi_i \Delta w_{t-i} + \varepsilon_t$$

turn affect the wage determination process. In this section we look at the responses of unemployment and inflation to a monetary policy shock under different degrees of labor market rigidity in the RTM model with wage rigidity.[24] The wage equation in the right-to-manage model in Section 3.3.2 contains several variables characterizing the state of the labor market such as the bargaining power of workers, the job destruction rate or the level of the reservation wage. Since we established a link between the wage outcome and inflation dynamics, the question arises how the determinants of the wage itself affect inflation dynamics.[25]

5.1 Bargaining Power of Workers

Collective wage bargaining is an important institutional feature that determines wages of workers. For example, despite a relatively low union density, union coverage is fairly high in most of Continental European countries, see e.g. Nickell, Nunziata, Ochel, and Quintini (2003). Generally, higher bargaining power of workers in the form of higher union membership and coverage is associated with an upward pressure on wages and hence higher unemployment.[26]

[24] The notion of the interaction between shocks and institutions was forwarded by e.g. Blanchard and Wolfers (2000) to statistically explain the evolution of European unemployment.

[25] Note that there have been a set of theoretical studies on the impact of labor market institutions such as hiring subsidies and unemployment benefits on labor market dynamics, see e.g. Yashiv (2004).

[26] Yet, in practise this effect can be offset if wage setting in the economy is coordinated, see e.g. Nickell and Layard (1999).

We start with analyzing inflation and unemployment dynamics with different degrees of workers' bargaining power represented by the parameter, η, see Figure 7.[27] If bargaining power is high the negotiated wage increases since workers can command higher wages for a given disutility of work. Thus, expected profits of firms decline and cause the number of vacant jobs to fall. This in turn results in higher unemployment. In line with the empirical evidence provided by e.g. Blanchard and Wolfers (2000), the interaction of a monetary policy shock and high bargaining power leads to an increase in unemployment in our model.

Higher bargaining power of workers induces inflation to respond more to a contractionary monetary policy shock, see Figure 7. When wages increase with higher bargaining power, marginal costs rise as well and feed into increased movements of inflation. A change in bargaining power affects both the magnitude of the response in unemployment and inflation and the persistence of the respective variables. Notice, however, that an increase in bargaining power does not only feeds into larger upward wage movements in the case of a positive demand shock, but due to the symmetry of the model, also to larger wage declines when the shock is negative. Therefore, higher wage movements translate also into larger movements in marginal costs and thus larger responses in inflation.

5.2 Employment Protection

European labor markets are characterized by lower job turnover rates than their U.S. counterpart, see e.g. Burda and Wyplosz (1994).[28] This is conventionally interpreted as stemming from higher employment protection and firing costs in Europe. On the one hand, employment protection leads firms to be more cautious in filling vacancies and on the other hand reduces involuntary separations. Lower job flows in our model correspond to a lower job destruction rate. For that reason we model employment protection simply through its effect on aggregate job flows. This neglects, however, the direct effect of employment protection on the bargaining position of workers and hence the impact on wages.

[27] The baseline parameter choice for bargaining power is $\eta = 0.4$ which is a conservative assumption on rents accruing to the workers. Much empirical work has of course been devoted to estimating bargaining power within a wage equation framework. For example Abowd and Lemieux (1993) estimated a workers' share of rents of about 30% in Canada.

[28] A prominent exception is, however, the comparison of the U.S. and the Portuguese labor flows as documented in Blanchard and Portugal (2001).

Figure 8 displays the responses of unemployment and inflation to a monetary policy shock when we vary the rate of exogenous job destruction. In a regime with lower job turnover, i.e. lower job destruction rates, unemployment reacts less to an adverse interest rate shock since aggregate labor flows are lower.[29] A lower job destruction rate reduces aggregate job creation and elevates the volatility in real wages.[30] Larger adjustments on the wage margin dampen aggregate wage persistence. The response of inflation to a monetary policy shock appears to be more pronounced and less persistent. This in turn means that in the case of high aggregate labor flows, wage adjustments tend to be small and thus translate into smaller and more persistent movements of the inflation rate.[31]

The analysis has shown that any "institutional" parameter that raises the volatility in wages, increases also the response of inflation and tends to reduce its persistence. On the other hand, anything that spurs the volatility in labor flows dampens the adjustments of wages and, therefore, tends to increase the persistence in inflation. This, however, is partly due to the simplistic modelling of labor market institutions in this model. Employment protection as well as bargaining power are usually associated with exerting an upward pressure on wages with downward rigidity at the same time. Since in our model wages react symmetrically, higher bargaining power results in stronger wage increases in the case of a positive shock and in larger reductions in the case of a negative shock, respectively. A better account of labor market institutions and their implications for unemployment and inflation dynamics in this model, is a task to be taken up in further research.

6 Conclusions

We include a labor market with wage rigidities as well as matching frictions into the New Keynesian model. In particular, we follow the approach by Trigari (2003) assuming that workers and firms bargain over wages according to a right-to-manage bargaining model. We extend the Trigari setting by incorporating wage rigidity into

[29] Note that the empirical evidence of a relationship between employment protection and unemployment is rather mixed, see e.g. Nickell and Layard (1999).

[30] Notice that the effect on wages would be potentially larger if we had a direct channel of employment protection on the bargained wage outcome in our model.

[31] In a similar vein, an increase in the natural rate of unemployment surges equilibrium job flows. Less adjustment takes place on the wage margin and, therefore, raises wage and hence inflation persistence.

the right-to-manage bargaining framework which has important implications for the joint dynamics of unemployment and inflation in our New Keynesian DSGE model. The model sheds light on the question whether the specific form of wage bargaining and the degree of wage rigidity affects the transmission process of monetary policy determining inflation dynamics.

The traditional New Keynesian dynamic stochastic general equilibrium model of business cycle fluctuations generally fails to account for the degree of inflation persistence observed in actual data. Employing a right-to-manage bargaining framework, wages feed directly into firm's marginal cost and hence into inflation dynamics via the New Keynesian Phillips curve. Introducing a wage rigidity in form of a Hall type wage norm, we can show that more rigid wages translate into more persistent movements of aggregate inflation. In contrast, the channel from wages to inflation is missing under the assumption of an efficient bargaining model and, therefore, fails to generate inflation persistence.

Our calibration also shows that unemployment and inflation dynamics do not only depend on rigid wages but also on the parameters that determine employment protection, bargaining power of workers and the natural rate of unemployment. Generally, "institutional" parameters that raise the volatility in wages, increase also the response of inflation and tend to reduce its persistence. On the other hand, anything that spurs the volatility in labor flows, dampens the adjustments of wages and, therefore, tends to increase the persistence in inflation.

The model reveals that the labor market has important implications for the transmission process of monetary policy. The inclusion of a labor market into the New Keynesian model introduces another channel along which real and nominal rigidities can be incorporated into the model. The "labor market channel" significantly affects the dynamics of employment and inflation. In particular, real wage rigidity appears to play a key role in shaping marginal cost dynamics and, consequently persistent movement in inflation rates. Our model suggests that the central bank may benefit from closely monitoring the labor market. From the developments in real labor flows as well as real wage movements the central bank can infer on the dynamics and particularly, on the degree of persistence of the inflation rate. Therefore, differences in labor market regimes may help to explain inflation dynamics across countries.

The theoretical results in our paper depend on the specific parameter choice in the model's calibration. In a companion paper, Christoffel, Küster, and Linzert (2005), the parameters of the model are estimated to make a quantitative assessment of the model. In particular, we analyze the role of labor labor market rigidities for the transmission of monetary policy. The estimated model allows us to make explicit statements on the importance of wage rigidities for inflation dynamics. Moreover, we shed light on the relevance of labor market shocks for business cycle dynamics and monetary policy in particular.

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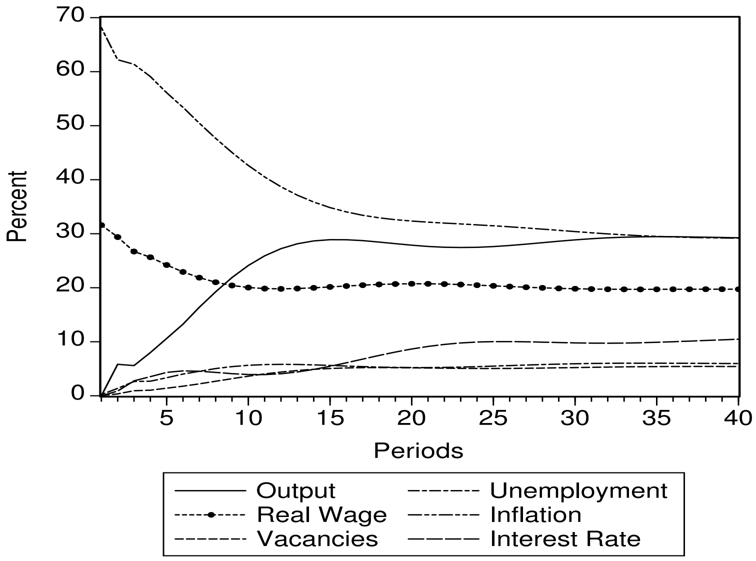
A Appendix

Table 2: Calibration for Benchmark Model without Wage Rigidity ($\delta = 0$)

Parameter	Description	Value
δ	Exogenously imposed wage rigidity	0
ρ_m	AR coefficient in monetary policy rule	0.9
γ_π	Coefficient on π_{t+1} in monetary policy rule	1.5
γ_y	Coefficient on y_t in monetary policy rule	0.5
σ	Coefficient of relative risk aversion	1.5
φ	$1-\varphi$: reset prob in stagg. price setting	0.68
β	Time discount factor	0.99
α	Labor elasticity in production funct.	0.667
ϕ	Disutility of work	5
ϱ	Exponent in matching function	0.9
ϱ_m	Scaling factor in matching function	0.4
ρ	Exogenous separation rate	0.08
η	Bargaining power	0.5
n	Steady-state non-employed workers	0.2

Figure 4: Variance Decomposition of German CPI Inflation



Notes: We estimate a VAR on quarterly data from 1978 to 2003 for German data using the empirical counterparts of the observed variables of our empirical model. Notice that similar results are obtained with U.S. data. The VAR is given by:

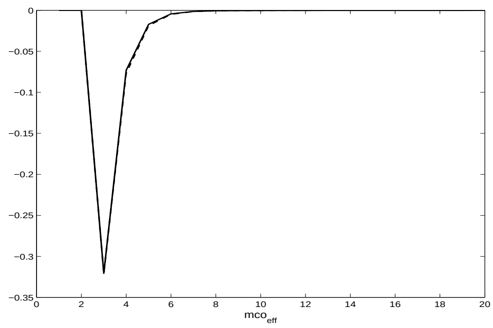
$$X_t = \alpha + \Theta_1 X_{t-1} + \ldots + \Theta_p X_{t-p} + \varepsilon_t \tag{34}$$

where ε is assumed to be an *i.i.d.* error term with zero mean and constant variance. The vector of endogenous variables is given by:

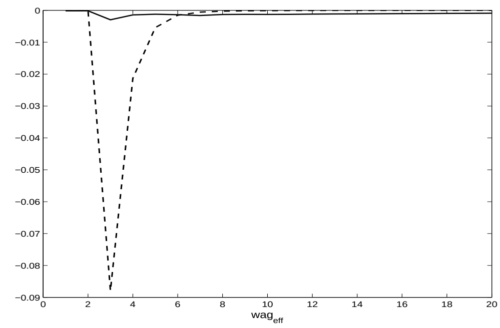
$$X_t = [i, y, v, e, u, wr, h, \pi] \tag{35}$$

denoting the interest rate, real income, vacancies, employment, unemployment, real wages, hours and inflation, respectively. All specification in logs and linearly detrended. Inflation is computed using the consumer price index. The augmented Dickey Fuller unit root test confirmed that all transformed variables were stationary. We estimate our VAR using one lag and also include a dummy for the unification break (first quarter in 1990) into VAR model. We use a simple Cholesky decomposition, i.e. an orthogonalized form of the covariance matrix to identify the shocks in the model. The problem of such an identification scheme is arbitrariness of the restrictions imposed in the sense that any ordering of the variables achieves identification of the system. We tried to order the variables according to the reasoning how a monetary policy shock is likely to be transmitted in our model, see Section 3.5. Note, however, that the results are robust to changes in the ordering of the data.

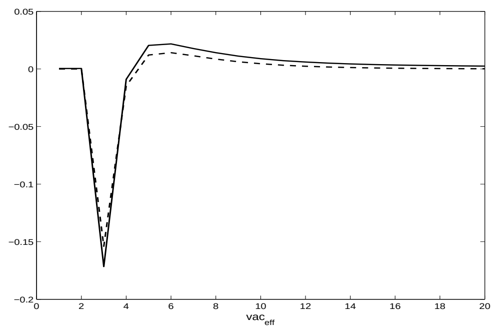
Figure 5: Impulse-Response Functions of a Monetary Policy Shock from Calibrated Model in an Efficient Bargaining Regime



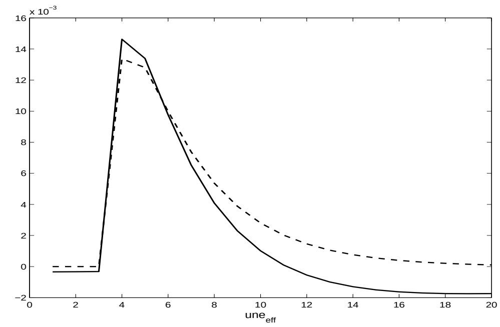
(a) Response of Marginal Cost



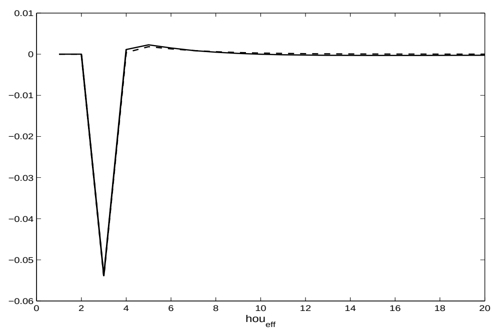
(b) Response of Real Wages



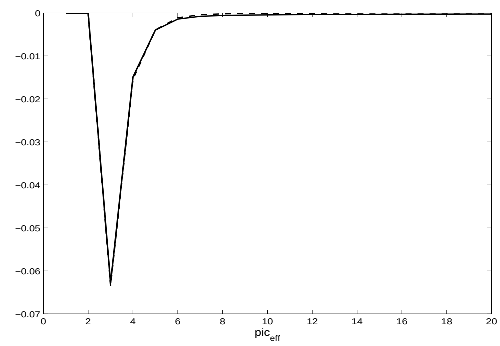
(c) Response of Vacancies



(d) Response of Unemployment



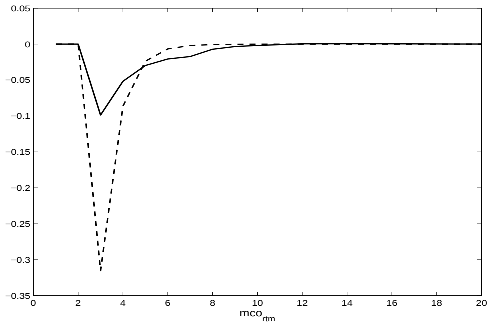
(e) Response of Hours of Work



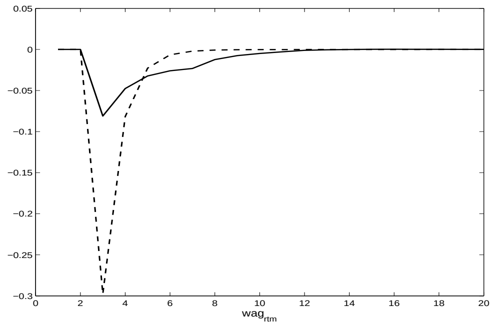
(f) Response of Inflation

Notes: The dashed line corresponds to the impulse-responses of the efficient bargaining without exogenously imposed wage rigidity, i.e. $\delta = 0$, see Equation (23). The solid line displays the impulse-response function of the efficient bargaining model with wage rigidity of $\delta = 0.9$. Notice that this is not an implausible value as it corresponds to an estimated AR(1) coefficient for an univariate real wage equation for U.S. and German data.

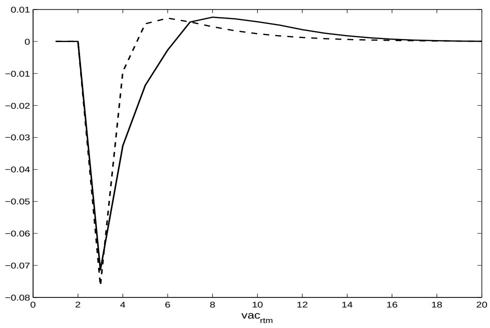
Figure 6: Impulse-Response Functions of a Monetary Policy Shock from Calibrated Model in a Right-to-Manage Bargaining Regime



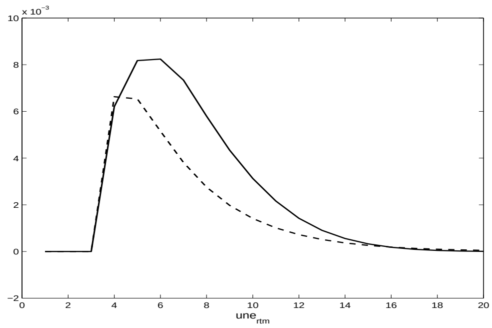
(a) Response of Marginal Cost



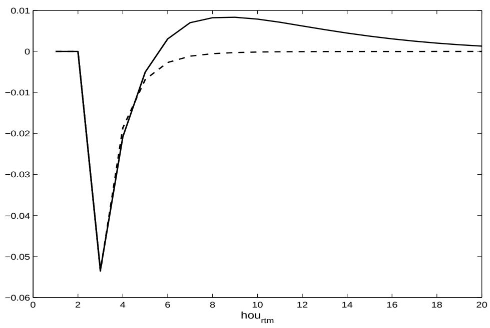
(b) Response of Real Wages



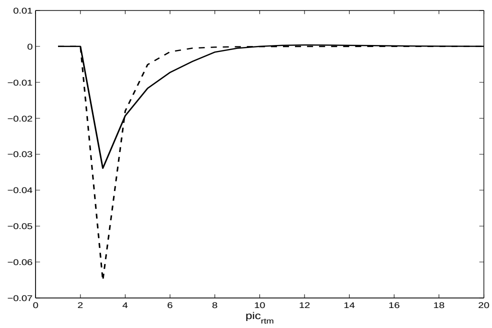
(c) Response of Vacancies



(d) Response of Unemployment



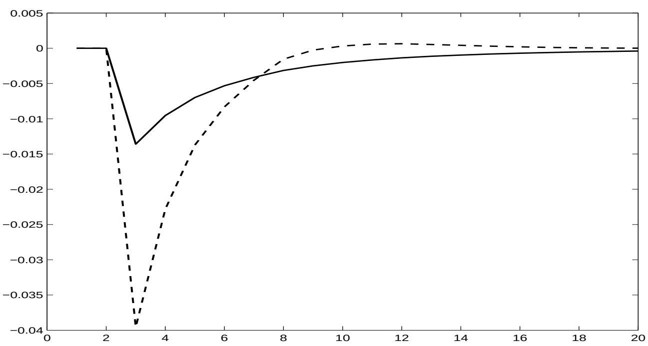
(e) Response of Hours of Work



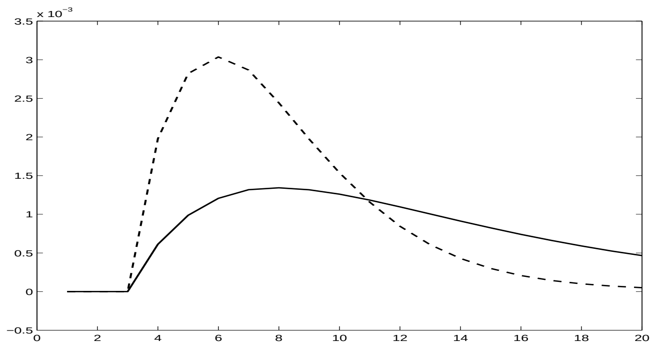
(f) Response of Inflation

Notes: The dashed line corresponds to the impulse-responses of the right-to-manage model without exogenously imposed wage rigidity, i.e. $\delta = 0$, see Equation (23). The solid line displays the impulse-response function of the right to manage model with wage rigidity of $\delta = 0.9$. Notice that this is not an implausible value as it corresponds to an estimated AR(1) coefficient for an univariate real wage equation for U.S. and German data.

Figure 7: Impulse-Response Functions of a Monetary Policy Shock from Calibrated Model with Decreased Workers' Bargaining Power



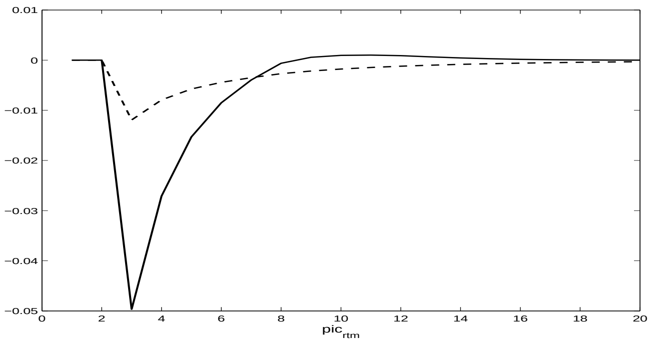
(a) Inflation



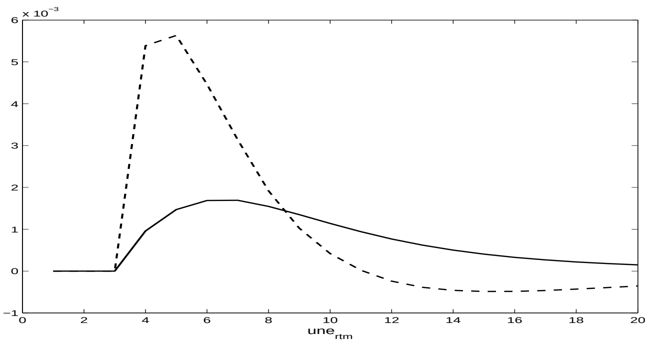
(b) Unemployment

Notes: The dashed line corresponds to the impulse-responses of the right-to-manage model with wage rigidity of $\delta = 0.9$. The solid line displays the impulse-response function of the model with a decrease from 0.5 to 0.03 in worker's bargaining power.

Figure 8: Impulse-Response Functions of a Monetary Policy Shock from Calibrated Model with Lower Job Destruction



(a) Inflation



(b) Unemployment

Notes: The dashed line corresponds to the impulse-responses of the right-to-manage model with wage rigidity of $\delta = 0.9$. The solid line displays the impulse-response function of the model with job destruction lowered from 8 percent to 0.1 percent.