Monetary Persistence and the Labor Market: A New Perspective

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Abstract

In this paper we propose a novel way to model the labor market in the context of a New-Keynesian general equilibrium model, incorporating labor market frictions in the form of hiring and firing costs. We show that such a model is able to replicate many important stylized facts of the business cycle. The reactions to monetary and real shocks become much more sluggish. Job creation and job destruction are negatively correlated. And the volatility of unemployment is much larger than in the standard search-and-matching model.

1 Introduction

This paper offers a novel approach of integrating labor market frictions into a standard New Keynesian model with sticky prices. The labor market frictions help explain (i) output and unemployment persistence in response to real and monetary shocks, (ii) strong amplification effects of real and monetary shocks on unemployment and the job finding rate, and (iii) the negative correlation between job creation and job destruction.

At the beginning of each period, unemployed workers choose randomly one of the firms and apply for a job. Worker-firm specific pairs are subject to idiosyncratic shocks. In addition, firms face linear hiring and firing costs. These simple assumptions are sufficient to replicate several important business cycle facts.

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First, our model generates output and unemployment persistence in reaction to monetary and real shocks and inflation persistence in response to real shocks. Labor turnover costs - which in this paper are represented by linear hiring and firing costs - lead to a sluggish adjustment in the labor market, even after the monetary impulse or the productivity shock have disappeared. Since labor turnover costs reduce the hiring and firing rates by making hiring and firing more costly, they reduce the levels of hiring and firing activity in the aftermath of a monetary shock. Sluggish labor market adjustment also leads to sluggish product market adjustment after a shock - more sluggish than in the standard New Keynesian models and in closer agreement with the empirical evidence.

Second, the labor market variables in the model show a strong amplification effect in response to both monetary and real shocks. In line with empirical evidence, the standard deviation of the job-finding rate and the unemployment is several times larger than the standard deviation of output. The reason is that idiosyncratic shocks play an important role for the creation of new jobs in our model.[1]

Third, our model is able to replicate a negative correlation between the job-finding rate and unemployment. Further, it generates a strong negative correlation between job creation and the job destruction.[2]

It is well known that the standard small-scale New Keynesian framework with a representative household and neoclassical labor markets does not generate any monetary persistence when the central bank deviates in uncorrelated manner from the Taylor rule interest rate behavior. To overcome this problem, medium scale DSGE models (e.g., Christiano et al., 2005, or Smets and Wouters, 2003, 2007) contain several assumptions which may be difficult to reconcile with microeconomic evidence (e.g., habit formation[3] or backward-looking indexation[4]).

Recently, the interaction of imperfect labor markets and labor adjustment costs with business cycle dynamics has drawn a lot of attention. Campbell and Fisher, 2000, analyze how hiring and firing costs affect job-turnover at the firm and industry level. Veracierto, 2008, shows in a model of employment lotteries that firing restrictions reduce business cycle fluctuations. In addition, there are several recent contributions that include search-and-matching frictions into the New Keynesian model (e.g., Walsh, 2005, Blanchard and Galí, 2007, Christoffel and Linzert, 2006, Faia, 2008, Krause and Lubik, 2007, Thomas, 2008, Barnichon, 2008).

As noted by Costain and Reiter, 2008, and Shimer, 2005, the standard

[1] In contrast, in the standard calibration of search-and-matching models, the idiosyncratic productivity shock is set to replicate the appropriate job destruction rate, while it plays only a minor role for job creation, which is primarily driven by the matching function. See Section 5 for a more detailed intuitive explanation.

[2] Search-and-matching models with endogenous separations and flexible wages are unable to do so. See Krause and Lubik, 2007.

[3] Habit formation may be present for specific goods or services, but not for the entire consumption bundle, as it is generally assumed in medium scale models.

[4] There is little empirical microeconomic evidence for such indexation. See Woodford, 2007, for a discussion of this issue.

search-and-matching model is not able to replicate the large volatilities of unemployment found in the data. There have been various attempts to remedy this problem. Hall, 2005 introduces wage rigidity. Hagedorn and Manovskii, 2008, propose an alternative calibration, using a very high value of unemployment, which implies that workers do not gain much from finding a job. They note that this is especially relevant for short-term unemployed people. Thus, their calibration obviously fits better to the US than to European countries with their comparably low job-finding rates. Cooper et al., 2005, build a very rich model with fixed and variable costs of hirings, adjustments on the intensive margin and autocorrelated firm-specific shocks. To be able to handle the complexity of the model, they deviate from the common assumption of wage negotiations and assume that firms can set the wage in a take-it-or-leave-it manner. We offer an alternative avenue of bringing the predictions of the new Keynesian model into closer consonance with the empirical evidence, namely, by introducing labor market frictions in the form of hiring and firing costs and providing a new analysis of labor market flows. The assumption of perfect labor markets is widely considered to be a conspicuous weakness of the standard new Keynesian models and this paper shows how this weakness may be addressed in a simple and tractable way and how doing so helps explain various well-know stylized facts.

Our analysis examines the influence of hiring and firing costs on the effectiveness of monetary policy.[5] These labor market rigidities are empirically observable[6] and the monetary policy transmission mechanism can be given a straightforward intuition on this basis.

In the absence of labor turnover costs, a worker's current employment probability is independent of whether she was previously employed or unemployed, so that her retention rate is equal to her job finding rate. In the presence of hiring and firing costs, by contrast, her retention rate exceeds her job finding rate, and thus current employment depends on past employment. In this setting, a current monetary shock affects not only current, but also future employment. Since labor is used to produce output, employment persistence is translated into output persistence.

Specifically, in the presence of a positive, temporary macroeconomic shock, workers are hired but, on account of firing costs, these workers are not promptly dismissed as soon as the shock is over. Thus, the effects of the shock on employment and output persist. But even in the absence of firing costs, hiring costs create employment and output persistence. For instance, once a temporary positive shock has passed, some workers are retained who would not have been hired in the absence of this shock, due to hiring costs. Thus the positive shock has persistent after-effects.[7] In this way, the inclusion of labor turnover

[5] Rotemberg and Woodford, 1999, analyze convex labor adjustment costs. But they focus solely on the implications of these costs for fluctuations of the markup over the business-cycle. Furthermore, their approach does not allow for unemployment.

[6] For the analysis and quantification of firing costs, see, for example, Botero et al., 2004, OECD, 2004, and World Bank, 2008.

[7] Alternatively, consider an employee whose productivity is just high enough to be retained.

costs can be shown to explain how monetary shocks have prolonged effects on output and employment.

We calibrate our model under realistic values of hiring and firing costs for a typical European economy. Under uncorrelated iid monetary shocks, it takes several quarters until the economy returns to the steady state, while the standard model generates no persistence at all. After autocorrelated productivity shocks, employment, output and inflation show hump-shaped responses. Thus labor adjustment costs offer a new explanation for output persistence, which has so far been largely unexplored.

The rest of the paper is structured as follows. Section 2 presents the theoretical model and Section 3 explains the calibration. Section 4 discusses the model outcomes, while Section 5 illustrates important business cycle statistics. Section 6 concludes.

2 The Model

Our model grafts a labor market with labor turnover costs, wage bargaining, and employed and unemployed workers onto a New Keynesian framework with Rotemberg adjustment costs. To endogenize hiring and firing decisions, it is assumed that the profitability of each worker is subject to an iid shock each period. Firms can change their price in any period but price changes are subject to quadratic adjustment costs. Monetary policy is represented by a Taylor rule.

2.1 Households

We assume that households have a standard utility function of the form:[8]

$$U_t = E_t \sum_{j=t}^{\infty} \beta^{j-t} \frac{c_j^{1-\sigma}}{1-\sigma}, \tag{1}$$

where β is the household's discount factor, σ the elasticity of intertemporal substitution, c a consumption aggregate (described below)[9] and E is the expectation operator.

As is common in the literature, we assume that each household consists of a large number of individuals, each individual supplies one unit of labor inelastically and shares all income with the other household members (see, e.g., Merz, 1995 or Andolfatto, 1996). This implies that consumption does not depend on a

An unemployed worker with the same productivity will not be offered a job, however, due to the positive hiring cost. In short, hiring costs create persistence in the aftermath of a shock, because in the presence of hiring costs, the retention probability of employees exceeds the hiring probability of the unemployed.

[8] This is similar to the utility function in Krause and Lubik, 2007, except that we do not need money in the utility function, since we model monetary policy by a Taylor rule rather than by a money growth rule.

[9] In what follows capital letters refer to nominal variables and small letters refer to real variables (i.e., detrended by the price level).

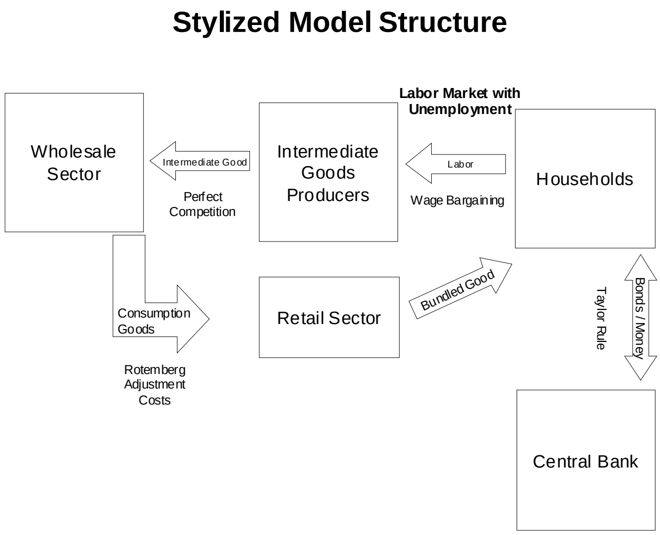

Figure 1: Model Structure

worker's employment status. Thus the representative household maximizes its utility subject to the budget constraint:

$$Bo_t + c_t P_t - T_t = W_t N_t + B_t U_t + (1 + i_{t-1}) Bo_{t-1} + \Pi_{a,t}, \tag{2}$$

where Bo are nominal bond holdings, P is the aggregate price level, T are tax payments, i is the nominal interest rate and Π_a are nominal aggregate profits, which are transferred in lump-sum manner, W is the nominal wage, N is the total household labor input, B the income of unemployed workers[10] and U the number of unemployed workers. The intertemporal utility maximization yields the standard consumption Euler equation:

$$c_t = \beta E_t c_{t+1} \left((1 + i_t) \frac{P_t}{P_{t+1}} \right)^{-\frac{1}{\sigma}}. \tag{3}$$

2.2 Production and the Labor Market

There are three types of firms. (i) Firms that produce intermediate goods employ labor, exhibit linear labor adjustment costs (i.e., hiring and firing costs) and sell their homogenous products on a perfectly competitive market to the wholesale sector. (ii) Firms in the wholesale sector transform the intermediate

[10] B can either be interpreted as home production or as unemployment benefits provided by the government (financed by lump-sum taxes).

goods into consumption goods and sell them under monopolistic competition to the retailers. They can change their price at any time but price adjustments are subject to a quadratic adjustment cost à la Rotemberg. (iii) The retailers, in turn, aggregate the consumption goods and sell them under perfect competition to the households. The structure of the model is illustrated in Figure 1.

2.2.1 Intermediate Goods Producers

Intermediate good firms hire labor to produce the intermediate good z. Their production function is:

$$z_t = a_t N_t, \tag{4}$$

where a is technology and N the number of employed workers. They sell the product at a relative price $p_{z,t} = P_{z,t}/P_t$, which they take as given in a perfectly competitive environment, where P_z is the absolute price of the intermediate good and P is the economy's overall price level.

The labor market approach follows Snower and Merkl, 2006, and Brown, Merkl and Snower, 2007, who model the labor market in a pure partial equilibrium setting, while we extend it to a general equilibrium setting.[11]

We assume an economy with a large number of firms and a large number of workers. At the beginning of each period, unemployed workers choose randomly one of the firms and apply for a job there. For the resulting worker-firm pair, an idiosyncratic distributional operating cost, ε_t, is drawn, e.g., during the subsequent interview the mutual fit is revealed. The operating costs are measured in terms of the final consumption good. If the shock is sufficiently bad, no match will be made, the worker stays unemployed this period and will contact an other firm next period. Employed workers are hit by a shock, drawn from the same distribution

The firms learn the value of the operating costs of every worker at the beginning of a period and base their employment decisions on it, i.e., an unemployed worker with a favorable shock will be employed while an employed worker with a bad shock will be fired. Hiring and firing is not costless, firms have to pay linear hiring costs, h, and linear firing costs, f, both measured in terms of the final consumption good. Wages are determined by bargaining between the median worker and the firm.

We assume the following sequence of decisions: First, the operating cost shock takes place. Second, wages are negotiated. And finally, firms make their hiring and firing decisions, taking the operating costs and the wage as given.

Thus, firms will only hire those workers who face low operating costs (see Figure 2) and fire those workers who face high operating costs. Note that the retention rate (i.e., 1 minus the firing rate) is always bigger than the firing rate. The hiring and firing costs drive a wedge between the hiring rate and the retention rate. Once workers are inside the firm, they are protected by firing

[11] The approach is similar to the way that separations are endogenized in search-and-matching models, see Morstensen and Pissarides, 1999.

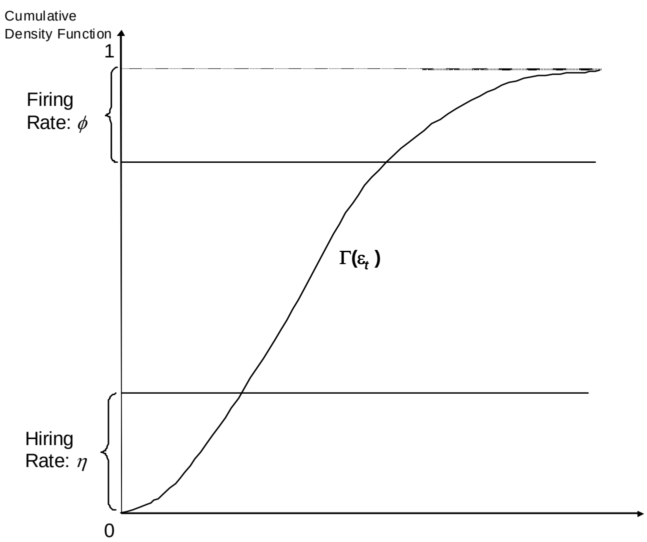

Figure 2: The effect of hiring and firing costs

costs (i.e., she will only be fired if her present value of profits is smaller than minus the firing costs), while the firm has to expense hiring costs to obtain a worker in the first place (i.e., she will only be hired if her present value of profits is bigger than the hiring costs).

Thus, the real expected profit generated by a worker with operating cost ε_t is:[12]

$$\tilde{\Pi}_{I,t}(\varepsilon_t) = a_t p_{z,t} - w_t - \varepsilon_t + E_t \sum_{j=t+1}^{\infty} \Delta_{t,j} \left[\begin{array}{c} \left(1-\phi_j\right)^{j-t} \left(\begin{array}{c} a_j p_{z,j} - w_j - \\ E_t(\varepsilon_j | 1-\phi_j) \end{array} \right) - \\ \phi_j f_j (1-\phi_j)^{j-t-1} \end{array} \right], \tag{5}$$

where w is the real wage, $\phi_t = \phi^x + (1-\phi^x)\,\phi_t^n$ is the separation probability,[13] $\Delta_{t,j}$ is the stochastic discount factor from period t to j (i.e., the subjective discount factor weighted with respective periods' marginal consumption utility) and $E_t(\varepsilon_{t+1}|1-\phi_{t+1})$ the expected value of operating costs for an insider (i.e., conditional on retention), given by:

$$E_t(\varepsilon_{t+1}|1-\phi_{t+1}) = E_t \left(\frac{1}{1-\phi_{t+1}} \int_{-\infty}^{\upsilon_f} \varepsilon_{t+1} g(\varepsilon_{t+1}) d\varepsilon_{t+1} \right). \tag{6}$$

[12] We only consider transitory productivity shocks in this paper and ignore productivity growth. In the working paper version, Lechthaler et al., 2008, we show that trending labor turnover costs and operating costs is sufficient to assure that unemployment is unaffected by growth.

[13] As usual in the literature (see, e.g., Krause and Lubik, 2007), we assume that separations consist of an exogenous part and an endogenous part.

where $g(\varepsilon_t)$ is the probability density function of the operating cost. To simplify the profit function, we rewrite it in recursive manner:

$$\tilde{\Pi}_{I,t} = a_t p_{z,t} - w_t - \varepsilon_t + E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}), \tag{7}$$

where $E_t(\tilde{\Pi}_{I,t+1})$ are expected future profits, defined as:

$$E_t(\tilde{\Pi}_{I,t+1}) = E_t \left(\begin{array}{c} (1-\phi_{t+1})(p_{z,t+1}a_{t+1} - w_{t+1} - E_t(\varepsilon_{t+1}|1-\phi_{t+1})) \\ +(1-\phi_{t+1})E_{t+1}(\Delta_{t,t+1}\tilde{\Pi}_{I,t+2}) - \phi_{t+1}f_{t+1} \end{array} \right). \tag{8}$$

Unemployed workers are hired whenever their operating cost does not exceed a certain threshold such that the profitability of this worker is higher than the hiring cost (see Figure 2 for the graphical illustration), i.e., $\tilde{\Pi}_{I,t}(\varepsilon_t) > h_t$. Thus, the hiring threshold $\upsilon_{h,t}$ (the value of the operating cost at which the firm is indifferent between hiring and not hiring an unemployed worker) is defined by:

$$\tilde{\Pi}_{I,t}(\upsilon_{h,t}) = a_t p_{z,t} - w_t - \upsilon_{h,t} + E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}) = h_t. \tag{9}$$

Unemployed workers whose operating cost is lower than this value get a job, while those whose operating cost is higher remain unemployed. The resulting hiring probability is given by:

$$\eta_t = \Gamma(\upsilon_{h,t}), \tag{10}$$

where Γ is the cumulative density function of ε. Similarly, the firm will fire a worker whenever $\tilde{\Pi}_{I,t}(\varepsilon_t) < -f_t$, i.e., when the operating costs are so high that it is more profitable for the firm to pay the firing cost. This defines the firing threshold (the value of the operating cost at which the firm is indifferent between firing and retaining the worker) as

$$\tilde{\Pi}_{I,t}(\upsilon_{f,t}) = a_t p_{z,t} - w_t - \upsilon_{f,t} + E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}) = -f_t, \tag{11}$$

and the rate of endogenous job destruction is given by

$$\phi_t^n = 1 - \Gamma(\upsilon_{f,t}). \tag{12}$$

2.2.2 Employment

The change in employment $(N_t - N_{t-1})$ is the difference between the hiring from the unemployment pool (ηU_{t-1}) and the firing from the employment pool (ϕN_{t-1}), where U_{t-1} and N_{t-1} are the aggregate unemployment and employment levels: $N_t - N_{t-1} = \eta U_{t-1} - \phi N_{t-1}$. Letting $(n_t = N_t/L_t)$ be the employment rate, we assume a constant workforce, L_t, and normalize it to one. Therefore, we obtain the following employment dynamics curve.

$$n_t = n_{t-1}(1 - \phi_t - \eta_t) + \eta_t. \tag{13}$$

The unemployment rate is simply $u_t = 1 - n_t$.

2.2.3 Wage Bargaining

We assume that wages are bargained between the firm and its median worker. This assumption fits especially well to the unionized labor markets of continental Europe, but even in the US many industries are influenced by trade unions.[14] In analogy to Hall and Milgrom, 2008, and Snower and Merkl, 2006, we assume that the fall-back position is to continue negotiations next period.[15] To highlight that our results are driven by labor turnover costs, the wage is calibrated in such a way that it responds strongly to changes in average productivity.

The wage is renegotiated in each period t. Under bargaining agreement, the worker receives the real wage w_t and the firm receives the expected profit $(a_t p_{z,t} - w_t - \bar{\varepsilon})$, where $\bar{\varepsilon}$ is the operating cost of the median worker. Under disagreement, the worker's fallback income is b, assumed for simplicity to be equal to real unemployment benefits.[16] The firm's fallback profit is $-s$, i.e., during disagreement there is no production, but the firm suffers some constant and exogenously given losses s. This may be a fixed cost or a cost that is imposed due to a strike. Assuming that disagreement in the current period does not affect future surpluses, the surplus of the worker is $w_t - b$, while the firm's surplus is $a_t p_{z,t} - w_t - \bar{\varepsilon} + s$. Consequently, the Nash-product is:

$$\Lambda_t = (w_t - b)^{\gamma} (a_t p_{z,t} - w_t - \bar{\varepsilon} + s)^{1-\gamma}, \tag{14}$$

where γ represents the bargaining strength of the worker relative to the firm. Maximizing the Nash-product with respect to the real wage, yields the following equation:

$$w_t = \gamma (a_t p_{z,t} - \bar{\varepsilon} + s) + (1-\gamma) b. \tag{15}$$

2.2.4 Wholesale Sector and Retail Sector

Firms in the wholesale sector are distributed on the unit interval and indexed by i. They produce a differentiated good $y_{i,t}$ using the linear production technology $y_{i,t} = z_{i,t}$, where $z_{i,t}$ is their demand for intermediate goods. They sell their goods under monopolistic competition to the retailers who use the differentiated goods to produce the final consumption good according to the Dixit-Stiglitz-aggregator:

$$y_t = \left(\int y_{i,t}^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{16}$$

which delivers the standard price index (where $P_{i,t}$ and $y_{i,t}$ denote the firm specific price and output level respectively):

[14] E.g. Hall and Milgrom, 2008, motivate their bargaining setup by referring to negotiations between General Motors and the United Auto Workers.

[15] See Cheron and Langot, 2004, for another way to break the close link between the labor market and wage negotiations.

[16] Note that b is the real unemployment benefit, while B, as used in the household's budget constraint, is the nominal unemployment benefit.

$$P_t = \left(\int P_{i,t}^{1-\varepsilon} di \right)^{\frac{1}{1-\varepsilon}}, \tag{17}$$

from the cost minimization problem of the aggregating firm. The implied demand function for differentiated products is:

$$y_{i,t} = y_t \left(\frac{P_{i,t}}{P_t} \right)^{-\varepsilon}. \tag{18}$$

Firms in the wholesale-sector can change their prices every period, facing quadratic price adjustment costs a la Rotemberg. They maximize the following profit function:

$$\tilde{\Pi}_{W,t} = E_t \sum_{j=t}^{\infty} \Delta_{t,j} \left[\frac{P_{i,j}}{P_j} y_{i,j} - p_{z,j} y_{i,j} - \frac{\Psi}{2} \left(\frac{P_{i,j}}{P_{i,j-1}} - \bar{\pi} \right)^2 y_j \right],$$

where Ψ is a parameter measuring the extent of price adjustment costs and $\bar{\pi}$ is the steady state inflation rate. Taking the derivative with respect to the price, yields – after some manipulations – the standard price-setting rule under Rotemberg adjustment costs:

$$\begin{aligned} &(1-\varepsilon) + \varepsilon p_{z,t} - \Psi \left(\pi_t - \bar{\pi} \right) \pi_t \\ &+ E_t \{ \Delta_{t,t+1} \Psi \left(\pi_{t+1} - \bar{\pi} \right) \frac{y_{t+1}}{y_t} \pi_{t+1} \} = 0. \end{aligned} \tag{19}$$

2.3 Aggregation

To be able to implement the resource constraint, we need to derive the sectors' profits. The real profits of intermediate firms ($\tilde{\Pi}_I$) are revenues minus wage payments minus operating costs minus labor turnover costs:

$$\tilde{\Pi}_{I,t} = p_{z,t} a_t n_t - w_t n_t - (1-\phi_t) n_{t-1} (1 - \Xi_t^i) - \tag{20}$$

$$(1 - n_{t-1}) \eta_t (1 - \Xi_t^e) - n_{t-1} \phi_t f_t - (1 - n_{t-1}) \eta_t h_t, \tag{21}$$

where Ξ_t^i is the expected value of operating costs for insiders, conditional on not being fired and Ξ_t^e is the expected value of operating costs for entrants, conditional on being hired, defined by:

$$\begin{aligned} \Xi_t^e &= \frac{\int_{-\infty}^{\upsilon_h} \epsilon_t f(\epsilon_t) d\epsilon_t}{\eta_t}, \\ \Xi_t^i &= \frac{\int_{-\infty}^{\upsilon_f} \epsilon_t f(\epsilon_t) d\epsilon_t}{1 - \phi_t}. \end{aligned}$$

The real profits ($\tilde{\Pi}_W$) of the monopolistic competitors (i.e., the wholesale sector) are:

$$\tilde{\Pi}_{W,t} = y_t - p_{z,t} a_t n_t - \frac{\Psi}{2} \left(\pi_t - \bar{\pi}\right)^2 y_t,$$

while the retailers make zero-profits. Hence overall real profits are given by:

$$\begin{aligned} \tilde{\Pi}_{a,t} &= y_t - w_t n_t - n_{t-1}\phi_t f_t - (1 - n_{t-1})\, \eta_t h_t - (1 - \phi_t) n_{t-1}(1 - \Xi_t^i) \quad (22) \\ & (1 - n_{t-1})\eta_t (1 - \Xi_t^e) - \frac{\Psi}{2} \left(\pi_t - \bar{\pi}\right)^2 y_t. \quad (23) \end{aligned}$$

Substituting this into the resource constraint (2) (together with $Bo_t = Bo_{t-1} = 0$), we get the relation between consumption and production:

$$\begin{aligned} c_t &= y_t - n_{t-1}\phi_t f_t - (1 - n_{t-1})\eta_t h_t - (1 - \phi_t) n_{t-1}(1 - \Xi_t^i) - \\ & (1 - n_{t-1})\eta_t (1 - \Xi_t^e) - \frac{\Psi}{2} \left(\pi_t - \bar{\pi}\right)^2 y_t. \end{aligned} \quad (24)$$

The resource constraint tells us that aggregate consumption is equal to aggregate production minus aggregate labor turnover costs (since real resources are used for the labor turnover costs) minus aggregate operating costs.

2.4 Monetary Policy

Monetary policy follows a standard Taylor rule:

$$\left(\frac{1 + i_t}{1 + \bar{\imath}}\right) = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi} \left(\frac{y_t}{y}\right)^{\alpha_y} e^{\lambda_t}, \quad (25)$$

where π_t is the gross inflation rate (i.e., P_t/P_{t-1}), $\bar{\pi}$ is the central bank inflation target, y_t is the actual output, y is the steady state level of output and $\bar{\imath}$ is the natural interest rate (for a given output and inflation level). λ_t is an exogenous shock to the Taylor rule.

3 Model Calibration

We parameterize our model and use a first order approximation to generate the impulse response functions, the second moments and the correlations between different variables.[17] We use a standard quarterly discount rate of one percent, $\beta = 0.99$, and an intertemporal elasticity of substitution of $\sigma = 2$. The elasticity of substitution between different product types, ε, is set to 10 (see, e.g., Galí, 2008).

[17] For the used solution algorithm see, e.g., Juillard, 1996.

Table 1: Parameters of the Numerical Model

Parameter	Description	Value	Source
β	Subjective discount factor	0.99	Standard value
σ	Intertemp. elasticitiy of subst.	2	Standard value
ε	Elasticity of subst.	10	Gali, 2003
Ψ	Price adjustment cost	104.85	Equivalent to $\theta = 0.75$
a	Productivity	1	Normalization
γ	Workers' bargaining power	0.5	Standard value
f	Firing cost	0.6	Bentolila and Bertola, 1990
h	Hiring cost	0.1	Chen and Funke, 2003
b	Unemployment benefits	0.65	OECD, 2007
$E(\varepsilon)$	Expected value of op. costs	0	Normalization
sd	Distr. scaling parameter	0.44	To match the flow rates
s	Payments under disagreement	0.2	To match the flow rates
α_π	Taylor-rule	1.5	Standard value
α_y	Taylor-rule	0.125	Standard value

As usual in the literature, we set the coefficients in the Taylor rule as follows: $\alpha_\pi = 1.5$ and $\alpha_y = 0.125$.[18]

The parameter of price adjustments, Ψ, is calibrated in line with microeconometric evidence for Europe (see Alvarez et al., 2006).[19] For simplicity, we normalize the yearly labor productivity to $a = 1$. The bargaining power of workers, γ, is set to the standard value 0.5.

We take continental Europe as our reference point. We set the firing costs to 60 percent ($f = 0.6$) of the annual productivity which amounts to approximately 68 percent of the annual wage[20] and the hiring costs[21] to 10 percent ($h = 0.1$)[22] of annual productivity. In our numerical exercise we will do robustness checks

[18] We assume a standard error of 0.01 for the interest rate shock.

[19] Thus, the log-linearized Phillips curve under Calvo price adjustment under an average price duration of four quarters ($\theta = 0.75$, see Appendix) and under our chosen calibration for Rotemberg adjustment costs are equivalent.

[20] For the period from 1975 to 1986 Bentolila and Bertola, 1990, calculate firing costs of 92 percent, 75 percent and 108 percent of the respective annual wage in France, Germany and Italy respectively. The OECD, 2004, reports that many European countries have reduced their job security legislation somewhat from the late 1980 to 2003 (in terms of the overall employment protection legislation strictness). Therefore, we consider $f = 0.6$ to be a realistic number for continental European countries.

[21] See Chen and Funke, 2003. Empirical studies on training costs show that training costs are very substantial. Dolfin, 2006, shows that the average training time of a worker takes 201 hours (i.e., roughly 25 working days) during the first quarter of employment. Thus, our number is probably rather a lower bound. To the best of our knowledge, there is no corresponding evidence for Europe.

[22] The choice of hiring costs vary widely in the search-and-matching literature. While Andolfatto, 1996, Thomas and Zanetti, 2009 or Gertler and Trigari, 2009 use hiring costs of approximately 1 percent of output, Shimer, 2005, uses 7 percent, Hall, 2005, uses 8 percent and Mortensen and Pissarides, 1999, use 15 percent. Thus, with our choice we lie well in the middle of the values used in the literature.

with respect to the magnitude of labor turnover costs. We set the unemployment benefits to 65 percent of the level of productivity ($b = 0.65$). This implies, that in steady state the wage replacement rate is roughly 74 percent, which is in line with evidence for continental European countries (see OECD, 2007).

Operating costs are assumed to follow a logistic distribution with zero mean.[23] The scaling parameter of the distribution and the payments under disagreement, s, are chosen in such a way that the resulting labor market flow rates match the empirical hiring and firing rates described further below. This yields a scale parameter of 0.44 and payments under disagreement of 0.2.

We calibrate our flow rates using evidence for West Germany, as there are only Kaplan-Meier functions for individual countries.[24] But we will show further below that these flow numbers are line with other important continental European countries. Wilke's, 2005, Kaplan-Meier functions indicate that about 20 percent of the unemployed leave their status after one quarter. For a steady state unemployment rate of 9 percent, a quarterly separation rate of 2 percent is necessary. This is roughly in line with Wilke's estimated yearly risk of unemployment. Further, we assume that the steady state share of exogenous separations is two thirds. This is in line with Krause and Lubik, 2007, and German evidence (see, e.g., Erlinghagen, 2005).

The used flow numbers are in line with the OECD, 2004, numbers for other continental European countries.[25] We conclude that a quarterly job-finding rate of $\eta = 0.20$ and a firing rate of $\phi = 0.02$ are reasonable averages for continental European countries.

4 Labor Turnover Costs and Output Persistence

This section demonstrates how labor turnover costs affect the response of output to monetary and real shocks. We first consider an uncorrelated iid shock to the central bank's Taylor rule. We next consider an autocorrelated shock to aggregate productivity. Finally, we illustrate in more detail the role of labor turnover costs on output persistence and demonstrate that our model also generates output persistence for lower values of labor turnover costs.

4.1 One-Off Shock

Let us assume that there is a one-off expansionary shock to the central bank's Taylor rule of one percent (i.e., the nominal interest is 1 percent below the interest rate under a purely rule based behavior). In the standard New-Keynesian

[23] The logistic distribution is very close to the normal distribution, but has an explicit closed form expressions.

[24] We choose the Kaplan-Meier functions for Germany, as it is the largest continental European country.

[25] Although the numbers of the OECD outlook are not directly applicable to our model, since they are built on a monthly basis, it is possible to adjust them using a method described in Shimer, 2007.

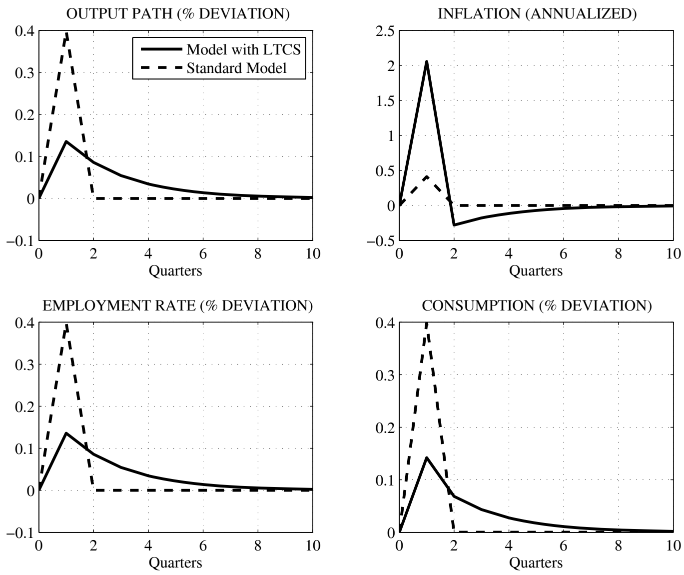

Figure 3: Reaction to an uncorrelated interest-rate shock in the model with LTCs and in the standard model

model (see Galí, 2008) this kind of shock generates no persistent change in output or inflation. The variables jump during the impact period and immediately return to their steady state values afterwards (see Figure 3). In the figure it can also be seen that the reaction is different under the new proposed model structure with labor turnover costs (LTCs). It turns out that hiring and firing costs create considerable persistence in the output response (see part 3 of this Section for further numerical illustrations). The figure also hints at the source of persistence. The slow adjustment of employment drives the result.

As usual, an expansionary shock lowers the real interest rate (as the nominal interest rate was adjusted downwards by the central bank and firms cannot adjust their prices flexibly). Therefore, households increase their demand for consumption goods (see consumption Euler equation). To satisfy the bigger demand, firms have to increase their workforce. They can do so via two different channels, by hiring more workers and firing fewer workers.[26] Since this is costly, the initial response is more dampened than in a model without labor turnover costs.

Even though the shock has disappeared after the first period, it shows long-

[26] It is well known in the literature that the extensive margin plays the dominant role for business cycle adjustment compared to the intensive margin. Hansen, 1985, shows that 55 percent of the variation in hours worked is due to variations in the number of employed people, while only 20 percent can be directly attributed to the average hours worked (the rest is due to the covariance term). Thus, the adjustment mechanism in our model is in line with this evidence. The underlying reason is that employment changes on the intensive margin are also associated with costs, namely, the costs of overtime.

lasting after-effects. Some of the workers who are below the firing threshold generate no profit for the firm (i.e., they would not be hired if they were not already within the firm), but it is not worthwhile to fire them, as the expected loss is smaller than the firing costs which would have to be expended. In this way, labor adjustment costs create a sluggish employment adjustment, which affects other markets in a general equilibrium setting.

Note that, in the context of the simplistic model above, inflation increases sharply in the first period and then undershoots its long-run equilibrium value.[27] This counterfactual result is no longer present when monetary shocks are sufficiently autocorrelated, as shown in the working paper version of this paper (see Lechthaler et al., 2008).[28]

4.2 Productivity Shocks

In this section, we describe the effects of an autocorrelated shock to aggregate productivity. As is standard in the literature, we use a coefficient of autocorrelation of 0.95 and a standard deviation of 0.008. Figure 4 illustrates the results.

While autocorrelated shocks are necessary to generate output persistence in the standard model, in our model they are sufficient to generate a hump-shaped response in output (see Figure 4). This feature is especially attractive, given that empirical studies typically find a hump-shape in output (see, e.g., Christiano et al., 2005, and Smets and Wouters, 2003).

Again this result is due to labor turnover costs. Hiring and firing costs imply that adjusting output is costly. Therefore, the impact reaction is dampened. By contrast, in later periods the level of output is already high and therefore further increases are relatively cheap. In other words, due to turnover costs the firm wants to smooth out the adjustment of the workforce.

In contrast, in the standard model without any adjustment costs, the output jumps up to its highest level in the first period and then slowly converges back to its steady state level, one-to-one with the movement in productivity. Note that, although the first reaction in output in our model is dampened by labor turnover costs, the jump in output is still larger than in the standard model. This is due to the decrease in employment in the standard model, as can be seen in the lower left panel of Figure 4, which counteracts the increase in output due to the increase in productivity. In our model, by contrast, employment increases (rather than decreases) in the immediate aftermath of the shock due to the labor turnover costs.[29]

[27] Since intermediate goods producers have the biggest employment adjustment during the shock period, marginal costs - and with it inflation - increase accordingly. Subsequently, firing increases and hiring falls, as the firm's employment gradually converges to its steady state. A lower hiring rate increases the quality of entrants, which manifests in lower operating costs. The higher firing improves the quality of insiders, as only the more productive workers are retained. Both effects reduce marginal cost in the aftermath of the shock and thus inflation undershoots.

[28] For evidence on autocorrelated monetary shocks see, e.g., Rudebusch, 2002, 2006, or Fève et al., 2007. Other common assumptions, such as backward indexing, would also avoid the occurrence of undershooting inflation.

[29] It should be kept in mind, that in the standard model employment adjusts via the inten-

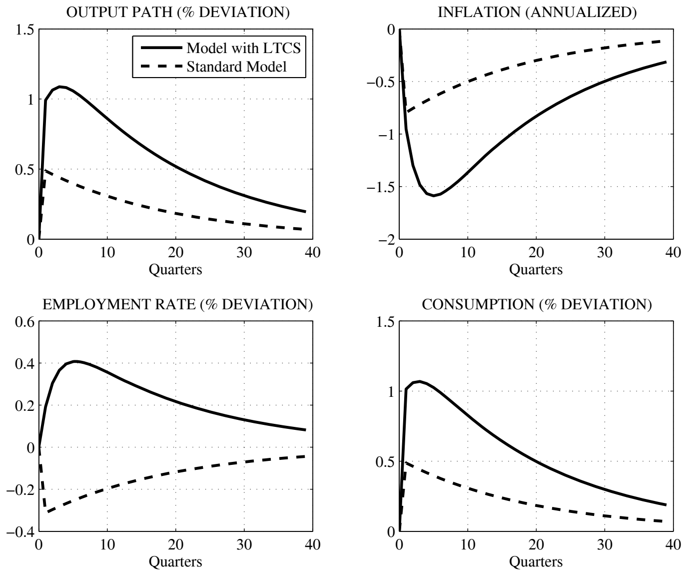

Figure 4: Reaction to a correlated productivity shock in the model with LTCs and in the standard model

4.3 The Effect of Labor Turnover Costs

The purpose of this section is twofold. On the one hand, we want to show that both hiring and firing costs tend to increase persistence. On the other hand, we will demonstrate that our model can generate a lot of persistence even for fairly low labor turnover costs.

In our model, labor turnover costs have two effects. First, they change the steady states. Lower labor turnover costs lead to higher employment rates and more production. This corresponds to the observation that the United States have higher employment rates and lower labor turnover costs than Europe.[30] Second, as will be shown below, labor turnover costs increase output persistence in response to monetary and real shocks.

To illustrate that, Figure 5 compares our standard calibration with an economy where firing costs are somewhat lower and somewhat higher than in the baseline calibration (i.e., 50 and 70 percent of the annual wage respectively instead of 60 percent as before), keeping all other deep parameters constant. For

sive margin, i.e., hours worked, while in our model adjustment takes place via the extensive margin. The employment reaction to productivity shocks is a hotly debated empirical issue. Some authors find a negative employment reaction after positive productivity shocks (see, for example, Galí, 1999), while others find the opposite (see, for example, Dedola and Neri, 2007).

[30] Under the given model structure, the employment rate does not generally increase with lower firing costs. For the chosen calibration this is however the case, as the hiring rate reacts more elastically than the firing rate (due to the calibration of the operating costs). This feature is in line with recent empirical evidence, which shows that hiring is more important than firing to explain the business cycle dynamics (see, e.g., Shimer, 2005).

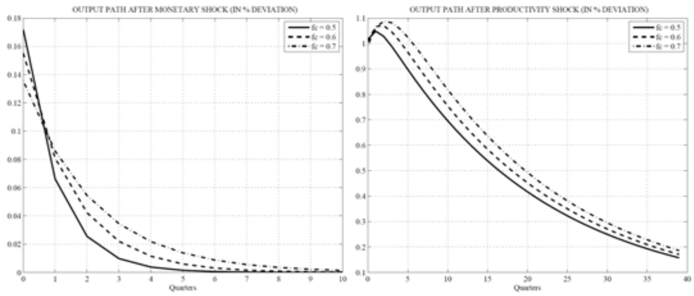

Figure 5: The effect of different firing costs

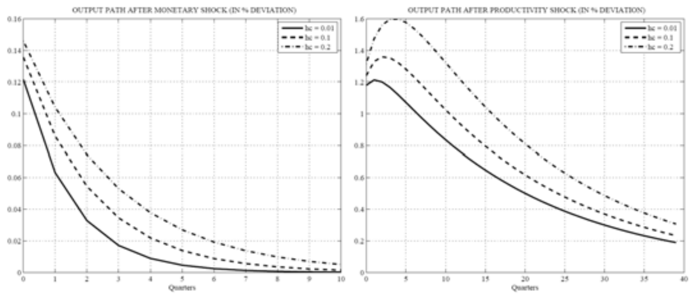

Figure 6: The effect of different hiring costs

comparability reasons (as there are steady state movements), we express all the effects in terms of percentage deviations from the respective steady state. The left hand panel shows the impulse response function after a one-period interest-rate shock, while the right hand panel illustrates an autocorrelated productivity shock. As before the autoregressive component is set to 0.95.

Figure 5 shows that higher labor turnover costs lead to more output persistence. The larger the firing costs are, the more sluggish is the adjustment process after both, interest rate and productivity shocks. While the adjustment during the impact period is more pronounced in an economy with lower labor adjustment costs, the economy also returns more quickly to the steady state (i.e., shows less persistence). Thus, the adjustment is slowed down by labor turnover costs. Note, however, that even for lower values of firing costs output is still considerably more persistent than in the standard model.

Figure 6 repeats the same exercise for varying degrees of hiring costs. Similar to firing costs, hiring costs tend to lead to more sluggish responses and higher persistence. Note, however, that the effects are relatively small and so our model still generates a large degree of output persistence even when we lower the hiring costs to 1% of annual output.

Given the fact, that European countries have considerably higher firing costs, our model would thus predict that persistence is higher in Europe than in the US, while econometric studies show a very similar pattern of the output response to a monetary policy shock (persistent and hump-shaped responses in both cases)

The evidence on the volatility of business cycles across is mixed. Backus et al., 1995, find that the unconditional volatilities in Europe (for output and employment) are lower than in the United States. This is consonant with the predictions of our model. However, there is also evidence from Vectorautoregressions that shows that the reactions to monetary policy shocks in Europe and in the United States are very similar (see, e.g., Angeloni et al., 2003).

One way to resolve this possible contradiction to our model would be to consider realistic countervailing effects (which, for brevity, we have not included in the model above). For example, it can be shown that the more competitive are product markets, the greater is the corresponding degree of output persistence in response to monetary shocks.[31] Since product markets in the US generally are considered more competitive than those in Europe, on average, this mechanism would be one way to reconcile our model with the empirical evidence. Furthermore, micro-econonometric studies suggest a higher degree of price stickiness in Europe than in the United States (see, for example, Bils and Klenow, 2004, and Alvarez et al., 2006), and this, too, has implications for the comparative degree of monetary persistence.

Moreover, it would be premature to believe that the empirical literature has resolved the question about whether monetary shocks are equally persistent in Europe and the US. In recent studies in this area, the microeconomic structure of estimated medium scale models for Europe and the United States (Smets and Wouters, 2003 and 2007) is specified in a similar manner. Thus these studies examine the data with the same priors on the labor market structure. This may be responsible for the fact that these estimated models generate similar amounts of monetary persistence for Europe and the United States. It remains for future research to examine whether the specification of different labor market structures in Europe and the United States - reflecting differences in labor market institutions in these areas - may lead to different results concerning comparative monetary persistence.

5 Business Cycle Statistics

To be able to make more profound statements on the performance of our model, we simulate the model economy stochastically and compare the outcome to the properties of time series data. As hiring and firing costs are particularly relevant in Europe, we have calibrated our model economy to a typical continental European country. Unfortunately, the relevant labor market data for the euro zone is not available.[32] Thus, we compare the model simulations to Germany,

[31] See, for example, Merkl and Snower, 2009, for more details.

[32] Christoffel et al., 2009, have constructed a labor market data set for the euro zone. Note, however, that it does not contain important variables such as the job-finding rate and the

the largest European economy. The labor market facts are taken from Gartner et al., 2009,[33] and the aggregate data on output and inflation from the OECD, 2009.

We proceed in two steps. First, we compare our model to the standard New Keynesian model (NKM), using productivity and interest rate shocks. Second, we compare our model to Krause and Lubik, 2007, who simulate a NKM with a matching function and endogenous separations. For comparability reasons, we replace our interest rate rule with money demand and money supply disturbances in this exercise, as in Krause and Lubik, 2007.

In line with the analysis above, we consider productivity shocks and interest rate shocks (i.e., aggregate supply and demand disturbances) when we compare our model to the standard NKM. Both exercises are done for an interest rate rule with and without interest rate smoothing (smoothing parameter 0.8) and compared to the outcome of the standard NKM. We also simulate the model economy with both shocks simultaneously.[34] As noted, our model generates substantial inflation, output, and unemployment persistence in response to productivity shocks (see last three columns in Figure 7). The autocorrelations for inflation, output and unemployment under productivity shocks with interest rate smoothing are very close to what can be found in the actual data. In a similar vein, our model generates output and unemployment persistence in response to interest rate shocks (with and without smoothing). Note, that both our model and the standard NKM do not perform well in replicating inflation persistence in response to an interest rate shock. Therefore, medium scale NKMs (see, e.g., Smets and Wouters, 2003, Christiano et al., 2005) introduce additional adjustment mechanisms to increase the inflation persistence. Of course, these mechanisms would also increase the inflation persistence in our model.

Our simple labor market model provides a new mechanism to the NKM, which generates considerable persistence and richer dynamics (see, for example, the correlation between output and inflation, which is not -1 or 1 any more). Note that in the standard model, output and inflation persistence in response to a productivity shock (without interest rate smoothing) basically follow the persistence of the underlying shock,[35] while they are considerably larger in our model.[36] With the two joint shocks, we can roughly replicate the autocorrela-

separation rate.

[33] For data availability reasons, we have to constrain ourselves to the time period from 1977-2004. See Gartner et al., 2009, for details.

[34] For this exercise, we set the smoothing parameter to 0.8, the autocorrelation of the productivity shock to 0.95 and the standard error of the interest rate and productivity shocks to 0.15% and 0.5% respectively. These numbers are broadly in line with de la Croix et al., 2007, and Smets and Wouters, 2003, 2005. Note that the productivity shock plays the dominant role in the simulation with both shocks. However, medium scale model contain several demand shocks, thereby giving a more important weight to them. See Figure 8 for an example where the demand shock is more important.

[35] The autocorrelation of inflation and output is the same as the autocorrelation of the productivity shock in the standard NKM.

[36] Den Haan et al., 2000, show that search and matching frictions also increases persistence. However, their model uses physical capital and flexible prices and is, therefore, not directly comparable to ours.

		Relative Standard Deviations (Divided by GDP SD)					Correlations			Autocorrelations		
		GDP	Inflation	U	JFR	JDR	U, JFR	JFR, JDR	GDP, Inflation	U	GDP	Inflation
	Data (1977-2004)	1.00	0.18	7.34	9.35	2.65	-0.91	-0.53	0.40	0.98	0.92	0.57
Prod. Shock (without Smoothing)	Model with LTCs	1.00	0.37	3.70	4.11	1.71	-0.78	-1.00	-0.98	0.97	0.92	0.96
	Standard NKM	1.00	0.41	-	-	-	-	-	-1.00	-	0.88	0.88
Prod. Shock (with Smoothing)	Model with LTCs	1.00	0.44	3.88	3.82	1.59	-0.84	-1.00	-0.83	0.98	0.94	0.59
	Standard NKM	1.00	0.43	-	-	-	-	-	-0.85	-	0.94	0.75
Interest Shock (without Smoothing)	Model with LTCs	1.00	3.12	10.00	29.34	12.20	-0.65	-1.00	0.66	0.59	0.59	-0.13
	Standard NKM	1.00	0.26	-	-	-	-	-	1.00	-	-0.03	-0.03
Interest Shock (with Smoothing)	Model with LTCs	1.00	2.57	10.00	23.94	9.96	-0.63	-1.00	0.64	0.74	0.74	0.02
	Standard NKM	1.00	0.59	-	-	-	-	-	1.00	-	0.53	0.53
Joint Shocks (with Smoothing)	Model with LTCs	1.00	0.49	3.96	4.33	1.80	-0.79	-1.00	-0.71	0.97	0.94	0.47
	Standard NKM	1.00	0.46	-	-	-	-	-	-0.47	-	0.88	0.69

Figure 7: Business cycle statistics (HP filtered)

tions that can be found in the data.

In the data, the standard deviation of the job-finding rate and the unemployment rate are several times larger than the standard deviation of output. Our model shows a strong amplification mechanism both for productivity shocks and interest rate shocks. Table 7 also shows that the amplification effect for interest rate shocks is stronger than for productivity shocks.[37] This result is in line with Balleer, 2009, who shows in a VAR estimation that the conditional volatility of job finding and unemployment to technology shocks is smaller than the unconditional volatility, leaving a large role to non-technology disturbances.[38]

The standard search-and-matching model does not have a strong amplification mechanism (see Costain and Reiter, 2008, and Shimer, 2005). This problem has led to a growing literature trying to solve this puzzle: Hall, 2005, introduces wage rigidity, Hagedorn and Manovskii, 2008,[39] suggest an alternative calibration, Cooper et al., 2007, build many additional features into the model, such as fixed and linear costs of vacancy posting, while Den Haan et al., 2000, introduce physical capital.[40] In contrast, our model offers a completely different approach, using a standard calibration, flexible wages[41] and a very simple and tractable structure.

The intuition for the amplification effect works as follows: Since the agents in our model face heterogeneous match-specific shocks, supply or demand shocks affect the range of match-specific shocks over which firms are willing to make job offers. Since aggregate productivity shocks are autocorrelated and demand shocks lead to strong and persistent changes in the price for intermediate goods (p_z), they have a substantial leverage effect on the expected present value of profits generated by newly hired workers, and thereby a strong effect on the hiring thresholds (which directly affects the job-finding rate and thus unemployment).

This effect is not at play in the standard search and matching model, as the creation of new jobs is primarily driven by the matching function and not the match-specific heterogeneities. This is certainly true with exogenous separations, where heterogeneities plays no role at all. But it is also true for matching models with endogenous separations, as they are typically calibrated. There match-specific heterogeneities are used to calibrate the appropriate job-destruction rate, which is equal to the probability that a new contact through

[37] Supply shocks change the production possibility frontier ($y_t = a_t n_t$) and generate short-run adjustment dynamics, which both affect the output path. In contrast, demand shocks only have the latter effect, thereby leading to smaller output variations (for given labor market variations). This explains why the standard deviations of the job-finding rate and the unemployment rate divided by the standard deviation of output are larger under demand shocks.

[38] Note that Balleer, 2009, did this analysis for the United States. So far, there is no evidence on this issue for Europe.

[39] For a discussion of the disadvantages of these two approaches, see Hornstein et al., 2005.

[40] See Fève and Langot, 1996, for a similar model, estimated for France and Cheron and Langot, 2000, for a model with sticky prices.

[41] Under our reference calibration, the standard deviation of wages is about 77% of the standard deviation of productivity. When we change the calibration to make wages and productivity move one to one, the amplification effect shows only slight changes.

	German data	US data	LMS Productivity	KL Productivity	LMS Money Supply	KL Money Supply	LMS Joint Shocks	KL Joint Shocks
Relative SD								
Unemployment	7.34	6.90	5.51	4.36	10.00	8.20	5.55	4.98
Job Creation Rate	9.35	4.00	4.68	7.87	23.25	17.17	6.67	9.44
Job Destruction Rate	2.65	3.73	2.29	8.00	8.72	22.94	2.88	11.02
Correlations								
JCR, JDR	-0.53	-0.57	-0.36	0.28	-0.88	0.18	-0.60	0.34
Y, inflation	0.40	0.39	-0.11	-0.11	0.63	0.65	0.01	0.12
Autocorrelations								
Output	0.92	0.87	0.96	0.98	0.81	0.78	0.96	0.95
Inflation	0.57	0.56	0.25	0.60	0.11	0.60	0.19	0.61

Figure 8: Comparison between Krause and Lubik (KL) and Lechthaler, Merkl and Snower (LMS). All variables are HP filtered.

the matching function is destroyed. In our model, all the dynamics are driven by match-specific heterogeneities. Linear hiring and firing costs drive a wedge between the probability of finding a job, which is reduced by linear hiring costs, and the probability that an existing job continues to exist, which is raised by linear firing costs. This generates markedly different dynamics than in a standard matching model.

Having shown, that our model can replicate several important stylized facts, we proceed with a careful comparison of our model with models using the matching function. The paper that is closest to ours is Krause and Lubik, 2007. They use a New Keynesian model with a matching function and endogenous separations (and without capital accumulation[42]). In Figure 8[43], we compare the properties of the two models. For comparability reasons, we also simulate our model with money supply disturbances instead of interest rate shocks.[44] In contrast to Krause und Lubik, 2007,[45] our model is able to replicate a negative sign for the correlation between the job creation rate and the job destruction rate. In our model, the job creation and job destruction are both driven by the endogenous cut-off points for the idiosyncratic match specific shocks. Thus, when job creation increases, job destruction decreases and vice versa. This result holds for both demand and supply shocks. Note that the matching model with endogenous separations generates counterfactual signs for the correlation between job creation and job destruction. The intuition is straightforward. The endogenous separation rate reacts very sensitively to aggregate shocks (due to an endogenous movement of the cut-off points), thereby changing the unem-

[42] For real business cycle models with capital accumulation see, for example, Andolfatto, 1996, Fève and Langot, 1996, and Den Haan et al.,2000.

[43] Note that the German data refers to the job-finding rate (i.e., new matches divided by unemployment), while Krause and Lubik (2007) and the simulation results refer to the job creation rate. The job creation rate is defined as new matches divided by employment in the previous period. The US data and the KL results are taken from Krause and Lubik (2007).

[44] We use the same numbers as Krause and Lubik, 2007. The standard deviation of the productivity shock and the money shock are 0.0049 and 0.00623, respectively. The coefficients of autocorrelation for the productivity shock and the money shock are 0.95 and 0.49, respectively. To obtain a money demand function, we add money to our utility function ($U(M_t) = \log(M_t/P_t)$).

[45] Note that Krause and Lubik, 2007, use a US calibration. However, Merkl and van Roye, 2009, show that Krause and Lubik's model has very similar properties with a European calibration.

ployment rate very quickly. This affects the ability of the matching function to generate new contacts. Assume a positive productivity shock, which will reduce the unemployment rate. As a consequence, the matching function's ability to create additional matches ($m = f(u, v)$, with $\frac{\partial m}{\partial u} > 0$) is reduced and the job destruction and job creation move in the same direction (see Figure 3 in Krause and Lubik, 2007). Another striking difference between the two models is that the separation rate in Krause and Lubik, 2007, is too volatile, which is not the case in our model.

In a nutshell, our model can replicate many important features of the data, which other models cannot account for. First, in contrast to the standard New Keynesian model with frictionless labor markets, it generates inflation, output and unemployment persistence. Second, in contrast to the matching model with exogenous separations, it offers a strong amplification mechanism for the job-finding rate and the unemployment rate in response to supply and demand shocks. Third, in contrast to the matching model with endogenous separations, it generates realistic correlations between the job creation rate and the job destruction rate.

6 Conclusion

This paper has offered a new labor market mechanism for the amplification and propagation of real and monetary shocks. In contrast to the standard small scale model, our model generates output and unemployment persistence in response to uncorrelated monetary shocks (deviations from the central bank's systematic rule). Further, it generates inflation, output and unemployment persistence in response to real shocks. Since hiring and firing costs reduce labor market flows, they make the labor market's reaction to monetary and macroeconomic shocks more sluggish. The slow reaction of the labor market is transmitted to the product market, thereby generating persistence.

The model offers a strong amplification mechanism in response to macroeconomic shocks (i.e., the job-finding rate and the unemployment are a lot more volatile than output). And the model generates a strong negative correlation between the job creation rate and the job destruction rate.

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8 Appendix: Set of Nonlinear Equations

To the convenience of the reader, the main equations of the model shall be repeated here. We have 15 endogenous variables: a, c, y, i, υ_h, η, υ_f, ϕ, n, w, p_z, π, Ξ^e, Ξ^i, $\tilde{\Pi}_I$ and the 15 equations are:

$$
\begin{aligned}
c_t &= \beta E_t c_{t+1}\left((1+i_t)\frac{1}{\pi_{t+1}}\right)^{-\frac{1}{\sigma}} \\
y_t &= a_t n_t \\
h_t &= a_t p_{z,t} - w_t - \upsilon_{h,t} + E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}) \\
\eta_t &= \Gamma(\upsilon_{h,t}) \\
-f_t &= a_t p_{z,t} - w_t - \upsilon_{f,t} + E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}) \\
\phi_t &= 1 - \Gamma(\upsilon_{f,t}) \\
E_t(\Delta_{t,t+1}\tilde{\Pi}_{I,t+1}) &= E_t\left(\begin{array}{c} \Delta_{t,t+1}(1-\phi_{t+1})(p_{z,t+1}a_{t+1} - w_{t+1} - E_t(\varepsilon_{t+1}|1-\phi_{t+1})) \\ +\Delta_{t,t+1}(1-\phi_{t+1})E_{t+1}(\Delta_{t,t+1}\tilde{\Pi}_{I,t+2}) - \Delta_{t,t+1}\phi_{t+1}f_{t+1} \end{array}\right) \\
n_t &= n_{t-1}(1-\phi_t-\eta_t) + \eta_t \\
w_t &= (1-\gamma)\,b + \ \gamma\,(a_t p_{z,t} - w_t - \bar{\varepsilon}) \\
0 &= (1-\varepsilon) + \varepsilon p_{z,t} - \Psi\,(\pi_t - \bar{\pi})\,\pi_t \\
&\quad + E_t\{\Delta_{t,t+1}\Psi\,(\pi_{t+1} - \bar{\pi})\,\frac{y_{t+1}}{y_t}\pi_{t+1}\}. \\
c_t &= y_t - n_{t-1}\phi_t f_t - (1-n_{t-1})\eta_t h - (1-\phi_t)n_{t-1}(1-\Xi_t^i) \\
&\quad -(1-n_{t-1})\eta_t(1-\Xi_t^e) - \frac{\Psi}{2}\,(\pi_t - \bar{\pi})^2\,y_t \\
\Xi_t^e &= \frac{\int_{-\infty}^{\upsilon_h} \epsilon_t f(\epsilon_t)d\epsilon_t}{\eta_t} \\
\Xi_t^i &= \frac{\int_{-\infty}^{\upsilon_f} \epsilon_t f(\epsilon_t)d\epsilon_t}{1-\phi_t} \\
\frac{1+i_t}{1+\bar{\imath}} &= \left(\frac{\pi_t}{\bar{\pi}}\right)^{\alpha_\pi}\left(\frac{y_t}{y}\right)^{\alpha_y} e^{\lambda_t} \\
a_t &= a_{ss}^{1-\rho_a} a_{t-1}^{\rho_a} e^{\mu_t}
\end{aligned}
$$