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Labor market institutions and aggregate fluctuations in a search and matching model

Francesco Zanetti *

Bank of England, Threadneedle Street, London EC2R 8AH, UK

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ABSTRACT

This paper explores the influence of labor market institutions on aggregate fluctuations. It uses a dynamic, stochastic, general equilibrium model characterized by search and matching frictions in the labor market and nominal rigidities in the goods market. It finds that firing costs and unemployment benefits can have substantial effects on aggregate fluctuations. Increasing firing costs decreases the volatility of output, employment, and job flows due to the reduction in the mass of jobs sensitive to disturbances and lower incentives for firms to hire and fire workers. Hence, firms adjust to shocks mainly through prices, causing inflation to become more volatile. Raising unemployment benefits has the reverse effect on aggregate fluctuations.

1. Introduction

Labor market institutions play an important role in the macroeconomic performance of an economy.[1] In principle, the structure of the labor market influences the long-run equilibrium of an economy and therefore the way in which macroeconomic aggregates fluctuate over time. The literature extensively focuses on the impact of labor market institutions on the underlying structural features of the economy,[2] but as detailed below, only a few papers have studied their impact on business cycle fluctuations. Of those, none has used a general equilibrium search and matching model of the labor market, nor have any of them incorporated nominal rigidities in the analysis.

In this paper, I takle this task. The main question is: how do labor market institutions affect aggregate fluctuations? To answer this question, I employ a dynamic stochastic general equilibrium (DSGE) model with search frictions in the labor market and nominal rigidities in the goods market.

I assess the quantitative implications of labor market institutions by studying the effects of unemployment benefits and firing costs. Unemployment benefits are modeled as payments that accrue to workers after separations, whereas firing costs are modeled as "firing taxes" that firms pay when a worker is dismissed. To make a quantitative assessment of how these labor market institutions influence aggregate fluctuations, I calibrate the benchmark economy to UK data. I then compare the implications of the benchmark economy to a situation where firing costs and unemployment benefits increase from their

* Tel.: + 44 207 6015602; fax: +44 207 6015018.
E-mail address: francesco.zanetti@bankofengland.co.uk

[1] See Bertola et al. (2002), Layard and Nickell (1999), Nickell (1997), and papers in Snower and de la Dehesa (1997).
[2] See the survey by Mortensen and Pissarides (1999) and Pissarides (2000, Chapter 9).

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benchmark calibration. For each of these changes, I analyze the effects on the steady-state equilibrium and business cycle dynamics.

In this model, the rate of job destruction is sensitive to idiosyncratic shocks affecting the firms. This is consistent with the empirical evidence given by Davis et al. (1996). Here, as in Mortensen and Pissarides (1994), in some of the cases in which firms face idiosyncratic productivity shocks, production is profitable, but in some others it is not. The firm chooses an equilibrium reservation productivity wherein jobs become profitable and jobs where productivity falls below this threshold are destroyed. As described in Moscarini (2005) empirical evidence suggests that the wage distribution has a log-normal distribution. The main consequence of this choice is that, as documented below, because the equilibrium threshold is below the mode of the distribution, depending on how labor market institutions affect the threshold, the number of jobs vulnerable to destruction would either increase or decrease and this would serve either to magnify or suppress the effect of labor market institutions on aggregate fluctuations. Hence, I undertake a robustness analysis exercise to assess how the critical threshold interacts with firing costs and the replacement ratio to produce the results.

The results suggest that an increase in firing costs decreases the volatility of output, unemployment, employment, and flows both in and out of employment, whereas the volatility of inflation, real wages, and the vacancy-unemployment ratio, referred to as labor market tightness, all increase. The presence of firing costs affects the inter-temporal employment decisions of firms, since an increase in current employment exposes firms to firing costs in the future. This induces firms to decrease layoffs and hiring, leading to higher unemployment duration and lower unemployment incidence. The mass of jobs sensitive to deterioration in the economy decreases, and thus, disturbances displace a lower number of workers. Since quantities are more costly to change and disturbances affect a lower number of jobs, firms adjust to shocks through prices, changing them aggressively. Hence, inflation becomes more volatile. An increase in unemployment benefits has the opposite effect.

As mentioned earlier, much of the existing analysis of labor market institutions has tended to focus on their impact on the deterministic equilibrium of the economy, with the business cycle consequences largely ignored. Millard and Mortensen (1997) and Mortensen and Pissarides (1999) analyze the impact of different labor market institutions on the steady-state of unemployment and output. Similarly, Chari et al. (2005) build on the labor matching framework to study the connection between labor institutions and investment in training. Alvarez and Veracierto (1999) explore the extent to which labor market policies can explain differences in employment across economies using a Lucas–Prescott equilibrium search model. Alonso-Borrego et al. (2005) evaluate specific labor market reforms such as temporary contracts and firing costs in a model with heterogeneous agents and labor search. Finally, Yashiv (2004) explores the consequences of macroeconomic policy for labor market outcomes in a partial-equilibrium model. I extend this line of research to a general equilibrium setting with a more comprehensive structure of the labor market, which is capable of analyzing a broader set of dynamics. All these papers limit their analysis to the deterministic equilibrium of the economy and do not consider nominal variables such as inflation. In contrast, this paper computes the full-blown stochastic equilibrium and accounts for nominal variables. Veracierto (2008) performs a general equilibrium analysis of the effects of firing taxes on cyclical fluctuations. However, he employs a real business cycle model that does not incorporate labor frictions, nor does it account for either inflation dynamics or nominal disturbances. This paper allows for both these features so as to capture the more detailed dynamics of the labor market in the economy.

This paper is not the first work that combines a New Keynesian setting with search and matching frictions in the labor market. An increasing number of papers, such as those by Christoffel and Linzert (2010), Krause and Lubik (2007), Trigari (2009), and Walsh (2005), use the search framework to incorporate labor market frictions into a monetary economy and find that they improve the ability of the standard New Keynesian framework to replicate the observed dynamics of unemployment and inflation. This paper uses a similar setting, but unlike any of these papers, incorporates labor market institutions and investigates their effect on aggregate fluctuations and in particular, on inflation. Hence, the contribution of this paper is twofold. First, it extends the standard search and matching framework by analyzing the effect of labor market institutions on aggregate fluctuations using a full-blown general equilibrium setting. Second, using a New Keynesian setting enriched with search and matching frictions, it explicitly focuses on labor market institutions and their influence on inflation.

The remainder of the paper is organized as follows: Section 2 sets up the model; Section 3 defines the equilibrium and presents the solution method; Section 4 describes the baseline calibration; Section 5 discusses the findings and performs robustness analysis; and finally, Section 6 presents the conclusion.

2. The model

The model resembles those used by Krause and Lubik (2007) and Walsh (2005), which embed the labor market specification of den Haan et al. (2000) into a New Keynesian setting.[3] This paper develops this framework by adding two specific labor market institutions: unemployment benefits and firing costs. The set-up describes the behavior of a representative household, a production sector comprised of a representative intermediate goods-producing firm, a continuum of retail firms indexed by $i \in [0,1]$, and a central bank.

[3] As detailed below, in this paper the labor market specification is closer to that described by Walsh (2005).

During each period t=0,1,2,…, each representative intermediate goods-producing firm posts a vacancy to recruit a worker, and once the firm and the worker agree on a specific wage contract, the firm produces a distinct, perishable good. During each period t=0,1,2,…, each retail firm purchases intermediate goods from an intermediate goods-producing firm and transforms each unit of these goods into a unit of retail goods, which it then resells to the households. The advantage of this modeling strategy for the goods market is that staggered price setting can be explicitly modeled in the retail market as in Calvo (1983).[4] Alternatively, as in Krause and Lubik (2007), I could have modeled staggered price setting as in Rotemberg (1982), where firms face quadratic costs when changing nominal prices. The advantage of using a staggered price setting as in Calvo (1983) is that the parameter that controls the degree of nominal rigidities is linked to the number of periods for which prices remain on average unchanged. In the Rotemberg approach, this parameter captures the general degree of nominal rigidities, and moreover, to make the model more realistic, it is often calibrated to replicate the results given by Calvo, so that the two approaches are observationally identical up to a first-order approximation.

The labor market model is based on that proposed by den Haan et al. (2000), which builds upon the standard search and matching framework, with endogenous job destruction as in Mortensen and Pissarides (1994). It relies on the assumption that the processes of job search and recruitment are time-consuming and costly for both the intermediate goods-producing firm and the worker. Each firm has a single job that can either be filled, or vacant and searches for a worker. As long as the value of a vacancy is greater than zero, firms post new vacancies. As the number of vacancies increases, the probability that any open vacancy finds a suitable match decreases, thereby reducing the profitability of recruiting workers and, consequently, reducing the value of an open vacancy. In equilibrium, free entry ensures that the present value of a vacancy equals zero.

The number of job matches depends on the matching technology $m(u_t,v_t)$, where v_t is the number of vacancies and u_t is the number of workers searching for a job. Following Petrongolo and Pissarides (2001), the matching technology assumes the form $m(u_t,v_t)=\chi u_t^{\xi} v_t^{1-\xi}$, where $0<\xi<1$, and χ is a scale parameter. It is convenient to introduce the variable $\theta_t=v_t/u_t$, labor market tightness, such that the probability that a searching firm finds a worker is denoted by $q(\theta_t)=m(u_t,v_t)/v_t=\chi\theta_t^{-\xi}$, while the probability that an unemployed worker finds a job is denoted by $p(\theta_t)=m(u_t,v_t)/u_t=\chi\theta_t^{1-\xi}$. Utilizing this notation, the mean duration of a vacant job is $1/q(\theta_t)$ and the mean duration of unemployment is $1/p(\theta_t)$. During each period, t=0,1,2,…, the flow into unemployment results from an exogenous negative shock with probability ρ^x, and from shocks to the idiosyncratic productivity of active jobs, a_t, leading to an endogenous job destruction with probability $\rho_t^n=F(\tilde{a}_t)$ when the idiosyncratic shock falls below some threshold, $\tilde{a}_t$. As described by Mortensen and Pissarides (1994), I assume that new matches have an idiosyncratic productivity, a_t^N, that is always higher than $\tilde{a}_t$ such that new matches are always productive and never separate. Total job separations are therefore $\rho_t=\rho^x+(1-\rho^x)\rho_t^n$. The idiosyncratic shock has a log-normal distribution with mean $\mu_{\ln}$ and standard deviation $\sigma_{\ln}$. When endogenous separation takes place, the firm incurs a firing cost, T. Given this setting, total employment for the representative intermediate goods-producing firm is $n_t=(1-\rho_t)n_{t-1}+m(u_{t-1},v_{t-1})$.

The central bank is modeled with a modified Taylor (1993) rule as proposed by Clarida et al. (1998): it gradually adjusts the nominal interest rate in response to output and inflation deviations from their steady-state levels.

The next subsections formalize the behavior of each agent.

2.1. The representative household

Members of the representative household can either work or be unemployed, so that n_t=$1-u_t$, where u_t is the number of unemployed, and the labor force is normalized to one. During each period t=0,1,2,…, the representative household maximizes an expected utility function of the form

$$E\sum_{t=0}^{\infty}\beta^t[(C_t^{1-\sigma}-1)/(1-\sigma)+\kappa_m\ln(M_t/P_t)], \tag{1}$$

where the variable C_t is consumption, M_t/P_t is real money holdings, κ_m is a scaling parameter $\kappa_m>0$, and β is the discount factor $0<\beta<1$. To avoid distributional issues from heterogeneity, I follow Merz (1995) and Andolfatto (1996) in assuming that members of the representative household perfectly insure each other against fluctuations in income. The representative household enters period t with bonds B_{t-1} and money M_{t-1}. At the beginning of the period, the household receives a lump-sum nominal transfer τ_t from the central bank, nominal profits D_t from the representative intermediate goods-producing firm, and total income Y_t. Then, the household's bonds mature, providing B_{t-1} additional units of money. The household uses part of this additional money to purchase B_t new bonds at nominal cost B_t/R_t, where R_t represents the gross nominal interest rate between t and t+1. The household uses its income for consumption, C_t, carries M_t units of money, and B_t bonds into period t+1, subject to the budget constraint

$$P_tC_t+B_t/R_t+M_t=B_{t-1}+P_tY_t+D_t+\tau_t+M_{t-1} \tag{2}$$

for all t=0,1,2,…. Thus the household chooses $\{C_t,B_t,M_t\}_{t=0}^{\infty}$ to maximize its utility subject to the budget constraint (2) for all t=0,1,2,…. Letting m_t=M_t/P_t denote real money balances, $\pi_t=P_t/P_{t-1}$ denote the gross inflation rate, and Λ_t denote the

[4] A similar specification is proposed by Bernanke et al. (1999).

non-negative Lagrange multiplier on the budget constraint (2), the first-order conditions for this problem are

$$C_t^{-\sigma} = \Lambda_t, \tag{3}$$

$$E_t \beta_{t,t+1} = E_t \pi_{t+1}/R_t, \tag{4}$$

and

$$\frac{\kappa_m}{m_t} = \Lambda_t - \beta E_t \frac{\Lambda_{t+1}}{\pi_{t+1}}, \tag{5}$$

where $\beta_{t,t+1} = \beta \Lambda_{t+1}/\Lambda_t$ is the stochastic discount factor. Eqs. (3)–(5) are standard Euler equations and describe the optimal path for consumption, bonds, and real money holdings, respectively.[5]

Let U_t, W_t^N, and $W_t(a_t)$ denote the present-discounted value of the expected income of an unemployed, newly employed, and continuously employed worker, respectively. The unemployed worker enjoys a return b while unemployed and expects to move into employment with probability $p(\theta_t)$. Hence, the present-discounted value of unemployment is

$$U_t = b + E_t \beta_{t,t+1}[p(\theta_t) W_{t+1}^N + (1-p(\theta_t)) U_{t+1}]. \tag{6}$$

This equation states that the value of unemployment is made up of the yield b and the expected-discounted capital gain from the change of state. As described by Pissarides (2000), I assume that $b = h + \rho_R w$, where h represents value of leisure or home production, w the average wage at the steady-state, and ρ_R the replacement ratio for unemployment benefits. I assume that $0 < \rho_R < 1$. Note that although the replacement ratio is linked to the average wage at the steady-state, to keep the setting simple, it is time-invariant and is financed through non-distortionary taxes. If taxes were distortionary, this would alter the agents' optimal employment decisions and introduce an additional channel of departure from the standard model. The detailed investigation of this scenario is left open for future research.

The employed worker earns a wage and may lose her job with probability ρ_t. Due to the presence of firing costs, the wage offered by the firm for new hires, w_t^N, differs from the one offered to continuing matches, $w_t(a_t)$. Hence, the present-discounted values of a new match, W_t^N, and of a continuing job, $W_t(a_t)$, are not necessarily the same, thus

$$W_t^N = w_t^N + E_t \beta_{t,t+1}\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}(a_{t+1}) dF(a_{t+1}) + \rho_{t+1} U_{t+1}\right], \tag{7}$$

and

$$W_t(a_t) = w_t(a_t) + E_t \beta_{t,t+1}\left[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}(a_{t+1}) dF(a_{t+1}) + \rho_{t+1} U_{t+1}\right]. \tag{8}$$

Eqs. (7) and (8) state that the value of a job for a worker is given by the wage and the expected-discounted net gain from continuing to work.

2.2. The goods market

As described above, the production sector comprises a representative intermediate goods-producing firm and a continuum of retail firms indexed by $i \in [0,1]$, characterized by staggered price setting as described by Calvo (1983).

2.2.1. The representative intermediate goods-producing firm

During each period t=0,1,2,…, each intermediate goods-producing firm posts a vacancy at a cost c to recruit a new worker and faces an idiosyncratic job-specific shock, a_t, with a common productivity disturbance, A_t, on established jobs. Following the standard assumption in the literature, as described by den Haan et al. (2000), I assume that idiosyncratic productivity, a, is log-normal and i.i.d., with c.d.f. $F(\cdot)$. If the idiosyncratic shock is below some threshold, $\tilde{a}_t$, the match becomes unprofitable and vanishes. If the match continues, production occurs with an output of y_t=$A_t a_t$. The productivity shock follows the autoregressive process $\ln(A_t) = \rho_A \ln(A_{t-1}) + \xi_{At}$, with $0 < \rho_A < 1$, where the zero-mean, serially uncorrelated innovation ξ_{At} is normally distributed with standard deviation σ_A. Let V_t denote the present-discounted value of expected profits from a vacant job. Hence, the present value of a vacancy is

$$V_t = -c + E_t \beta_{t,t+1}[q(\theta_t) J_{t+1}^N + (1-q(\theta_t)) V_{t+1}]. \tag{9}$$

This equation states that a vacant job costs c and becomes filled with a probability of $q(\theta_t)$ with a return J_{t+1}^N, and with a probability of $1-q(\theta_t)$ with a return V_{t+1}.

[5] Note that in the presence of an interest rate rule, which is assumed below, the money demand equation simply determines the nominal level of money balances. For this reason, it can be safely ignored in the computation of the equilibrium.

Once a worker has been hired, the present-discounted value of a new match to the employer, J_t^N, is

$$J_t^N = \varepsilon_t A_t a_t^N - w_t^N + E_t\beta_{t,t+1}(1-\rho^x)\left[\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a_{t+1})dF(a_{t+1}) - F(\tilde{a}_{t+1})T\right], \tag{10}$$

where ε_t is the ratio between the price charged by the intermediate goods-producing firm for its output and the aggregate price index in the economy. As in Walsh (2005), ε_t represents the real value of a unit of output, which is equivalent to the real marginal cost for the representative retail firm. Similarly, the present-discounted value of a continuing job to the employer, $J_t(a_t)$, is

$$J_t(a_t) = \varepsilon_t A_t a_t - w_t(a_t) + E_t\beta_{t,t+1}(1-\rho^x)\left[\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a_{t+1})dF(a_{t+1}) - F(\tilde{a}_{t+1})T\right]. \tag{11}$$

Eqs. (10) and (11) state that the value of a new match yields a net return, $\varepsilon_t A_t a_t - w_t(a_t)$, and a present-discounted net value, $J_{t+1}(a_{t+1}) - F(\tilde{a}_{t+1})T$, if the job is not destroyed.[6]

The real marginal cost expresses the cost of increasing production by one unit, once hiring has taken place. In this model, the expression of marginal cost, ε_t, can be derived from Eq. (11) and by imposing that a match is profitable for the firm. Since the outside option for the firm is firing the worker and paying the firing cost, a match is profitable when $J_{t+1}(\tilde{a}_t) - (-T) = J_{t+1}(\tilde{a}_t) + T = 0$.[7] By using this condition and solving Eq. (11) explicitly for the real value of a unit of output I obtain:

$$\varepsilon_t = \frac{1}{A_t \tilde{a}_t}\left\{ w_t(\tilde{a}_t) - T - E_t\beta_{t,t+1}(1-\rho^x)\left[\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a_{t+1})\, dF(a_{t+1}) - F(\tilde{a}_{t+1})T\right]\right\}. \tag{12}$$

From Eq. (12), the real marginal cost is equal to the wage minus the cost of firing a worker and the expected future benefit that the job generates, divided by the marginal product of labor. As described by Krause and Lubik (2007), in the presence of search and matching frictions in the labor market, the real marginal cost does not depend uniquely on the wage divided by the marginal product of labor, but also on the expected-discounted value of the job, which internalizes the costs of forming a match and firing.

2.2.2. *Wage setting*

The structure of the model guarantees that a realized job match yields some pure economic surplus. The split of this surplus between the worker and the firm is determined by the wage level. As described by Pissarides (2000), the wage is set according to the Nash bargaining solution. Note that the standard implicit assumption to this setting is that wages are bargained in every period, so that they are closely linked to current productivity, both at the individual and aggregate levels. This assumption may appear to be incongruous with the assumption that, on average, prices are not allowed to change in each period, as detailed below. It would probably be more realistic to incorporate some degree of wage stickiness in the model, as has been recently advocated by Gertler and Trigari (2009). To keep as simple and standard a theoretical framework as possible in this paper, I leave the investigation of this issue open for future research. The worker and the firm split the surplus of their matches with share $0<\eta<1$. Since the wage is match-specific, depending on the idiosyncratic productivity of the job, the wage bargaining rule for continuing matches and new matches are, respectively,

$$\eta(J_t(a_t)+T) = (1-\eta)(W_t(a_t) - U_t), \tag{13}$$

and

$$\eta J_t^N(a_t) = (1-\eta)(W_t^N - U_t). \tag{14}$$

Since continuing matches are subject to firing costs, the wage bargaining rule for continuing matches, as shown in Eq. (13), internalizes firing costs, T.[8] On the other hand, firing costs do not appear in Eq. (14) because the idiosyncratic productivity of new jobs is always higher than the threshold by construction. Mortensen and Pissarides (2003) use a similar set-up. I make this assumption because it is more realistic, otherwise firms might pay firing costs for workers just employed but whose productivity is below the equilibrium threshold, even before these workers produce any goods. Moreover, since the proportion of new hires is small compared to the incumbent workers, as detailed below, this assumption does not significantly affect the dynamics of the average wage and hence, the overall results. Therefore, using Eqs. (6)–(11), the agreed wage for continuing workers, $w_t(a_t)$, and new workers, w_t^N, are

$$w_t(a_t) = \eta[\varepsilon_t A_t a_t + c\theta_t + (1-\zeta_t)T] + (1-\eta)b, \tag{15}$$

and

$$w_t^N = \eta[\varepsilon_t A_t a_t^N + c\theta_t - \zeta_t T] + (1-\eta)b, \tag{16}$$

[6] Note that in Eqs. (10) and (11) it is assumed that with probability ρ_{t+1} the match is discontinued and its present-discounted value is zero.

[7] See Mortensen and Pissarides (2003).

[8] Note that, as described by Mortensen and Pissarides (1999, 2003), the term $J_t(a_t)+T$ represents the firm's threat point. Firing costs, T, appear because if the job is destroyed the firm must pay them.

where $\zeta_t = E_t\beta_{t,t+1}(1-\rho^x)$. Eqs. (15) and (16) state that workers receive a wage made up of two parts.[9] First, for a fraction η, from the revenue product generated, $\varepsilon_t A_t a_t$, plus a reward for the savings on hiring costs, $c\theta_t$, minus a charge for the future expected firing costs in both cases, $\zeta_t T$, and plus a compensation for the savings on firing costs, T, in the case of continuing workers. Second, for a fraction $1-\eta$, from the real return of unemployment, b. Note that here firing costs, T, do not appear in the wage for newly hired workers because their idiosyncratic productivity is always above the equilibrium productivity threshold, such that new workers are never fired in the same period in which they are first employed. Therefore, firms never pay firing costs for these employees for the period in which they are employed. Nonetheless, since newly hired workers may be fired in the future, the wage for newly hired workers internalizes future expected firing costs, $\zeta_t T$. Furthermore, firing costs are assumed to be a sunk cost and do not transfer to the worker. This assumption is important because, as pointed out by Lazear (1990), Mortensen and Pissarides (1999), and Ljungqvist (2002), any mandated severance transfer can be offset by an efficient labor contract, and hence there would be no real effects. Thus, to study the effect of firing costs, I need to model them as a sunk cost. A similar assumption is undertaken by Thomas (2006), where firing costs do not appear in the new hire's bargaining rule and whose findings closely accord with those described here.

2.2.3. The retail sector

There is a continuum of monopolistically competitive retailers indexed by $i \in [0,1]$. Retailers buy goods from the intermediate goods-producing firms, transform each unit of these goods into a unit of retail goods and resell them to households. During each period t=0,1,2,…, each retailer sells $Y_t(i)$ units of the intermediate good at the nominal price $P_t(i)$. Final output Y_t is composed of individual retail goods according to the constant-returns-to-scale technology described by

$$Y_t = \int_0^1 \left[Y_t(i)^{(\gamma-1)/\gamma} di\right]^{\gamma/(\gamma-1)}, \tag{17}$$

where γ is the elasticity of demand for each intermediate good. Consequently, the demand curve that each retailer i faces is

$$Y_t(i) = [P_t(i)/P_t]^{-\gamma} Y_t,$$

where P_t is the aggregate price index

$$P_t = \left[\int_0^1 P_t(i)^{1-\gamma}\, di\right]^{1/(1-\gamma)} \tag{18}$$

for all $t = 0,1,2,\ldots$. Each retail firm sets prices as described by Calvo (1983). During each period t=0,1,2,…, a fraction $(1-\nu)$ of retail firms sets a new price, while the remaining fraction, ν, charges the previous period's price times steady-state inflation. The probability of a price change is constant over time and independent of the firm's price history. Hence, firm i that sets a new price $P_t(i)$ in time t maximizes

$$E_t \sum_{j=0}^{\infty} (\beta\nu)^j \beta_{t,t+j}\{[P_t(i)/P_t]^{-\gamma} Y_{t+j}[P_t(i)/P_{t+j} - \varepsilon_{t+j}]\},$$

where $\beta_{t,t+j}$ is the rate at which the firm discounts its earnings at time $t+j$, and ε_t is the real marginal cost. First-order conditions for this problem are

$$P_t(i) = \frac{\gamma \sum_{j=0}^{\infty} (\nu\beta)^j E_t(\Lambda_{t+j} P_{t+j}^{\gamma} Y_{t+j}\varepsilon_{t+j})}{(\gamma-1)\sum_{j=0}^{\infty} (\nu\beta\pi)^j E_t(\Lambda_{t+j} P_{t+j}^{\gamma-1} Y_{t+j})}. \tag{19}$$

2.3. The central bank

The central bank conducts monetary policy using the modified Taylor (1993) rule

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + \rho_y \ln(Y_t/Y) + \rho_\pi \ln(\pi_t/\pi) + \xi_{rt}, \tag{20}$$

where R, Y, and π are the steady-state values of the gross nominal interest rate, output, and gross inflation rate, respectively. According to Eq. (20), the central bank gradually adjusts the nominal interest rate in response to movements in output and inflation. The zero-mean serially uncorrelated policy shock, ξ_{rt}, is normally distributed with a standard deviation σ_r^2. As pointed out by Clarida et al. (1998) and Nelson (2003), this modeling strategy for the central bank is broadly consistent with the actual monetary policy for the United Kingdom since the early 90's.

3. Symmetric equilibrium

In a symmetric dynamic equilibrium, all retail firms make identical decisions, such that $P_t(i)$=P_t and $Y_t(i)$=Y_t. In equilibrium, free entry drives the profit from an open vacancy to zero, such that V_t=0. This result, combined with Eqs. (9), (10),

[9] An appendix with the full derivation of the wage equation and a comparison to the literature is available upon request from the author.

and (16), yields the job creation condition

$$c/q(\theta_t)=(1-\eta)E_t\beta_{t,t+1}[\varepsilon_{t+1}A_{t+1}(a^N_{t+1}-\tilde{a}_{t+1})-T]. \tag{21}$$

In equilibrium, jobs are destroyed when the surplus that the firm receives from the job, $J_t(a_t)+T$, falls below zero. The variable $\tilde{a}_t$ is the threshold of the idiosyncratic shock below which a job is not profitable, that is, $J_t(\tilde{a}_t)+T=0$. This result, combined with Eqs. (11) and (15), yields the job destruction condition

$$\varepsilon_tA_t\tilde{a}_t-b-[\eta/(1-\eta)]c\theta_t+(1-\zeta_t)T+E_t\beta_{t,t+1}(1-\rho^x)\varepsilon_{t+1}A_{t+1}\int_{\tilde{a}_{t+1}}^{\infty}(a_{t+1}-\tilde{a}_{t+1})dF(a_{t+1})=0. \tag{22}$$

In equilibrium, the average wage, w_t, is a weighted average of Eqs. (15) and (16) with weights $\omega^C_t=(1-\rho_t)n_{t-1}/n_t$ for continuing workers and $1-\omega^C_t$ for new matches, such that

$$w_t=\eta[\varepsilon_tA_t\overline{a}_t+c\theta_t+(\omega^C_t-\zeta_t)T]+(1-\eta)b, \tag{23}$$

where $\overline{a}_t=\omega^C_tH(\tilde{a}_t)+(1-\omega^C_t)a^N_t$ is the average idiosyncratic productivity across jobs and $H(\tilde{a}_t)=E(a_t|a_t>\tilde{a}_t)$ is the average productivity for continuing jobs.[10] In equilibrium, the aggregate income is $y_t=n_tA_t\overline{a}_t-cv_t$, B_t=B_{t+1}=0, and $\tau_t=M_t-M_{t-1}$.[11] As discussed above, since the proportion of new jobs is small compared to that of incumbent workers, the assumption that new jobs start with productivity higher than the equilibrium threshold does not significantly affect the results of the model. Hence, the overall dynamics of $\overline{a}_t$ are mainly driven by the idiosyncratic productivity of continuing jobs.

The equilibrium is described by the evolution of employment, total job separation, labor market tightness, the definition of employed workers, Eqs. (3) and (4), the return from employment, the definition of the stochastic discount factor, Eqs. (18)–(23), the specification of the shocks, and the aggregate income. The system is approximated by log-linearizing its equations around the stationary steady-state. In this way, a linear dynamic system describes the path of the endogenous variables' relative deviations from their steady-state value, accounting for the exogenous shocks. The solution to this system is derived using Klein (2000), which is a modification of Blanchard and Khan (1980).

4. Calibration

The benchmark economy is calibrated to reproduce the structural characteristics of the UK economy for the period 1980:Q1–2005:Q3. I calibrate the model on quarterly frequencies and the value for each parameter is reported as follows. I set the discount factor, β, equal to 0.99, and the coefficient of relative risk aversion, σ, equal to 2, as described by King and Rebelo (1999).

The steady-state unemployment rate is set to 5.5%. The estimation of the job separation rate ranges from 3%, as estimated by Bell and Smith (2002), to 4.5%, as given by Hobijn and Sahin (2007).[12] For this reason, I set the steady-state separation rate $\rho=0.035$, which is approximately the middle ground between these different estimates. These two parameters pin down the probability that an unemployed worker finds a job in any given period, $p=\rho(1-u)/u$, equal to 0.6. The data do not contain information on the split between endogenous and exogenous separation rates. For this reason, I assume that the total job separation rate is approximately one and a half times the exogenous separation rate, in line with den Haan et al. (2000). Since Bell and Smith (2002) estimates the employment outflows as a percentage of the working population equal to approximately 3%, I calibrate the exogenous job destruction rate $\rho^x=0.2$. Consequently, the endogenous separation rate can be computed as $\rho^n=(\rho-\rho^x)/(1-\rho^x)=0.015$. The implied reservation productivity threshold is $\tilde{a}=F^{-1}(\rho^n)=2.16$. As described above, following den Haan et al. (2000), I assume that idiosyncratic productivity, a, is log-normal and i.i.d., with c.d.f. $F(\cdot)$. To closely mimic the estimated wage density distribution for the UK (as reported in Fig. 3b by Jolivet et al., 2006), I calibrate the value for the mean of $F(\cdot)$, $\mu_{\ln}$, equal to 1.4, and the value of its standard deviation, $\sigma_{\ln}$, equal to 0.29. I assume that the idiosyncratic productivity for new matches is always in the 95th percentile of $F(\cdot)$, so that $a^N>\tilde{a}$ and new matches never separate.

As described by Burgess and Turon (2010), I set the firm matching rate $q(\theta)=0.9$. The match elasticity, ξ, is calibrated to 0.7, based on the empirical estimates by Bean (1994) and in line with the survey by Petrongolo and Pissarides (2001).[13] The level parameter of the matching function, χ, is calibrated to match the steady-state number of matches, $\rho(1-u)$. As it is standard in the literature, I calibrate the worker's share parameter, η, to 0.5, such that the household and the firm have the same bargaining power. The vacancy posting cost, c, and unemployment benefits, b, are inferred from the steady-state job creation and job destruction conditions, respectively. Hence, the parameter for value of leisure, h, is calibrated accordingly to 0.59. This value is broadly consistent with the results in Mortensen and Pissarides (1999). Firing costs, T, and the replacement ratio, ρ_R, amount to 30% of the mean wage. These values are similar to those found in the UK economy as described by Bean (1994) and Nickell (1997).

I set the parameter γ, which measures the degree of market power of firms in the retail sector, equal to 11. Since the steady-state value of γ determines the mark-up of prices over marginal costs, this value implies a mark-up of 10%, which is in line with that suggested by Britton et al. (2000). I set the parameter that governs the frequency of price adjustment, v, equal to

[10] Note that $H(\tilde{a}_t)=\int_{\tilde{a}_t}^{\infty}af(a)/(1-F(\tilde{a}_t))\,da$.

[11] This condition assures that any seigniorage revenue is rebated to the household.

[12] These studies pertain to the UK economy and refer to different time periods.

[13] On this parameter, an extensive sensitivity analysis suggests that it does not materially affect the quality of the results.

0.75, such that the average contract length is four quarters, as described by Taylor (1999). Therefore, the elasticity of inflation with respect to marginal costs is $\kappa=(1-\nu)(1-\nu\beta)/\nu=0.09$. As described by Krause and Lubik (2007), I set the value for steady-state gross inflation, π, equal to 1.[14]

I calibrate the parameters of the monetary policy rule using Taylor (1999) and Nelson (2003). In particular, the interest rate response to inflation, ρ_π, is set equal to 1.5; the interest rate response to output, ρ_y, equals 0.5; and the degree of interest rate smoothing, ρ_r, is set equal to 0.32.

Finally, I calibrate the shock processes. The value of the standard deviation of the policy shock is in line with that given by Clarida et al. (1998), who estimate a similar specification for this shock with the generalized method of moments for the UK. Its standard deviation, σ_r, equals 0.0012. In line with most of the literature, I set the serial correlation for the technology shock, ρ_A, equal to 0.94. Following the common practice in the literature,[15] I calibrate the innovation variance such that the baseline model predictions replicate the standard deviation of output, which is 1.08%. Consequently, the standard deviation of the technology shock, σ_A, equals 0.0045.

5. Findings

This section is divided into four parts: first, I describe how the model's steady state is affected by labor market institutions; second, I analyze the model's impulse responses to demand and supply shocks; third, I simulate the model to determine the effects of firing costs and the replacement ratio on business cycle dynamics; and finally, I undertake a robustness analysis exercise.

5.1. Steady-state analysis

As described in Section 4, the benchmark calibration enables the steady-state of the model to reproduce the structural features of the UK economy. The second column of Table 1 summarizes the numerical values of the benchmark calibration.

The third column of Table 1 shows the effects of increasing the replacement ratio by five-percentage points, from 30% to 35%.[16] An increase in the replacement ratio increases the relative value of the unemployment option to workers such that the average wage, specified by Eq. (23), increases from 2.84 to 2.88. The increase in the replacement ratio generates an upward shift in the job destruction relation, as expressed in Eq. (22) and represented in panel A of Fig. 1. Since the job creation condition, as in Eq. (21), is not affected, the equilibrium reservation productivity rises so as to increase the endogenous job separation rate. As the increase in reservation productivity induces a movement up along the job creation schedule from point *A* to *B* in the figure, the equilibrium job-finding rate, which is a function of labor market tightness, is adversely affected. Consequently, unemployment duration increases and job flows in and out of employment decline. The unemployment rate is the product of both the flows into unemployment and unemployment duration; hence, the increase in both unambiguously raises the unemployment rate.

The fourth column of Table 1 shows the effects of increasing firing costs by five-percentage points, from 30% to 35%. An increase in firing costs has an opposite effect on the job destruction relation compared to an increase in the replacement ratio. From the job creation condition, Eq. (21), other things being equal, an increase in firing costs induces the firm to decrease the threshold that makes a job profitable such that the marginal revenue of the job remains unchanged. Hence, the job creation schedule, as specified in Eq. (21), shifts left. Similarly, from the job destruction condition, Eq. (22), other things being equal, the firm reduces the productivity threshold to counteract the increase in the present-discounted value of the job that firing costs generate, so that the job destruction condition, as in Eq. (22), shifts right. The equilibrium goes from point *C* to *D* in the figure. Hence, the equilibrium productivity threshold unambiguously declines, and labor market tightness also decreases.[17] Intuitively, an increase in firing costs augments the firm's surplus from the match and thus requires a lower productivity threshold to make the match profitable. The reduction of labor market tightness increases unemployment duration and decreases the probability of finding a job. In the calibration, the second effect dominates causing the unemployment rate to decrease. Overall, these findings show that higher firing costs or unemployment benefits have contradictory effects on the mean levels around which the economy fluctuates.

As a final exercise in this section, the last column of Table 1 shows the effects of increasing both the replacement ratio and firing costs by five-percentage points, from 30% to 35%. As a result, the job creation condition shifts left, due to the increase in firing costs. In principle, the job destruction condition could change either way, as these policy actions shift the schedule in opposite directions. Effectively, the job destruction schedule shifts downwards, since the effect from the increase in firing costs dominates that from the increase in the replacement ratio. As a result, equilibrium labor market tightness decreases by around 5% and equilibrium reservation productivity by around 7%. These changes trigger a decrease in the rate of endogenous and total

[14] By assuming the discount factor, β, equal to 0.99 and the steady-state gross inflation, π, equal to 1, the steady-state of the annual real interest rate equals 4% per year.

[15] See Krause and Lubik (2007) and references therein.

[16] The choice of a five-percentage-point increase is arbitrary and meant only to demonstrate the workings of the model.

[17] In principle, as Mortensen and Pissarides (1999) point out, the net effect of a change in firing costs on labor market tightness is ambiguous and it depends on the sensitivity of job creation and job destruction to firing costs. In this model, numerical simulations show that an increase in firing costs decreases labor market tightness since the job creation condition is more sensitive to changes in firing costs than the job destruction condition.

Table 1
Steady-state values, different calibrations.

Variable	Benchmark economy	Increase in the replacement ratio	Increase in firing costs	Increase in the replacement ratio and firing costs
Output	2.97	2.93	3.01	3.01
Unemployment rate	5.5	7.1	3.7	4.4
Vacancies	3.7	4.3	2.9	2.8
Tightness	0.66	0.60	0.64	0.63
Threshold productivity	2.16	2.30	1.81	2.00
Real wages	2.84	2.88	2.91	2.89
Endogenous job destruction rate	1.5	2.5	0.3	0.7
Total job destruction rate	3.5	4.5	2.2	2.7

Notes: Entries in this table are computed using the calibration described in Section 4.

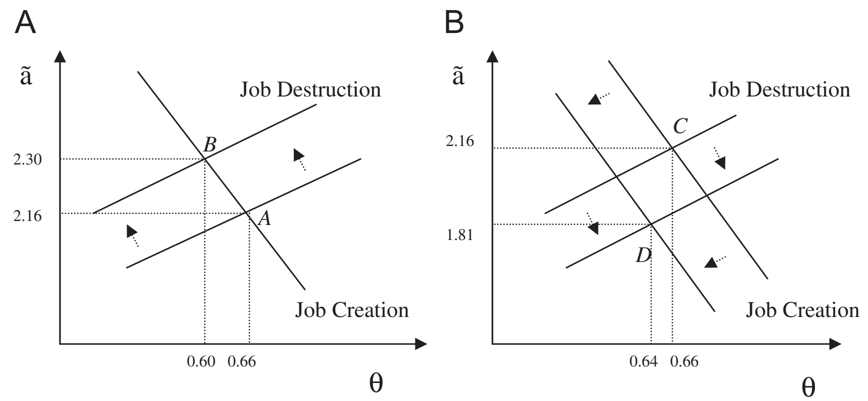

Fig. 1. Steady-state analysis. Notes: Panel A shows the reaction of job creation and destruction conditions to an increase in the replacement ratio. Panel B shows the reaction to an increase in firing costs.

job destruction from 1.5% to 0.7% and from 3.5% to 2.7%, respectively. The unemployment rate decreases from 5.5% to 4.4%, whereas output increases by around 1%. This exercise suggests that for a similar increase in the replacement ratio and firing costs, the latter leads the job destruction condition to shift downwards, which determines the new equilibrium of the economy.

5.2. Impulse response analysis

This section discusses the impulse responses to technology and monetary shocks for the benchmark calibration of the model. Fig. 2 shows the model's response to a one-percentage point positive technology shock. On impact, inflation declines, and output and employment rise, followed by a pronounced hump-shaped adjustment path. Higher productivity leads to an increase in real wages, while real marginal costs fall and then return to the initial equilibrium. Vacancies increase and unemployment falls, both leading to the rise in labor market tightness, and then gradually returning to equilibrium. The rise in labor market tightness depresses the probability of filling vacancies and this leads to a smooth decline in flows into employment. Flows out of employment fall on impact due to the substantial decrease in the endogenous job destruction rate caused by the fall in reservation productivity.

Fig. 3 shows the model's response to a one-percentage point positive nominal interest rate shock. Output, employment, and inflation all fall before returning to their steady-state levels. Employment decreases proportionally more than output since the rise in the critical threshold for the idiosyncratic productivity rate makes some formerly profitable firm-worker matches now unprofitable. Real wages and marginal costs fall on impact and then quickly return to their steady-state levels. Labor market tightness increases due to a higher increase in vacancies than in unemployment. This effect results from a large increase in separations, which is reflected in the behavior of the job destruction rate. In fact, firms tend to reduce employment by dismissing more jobs, even more productive ones, rather than reducing the rate at which jobs are created. In general, the effect of a nominal interest rate shock dies out more quickly than that of a productivity shock. This effect results because the disturbance is serially uncorrelated and the smoothing parameter, ρ_r, in the modified Taylor rule is small.

5.3. Business cycle dynamics

This section analyzes the effects of changes in firing costs and the replacement ratio on business cycle dynamics. First, I discuss the empirical plausibility of business cycles generated by the benchmark calibration of the model. Then, I evaluate the effects of an increase in firing costs and in the replacement ratio on business cycle dynamics.

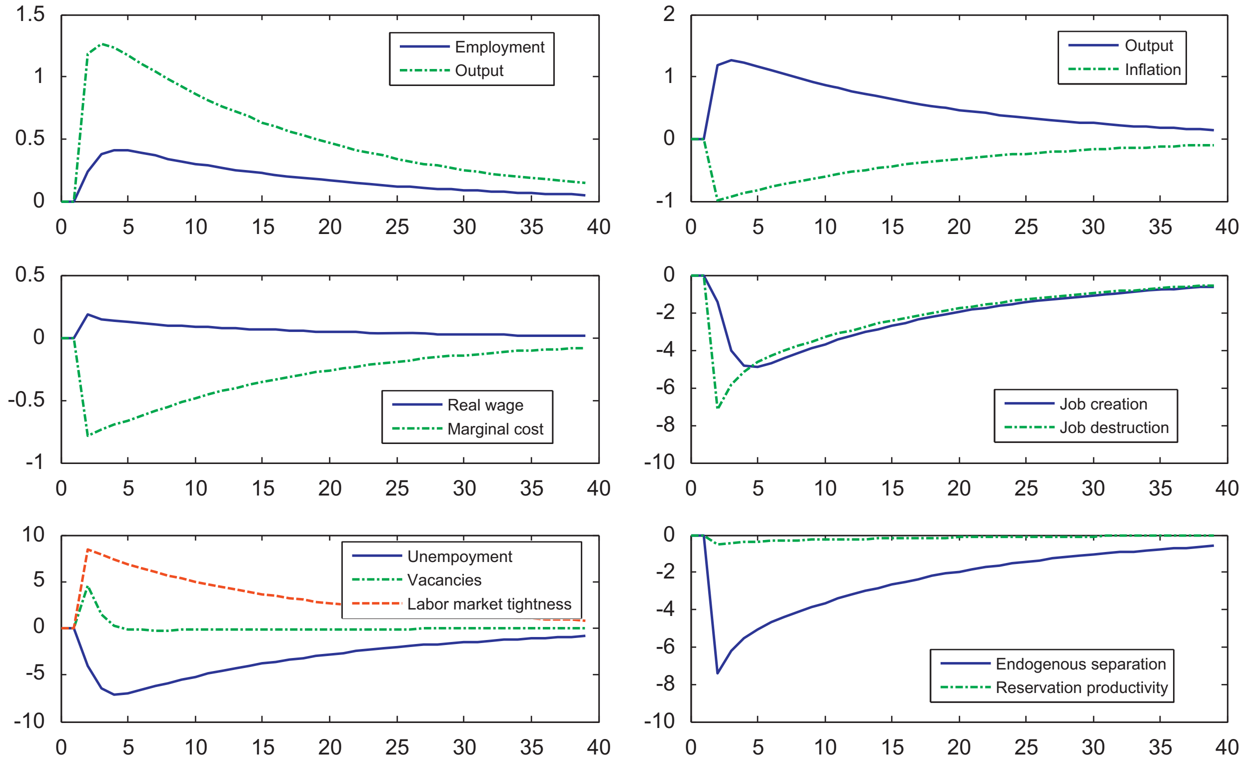

Fig. 2. Impulse response functions to a positive technology shock. Notes: Each panel shows the percentage-point response of the models' variables to a one-percentage-point technology shock. The horizontal axes measure time, expressed in quarters.

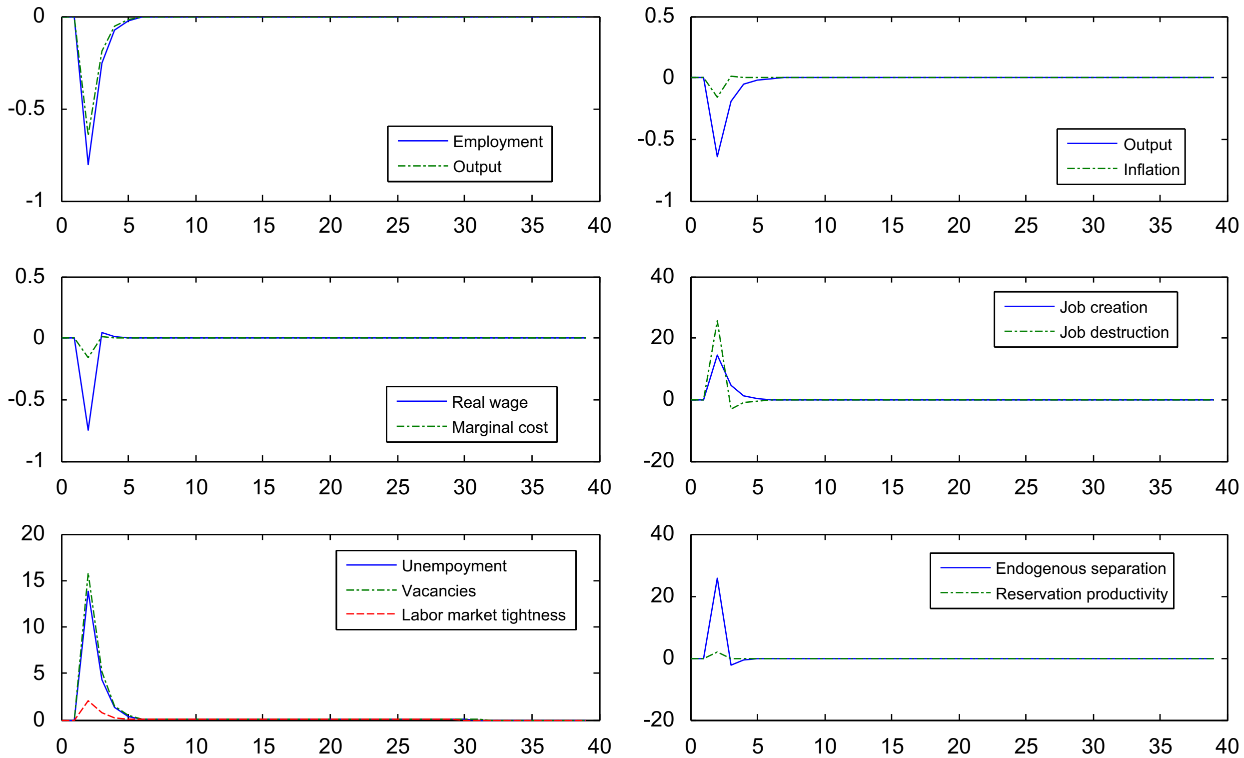

Fig. 3. Impulse response functions to a monetary policy shock. Notes: Each panel shows the percentage-point response of the models' variables to a one-percentage-point increase in the interest rate. The horizontal axes measure time, expressed in quarters.

Table 2
Business cycle properties, different calibrations.

Variable	UK economy	Benchmark calibration	Increase in firing costs	Increase in rep. ratio	Increase in the replacement ratio and firing costs
Standard deviations					
Output	1.08	1.08	0.85	1.32	1.01
Employment	1.12	0.53	0.32	0.72	0.37
Unemployment	10.62	10.01	7.71	14.57	9.38
Vacancies	11.95	8.21	19.45	5.54	25.11
Flows out of employment	0.08	0.15	0.11	0.25	0.32
Flows into employment	0.05	0.081	0.062	0.105	0.011
Inflation	1.50	0.85	1.25	0.72	0.93
Real wages	0.99	0.72	4.32	0.52	3.27
Relative standard deviations					
Output	1.00	1.00	1.00	1.00	1.00
Employment	1.04	0.49	0.37	0.54	0.41
Unemployment	9.87	9.27	9.07	11.04	9.29
Vacancies	11.11	7.60	22.88	4.19	24.86
Flows out of employment	0.074	0.14	0.12	0.19	0.32
Flows into employment	0.046	0.075	0.073	0.079	0.010
Inflation	1.40	0.79	1.47	0.54	0.92
Real wages	0.92	0.66	5.08	0.39	3.24
Cross-correlations					
Output, real wages	0.25	0.48	0.18	0.42	0.27
Output, Inflation	−0.25	−0.97	−0.35	−0.90	−0.80
Real wages, inflation	−0.42	−0.32	0.72	−0.38	0.53
Unemployment, vacancies	−0.53	−0.06	−0.10	−0.01	−0.08

Notes: Observed (UK economy) and simulated business cycle properties. The observed statistics are based on seasonally adjusted quarterly data from 1980:Q1 to 2005:Q3. Variables, except inflation, are transformed into logarithms. All the series are HP filtered, so that only the cyclical component remains. The simulated business cycle statistics are based on 1000 simulations over 100 quarter horizon and are HP filtered for comparison purposes. Simulated figures are averages across simulations.

The third column of Table 2 reports the behavior of the benchmark calibration of the model. It is interesting to assess the contemporaneous cross-correlations reported in the table. An established aggregate labor market fact is that real wages are only slightly pro-cyclical. This is difficult to reconcile with a neoclassical labor market where wages are determined by their marginal productivity, which is highly correlated with output. As pointed out by Krause and Lubik (2007), the search and matching framework breaks this relationship because wages share the surplus of an employment relationship. However, the simulated value of 0.48 is still higher than the correlation of 0.25 between output and real wages in the data. Wages are still too pro-cyclical. The observed negative correlation between unemployment and vacancies, −0.53 in the data, is not matched by the model, which displays a correlation of −0.06. Next, I consider the behavior of inflation. Empirically, inflation has a negative correlation with output of −0.25, and its correlation with real wages is −0.42. In the model, inflation and output are strongly negatively correlated at −0.97, while the correlation between inflation and the real wage is −0.32, close to the data. Some conclusions can be drawn at this point. In general, the baseline model is unable to mimic closely some of the business cycle properties of the UK economy. In particular, the model fails to account for the strong correlation of vacancies with unemployment.

Before focusing on the effects of firing costs and unemployment benefits on the dynamics of the system, I point out what makes the model perform somewhat differently from that proposed by Krause and Lubik (2007). This is particularly important in order to isolate the contribution of firing costs and unemployment benefits. The model differs from Krause and Lubik's (2007) setting in three aspects: first, as previously mentioned, by using Calvo's price setting rule instead of quadratic adjustment costs as described by Rotemberg (1982); second, by using an interest rate rule rather than a money growth rule; and, finally, labor firing costs are included. The Calvo price setting mechanism is not responsible for this difference, since the stickiness parameter in the quadratic adjustment costs formulation can be calibrated such that the two approaches produce observationally equivalent results. Similarly, as Krause and Lubik (2007) point out, if I had used a money supply process instead of an interest rate rule, the results would be similar, since these two approaches are virtually identical. Hence, what makes the model perform differently from that proposed by Krause and Lubik (2007) is the presence of firing costs. For instance, one striking difference in the performance of the model is the lack of correlation between unemployment and vacancies, which is close to zero, instead of being strongly positive as described by Krause and Lubik (2007). Here, the absence of correlation can be explained by the presence of firing costs. As described, an increase in firing costs reduces the productivity threshold that makes a match profitable and consequently diminishes the mass of jobs sensitive to deterioration. This implies that when a shock hits the economy and temporarily displaces the productivity threshold from its steady-state value, the number of jobs sensitive to deterioration is smaller. As a result, the job separation rate reacts less in response to shocks, and so does unemployment. This result generates a less positive, and in this case close to zero correlation between vacancies and

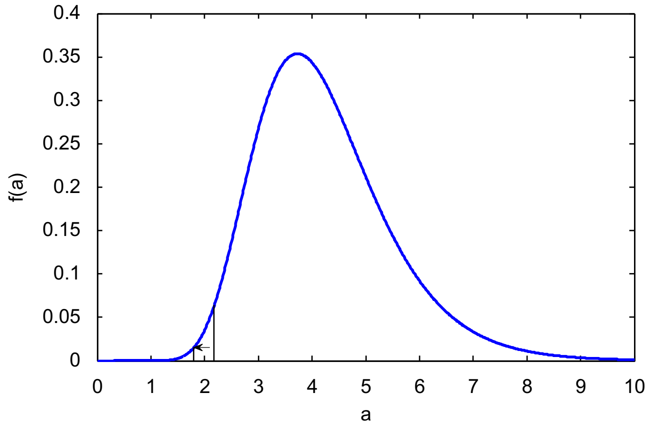

Fig. 4. The idiosyncratic productivity distribution, increase in firing costs. Notes: The figure shows the effect of an increase by five percentage points in firing costs on the idiosyncratic productivity threshold, $\tilde{a}$.

unemployment. Thomas (2006) shows similar findings in the context of a real business cycle model that accounts for firing costs and Zanetti (forthcoming) finds that labor market institutions, including firing costs, enhance the performance of the model to replicate the negative correlation of vacancies and unemployment in the data.

I can now analyze how changes in firing costs and the replacement ratio affect business cycle dynamics. The fourth column of Table 2 shows business cycle statistics of the variables when firing costs increase by five-percentage points, from 30% to 35%. The standard deviation of output decreases together with those of employment and unemployment and flows into and out of employment, while those of vacancies, real wages, and inflation increase. The same findings hold for the relative standard deviation of the variables. The volatility of inflation and real wages increases as a result of firing costs. Why does it happen? The behavior of the equilibrium productivity threshold plays a key role in the explanation. As firing costs increase, the equilibrium productivity threshold decreases, as previously described, so that the number of jobs sensitive to deterioration in the economy is lower. Fig. 4 plots the distribution of the idiosyncratic productivity value a, along with the zero surplus level, $\tilde{a}$. The figure captures the fact that the mass of jobs sensitive to deterioration decreases. Shocks would displace fewer jobs and this would immediately translate into lower volatility of flows out of employment. Firing costs affect the inter-temporal employment decision of the firm, since increasing current employment exposes the firm to future firing costs. It becomes more expensive for the firm to hire or fire workers; the firm relies more on job destruction rather than firings to reduce its labor force. It continues to post vacancies, many of which will not be filled, so that their volatility increases. At the same time, the volatility of output, employment, unemployment, and flows in and out of employment decreases. Real wages become more volatile because an increase in firing costs amplifies the impact of the changes in the proportion of continuing workers on the average wage, as can be seen from Eq. (23). As real wages and thus marginal costs become more volatile, inflation displays higher volatility. Real wages remain slightly pro-cyclical, with a correlation to output of 0.18, closer to the data compared to that of the benchmark model. Since firing costs affect output and inflation in an opposite respects, their correlation decreases substantially and becomes closer to the data. The negative correlation between vacancies and unemployment increases slightly.

The fifth column of Table 2 shows the business cycle statistics of the variables when the replacement ratio increases by five-percentage points, from 30% to 35%. These results are opposite to the ones produced by an increase in firing costs. The key mechanism at work is again the response of the equilibrium reservation productivity to a change in unemployment benefits.

The last column of Table 2 shows the effect of increasing both the replacement ratio and firing costs by five-percentage points, from 30% to 35%. Consistent with the steady-state analysis, where the effect of firing costs is more significant than unemployment benefits in determining the equilibrium of the economy, the changes in volatilities from the benchmark calibration of the model are qualitatively closer to the case of an increase in firing costs.

5.4. Robustness analysis

The results presented above clearly depend to some extent on the distribution of the idiosyncratic productivity shocks. I therefore investigate the robustness of the results with respect to alternative calibrations of the baseline log-normal distribution.

I consider alternative parameter choices that are of particular interest. Since the calibration of 0.29 for the standard deviation of the distribution of the idiosyncratic shocks, $\sigma_{\ln}$, can be considered as a mid-point value, given the parameterization used elsewhere in the literature, I experiment using the parameter values of 0.10, as described by den Haan et al. (2000), and 0.4, as described in Trigari (2009). An increase in the variance of the idiosyncratic shocks moves the mode of the distribution to the left, increases the positive skewness of the distribution, and enlarges the "fat" right tail of the Pareto functional form. The opposite occurs for a decrease in the variance of the idiosyncratic productivity shocks, where the

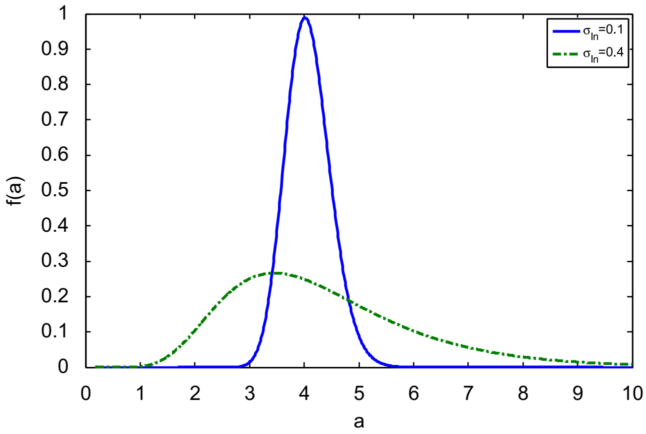

Fig. 5. The idiosyncratic productivity distribution, different calibrations, $\sigma_{\ln} = 0.1$ and 0.4. Notes: The figure shows different calibrations for the standard deviation of the distribution of the idiosyncratic productivity shock, $\sigma_{\ln}$.

Table 3
Business cycle properties, different calibrations, $\sigma_{\ln} = 0.1$ and 0.4.

Variable	Benchmark calibration	Increase in firing costs	Increase in rep. ratio
Standard deviations: $\sigma_{\ln} = 0.1$			
Output	1.10	0.92	1.25
Employment	0.62	0.55	0.72
Unemployment	11.22	9.11	12.14
Vacancies	9.33	15.12	7.11
Flows out of employment	0.17	0.14	0.22
Flows into employment	0.22	0.17	0.31
Inflation	0.70	0.82	0.66
Real wages	0.55	0.62	0.45
Standard deviations: $\sigma_{\ln} = 0.4$			
Output	0.82	0.63	0.93
Employment	0.43	0.37	0.55
Unemployment	8.70	6.20	9.32
Vacancies	6.12	7.12	5.12
Flows out of employment	0.07	0.03	0.11
Flows into employment	0.10	0.05	0.17
Inflation	2.59	3.39	2.18
Real wages	1.43	1.74	0.98

Notes: For further information, see notes to Table 2.

distribution becomes closer to a normal one. This result is shown in Fig. 5, where I compare a calibration of $\sigma_{\ln} = 0.1$ with $\sigma_{\ln} = 0.4$.

In this model, a change in the distribution of the idiosyncratic shocks also changes the critical threshold at which jobs are destroyed and hence, the endogenous job destruction rate. Specifically, an increase in the variance of the distribution of the idiosyncratic shocks decreases the equilibrium productivity threshold, which reduces the rate of endogenous separation. A decrease in the variance of the distribution of the idiosyncratic shocks has the opposite effect.[18] Table 3 presents the standard deviations of the variables under these new calibrations to quantify, similar to the previous analysis, how changes in firing costs and the replacement ratio affect the business cycle dynamics for different shapes of the distribution of idiosyncratic shocks. Note that the standard deviation of the distribution of the idiosyncratic productivity shocks is the only parameter that directly changes in the exercise. However, a change in the standard deviation of the idiosyncratic productivity shocks produces a new value for the equilibrium productivity threshold and consequently, a full new calibration. Nonetheless because decreasing (increasing) the variance of the distribution of the idiosyncratic shocks shifts the equilibrium productivity threshold to the right (left), and keeps it below the mode of the distribution, the underlying qualitative results of the previous analysis remain unchanged. Depending on how firing costs and the replacement ratio move the equilibrium productivity threshold, the variables would display different magnitudes of volatilities; however, they would remain qualitatively in line with previous analyses. For instance, for both calibrations, increasing firing costs decreases, the volatility

[18] Note that, in this instance also, although the equilibrium productivity threshold increases, it remains below the mode of the distribution.

of output while increasing that of inflation, and the reverse occurs for an increase in the replacement ratio. Of course, the magnitude of the fluctuations is different since a lower calibration of $\sigma_{\ln} = 0.1$ increases the equilibrium productivity threshold; aggregate shocks would displace more jobs and thus increase the impact of labor market institutions on aggregate fluctuations. On the other hand, a higher calibration of $\sigma_{\ln} = 0.4$ produces lower volatility overall. Although the quantitative results differ from the benchmark case, the qualitative similarities between this section and the previous one suggest that the main findings are robust to different calibrations of the log-normal distribution.

6. Conclusions

This paper has analyzed the effects of labor market institutions on aggregate fluctuations. The analysis focused on firing costs and unemployment benefits in a DSGE framework characterized by search and matching frictions in the labor market and nominal rigidities in the goods market. Labor market institutions have significant effects on the structural features of the economy. Changes in labor market institutions alter the deep structure of the economy and hence, the way it reacts to disturbances. Firing costs lower the response of output, employment and job flows, while increasing that of inflation. Unemployment benefits produce reverse effects. It must be noted that the distribution of the idiosyncratic productivity shocks that firms face is important. Here, in line with empirical evidence and previous theoretical studies, the distribution is log-normal. Its calibration, as determined by the robustness analysis, is important in determining the precise quantitative effects of firing costs and unemployment benefits on aggregate fluctuations. Nonetheless, the qualitative results continue to hold for different calibrations of the log-normal distribution.

Since firing costs and unemployment benefits affect the volatility of output and inflation, they may have non-trivial effects on the actions that a welfare-maximizing monetary policymaker should undertake. As each labor market institution has opposite effects on output and inflation, and moreover, since the two institutions together affect the volatility of output and inflation in opposite directions, it is difficult to assess their implications for optimal monetary policy without performing a formal evaluation exercise. I leave the investigation of this topic open for future research.

While the results support the importance of labor market institutions for business cycle dynamics, it should also be noted that, as Blanchard and Wolfers (2000) pointed out, the combined interaction of disturbances and labor market institutions might have a non-trivial impact on aggregate fluctuations. Although the model developed here allows aggregate productivity and nominal disturbances to affect the economy, in practice, a variety of other aggregate shocks may play a role. The inclusion of additional disturbances and the study of the interaction between labor market institutions and a broader set of aggregate shocks remain outstanding tasks for future research.

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Appendix A. Data description

The labor market data that I use to present the stylized facts in this paper come from two main sources: Labour Market Trends and the Labour Force Survey, both published by the Office for National Statistics. All data are for the United Kingdom and are seasonally adjusted. Data are quarterly and cover the period 1980:Q1–2005:Q3. Employment is defined as employees in employment. Unemployment is claimant unemployment. Vacancies are vacancies at job centers while real wages are indexes of whole-economy average earnings deflated by the consumer price index excluding mortgage interest payments. Job creation and job destruction are employment inflow and outflow rates as described in Bell and Smith (2002). Output is measured by gross domestic product excluding oil and gas extraction. Inflation is the percentage change in the consumer price index compared with the same month one year back.

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