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Abstract

This paper explores the influence of some key institutional features of the labour market on aggregate fluctuations. It uses a dynamic, stochastic, general equilibrium model characterised by search and matching frictions in the labour 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 of 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, and inflation then becomes more volatile. Raising unemployment benefits has the reverse effect on aggregate fluctuations.

Key words: Labour market institutions, search and matching, New Keynesian model, business cycles.

JEL classification: E24, E32, E52, J64.

Summary

It is recognised that the labour market plays an important role in the assessment of the economy. The value of labour accounts for two thirds of the total value of goods and services produced in the economy. That makes labour costs a crucial influence on most firm's production and pricing decisions, and, therefore, on the dynamics of inflation and other important macroeconomic variables. This paper explores the influence of some key institutional features of the labour market on aggregate fluctuations in real quantities like output and unemployment, and inflation. It assesses their quantitative implications by studying the effects of unemployment benefits and firing costs. Unemployment benefits are modelled as payments that accrue to workers after separations from jobs, while firing costs are modelled as firing taxes that firms pay when a worker is dismissed. It is widely thought that the best approach to macroeconomics is to use a general equilibrium approach, where the evolution of the economy over time is fully integrated into the model, and the uncertain ('stochastic') nature of the world is explicitly recognised. These are known as dynamic stochastic general equilibrium (DSGE) models. This paper uses a DSGE model characterised by search and matching frictions in the labour market and nominal rigidities in the goods market, a relatively new approach.

Results suggest that an increase in firing costs decreases the volatility of output, unemployment, employment and flows both into and out of employment, while the volatility of inflation, real wages and labour market tightness all increase. The presence of firing costs affects the intertemporal employment decision of firms, since an increase in current employment exposes firms to future firing costs. This induces firms to decrease lay-offs and hiring, leading to higher unemployment duration and lower unemployment incidence. 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 reverse effect. The volatility of output, unemployment, employment, and flows in and out of the labour market increases, while the volatility of inflation, real wages and labour market tightness decreases. Higher unemployment benefits make unemployment less painful for workers, causing the duration and flows into unemployment to increase. Since workers have an incentive to stay out of employment as long as they are eligible for unemployment benefits, and shocks displace a larger number of jobs, the

volatility of labour market quantities increases. Firms find it more convenient to adjust the employment level in response to shocks, so that they are less likely to adjust their prices in response to disturbances. As a result, inflation volatility decreases.

1 Introduction

Labour market institutions play an important role in the macroeconomic performance of an economy.[1] In principle, the structure of the labour market impacts on 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 labour market institutions on the underlying structural features of the economy,[2] but, as detailed below, only a few papers study their impact on business cycle fluctuations. Of those, none has used a general equilibrium search and matching model of the labour market, nor have any of them incorporated nominal rigidities in the analysis.

In this paper, we take on this task. Our main question is: how do labour market institutions affect aggregate fluctuations? To answer this question we employ a dynamic, stochastic, general equilibrium (DSGE) model with search frictions in the labour market and nominal rigidities in the goods market. The use of a DSGE approach allows us to control for the effects of other possible factors that can affect aggregate dynamics, to isolate the effects of labour market institutions. We use a search framework in the labour market with endogenous job destruction as in Mortensen and Pissarides (1994) because for analysing positive and normative questions about labour institutions, 'we need a theory that includes reasons why people allocate time to a particular activity – like unemployment' as noted by Lucas (1987, page 50). In this theoretical framework, equilibrium unemployment arises endogenously because workers and employers encounter frictions that limit their flows of meetings. We adopt nominal rigidities in the goods market because this enables us to investigate the impact of labour market institutions on the pricing decisions of firms and, hence, on inflation. Moreover, in this way, we can analyse the effect of nominal shocks on aggregate fluctuations.

We assess the quantitative implications of labour market institutions by studying the effects of unemployment benefits and firing costs. Unemployment benefits are modelled as payments that accrue to workers after separations, while firing costs are modelled as 'firing taxes' that firms pay when a worker is dismissed. The choice of these particular labour market institutions is motivated by both empirical evidence and theoretical considerations. Empirically, Nickell (1997) and Blanchard and Wolfers (2000) conclude that such institutions in practice have a statistically

(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).

significant influence on labour market performance. On theoretical grounds, Pissarides (2000, Chapter 9) points out that these institutions are particularly relevant to explain structural features of the labour market. To make a quantitative assessment of how these labour market institutions impact on aggregate fluctuations, we calibrate our benchmark economy to UK data. We then compare the implications of our benchmark economy to a situation where firing costs and unemployment benefits increase from their benchmark calibration. For each of these changes we analyse the effects on the steady-state equilibrium and business cycle dynamics.

Our results suggest that an increase in firing costs decreases the volatility of output, unemployment, employment, and flows both in and out of employment, while the volatility of inflation, real wages and labour market tightness all increase. The presence of firing costs affects the intertemporal employment decision of firms, since an increase in current employment exposes firms to future firing costs. This induces firms to decrease lay-offs and hiring, leading to higher unemployment duration and lower unemployment incidence. The mass of jobs sensitive to deteriorations in the economy decreases and so 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. The volatility of output, unemployment, employment, and flows in and out of the labour market increases, while the volatility of inflation, real wages and labour market tightness decreases. Higher unemployment benefits make unemployment less painful for workers, causing the duration and flows into unemployment to increase. The mass of jobs sensitive to deteriorations in the economy increases, which amplifies the effect of shocks on labour quantities and output. Since workers have an incentive to stay out of employment as long as they are eligible for unemployment benefits, and shocks displace a larger number of jobs, the volatility of labour market quantities increases. Firms find it more convenient to adjust the employment level in response to shocks, so that they are less likely to adjust their prices in response to disturbances. As a result, inflation volatility decreases.

As mentioned earlier, much of the existing analysis of labour market institutions has tended to focus on their impact on the deterministic equilibrium of the economy, with the inflationary consequences largely ignored. Millard and Mortensen (1997) and Mortensen and Pissarides

(1999) analyse the impact of different labour market institutions on the steady state of unemployment and output. Similarly, Chari *et al* (2005) build on the labour matching framework to study the connection between labour institutions and investment in training. Alvarez and Veracierto (1999) explore the extent to which labour market policies can explain differences in employment across economies using a Lucas-Prescott equilibrium search model. Alonso-Borrego *et al* (2005) evaluate specific labour market reforms such as temporary contracts and firing costs in a model with heterogeneous agents and labour search. Finally, Yashiv (2004) explores the consequences of macroeconomic policy for labour market outcomes in a partial-equilibrium model. We extend this line of research to a general equilibrium setting with a more comprehensive structure of the labour market, that is capable of analysing a broader set of dynamics. All these works limit their analysis to the deterministic equilibrium of the economy, and they do not consider nominal variables such as inflation. In contrast, this paper computes the full-blown stochastic equilibrium and account for nominal variables. Veracierto (2005) 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 labour 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 labour market in the economy.

This paper is not the first work that combines a New Keynesian setting with search and matching frictions in the labour market. An increasing number of papers, such as Blanchard and Gali (2006), Christoffel and Linzert (2005), Krause and Lubik (2007), Trigari (2005), and Walsh (2005) use the search framework to incorporate the labour market frictions into a monetary economy and find that those improve the ability of the standard New Keynesian framework to replicate the actually observed dynamics of unemployment and inflation. This paper uses a similar setting, but, unlike any of these works, incorporates labour 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 analysing the effect of labour 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 labour market institutions and their influence on inflation.

The remainder of the paper is organised as follows: Section 2 describes the economic environment, Section 3 sets up the model, Section 4 defines the equilibrium and presents the solution method, Section 5 describes the baseline calibration, Section 6 discusses the findings, and Section 7 concludes.

2 The economic environment

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

During each period $t = 0, 1, 2, \ldots$, each representative goods-producing firm posts vacancies to recruit workers and, once the firm and worker agree on a specific wage contract, the firm produces a distinct, perishable good. During each period $t = 0, 1, 2, \ldots$, each retail firm purchases intermediate goods from a representative goods-producing firm and sells it at an established price on the market. The advantage of this modelling strategy for the goods market is that staggered price-setting can be explicitly modelled in the retail market as in Calvo (1983).[3]

The labour market is based on den Haan *et al* (2000), which build 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 is time consuming, and costly for both the representative goods-producing firm and worker. To capture this idea, a matching function describes the number of jobs formed at any moment in time as a function of the number of unemployed workers looking for a job, and the number of vacancies posted by firms. Job creation takes place when a firm and a searching worker meet and agree to form a match at a negotiated wage. The match continues until a negative idiosyncratic shock arrives or the parties exogenously decide to terminate the relationship. When one of these events realise, job destruction takes place and the worker moves from employment to unemployment, and the representative goods-producing firm can either withdraw from the market or re-open a job as a new vacancy.

The central bank is modelled with a modified Taylor (1993) rule as in Clarida *et al* (1998): it

(3) A similar specification is proposed by Bernanke *et al* (1999).

gradually adjusts the nominal interest rate in response to output and inflation deviations from their steady-state levels.

The next section formalises these concepts.

3 The model

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 $\theta_t = v_t/u_t$, labour market tightness, so 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 $p(\theta_t) = m(u_t, v_t)/u_t = \chi \theta_t^{1-\xi}$. With 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 $t = 0, 1, 2, \ldots$, 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 ρ_t^n, when the idiosyncratic shock falls below some threshold, $\widetilde{a_t}$. As in Mortensen and Pissarides (1994), we assume that new matches have an idiosyncratic productivity, a^N, that is always higher than $\widetilde{a_t}$ so 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 lognormal distribution with mean $\mu_{\ln}$, and standard deviation $\sigma_{\ln}^2$. When endogenous separation takes place, the firm incurs a firing cost, F. Given this setting, total employment for the representative goods-producing firm is $n_t = (1 - \rho_t)n_{t-1} + m(u_{t-1}, v_{t-1})$.

3.1 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 labour force is normalised to one. During each period $t = 0, 1, 2, \ldots$, the representative household maximises an expected utility function of the form

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

where the variable C_t is consumption, M_t/P_t is real money holdings, and β is the discount factor $0 < \beta < 1$. 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 T_t from the central bank, nominal profits Π_t from the representative intermediate goods-producing firm, and labour 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, and carries M_t units of money, and B_t bonds into period $t+1$, subject to the budget constraint

$$P_t C_t + B_t/R_t + M_t = B_{t-1} + Y_t + \Pi_t + T_t + M_{t-1} \qquad \textbf{(2)}$$

for all $t = 0, 1, 2, ...$ Thus the household chooses $\{C_t, B_t, M_t\}_{t=0}^{\infty}$ to maximise 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, $\pi_t = P_t/P_{t-1}$ the gross inflation rate, and Λ_t the non-negative Lagrange multiplier on the budget constraint **(2)**, the first-order conditions for this problem are

$$C_t^{-\sigma} = \Lambda_t \qquad \textbf{(3)}$$

and

$$\beta E_t \beta_{t,t+1} = E_t \pi_{t+1}/R_t \qquad \textbf{(4)}$$

where $\beta_{t,t+1} = \Lambda_{t+1}/\Lambda_t$ is the stochastic discount factor. Equations **(3)** and **(4)**, are standard Euler equations and describe the optimal path for consumption and bonds respectively.(4)

Let U_t, W_t^N, and $W_t(a_t)$ denote the present-discounted value of the expected income of an unemployed, new employed, and continuing 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

$$U_t = b + E_t \beta_{t,t+1}[p(\theta_t) W_{t+1}^N + (1 - p(\theta_t)) U_{t+1}] \qquad \textbf{(5)}$$

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 in Pissarides (2000), we assume that $b = h + \rho_R w$, where h represent value of leisure or home production, w the average wage at the

(4) 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.

steady state, and ρ_R the replacement ratio for unemployment benefits. We assume that $0 < \rho_R < 1$.

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, $w_t(a_t)$. In this way, if a new match is immediately dismissed, the firm does not have the burden of firing costs. 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, and are:

$$W_t^N = w_t^N + E_t\beta_{t,t+1}[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}(a_{t+1})dG(a_{t+1}) + \rho_{t+1}U_{t+1}] \quad \textbf{(6)}$$

and

$$W_t(a_t) = w_t(a_t) + E_t\beta_{t,t+1}[(1-\rho^x)\int_{\tilde{a}_{t+1}}^{\infty} W_{t+1}(a_{t+1})dG(a_{t+1}) + \rho_{t+1}U_{t+1}] \quad \textbf{(7)}$$

Equations **(6)** and **(7)** 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.

3.2 The goods market

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

3.2.1 The representative goods-producing firm

During each period $t = 0, 1, 2, \ldots$, each representative goods-producing firm posts vacancies at a cost c to recruit a new worker and faces an idiosyncratic job-specific shock, a_t, and a common productivity disturbance, A_t, on established jobs. If the idiosyncratic shock is below some threshold, $\widetilde{a_t}$, 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 $\ln(A_t) = \rho_A \ln(A_{t-1}) + \varepsilon_{At}$, with $0 < \rho_A < 1$, where the zero-mean, serially uncorrelated innovation ε_{At} is normally distributed with standard deviation σ_A^2. Let V_t denote the present-discounted value of expected profits from a vacant job. Hence, the present value of a vacancy is

$$V_t = -c + E_t\beta_{t,t+1}\left[q(\theta_t)J_{t+1}^N + (1-q(\theta_t))V_{t+1}\right] \quad \textbf{(8)}$$

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

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

$$J^N_t = \epsilon_t A_t a^N - w^N_t + E_t \beta_{t,t+1}(1-\rho^x)[\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a_{t+1}) dG(a_{t+1}) - G(\tilde{a}_{t+1})F] \quad \textbf{(9)}$$

where ϵ_t is 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

$$J_t(a_t) = \epsilon_t A_t a_t - w_t(a_t) + E_t \beta_{t,t+1}(1-\rho^x)[\int_{\tilde{a}_{t+1}}^{\infty} J_{t+1}(a_{t+1}) dG(a_{t+1}) - G(\tilde{a}_{t+1})F] \quad \textbf{(10)}$$

Equations **(9)** and **(10)** state that the value of a new match yields a net return $\epsilon_t A_t a_t - w_t(a_t)$ and a present-discounted net value $J_{t+1}(a_{t+1}) - G(\tilde{a}_{t+1})F$, if the job is not destroyed.

3.2.2 Wage-setting

The structure of the model guarantees that a realised job match yields some pure economic surplus. The share of this surplus between the worker and the firm is determined by the wage level, in addition to compensating each side for its costs from forming the job. As in Pissarides (2000), the wage is set according to the Nash bargaining solution. 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

$$\eta(J_t(a_t) + F) = (1-\eta)(W_t(a_t) - U_t)$$

and

$$\eta J^N_t(a_t) = (1-\eta)(W^N_t - U_t)$$

As the job idiosyncratic productivity of new jobs is always higher than the threshold, firing costs do not appear in the second equation. Hence, using equations **(5)-(10)**, the agreed wage for continuing, $w_t(a_t)$, and new workers, w^N_t, are

$$w_t(a_t) = \eta[\epsilon_t A_t a_t + c\theta_t + (1-\zeta_t)F] + (1-\eta)\, b \quad \textbf{(11)}$$

and

$$w^N_t = \eta[\epsilon_t A_t a^N + c\theta_t - \zeta_t F] + (1-\eta)\, b \quad \textbf{(12)}$$

where $\zeta_t = E_t \beta_{t,t+1}(1-\rho^x)$. Equations **(11)** and **(12)** state that workers receive a wage made up of two parts. First, for a fraction η, from the revenue product generated, $\epsilon_t A_t a_t$, a reward for the saving of hiring costs, $c\theta_t$, a charge for the future expected firing costs in both cases, $\zeta_t F$, and a compensation for the saving of firing costs, F, in the case of continuing workers. Second, for a fraction $1 - \eta$, from the real return of unemployment, b.

3.2.3 The retail sector

During each period $t = 0, 1, 2, ...$, the representative retail firm uses $Y_t(i)$ units of each intermediate good $i \in [0, 1]$, purchased at the nominal price $P_t(i)$, to manufacture Y_t units of the finished good according to the constant-returns-to-scale technology described by

$$Y_t = \int_0^1 \left[Y_t(i)^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}} \qquad \textbf{(13)}$$

where γ is the elasticity of demand for each intermediate good.

The firm acts to maximise its profits; the first-order conditions for this problem are

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

for all $i \in [0, 1]$ and $t = 0, 1, 2, ...$ Competition drives the goods-producing firm's profits to zero in equilibrium, determining P_t as

$$P_t = \left[\int_0^1 P_t(i)^{1-\gamma} di \right]^{\frac{1}{1-\gamma}} \qquad \textbf{(14)}$$

for all $t = 0, 1, 2, ...$ The representative retail firm sets prices as in 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 time 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 maximises

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

where $\beta_{t,t+1}^j$ 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

$$P_t(i) = \frac{\gamma \sum_{j=0}^{\infty} (\nu\beta)^j E_t \left(\Lambda_{t+j} P_{t+j}^{\gamma} Y_{t+j} \epsilon_{t+j} \right)}{(\gamma - 1) \sum_{j=0}^{\infty} (\nu\beta\pi)^j E_t \left(\Lambda_{t+j} P_{t+j}^{\gamma-1} Y_{t+j} \right)} \qquad \textbf{(15)}$$

3.3 The central bank

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

$$\ln(R_t/R) = \rho_r \ln(R_{t-1}/R) + \rho_y \ln(Y_t/Y) + \rho_\pi \ln(\pi_t/\pi) + \varepsilon_{rt} \qquad \textbf{(16)}$$

where R, Y, and π are the steady-state values of the nominal interest rate, output, and gross inflation rate respectively. According to equation **(16)**, the central bank gradually adjusts the nominal interest rate in response to movements in output and inflation. The zero-mean, serially uncorrelated policy shock ε_{rt} is normally distributed with a standard deviation σ_r^2. As pointed out in Clarida *et al* (1998) and Nelson (2003), this modelling strategy for the central bank is broadly consistent with actual monetary policy for the United Kingdom since the early 1990s.

4 Symmetric equilibrium

In a symmetric, dynamic, equilibrium all retail firms make identical decisions, so that $P_t(i) = P_t$. In equilibrium, free entry drives the profit from an open vacancy to zero, so that $V_t = 0$. This combined with equations **(8)**, **(9)**, and **(12)** yields the job creation condition

$$c/q(\theta_t) = (1-\eta)E_t\beta_{t,t+1}[\epsilon_{t+1}A_{t+1}(a^N - \tilde{a}_{t+1}) - F] \qquad \textbf{(17)}$$

In equilibrium, jobs are destroyed when the surplus that the firm receives from the job, $J_t(a_t) + F$, falls below zero. The variable $\tilde{a}_t$ is the threshold of the idiosyncratic shock below which a job is not profitable, that is $J_t(\widetilde{a}_t) + F = 0$. This combined with equations **(10)** and **(11)** yields the job destruction condition

$$\begin{aligned} &\epsilon_t A_t \tilde{a}_t - b - \left[\eta/(1-\eta)\right] c\theta_t + (1-\zeta_t)F \\ &+E_t\beta_{t,t+1}(1-\rho^x)\epsilon_{t+1}A_{t+1}\int_{\tilde{a}_{t+1}}^{\infty}(a_{t+1}-\tilde{a}_{t+1})dG(a_{t+1}) = 0 \end{aligned} \qquad \textbf{(18)}$$

In equilibrium, the average wage, w_t, is a weighted average of equations **(11)** and **(12)** with weights $\omega_t^C = (1-\rho_t)n_{t-1}/n_t$ for continuing workers, and $1-\omega_t^C$ for new matches so that

$$w_t = \eta[\epsilon_t A_t \bar{a}_t + c\theta_t + (\omega_t^C - \zeta_t)F] + (1-\eta)b \qquad \textbf{(19)}$$

where $\bar{a}_t = \omega_t^C H(\tilde{a}_t) + (1-\omega_t^C)a^N$ 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. In equilibrium, the aggregate income is $y_t = n_t A_t \bar{a}_t - cv_t$.

The equilibrium is described by the evolution of employment, total job separation, labour market tightness, the definition of employed workers, equations **(3)** and **(4)**, the return from employment, the definition of the stochastic discount factor, equations **(14)-(19)**, the specification of the shocks, and the aggregate income. The system is approximated by log-linearising 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 Kahn (1980).

5 Calibration

The benchmark economy is calibrated to reproduce the structural characteristics of the UK economy for the period 1980 Q1 – 2005 Q3. We calibrate the model on quarterly frequencies and the value for each parameter is reported as follows. We set the discount factor, β, equal to 0.99, which implies an annual steady-state real interest rate of 4%. The coefficient of relative risk aversion, σ, equals 2 as in King and Rebelo (2000).

The steady-state unemployment rate is set to 4.5%. We set the steady-state separation rate $\rho = 0.02$. These two parameters pin down the probability that an unemployed worker will find a job in any given period, $p = \rho(1-u)/u$, equal to 0.6. These values are consistent for the UK economy, as suggested in Burgess and Turon (2005). Following the evidence in Bell and Smith (2002), we impose an exogenous job destruction rate of $\rho^x = 0.01$. Consequently, the endogenous separation rate can be computed as $\rho^n = (\rho - \rho^x)/(1-\rho^x) = 0.005$. The implied reservation productivity threshold is $\widetilde{a} = G^{-1}(\rho^n) = 0.77$. Following the standard assumption in the literature, as in den Haan *et al* (2000), we assume that idiosyncratic productivity, $\widetilde{a}$, is lognormal and i.i.d., with c.d.f. $G(\cdot)$. We calibrate the value for the mean of $G(\cdot)$, $\mu_{\ln}$, equal to zero, and the value of its standard deviation, $\sigma^2_{\ln}$, equal to 0.1. Similar values are used in Burgess and Turon (2005). We assume that the idiosyncratic productivity for new matches is always in the 95th percentile of $G(\cdot)$, so that $a^N > \widetilde{a}$ and new matches never separate.

As in Burgess and Turon (2005), we set the firm matching rate $q(\theta) = 0.9$. The match elasticity, ξ, is calibrated to 0.7, based on the empirical estimates in Bean (1994). The level parameter of the matching function, χ, is computed using the fact that the steady-state number of matches is

$\rho(1-u)$. As it is standard in the literature, we calibrate the worker's share parameter, η, to 0.5, so 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 is broadly consistent with Mortensen and Pissarides (1999). Firing costs, F, and the replacement ratio, ρ_R, amount to 30% of the mean wage. These values are similar to those found in the UK economy in Bean (1994) and Nickell (1997).

We 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 in Rotemberg and Woodford (1992). We set the parameter ν equal to 0.75, such that the average contract length is four quarters, as in Taylor (1999). Therefore, the elasticity of inflation with respect to marginal costs is $\kappa = (1-\nu)(1-\nu\beta)/\nu = 0.09$. As in Krause and Lubik (2007), we set the value for steady-state gross inflation, π, equal to 1.

We 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, we calibrate the shock processes. The value of the standard deviation of the policy shock is in line with Clarida *et al* (1998), who estimate a similar specification for this shock with the generalised method of moments for the United Kingdom. Its standard deviation, σ_r, equals 0.0012. In line with most of the literature, we set the serial correlation for the technology shock, ρ_A, equal to 0.94. Following the common practice in the literature,[5] we 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 0.003.

6 Findings

This section is divided into three parts: first, we describe the changes labour market institutions produce in the model steady state; second, we analyse the model's impulse responses to demand

(5) See Krause and Lubik (2005) and references therein.

and supply shocks; and, finally, we simulate the model in order to determine the effects of firing costs and the replacement ratio on business cycle dynamics.

6.1 Steady-state analysis

The third column of Table A shows the effects of increasing the replacement ratio by 5 percentage points, from 30% to 35%. An increase in the replacement ratio increases the relative value of the unemployment option to workers so that the average wage, specified by equation **(19)**, increases from 0.91 to 0.92. The increase in the replacement ratio generates an upwards shift in the job destruction relation, as expressed in equation **(18)** and represented in Chart 1. Since the job creation condition, as in equation **(17)**, 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 in the chart, the equilibrium job-finding rate, as reflected in labour 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. Quantitatively, the equilibrium productivity threshold increases by around 3%, causing the rate of endogenous job destruction to increase from 0.5% to 0.9% and, similarly, the overall rate of job destruction rises from 1.5% to 1.9%. The unemployment rate increases from 4.5% to 5.5% and, conversely, vacancies decline by around 7%.

The fourth column of Table A shows the effects of increasing firing costs by 5 percentage points, from 30% to 35%. An increase in firing costs has an opposite effect on the job destruction relation as an increase in the replacement ratio. As depicted in Chart 2, the increase in firing costs also raises future profitability given reservation productivity, so that the job creation schedule, as specified in equation **(17)**, shifts left. At the same time, the job destruction condition, as in equation **(18)**, shifts downwards. The equilibrium productivity threshold unambiguously declines, and also labour market tightness decreases. The reduction of labour market tightness increases unemployment duration, while job flows decrease. In our calibration, the second effect dominates so that the unemployment rate decreases. Quantitatively, equilibrium labour market tightness decreases by around 9% and, similarly, the equilibrium reservation productivity by around 8%. As a consequence, the endogenous job destruction rate decreases from 0.5% to 0.2% and, similarly, the rate of total job destruction falls from 1.5% to 1.2%. Both the decrease in the job destruction rate and the lower duration of unemployment leads to a fall in the unemployment rate, from 4.5% to 3.4%. Overall, these findings show that an expansion of labour market institutions in the form of either firing costs or unemployment benefits have a reverse effect on the mean levels around which the economy fluctuates.

As a final exercise of this section, the last column of Table A shows the effects of increasing both the replacement ratio and firing costs by 5 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 institutions 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 labour market tightness decreases by around 9%, and the equilibrium reservation productivity by around 7%. These changes trigger a decrease of the rate of endogenous and total job destruction from 0.5% to 0.1% and 1.5% to 1.1% respectively. The unemployment rate decreases from 4.5% to 4.2%, while output increases by around 1%. This exercise suggests that for a similar increase in the replacement ratio and firing costs, the latter leads the reaction of the job destruction condition such that it shapes the equilibrium of the economy.

6.2 Impulse response analysis

This section discusses the impulse responses to technology and monetary shocks for the benchmark calibration of the model. Chart 3 shows the model's response to a 1 percentage point 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 rise on impact and then decline back to the initial equilibrium. Vacancies increase, unemployment falls both leading to a rise in labour market tightness, and then return gently to equilibrium. A rise in labour 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 a fall in reservation productivity.

Chart 4 shows the model's response to a 1 percentage point 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, then quickly return to their steady-state levels. Labour market tightness increases due to a higher increase in vacancies than in unemployment. This is in contrast with the data, as discussed in the next section. It results from a large increase in separations, which is reflected in the behaviour of the job destruction rate. In fact, firms tend to reduce employment by destroying more jobs, even more productive ones, rather then 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 is because the disturbance is serially uncorrelated and the smoothing parameter, ρ_r, in the modified Taylor rule is small.

At this point, it is important to note that in the model changes in firing costs and the replacement ratio have no strong qualitative effects on the way shocks propagate. Nonetheless, they have a significant quantitative effect on the amplification of disturbances; this is evaluated in the next section.

6.3 Business cycle dynamics

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

Before examining the performance of the model when both shocks are considered, Table B evaluates the volatility of the variables in the model conditional on each of the two shocks at a time. In this way, we can establish the contribution that each disturbance makes to the model dynamics. When we condition the model on technology shocks, the volatility of the variables becomes close to that in the data, and higher than in the case of using nominal interest rate shocks only. Instead, when we condition the model on interest rate shocks, the size of the volatility of the variables is substantially lower than that in the data.

The third column of Table C considers the behaviour of the benchmark calibration of the model under both shocks. Since the volatility of the variables induced by nominal shocks is small compared to technology shocks, the behaviour of the two shocks combined is dominated by the latter. Despite this, we find that the volatility is much closer now to the data than when only one type of shock is considered. In general, compared to the data, the volatility of the variables is of a smaller magnitude. The benchmark calibration of the model performs well in capturing the relative volatility of the data. The values are somewhat lower than that in the data, but remarkably close.

The next step is to assess the contemporaneous cross-correlations reported in the table. An established aggregate labour market fact is that real wages are only slightly procyclical. This is difficult to reconcile with a neoclassical labour market where wages are determined by their marginal productivity which is highly correlated with output. As pointed out in Krause and Lubik (2007), the search and matching framework breaks this relationship because wages share the surplus of an employment relationship. However, our simulated value of 0.42 is still higher than the correlation of 0.25 that we find between output and real wages in the data. Wages are still too procyclical. The observed negative correlation between unemployment and vacancies, -0.53 in the data, is broadly captured by the model though at a lower magnitude, -0.07. Next, we consider the behaviour 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 negatively correlated at -0.9, while the correlation between inflation and the real wage is -0.27, close to the data. Some conclusions can be drawn at this point. On the one hand, in general, the baseline model mimics reasonably well the variables' volatility, and both the correlation of wages with output and inflation, and the correlation of inflation with output. On the other hand, the model fails to account for the correlations of vacancies with unemployment.

We can now analyse how changes in firing costs and the replacement ratio affect business cycle dynamics. The fourth column of Table C shows business cycle statistics of the variables when firing costs increase by 5 percentage points, from 30% to 35%. The standard deviation of output decreases together with those of employment, unemployment, 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 variables volatility of inflation and real wages increases as a result of firing costs. Why does it happen? The behaviour of the equilibrium productivity threshold plays a key role in the explanation. As firing costs increase, the equilibrium productivity threshold decreases, as described previously, so that the number of jobs sensitive to a deterioration in the economy is lower. Chart 5 plots the distribution of the idiosyncratic productivity value a, along with the zero surplus level, $\widetilde{a}$. 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 intertemporal 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 on voluntary quits rather than firings to reduce its labour force. It continues to post vacancies, many of which would not be filled so that their volatility increases. At the same time, the volatility of output, employment, unemployment, 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 equation **(19)**. As real wages and, thus, marginal costs become more volatile so also inflation displays higher volatility. Real wages remain slightly procyclical, with a correlation to output of 0.20, closer to the data compared to the benchmark model. Since firing costs affect output and inflation in an opposite way, their correlation decreases substantially, and becomes closer to the data. The correlation between vacancies and unemployment becomes close to zero, in contrast with the data.

The last column of Table C shows the business cycle statistics of the variables when the replacement ratio increases by 5 percentage points, from 30% to 35%. The standard deviation of output increases together with those of employment, unemployment, flows in and out of employment, while those of real wages, and inflation decrease. These results are the opposite to the ones an increase in firing costs produces. The key mechanism at work is again the response of equilibrium reservation productivity to a change in unemployment benefits. In this instance, the productivity threshold increases, which increases the mass of jobs affected by shocks. Hence disturbances would displace a higher number of jobs so that the volatility of flows out of employment increases. A higher replacement ratio gives incentives to workers to leave employment and not to search as long as they are eligible for unemployment benefits. Hence, the volatility of flows in employment, and unemployment increases. From equation **(19)**, a higher replacement ratio does not affect the volatility of real wages, which indeed decreases, due to the decline in the volatility of the idiosyncratic shock and labour market tightness. Real wages remain slightly procyclical, they have a correlation with output of 0.40, closer to the data compared to the benchmark model. The correlation between output and inflation remains substantially unchanged. The correlation between vacancies and unemployment continues to be negative but closer to zero, lower than in the benchmark model. The correlation between wages and output decreases to 0.40, closer to the one in the data. Finally, the correlation between wages and inflation increases to -0.36, closer to the data.

7 Conclusion

This paper has analysed the effect of labour market institutions on aggregate fluctuations. The analysis focused on firing costs and unemployment benefits in a DSGE framework characterised by search and matching frictions in the labour market and nominal rigidities in the goods market. Labour market institutions have a significant effect on the structural features of an economy. Changes in labour 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 the reverse effect.

But while the results do lead support to the importance of labour market institutions for business cycle dynamics, it should also be noted that, as the empirical evidence in Blanchard and Wolfers (2000) suggests, the combined interaction of disturbances and labour market institutions may have a non-trivial impact on aggregate fluctuations. Although the model developed here allows aggregate productivity and nominal disturbances to have effects on 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 labour market institutions and a broader set of aggregate shocks remain outstanding tasks for future research.

Appendix A

The labour market data that we use to present the stylised 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 centres while real wages are index of whole-economy average earnings deflated by the consumer prices index. Job creation and job destruction are defined as 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 prices index compared with same month one year previously.

Table A: Steady-state properties, different calibrations

Variable	Benchmark Economy	Increase in the Replacement Ratio	Increase in Firing Costs	Increase in the Replacement Ratio and Firing Costs
Output (L)	0.96	0.93	0.98	0.97
Unemployment (R)	4.5	5.5	3.4	4.2
Vacancies (L)	0.015	0.014	0.011	0.012
Tightness (L)	0.33	0.21	0.30	0.28
Threshold Productivity (L)	0.77	0.79	0.71	0.74
Real Wage (L)	0.91	0.92	0.92	0.94
Endog. Job Destruction (R)	0.5	0.9	0.2	0.1
Total Job Destruction (R)	1.5	1.9	1.2	1.1

Notes: Figures in this table are computed simulating the theoretical model with the parameterisation described in Section 5. Variables are either in levels (L) or rates (R).

Table B: Business cycle properties, single shock

Standard Deviations			
Variable	UK Economy	Technology Shocks	Interest Rate Shocks
Output	1.08	1.44	0.09
Inflation	1.50	1.02	0.08
Real Wage	0.99	0.53	0.47
Employment	1.12	0.59	0.11
Unemployment	10.62	12.55	2.36
Vacancies	11.95	4.57	6.47
Flows out employm.	0.08	0.19	0.10
Flows in employm.	0.05	0.11	0.05

Notes: Observed (UK economy) and simulated business cycle properties. The observed statistics are based on seasonally adjusted quarterly data from 1980:1 to 2005:3. Variables, except inflation are transformed in 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.

Table C: Business cycle properties, different calibrations

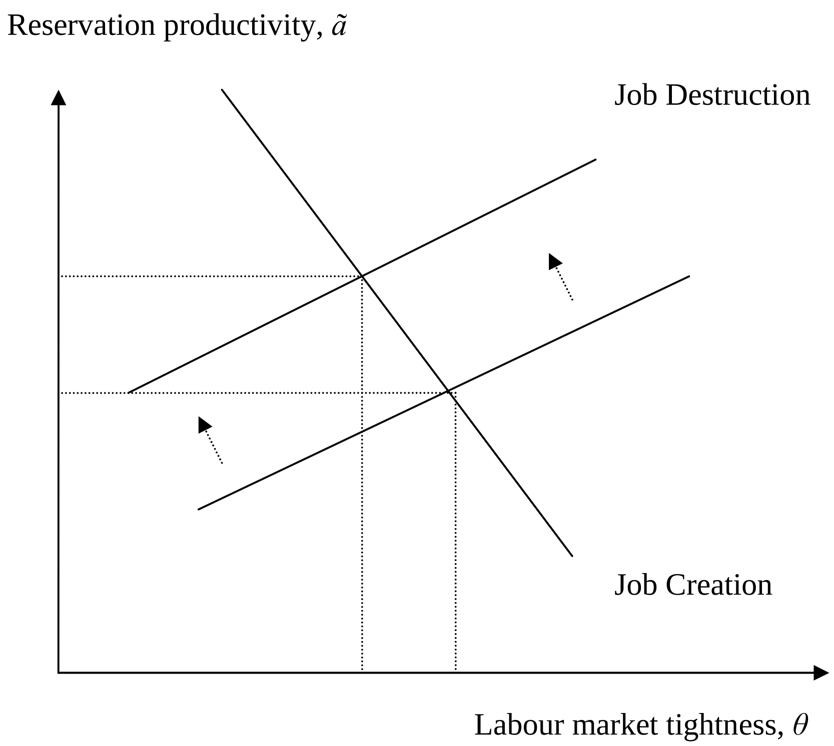
Standard Deviations				
Variable	UK Economy	Benchmark Calibration	Increase in Firing Costs	Increase in Rep. Ratio
Output	1.08	1.08	0.91	1.21
Employment	1.12	0.46	0.27	0.62
Unemployment	10.62	9.75	7.88	12.19
Vacancies	11.95	7.31	21.467	4.78
Flows out employm.	0.08	0.17	0.13	0.22
Flows in employm.	0.05	0.09	0.07	0.11
Inflation	1.50	0.77	1.15	0.68
Real Wage	0.99	0.61	5.46	0.35

Relative Standard Deviations				
Variable	UK Economy	Benchmark Calibration	Increase in Firing Costs	Increase in Rep. Ratio
Output	1.00	1.00	1.00	1.00
Employment	1.04	0.42	0.31	0.51
Unemployment	9.87	8.97	8.87	10.08
Vacancies	11.11	7.26	25.13	4.28
Flows out employm.	0.074	0.17	0.14	0.19
Flows in employm.	0.046	0.09	0.08	0.09
Inflation	1.40	0.71	1.35	0.56
Real Wage	0.92	0.61	6.53	0.31

Cross-Correlations				
Variables	UK Economy	Benchmark Calibration	Increase in Firing Costs	Increase in Rep. Ratio
Output, Real Wages	0.25	0.42	0.20	0.40
Output, Inflation	-0.25	-0.90	-0.40	-0.86
Real Wages, Inflation	-0.42	-0.27	0.80	-0.36
Unempl., Vacancies	-0.53	-0.07	-0.12	-0.03

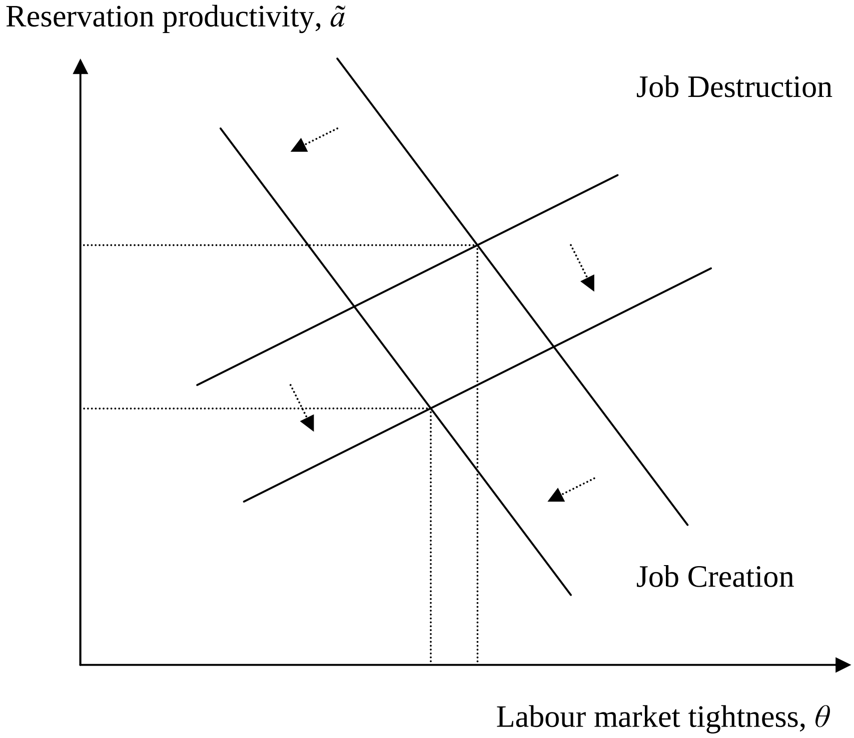
Notes: Observed (UK economy) and simulated business cycle properties. The observed statistics are based on seasonally adjusted quarterly data from 1980:1 to 2005:3. Variables, except inflation are transformed in logarithms. All the series are HP filtered so that only the cyclical component remains. The 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.

Chart 1: Job creation and destruction conditions, an increase in the replacement ratio



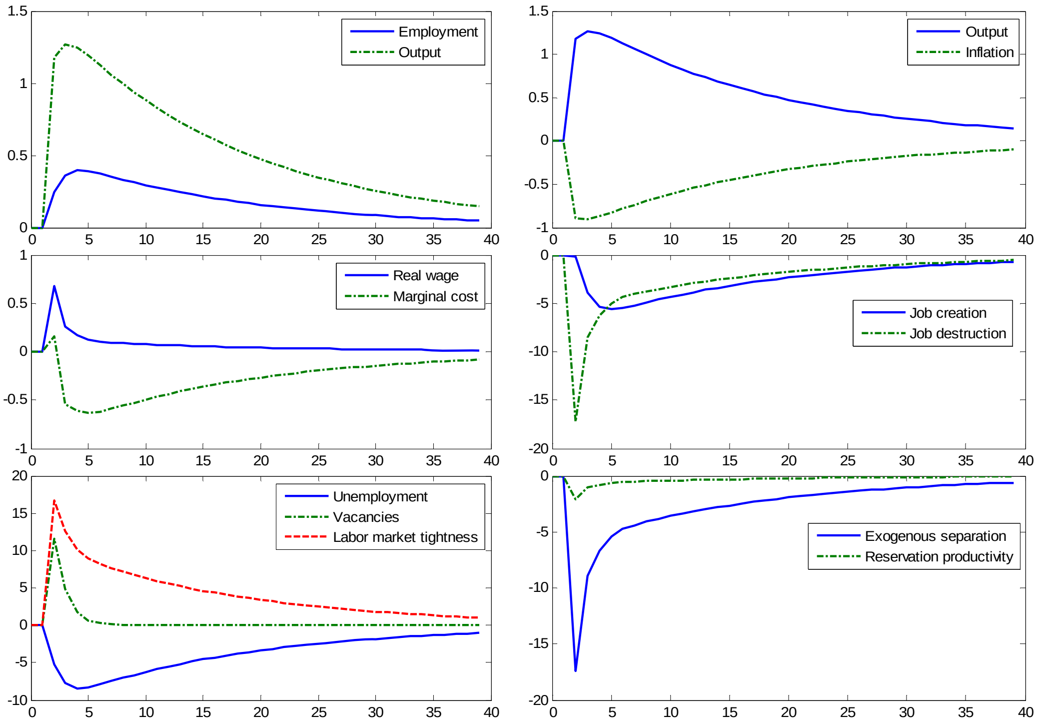
The chart shows the effect of an increase in the replacement ratio on the job creation and job destruction schedules.

Chart 2: Job creation and destruction conditions, an increase in firing costs



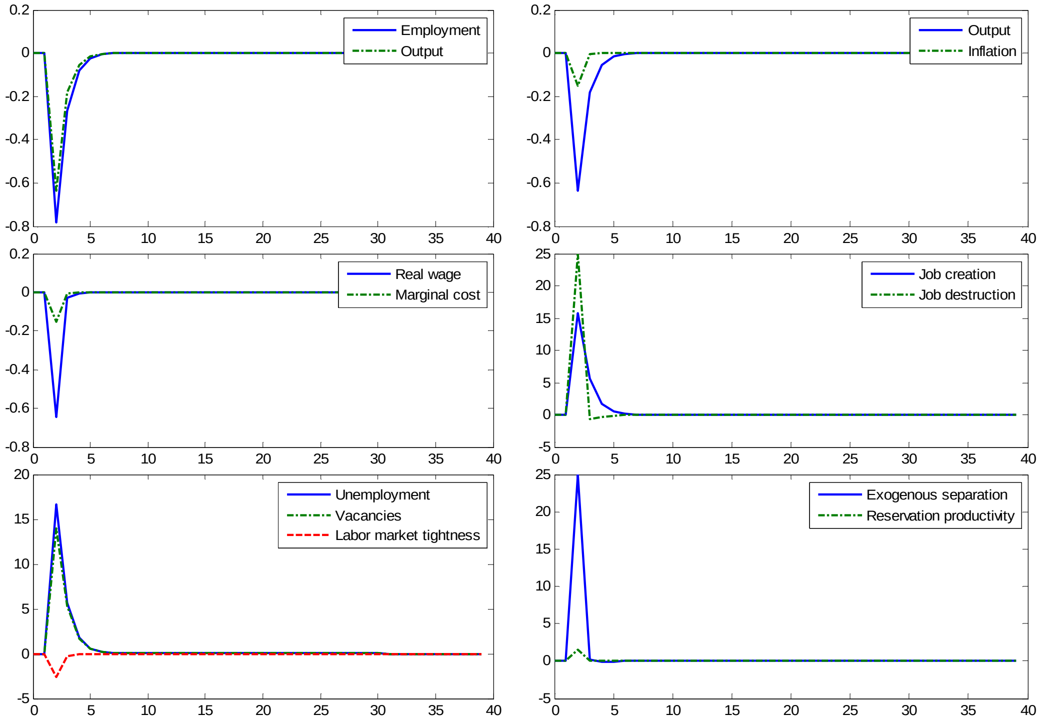
The chart shows the effect of an increase in firing costs on the job creation and job destruction schedules.

Chart 3: Impulse response functions to a technology shock



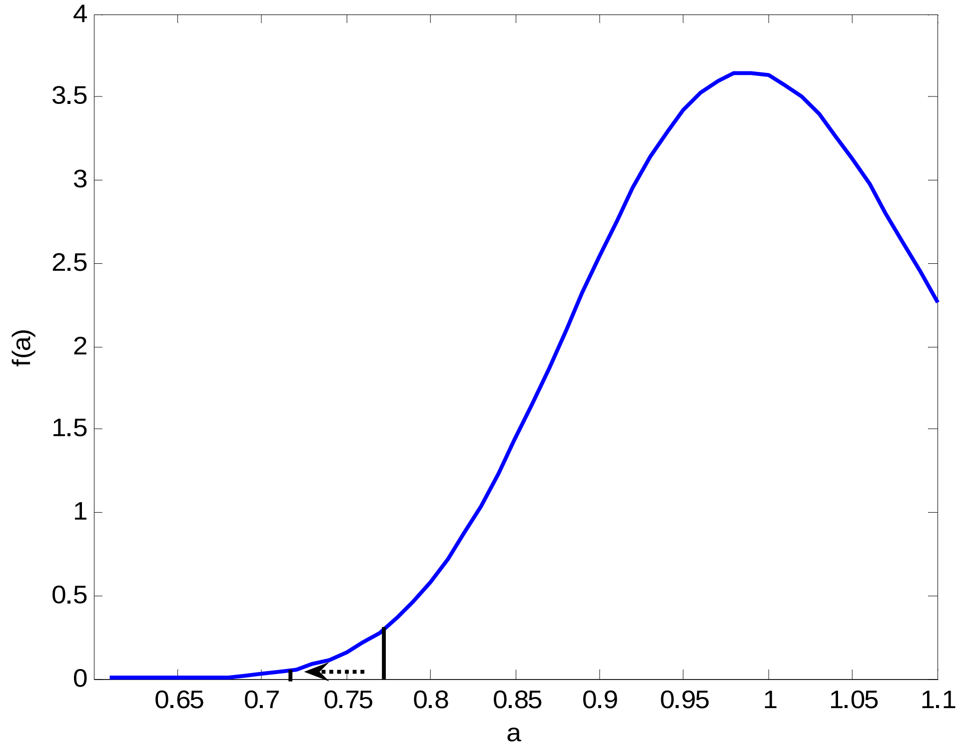
Each panel shows the percentage point response of the models' variables to one standard deviation productivity shock.

Chart 4: Impulse response functions to a monetary policy shock



Each panel shows the percentage point response of the models' variables to one standard deviation monetary policy shock.

Chart 5: Idiosyncratic productivity distribution



The chart shows the effect of an increase by 5 percentage points in firing costs on the distribution of the idiosyncratic productivity value a, along with the zero surplus level, $\tilde{a}$.

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