Labor market reform and price stability: an application to the Euro Area*

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Abstract

This paper studies the effect of labor market reform, in the form of reductions in firing costs and unemployment benefits, on inflation volatility. With this purpose, we build a New Keynesian model with search and matching frictions in the labor market, and estimate it using Euro Area data. Qualitatively, changes in labor market policies alter the volatility of inflation in response to shocks, by affecting the volatility of the three components of real marginal costs (hiring costs, firing costs and wage costs). Quantitatively, we find however that neither policy is likely to have an important effect on inflation volatility, due to the small impact of changes in the volatility of the labor market on inflation dynamics.

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1 Introduction

Policies aimed at regulating the labor market affect the incentives of workers and firms to form and keep employment relationships, thereby influencing the profit-maximizing behavior of firms. In particular, changes in labor market policies may affect the extent to which firms adjust their nominal prices in order to accommodate variations in cost and demand conditions, and hence may alter the response of the overall price level as the economy is hit by shocks. The view that labor market policies have an effect on price dynamics is also held in policy circles. For example, Jean Claude Trichet, current president of the European Central Bank (ECB), has recently emphasized that structural reforms in the labor market may support stable inflation in the Euro Area: "the implementation of the reforms in the Lisbon agenda, by easing labor and product market rigidities, (...) will also improve the effectiveness of monetary policy by facilitating price stability."[1]

Despite the importance of this topic for policy-makers, surprisingly little academic work has focused on the effect of labor market reform on price stability. The aim of this paper is to contribute to the topic by studying how changes in unemployment benefits (UB) and firing costs (FC) may influence the volatility of inflation. We focus on UB and FC because they are generally considered to be important contributors to the rigidity of continental European labor markets.[2] Therefore, a structural reform aimed at increasing the flexibility of the labor market would certainly involve modifications to these two labor market features.

In order to investigate this topic we set up a New Keynesian model with search and matching frictions in the labor market *à la* Mortensen and Pissarides (1994). In this framework, monopolistically competitive firms set their nominal prices in a staggered fashion. They optimally adjust the size of their workforce through both job creation and job destruction. On the job creation side, firms post vacancies. On the job destruction side, firms destroy those jobs that become unprofitable and pay firing costs for each job destroyed. On the other side of the labor market, unemployed workers search for jobs and receive unemployment benefits in the meantime. Finally, vacancies and unemployed workers meet in the so-called matching function. This framework therefore provides a comprehensive treatment of the interaction between labor market policies, macroeconomic shocks and pricing decisions.

The mechanism by which unemployment benefits and firing costs affect the cyclical volatility of inflation is the following. In this model, hiring and firing are costly. As a result, hiring and firing costs become part of firms' real marginal costs and therefore affect inflation dynamics. A reduction in unemployment benefits reduces workers' outside option and thus increases the joint surplus of employment relationships. Since firms receive a constant fraction of the joint surplus, vacancy posting increases. This makes the labor market tighter, which in turn makes it more costly for firms to hire workers. As a result, the hiring component of real marginal costs experiences larger

[1] The 2007 Jean Monnet Lecture to the Lisbon Council, June 4.

[2] See for instance Bentolila and Bertola (1990), Yashiv (2004), Layard *et al.* (2005) and Ljungqvist and Sargent (2006).

fluctuations, and inflation becomes *more* volatile. On the other hand, a reduction in firing costs automatically reduces the size of fluctuations in the firing component of real marginal costs. As a result, inflation becomes *less* volatile.

In order to assess the quantitative importance of this mechanism, we parameterize our model economy to Euro Area data, using a mixed method of calibration and maximum likelihood estimation. After showing that our model economy fits Euro Area data reasonably well, we simulate the effects of hypothetical reductions in UB and FC on inflation volatility. Our baseline results suggest that these labor market reforms would have only small effects on inflation volatility. In particular, reducing the replacement ratio of UB by 10 percentage points would increase the annualized standard deviation of inflation by only 5 basis points (from 0.84% to 0.89%), whereas reducing firing costs as a fraction of the average wage by 10 percentage points would reduce inflation volatility by only 2 basis points (from 0.84% to 0.82%). We then test the robustness of our result to alternative model parameterizations. The effects of labor market reform on inflation volatility remain small. In the case of FC, the fall in the annualized standard deviation of inflation remains negligible (of up to 3 basis points), whereas in the case of UB our measure of inflation volatility increases by 20 basis points at most. The explanation for our results is the following. In the case of FC, job destruction rates barely fluctuate in our estimated model, such that the contribution of the firing component of marginal costs to inflation dynamics is very small. As a result, changes in FC have almost no effect on inflation volatility. In the case of UB, the data favors model parameterizations in which hiring costs are small, which is necessary in order to match observed employment fluctuations. This implies that changes in UB, and the resulting changes in the volatility of hiring costs, have small effects on inflation volatility.

Our analysis is closely related to earlier work by Campolmi and Faia (2006) and Zanetti (2007). Campolmi and Faia (2006) document a negative relationship between the replacement ratio of unemployment benefits and inflation volatility across Euro Area members. They subsequently build a two-country model of a currency union characterized by matching frictions and nominal price rigidities, and show that their model is able to reproduce the observed relationship between unemployment benefits and inflation volatility. Here we abstract from international spill-overs, by treating the Euro Area as a single country, and extend the analysis of labor market policies by considering also the effects of firing costs. Zanetti (2007) sets up a New Keynesian model with labor market search to study how changes in unemployment benefits and firing costs affect aggregate fluctuations. After calibrating his model to UK data, he finds among other results that an increase in unemployment benefits reduces the volatility of inflation, while an increase in firing costs makes inflation more volatile, which is consistent with our results. Differently from Zanetti (2007), where the firms making the pricing decisions are different from the firms facing search frictions, in our framework firms are subject both to search frictions and staggered price adjustment, which makes the analysis more appealing from a theoretical point of view. Importantly, we differ from these two papers in that we estimate a number of key parameters that determine the transmission of shocks to inflation, such as the size and persistence of shocks, the duration of price contracts and the response of monetary policy to the state of the economy. In our view, this approach provides a more reliable assessment of the quantitative consequences of changes in labor market policies on inflation dynamics.

In a broader perspective, our paper is related to previous research that analyzes the effect of search frictions in the labor market on inflation dynamics. In particular, Krause, Lopez-Salido and Lubik (2008) use US data on inflation, unit labor costs and several indicators of labor market activity in order to estimate the New Keynesian Phillips curve that arises in models with search frictions.[3] In such models, the cost of hiring workers adds to the usual wage costs as a determinant of marginal costs. Our model features a similar expression for marginal costs, with the addition of a firing cost component. Krause, Lopez-Salido and Lubik (2008) find that hiring costs have a small contribution to real marginal costs and hence to inflation, which points in the same direction as our results for the Euro Area.[4]

The remainder of the paper is organized as follows. Section 2 lays out the model. Section 3 parameterizes the model to Euro Area data, using both calibration and maximum likelihood estimation. It then assesses the model's ability to match the data and analyzes the economy's response to different shocks. Section 4 presents our baseline results regarding the effect of labor market reform on price stability and performs robustness exercises. Section 5 concludes.

2 Model

We now present a New Keynesian model with search and matching frictions and endogenous job destruction a la Mortensen and Pissarides (1994). Our model is therefore similar to existing work by Trigari (2005), Walsh (2005), Krause and Lubik (2007), Campolmi and Faia (2006) and Zanetti (2007). We depart from these studies however in the timing of hiring: rather than assuming that hiring takes place with a lag, we assume that workers hired in a certain period start producing before the end of that period, as in Blanchard and Gali (2006) and Gertler, Sala and Trigari (2007). The reason is twofold. First, we believe the time-to-hire assumption is reasonable in a model with a monthly frequency, but it may be less plausible in a model with a quarterly frequency.[5] Since our model is estimated with quarterly Euro Area data, we opt for the instantaneous-hiring assumption. Second, as shown by Krause and Lubik (2007), time-to-hire makes job destruction too volatile and job creation not volatile enough in response to shocks.[6]

[3] Their empirical implementation is based on theoretical work by Krause and Lubik (2007), Blanchard and Gali (2006) and Rotemberg (2006). See also Ravenna and Walsh (2008).

[4] They do find however that search frictions reduce the role of backward-looking price setting for generating inflation persistence.

[5] See Thomas (2008a,b) for New Keynesian models with time-to-hire calibrated on a monthly frequency.

[6] This need not be the case in models that incorporate an intensive margin of labor (hours per employee), such as Trigari (2005).

The model economy is populated by four types of agents: households, firms, a fiscal authority and a monetary authority. Households consist of a large number of members, a fraction of which are unemployed and search for jobs. On the other side of the labor market, firms post a number of vacancies. Unemployed workers and vacancies, which we denote by u_t and v_t respectively, meet in the so-called *matching function*, $m(v_t, u_t)$. Normalizing the size of the labor force to 1, u_t also represents the unemployment rate. Under the assumption of constant returns to scale in the matching function, the matching probability for unemployed workers,

$$\frac{m(v_t, u_t)}{u_t} = m\left(\frac{v_t}{u_t}, 1\right) \equiv p\left(\frac{v_t}{u_t}\right),$$

and for vacancies,

$$\frac{m(v_t, u_t)}{v_t} = m\left(1, \frac{1}{v_t/u_t}\right) \equiv q\left(\frac{v_t}{u_t}\right),$$

are functions of the ratio of vacancies to unemployment, also called *labor market tightness*. From now onwards, we denote labor market tightness by $\theta_t \equiv v_t/u_t$. Notice that $p'(\theta_t) > 0$ and $q'(\theta_t) < 0$, i.e. in a tighter labor market jobseekers are more likely to find jobs and firms are less likely to fill their vacancies. Notice also that $p(\theta_t) = \theta_t q(\theta_t)$.

2.1 Firms

There exists a continuum of monopolistically competitive firms indexed on the unit interval. Inside any firm i, the timing of hiring and firing proceeds as follows. At the start of the period, a fraction λ^x of last period's workers are exogenously separated from the firm. Aggregate shocks are then realized, after which the firm posts a number v_{it} of vacancies. Firms are assumed to be large, such that the fraction of vacancies filled by the firm is given by $q(\theta_t)$. Once the hiring round has taken place, both newly-hired and continuing workers receive an iid idiosyncratic productivity shock, z. Let $G(z)$ and $g(z)$ denote the cumulative distribution function and the density of z, respectively. Those workers whose new idiosyncratic productivity falls below a certain reservation productivity z_{it}^R (to be determined later) become unprofitable and their jobs are destroyed, whereas the remaining workers start producing immediately. The law of motion of the firm's workforce, n_{it}, is therefore given by

$$n_{it} = \left[1 - G(z_{it}^R)\right] \left[(1 - \lambda^x) n_{it-1} + q(\theta_t) v_{it}\right], \tag{1}$$

where $G(z_{it}^R)$ is the fraction of new and continuing workers that are endogenously separated from the firm. The firm's production function is given by

$$y_{it} = A_t n_{it} \int_{z_{it}^R} z \frac{g(z)}{1 - G(z_{it}^R)} dz, \tag{2}$$

where A_t is an aggregate productivity shock with law of motion $\log A_t = \rho_A \log A_{t-1} + \varepsilon_t^A$, $\varepsilon_t^A \sim iid(0, \sigma_A)$.

2.1.1 Cost minimization

Subject to equations (1) and (2), the firm minimizes its production costs,

$$E_0 \sum_{t=0}^{\infty} \beta_{0,t} \left\{ n_{it} \int_{z_{it}^R} w_{it}(z) \frac{g(z)}{1-G(z_{it}^R)} dz + \chi v_{it} + G(z_{it}^R) \left[(1-\lambda^x) n_{it-1} + q(\theta_t) v_{it} \right] F \right\},$$

where β and $\beta_{s,t} \equiv \beta^{t-s} c_s / c_t$ are respectively the subjective discount factor and the stochastic discount factor between any two periods s and t ($s < t$), $w_{it}(z)$ is the real wage paid to the worker with idiosyncratic productivity z (to be determined later), $\chi > 0$ is the real cost of posting a vacancy and F is the real firing cost paid by the firm for each endogenous separation. Let ϕ_{it} and φ_{it} denote the Lagrange multipliers associated to equations (1) and (2), respectively. Therefore, ϕ_{it} represents the real marginal value of employment, and φ_{it} the *real marginal cost* of production. The first order conditions with respect to v_{it}, n_{it} and z_{it}^R are given respectively by

$$\chi = q(\theta_t) \left\{ \left[1 - G(z_{it}^R) \right] \phi_{it} - G(z_{it}^R) F \right\}, \tag{3}$$

$$\phi_{it} = \int_{z_{it}^R} \left(\varphi_{it} A_t z - w_{it}(z) \right) \frac{g(z)}{1-G(z_{it}^R)} dz + (1-\lambda^x) E_t \beta_{t,t+1} \left\{ \left[1 - G(z_{it+1}^R) \right] \phi_{it+1} - G(z_{it+1}^R) F \right\}, \tag{4}$$

$$\varphi_{it} A_t z_{it}^R - w_{it}(z_{it}^R) + F + (1-\lambda^x) E_t \beta_{t,t+1} \left\{ \left[1 - G(z_{it+1}^R) \right] \phi_{it+1} - G(z_{it+1}^R) F \right\} = 0. \tag{5}$$

Equation (3) equalizes the marginal cost and the marginal benefit of posting a vacancy. With probability $q(\theta_t)$ the vacancy is filled, in which case two events are possible: either the new recruit is fired (which happens with probability $G(z_{it}^R)$), in which case the firm must pay firing costs, or she survives the job destruction round, in which case she generates value for the firm. The contribution of the worker with idiosyncratic productivity z to the flow of profits is given by $\varphi_{it} A_t z - w_{it}(z)$, which is the gap between the cost reduction due to the worker and her real wage. Since workers have random idiosyncratic productivities, from equation (4) a worker that survives job destruction is expected to contribute the average gap between cost reduction and real wage, plus a continuation value which is the same for all workers in the firm. Finally, equation (5) states that the value of the worker with idiosyncratic productivity z_{it}^R is exactly equal to zero, i.e. the firm is indifferent between keeping this worker or not. Using equations (3) and (5), we can rewrite equation (4) as

$$\frac{\chi}{q(\theta_t)} = \int_{z_{it}^R} \left[\varphi_{it} A_t \left(z - z_{it}^R \right) - \left(w_{it}(z) - w_{it}(z_{it}^R) \right) \right] g(z) dz - F. \tag{6}$$

Similarly, using equation (3) we can express equation (5) as

$$\varphi_{it} A_t z_{it}^R = w_{it}(z_{it}^R) - F - (1-\lambda^x) E_t \beta_{t,t+1} \frac{\chi}{q(\theta_{t+1})}. \tag{7}$$

2.1.2 Pricing decision

Due to imperfect substitutability between individual consumption goods, each firm faces the following demand curve for its product,

$$y_{it} = \left(\frac{P_{it}}{P_t}\right)^{-\gamma_t} y_t, \tag{8}$$

where P_{it} is the firm's price, P_t is the overall price level, $\gamma_t > 1$ is the time-varying elasticity of substitution between individual goods in households' consumption basket and y_t is aggregate demand. As is standard in the New Keynesian literature, we assume staggered price adjustment *à la* Calvo (1983). Let δ denote the probability of changing price common to all firms. A price-setting firm maximizes

$$E_t \sum_{T=t}^{\infty} \delta^{T-t} \beta_{t,T} \left(\frac{P_{it}}{P_T} - \varphi_{iT}\right) \left(\frac{P_{it}}{P_T}\right)^{-\gamma_t} y_T$$

with respect to P_{it}. The first order condition is given by

$$E_t \sum_{T=t}^{\infty} \delta^{T-t} \beta_{t,T} P_T^{-\gamma_T} y_T \left(\frac{P_{it}^*}{P_T} - \mu_T \varphi_{iT}\right) = 0, \tag{9}$$

where P_{it}^* is the optimal price decision and $\mu_t \equiv \gamma_t/(\gamma_t - 1)$ is a mark-up shock. The latter has law of motion $\log \mu_t = (1-\rho_\mu) \log [\gamma/(\gamma-1)] + \rho_\mu \log \mu_{t-1} + \varepsilon_t^\mu$, where γ is the steady-state value of γ_t and $\varepsilon_t^\mu \sim iid(0, \sigma_\mu)$.

2.2 Households

There exists a large, representative household with a measure-one continuum of members. A fraction $n_t = \int_0^1 n_{it} di$ of its members are employed. The remaining members are engaged in home production, receive unemployment benefits and search for jobs. All members pool their resources so as to ensure equal consumption.[7] The household consumes the following basket of differentiated goods,

$$c_t \equiv \left(\int_0^1 c_{it}^{(\gamma_t - 1)/\gamma_t} di\right)^{\gamma_t/(\gamma_t - 1)}.$$

[7] The assumption of perfect insurance of unemployment risk is standard in the search and matching literature. See e.g. Merz (1995) and Andolfatto (1996).

Cost-minimization by the household implies that nominal consumption expenditure equals $P_t c_t$, where

$$P_t \equiv \left(\int_0^1 P_{it}^{1-\gamma_t} di \right)^{1/(1-\gamma_t)}$$

is the overall price index. The household maximizes utility from consumption,

$$E_0 \sum_{t=0}^{\infty} \beta^t \log(c_t),$$

subject to the following period budget constraint,

$$(1+i_{t-1})\frac{B_{t-1}}{P_t} + \int_0^1 n_{it} \int_{z_{it}^R} w_{it}(z) \frac{g(z)}{1-G(z_{it}^R)} dz di + (1-n_t)\rho_B \bar{w} + \Pi_t = c_t + \frac{B_t}{P_t} + \tau_t,$$

where B_{t-1} are holdings of one-period nominal bonds purchased in $t-1$, i_{t-1} is the nominal interest rate paid on such bonds, $\bar{w} \equiv \int_{z^R} w(z) \frac{g(z)}{1-G(z^R)} dz$ is the steady-state average real wage, ρ_B is the replacement ratio of unemployment benefits, Π_t are real profits reverted from the firm sector to households in a lump-sum manner and τ_t are real lump-sum taxes. The first order conditions with respect to B_t and c_t can be combined into the following consumption Euler equation,

$$c_t^{-1} = \beta(1+i_t) E_t \left[\frac{P_t}{P_{t+1}} c_{t+1}^{-1} \right]. \tag{10}$$

2.3 Wage bargaining

Each firm negotiates wages with its employees on a period-by-period basis. As is standard in the search and matching literature, we assume Nash wage bargaining, which implies that the firm and each worker split the joint surplus of their employment relationship. The joint surplus is the sum of the firm's surplus and the worker's surplus. The worker with idiosyncratic productivity z enjoys the following surplus,

$$S_{it}^w(z) = w_{it}(z) - \underline{w}_t + (1-\lambda^x) E_t \beta_{t,t+1} \int_{z_{it+1}^R} S_{it+1}^w(x) g(x) dx,$$

where

$$\underline{w}_t \equiv h + \rho_B \bar{w} + (1-\lambda^x) E_t \beta_{t,t+1} p(\theta_{t+1}) \int_0^1 \frac{v_{jt+1}}{v_{t+1}} \int_{z_{jt+1}^R} S_{jt+1}^w(x) g(x) dx dj$$

is the outside option of the worker. The latter is the sum of home production, h, unemployment benefits, $\rho_B \bar{w}$, and the value of searching for other jobs, where $p(\theta_{t+1}) v_{jt+1}/v_{t+1}$ is the probability of being matched to any firm j in period $t+1$.[8]

[8] Notice that the worker's surplus does not depend on F. As is well-known, those components of the cost of firing a worker that represent a transfer from the firm to the worker (such as severance payments) leave the joint match

The value that the firm derives from the worker with idiosyncratic productivity z is given by

$$J_{it}(z) = \varphi_{it} A_t z - w_{it}(z) + (1-\lambda^x) E_t \beta_{t,t+1} \left[\int_{z^R_{it+1}} J_{it+1}(x) g(x) dx - G(z^R_{it+1}) F \right]. \tag{11}$$

The worker's contribution to current profits is given by the amount of product produced by the worker, $A_t z$, times the real marginal cost of production, φ_{it}. Given that the firm must always meet its demand, should the worker leave the firm the latter would have to make up for the lost production, which comes at the cost $\varphi_{it} A_t z$. The continuation value in equation (11) is obtained as follows. Provided the worker is not exogenously separated (which happens with probability $1-\lambda^x$), she draws a new idiosyncratic productivity x in the following period. If $x \geq z^R_{it+1}$, the worker contributes $J_{it+1}(x)$; otherwise, the job is destroyed and the firm must pay firing costs, F. Since the outside option for the firm is firing the worker and paying the firing cost, the firm's surplus is given by $J_{it}(z) - (-F) = J_{it}(z) + F$.[9]

Let $\xi \in (0,1)$ denote the firm's bargaining power. Nash bargaining implies the following surplus-sharing rule,

$$(1-\xi)\left(J_{it}(z) + F\right) = \xi S^w_{it}(z).$$

Combining the latter equation with the expressions for $J_{it}(z)$, $S^w_{it}(z)$ and $\underline{w}_t$, we obtain the following solution for the real wage,

$$w_{it}(z) = (1-\xi)\left[\varphi_{it} A_t z + \left(1 - E_t \beta^x_{t,t+1}\right) F\right] + \xi \underline{w}_t,$$

where $\beta^x_{t,t+1} \equiv \beta_{t,t+1}(1-\lambda^x)$. The worker therefore receives a weighted average of her outside option, $\underline{w}_t$, and the sum of her contribution to current profits and a firing-cost component. Firing costs affect wage payments in the following way: the firm rewards the worker for the saving in firing costs today, but penalizes her for the fact it will have to pay firing costs tomorrow in the worst-case scenario.

The outside-option term $\underline{w}_t$ and thus the real wage equation can be simplified in the following way. Notice first that equations (3), (4) and (11) imply that the total surplus derived by the firm from its workers can be written as

$$\int_{z^R_{it}} \left(J_{it}(z) + F\right) g(z) dz = \left[1 - G(z^R_{it})\right] \left(\phi_{it} + F\right) = \frac{\chi}{q(\theta_t)} + F.$$

Using this and the fact that the surplus-sharing rule holds in every period, we can write the total

surplus unaffected and therefore have no effect on job creation and job destruction under Nash wage bargaining; see e.g. Mortensen and Pissarides (2003). Our parameter F therefore includes only the non-transfer components of firing costs, such as legal costs, sanctions for delayed payments, as well as foregone health insurance and social security contributions.

[9] See e.g. Mortensen and Pissarides (2003).

worker surplus in alternative jobs as

$$\begin{aligned}\int_{z^R_{jt+1}} S^w_{jt+1}(x)g(x)dx &= \frac{1-\xi}{\xi}\int_{z^R_{jt+1}} \left[J_{jt+1}(x)+F\right]g(x)dx \\ &= \frac{1-\xi}{\xi}\left[\frac{\chi}{q(\theta_{t+1})}+F\right].\end{aligned}$$

Combining this with the definition of $\underline{w}_t$ and the real wage equation, we can finally write the latter as

$$w_{it}(z) = (1-\xi)\left\{\varphi_{it}A_t z + \left[1 - E_t\left(1-p(\theta_{t+1})\right)\beta^x_{t,t+1}\right]F + E_t\beta^x_{t,t+1}\chi\theta_{t+1}\right\} + \xi\left(h+\rho_B\bar{w}\right), \quad (12)$$

where we have also used the fact that $p(\theta_{t+1})/q(\theta_{t+1}) = \theta_{t+1}$.

2.4 Fiscal and monetary policy

Assume for simplicity that firing costs revert to the government. The fiscal authority is assumed to adjust lump-sum taxes, τ_t, so as to balance its budget in every period,

$$\tau_t = (1-n_t)\rho_B\bar{w} + g_t - F\int_0^1 G(z^R_{it})\left[(1-\lambda^x)n_{it-1} + q(\theta_t)v_{it}\right]di,$$

where g_t is exogenous government expenditure, with law of motion $\log(g_t) = \rho_g\log(g_t) + \varepsilon^g_t$, $\varepsilon^g_t \sim iid(0,\sigma_g)$. On the other hand, the monetary authority sets interest rates according to a Taylor-type rule,

$$i_t = \phi_i i_{t-1} + (1-\phi_i)\left[\phi_\pi E_t\log\left(\frac{P_{t+1}}{P_t}\right) + \phi_y\log\left(\frac{y_t}{y}\right)\right] + \varepsilon^m_t, \quad (13)$$

where y is steady-state output, ϕ_i is the degree of interest rate smoothing and $\varepsilon^m_t \sim iid(0,\sigma_m)$.

2.5 Equilibrium

We are now ready to characterize the economy's equilibrium. At this point we guess that all firms face the same real marginal cost, $\varphi_{it} = \varphi_t$, and choose the same reservation productivity, $z^R_{it} = z^R_t$. Equation (12) implies that $w_t(z) - w_t(z^R_t) = (1-\xi)\varphi_t A_t\left(z - z^R_t\right)$. This allows us to write equation (6) as

$$\frac{\chi}{q(\theta_t)} = \xi\varphi_t A_t\int_{z^R_t}\left(z - z^R_t\right)g(z)dz - F. \quad (14)$$

Evaluating the real wage function at z_t^R and using the resulting expression in equation (7), we can write the latter as

$$\xi A_t z_t^R \varphi_t = E_t \beta^x \frac{c_t}{c_{t+1}} \left[(1-\xi)\chi\theta_{t+1} - \frac{\chi}{q(\theta_{t+1})} \right] + \xi \left(h + \rho_B \bar{w} \right)$$
$$- \left[\xi + (1-\xi) E_t \beta^x \frac{c_t}{c_{t+1}} \left(1 - p(\theta_{t+1}) \right) \right] F, \tag{15}$$

where $\beta^x \equiv \beta(1-\lambda^x)$. Equations (14) and (15) jointly determine the firm's real marginal cost, φ_t, and reservation productivity, z_t^R, given the evolution of the aggregate variables A_t, θ_t and c_t. Since the latter are common to all firms, our previous guess that φ_t and z_t^R are equalized across firms is verified.[10] A common real marginal cost also implies that all price-setters make the same price decision, that is, $P_{it}^* = P_t^*$ in equation (9). The law of motion of aggregate employment can be obtained by aggregating equation (1) across firms,

$$n_t = \left[1 - G(z_t^R) \right] \left[(1-\lambda^x) n_{t-1} + q(\theta_t) v_t \right], \tag{16}$$

where $v_t = \int_0^1 v_{it} di$ is the aggregate number of vacancies. Labor market tightness is given by

$$\theta_t = v_t / u_t. \tag{17}$$

The stock of job-seekers at the start of the period evolves according to

$$u_t = 1 - n_{t-1} + \lambda^x n_{t-1}. \tag{18}$$

Aggregate demand is given by

$$y_t = c_t + \chi v_t + g_t. \tag{19}$$

Equations (2) and (8) imply that $A_t n_{it} \int_{z_t^R} z \left[g(z) / \left(1 - G(z_t^R) \right) \right] dz = \left(P_{it} / P_t \right)^{-\gamma_t} y_t$, that is, each firm's supply must meet its own demand. Integrating this condition across all firms yields the following,

$$A_t n_t \int_{z_t^R} z \frac{g(z)}{1 - G(z_t^R)} dz = y_t \Delta_t, \tag{20}$$

where $\Delta_t \equiv \int_0^1 \left(P_{it} / P_t \right)^{-\gamma_t} di$ is a measure of price dispersion with law of motion[11]

$$\Delta_t = (1-\delta) \left(\frac{P_t^*}{P_t} \right)^{-\gamma_t} + \delta \left(\frac{P_t}{P_{t-1}} \right)^{\gamma_t} \Delta_{t-1}. \tag{21}$$

[10] This does not mean however that all firms are symmetric in equilibrium. Given the price dispersion created by staggered price adjustment, firms will also differ in their output levels, y_{it}, the size of their workforce, n_{it}, and their number of vacancies, v_{it}.

[11] See e.g. Yun (1996).

Finally, the price level evolves according to

$$P_t = \left[\delta P_{t-1}^{1-\gamma_t} + (1-\delta)\left(P_t^*\right)^{1-\gamma_t}\right]^{1/(1-\gamma_t)}. \tag{22}$$

Equilibrium in this economy is defined as the path $\left\{i_t, c_t, y_t, n_t, u_t, \Delta_t, z_t^R, \theta_t, \varphi_t, v_t, P_t, P_t^*\right\}_{t=0}^{\infty}$ that satisfies equations (9) (without i subscripts), (10) and (13) to (22) for all $t \geq 0$, given the evolution of the exogenous shocks, $\left\{\varepsilon_t^A, \varepsilon_t^g, \varepsilon_t^\mu, \varepsilon_t^m\right\}_{t=0}^{\infty}$, the laws of motion of $\{\log(A_t), \log(g_t), \log(\mu_t)\}$ and the initial values of the endogenous state variables, $\{i_{-1}, n_{-1}, \Delta_{-1}, P_{-1}\}$. For future reference, we also define *after-hiring unemployment*,

$$U_t \equiv 1 - n_t,$$

which is the fraction of the labor force that is left without a job after hiring has taken place in period t. We also define *job creation* and *job destruction* as

$$jc_t \equiv q(\theta_t)v_t,$$

$$jd_t \equiv \lambda_t n_{t-1} + G(z_t^R)jc_t,$$

respectively, where $\lambda_t \equiv \left[\lambda^x + (1-\lambda^x)G(z_t^R)\right]$ is the total separation rate. Equation (16) can then be written as $n_t = n_{t-1} + jc_t - jd_t$.

3 Model parameterization and assessment

The model is partly calibrated and partly estimated with quarterly Euro Area data. Our strategy consists of calibrating those parameters that affect the steady state and estimating the remaining parameters. We discuss first our calibration.

3.1 Calibration

As is common in real business cycle studies, we set the quarterly discount rate, β, to 0.99. Following Blanchard and Gali (2006), we set the steady-state after-hiring unemployment rate, U, to 0.10 and the steady-state quarterly job finding rate, $p(\theta)$, to 0.25. The employment rate is then given by $n = 1 - U = 0.90$. Equation (16), together with $q(\theta_t)v_t = p(\theta_t)u_t$ and equation (18), imply that the following condition must hold in the steady state,

$$n = (1-\lambda^n)p(\theta)/\left[\lambda + (1-\lambda)p(\theta)\right], \tag{23}$$

where $\lambda^n \equiv G(z^R)$ and $\lambda \equiv \lambda^x + (1-\lambda^x)\lambda^n$ are respectively the endogenous separation rate and the total separation rate in the steady state. The values of λ^n estimated for the US are typically centered around one half of the total separation rate.[12] Lacking similar evidence for the euro area, we assume $\lambda^n = \lambda/2$. Using this in equation (23), and given our values of $p(\theta)$ and n, we obtain $\lambda = 0.0312$, which implies $\lambda^n = 0.0156$ and $\lambda^x = (\lambda - \lambda^n)/(1-\lambda^n) = 0.0159$. The stock of jobseekers equals $u = 1 - (1 - \lambda^x)n = 0.11$. We adopt Andolfatto's (1996) calibration of the US quarterly vacancy-filling rate, $q(\theta) = 0.90$. We then have $\theta = p(\theta)/q(\theta) = 0.28$. This implies $v = \theta u = 0.032$. We assume a Cobb-Douglas matching function, $m(v,u) = \varsigma v^\epsilon u^{1-\epsilon}$. Extrapolating again from US evidence, we set ϵ to 0.6 (Blanchard and Diamond, 1989). Since $p(\theta) = \varsigma\theta^\epsilon$, the scale parameter ς must equal $p(\theta)/\theta^\epsilon = 0.54$. Following common practice, we set the bargaining power parameter equal to the elasticity of the matching function, $\xi = \epsilon$. The elasticity of demand curves, γ, is set to 6 following Blanchard and Gali (2006), which implies a steady-state real marginal cost of $\varphi = (\gamma - 1)/\gamma = 0.83$.

The parameters controlling labor market reform are calibrated as follows. In our model, F is the part of the total cost of firing a worker that does not represent a transfer from the firm to the worker. Given the lack of a reliable estimate of this cost for the euro area as a whole, we set it to 20% of the quarterly average real wage. Expressing firing costs as $F = \rho_F \bar{w}$, we thus assume $\rho_F = 0.20$. According to Nickell and Nunziata (2007), average replacement ratios in the four largest euro area members in the period 1998 to 2004 (i.e., roughly our estimation sample) range from 39% (Spain) to 58% (Germany). Given that such benefits accrue indefinitely to unemployed workers in our model but have a limited duration in actual legislations, we set the common euro area replacement ratio to $\rho_B = 0.40$.

The idiosyncratic productivity shock z is lognormally distributed: $\log(z) \sim N(\mu_z, \sigma_z)$. Following standard practice in the literature, we normalize μ_z to 0. Regarding σ_z, since we lack direct evidence on this parameter we adopt the following procedure. Given the values of μ_z, σ_z and λ^n, the reservation productivity equals $z^R = G^{-1}(\lambda^n)$, where $G(\cdot)$ is the cdf of the lognormal distribution. In the steady state, equations (14) and (15) and the cross-sectional average of equation (12) form the following 3-equation system,[13]

$$\frac{\chi}{q(\theta)} = \xi\varphi \int_{z^R} \left(z - z^R\right) g(z)dz - \rho_F \bar{w}, \tag{24}$$

$$\xi z^R \varphi = \beta(1-\lambda^x)\left[(1-\xi)\chi\theta - \frac{\chi}{q(\theta)}\right] + \xi\left(h + \rho_B \bar{w}\right) - \left[\xi + (1-\xi)\beta(1-\lambda^x)\left(1 - p(\theta)\right)\right]\rho_F \bar{w}, \tag{25}$$

$$\bar{w} = (1-\xi)\left\{\varphi \int_{z^R} z \frac{g(z)}{1 - G(z^R)} dz + \left[1 - \left(1 - p(\theta)\right)\beta(1-\lambda^x)\right] F + \beta(1-\lambda^x)\chi\theta\right\} + \xi\left(h + \rho_B \bar{w}\right),$$

which can be used to solve for home production, h, the cost of posting a vacancy, χ, and the average real wage, $\bar{w}$. For values of σ_z lower than 0.18, the latter three equations imply negative values

[12] Den Haan et al. (2000) set λ^n/λ to 32%, whereas Pissarides (2007) estimates that endogenous separations account for 60% of all separations. The midpoint of these estimates is 46%.

[13] We are normalizing the steady-state level of exogenous productivity, A, to 1.

for χ, which violates the non-negativity constraint on this parameter. For this reason, we opt for estimating the model under four different values of σ_z: 0.20, 0.30, 0.40 and 0.50. For each value, we obtain the corresponding values of $\{h, \chi, \bar{w}\}$, log-linearize the model around the steady state and estimate it by maximum likelihood. We find that the likelihood of the model is highest for the case of $\sigma_z = 0.20$. We therefore choose this value as our baseline. Reservation and average productivity then equal $z^R = 0.65$ and $\bar{z} \equiv \int_{z^R} z \frac{g(z)}{1-G(z^R)} dz = 1.03$, respectively, whereas the solution to the 3-equation system above is $\chi = 0.013$, $h = 0.48$ and $\bar{w} = 0.85$. Aggregate output equals $y = n\bar{z} = 0.92$. Finally, assuming a ratio of government spending to GDP of $g/y = 0.20$, consumption is given by $c = y(1 - g/y) - \chi v = 0.74$.

3.2 Estimation

We estimate the remaining structural parameters $(\sigma_A, \sigma_g, \sigma_\mu, \sigma_m, \rho_A, \rho_g, \rho_\mu, \phi_\pi, \phi_i, \delta)$ by constrained maximum likelihood.[14] In particular, we impose an upper bound of 10% on the standard deviation of all shocks. In order to match the number of shocks in our model, we choose four observable variables: real output (y_t), employment (n_t), year-on-year inflation ($\pi_t^{yoy} \equiv \log P_t - \log P_{t-4}$) and the nominal interest rate (i_t). The euro area as such exists since 1999:Q1. This leaves us with a relatively short sample. We follow the argument in Rabanal (2006) that by 1997 convergence in national nominal interest rates had been nearly reached. We therefore use data from 1997:Q1 to 2007:Q4, which gives us 44 observations.[15] Employment and real GDP are logged and linearly detrended, whereas inflation and nominal interest rates are linearly detrended.

[14] The estimation and all the subsequent simulations are performed using a log-linear approximation of the model around a zero-inflation steady state. We use the software DYNARE in all our exercises.

[15] Our data is obtained from the ECB Statistical Data Warehouse. Our series are GDP at constant prices, total domestic employment, the GDP deflator and the 3-month Euribor. All series are seasonally adjusted. We also estimated the model using the rate of change of the Harmonized CPI as our measure of inflation (the CPI and the GDP deflator are equivalent in our model). We found the estimation results to be nearly identical.

Table 1. Maximum likelihood estimation results

	Estimate	Standard error	Description
σ_A	0.0026	0.0003	standard dev., productivity shock
σ_g	0.0810	0.0428	standard dev., government shock
σ_μ	0.1000	-	standard dev., mark-up shock
σ_m	0.0010	0.0001	standard dev., interest rate shock
ρ_A	0.86	0.0382	autocorrelation, productivity shock
ρ_g	0.97	0.0165	autocorrelation, government shock
ρ_μ	0.00	-	autocorrelation, mark-up shock
ϕ_π	3.15	1.1990	Taylor rule coefficient, inflation
ϕ_y	0.02	0.0662	Taylor rule coefficient, output
ϕ_i	0.70	0.0640	interest rate smoothing
δ	0.88	0.0061	fraction of sticky prices

Table 1 displays the estimation results. Overall, parameter estimates are fairly precise, with the exception of the standard error of the government shock (σ_g), and the coefficient on expected inflation in the Taylor rule (ϕ_π). The productivity and government shocks turn out to be quite persistent, whereas the data favors a mark-up shock with no persistence. The estimated Calvo parameter implies an average duration of price contracts, $1/(1-\delta)$, of about 7 and a half quarters, i.e. almost two years. This is clearly too long in the light of micro evidence for the euro area, but is a common result in models that lack a real price rigidity mechanism.[16] Finally, the upper bound on the shock standard deviations becomes binding in the case of σ_μ.

3.3 Model assessment

We next assess the estimated model's ability to match the data in our sample. Figure 1 compares each observed series with the corresponding one-period-ahead forecast obtained by applying the Kalman filter on the state-space representation of the model.[17] The latter can be loosely interpreted as the in-sample fit of the model, as discussed by Adolfsson et al. (2005). Overall, the fit is quite good, especially for output, employment and year-on-year inflation.

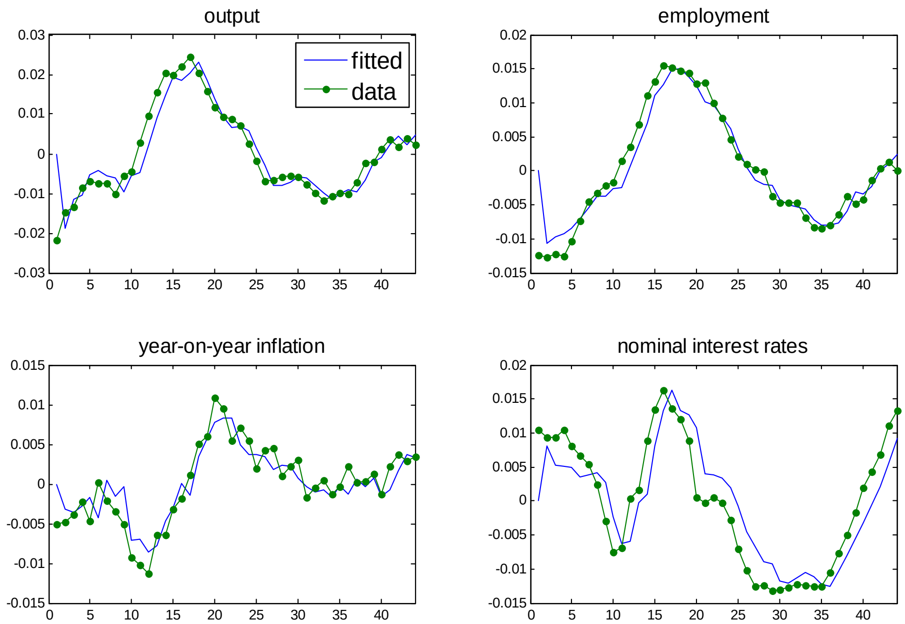
As a further check, Figure 2 compares the autocovariance function of the observable variables in the estimated model with that of the actual data. The figure also plots the 95% confidence intervals of the model autocovariances.[18] Overall the fit is fairly good. In particular, both the size and the

[16] Real price rigidities arise in situations in which individual marginal cost curves are upward-sloping, which is not the case in the present framework. Such rigidities have the effect of slowing price adjustment for a given average frequency of price adjustment. Equivalently, they reduce the amount of price stickiness that is needed to match inflation dynamics. On this question, see Altig et al. (2004) or Woodford (2005).

[17] Nominal interest rates in the lower-right panel are shown in annual terms ($4i_t$).

[18] Following Ireland (2004), the confidence intervals are obtained as follows. Each second moment in the model can be expressed as a function $g(\zeta)$ of the estimated parameters, ζ. Letting Ω denote the covariance matrix of ζ,

Figure 1: Data vs. fitted values of the observable variables



persistence of fluctuations in the observable variables are very well captured, as shown by the panels in the diagonal. Also, all confidence intervals contain the corresponding data autocovariance, with the only exception of the autocovariance between y_t and π_{t-5}^{yoy}.

3.4 Impulse-response analysis

In order to illustrate the transmission mechanism in our model, we now simulate the economy's response to shocks. Figures 3 to 5 display the response of a number of variables to a one-standard-deviation shock to productivity, government spending and the nominal interest rate, respectively.[19] As shown in Table 2, in the model these three shocks account for 100% of the variance of output, employment and nominal interest rates, and 57% of the variance of year-on-year inflation. Mark-up shocks account for the remaining 43% of fluctuations in year-on-year inflation, but their lack of autocorrelation and the fact that interest rates respond to expected inflation imply that such shocks have no effect on any of the other variables.

the variance of $g(\zeta)$ can be approximated by $[\partial g(\zeta)/\partial\zeta]' \, \Omega \, [\partial g(\zeta)/\partial\zeta]$, where the derivatives $\partial g(\zeta)/\partial\zeta$ are calculated numerically. The amplitude of the confidence interval, centered around the value of $g(\zeta)$ in the estimated model, is simply two standard deviations of $g(\zeta)$. Since this approximation is only valid when the estimates do not fall on a boundary of the assumed parameter space, in this exercise we treat ρ_μ and σ_μ as calibrated parameters.

[19] In the figures, the variable "inflation" refers to quarterly inflation, $\pi_t \equiv \log(P_t/P_{t-1})$, and both nominal interest rates and quarterly inflation are shown in annual terms ($4i_t$, $4\pi_t$).

Figure 2: Autocovariance function of the observable variables, data vs. estimated model

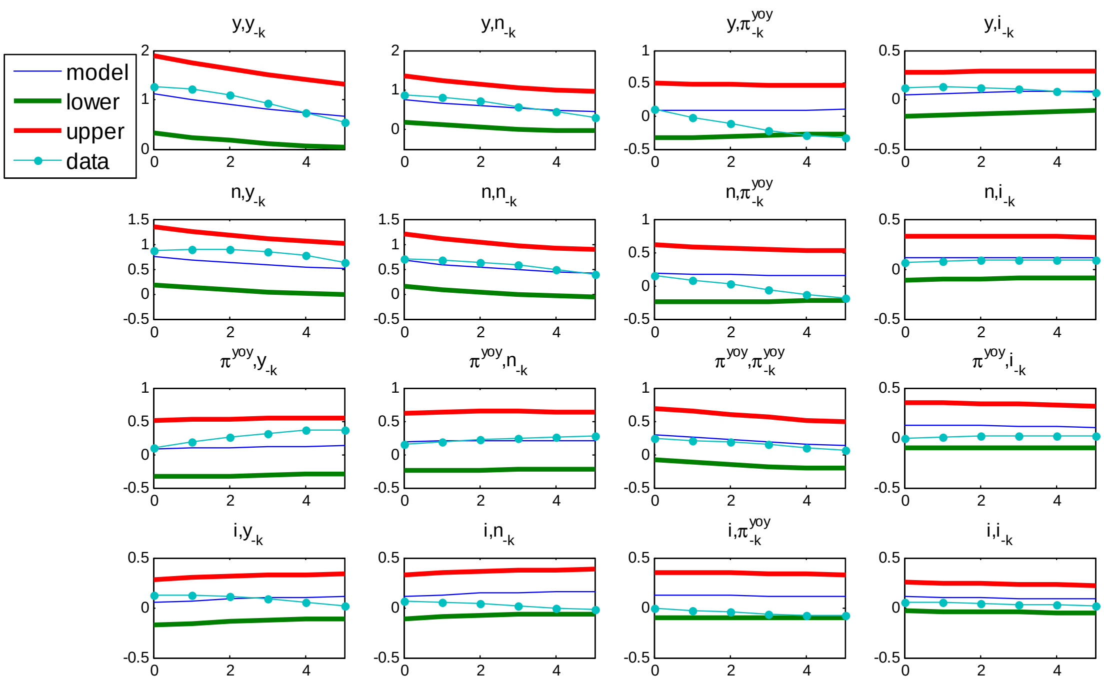


Table 2. Variance decomposition of the observable variables in the estimated model (%)

Shock	y	n	π^{yoy}	i
Productivity	44.24	6.57	14.79	12.64
Government	45.08	75.08	42.25	71.29
Mark-up	0.00	0.00	42.95	0.00
Interest rate	10.68	18.35	0.01	16.08
Total	100	100	100	100

Following a positive productivity shock (Figure 3), inflation goes down and the central bank cuts nominal interest rates, which boosts consumption spending. At the same time, the increase in labor productivity leads firms to increase the resources devoted to vacancy posting. These last two effects drive aggregate demand upwards. The upsurge in demand is strong enough that firms still need to increase employment despite the improvement in productivity. As shown in the lower-right panel, most of the employment adjustment takes place along the job creation margin.

Following a government shock (Figure 4), output and employment increase. The response of both variables is almost identical, which implies that average idiosyncratic productivity, $\bar{z}_t$, barely changes. Once again, employment adjusts mainly along the job creation margin, thanks in particular to a large expansion of vacancy posting in the impact period. The expansion in economic activity puts upward pressure on real marginal costs, leading to a persistent increase in inflation. The effects of an exogenous increase in the nominal interest rate (Figure 5) are very similar to those of a government shock, but with the opposite signs; the only exception is the magnitude of the interest rate response, which is now much larger than that of inflation. Finally, the lower left panels of figures 3 to 5 show that after-hiring unemployment (U_t) and vacancies are negatively correlated for all three shocks. In particular, we find conditional correlations of -55%, -49% and -52%, respectively, and an unconditional correlation of -48%. That is, a Beveridge curve materializes.

4 Effects of labor market reform on price stability

We are ready to simulate the effects on price stability of a hypothetical labor market reform in our estimated model of the euro area. At this point, we find it useful to take a closer look at the determinants of inflation. Once the model is loglinearized, the dynamics of quarterly inflation ($\pi_t \equiv \log P_t - \log P_{t-1}$) are described by the standard New Keynesian Phillips curve,

$$\pi_t = \kappa \hat{\varphi}_t + \beta E_t \pi_{t+1} + \kappa \hat{\mu}_t, \tag{26}$$

where $\kappa \equiv (1-\delta)(1-\delta\beta)/\delta$ and hats denote log-deviations from steady state. Inflation is thus driven by real marginal costs and mark-up shocks. Equations (3) and (4) allow us to express real

Figure 3: Impulse-responses to a positive productivity shock

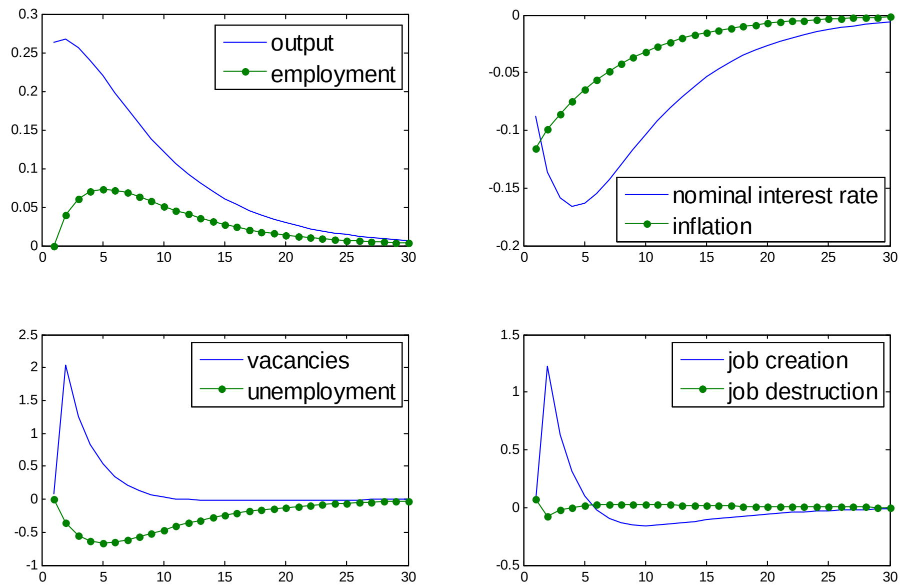


Figure 4: Impulse-responses to a positive government shock

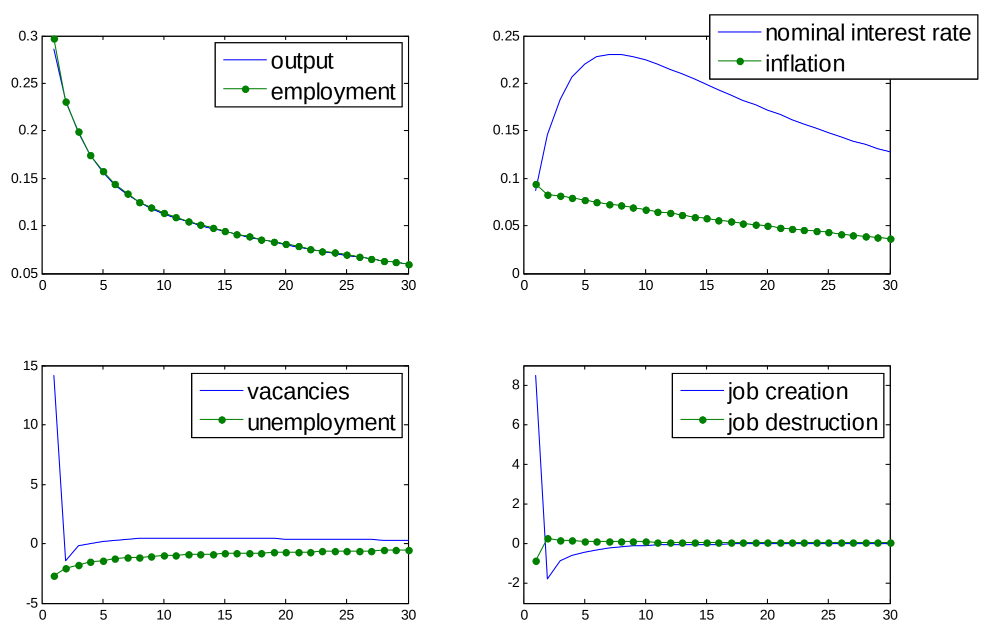
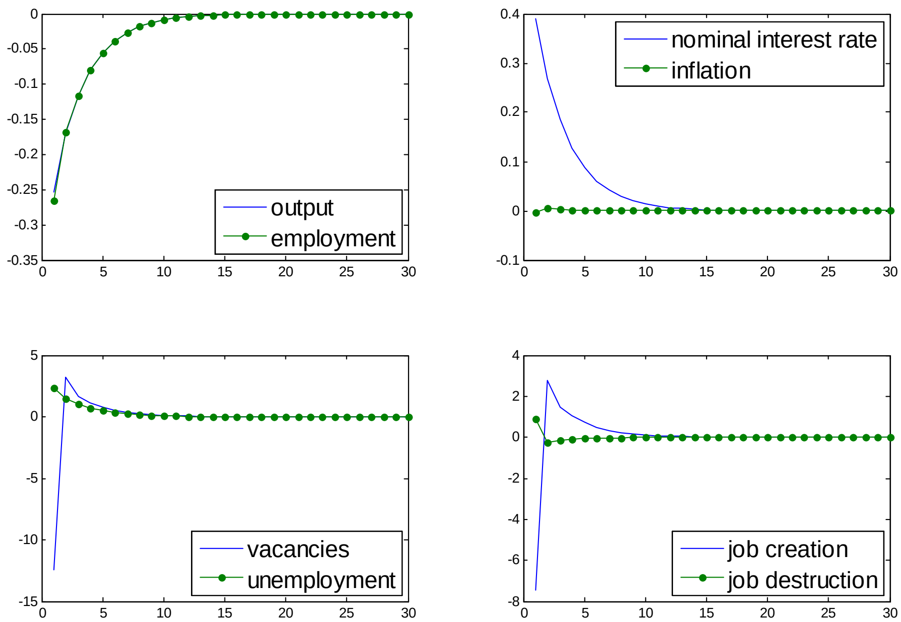


Figure 5: Impulse-responses to a positive shock to the nominal interest rate



marginal costs as

$$\varphi_t = \left[\frac{\chi}{q(\theta_t)\,(1-\lambda_t^n)} + \frac{\lambda_t^n}{1-\lambda_t^n} F + \bar{w}_t - (1-\lambda^x) E_t \beta_{t,t+1} \frac{\chi}{q(\theta_{t+1})} \right] \frac{1}{A_t \bar{z}_t},$$

where $\bar{w}_t \equiv \int_{z_t^R} w_t(z) \frac{g(z)}{1-G(z_t^R)} dz$ and $\bar{z}_t \equiv \int_{z_t^R} z \frac{g(z)}{1-G(z_t^R)} dz$ are the average real wage and the average idiosyncratic productivity, respectively, and $\lambda_t^n \equiv G(z_t^R)$ is the endogenous job destruction rate. Therefore, the real marginal costs equals the ratio of the effective cost of increasing employment at the margin (the expression in square brackets) and the increase in production due to the new hires $(A_t \bar{z}_t)$. The effective cost of increasing employment equals the cost of hiring workers corrected by the probability that they do not survive job destruction, $\chi / [q(\theta_t)\,(1-\lambda_t^n)]$, plus the cost of firing those who fall below the reservation productivity, $[\lambda_t^n / (1-\lambda_t^n)]\, F$, plus the average wage paid to those who stay in the firm, $\bar{w}_t$, minus their continuation value for the firm, $E_t \beta_{t,t+1}^x \chi / q(\theta_{t+1})$. Using the aggregate production function, $y_t = A_t n_t \bar{z}_t$, we can rewrite real marginal costs as

$$\varphi_t = \frac{n_t / y_t}{1-\lambda_t^n} \left[\frac{\chi}{q(\theta_t)} - (1-\lambda_t)\, E_t \beta_{t,t+1} \frac{\chi}{q(\theta_{t+1})} \right] + \frac{\lambda_t^n}{1-\lambda_t^n} \frac{n_t F}{y_t} + \frac{n_t \bar{w}_t}{y_t},$$

where we have also used the fact that $(1-\lambda_t^n)(1-\lambda^x) = 1-\lambda_t$. Therefore, marginal costs are the sum of a hiring component (the expression in square brackets), a firing component, and the labor share of GDP, $n_t \bar{w}_t / y_t$. We now make use of an approximation similar to the one employed by Blanchard and Gali (2006). We start by noticing that vacancy posting costs, $\chi = 0.013$, and separation rates, $\lambda^n = 0.016 = \lambda/2$, are of the same order of magnitude as the fluctuations of the endogenous variables in the marginal cost expression, with the exception of θ_t, which experiences larger fluctuations.[20] Once the above equation is log-linearized, all terms multiplied by χ, λ^n or λ become second-order terms, except for those involving $\hat{\theta}_t$. This yields the following first-order approximation of real marginal costs,

$$\hat{\varphi}_t = \frac{\chi}{q(\theta)\varphi \bar{z}}(1-\epsilon)\left(\hat{\theta}_t - \beta E_t \hat{\theta}_{t+1}\right) + \frac{F}{\varphi \bar{z}}\left(\tilde{\lambda}_t^n + \hat{n}_t - \hat{y}_t\right) + \frac{\bar{w}}{\varphi \bar{z}}\left(\widehat{\bar{w}}_t + \hat{n}_t - \hat{y}_t\right),$$

where $\tilde{\lambda}_t^n \equiv \lambda_t^n - \lambda^n$. Combining the latter equation with equation (26) finally yields the following approximate expression for inflation dynamics,

$$\pi_t^{approx} \equiv hc_t + fc_t + ls_t + \frac{\kappa}{1-\beta\rho_\mu}\hat{\mu}_t.$$

Inflation is (approximately) equal to the sum of a *hiring component*,

$$hc_t \equiv \frac{\kappa}{\varphi}\frac{\chi}{q(\theta)\bar{z}}(1-\epsilon)\hat{\theta}_t,$$

a *firing component*,

$$fc_t \equiv \frac{\kappa}{\varphi}\frac{F}{\bar{z}}\sum_{T=t}^{\infty}\beta^{T-t}E_t\left(\tilde{\lambda}_T^n + \hat{n}_T - \hat{y}_T\right),$$

a *labor share component*,

$$ls_t \equiv \frac{\kappa}{\varphi}\frac{\bar{w}}{\bar{z}}\sum_{T=t}^{\infty}\beta^{T-t}E_t\left(\widehat{\bar{w}}_T + \hat{n}_T - \hat{y}_T\right),$$

and the exogenous mark-up shock component, $\kappa\hat{\mu}_t / \left(1-\beta\rho_\mu\right)$. We can then decompose the variance of approximate inflation as follows,

$$var\left(\pi_t^{approx}\right) = var(hc_t) + var(fc_t) + var(ls_t) + \left(\frac{\kappa}{1-\beta\rho_\mu}\right)^2\frac{\sigma_\mu^2}{1-\rho_\mu^2} + covs, \tag{27}$$

where *covs* collects the sum of all covariances between the four components of inflation.

What is the effect on price stability that we should expect from reductions in unemployment

[20] Log-linearizing equations (16) and (18) and combining the resulting expressions, we obtain the following law of motion of employment,

$$\hat{n}_t = (1-\lambda)(1-p(\theta))\hat{n}_{t-1} + \frac{1}{1-\lambda^n}(\lambda_t^n - \lambda^n) + \epsilon\lambda\hat{\theta}_t,$$

where $\epsilon = 0.6$ in our calibration. Therefore, first-order fluctuations in employment and the endogenous job destruction rate must be accompanied by first-order fluctuations in $\lambda\hat{\theta}_t$. Since λ is itself first-order, $\hat{\theta}_t$ must experience fluctuations of a larger magnitude. Under our baseline calibration, the standard deviation of $\hat{\theta}_t$ is 20.5%, versus 0.83% for $\hat{n}_t$, 1.06% for $\hat{y}_t$ and 0.05% for $\lambda_t^n - \lambda^n$.

benefits and firing costs? A reduction in *unemployment benefits* reduces the outside option of workers and thus increases the joint surplus of all jobs. Since firms receive a constant fraction of the joint surplus (by virtue of Nash wage bargaining), the expected benefit from new hires increases and so does vacancy posting. As the labor market becomes tighter, the steady-state probability of filling a vacancy, $q(\theta)$, falls and thus the steady-state cost of hiring, $\chi/q(\theta)$, increases. As a result, in response to shocks the same percentage fluctuations in labor market tightness, $\hat{\theta}_t$, produce larger percentage fluctuations in hiring costs, $[\chi/q(\theta)]\,(1-\epsilon)\hat{\theta}_t$. This should increase the volatility of the hiring component of inflation, hc_t, thus making inflation *more* volatile. This effect is reinforced by the effect of hiring costs on average real wages, $\bar{w}_t$. The latter are increasing in $E_t\beta^x_{t,t+1}\chi\theta_{t+1}$, which is the (expected discounted value of the) product of the probability of finding another job, $p(\theta_{t+1})$, times hiring costs, $\chi/q(\theta_{t+1})$.[21] Since percentage fluctuations in $E_t\beta^x_{t,t+1}\chi\theta_{t+1}$ are given by $\beta^x\chi\theta E_t\left(\hat{\beta}^x_{t,t+1}+\hat{\theta}_{t+1}\right)$, we have that the increase in θ increases the size of percentage fluctuations in average real wages. As a result, we should observe an increase both in the variance of the labor share component of inflation, ls_t, and in its covariance with hc_t. This should reinforce the increase in inflation volatility.

On the other hand, a reduction in *firing costs* automatically decreases the size of fluctuations in the firing component of inflation, fc_t, for given fluctuations in the expected discounted path of endogenous separation rates, $\sum_{T=t}^{\infty}\beta^{T-t}E_t\tilde{\lambda}^n_T$, and average labor productivity, $\sum_{T=t}^{\infty}\beta^{T-t}E_t\left(\hat{y}_T-\hat{n}_T\right)$. This should make inflation *less* volatile.

Figure 6 plots the evolution of the variance of π_t^{approx} and its components (except for the variance of the mark-up shock component, which remains constant) as we decrease the replacement ratio of unemployment benefits (from 40% to 30%) and firing costs (from 20% to 10%). The plots must therefore be read from right to left.[22] In order to check the accuracy of our approximation, we also plot the actual variance of inflation in the log-linearized economy (the thick solid lines).

In the case of a reduction in unemployment benefits (left panel), three results stand out. First, inflation volatility increases, as we anticipated, but it does so by a very small amount. Transforming the variance of inflation displayed in the figure into a more informative metric such as the annualized standard deviation, $4\sqrt{var(\pi_t)}$, we find that the latter increases by just 5 basis points, from 0.84% to 0.89%. Second, this small increase is driven mainly by an increase in the variance of the labor share component, which in turn is due almost entirely to a rise in the variance of the expected discounted path of average real wages.[23] Third, the hiring component and its covariance with the

[21] As shown in section 2.3, the worker surplus in alternative jobs is increasing in hiring costs.

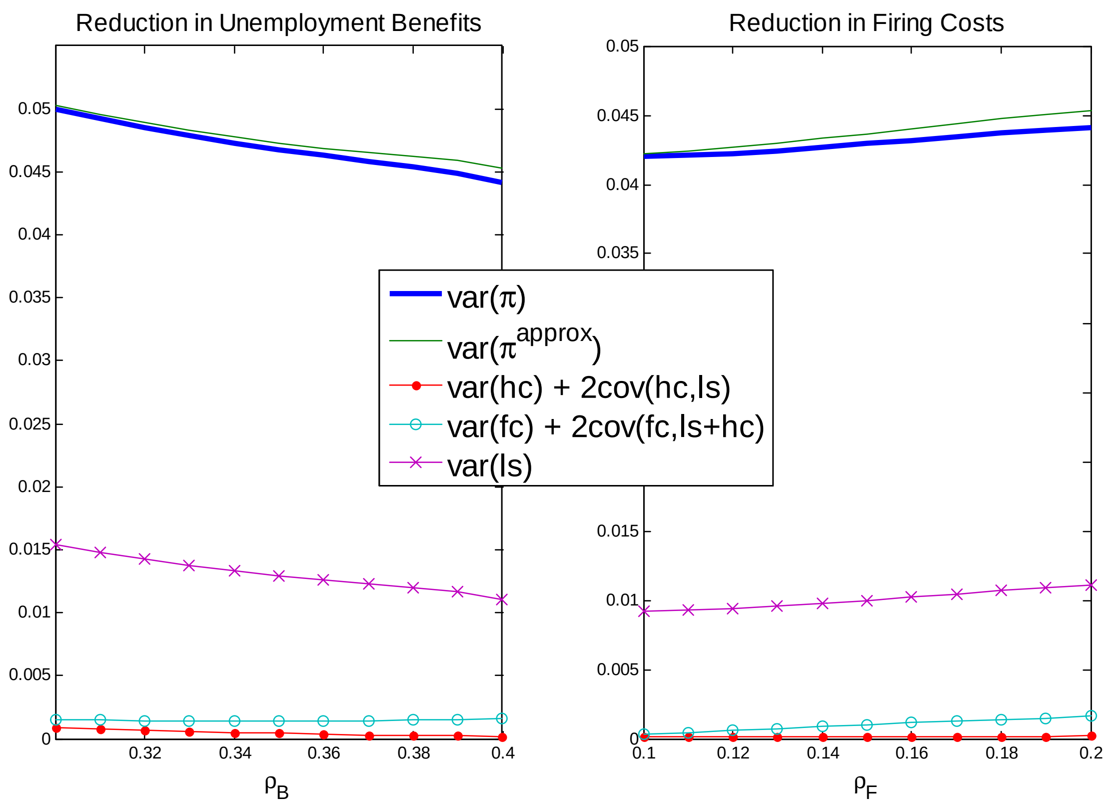
[22] Since mark-up shocks have no effect on any endogenous variable other than quarterly inflation in the log-linear approximation of the model, the covariance between the mark-up shock component and the other components of π_t^{approx} is zero. It follows that the term *covs* in equation (27) is given by

$$covs = 2cov(hc_t, fc_t) + 2cov(hc_t, ls_t) + 2cov(fc_t, ls_t).$$

Therefore, the thin solid lines in Figure 6 are the vertical sum of the different components shown in the figure *plus* the (constant) variance of the mark-up shock component.

[23] Changes in $var(ls_t)$ could also be due to changes in the steady-state labor share, $\bar{w}/\bar{z} = n\bar{w}/y$, or changes in

Figure 6: Effects of labor market reform on the variance of inflation, baseline parameterization



labor share component move in the direction we anticipated, but their contribution to the change in inflation volatility is very modest. The reason is very simple. In order to match the volatility of employment in the Euro Area, our estimation procedure favors model parameterizations in which hiring costs are small. As shown in the first row of Table 3, steady-state hiring costs in the baseline economy are just 1.46% of average worker productivity. This way, even though fluctuations in labor market tightness are substantial, the size of hiring costs implies that such fluctuations have a small effect on inflation. As a result, a certain percentage change in $var(hc_t)$ will have a small *absolute* effect on $var\left(\pi_t^{approx}\right)$.

Table 3. Steady-state effects of labor market reform, baseline parameterization

	Baseline	$\rho_B = 0.30$	$\rho_F = 0.10$
$\chi / [q(\theta)\bar{z}]$	0.0146	0.0335	0.0209
$F/\bar{z}$	0.1660	0.1662	0.0815
$\bar{w}/\bar{z}$	0.8301	0.8311	0.8148
$\bar{z}$	1.0268	1.0233	1.0704

In the case of a reduction in firing costs (right panel), inflation volatility falls, as we hypothesized, but the change is again very small: from 0.84% to 0.82% in terms of the annualized standard deviation. As we anticipated, the firing component of inflation, fc_t, becomes less volatile. However, the fact that the endogenous separation rate, $\hat{\lambda}_t^n$, barely fluctuates in the baseline economy (with a 0.05% standard deviation) implies that the variance of the firing component makes a negligible contribution to inflation volatility. As a result, a certain percentage change in $var(fc_t)$ will have again small absolute effects on $var\left(\pi_t^{approx}\right)$.

4.1 Robustness analysis

As we discussed in section 3, we calibrated and estimated our model under four different values of the standard deviation of idiosyncratic productivity shocks (0.20, 0.30, 0.40 and 0.50) and found that the model's fit of the data was best for $\sigma_z = 0.20$. In fact, the likelihood function evaluated at the estimated parameters decreases monotonically as we increase σ_z. A feature of our baseline calibration is that the value of vacancy posting costs (χ) consistent with the steady state of the model is very small, such that hiring costs play almost no role in inflation dynamics. As σ_z increases and the distribution of idiosyncratic productivity shocks becomes more spread out, the distance between the average and the reservation productivity increases, which from equation (24) increases the marginal benefit of hiring in the steady state. As a result, the value of χ consistent with the

the expected discounted path of average labor productivity, $\sum_{T=t}^{\infty} \beta^{T-t} E_t \left(\hat{y}_T - \hat{n}_T\right)$. These terms however have a negligible effect. First, $\bar{w}/\bar{z}$ barely changes following the reduction in ρ_B, as shown in the third row of Table 3. Also, since $\hat{y}_t - \hat{n}_t = \log A_t - \widehat{\tilde{z}}_t$ and average idiosyncratic productivity $(\widehat{\tilde{z}}_t)$ is nearly acyclical, the expected path of labor productivity is basically exogenous and thus its variance remains virtually unaffected.

steady state of the model increases, and with it the relevance of hiring costs for inflation volatility. As a robustness check, we now simulate the effect of labor market reform on price stability under two alternative values of σ_z: 0.30 and 0.40.[24] The results for $\sigma_z = 0.30$ are displayed in Figure 7. The change in inflation volatility following a reduction in unemployment benefits is now somewhat more pronounced than under our baseline parameterization. The annualized standard deviation of inflation increases by 9 basis points, from 0.86% to 0.95%. The reasons is that, as hiring costs become larger in the baseline economy (we now have $\chi/q(\theta) = 0.082\bar{z}$; see Table 4), changes in the volatility of hiring costs become more relevant for inflation dynamics. Indeed, most of the rise in the variance of inflation is now explained by the rise in the variance of hc_t and its covariance with ls_t. In the case of a reduction in firing costs, the message barely changes with respect to the baseline parameterization: the annualized standard deviation of inflation falls again by just 2 basis points, from 0.86% to 0.84%.

Table 4. Steady-state effects of labor market reform, alternative parameterizations

	$\sigma_z = 0.30$			$\sigma_z = 0.40$		
	Baseline	$\rho_B = 0.30$	$\rho_F = 0.10$	Baseline	$\rho_B = 0.30$	$\rho_F = 0.10$
$\chi/\left[q(\theta)\bar{z}\right]$	0.0823	0.1483	0.0972	0.1372	0.2244	0.1527
$F/\bar{z}$	0.1655	0.1659	0.0814	0.1650	0.1655	0.0811
$\bar{w}/\bar{z}$	0.8273	0.8293	0.8140	0.8250	0.8275	0.8108
$\bar{z}$	1.0551	1.0466	1.0896	1.0946	1.0834	1.1319

Finally, Figure 8 displays the results in the case of $\sigma_z = 0.40$. Under this parameterization, steady-state hiring costs are even higher ($\chi/q(\theta) = 0.137\bar{z}$), and fluctuations in hiring costs become therefore more important for inflation dynamics. The effects of a reduction in unemployment benefits are amplified with respect to the case of $\sigma_z = 0.30$. The annualized standard deviation of inflation rises now by 20 basis points, from 0.89% to 1.09%, and the contribution to this change of the variance of the hiring component (and its covariance with the labor share component) is even more visible. Once again, a reduction in firing costs has very little effect on inflation volatility, which falls from 0.89% to 0.86% in terms of the annualized standard deviation.

To summarize our robustness results, increasing the variance of the distribution of idiosyncratic shocks magnifies the effect of reductions in unemployment benefits on inflation volatility, due to the greater importance of hiring costs for inflation dynamics. However, these results should be taken with care, because the model's fit of the data also worsens as we increase σ_z, as indicated by the value of the likelihood function. And in any case, the effects remain small: following a 10 percentage point reduction in the replacement ratio, the annualized standard deviation of inflation increases by 9 basis points for $\sigma_z = 0.30$, and by 20 basis points for $\sigma_z = 0.40$.

[24] For brevity, we omit the results in the case of $\sigma_z = 0.50$, which go in the same direction as those displayed for $\sigma_z = 0.30$ and $\sigma_z = 0.40$.

Figure 7: Effects of labor market reform on the variance of inflation, $\sigma_z = 0.30$

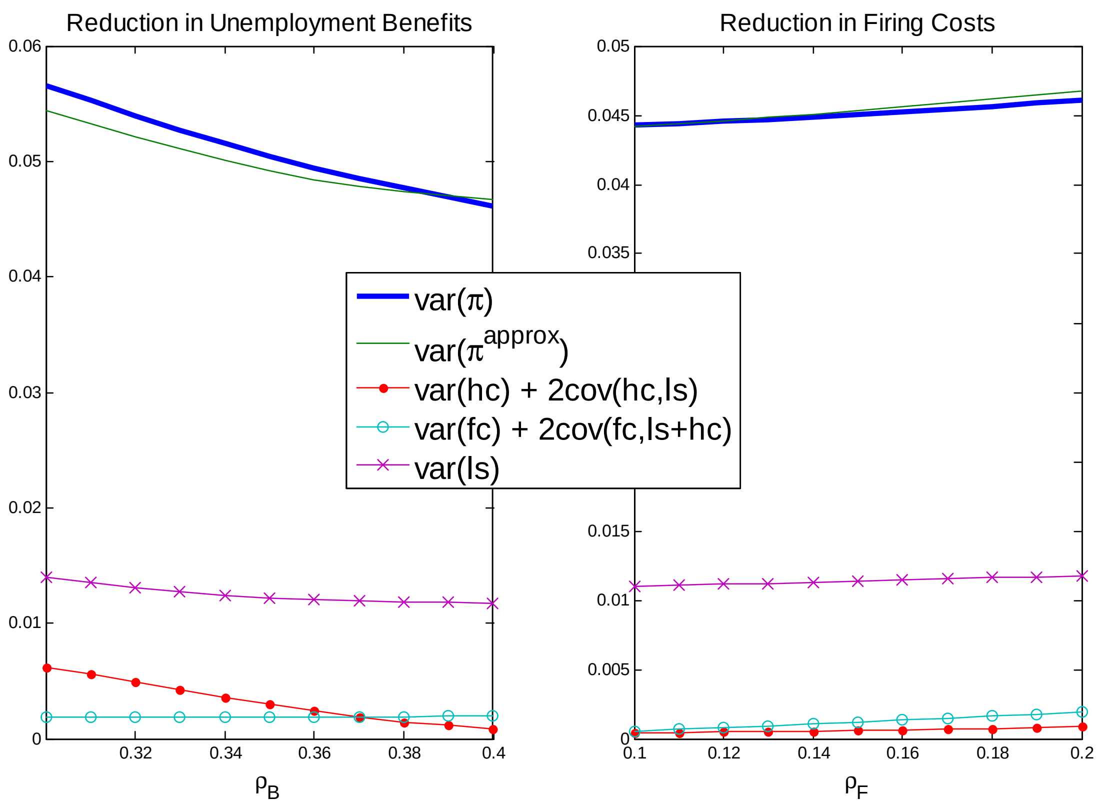
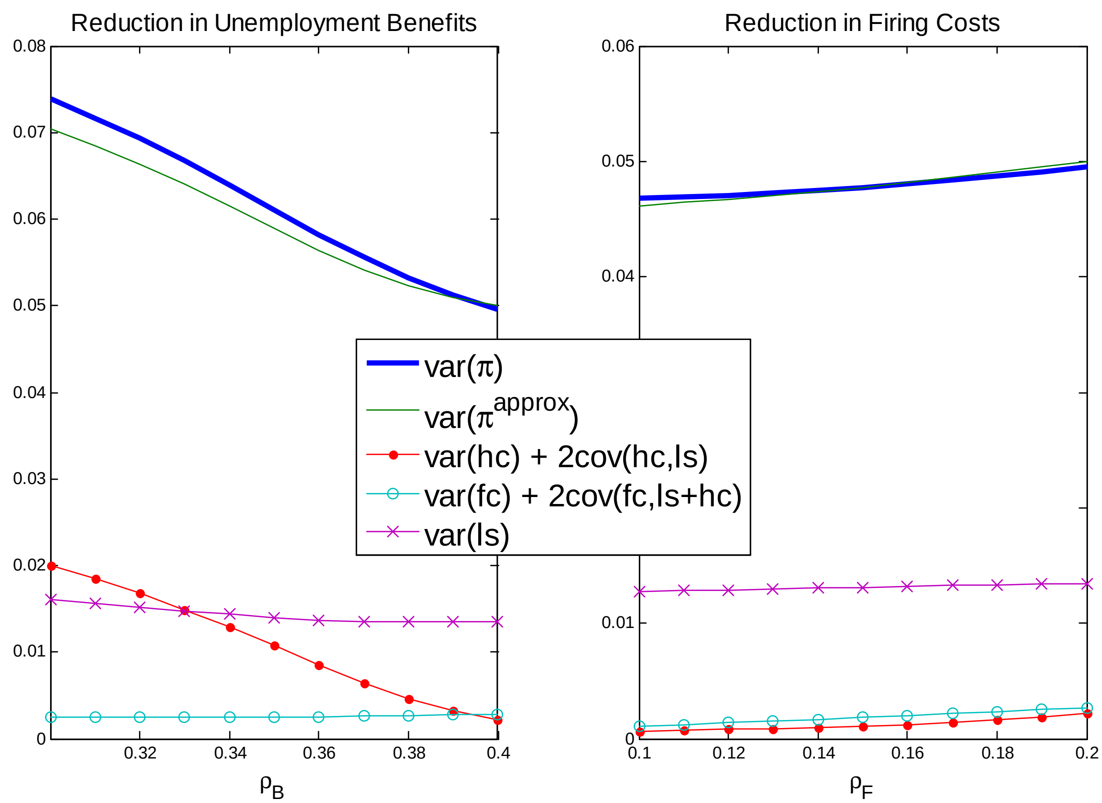


Figure 8: Effects of labor market reform on the variance of inflation, $\sigma_z = 0.40$



5 Conclusions

This paper has studied the effect that changes in labor market policies, in the form of unemployment benefits and firing costs, may have on price stability. Our analysis is based on a New Keynesian model in which the labor market is subject to search and matching frictions. We take our theoretical model to Euro Area data and provide a quantitative answer to our question. We find that changes in unemployment benefits or firing costs are unlikely to have a significant impact on the volatility of inflation. As far as firing costs are concerned, job destruction rates are nearly acyclical in our estimated model, such that changes in firing costs have very little effect on the firing component of real marginal costs and hence on inflation. Changes in unemployment benefits can have important effects on the volatility of the hiring component of real marginal costs. This however has a small effect on inflation volatility, because Euro Area data favors model parameterizations in which hiring costs are small.

The analysis of this paper is conducted using a search and matching model of the labor market, which is only one possible way of analyzing the effect of labor market reforms on inflation dynamics. It would be interesting to establish whether the same results carry over to other environments such as the search-island model (Lucas and Prescott, 1974; Ljungqvist and Sargent, 1998, 2006), the insider-outsider model (Blanchard and Summer, 1986; Lindbeck and Snower, 1988), or a model where firms fire workers only in certain states (Bentolila and Bertola, 1990).

Within the realm of the search and matching framework, an important extension of the analysis presented here would be to incorporate stickiness in real wages, which is likely to interact with labor market policies in shaping the behavior of inflation. This will prove to be a difficult task however, because of the theoretical requirement known as the 'Barro critique', namely that wage stickiness should not lead to the destruction of jobs that command a positive joint surplus. Hall (2005) derives the analytical conditions under which such a requirement holds in a simple matching model, and Gertler and Trigari (2006) and Thomas (2008a) show numerically that more complex DSGE models with matching frictions can also be virtually immune to the Barro critique. All these papers however assume exogenous job destruction. Developing a model with endogenous job destruction and wage stickiness that avoids the Barro critique is therefore an important task for future research.

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