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Optimal monetary policy rules with labor market frictions

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Abstract

This paper studies optimal monetary policy rules in a framework with sticky prices, matching frictions and real wage rigidities. Optimal policy is given by a constrained Ramsey plan in which the monetary authority maximizes the agents' welfare subject to the competitive economy relations and the assumed monetary policy rule. I find that the optimal rule should respond to unemployment alongside with inflation. This is so since models with matching frictions (unlike standard new Keynesian models) feature a congestion externality that makes unemployment inefficiently high. A strong response to inflation remains optimal while a response to output is always welfare detrimental.

JEL classification: E52; E24

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1. Introduction

Nowadays most central banks follow (or at least so they state) inflation targeting or price stability rules with little weight assigned to output stabilization and almost

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no attention devoted to other economic indicators such as unemployment. One common argument for such choice is that stabilizing prices optimizes the output-inflation volatility trade-off which implies that inflation stabilization can be achieved with a relatively small output cost. Theoretically this hypothesis is true in models with nominal rigidities and walrasian labor markets. This paper assesses the importance of responding to other real economic variables in a model with sticky prices, non-walrasian labor markets and real wage rigidities.

To conduct such an analysis I employ a unitary framework which combines nominal and real rigidities and which has become common in the recent new Keynesian literature. More specifically the model economy is characterized by monopolistic competition, adjustment costs on pricing, matching frictions in the labor market and real wage rigidity.[1] The assumption of monopolistic competition and adjustment cost on pricing a' la Rotemberg (1982) is needed to obtain non-neutral effects of monetary policy and to make a meaningful comparison across different monetary policy rules. Introducing matching frictions a' la Mortensen and Pissarides (1999) in the labor market allows to consider frictional unemployment in the steady state and provides a rich dynamics for the formation and dissolution of employment relations. The introduction of this congestion externality helps to recover a trade-off between the cost of volatile inflation and the cost of inefficient unemployment fluctuations.[2] Such trade-off, absent in standard new Keynesian models, is an essential feature to determine whether optimal monetary policy should deviate from full price stabilization. Finally I introduce real wage rigidity since some authors have shown that this helps to resolve some inconsistencies between the standard matching friction model and the empirical evidence.[3]

Our economy is characterized by three sources of inefficiency, both in the long and in the short run. The first is monopolistic competition, which induces an inefficiently low level of output thereby calling for mild deviations from strict price stability.[4] The second type of distortion stems form the cost of adjusting prices which reduces output thereby calling for closing the 'inflation gap'. Finally the search theoretic framework is characterized by a congestion externality that tends to tighten the labor market. The chance that workers and firms have to match depends on the number of unemployed people or vacant firms in the market; if either of the two is too high the reduction in the probability of forming a match induces an inefficiently high level of unemployment. Whether there is excessive vacancy creation or an excessive number of searching workers depends on the workers' bargaining power: when the workers' share of the matching surplus is too small (hence firms' share is too high) there will

[1]The laboratory economy that I use is very close to the one proposed in Krause and Lubik (2007). Several other authors, ranging from Walsh (2003) to Blanchard and Gali' (2006), have recently introduced matching frictions and real wage rigidity into New Keynesian models.

[2]Erceg et al. (2000) and Blanchard and Gali' (2005, 2006) present models in which an unemployment/inflation trade-off emerges because of the nominal wage rigidity.

[3]Hall (2005) and Shimer (2005) noticed that in models with matching frictions labor market adjustment takes place solely through wages. The introduction of real wage rigidity shifts part of the adjustment on employment and reduces real wage volatility in accordance with empirical evidence.

[4]See Schmitt-Grohe and Uribe (2004a) and Faia (2005) among others.

be excessive vacancy creation and viceversa (see Hosios, 1990). Whenever there is a inefficiently low level of employment the monetary authority finds optimal to respond to unemployment fluctuations.

The recent optimal monetary policy literature has dealt with the role of distortions in alternative ways. The vast majority of papers neutralize the steady state distortions by specifying a complementary (and arguably unrealistic) role of fiscal policy or by choosing specific parameter spaces. This assures, even in presence of price stickiness, that the average level of output coincides (under zero inflation) with the efficient one, thereby allowing to neglect the role of stochastic uncertainty on the mean level of those variables.[5] The approach followed here is based on *higher order approximation* of all the conditions that characterize the competitive equilibrium of the economy and, as in Kollmann (2003a,b), Schmitt-Grohe and Uribe (2004a,b) and Faia and Monacelli (2005) among others, and allows to study policy rules in a dynamic economy that evolves around a distorted steady state. Optimal monetary policy in this context is obtained by solving a constrained Ramsey problem in which the monetary authority maximizes the welfare of agents subject to the constraints represented by the competitive economy relations and the assumed monetary policy rule.[6]

I find that a rule responding only to inflation is no longer optimal. In the typical new Keynesian model stabilizing inflation also allows to reach the Pareto efficient frontier. Adao et al. (2003) show that this is true for most households' preferences and in absence of cyclical variations in the demand–output ratios. In my model the congestion externality induces an inefficiently low level of employment and introduces a distortion both in the long run and along the dynamics. Optimality in this case requires that the policy maker responds to unemployment alongside with inflation. This is so since search externalities generate an unemployment/inflation trade-off which induces the monetary authority to strike a balance between reducing the cost of adjusting prices and increasing an inefficiently low employment. A strong response to inflation remains optimal while responding to output or output gaps (deviations of actual output from potential output) are always welfare detrimental. Finally responding to real wage growth does not enhance welfare; in the present model marginal cost is not equalized to real wages but depends also on the future value of employees (which in turn depends on the evolution of unemployment), hence stabilizing wage growth is not sufficient to stabilize marginal cost and inflation. On the contrary by responding to unemployment the policy maker is able to close the whole marginal cost gap, hence the whole inflation gap.

[5]See Rotemberg and Woodford (1997), Clarida et al. (2000), King and Wolman (1996), Woodford (2003).

[6]The use of the Ramsey approach is one of the key differences between this paper and the Blanchard and Gali' (2006). Blanchard and Gali' (2006) study optimal policy in a search theoretic framework with price stickiness a' la Calvo. They employ the linear quadratic approach and for this reason they are forced to restrict attention to a parameter space that allows approximations of the model relations around a non-distorted steady state. Deviations from strict inflation targeting in the Blanchard and Gali' (2006) model depend upon the presence of nominal wage rigidity and upon the impact of the latter on the value of a match.

The paper also compares operational rules with the globally optimal Ramsey policy. The main finding of this comparison are as follows. First, the optimal Ramsey plan also features deviations from price stability. Second, the globally optimal Ramsey plan is characterized by higher volatility compared to all other monetary regimes. This is so since under standard operational rules the monetary authority aims solely at stabilizing the economy, while the Ramsey planner has the incentive to take full advantage of the productivity increase so as to amplify and protract the boom phase.

The findings in this paper are consistent with those in Cooley and Quadrini (2000). They study unconstrained Ramsey monetary policy in an economy with matching frictions and limited participation in financial market and find that optimal policy implies positive money growth.

The paper proceeds as follow. Section 2 presents the model. Section 3 comments on the model dynamics under different rules and in response to shocks. Section 4 analyzes optimal policy and welfare costs of different rules. Section 5 concludes. Figures and tables follow.

2. The model economy

There is a continuum of agents whose total measure is normalized to one. The economy is populated by households who consume different varieties of goods, save and work. Households save in both non-state contingent securities and in an insurance fund that allows them to smooth income fluctuations associated with periods of unemployment. Each agent can indeed be either employed or unemployed. In the first case he receives a wage that is determined according to a Nash bargaining, in the second case he receives an unemployment benefit. The labor market is characterized by matching frictions and exogenous job separation. The production sector acts as a monopolistic competitive sector which produces a differentiated good using labor as input and faces adjustment costs a' la Rotemberg (1982).

2.1. Households

Let $c_t \equiv \int_0^1 [(c_t^i)^{(\varepsilon-1)/\varepsilon}\,\mathrm{d}i]^{\varepsilon/(\varepsilon-1)}$ be a Dixit–Stiglitz aggregator of different varieties of goods. The optimal allocation of expenditure on each variety is given by $c_t = \left(p_t^i/p_t\right)^{-\varepsilon} c_t$, where $p_t \equiv \int_0^1 [(p_t^i)^{\varepsilon-1/\varepsilon}\,\mathrm{d}i]^{\varepsilon/(\varepsilon-1)}$ is the price index. There is continuum of agents who maximize the expected lifetime utility[7]:

$$\mathrm{E}_t\left\{\sum_{t=0}^{\infty} \beta^t \,\frac{c_t^{1-\sigma}}{1-\sigma}\right\}, \tag{1}$$

[7]Let $s^t = \{s_0, \ldots, s_t\}$ denote the history of events up to date t, where s_t denotes the event realization at date t. The date 0 probability of observing history s^t is given by ρ_t. The initial state s^0 is given so that $\rho_0 = 1$. Henceforth, and for the sake of simplifying the notation, let's define the operator $\mathrm{E}_t\{.\} \equiv \sum_{s_{t+1}} \rho(s^{t+1}|s^t)$ as the mathematical expectations over all possible states of nature conditional on history s^t.

where c denotes aggregate consumption in final goods. Households supply labor hours inelastically h (which is normalized to 1). Unemployed households members, u_t, receive an unemployment benefit, b. Total real labor income is given by $w_t(1-u_t)$. The contract signed between the worker and the firm specifies the wage and is obtained through a Nash bargaining process. In order to finance consumption at time t each agent also invests in non-state contingent nominal bonds b_t which pay a gross nominal interest rate $(1+r_t^n)$ one period later. As in Andolfatto (1996) and Merz (1995) it is assumed that workers can insure themselves against earning uncertainty and unemployment. For this reason the wage earnings have to be interpreted as net of insurance costs. Finally agents receive profits from the monopolistic sector which they own, Θ_t, and pay lump sum taxes, τ_t. The sequence of real budget constraints reads as follows:

$$c_t + \frac{b_t}{p_t} \leqslant w_t(1-u_t) + bu_t + \frac{\Theta_t}{p_t} - \frac{\tau_t}{p_t} + (1+r_{t-1}^n)\frac{b_{t-1}}{p_t}. \tag{2}$$

Households choose the set of processes $\{c_t, b_t\}_{t=0}^{\infty}$ taking as given the set of processes $\{p_t, w_t, r_t^n\}_{t=0}^{\infty}$ and the initial wealth b_0, so as to maximize (1) subject to (2). Let us define λ_t as the Lagrange multiplier on constraint (2). The following optimality conditions must hold

$$\lambda_t = c_t^{-\sigma}, \tag{3}$$

$$c_t^{-\sigma} = \beta(1+r_t^n)\mathrm{E}_t\left\{c_{t+1}^{-\sigma}\frac{p_t}{p_{t+1}}\right\}. \tag{4}$$

Eq. (3) is the marginal utility of consumption and Eq. (4) is the Euler condition with respect to bonds. Optimality requires that No-Ponzi condition on wealth is also satisfied.

2.2. The production sector

Firms in the production sector sell their output in a monopolistic competitive market and meet workers on a matching market. The labor relations are determined according to a standard Mortensen and Pissarides (1999) framework. Workers must be hired from the unemployment pool and searching for a worker involves a fixed cost. Workers wages are determined through a Nash decentralized bargaining process which takes place on an individual basis.

2.2.1. Search and matching in the labor market

The search for a worker involves a fixed cost κ and the probability of finding a worker depends on a constant return to scale matching technology which converts unemployed workers u and vacancies v into matches, m:

$$m(u_t, v_t) = m u_t^{\xi} v_t^{1-\xi}, \tag{5}$$

where $v_t = \int_0^1 v_{i,t}\,\mathrm{d}i$. Defining labor market tightness as $\theta_t \equiv v_t/u_t$, the firm meets unemployed workers at rate $q(\theta) = m(u_t, v_t)/v_t = m\theta_t^{-\xi}$, while the unemployed workers meet vacancies at rate $\theta_t q(\theta_t) = m\theta_t^{1-\xi}$. If the search process is successful, the firm in the monopolistic good sector operates the following technology:

$$y_{i,t} = z_t n_{i,t}, \tag{6}$$

where z_t is the aggregate productivity shock which follows a first-order autoregressive process, $e^{z_t} = e^{\rho_z z_{t-1}} \varepsilon_{z,t}$, and $n_{i,t}$ is the number of workers hired by each firm. Matches are destroyed at an exogenous rate ρ.[8] We are now in the position to determine the law of motion for the workers employed and the ones seeking for a job. Labor force is normalized to unity. The number of employed people at time t in each firm i is given by the number of employed people at time $t-1$ plus the flow of new matches concluded in period $t-1$ who did not discontinue the match

$$n_{i,t} = (1-\rho)(n_{i,t-1} + v_{i,t-1} q(\theta_{i,t-1})). \tag{7}$$

Unemployment is given by total labor force minus the number of employed workers

$$u_t = 1 - n_t. \tag{8}$$

Finally job creation rate is given by

$$jc_t = \frac{(1-\rho) v_{t-1} q(\theta_{t-1})}{n_{t-1}}. \tag{9}$$

2.2.2. Monopolistic firms

Firms in the monopolistic sector use labor to produce different varieties of consumption good and face a quadratic cost of adjusting prices. Wages are determined through the bargaining problem analyzed in the next section. Here we develop the dynamic optimization decision of firms choosing prices, p_t^i, number of employees, $n_{i,t}$, number of vacancies, $v_{i,t}$, to maximize the discounted value of future profits and taking as given the wage schedule. The representative firm chooses $\{p_t^i, n_{i,t}, v_{i,t}\}$ to solve the following maximization problem (in real terms):

$$\text{Max} \quad \Pi_{i,t} = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{p_t^i}{p_t} y_t^i - w_{i,t} n_{i,t} - \kappa v_{i,t} - \frac{\psi}{2} \left(\frac{p_t^i}{p_{t-1}^i} - 1 \right)^2 y_t^i \right\} \tag{10}$$

s.t.

$$y_t^i = \left(\frac{p_t^i}{p_t} \right)^{-\varepsilon} \cdot y_t = z_t n_{i,t} \tag{11}$$

$$\text{and} \quad n_{i,t} = (1-\rho)(n_{i,t-1} + v_{i,t-1} q(\theta_{i,t-1})), \tag{12}$$

[8] The alternative assumption of endogenous job destruction would induce, consistently with empirical observations, additional persistence as shown in den Haan et al. (2000). However, due to the normative focus of this paper I choose the more simple assumption of exogenous job separation. This greatly reduces the complexity of the numerical solution to the optimal policy problem without altering the results compared to the alternative assumption of endogenous job separation. Indeed the main policy trade-offs do not change under the two alternative assumptions.

where $(\psi/2)(p_t^i/p_{t-1}^i - 1)^2 y_t^i$ represent the cost of adjusting prices, ψ can be thought as the sluggishness in the price adjustment process, κ as the cost of posting vacancies and w_t denotes the fact that the bargained wage might depend on time varying factors. Let us define mc_t, the Lagrange multiplier on constraint (11), as the marginal cost of firms and μ_t, the Lagrange multiplier on constraint (12), as the marginal value of one worker. Since all firms will chose in equilibrium the same price and allocation we can now assume symmetry and drop the index i. First-order conditions for the above problem read as follows:

- n_t:

$$\mu_t = mc_t z_t - w_t + \beta \mathrm{E}_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)((1-\rho)\mu_{t+1}), \tag{13}$$

- v_t:

$$\frac{\kappa}{q(\theta_t)} = \beta \mathrm{E}_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)((1-\rho)\mu_{t+1}), \tag{14}$$

- p_t:

$$1 - \psi(\pi_t - 1)\pi_t + \beta \mathrm{E}_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[\psi(\pi_{t+1} - 1)\pi_{t+1}\frac{y_{t+1}}{y_t}\right] = (1 - mc_t)\varepsilon. \tag{15}$$

Merging Eqs. (13) and (14) and rearranging we obtain the marginal cost of firms, mc_t,

$$mc_t = \frac{[\mu_{t\_}(\kappa/q(\theta_t))]}{z_t} + \frac{w_t}{z_t}. \tag{16}$$

As already noticed in Krause and Lubik (2007) in a new Keynesian model with matching frictions the marginal cost of firms is given by the marginal productivity of each single employee, w_t/z_t, and by an extra component, $\{[\mu_{t\_}(\kappa/q(\theta_t))]/z_t\}$, which gives the future value of current employees. Since posting vacancy is costly a successful match today is valuable as it reduces future search costs. Notice that the future value of current employees depends on the evolution of unemployment: if the number of searching workers increases, the probability of filling a future vacancy increases and the future value of current employees decreases.

2.2.3. Bellman equations, wage setting and Nash bargaining

The wage schedule is obtained through the solution to an individual Nash bargaining process. To obtain the wage schedule we need to derive the marginal values of a match for both, firms and workers. Those values enter the sharing rule of the bargaining process. Let us denote by V_t^J the marginal discounted value of a vacancy for a firm. From Eq. (13) and noticing that $V_t^J = \mu_t$ we obtain

$$V_t^J = mc_t z_t - w_t + \mathrm{E}_t\left\{\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)[(1-\rho)V_{t+1}^J]\right\}. \tag{17}$$

The marginal value of a vacancy depends on real revenues minus the real wage plus the discounted continuation value. With probability $(1-\rho)$ the job remains filled and earns the expected value and with probability, ρ, the job is destroyed and has zero value. Using Eqs. (16), (17) and (13) we obtain

$$V_t^J = \frac{-\kappa}{q(\theta_t)} + \mathrm{E}_t\left\{\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)[(1-\rho)V_{t+1}^J]\right\}. \tag{18}$$

Since the value of posting a vacancy must be zero in equilibrium the following zero profit condition must be satisfied:

$$\frac{\kappa}{q(\theta_t)} = \mathrm{E}_t\left\{\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)[(1-\rho)V_{t+1}^J]\right\}. \tag{19}$$

Eq. (19) is an arbitrage condition for the posting of new vacancies. It implies that in equilibrium the cost of posting a vacancy must equate the discounted expected return of a filled vacancy. For each worker, the values of being employed and unemployed are given by V_t^{E} and V_t^{U}:

$$V_t^{\mathrm{E}} = \left[w_t + \mathrm{E}_t\left\{\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)[(1-\rho)V_{t+1}^{\mathrm{E}} + \rho V_{t+1}^{\mathrm{U}}]\right\}\right], \tag{20}$$

$$V_t^{\mathrm{U}} = \left[b + \mathrm{E}_t\left\{\left(\beta\frac{\lambda_{t+1}}{\lambda_t}\right)[\theta_t q(\theta_t)(1-\rho)V_{t+1}^{\mathrm{E}} + (1-\theta_t q(\theta_t)(1-\rho))V_{t+1}^{\mathrm{U}}]\right\}\right], \tag{21}$$

where b denotes real unemployment benefits.

Workers and firms are engaged in a Nash bargaining process to determine wages. The optimal sharing rule of the standard Nash bargaining is given by

$$(V_t^{\mathrm{E}} - V_t^{\mathrm{U}}) = \frac{\varsigma}{1-\varsigma}V_t^J. \tag{22}$$

After substituting the previously defined value functions it is possible to derive the following wage schedule:

$$w_t = \varsigma(mc_t z_t + \theta_t\kappa) + (1-\varsigma)b. \tag{23}$$

Real wage rigidity: Shimer (2005) and Hall (2005) noticed that in a matching model a' la Mortensen and Pissarides wages are too volatile since little adjustment takes place along the employment margin. They also noticed that the introduction of real wage rigidity helps to resolve some of the puzzling features of the standard matching model. Thereby following Hall (2005), I assume that the individual real wage is a weighted average of the one obtained through the Nash bargaining process and the one obtained as solution to the steady state[9]:

$$w_t = \lambda[\varsigma(mc_t z_t + \theta_t \kappa) + (1-\varsigma)b] + (1-\lambda)w. \tag{24}$$

2.3. Monetary policy

I assume that monetary policy is conducted by means of an interest rate reaction function of this form

$$\ln\left(\frac{1+r_t^n}{1+r^n}\right) = (1-\phi_r)\left(\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{y_t}{y}\right) + \phi_u \ln\left(\frac{u_t}{u}\right)\right) + \phi_r \ln\left(\frac{1+r_{t-1}^n}{1+r^n}\right). \tag{25}$$

The class of rules considered features deviations of each variable form the target. For inflation and unemployment we consider deviations from steady state values. In the benchmark parametrization the steady-state value of (net) inflation is set to zero; notice however that results are unchanged if we allow for positive steady-state inflation. For output we consider both, deviations from steady-state and deviations from potential output. The latter is given by the steady-state solution to the unconstrained Ramsey problem. The monetary authority sets optimal policy by solving a constrained Ramsey problem. Indeed the monetary authority maximizes the welfare of agents subject to the constraints represented by the competitive economy relations and to the class of monetary policy rules represented by (25). Numerically [10] I search for the specification $\{\phi_\pi, \phi_y, \phi_u, \phi_r\}$ that maximizes household's welfare and I evaluate the welfare ranking of rules which impose alternative restrictions on (25).[11]

2.4. Equilibrium conditions

Aggregate output is obtained by aggregating production of individual firms and by subtracting the resources wasted into the search activity and the cost of adjusting prices

$$y_t = n_t z_t - \kappa v_t - \int_0^1 \frac{\psi}{2}\left(\frac{p_t^i}{p_{t-1}^i} - 1\right)^2 y_t^i. \tag{26}$$

I also assume that there is exogenous government expenditure financed through lump sum taxation. Hence the resource constraint reads as follows:

$$y_t = c_t + g_t. \tag{27}$$

Furthermore, I assume zero total net supply of bonds.

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[9]Notice that the results in this paper remain valid when the wage is set as a weighted average of current and past values.

[10]I solve the model by computing a *second-order approximation* of the policy functions around the non-stochastic distorted steady state. The distortions that characterize the steady state are monopolistic competition along with a non-walrasian labor market.

[11]See also Kim and Kim (2003), Kim and Levin (2004), Kollmann (2003a, b), Schmitt-Grohe and Uribe (2003, 2004b) and Faia and Monacelli (2005) for a similar approach.

2.5. Calibration

Preferences: Time is measured in quarters. I set the discount factor $\beta = 0.99$, so that the annual interest rate is equal to 4%. The parameter on consumption in the utility function is set equal to 2.

Production: Following Basu and Fernald (1997), I set the value added mark-up of prices over marginal cost to 0.2. This generates a value for the price elasticity of demand, ε, of 6. I set the cost of adjusting prices $\psi = 50$ so as to generate a slope of the log-linear Phillips curve consistent with empirical and theoretical studies.

Labor market frictions parameters: The matching technology is a homogenous of degree one function and is characterized by the parameter ξ. Consistently with estimates by Blanchard and Diamond (1991) I set this parameter to 0.4. I set the steady-state firm matching rate, $q(\theta)$, to 0.7 which is the value used by den Haan et al. (2000). The probability for a worker of finding a job, $\theta q(\theta)$, is set equal to 0.6, which implies an average duration of unemployment of 1.67 as reported in Cole and Rogerson (1999). With those values it is possible to determine the number of vacancies as well as the vacancy/unemployment ratio. The exogenous separation probability, ρ, is set to 0.08 which is compatible with those used in the literature which range from 0.07 (Merz, 1995) to 0.15 (Andolfatto, 1996). The degree of wage rigidity, λ, is set equal to 0.6 and is compatible with estimates from Smets and Wouters (2003). The value for b is set so as to generate a steady-state ratio, b/w, of 0.5 which corresponds to the average value observed for industrialized countries (see Nickell and Nunziata, 2001). The steady-state scale parameter, m, is obtained using the observation that steady-state number of matches is given by $(\rho/(1-\rho))(1-u)$ and the steady-state unemployment rate is set equal to 0.06. The bargaining power of workers, ς, is set to 0.5 as in most papers in the literature, while the value for the cost of posting vacancies is obtained from the steady-state version of labor market tightness evolution.

Exogenous shocks and monetary policy: The process for the aggregate productivity shock, z_t, follows an AR(1) and based on the RBC literature is calibrated so that its standard deviations is set to 0.008 and its persistence to 0.95. Log-government consumption evolves according to the following exogenous process, $\ln(g_t/g) = \rho_g \ln(g_{t-1}/g) + \varepsilon_t^g$, where the steady-state share of government consumption, g, is set so that $g/y = 0.25$ and ε_t^g is an i.i.d. shock with standard deviation σ_g. Empirical evidence for the US in Perotti (2004) suggests $\sigma_g = 0.008$ and $\rho_g = 0.9$. When considering interest rate smoothing I follow several empirical studies for US and Europe (see Clarida et al., 2000; Angeloni and Dedola, 1998; Andrés et al., 2006 among others) and set ϕ_r equal to 0.9.

3. Dynamic properties of the model under different monetary policy rules

Before turning to the welfare implications of the various monetary policy regime it is instructive to consider the dynamic properties of the model under different monetary policy rules also in terms of the model ability to replicate the main stylized

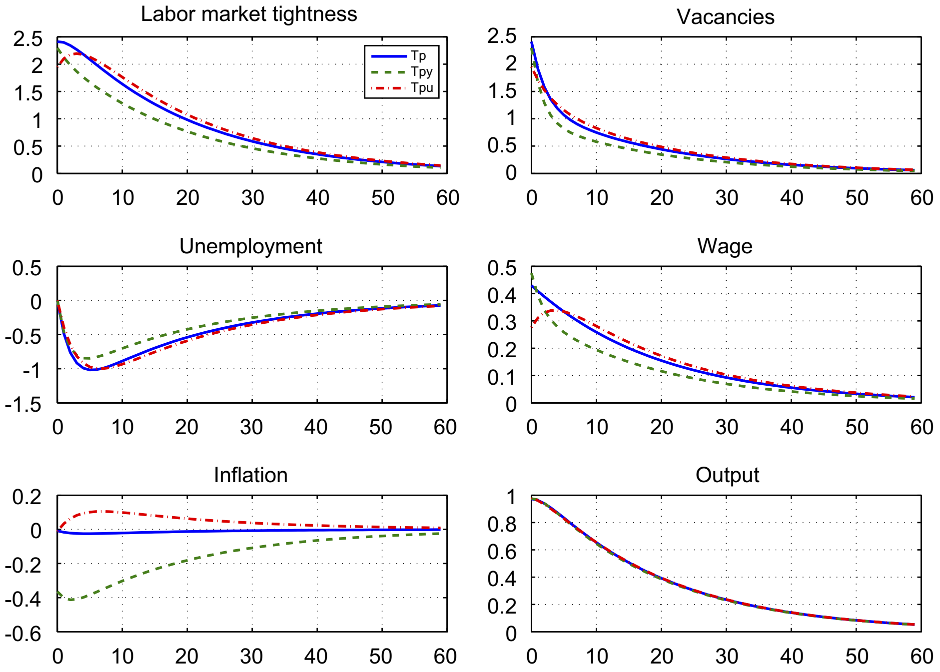

Fig. 1. Impulse responses of selected variables to productivity shocks under the following three rules: (1) strong inflation response: $\phi_\pi = 5, \phi_y = 0, \phi_u = 0$; (2) Taylor rule: $\phi_\pi = 1.5, \phi_y = 0.5/4, \phi_u = 0$; and (3) response to unemployment: $\phi_\pi = 1.5, \phi_y = 0, \phi_u = 0.6/4$.

facts concerning the labor market. In what follows I will comment on the impulse responses of several variables under productivity and government expenditure shocks. I consider three type of rules: (1) a strong response to inflation, $\phi_\pi = 5, \phi_y = 0, \phi_u = 0$; (2) a standard Taylor rule, $\phi_\pi = 1.5, \phi_y = 0.5/4, \phi_u = 0$; (3) a rule responding to unemployment, $\phi_\pi = 1.5, \phi_y = 0, \phi_u = 0.6/4$.[12]

Productivity shocks: Fig. 1 shows impulse responses of selected variables to a positive productivity shock. Output raises and inflation falls. As firms increase production, they also increase vacancies and the labor market tightens. As a consequence real wages increase and unemployment falls. The latter variable moves in the opposite direction with respect to vacancies thereby reproducing the Beveridge curve. Under all rules and consistently with empirical evidence labor market tightness is pro-cyclical and unemployment shows a high degree of persistence.

[12]For this rule I set the coefficient on inflation equal to 1.5 as in the Taylor rule so that one can appreciate the difference stemming from targeting unemployment as opposed to output for given response to inflation. The parameter responding to unemployment has a slight higher value than the parameter responding to output in a standard Taylor rule. This is so since in the model unemployment volatility is higher than output volatility, hence we expect the policy maker to be more aggressive in response to unemployment.

In comparing the different monetary regimes we notice that a rule responding only to inflation has a strong stabilizing effect on inflation but tends to destabilize labor market variables, while Taylor rules have the opposite effect. Responding to unemployment stabilizes inflation more than a Taylor rule and tends to stabilize the real economy more than a rule with strong inflation response. In this respect a rule responding to unemployment is able to strike a balance between stabilizing nominal and real variables.

A final consideration concerns the fact that a rule responding to unemployment (which is highly persistent in the model) tends to increase the persistence of all variables in the economy.

Government expenditure shocks: Fig. 2 shows impulse responses of selected variables to a government expenditure shock, which is used to discuss the effects of a demand shock. Due to a decrease in consumption demand firms reduce vacancies thereby lowering labour market tightness.

Once again the rule that responds solely to inflation tends to destabilize labor market variables and to smooth inflation dynamic. On the opposite side stands the Taylor rule. A rule responding to unemployment along with inflation helps to stabilize both inflation and labor market variables.

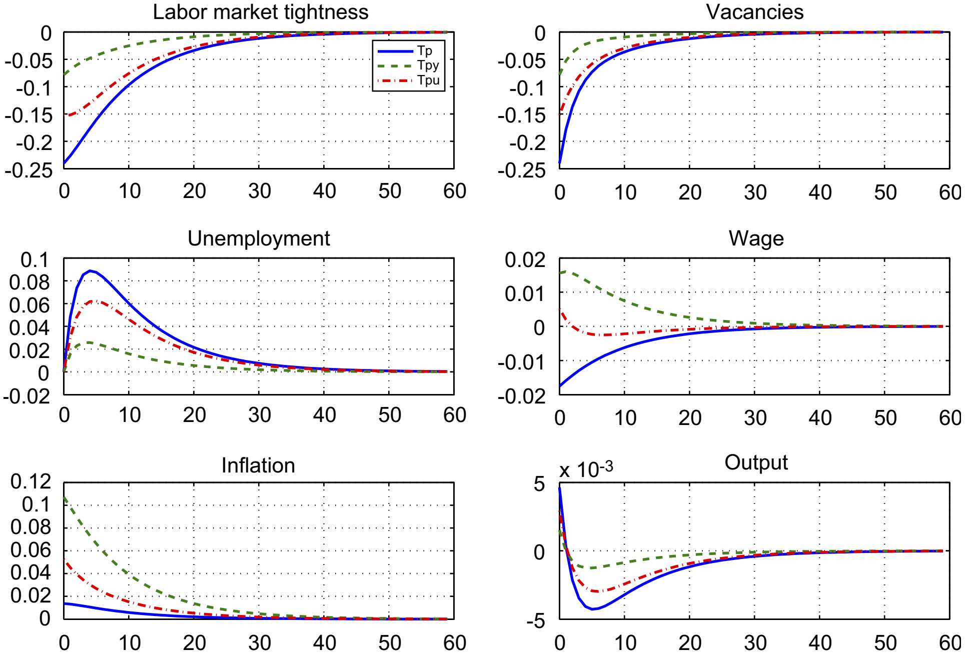

Fig. 2. Impulse responses of selected variables to government expenditure shocks under the following three rules: (1) strong inflation response: $\phi_\pi = 5, \phi_y = 0, \phi_u = 0$; (2) Taylor rule: $\phi_\pi = 1.5, \phi_y = 0.5/4$, $\phi_u = 0$; and (3) response to unemployment: $\phi_\pi = 1.5, \phi_y = 0, \phi_u = 0.6/4$.

4. Welfare analysis

As specified above the optimal policy problem in this context is solved by assuming that the monetary authority maximizes households welfare subject to the competitive equilibrium conditions and the class of monetary policy rules represented by (25). Specifically, I search for parametrization of interest rate rules that satisfy the following three conditions: (a) they are simple since they involve only observable variables, (b) they guarantee uniqueness of the rational expectation equilibrium, (c) they maximize the expected lifetime utility of the representative agent.

Some observations on the computation of welfare in this context are in order. First, one cannot safely rely on standard first-order approximation methods to compare the relative welfare associated to each monetary policy arrangement. Indeed in an economy with a distorted steady-state stochastic volatility affects both first and second moments of those variables that are critical for welfare. Since in a first-order approximation of the model's solution the expected value of a variable coincides with its non-stochastic steady-state, the effects of volatility on the variables' mean values is by construction neglected. Hence policy arrangements can be correctly ranked only by resorting to a higher order approximation of the policy functions.[13] Additionally one needs to focus on the *conditional* expected discounted utility of the representative agent. This allows to account for the transitional effects from the deterministic to the different stochastic steady states respectively implied by each alternative policy rule.[14] Define Ω as the fraction of household's consumption that would be needed to equate conditional welfare $\mathscr{W}_0$ under a generic interest rate policy to the level of welfare $\widetilde{\mathscr{W}}_0$ implied by the optimal rule. Hence Ω should satisfy the following equation:

$$\mathscr{W}_{0,\Omega} = \mathrm{E}_0\left\{\sum_{t=0}^{\infty}\beta^t U((1+\Omega)C_t)\right\} = \widetilde{\mathscr{W}}_0.$$

Under a given specification of utility one can solve for Ω and obtain:

$$\Omega = \exp\{(\widetilde{\mathscr{W}}_0 - \mathscr{W}_0)(1-\beta)\} - 1.$$

4.1. Comparing simple rules with the optimal policy rule

I simulate the model economy under the two sources of aggregate uncertainty, productivity and government consumption shocks. I then conduct two experiments. First, I compute welfare under different (ad hoc) specifications of the monetary policy rule. The rules are the following:

(i) *Simple Taylor rule*, with $\phi_\pi = 1.5$, $\phi_y = 0.5/4, \phi_u = \phi_r = 0$.
(ii) *Simple Taylor rule with smoothing*, with $\phi_\pi = 1.5$ and $\phi_y = 0.5/4, \phi_u = 0$, $\phi_r = 0.9$.

[13]See Kim and Kim (2003) for an analysis of the inaccuracy of welfare calculations based on log-linear approximations in dynamic open economies.
[14]See Kim and Levin (2004) for a detailed analysis on this point.

(iii) *Response to inflation and output gap*,[15] with $\phi_\pi = 1.5$ and $\phi_y = 0.5/4, \phi_u = 0$, $\phi_r = 0$.
(iv) *Strict inflation response*, $\phi_\pi = 3, \phi_y = \phi_u = \phi_r = 0$.
(v) *Response to inflation and unemployment*, with $\phi_\pi = 1.5,\ \phi_u = 0.6/4,\ \phi_y = \phi_r = 0$.
(vi) *Strong response to inflation and response to unemployment*, with $\phi_\pi = 3,\ \phi_u = 0.6/4,\ \phi_y = 0, \phi_r = 0$.
(vii) *Response to inflation and wage growth*, with$\phi_\pi = 3,\ \phi_u = 0,\ \phi_y = \phi_r = 0$, $\phi_w = 0.5/4$, where ϕ_w indicates the parameter on wage growth.

Secondly, I search in the grid of parameters $\{\phi_\pi, \phi_y, \phi_u, \phi_r\}$ for the rule which delivers the highest level of welfare, which is defined as the optimal policy rule[16] and I compare welfare under optimal policy and simple rules.

The choice of including unemployment as an independent argument comes from the consideration that most central banks face a trade-off between inflation and unemployment stabilization. In this respect it is natural to ask whether the price stability objective so much professed lately can be really considered the optimal policy.

Table 1 summarizes the findings in terms of the welfare loss Ω (relative to the optimal policy) of alternative simple rules.

Results are as follows. First, responding to unemployment along with inflation is the optimal rule. More specifically the optimal rule features the following coefficients: $\phi_\pi = 3,\ \phi_u = 0.6/4,\ \phi_y = 0, \phi_r = 0$. The reason is as follows. The introduction of matching frictions adds a congestion externality for which an excessive number of searching workers or vacancies might reduce the probability of forming matches. In this case unemployment is inefficiently high and the policy maker faces an unemployment/inflation trade-off that calls for responding to unemployment along with inflation. Since the flexible price allocation is different from the first best a strong response to inflation alone does not allow the policy maker to achieve the constrained first best allocation. On the other side by responding to inefficient unemployment movements the policy maker is able get closer to the first best. Notice, however, that the optimal rule features also a strong response to inflation.

Secondly, responding to output alongside with inflation is welfare detrimental. This is also true when we consider a rule that responds to the output gap (deviation of output from potential output, the latter defined as the solution to the global Ramsey policy). This result is consistent with the one obtained by Schmitt-Grohe and Uribe (2003) in a model economy with capital accumulation and frictionless

[15] For output gap we consider the deviation of actual output from potential output; the latter is defined as the output obtained as solution to the globally optimal Ramsey policy.

[16] The search is made over the following ranges: [1.5, 4] for ϕ_π, [0, 2] for ϕ_u, [0, 2] for ϕ_y. Notice that the parameters ϕ_y and ϕ_u are divided by four given the standard assumption on the length of a period (quarterly) and given that inflation in Taylor type rules is expressed at annual rates. I also compare rules with interest rate smoothing ($\phi_r = 0.9$) to rules without smoothing ($\phi_r = 0$). It is judged as admissible a combination of policy parameters that delivered a unique rational expectations equilibrium.

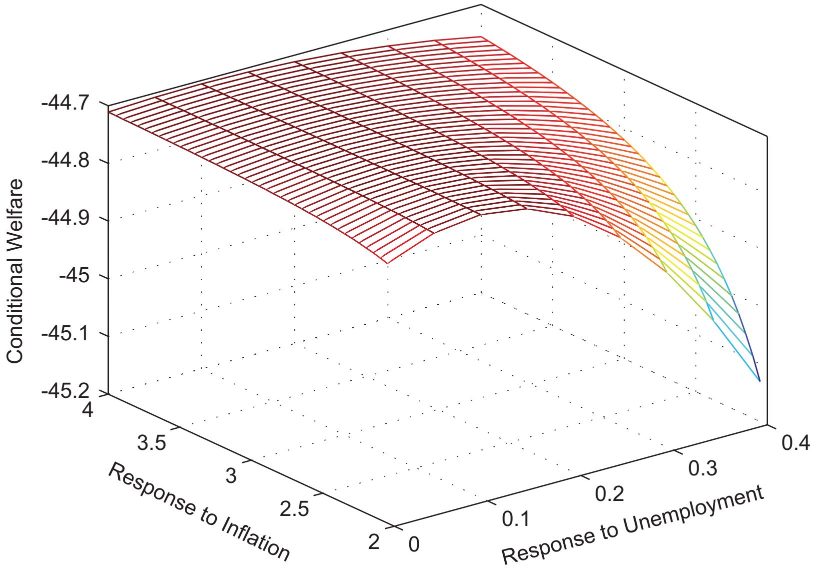

Fig. 3. Effect on welfare of varying the response to inflation and unemployment (no smoothing).

Table 1
Welfare comparison of alternative monetary policy rules

Monetary policy rule	% Loss relative to optimal rule			
	$\rho = 0.08$ $\varsigma = 0.3$	$\rho = 0.08$ $\varsigma = 0.5$	$\rho = 0.15$ $\varsigma = 0.3$	$\rho = 0.15$ $\varsigma = 0.5$
Taylor rule	0.4873	0.4947	0.4869	0.4933
Taylor rule with smoothing	0.0224	0.0240	0.0243	0.0251
Strict response to inflation	0.0041	0.0056	0.0064	0.0070
Inflation and unemployment response	0.0680	0.0474	0.0339	0.0278
Strong inflation and unemployment response	0	0	0	0
Inflation and output gap response	0.48	0.4947	0.48	0.49
Inflation and wage growth response	0.0125	0.0134	0.0144	0.0146

labor markets. The reason for this result in the context of the present paper lies in the fact that the policy maker aims at stabilizing only variables or gaps which signal an inefficiency. In this case since the frictions considered affect mainly the labor market responding to unemployment allows the policy maker to tackle the distortion more directly.

Third, interest smoothing is always welfare enhancing. Also this result is consistent with the one obtained by Schmitt-Grohe and Uribe (2003) and can be explained by considering that interest rate smoothing allows to protract the stabilization effects of the monetary policy targets.

Finally responding to wage growth does not enhance welfare. The latter result can be explained by the fact that the marginal cost in this model is not equalized to real wages but depends also on the future value of employees (which in turn depends on the evolution of unemployment), hence stabilizing wage growth is not sufficient to stabilize marginal cost and inflation. On the contrary by responding to unemployment the policy maker is able to close the whole marginal cost gap hence the whole inflation gap.

4.2. Responding to unemployment and wages

We now provide further elements to generalize previous results. Fig. 3 depict the effects on the conditional welfare surface of varying both the inflation coefficient ϕ_π and the unemployment coefficient ϕ_u in the monetary policy rule (25). Results shown here correspond to cases in which the coefficient ϕ_y is set equal to zero. As hinted above, rules featuring a positive response to output are invariably welfare inferior to rules in which the same response is zero. The welfare surface has a concave shape: it reaches a maximum for a value of $\phi_u = 0.6/4$ and for any value of ϕ_π. Increasing the parameter of the response to inflation is always welfare enhancing, while increasing the parameter of the response to unemployment beyond the level of $\phi_u = 0.6/4$ becomes welfare detrimental. This is so since a high weight on unemployment makes the cost of variable inflation too high compared to the gain of reducing unemployment fluctuations. The results shown in (3) hold also for the case in which we assume a positive interest rate smoothing.

This result is in contrast with optimal policy prescriptions obtained by the vast majority of papers which employed a new Keynesian framework (whose relevant frictions are price rigidity and monopolistic competition). In the standard new Keynesian framework the policy maker does not face any trade-off between output and inflation and closing the gap between the flexible and the sticky price allocation allows to reach the first best. In the context of the present paper the presence of search frictions produce an inefficiently low level of employment and this induces the policy maker to deviate from a strict price stability rule. In presence of a trade-off between stabilizing inflation and inefficient unemployment fluctuations the monetary authority must strike a balance between reducing the cost of adjusting prices and increasing employment.

It must be stressed that a crucial feature of our analysis is the possibility, granted by the use of a constrained Ramsey plan and by the use of second order approximations, of maintaining the relevant distortions both in the short and in the long run. In this context the trade-off between reducing the cost of adjusting prices and the cost of high unemployment comes genuinely from the presence of a search externality which makes employment inefficiently low. Blanchard and Gali' (2006) (Blanchard and Gali' (2006) hereafter) also analyze the emergence of an unemployment/inflation trade-off in a new Keynesian model with matching frictions and rigid wages. However Blanchard and Gali' (2006) resort on a linear quadratic approach to the design of optimal policy and for this reason they restrict their

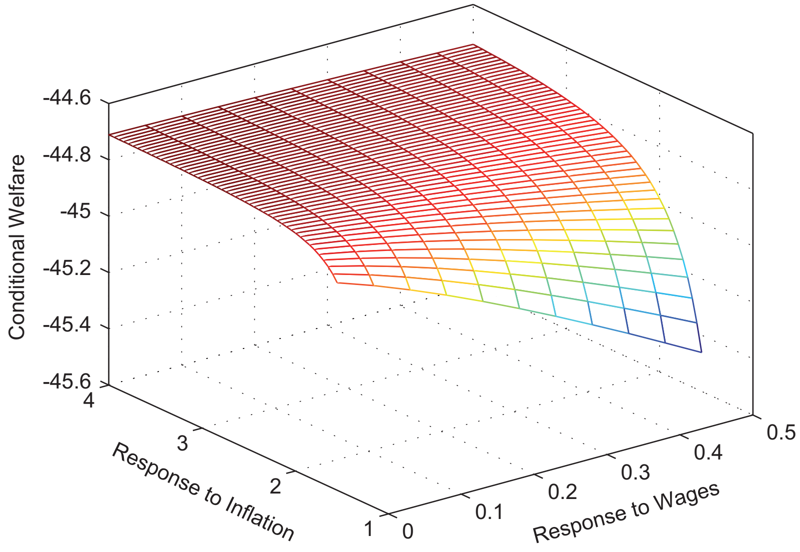

Fig. 4. Effect on welfare of varying the response to inflation and wages.

analysis in the neighborhood of a non-distorted steady-state (the search externality is eliminated by assuming that the Hosios (1990) conditions hold).[17] Hence the trade-off depicted in Blanchard and Gali' (2006) comes more from the impact that rigid wages have on the future hires rather than from the matching frictions themselves.[18] In other words the trade-off depicted by Blanchard and Gali' (2006) follows more the spirit of the one depicted in Erceg et al. (2000).

To conclude our analysis, Fig. 4 reports the effects on conditional welfare of varying coefficients in the monetary policy rule for both inflation and real wage growth.[19] We observe that responding to wage growth does not improve welfare for any value of the parameter on inflation. The result is confirmed also under a high degree of real wage stickiness ($\lambda = 0.9$).[20] Notice that this seems in contrast with results previously obtained in the literature. More specifically, Erceg et al. (2000) and Canzoneri et al. (2005) find that it is optimal to respond to wage inflation. The difference between this paper result and the previous ones can be explained by the following considerations. First, previous authors have considered rules responding

[17]See also Thomas (2006) for a similar analysis.

[18]In the analysis of the present paper the result concerning the optimality of the deviation from price stability remains valid even when shutting off wage rigidity, on the contrary Blanchard and Gali' (2006) optimality of price stability is recovered under flexible wages.

[19]It is worth noticing that the determinacy region under wage growth targeting shrinks compared to the case of unemployment targeting. It is not surprising to observe indeterminacy for some parameters' regions in models with matching frictions. Indeed as it has been observed in Krause and Lubik (2005) and Hashimzade and Ortigueira (2005) the presence of search externality tends to produce indeterminacy.

[20]Results not reported for brevity but available upon request.

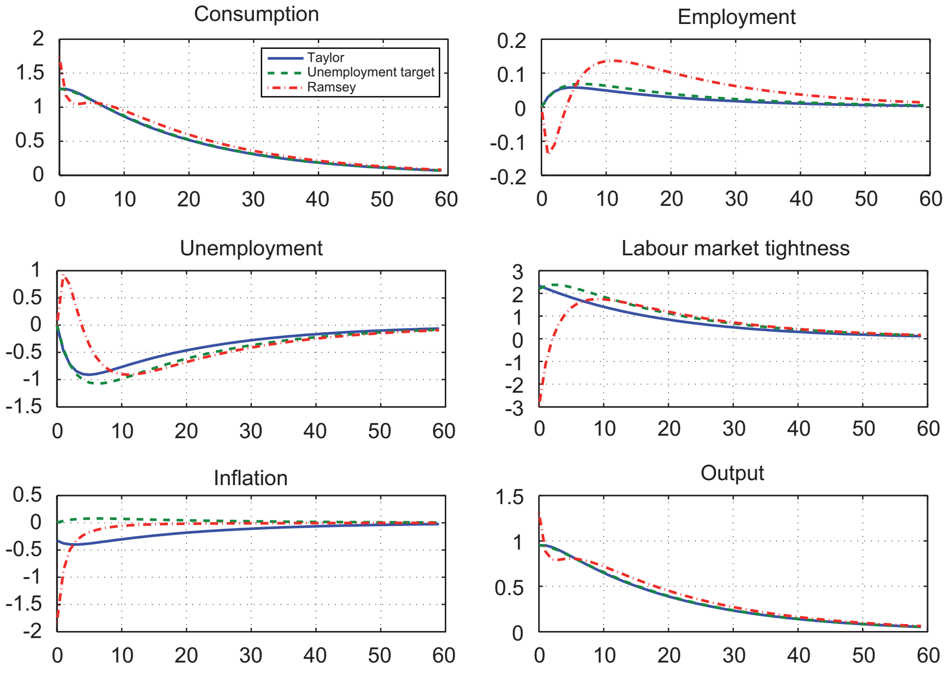

Fig. 5. Impulse responses of selected variables to productivity shocks under the following three rules: (1) Taylor rule: $\phi_\pi = 1.5, \phi_y = 0.5/4, \phi_u = 0$; (2) response to unemployment: $\phi_\pi = 1.5, \phi_y = 0, \phi_u = 0.6/4$; and (3) globally optimal Ramsey solution.

to nominal wage growth or wage inflation targeting while here I consider real wage growth. Secondly, previous literature had introduced labor market frictions only in then form of nominal wage rigidity a' la Calvo while I also consider a non-walrasian labor market[21]; in this context the relevant frictions is represented by the search externality and the monetary authority can tackle such an externality much better by responding to unemployment rather than to wages.

4.3. Comparing rules versus globally optimal Ramsey plan

To fully assess the effects of labor market frictions on optimal policy design this section compares rules with the globally optimal solution of the Ramsey plan. Appendix A shows that solution to the globally optimal plan. Fig. 5 shows the dynamic of selected variables in response to productivity shocks and under three

[21]It must be noticed that the absence of an intensive margin in the present paper reduces the role of wage rigidity since adjustment in employment only takes place along the extensive margin. We do not consider the role of wage rigidity in presence of an intensive margin since this has been considered extensively in the previous literature.

different regime. The first regime is represented by a Taylor rule ($\phi_\pi = 1.5$ and $\phi_y = 0.5/4$). The second regime is represented by a rule responding to unemployment along with inflation ($\phi_\pi = 1.5$ and $\phi_u = 0.5/4$). Finally the third regime is given by the globally optimal Ramsey plan.[22]

From the inspection of (3) a few considerations emerge. First, the optimal Ramsey plan features a significant inflation volatility which implies deviations from price stability. Secondly, it stands clear that the globally optimal Ramsey plan implies a higher volatility with respect to the other two monetary regimes. This is so since in the Ramsey plan the nominal interest rates responds to shocks to the economy and for this reason induces higher volatility than rules responding to endogenous variables. In general the Ramsey plan aims at taking full advantage of the productivity increase thereby amplifying and making more persistent the boom phase.[23] On the contrary a policy maker employing an operational rule which responds to endogenous variables aims solely at stabilizing the economy in the short run and neglects the impact of its policy on future periods.

5. Conclusion

This paper derives a constrained Ramsey policy in a model with monopolistic competition and sticky prices, matching frictions and real wage rigidity in the labor market. Furthermore, it compares welfare under different monetary policy rules. It concludes that the introduction of labor market rigidities implies that the optimal rule should feature some response to unemployment. This is so since the introduction of matching frictions adds a congestion externality for which an excessive number of searching workers or vacancies might reduce the probability of forming matches. In those cases unemployment is inefficiently high and the policy maker faces an unemployment/inflation trade-off that calls for responding to unemployment along with inflation.

In this paper it is assumed that households are able to insure the unemployment risk. An interesting extension would be to consider the impact of imperfect risk sharing arrangements on the optimal monetary policy. Incomplete risk sharing arrangements would probably increase the cost of unemployment and reinforce the incentive of the policy maker to stabilize labor market variables.

Acknowledgments

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[22]For this experiment I set the bargaining power of workers equal to 0.35 in all rules. This allows me to reduce the volatility under the Ramsey regime which would otherwise be unrealistically high. However all results hold also under other parameterizations.

[23]High unemployment volatility is not sub-optimal in this model since agents are able to fully insure the risk of loosing jobs. An interesting extension would be to consider the effects of incomplete risk sharing arrangements on the optimal Ramsey policy.

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Appendix A. The stationary Lagrangian problem

Let $\Lambda_t^n \equiv \{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}\}_{t=0}^{\infty}$ and $\Xi_t^n \equiv \{c_t, n_t, v_t, \pi_t, mc_t\}_{t=0}^{\infty}$ to

$$\mathrm{Min}_{\{\Lambda_t^n\}_{t=0}^{\infty}} \mathrm{Max}_{\{\Xi_t^n\}_{t=0}^{\infty}} \mathrm{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \mathrm{E}_t \left\{ W(c_t, n_t, v_t, \pi_t, mc_t) \right.\right.$$
$$+ \lambda_{1,t}[1 - \psi(\pi_t - 1)\pi_t y_t c_t - (1 - mc_t)c_t y_t \varepsilon]$$
$$+ \lambda_{2,t}\left[\frac{\kappa}{m}\theta_t^{\xi} c_t\right] + \lambda_{3,t}\left[n_t z_t - \kappa v_t - \frac{\psi}{2}(\pi_t - 1)^2 y_t - c_t - g_t\right]$$
$$\left.\left. + \lambda_{4,t}[n_t - (1-\rho)(n_{t-1} + v_{t-1} m u_t^{\xi} v_t^{1-\xi})] \right\} \right\} \tag{28}$$

where,

$$W(c_t, n_t, v_t, \pi_t, mc_t)$$
$$= \mathrm{U}(c_t) + \chi_{1,t}\beta \mathrm{E}_t(c_t)^{-\sigma}[\psi(\pi_t - 1)\pi_t y_t]$$
$$- \chi_{2,t}\mathrm{E}_t\{\beta(c_t)^{-\sigma}(1-\rho)\left[(1-\varsigma)mc_t z_t - \varsigma\theta_t\kappa - (1-\varsigma)b + \frac{\kappa}{m}\theta_t^{\xi}\right] \tag{29}$$

with $\theta_t \equiv v_t/u_t$, $u_t = 1 - n_t, \chi_{1,t} = \lambda_{1,t-1}$ and $\chi_{2,t} = \lambda_{2,t-1}$.

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