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by Ester Faia and Lorenza Rossi

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Keywords: optimal monetary policy, labour market unionization, threat points

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We study the design of optimal monetary policy (Ramsey policies) in a model with sticky prices and unionized labour markets. Collective wage bargaining and unions monopoly power tend to dampen wage fluctuations and to amplify employment fluctuations relatively to a DNK model with walrasian labour markets. The optimal monetary policy must trade-off counteracting forces. On the one side deviations from zero inflation allow the policy maker to smooth inefficient employment fluctuations. On other side, the presence of wage mark-ups and wage stickiness produce inflationary pressures that require aggressive inflation targeting. Overall we find that the Ramsey planner deviates from full price stability and that an optimal rule targets inflation the real economic activity alongside inflation.

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1 Introduction

In most euro area countries labour unions and collective bargaining[1] play an important role in determining labour market dynamics. It is often argued that centralized bargaining tends to dampen wage dynamic and to amplify inefficient unemployment dynamics[2]. While the presence of inefficient unemployment dynamics calls for active monetary policies, dampened wage dynamics might hinder the effects of the monetary transmission mechanism. Despite the importance of those type of labour market institutions for macroeconomic performance, they have been largely neglected for the analysis of optimal monetary policy within DSGE models.

To address those issues we build a model with price rigidities and unionized labour markets. The assumption of price rigidity allows us to account for a direct link between unemployment and inflation. Workers' unionization implies that the labour market is non-walrasian and that wages are set as a mark-up over their reservation value. The presence of a wage mark-up produces a wedge in the labour market equilibrium conditions which induce inefficient unemployment fluctuations. In addition the type of union setup we employ allow wages to display persistent dynamics. Two elements are crucial in this respect. First, unions set wages by maximizing a weighted average of the workers' aggregate surplus from the job and aggregate employment[3]. Workers' surplus from the job is given by the difference between the aggregate wage and the reservation wage which represents unions threat points, namely the wage process below which workers would not enter negotiations. We assume that reservation wages are a geometric average of past wages and the wages that would arise in a fully competitive market. This assumptions allows to introduce real wage rigidity into the model in a tractable way[4]. Secondly, negotiations take the form of a *right to manage bargaining*: after wages are set collectively, individual firms determine employment along the labour demand schedule[5]. In this context the labour market equilibrium is obtained as solution to a Stackelberg game between the union and the firm. Since firms take wages as given, they react to productivity shocks by adjusting the employment margin. Such a mechanism tends to dampen

[1] A recent survey conducted for 23 EU countries, the US and Japan by the Wage Dynamic Network of the ECB and summarized by Du Caju, Gautier, Momferatou and Ward-Warmedinger [22] establishes that in most countries negotiations take place at sectoral level and that unions play am important role.

[2] The relation between wage bargaining centralization and macroeconomic performance dates back to Calmfors and Driffill [10].

[3] See Brown and Ashenfelter [9], Card [11], Carruth and Oswald [13], Dertouzos and Pencavel [19], Farber [25],[26], MaCurdy and Pencavel [39] for empirical support of this function.

[4] The importance of real wage rigidity has been widely recognized in recent theoretical and empirical studies. See Smest and Wouters [57] and Hall [28] among others.

[5] This follows the lines of the *monopoly union* model proposed in Dunlop 1944 and Oswald [46], which is itself a generalization of the sequential bargaining model proposed in Manning [42].

wage and marginal cost dynamics and tends to amplify employment dynamics consistently with empirical evidence.

In this context the design of the optimal monetary policy rule is complex as the policy maker is confronted with several trade-offs. First, and since labour markets are inefficient, the policy maker must trade-off between inflation and output/unemployment stabilization. Second, the policy maker is confronted with a type of dynamic trade-off. In fact in our model firms and unions act non-cooperatively and the solution to their strategic interaction is given by a Markov stationary process. Preventing firms and unions by pre-committing to a full path of wage and employment schedules implies that neither firms not workers consider the impact of their decisions on future marginal cost and inflation. This type of dynamic externality increase the temptation of the policy maker to employ inflation surprises.

The design of optimal policy is done in two steps. First, we characterize the optimal path of variables by following the Ramsey approach[6]. This approach allows to study optimal policy in economies that evolve around a distorted steady state by relying on public finance principles (Ramsey [49], Atkinson and Stiglitz [4], Lucas and Stokey [38], Chari, Christiano and Kehoe [15]). Specifically the Ramsey planner maximizes household's welfare subject to a resource constraint, to the constraints describing the equilibrium in the private sector economy, and via an explicit consideration of all the distortions that characterize both the long-run and the cyclical behavior of the economy. Second, we search for the optimal rule by maximizing agents´ conditional welfare. Crucial in our analysis and in the evaluation of welfare is the use of second order approximations of the full competitive equilibrium relations and of the agents' utility[7]. This allows us to account for the effects of second moments on mean welfare. Once again, those effects are particularly relevant in economies with large real distortions. All results are obtained by simulating the model under productivity and government expenditure shocks.

We find the following results. First, we show that overall the presence of wage mark-ups and the dependence of reservation wages on past wages dampens wage dynamics and amplify employment dynamics relative to a standard New Keynesian model with walrasian labour markets. Second, the Ramsey planner will deviate from full price stability. The monetary policy in this environment faces two main distortions, sticky prices which call for zero inflation policies and a labour market wedge which, by inducing inefficient employment fluctuations, calls for an active

[6] Several recent contribution apply Ramsey policies into New Keyensian models: see Khan, King and Wolman [33] and Schmitt-Grohe and Uribe [56]. Several contributions have employed this approach to study optimal policies in New Keynesian and RBC models with real frictions: see Faia [23], Arsenau and Chugh [3].

[7] See also Kollmann [34], [35], Schmitt-Grohe and Uribe [55] and [56], Faia and Monacelli [24] and Faia [23].

monetary policy. As the monetary authority is endowed with a single instrument, it must trade-off between those two distortions. As a result it will deviate from full price stability. Third, we find that the optimal volatility of inflation raises when we increase the dependence of threat points on past wages and falls when we increase the wage mark-up. An increase in the dependence on past wages, by dampening wage adjustment at expenses of higher employment fluctuations, calls for more active policies. On the contrary, higher mark-ups allow wages (therefore inflation) to become more responsive to aggregate conditions: this reduces the role for unemployment targeting and reinforces the case for aggressive inflation targeting. Finally, and in line with our previous results, we find that the optimal rule should target inflation aggressively but should also allow for a positive weight on unemployment.

The paper proceed as follows. Section 2 describes the model. Section 3 provides a description of the transmission mechanism which characterizes our model. Section 4 presents the analysis of the optimal policy. Section 5 shows results from the search of an optimal rule and the welfare costs for a subset of selected rules. Section 6 concludes. Tables and figures follow.

2 The model

There is a continuum of households who consume and invest. Workers are non-atomistic as they organize themselves in labour unions. The latter are "large" compared to the workers but are atomistic compared to the economy and for this reason they take prices as given. Unions set aggregate wages based on a *right to manage bargaining* (see Nickell [45]) process that allows firms to set employment along the labour demand schedule. The presence of a monopoly union generates unemployment in equilibrium and because of this workers can be employed or unemployed. As is common in the literature (see Ireland [31] among others), we assume that each household consists of a large number of individuals, each individual supplies some units of labor and shares all income with the other household members. This implies that consumption does not depend on a worker's employment status. Finally firms are monopolistic competitive, produce different varieties of goods and face a cost of adjusting prices a' la Rotemberg [54].

2.1 Households

The representative household is made up by a continuum of members represented by the unit interval. The household's lifetime utility depends on consumption C_t and on the disutility of work

N_t as follows:

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{C_t^{1-\sigma}}{1-\sigma} - \chi \frac{N_t^{1+\phi}}{1+\phi} \right\}, \quad \sigma, \phi > 0 \tag{1}$$

where $E_0 \{\}$ denotes the mathematical expectations operator conditional at information at time t. C_t is a Dixit-Stiglitz [20] consumption basket, whereas N_t denotes the number of employed individuals at time t. As is common in the literature, we assume that each household consists of a large number of individuals, each individual supplies one unit of labor inelastically and shares all income with the other household members. This implies that consumption does not depend on a worker's employment status.[8] Thus the representative household maximizes its utility subject to the budget constraint:

$$(1 + i_t)^{-1} B_{t+1} + C_t P_t - T_t = W_t N_t + B_t + \Pi_t \tag{2}$$

where B_t are nominal holdings of one period discounted bonds, W_t are nominal wages, T_t are government net transfers and Π_t are the profits of monopolistic firms, whose shares are owned by the domestic residents. Households choose processes $\{C_t,\, N_t\}_{t=0}^{\infty}$ and bonds $\{B_{t+1}\}_{t=0}^{\infty}$ taking as given the set of processes $\{P_t,\, W_t,\, i_t\}_{t=0}^{\infty}$ and the initial wealth B_0 so as to maximize 1 subject to 2.

For any given state of the world, the following efficiency condition must hold:

$$C_t = \beta E_t C_{t+1} \left(\frac{(1 + i_t)}{\pi_{t+1}} \right)^{-\frac{1}{\sigma}}. \tag{3}$$

where we define $\pi_t = \frac{P_t}{P_{t-1}}$ as the inflation rate. Equation 3 describes a set of optimality conditions for bond holding. Optimality requires that the Euler condition, 3 is satisfied alongside with a no-Ponzi condition on nominal bonds. Notice that, following large part of the recent literature, we do not introduce money explicitly, but rather think of it as playing the role of nominal unit of account.[9].

[8] We abstract from any transiction in and out the labor force, which as in Merz [44] is assumed to be constant and equal to one. Alternatively, as in Blanchard and Galì [7] we could have assumed that the equilibrium wage is set at a level such that at all times all individuals are either employed or willing to work. The choice of one or the other assumption does not change our main results.

[9] See Woodford (2003a), chapter 3. Thus the present model may be viewed as approximating the limiting case of a money-in-the-utility model in which the weight of real balances in the utility function is arbitrarily close to zero.

2.2 The Final Good Sector

In the economy there is a continuum $[0, 1]$ of intermediate goods which are aggregated into the final good using the following technology:

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\theta-1}{\theta}} \, di \right]^{\frac{\theta}{\theta-1}}. \tag{4}$$

The final good sector operates in perfect competition. Profits maximization yields to:

$$Y_t(i) = \left(\frac{P_t(i)}{P_t} \right)^{-\theta} Y_t \tag{5}$$

where θ represents the elasticity of substitution across varieties and $P_t = \left[\int_0^1 P_t(i)^{1-\theta} \, di \right]^{\frac{1}{1-\theta}}$.

2.3 The Intermediate Good Sector

A typical firm produces a differentiated good with a technology represented by the following decreasing return to scale production function:

$$Y_t(i) = A_t N_t(i)^{\delta} \tag{6}$$

where $i \in (0, 1)$ is a firm specific index. A_t is an aggregate productivity shock, with the following autoregressive process

$$\log A_t = \rho_a \log A_{t-1} + \varepsilon_t^a \tag{7}$$

where $\rho_a < 1$ and ε_t^a is a normally distributed serially uncorrelated innovation with zero mean and standard deviation σ_a.

Each firm i has monopolistic power in the production of its own variety and therefore has leverage in setting the price. In doing so it faces a quadratic cost of adjusting nominal prices, measured in terms of the finished goods and given by:

$$\frac{\varphi_p}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 \tag{8}$$

where $\varphi_p > 0$ proxies the degree of nominal price rigidity. The problem of the firm is that of choosing $\{P_t(i), N_t(i)\}_{t=0}^{\infty}$ to maximize the sum of expected discounted profits:

$$\begin{aligned}
\max_{\{N_t(i),P_t(i)\}} \frac{\Pi_t}{P_t} &= E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{P_t(i)}{P_t} Y_t(i) - \frac{W_t(i)}{P_t} N_t(i) - \frac{\varphi_p}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} - 1 \right)^2 \right\}, \\
& s.t \\
Y_t(i) &= \left(\frac{P_t(i)}{P_t} \right)^{-\theta} Y_t^D = A_t N_t(i)^{\delta}
\end{aligned}$$

where $Y_t^D = C_t + G_t$ is the aggregate demand, G_t is exogenous government expenditure and $\lambda_t = C_t^{-\sigma}$. Let's define mc_t, the Lagrangian multiplier of the production function, as the real margin cost. Also, since all firms will charge the same price in equilibrium we can assume symmetry and skip the index i. The following first order condition with respect to labor demand holds:

$$\frac{W_t}{P_t} = \delta mc_t N_t^{\delta-1}(i) A_t \tag{9}$$

The first order condition of the above problem with respect to prices lead to the following expectational Phillips curve equation:

$$\begin{aligned}
0 &= [1 - (1 - mc_t)\theta] Y_t^D - \varphi_p (\pi_t - 1) \pi_t + \\
& + \varphi_p \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (\pi_{t+1} - 1) \pi_{t+1}
\end{aligned} \tag{10}$$

2.4 Labour Unions

Since each household supplies its labor to only one firm, which can be clearly identified, workers try to extract some producer surplus by organizing themselves into a firm-specific trade union[10]. Firms hire workers from a pool composed of infinitely many households so that the individual household member is again of measure zero. The economy is populated by decentralized trade unions, so that each intermediate goods-producing firm negotiates with a single union $i \in (0, 1)$ which is too small to influence the outcome of the market. Unions negotiate the wage on behalf of their members.

Once unions are introduced in the analysis, two important issues arise: what is the objective function of the union and what are the variables subject to bargaining. One approach often followed in the literature is the "utilitarian" approach pioneered by Oswald [46] which consists on assuming that all workers are equal and that the union simply maximizes the sum of workers' utility, defined over wages. Although simple and appealing because coherent with a standard economic approach,

[10] As in Maffezzoli [40] we do not model explicitly the process of union formation. Horn and Wolinsky [30] is a classical reference and also Westermark [58].

the *utilitarian* approach pioneered by Oswald [46] does not allow for political considerations.[11] In this respect we take side on the never settled debate initiated by Dunlop [21] and Ross [53] over the appropriate maximand for the unions' utility function, and we assume that unions, do not simply maximize the utility of their members, but are institutions that also have political objectives.

The unions we consider maximize a Stone-Geary utility function. Our choice is motivated by the fact that the literature on labour union resorted extensively on this type of objective function[12] and that it received a significant empirical support[13]. They assume that unions maximize a modified Stone-Geary utility function of the form:

$$V\left(\frac{W_t(i)}{P_t}, N_t(i)\right) = \left(\frac{W_t(i)}{P_t} - \frac{W_t^r}{P_t}\right)^{\gamma} N_t(i)^{\varsigma} \tag{11}$$

The objective function of the union include both wages and employment[14]. The relative value of γ and ς is an indicator of the relative importance of the excess wage $\frac{W_t(i)}{P_t} - \frac{W_t^r}{P_t}$ and employment in in the union's objective function. The real reservation wage $\frac{W_t^r}{P_t}$ is the absolute minimum wage the union can tolerate. This reservation wage has many possible interpretations. One possible interpretation is that $\frac{W_t^r}{P_t}$ is the opportunity wage of the workers (Pencavel [47]) since it is unlikely that a union can survive if it negotiates a wage below such level. Unions' reservation wage is generally unobservable and therefore hard to model. We assume that the reservation wage is the same across unions and is function of the past aggregate real wage $\frac{W_{t-1}}{P_t}$ and of an alternative aggregate real wage $\frac{W_t^a}{P_t}$, as follows:

$$\frac{W_t^r}{P_t} = \left(\frac{W_{t-1}}{P_{t-1}}\right)^{\phi_w} \left(\frac{W_t^a}{P_t}\right)^{(1-\phi_w)} \tag{12}$$

We assume that the alternative wage considered by the unions is the one realized under a competitive labor market[15]. This choice is very convenient, as opposed for instance to the choice of using unemployment benefits, since it allows a direct comparison with the model under competitive markets:

$$\frac{W_t^a}{P_t} = \left(\chi C_t^{\sigma} N_t^{\phi}\right) \tag{13}$$

[11] For political considerations we intend how the preferences of workers, the preference of union leaders and market constraints interact in determining a union's objective.

[12] See Pencavel [47] and, more recently, De la Croix et al. [18], Raurich and Sorolla [50], Chang et al. [14] and Mattesini and Rossi [43].

[13] See Brown and Ashenfelter [9], Card [11], Carruth and Oswald [13], Dertouzos and Pencavel [19], Farber [25],[26], MaCurdy and Pencavel [39] among others.

[14] This is consistent with a study by MaCurdy and Pencavel [39].

[15] This is consistent with evidence provided by Card [11].

which can be easily obtained by setting unions´ bargaining power and the wage stickiness parameter, ϕ_w, to zero. Under this assumption the real reservation wage becomes (12)

$$\frac{W_t^r}{P_t} = \left(\frac{W_{t-1}}{P_{t-1}}\right)^{\phi_w} \left(\chi C_t^{\sigma} N_t^{\phi}\right)^{(1-\phi_w)} \tag{14}$$

As pointed out by Pencavel [47] and more recently in the New Keynesian literature by Mattesini and Rossi [43] and by Chang et al [14], the Stone-Geary utility function not only is appealing, both for its ability to approximate the actual behavior of unions and for its flexibility and tractability, but also for its generality. The parameters γ and ς correspond to the elasticities of the union's objective $V(\cdot)$ to the excess wage $\frac{W_t(i)}{P_t} - \frac{W_t^r}{P_t}$ and to the employment level $N_t(i)$ respectively. The larger the difference $\varsigma - \gamma$, the more the union approaches the extreme of a "democratic" (or "populist") union. If unions are "wage oriented" then $\gamma > \varsigma$, on the other hand if they are "employment oriented" $\gamma < \varsigma$. If we set $\gamma = 1$, $\varsigma = 1$, the unions' objective function becomes equivalent to the one assumed by Maffezzoli [40] and Zanetti [59] in their recent papers. Note that, in this case, the union is risk neutral.

The bargaining process we consider here is in the tradition of the *right to manage* models introduced by Nickell [45]. The employment rate and the wage rate are determined in a non-cooperative dynamic game between unions and firms. We restrict the attention to Markov strategies, so that in each period unions and firms solve a sequence of independent static games. Each union behaves as a Stackelberg leader and each firm as a Stackelberg follower. Therefore each union maximizes equation (11) subject to the labor demand (9). Once the wage has been chosen, each firm decides the employment rate along its labor demand function. Even if unions are large at the firm level, they are small at the economy level and therefore they take all the aggregate variables as give.
From the first order conditions of the union's maximization problem with respect to $W_t(i)$, given that in this model the labor demand elasticity with respect to the real wage $\frac{1}{1-\delta}$ is constant, after imposing the symmetric equilibrium we obtain:

$$\frac{W_t}{P_t} = \mu_w \frac{W_t^r}{P_t} \tag{15}$$

where $\mu_w = \frac{\varsigma}{\varsigma - \gamma(1-\delta)} > 1$ and $\varsigma > \gamma(1-\delta)$. This implies that $\frac{\partial \mu_w}{\partial \varsigma} < 0$ while $\frac{\partial \mu_w}{\partial \gamma} > 0$. The real wage chosen by the monopolist union is a markup μ_w over the real reservation wage. Unions' markup is a function of δ, and also of the parameters γ and ς, that is, of the relative importance that unions give to wages and employment. Figure 1 shows the effect on wage markup of varying γ when ς is set equal to 0.5. As expected the higher is the value of γ, i.e., the higher is the weight that unions attach to the excess wage $\frac{W_t(i)}{P_t} - \frac{W_t^r}{P_t}$, the higher is the wage markup[16] and the rent that the unions extracts.

Two observation are in order at this point. First, the presence of a wage mark-up makes the allocation under the non-walrasian labour market inefficient compared to the one under the competitive market. We will return on this point more extensively later on. Second, the assumption that the reservation wage is indexed over both past wages and competitive wages allow us to introduce real wage rigidity in a tractable way. The importance of real wage rigidity has been widely recognized in recent theoretical and empirical studies (see for instance Smets and Wouters [57] and Hall [28] among others).

2.5 Equilibrium Conditions

After imposing market clearing and aggregating, we can express the resource constraint as:

$$A_t N_t^{\delta} = C_t + G_t + \frac{\varphi_p}{2}(\pi_t - 1)^2 \tag{16}$$

2.6 The Distorted Competitive Equilibrium and The Role of Wedges

Definition 1. *For a given nominal interest rate* $\{i_t\}_{t=0}^{\infty}$ *and for a given set of the exogenous processes* $\{A_t, G_t\}_{t=0}^{\infty}$ *a determinate competitive equilibrium for the distorted competitive economy is a sequence of allocations and prices* $\{C_t, \pi_t, mc_t, \frac{W_t}{P_t}, N_t\}_{t=0}^{\infty}$ *which, for given initial* B_0 *satisfies equations* 3, 10, 9, 15 , 16.

The economy considered is distorted by the presence of a wedge in the labour market. Equilibrium in the labour market is obtained by equalizing labour demand schedule, as given by equation 9, with the optimal wage set by the union, as given by equation 15. As in the standard right to manage bargaining model for given wages firms set the level of employment based on their labour demand schedule. The resulting firms' marginal cost is given by:

$$mc_t = \frac{1}{\delta}\frac{(N_t)^{1-\delta}}{A_t}\frac{\varsigma}{\varsigma - \gamma(1-\delta)}\frac{W_t^r}{P_t} \tag{17}$$

Several considerations on the labour market equilibrium are worth.

First, as clearly shown by equation 17, firms marginal cost is directly affected by unions' monopoly power and by the dynamic properties of the reservation wage. In this respect and

[16] If the union is risk neutral as in Zanetti and Maffezzoli, i.e., if we set $\gamma = 1$, $\varsigma = 1$, then the wage markup is $\mu_w = \frac{1}{1-\delta}$.

contrary to standard new keynesian models, labour unitary costs do not depend solely on labour productivity but are distorted by union mark-ups.

Second, as long as reservation wages respond persistently to shocks, due to the indexation on past wages, marginal costs do so as well. The persistent response of marginal costs feeds then into inflation through the Phillips curve relation. This is the sense in which right to manage bargaining models allow for a direct link between wage persistence and marginal cost and inflation persistence. Sluggish wage, marginal cost and inflation dynamics tend to dampen the transmission mechanism of monetary policy, hence higher persistence makes the inflation stabilization objective more difficult to achieve.

Let´s now look at the role of this union monopoly wedge for employment dynamic in our model. To obtain the employment equilibrium level we make use of equations 9 and 15 to obtain the following expression:

$$N_t = \left[\frac{\delta A_t mc_t}{\mu_w} \left(\frac{W_{t-1}}{P_{t-1}} \right)^{-\phi_w} (\chi C_t^{\sigma})^{(\phi_w - 1)} \right]^{\frac{1}{1-\delta+\phi(1-\phi_w)}} \tag{18}$$

First, consider the case of zero wage rigidity, $\phi_w = 0$. In this case the employment level is given by:

$$N_t = \left[\frac{\delta A_t mc_t}{\mu_w} (\chi C_t^{\sigma})^{(-1)} \right]^{\frac{1}{1-\delta+\phi}} \tag{19}$$

Let´s now compare this level with he one arising in the walrasian labour market. The latter is obtained by merging equations 9 and 13:

$$N_t^w = \left[\delta A_t mc_t (\chi C_t^{\sigma})^{(-1)} \right]^{\frac{1}{1-\delta+\phi}} \tag{20}$$

Two considerations emerge from the comparison. First, the employment level under the monopoly union is clearly lower than the one arising under the competitive market, N_t^w. Second, due to the right to manage structure of the bargaining process, the employment schedule is derived after the wage schedule. This increases the sensitivity of employment to shocks as, when setting wages, firms and unions act non-cooperatively and fail to recognize the dynamic consequences of shocks on employment. Since employment and output remain below the Pareto efficient level and since they tend to fluctuate much more than they would do in a walrasian labour market, the monetary authority is tempted to use surprise inflation to foster growth and stabilize the economy. This is the sense in which non-walrasian labour markets call for active monetary policies.

Given the structure of our economy the monetary policy faces two types of trade-offs. First, it faces a tension between inflation and employment stabilization. Indeed on the one side it is optimal to set zero inflation in order to offset the nominal frictions and close the gap with the flexible price allocation, however on the other side it is optimal to use surprise inflation in order to move the economy toward the Pareto frontier. As the monetary authority is endowed with a single instrument, overall optimality requires setting inflation at an intermediate level between zero and the level that would push employment toward the Pareto frontier. The second tension faced by the monetary authority has a more dynamic flavor. As wages and marginal costs respond sluggishly to shocks the monetary transmission mechanism is dampened. This increases the incentive of the monetary authority toward aggressive inflation target. However the latter objective conflicts with stabilization in the labour market. This implies that the monetary authority will have to trade-off between aggressive inflation targeting and stabilization of the real activity.

Proposition 1. *For the model economy described in Definition 1, a flexible price allocation is not feasible, therefore not implementable under zero inflation policies.*

Proof. Consider the economy with constant return to scale production function and preferences with constant labour elasticity[17]. In this economy the wage equation rteads as follows:

$$\frac{\theta-1}{\theta}=\frac{w_t}{A_t} \tag{21}$$

which implies that wages must adjust one to one with productivity. In a non-walrasian setting, as the one emerging from a model with labour unions, such an allocation is not feasible. Consider the reduced form of the Phillips curve in our model:

$$\begin{aligned} 0 \;=\;& \left[1-\left(1-\frac{1}{\delta}\frac{(N_t)^{1-\delta}}{A_t}\frac{\varsigma}{\varsigma-\gamma(1-\delta)}\left(\frac{W_{t-1}}{P_t}\right)^{\phi_w}\left(\chi C_t^{\sigma}N_t^{\phi},\right)^{(1-\phi_w)}\right)\theta\right]\left(\frac{C_t+G_t}{Y_t}\right) && (22)\\ & -\varphi_p(\pi_t-1)\pi_t+\varphi_p\beta E_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(\pi_{t+1}-1)\pi_{t+1} && (23)\end{aligned}$$

By imposing zero inflation policy we obtain:

$$\frac{\theta_t-1}{\theta_t}=\left[\frac{1}{\delta}\frac{(N_t)^{1-\delta}}{A_t}\frac{\varsigma}{\varsigma-\gamma(1-\delta)}\left(\frac{W_{t-1}}{P_t}\right)^{\phi_w}\left(\chi C_t^{\sigma}N_t^{\phi},\right)^{(1-\phi_w)}\right] \tag{24}$$

From equation 24 it stands clear that the marginal cost (therefore the mark-up) in our model can never be constant in response to productivity shocks.

[17] This is the benchmark case for which Adao, Correia and Teles 2003 prove the optimality of zero inflation policies.

In response to a positive productivity shocks unions will adjust the wage by less than the increase in productivity. The reason for this is twofold. First, due to the assumption of indexation on past wages, real wages are contingent to the past history. The path dependence which characterizes real wages in this model reduces the elasticity of firms´ marginal costs to output, therefore induces persistent dynamics. Second, due to the right to manage bargaining structure, firms choose employment along the demand schedule by taking real wages as given. In this context real wages loose their allocative role and the effect of shocks is absorbed mainly by employment fluctuations.

The non-implementability of the constant mark-up policy implies the non-implementability of the zero inflation policy.

3 Dynamic Properties of the Model Under Taylor Rules

Before turning to the full-fledge analysis of the optimal policy problem it is instructive to consider the dynamic properties of the model under different monetary policy rules. To this purpose we analyze impulse response functions for a set of selected variables (output, inflation, employment, marginal cost, wages and interest rates) to productivity shocks. We assume that monetary policy sets the interest rate by following a standard Taylor rule with coefficients of 1.5 on inflation and 0.5/4 on output. The rest of the calibration of the model is done as follows.

Preferences. Time is measured in quarters. We set the discount factor $\beta = 0.99$, so that the annual interest rate is equal to 4 percent. The parameter on consumption in the utility function σ is set equal to 2 and the parameter on labour disutility, ϕ, is set equal to 2. Sensitivity checks have performed on alternative preference parameters spaces: results are unchanged.

Production. Following Basu and Fernald [5] we set the value added mark-up of prices over marginal cost to 0.2. This generates a value for the price elasticity of demand, θ of 6. We set the cost of adjusting prices $\varphi_p = 20$ so as to generate a slope of the log-linear Phillips curve consistent with empirical and theoretical studies.

Labour markets. The output elasticity of labour, δ, is set to 0.72 following Christoffel et al. [16]. Knowing the value of δ, assuming that $\varsigma > \gamma(1-\delta)$ and assuming a wage mark-up of 1.5 we set the baseline parameters $\varsigma = 0.5$ and $\gamma = 0.6$. The baseline calibration wants to capture the idea that unions tend to put higher weights on wages as shown by empirical studies. In the analysis of optimal policy results will be derived for alternative parameters spaces. The baseline wage stickiness parameter, ϕ_w, is calibrated to 0.4 a value compatible with estimates by from Smets and Wouters [57].

Exogenous shocks and monetary policy: The process for the aggregate productivity shock, A_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, $\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) + \varepsilon_t^g$, where the steady-state share of government consumption, g, is set so that $\frac{g}{y} = 0.25$ and ε_t^g is an i.i.d. shock with standard deviation σ_g. Empirical evidence for the US in Perotti [48] suggests $\sigma_g = 0.008$ and $\rho_g = 0.9$. When considering interest rate smoothing we follow several empirical studies for US and Europe (see Clarida, Gali' and Gertler [17], Angeloni and Dedola [2] and Andres, Lopez-Salido and Valles [1] among others) and set ϕ_r equal to 0.9.

Figure 2 shows impulse response functions to 1% increase in productivity under two different values of the wage stickiness parameter, ϕ_w. The first value of zero identifies the case with flexible wages, the second value is compatible with estimates of Smets and Wouters [57]. The qualitative responses of variables under the two cases are the same. An increase in productivity raises output, real wages and reduces inflation. Due to sticky prices employment fall; since prices adjust slowly in the short run firms take advantage of the productivity increase by reducing labour demand. The fall in employment brings about a fall in firms´ marginal costs. The fall in inflation is associated with a fall in interest rates as the monetary policy reacts according to a Taylor type rule. The quantitative response of variables is instead different under the two scenarios. When wages adjust slowly, employment tends to be both more volatile and more persistent as it is more severely affected by the shock. Marginal costs depend both on wages and employments dynamic: while the first adjust more slowly, the second tends to be more volatile in presence of wage stickiness. The effect coming from the employment dynamic tend to prevail, therefore marginal costs also tend to be more volatile under wage rigidity. On the other side inflation inherits more of the persistence coming from the wage dynamic.

Figure 3 shows the response of selected variables to 1% increase in productivity under two different values of the wage mark-up, μ_w. We let μ_w vary between 1.1 and 1.8: given a value of $\varsigma = 0.5$ this implies that we let γ vary between 0.1 and 0.8. Once again the qualitative dynamic of variables tend to be similar across the two scenarios. Quantitatively higher wage mark-ups induce higher persistence on wages and inflation and higher volatility in employment and output. Higher mark-ups arise when labour unions place higher weights on wages than on employment in their objective function. This induces firms to adjust more along the labour demand curve therefore inducing more volatile employment dynamics. Overall higher mark-ups, by increasing the labour market wedge, tend to increase inefficient unemployment fluctuations. Higher volatility in employment brings about higher volatility in output. On the other side higher wage mark-up tends to tie wage dynamics to past wages: history dependence brings about higher persistence in wages, marginal costs and inflation.

For brevity we do not report the results for the government expenditure shocks as the results are in line with the ones shown for the productivity shocks. Overall higher wage mark-ups and higher indexation to past wages tends to dampens wage and inflation dynamic and tends to amplify employment and output dynamic. It is worth mentioning that in all cases output and employment show a hump shaped response implying that the model is able to reproduce the persistent responses shown in the data.

4 The Optimal Monetary Policy Problem

The optimal policy is determined by a monetary authority that maximizes the discounted sum of utilities of all agents given the constraints of the competitive economy. Such an approach allows to analyze economies which evolve around a distorted steady state as it is in our case and to analyze the second order effects of such distortions (see Khan, King and Wolman [33], Schmitt-Grohe and Uribe [56], Faia [23]). We assume that *ex-ante commitment* is feasible. The first task is to select the minimal set of competitive equilibrium conditions that represent the relevant constraints in the planner's optimal policy problem following the primal approach described in Lucas and Stokey [38]. The constraints for the monetary authority can be summarized as follows:

$$w_t = \mu_w \left(w_{t-1}\right)^{\phi_w} \left(\chi C_t^{\sigma} N_t^{\phi}\right)^{(1-\phi_w)} \tag{25}$$

$$w_t = \delta mc_t N_t^{\delta-1} A_t \tag{26}$$

$$\begin{aligned} 0 \ = \ & \left[1-(1-mc_t)\,\theta\right]\left(\frac{C_t+G_t}{Y_t}\right) - \varphi_p\left(\pi_t-1\right)\pi_t + \\ & + \varphi_p \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\pi_{t+1}-1\right)\pi_{t+1} \end{aligned} \tag{27}$$

$$A_t N_t^{\delta} = \ C_t + G_t + \frac{\varphi_p}{2}\left(\pi_t - 1\right)^2 \tag{28}$$

where $w_t = \frac{W_t}{P_t}$. The monetary authority will choose the policy instrument, the inflation rate, to implement the optimal allocation obtained as solution to the following Lagrangian problem. Few observations are in order concerning the choice of the constraints. First, as we have a passive fiscal policy (only lump sum transfers occur) we do not need to include the government budget constraint. Second, given the absence of liquidity frictions in our model we look for a real equilibrium which is determined for given nominal interest rate. This allows us to exclude the Euler equation.

Definition 2. *Let $\lambda_{1,t}$, $\lambda_{2,t}$,$\lambda_{3,t}$, $\lambda_{4,t}$ represent the Lagrange multipliers on the constraints 25, 26, 27 and 28 respectively. For given B_0 and processes for the exogenous shocks $\{A_t, G_t\}_{t=0}^{\infty}$, the allocations plans for the control variables $\Xi_t \equiv \{C_t, N_t, mc_t, \pi_t, w_t\}_{t=0}^{\infty}$ and for the co-state variables $\Lambda_t \equiv \{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}\}_{t=0}^{\infty}$ represent a first best constrained allocation if they solve the following maximization problem:*

$$Min_{\{\Lambda_t\}_{t=0}^{\infty}} Max_{\{\Xi_t\}_{t=0}^{\infty}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U(C_t, N_t) \right\} \tag{29}$$

subject to 25, 26, 27 and 28.

Notice that constraint 27 exhibits future expectations of control variables. For this reason the maximization problem is intrinsically non-recursive[18]. As shown by Marcet and Marimon [41], a formal way to rewrite the same problem in a recursive stationary form is to enlarge the planner's state space with additional (pseudo) co-state variables, which bear the meaning of tracking, along the dynamics, the value to the planner of committing to the pre-announced policy plan. The co-state variable $\chi_{3,t}$ obeys to the following law of motions, $\frac{\chi_{3,t+1}}{\beta} = \lambda_{3,t}$.

4.1 Long Run Behavior Under Optimal Policy

We asses the optimal monetary policy design in the long-run by looking at the long run unconstrained optimal inflation rate. In analogy with the Ramsey-Cass-Koopmans model, such steady state amounts to computing the *modified golden rule* steady state[19]. The unconstrained optimal long-run rate of inflation (arising from the modified golden rule) is the one to which the planner would like the economy to converge to if allowed to undertake its optimization unconditionally. It is obtained by imposing steady state conditions ex-post on the first order conditions of the Ramsey plan. In particular we find:

[18] See Kydland and Prescott [36].

[19] Notice that an important distinction must be made between the optimal level of inflation characterizing the *modified golden rule* and the one characterizing the *golden rule (*See also King and Wolman 1996). In dynamic economies with discounted utility in fact the two level of inflations do not necessarily coincide. The golden rule level of inflation is the one that maximizes households' instantaneous utility under the constraint that the steady state conditions are imposed ex-ante. The impatience reflected in the rate of time preferences gives rise to a negatively sloped long run Phillips curve which by constraining the optimal policy problem maintains alive the tension between closing the inflation gap on the one side and the inefficient unemployment gap on the other.

Lemma 1. *The (net) inflation rate associated with the unconstrained long run optimal policy is zero.*

Proof. Consider the first order condition with respect to inflation of the Ramsey plan´:

$$0 = (\lambda_{3,t} - \chi_{3,t})(1-\beta)(2\pi_t - 1) - \lambda_{3,t}\theta(\pi_t - 1) \tag{30}$$

Since in steady state $\lambda_3 = \chi_3$, and given that $\theta > 0$ and that $\lambda_3 > 0$, it follows that $\pi = 1$.

Hence the Ramsey planner would like to generate an average (net) inflation rate of zero. The intuition for why the long-run optimal inflation rate is zero is simple. Under commitment, the planner cannot resort to ex-post inflation as a device for eliminating the inefficiency related to the labor markets. Hence the planner aims at choosing that rate of inflation that allows to minimize the cost of adjusting prices as summarized by the quadratic term $\frac{\vartheta}{2}(\pi_t - 1)^2$.

4.2 Optimal Dynamic Ramsey Policy in Response to Shocks

Let's now analyze the dynamic properties of the Ramsey plan in a calibrated version of the model. The dynamic responses of the Ramsey plan are computed by taking second order approximations[20] of the set of first order conditions around the steady state. Calibration of the model follow the one outlined in section 3.

Figure 4 shows impulse response functions to a one percent positive productivity shock for consumption, employment, marginal costs and inflation. Due to the increase in the marginal productivity output and consumption increase. The monetary policy in this environment faces two distortions, sticky prices and a labour market wedge which induces inefficient employment fluctuations. The first distortion calls for zero inflation policy to close the gap with the flexible price allocations, while the second distortion calls for an active monetary policy. The temptation to stabilize the labour market is even stronger as employment fluctuations are amplified by the right to manage bargaining process. As the monetary authority is endowed with a single instrument, it must trade-offs between the two competing distortions. As a result optimal policy deviates from full price stability. Specifically the monetary authority wants to take full advantage of the productivity increase, therefore it reduces inflation to support higher demand. Interestingly inflation shows a significant overshoot after a few periods. This captures the value of commitment as the monetary policy tries to influence future expectation to obtain faster convergence toward the steady state.

In response to government expenditure shocks (Figure 5) optimal monetary policy implies a fall in consumption and inflation. An increase in government expenditure crowds out consumption

[20] See Schmitt-Grohe and Uribe [55].

demand. As demand falls, this triggers a fall in inflation. Overall however the deviations of the price level from the full price stability case are rather small. This is so since the shock does not affect directly labour productivity.

To fully understand the properties of the optimal policy we examine the optimal volatility of inflation under different parameter settings. Figure 6 shows that the optimal volatility of inflation increases when the wage stickiness parameter increases. An increase in wage stickiness has two effects. One the one it induces a higher wedge in the labour market, therefore higher inefficient fluctuations in employment. On the other side higher indexation to past wages, by dampening wage dynamic, tends to amplify inefficient employment fluctuations. Both effects tend to tilt the balance of the monetary authority toward a more active role.

Finally 7 shows that the optimal volatility of inflation falls when the wage mark-up increases. The intuition for this result is as follows. On the one side an increase in the mark-up, by reinforcing the labour market wedge, induces large inefficient employment fluctuations. This would call for more active policy. On the other side, higher wage mark-ups tends to dampen wage dynamics (therefore marginal costs and inflation), therefore making the inflation stabilization objective more difficult to achieve. This second effect calls for a more aggressive response to inflation fluctuations. Overall higher mark-ups tend to tilt the balance toward fighting inflation more aggressively.

5 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 (31). Specifically we search for parametrization of interest rate rules that satisfy the following 3 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 life-time 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[21]. 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. Define Ω as the fraction of household's consumption that would be needed to equate conditional welfare $\mathcal{W}_0$ under a generic interest rate policy to the level of welfare $\widetilde{\mathcal{W}_0}$ implied by the optimal rule. Hence Ω should satisfy the following equation:

$$\mathcal{W}_{0,\Omega} = E_0 \left\{ \sum_{t=0}^{\infty} \beta^t U((1+\Omega)C_t) \right\} = \widetilde{\mathcal{W}_0}$$

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

$$\Omega = \exp\left\{ \left(\widetilde{\mathcal{W}_0} - \mathcal{W}_0 \right) (1-\beta) \right\} - 1$$

For the analysis of the optimal rules and the welfare comparison with ad hoc rules we consider the following Taylor-type class of rules:

$$\begin{aligned} \ln\left(\frac{i_t}{i}\right) &= (1-\phi_r)\left(\phi_\pi \ln\left(\frac{\pi_t}{\pi}\right) + \phi_y \ln\left(\frac{Y_t}{Y}\right) + \phi_n \ln\left(\frac{N_t}{N}\right)\right) \\ &\quad + \phi_r \ln\left(\frac{i_{t-1}}{i}\right) \end{aligned} \tag{31}$$

The class of rules considered features deviations of each variable form the target. The monetary authority search for the optimal rule by maximizing the welfare of agents subject to the constraints represented by the competitive economy relations and to the class of monetary policy rules represented by 31. Numerically[22] we search for the specification $\{\phi_\pi, \phi_y, \phi_n, \phi_r\}$ that maximizes household's welfare and we evaluate the welfare ranking of rules which impose alternative restrictions on 31.

Our results are as follows. First, the optimal rule carries a positive weight on GDP. This is in contrast with previous analysis (see Schmitt-Grohe and Uribe 2006, Faia and Monacelli 2008, Faia 2008) which find that output targeting is always detrimental. In our set-up a target of the

[21] See Kim and Kim [33] for an analysis of the inaccuracy of welfare calculations based on log-linear approximations in dynamic open economies.

[22] We 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.

real economic activity is optimal as the monetary authority aims to push the economy toward the Pareto frontier. Second, we assess the welfare costs of alternative monetary rules compared to the optimal one. Table 1 shows the results. Our results show that interest rate smoothing is welfare detrimental. This is so since our economy features a high degree of persistence, therefore interest rate smoothing would further dampen the effectiveness of the monetary transmission mechanism, something which would make the stabilization goals more difficult to achieve. Results also show that a rule targeting employment performs worst than a rule targeting output. Employment in our model is affected by significant inefficient fluctuations; a response of the interest rate to those fluctuations would feed the same degree of inefficiency into the whole economy. Finally, welfare results show that strong inflation targeting is still preferred to mild inflation targeting. The presence of nominal frictions in our economy requires an inflation stabilization objective. In addition the persistence in inflation and marginal costs, induced by the presence of real wage stickiness, tends to strenghten the inflation stabilization motive.

6 Conclusions

Labour unions play an important role in most euro area countries, therefore an analysis of optimal monetary policy cannot neglect the implications that such institutions play for the labour market. We present a New Keynesian model in which labour unions negotiates wages collectively through a right to manage bargaining. In equilibrium wages are given by a mark-up over a reservation level which depends on past wages and aggregate employment. Overall the model produces higher volatilities of employment and higher persistence in wage, marginal cost and inflation dynamic, consistently with the data. Most importantly the model induces inefficient unemployment fluctuations that call for active monetary policies. The design of optimal policy, which is done through Ramsey policies, implies that cyclical inflation must deviate from zero, the more so the higher the degree of wage rigidity. The optimal monetary policy rule should target the real economic activity alongside with inflation, this is so as the monetary authority must trade-off between closing the gap with the flexible price allocation and stabilizing inefficient fluctuations in the labour market.

A natural extension of this analysis would be to consider the role of this type of labour market frictions for the transmission of monetary policy in the euro area. A line of research that we plan to pursue in the future.

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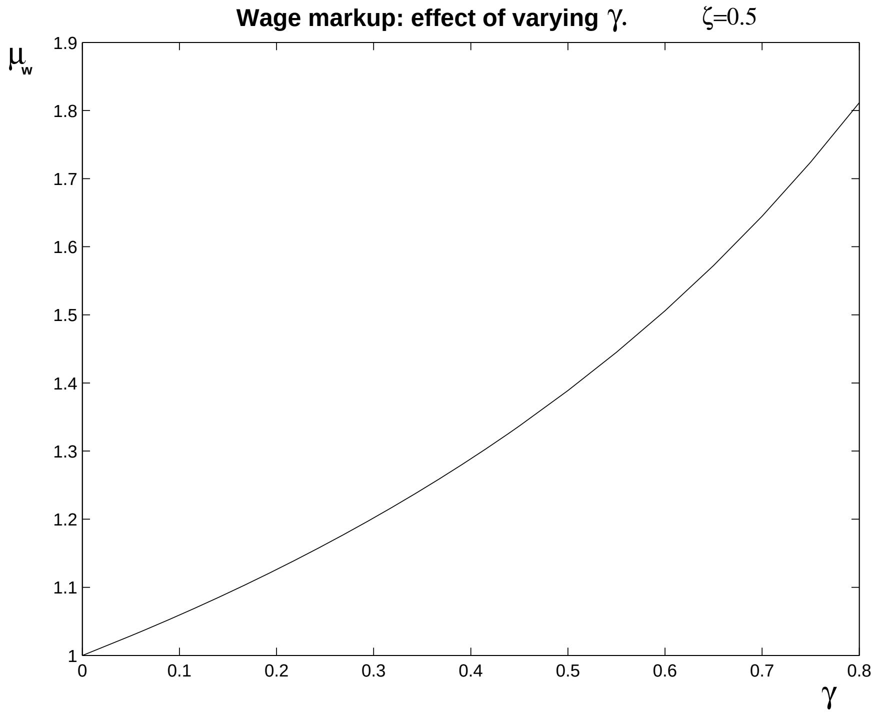

Figure 1: .

Table 1: **Welfare comparison of alternative monetary policy rules.**

Monetary Policy Rule	% Loss relative to optimal rule
$\phi_\pi = 1.5, \phi_y = 0.5/4, \phi_n = 0, \phi_r = 0.9$	1.1132
$\phi_\pi = 3, \phi_y = 0, \phi_n = 0, \phi_r = 0$	1.1101
$\phi_\pi = 3, \phi_y = 0, \phi_n = 0.5/4, \phi_r = 0$	1.0981
$\phi_\pi = 1.5, \phi_y = 0, \phi_n = 0.5/4, \phi_r = 0$	1.6281
$\phi_\pi = 1.5, \phi_y = 0, \phi_n = 0.5/4, \phi_r = 0.9$	0.9280

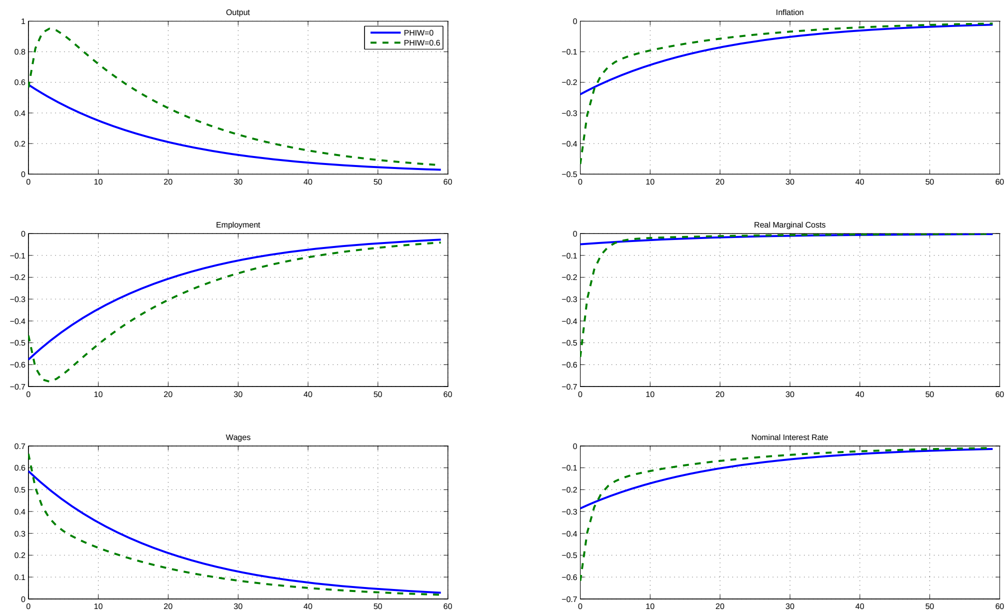

Figure 2: Impulse responses to productivity shocks under standard Taylor rule. Solid line $\phi_w = 0$ dashed line $\phi_w = 0.6$.

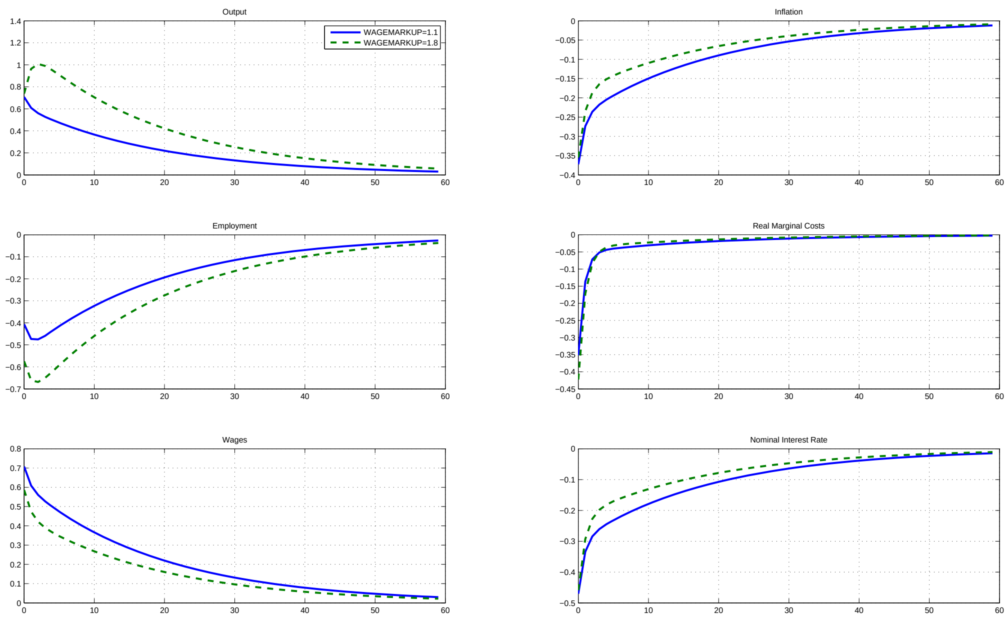

Figure 3: Impulse responses to productivity shocks under standard Taylor rule. Solid line $\mu_w = 1.1$, dashed line $\mu_w = 1.8$.

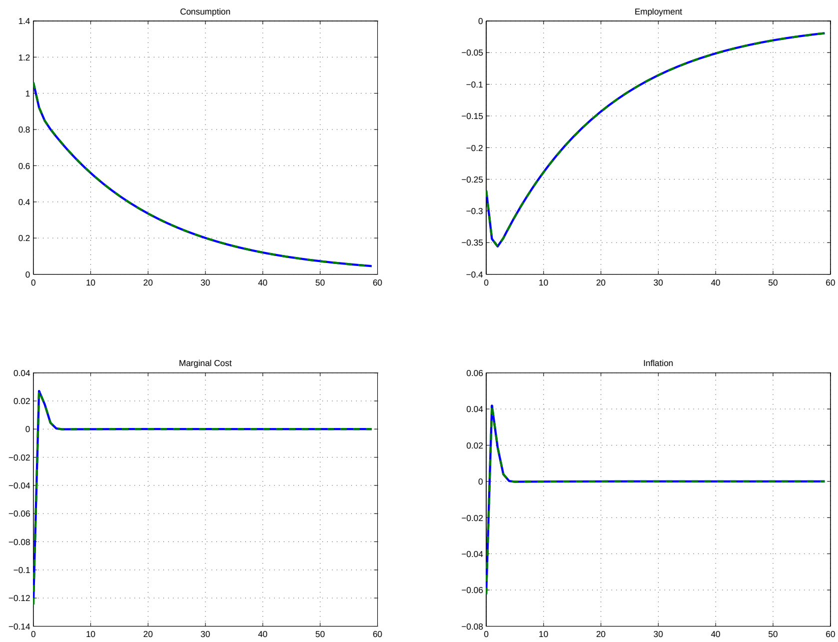

Figure 4: Impulse responses of Ramsey policy under productivity shocks.

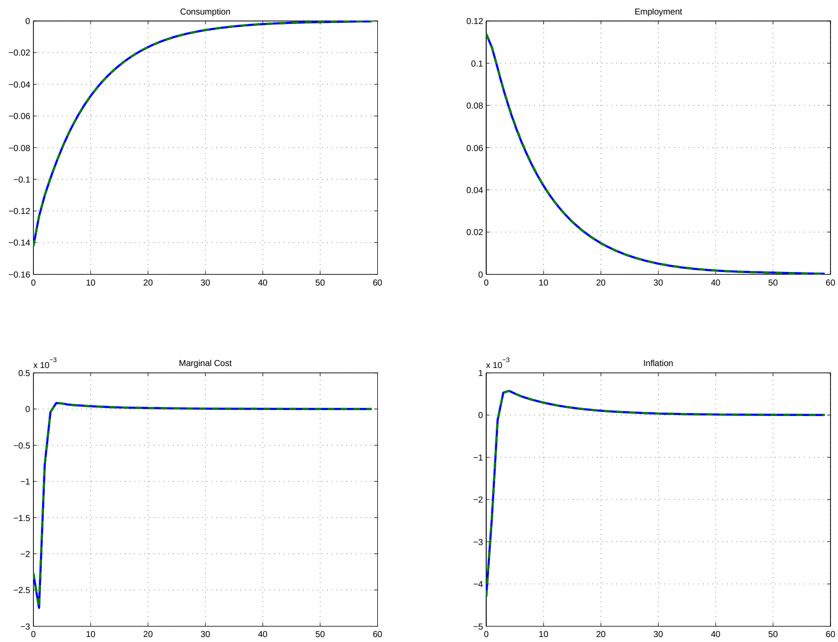

Figure 5: Impulse responses of Ramsey policy under government expenditure shocks.

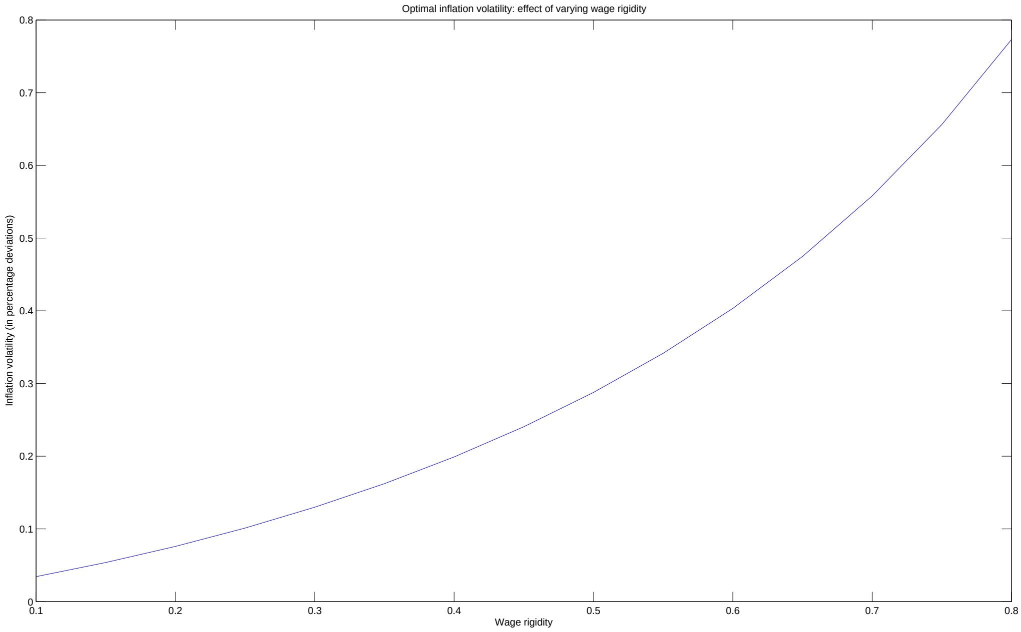
Optimal inflation volatility: effect of varying wage rigidity
Inflation volatility (in percentage deviations)
Wage rigidity
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0

Figure 6:

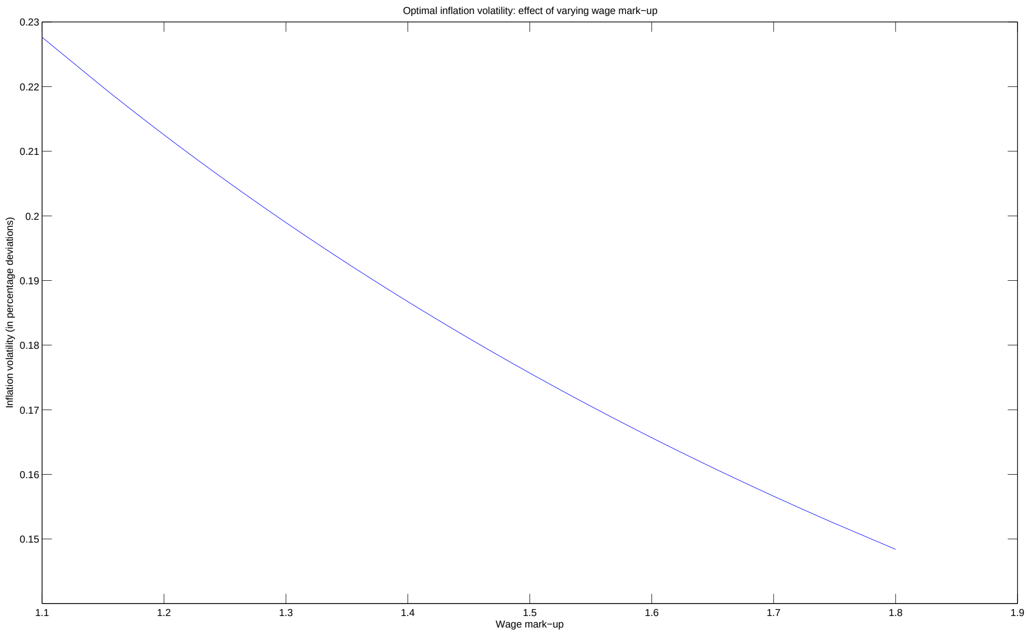
Optimal inflation volatility: effect of varying wage mark−up
Inflation volatility (in percentage deviations)
0.23
0.22
0.21
0.2
0.19
0.18
0.17
0.16
0.15
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
Wage mark−up

Figure 7: