Ramsey Monetary Policy with Labour Market Frictions

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Abstract

Traditional New Keynesian models prescribe that optimal monetary policy should aim at price stability. In the absence of a labor market frictions, the monetary authority faces no unemployment/inflation trade-off. I study the design of optimal monetary policy in a framework with sticky prices and matching frictions in the labor market. Optimal policy features deviations from price stability in response to both productivity and government expenditure shocks. When the Hosios 1990 condition is not met, search externalities make the flexible price allocation unfeasible. Optimal deviations from price stability increase with workers' bargaining power, as firms´ incentives to post vacancies fall and unemployment fluctuates above the Pareto efficient one.

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1. Introduction

Most of the recent literature on optimal monetary policy design using New Keynesian models neglects labour market frictions, which are the main cause of the existence of a short-run unemployment/inflation trade-off. Absent this, optimal monetary policy invariably consists in implementing the flexible price allocation through a zero inflation policy.

This paper instead analyzes optimal monetary policy in a model economy characterized by price adjustment costs a' la Rotemberg 1982 and matching frictions in the labour market a' la Mortensen and Pissarides 1999. Several recent papers have studied the quantitative implications of introducing matching frictions in a standard New Keynesian framework[1], but very little has been done on the normative side. Our economy has 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. The second type of distortion stems form the cost of adjusting prices, which reduces output below the efficient level thereby calling for closing the "inflation gap". The third stems from a congestion externality, that tightens the labour market and induces inefficient unemployment fluctuations. In this context the policy maker faces a trade-off between stabilizing inflation and reducing inefficient unemployment fluctuations and an incentive to deviate from full price stabilization.

The design of optimal monetary policy in this paper follows the Ramsey approach (Atkinson and Stiglitz 1976, Lucas and Stokey 1983, Chari, Christiano and Kehoe 1991) in which

[1] 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.

the optimal path of all variables is obtained by maximizing agents' welfare subject to the relations describing the competitive economy and via an explicit consideration of all wedges that characterize both the long run and the cyclical dynamics. Recent studies apply this approach to the analysis of optimal policy in the context of New Keynesian models (Adao et al. 2003, Khan et al.2003, Schmitt-Grohe and Uribe 2004b and Siu 2004).

Results are as follows. Optimal monetary policy deviates from price stability in response to both productivity and government expenditure shocks, in contrast with previous results from new keynesian models[2]. Optimal deviations from price stability arise since search externalities generate an unemployment/inflation trade-off which requires the monetary authority striking a balance between reducing price adjustment costs and increasing an inefficiently low employment. More specifically, in response to productivity increases optimality requires a pro-cyclical policy, as the monetary authority should decrease inflation to allow an increase in demand. By raising firms' discounted marginal profits, the increase in demand raises the incentive to post vacancies, thereby reduces unemployment. Deviations from price stability increase with workers' bargaining power. This result hinges on role of the Hosios 1990 condition, which defines the socially efficient unemployment rate as the one prevailing when workers' bargaining power equalizes the share of unemployed workers in the matching technology. When workers' bargaining power is above this value, firms have little incentive to post vacancies. In this case equilibrium unemployment is above the social optimum. The

[2] Zero inflation is the core result in the analysis of Woodford 2003, Clarida, Gali and Gertler 2000, Adao, Correia and Teles 2003, all of which feature price rigidity. Khan, King and Wolman 2003 and Schmitt-Grohe and Uribe 2004b have shown that price stability remains robust even in presence of monetary frictions. See Benigno and Benigno 2004 and Faia and Monacelli 2008b in the open economy context.

opposite is true in the alternative case. Hosios 1990 has shown, in a static context, that an optimal hiring subsidy is needed to offset the search externality, stemming from the cost of posting vacancies, and the congestion externality, caused by deviations from the efficiency condition. The optimal subsidy must be higher when the unemployment rate is above the socially efficient level and smaller otherwise. In our context the monetary authority uses a single instrument, inflation, to foster incentives toward vacancy posting. If the unemployment rate is above the social optimum, the monetary authority reduces inflation to boost firms' profits and to increase vacancy posting. In the opposite case optimal volatitlity of inflation becomes almost zero as the monetary authority is concerned solely with reducing the cost of adjusting prices.

To provide a full assessment of the Ramsey policy the model dynamic under this plan is compared with the one arising under strict inflation targeting. The comparison shows that the Ramsey plan is welfare-improving because it allows to strike a balance between stabilizing inflation and unemployment.

The analysis in this paper is related to some other recent studies. Cooley and Quadrini 2004 introduce matching frictions into a model economy featuring the cost channel. The authors find that optimal policy should be pro-cyclical in response to productivity shocks. Blanchard and Gali' 2008 and Thomas 2006 augment a New Keynesian model with matching frictions and wage rigidity and analyze optimal monetary policy. Their analyses employ a linear quadratic approach based on first order approximation of the competitive equilibrium conditions and on second order approximation of the agents' utility. For the approximation to provide correct welfare rankings both papers assume a non distorted steady state obtained by imposing the Hosios 1990 condition at all states and times. In this context, and in absence of wage rigidity, price stability remains optimal, as congestion externalities are eliminated through steady state subsidies. When wages are rigid, deviations from price stability arise as wage rigidity translates into inefficient job creation and inefficient unemployment fluctuations. Arseneau and Chugh 2007 analyze optimal fiscal and monetary policy in a model with matching frictions, costly nominal wage adjustment and monetary frictions. They also restrict the analysis to the case in which the Hosios 1990 condition holds, nonetheless they find deviations from price stability and from constant labour tax rates. Finally, Faia 2008b shows that an optimal monetary policy rule should target the unemployment gap alongside with the inflation gap in presence of matching frictions and wage rigidity.

The paper proceeds as follow. Section 2 presents the model. Section 3 analyzes the optimal policy plan. Section 4 shows results for the long run optimal policy. Section 5 analyses the optimal short-run response to shocks. Section 6 concludes.

2. 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. Firms in the production sector are monopolistic competitive, produce a differentiated good using labor as input and face adjustment costs a' la Rotemberg 1982.

Notice that, as in large part of the recent literature, money plays the role of nominal unit of account[3]. The assumption of a cashless economy implies that zero inflation will be an outcome in the long-run. Departure from price stability occurs in the short run as the monetary authority responds to productivity and government expenditure shocks in order to reduce the impact of congestion externalities.

2.1. Households

Let $c_t \equiv \int_0^1 [(c_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ be a Dixit-Stiglitz aggregator of different varieties of goods. The optimal allocation of expenditure on each variety is given by $c_t = \left(\frac{p_t^i}{p_t}\right)^{-\varepsilon} c_t$, where $p_t \equiv \int_0^1 [(p_t^i)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$ is the price index. There is continuum of agents who maximize the expected lifetime utility[4].

$$E_t \left\{ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma} \right\} \tag{1}$$

where c denotes aggregate consumption in final goods. Households supply labor hours inelastically h (which is normalized to 1). Total real labor income is given by w_t and is specified

[3] See Woodford 2003, 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.

[4] Let $s^t = \{s_0, ...s_t\}$ 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 $E_t\{.\} \equiv \sum_{s_{t+1}} \rho(s^{t+1}|s^t)$ as the mathematical expectations over all possible states of nature conditional on history s^t.

below. Unemployed households members, u_t, receive an unemployment benefit, b. 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:

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

Households choose the set of processes $\{c_t, b_t\}_{t=0}^{\infty}$ by 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. The following optimality condition must hold:

$$c_t^{-\sigma} = \beta(1+r_t^n)E_t\left\{c_{t+1}^{-\sigma}\frac{p_t}{p_{t+1}}\right\} \tag{3}$$

Equation 3 is the Euler condition with respect to bonds. Optimality requires that a No-Ponzi condition on wealth is also satisfied.

2.2. Production Sector

Firms in the production sector sell their output in a monopolistic competitive market and meet workers in 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 opening up a vacancy 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

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, $mu_t^{\xi}v_t^{1-\xi}$, which converts unemployed workers u and vacancies v into matches, m. Given the definition of labor market tightness as $\theta_t \equiv \frac{v_t}{u_t}$, we can derive the probability that firms can fill a vacancy, which is given by $q(\theta) = \frac{m(u_t,v_t)}{v_t} = m\theta_t^{-\xi}$, as well as the probability that unemployed workers meet vacancies, which is given by $\theta_t q(\theta_t) = m\theta_t^{1-\xi}$. If the search process is successful, the firm in the monopolistic good sector operates the following technology, $y_{i,t} = z_t n_{i,t}$, where z_t is the aggregate productivity shock and $n_{i,t}$ is the number of workers hired by each firm. Matches are destroyed at an exogenous rate ρ which takes place at the end of period t. 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 who did not discontinue the match:

$$n_{i,t} = (1-\rho)n_{i,t-1} + v_{i,t}q(\theta_{i,t}) \tag{4}$$

Hiring in this model is istantaneous[5]. At the beginning of period t firms observe the realization of the stochastic variables and post vacancies accordingly. Those vacancies are matched with the pool of searching workers which is given by the workers not employed at the end of period $t-1$, $u_t = 1-(1-\rho)n_{t-1}$.

2.2.2. Monopolistic Firms

There is continuum of firms which hire a continuum of workers. Firms in the monopolistic sector use labor to produce different varieties of consumption good, face a quadratic cost of adjusting prices and a cost of posting vacancies which is linear in the number of vacancies. Due to the constant return to scale of vacancy posting technology, firms can take wages as given when choosing prices and employment. Wages are determined through the bargaining problem analyzed in the next section. Firms choose prices, p_t^i, number of employees, $n_{i,t}$, and number of vacancies, $v_{i,t}$, to maximize the discounted value of future profits by 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):

$$Max\Pi_{i,t} = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\lambda_t}{\lambda_0} \left\{ \frac{p_t^i}{p_t} y_t^i - w_{i,t} n_{i,t} - \kappa v_{i,t} - \frac{\psi}{2} \left(\frac{p_t^i}{p_{t-1}^i} - 1 \right)^2 \right\} \tag{5}$$

subject to the demand for each variety, $y_t^i = \left(\frac{p_t^i}{p_t}\right)^{-\epsilon} y_t = z_t n_{i,t}$, and the employment evolution, given by equation 4. Variables are defined as follows: $\lambda_t = c_t^{-\sigma}$, $y_t = c_t + g_t$, g_t is government expenditure, $\frac{\psi}{2}\left(\frac{p_t^i}{p_{t-1}^i} - 1\right)^2$ represents the cost of adjusting prices, ψ can be thought as the sluggishness in the price adjustment process, κ as the cost of posting vacan-

[5] Recently several papers (Blanchard and Gali' 2008, Krause, Lopez-Salido and Lubik 2008 and Rotemberg 2008) argued that this assumptions might fit better the labour market particularly in presence of sticky prices.

cies and w_t denotes the fact that the bargained wage might depend on time varying factors. Let's define mc_t, the lagrange multiplier on the demand constraint, as the marginal cost of firms, and μ_t, the lagrange multiplier on constraint 4, 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. After deriving first order conditions and rearranging, firms optimality conditions can be summarized as follows:

$$\frac{\kappa}{q(\theta_t)} = mc_t z_t - w_t + \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\} \tag{6}$$

$$\psi(\pi_t - 1)\pi_t - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}\psi(\pi_{t+1} - 1)\pi_{t+1}\} = (c_t + g_t)((1-\varepsilon) - \varepsilon mc_t) \tag{7}$$

Equation 6 gives the evolution of labour market tightness, $\frac{\kappa}{q(\theta_t)}$ and is obtained by merging first order conditions with respect to n_t and v_t. Equation 7, a non-linear expectational Phillips curve, is obtained by taking the first order condition with respect to prices.

Rearranging equation 6 delivers the following expression for the marginal cost:

$$mc_t = \frac{w_t}{z_t} + \frac{\frac{\kappa}{q(\theta_t)} - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\}}{z_t} \tag{8}$$

As already noticed in Krause and Lubik 2005, in a matching model the marginal cost of firms is made up of two components. The first is the marginal productivity of each single employee, $\frac{w_t}{z_t}$, which characterizes labour productivity also in walrasian models. The second component, $\frac{\frac{\kappa}{q(\theta_t)} - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\}}{z_t}$, depends on the future value of a match. Posting vacancy is costly hence a successful match today is valuable since it reduces future search costs. In this context wages maintain their allocative role only for future matches[6].

[6] See Goodfriend and King 2001.

2.2.3. Wage Setting and Nash Bargaining

The wage schedule is obtained through the solution to an individual Nash bargaining process. After deriving the marginal value of a match for the firms and the marginal values for workers, both in the employment and the unemployment status, we can apply the Nash bargaining rule and obtain the following wage schedule:

$$w_t = \varsigma mc_t z_t + \varsigma\beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\kappa\theta_{t+1}\} + (1-\varsigma)b \tag{9}$$

2.3. Equilibrium Conditions

Aggregate output is obtained by aggregating production of individual firms. Government expenditure, g_t, is exogenous and is financed through lump sum taxation. The assumption of a passive fiscal authority allows us to neglect the government budget in the list of constraints characterizing the optimal policy problem. The exogenous shock g_t follows an $AR(1)$ process. Hence the resource constraint reads as follows:

$$y_t = n_t z_t = c_t + g_t + \kappa v_t + \int_0^1 \frac{\psi}{2}\left(\frac{p_t^i}{p_{t-1}^i} - 1\right)^2 \tag{10}$$

Total net supply of bonds is zero.

Definition 1. For given nominal interest rate $\{r_t^n\}_{t=0}^{\infty}$ *and for given set of the exogenous processes* $\{z_t, , g_t\}_{t=0}^{\infty}$ *a determinate competitive equilibrium for the distorted competitive economy is a sequence of allocation and prices* $\{c_t, n_t, \theta_t, \pi_t, y_t, w_t, mc_t\}_{t=0}^{\infty}$ *which, for given initial* b_0 *satisfies equations 3,4,6,7,9,10 and* $y_t = z_t n_t$.

3. Implementability Conditions

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. The next task is to select the relations that represent the relevant constraints in the planner's optimal policy problem. This amounts at describing the competitive equilibrium in terms of a minimal set of relations involving only real allocations, in the spirit of the primal approach described in Lucas and Stokey 1983. There is a fundamental difference, though, between that classic approach and the one followed here, which stems from the impossibility, in the presence of sticky prices and matching frictions, of reducing the planner's problem to a maximization problem with a single implementability constraint[7].

Optimality conditions for both, consumers' and firms, can be summarized as follows:

$$\psi(\pi_t - 1)\pi_t - \beta E_t\{(\frac{c_{t+1}}{c_t})^{-\sigma}\psi(\pi_{t+1} - 1)\pi_{t+1}\} = (c_t + g_t)((1-\varepsilon) - \varepsilon mc_t) \tag{11}$$

$$\frac{\kappa}{m}\theta_t^{\xi} = (1-\varsigma)mc_t z_t - (1-\varsigma)b + (1-\rho)\beta E_t\{(\frac{c_{t+1}}{c_t})^{-\sigma}[-\varsigma\theta_{t+1}\kappa + \frac{\kappa}{m}\theta_{t+1}^{\xi}]\} \tag{12}$$

where $\theta_t \equiv \frac{v_t}{u_t}$ and $u_t = 1 - (1-\rho)n_{t-1}$. Equation 12 gives the evolution of labour market tightness and is obtained by substituting equation 9 into 6. Finally implementability conditions include aggregate resource constraint and employment dynamic:

$$n_t z_t = c_t + g_t + \kappa v_t + \frac{\psi}{2}(\pi_t - 1)^2 y_t \tag{13}$$

$$n_t = (1-\rho)n_{t-1} + m u_t^{\xi} v_t^{1-\xi} \tag{14}$$

[7] See also Khan, King and Wolman 2003, Schmitt-Grohe and Uribe 2004b and Faia 2008a.

3.1. The Role of Frictions

As discussed previously this economy is characterized by three main frictions: price stickiness, monopolistic competition and matching frictions in the labor market. A monetary policy maker endowed with a single instrument is not able to eliminate all the three distortions but can only trade-off among them. To understand the type of trade-offs present in this model it is instructive to discuss the role of each friction singularly and the level of the policy instrument required to offset them.

Let´s start by analyzing the role of matching frictions in the labor market since they provide the novel aspect for the design of the optimal monetary policy. The planner problem in absence of price stickiness reads as follows:

$$MaxE_t \left\{ \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma} \right\} \tag{15}$$

s. to

$$z_t n_t - b(1-n_t) - \kappa v_t = c_t \tag{16}$$

$$n_t = (1-\rho)n_{t-1} + v_t q(\theta_t) \tag{17}$$

Merging first order conditions of the above plan with respect to c_t, n_t, v_t and rearranging them delivers the following optimal evolution for labour market tightness:

$$\frac{\kappa}{m}\theta_t^{\xi} = (1-\xi)z_t - (1-\xi)b + \beta(1-\rho)E_t\{(\frac{c_{t+1}}{c_t})^{-\sigma}[-\xi\theta_{t+1}\kappa + \frac{\kappa}{m}\theta_{t+1}^{\xi}]\} \tag{18}$$

Notice that equation 18 is equivalent to 12 when $mc_t = 1$ and $\xi = \varsigma$ at all dates and states. The first condition states that firms must act in perfectly competitive markets. The second is a constrained pareto effiency condition which corresponds to the one obtained in Hosios 1990. Efficiency requires workers' bargaining power being equivalent to their share in the matching technology. When workers bargaining power is too low ($\xi \leq \varsigma$) firms find very profitable to form a match. This induces excessive vacancy creation and unemployment rate falls below the pareto efficient one. Viceversa, when workers' bargaining power is too high there is little incentive for firms to post vacancies. In this case unemployment is above the pareto efficient one. Hosios 1990 shows that, if deviations from the equality $\xi = \varsigma$ occur, a hiring subsidy is needed to restore efficiency. As we shall see below, in absence of such subsidy the monetary authority can use inflation to restore the optimal level of unemployment in the economy. We shall therefore expect the policy maker to deviate from zero inflation policy whenever the Hosios 1990 condition is not met.

Let's now consider the role of price stickiness and monopolistic competition. Price stickiness induces a gap with the flexible price allocation since part of resources are wasted in the activity of adjusting prices, $(\pi_t - 1)^2$. The cost of adjusting prices is eliminated by setting $\pi_t = 1$ at all times, thereby following a strict price stability policy. Finally monopolistic competition reduces the level of economic activity by decreasing optimal demand and calls for mild deviation from price stability (see also Schmitt-Grohe and Uribe 2004).

Further intuition on how the monetary authority can mitigate inefficient unemployment fluctuations ($\xi \geqslant \varsigma$) in response to shocks can be gained by examining the evolution of marginal discounted value of a vacancy, denoted by V_t^J:

$$V_t^J = mc_t z_t - w_t + E_t\{(\beta \frac{\lambda_{t+1}}{\lambda_t})[(1-\rho)V_{t+1}^J]\} \tag{19}$$

The marginal value of a vacancy depends on real revenues minus real wages plus discounted continuation value. With probability $(1-\rho)$ jobs remain filled and earn the expected value V_{t+1}^{J} and with probability, ρ, jobs are destroyed and earn zero value. In equilibrium the marginal discounted value of vacancies equalizes expected costs of posting vacancies. Given this assumption, recursive solution of equation 19 delivers the following expression:

$$\frac{\kappa}{q(\theta_t)} = \sum_{j=0}^{\infty} E_{t+j}\{\beta \frac{\lambda_{t+j+1}}{\lambda_{t+j}}(1-\rho)\Pi_{t+j}\} \tag{20}$$

where $\Pi_{t+j} = mc_{t+j}z_{t+j} - w_{t+j}$. Recall that marginal costs are given by the inverse of the mark-up and that in presence of sticky prices mark-ups behave countercyclically: as prices adjust slowly an increase in demand reduces mark-ups. Consider now the case in which workers' bargaining power is too high, $\xi \geq \varsigma$. As there is scarcity of vacancies, the unemployment rate is above the pareto efficient one. In order to reduce inefficient unemployment fluctuations the monetary authority must increase the profitability of vacancies so as to rebalance the equilibrium in the labour market. It can do that by inducing countercyclical mark-up dynamics. Consider a positive productivity shock. If the monetary authority reduces inflation, the ensuing increase in demand reduces mark-ups and increases unitary profits, $\Pi_{t+j} = mc_{t+j}z_{t+j} - w_{t+j}$, at each point in time. As shown in equation 20 an increase in the discounted stream of profits, for given cost of posting vacancy κ, reduces labor market tightness, $q(\theta_t)$,thereby mitigates congestion externalities and inefficient employment fluctuations.

Overall in our set up two distortions, monopolistic competition and search externality, call for time-varying inflation while the third distortion, price stickiness, calls for zero net inflation. As the policy maker must trade-off among those three distortions, we expect the optimal policy to deviate from strict price stability.

3.1.1. Implementability of flexible price allocation

An important aspect concerning the design of optimal policy is the implementability of the flexible price allocation. In the standard new keynesian model a' la Clarida, Gali' and Gertler 2000 optimal monetary policy prescribes that neither inflation nor the output gap should deviate from the flexible price allocation. This is true both, under productivity and government expenditure shocks. A necessary condition for this outcome to arise is that the flexible price allocation is always implementable; this is so under Walrasian labour markets. Policy trade-offs arise in the standard New Keynesian model only in presence of cost push shocks. Things are different in presence of search and matching frictions.

Proposition 1. The flexible price allocation with constant mark-ups is not implementable in a new keynesian model with matching frictions.

Consider the aggregate Phillips curve in reduced form:

$$\psi(\pi_t - 1)\pi_t - \beta E_t\{(\frac{c_{t+1}}{c_t})^{-\sigma}\psi(\pi_{t+1} - 1)\pi_{t+1}\} \tag{21}$$

$$= \quad y_t((1-\varepsilon) - \varepsilon[\frac{w_t}{z_t} + \frac{\frac{\kappa}{q(\theta_t)} - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\}}{z_t}]) \tag{22}$$

Imposing zero inflation delivers the following marginal cost relation:

$$mc_t = \frac{w_t}{z_t} + \frac{\frac{\kappa}{q(\theta_t)} - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\}}{z_t} = \frac{\varepsilon_t - 1}{\varepsilon_t} \tag{23}$$

In presence of matching frictions the marginal cost embeds an extra component represented by the long run value of a match, $\frac{w_t}{z_t} + \frac{\frac{\kappa}{q(\theta_t)} - \beta E_t\{\frac{\lambda_{t+1}}{\lambda_t}(1-\rho)\frac{\kappa}{q(\theta_{t+1})}\}}{z_t}$, which varies in response to productivity shocks and prevents implementability of the flexible price allocation with constant mark-ups. Indeed as long as the long run value of a current match varies in response to shocks, the mark up must also vary across states and dates. In this context the discounted expected value of a match plays the role of an endogenous cost push shock. This is the sense in which matching frictions generate a dynamic trade-off for the policy maker.

3.2. The Optimal Monetary Policy Plan

This section is devoted to the specification of a general set-up for the optimal policy design.

Definition 2. Let $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}\}_{t=0}^{\infty}$ *represent sequences of Lagrange multipliers on the constraints 11, 12, 13 and 14 respectively. Then, for given stochastic processes* $\{z_t, g_t\}_{t=0}^{\infty}$ *and for given* b_0*, plans for the control variables* $\{c_t, n_t, v_t, \pi_t, mc_t\}_{t=0}^{\infty}$ *and for the co-state variables* $\{\lambda_{1,t}, \lambda_{2,t}, \lambda_{3,t}, \lambda_{4,t}\}_{t=0}^{\infty}$ *represent a first best constrained allocation if they solve the following maximization problem:*

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

$$
\begin{aligned}
&Min_{\{\Lambda_t^n\}_{t=0}^{\infty}}\ Max_{\{\Xi_t^n\}_{t=0}^{\infty}}\ E_0\{\sum_{t=0}^{\infty}\beta^t E_t\{\frac{c_t^{1-\sigma}}{1-\sigma}+ \qquad (24)\\
&+\lambda_{1,t}[-\psi(\pi_t-1)\pi_t(c_t)^{-\sigma}+\beta E_t\{(c_{t+1})^{-\sigma}\psi(\pi_{t+1}-1)\pi_{t+1}\}-y_t(c_t)^{-\sigma}((1-\varepsilon)-\varepsilon mc_t)]+\\
&+\lambda_{2,t}\left[\frac{\kappa}{m}\theta_t^{\xi}-(1-\varsigma)mc_t z_t-(1-\varsigma)b+\beta(1-\rho)E_t\{(\frac{c_{t+1}}{c_t})^{-\sigma}[-\varsigma\theta_{t+1}\kappa+\frac{\kappa}{m}\theta_{t+1}^{\xi}]\}\right]+\\
&+\lambda_{3,t}\left[n_t z_t-\kappa v_t-\frac{\psi}{2}(\pi_t-1)^2-c_t-g_t\right]+\\
&+\lambda_{4,t}\left[n_t-(1-\rho)n_{t-1}+m u_t^{\xi}v_t^{1-\xi}\right]\}\}
\end{aligned}
$$

where $\theta_t \equiv \frac{v_t}{u_t}$ and $u_t = 1-(1-\rho)n_{t-1}$. As a result of the constraint 11 and 12 exhibiting future expectations of control variables, the maximization problem as spelled out in 24 is intrinsically non-recursive.[8] As first emphasized in Kydland and Prescott 1980, and then developed by Marcet and Marimon 1999, 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. Such co-state variables bear the crucial meaning of tracking, along the dynamic, the value to the planner of committing to the pre-announced policy plan. To avoid time consistency problems and consistently with a timeless perspective, the values of the two co-state variables at time zero are set equal to their solution in the steady state.

[8] See Kydland and Prescott 1977, Calvo 1978. As such the system does not satisfy per se the principle of recursivity, according to which the optimal decision at time t is a time invariant function only of a small set of state variables.

3.3. Calibration

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

Production. Following Basu and Fernald 1997, the value added mark-up of prices over marginal cost is set equal to 0.2. This generates a value for the price elasticity of demand, ε, of 6. Structural estimates of New Keynesian models find values for the sensitivity of inflation to marginal costs around 0.5 (Lubik and Schorfheide 2004), which implies a cost of adjusting prices $\psi = 20$.

Labor market frictions parameters. The matching technology is homogenous of degree one function and is characterized by the parameter ξ. Consistently with estimates by Blanchard and Diamond 1991, this parameter is set to 0.4. The steady state firm matching rate, $q(\theta)$, is set to 0.7, which is the value used by denHaan, Ramsey and Watson 1997. The exogenous separation probability, ρ, is set to 0.1, consistently with estimates from Hall 1995 and Davis et al. 1996 for the U.S. quarterly worker separation rate; this value is also compatible with those used in the literature which range from 0.07 (Merz 1995) to 0.15 (Andolfatto 1996). The value for b is set so as to generate a steady state ratio, $\frac{b}{w}$, of 0.6 which corresponds to the average value observed for industrialized countries (see Nickell and Nunziata 2004). The steady state unemployment rate is set to $u = 0.4$; this value is consistent with a broad definition of searching workers which includes potential participants in the labour market such as discouraged workers and workers loosely attached to the labour force[9]. Given those values, the scale parameter, m, is obtained from the solution of the steady state using the observation that the steady state number of matches is given by $\rho(1-u)\frac{\theta^{\xi}}{v}$. The values assigned to the parameter governing workers' bargaining power, ς, is varied in the quantitative experiments, while the value for the cost of posting vacancies, κ, is obtained from the steady state version of labour market tightness evolution.

Exogenous shocks. 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, $\ln\left(\frac{g_t}{g}\right) = \rho_g \ln\left(\frac{g_{t-1}}{g}\right) + \varepsilon_t^g$, 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 2004 suggests $\sigma_g = 0.0074$ and $\rho_g = 0.9$.

4. Long Run Optimal Policy

Before turning to the optimal stabilization policy in response to shocks we need to characterize the log-run optimal policy as the one to which the policy maker would like to converge. To develop an analogy with the Ramsey-Cass-Koopmans model, this amounts to computing the *modified golden rule* steady state. To determine the optimal inflation rate in the long run, one needs to solve the first order conditions of the Ramsey plan in the steady-state. Let´s analyze the first order condition with respect to inflation:

$$(\lambda_{1,t} - \chi_{1,t})c_t^{-\sigma}\psi(2\pi_t - 1)y_t - \lambda_{3,t}\psi\left(\pi_t - 1\right)y_t = 0 \tag{25}$$

[9] This value is consistent with those used in the literature that range from a low value of $u = 0.12$ in Cole and Rogerson 1999 and Krause and Lubik 2005 and high values as in Cooley and Quardini 2004 who set $u = 0.43$ and Andolfatto 1996 who sets $u = 0.58$.

which in steady-state ($\lambda_{1,t} = \lambda_{1,t-1} = \chi_{1,t}$) implies:

$$\lambda_3 \psi (\pi - 1) y = 0 \tag{26}$$

Since $\lambda_3 > 0$ (the resource constraint must hold with equality), $y > 0$ and $\psi > 0$ (we are not imposing *a priori* that the steady-state coincides with the flexible price allocation), equation 26 implies $\pi = 1$ or a zero average (net) inflation rate. The intuition for this result is simple. Under commitment, the planner cannot resort to ex-post inflation as a device for eliminating market inefficiencies. Hence the planner chooses the inflation rate that allows to minimize the cost of adjusting prices, $\frac{\vartheta}{2}(\pi_t - 1)^2$.

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*[10]. In dynamic economies with discounted utility in fact the two level of inflations do not necessarily coincide. 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. On the contrary 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 calls for a positive optimal inflation rate in the long run.

[10] See also King and Wolman 1999.

5. Optimal Monetary Policy Response to Shocks

This section examines the dynamic of the Ramsey plan in response to shocks. The focus is on productivity and government expenditure shocks, the main drivers of business cycle fluctuations in industrialized economies. The optimal monetary policy response to shocks is computed using second order approximations[11] of the first order conditions for the recursively stationary Lagrangian problem that characterizes the Ramsey plan. Technically one needs to compute the stationary allocation that characterizes the deterministic steady state of the first order conditions to the Ramsey plan. One can then compute a second order approximation of the respective policy functions in the neighborhood of the same steady state. This amounts to implicitly assuming that the economy has been evolving and policy has been conducted around such a steady already for a long period of time (in a timeless perspective).

Figure 1 shows impulse responses of selected variables to an 1% increase in productivity. To appreciate the role of the Hosios 1990 condition the figure reports results for different values of the bargaining power, ς. First, an increase in productivity induces an increase in output, employment and consumption. The Ramsey planner aims at taking full advantage of the productivity improvement, therefore inflation decreases. This reduces mark-ups and increases unitary profits. Higher profits induce firms to increase the number of vacancies which in turn reduces inefficient unemployment fluctuations. All variables show an hump-

[11] Second order approximation methods have the particular advantage of accounting for the effects of volatility of variables on the mean levels. See Schmitt-Grohe and Uribe 2004 a,c,d Kollman 2003,2004 and Faia and Monacelli 2008a among others.

shaped response due to the history dependence induced by matching frictions[12]. Importantly, inflation tends to overshoot the steady state after a few periods; this is due to a combination of two effects. First, the decision to post vacancies is affected by future profits (hence by future policy choices). Second, a policy maker acting under commitment can credibly affect expectations about future variables, hence it might want to increase inflation above its steady state level for some periods in order to allow a faster convergence toward the steady state itself.

Let's now focus on the role of the workers' bargaining power. As shown in figure 1, deviations from price stability are larger, whereas unemployment fluctuations are smaller, for higher values of the bargaining power. Recall that the share of searching workers in the matching technology, ξ, is set to 0.4. This implies that when bargaining power, ς, is equal to 0.2, unemployment is above the Pareto efficient one as there are many available vacancies. In this case the monetary authority shifts its efforts toward reducing costs of adjusting prices and sets inflation close to zero. On the contrary, when bargaining power, ς, is equal to 0.9, firms´ share of surplus is small and incentives to post vacancies are low. This renders the unemployment rate bigger than the Pareto efficient one. In this case the monetary authority shifts its efforts toward fighting an inefficiently high unemployment through time-varying inflation and mark-ups, hence inflation deviates significantly from zero. Inflation overshooting is both faster and larger.

[12] It is worth noticing that the Ramsey plan preserves the salient empirical features characterizing the labour market. In particular we observe the existence of a Beveridge curve (negative relation between vacancies and unemployment), procyclicality of labour market tightness, hump-shaped response of output and unemployment and a volatility of unemployment bigger than the one of output. Those feature characterize the dynamic path of the present model also under standard Taylor rules.

It is important to notice that deviations from price stability occur precisily under productivity shocks. This is in contrast with results reported by previous studies which had shown that deviations from price stability were nil or negligible mostly in response to productivity shocks.

Figure 2 shows impulse responses of selected variables to an increase in government expenditure, again for different values of the bargaining power, ς. Deviations from price stability arise under this shock too. This result echos Adao, Correia and Teles 2003 and Khan, King and Wolman 2003, who have shown that public expenditure shocks cause fluctuations in the ratio of aggregate demand to output and prevent implementability of the flexible price allocation. Notice however that, consistently with previous studies, deviations from zero inflation are rather small under this shock. Optimal monetary policy also implies a fall in consumption and in the price level. The government wishes to reduce private consumption when government purchases are high since this makes the state contingent claims value of public spending high, making it easier to satisfy monopoly producers. This argument is valid when the utility of the representative agent is separable so that the price of the state contingent security only depends on consumption[13]. In order to generate a fall in consumption the government increases the nominal interest rate and this also implies a fall in the price level.

Finally figure 3 shows the optimal volatitliy of inflation for different values of the bargaining power. As expected, the optimal volatility of inflation is an increasing function of the workers' bargaining power. The higher are inefficient unemployment fluctuations, the higher

[13] See Khan, King and Wolman 2003.

are the incentive of the policy maker to deviate from full price stability. Inflation plays in our context the same role that hiring subsidies play in Hosios 1990. Such subsidy must be bigger when the unemployment rate is above the Pareto efficient one.

It is clear that the workers' bargaining power has important implications for the monetary policy design. One might therefore wonder whether empirical studies can help to give guidelines on how to pin down the bargaining parameter. This is controversial, because it very difficult to obtain adequate proxies for this parameter. Most of the studies focus on panel estimates of wage equations obtained through Nash bargaining mechanisms. Christophides and Oswald 1992, Blanchflower, Oswald and Sanfey 1996 and Hildreth and Oswald 1997, all based on US data, find that there is a strong empirical support for the wage bargaining hypothesis and that estimates for the workers' bargaining power are around a value of 0.9. Obviously this measure may vary a lot across sectors and countries, but this value strikes as being fairly high.

5.1. Ramsey Policy versus Price Stability

A large evidence has shown that many central banks follow Taylor-type rules with a coefficient on inflation bigger than ones. In recent years, most central banks have adopted explicit "inflation targeting" strategies focusing exclusively on inflation. For this reason it is instructive to show the comparison between the dynamic under the Ramsey policy and the dynamic generated by strict inflation targeting rule (Taylor type rules with a high weight on inflation). Figure 4 shows the dynamic of selected variables in response to productivity shocks and under both regimes, Ramsey policy and strict inflation targeting rules. For this comparison the workers' bargaining power is set to 0.6. The rule considered is a standard Taylor rule with parameter on inflation $\phi_\pi = 3$, and parameter on output, $\phi_y = \frac{0.5}{4}$[14]. Three observations arise. First, figure 4 shows that under the optimal plan both inflation and employment are less volatitle; this is so since the Ramsey planner strikes a balance between reducing the cost of adjusting prices and mitigating inefficient unemployment fluctuations. Second, under the Ramsey plan the convergence of inflation and prices toward the steady state is faster as under commitment the policy maker is able to influence future expectations. Third, under the Ramsey plan the initial upward movement of inflation is compensated by the expected overshooting. This time-dependent path is a typical feature of a planner acting under commitment who internalizes the effects of its policies on the future path of inflation.

6. Conclusions

This paper derives optimal monetary policy in a model with monopolistic competition, sticky prices and matching frictions. In response to both productivity and government expenditure shocks, the optimal policy deviates from price stability. This is because search externalities generate an unemployment/inflation trade-off, and the monetary authority has to strike a balance between reducing the cost of adjusting prices and increasing an inefficiently low employment. In response to both shocks the optimal inflation volatility increases with the workers' bargaining power. As the latter increases, the share of surplus allocated

[14] Given the standard assumption about the length of a period (quarterly) and given that Taylor type rules feature an inflation rate defined on annual basis the coefficient on output must then be divided by 4.

to workers increases and firms have little incentives to post vacancies. Under those circumstances the unemployment rate rises above the Pareto efficient one and the monetary authority faces a steeper trade-off between stabilizing inflation and reducing inefficient unemployment fluctuations.

The design of optimal policy in this paper follows a recent research line that analyzes Ramsey plans in new keynesian frameworks with various frictions (see Khan, King and Wolman 2003 and Schmitt-Grohe and Uribe 2004). The public finance approach featured by the Ramsey plan is particularly helpful in disentangling the role of frictions and externalities for the design of optimal policy.

The type of labor market frictions considered in this paper affect mainly labour demand. An interesting extension would be to consider the implications for optimal policy of frictions that affect the labour supply schedule along the extensive margin. One possibility would be to endogeneize the workers' bargaining power so that labour supply depends upon business cycle conditions. Finally more research is needed to assess the monetary policy implications of other mechanisms that induce labour market frictions (alternative bargaining mechanisms, union agreements, insider outsider models, efficiency wages, implicit contracts).

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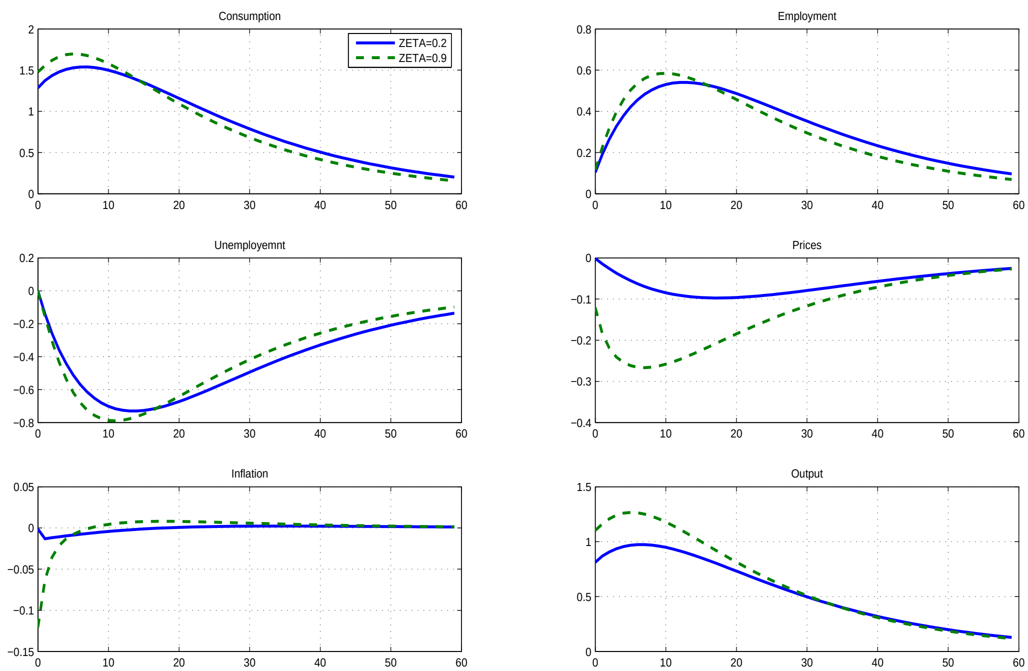

Figure 1: Impulse responses of selected variables under the Ramsey plan to 1% productivity shocks and for two different values of the bargaining power, $\varsigma = 0.2$ and $\varsigma = 0.9$.

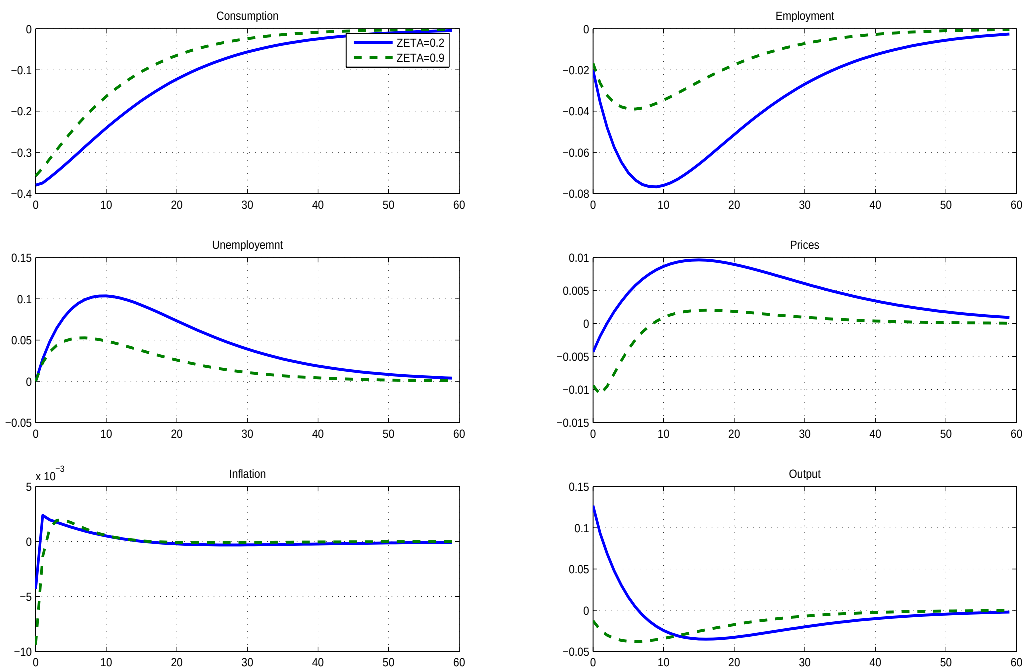

Figure 2: Impulse responses of selected variables under the Ramsey plan to 1% government expenditure shocks and for two different values of the bargaining power, $\varsigma = 0.2$ and $\varsigma = 0.9$.

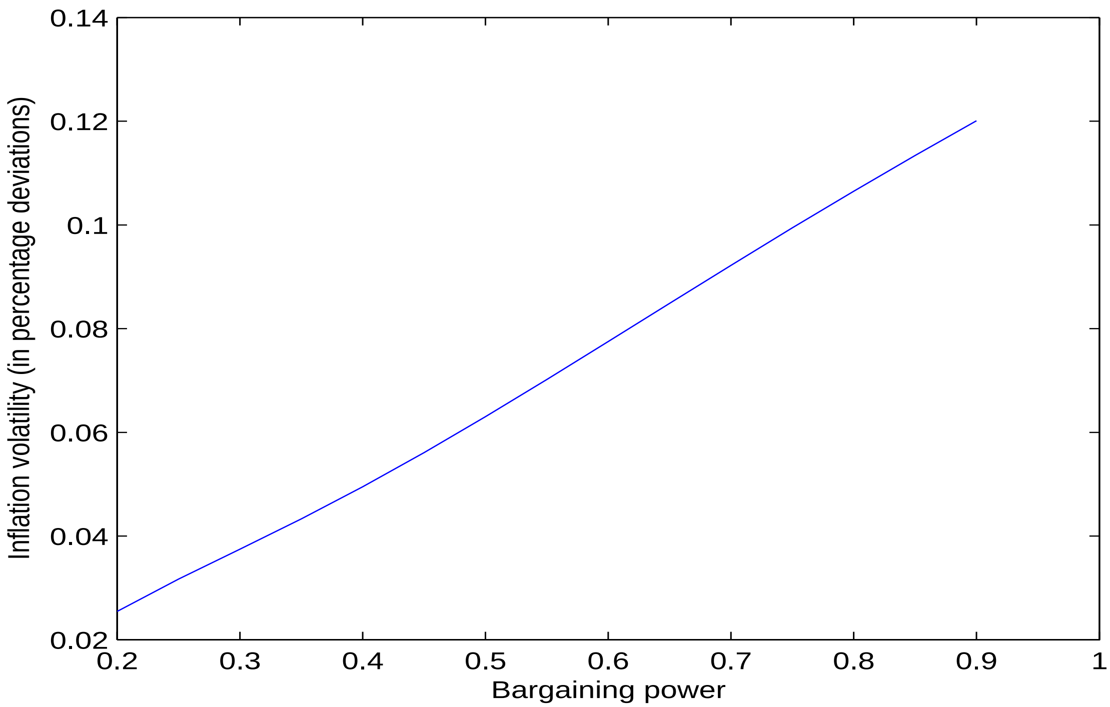

Figure 3: Optimal (Ramsey) volatility of (quarterly) inflation rate (in percentage deviations) for different values of bargaining power, ς. Volatility of inflation is computed in response to both productivity and government expenditure shocks.

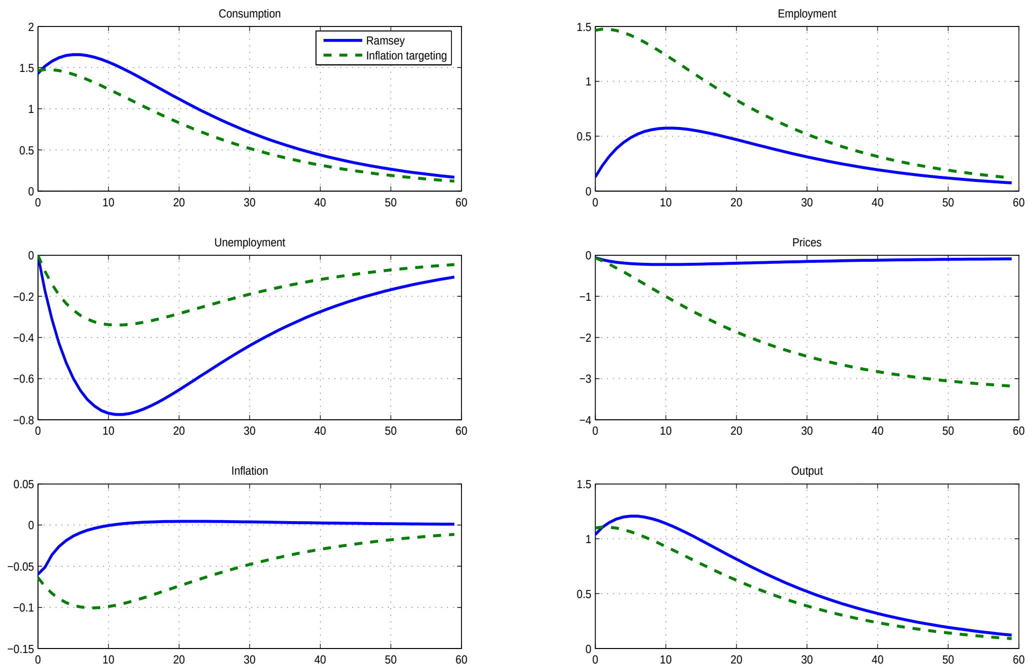

Figure 4: Impulse responses of selected variables to 1% productivity shocks with bargaining power $\varsigma = 0.6$. Comparison between dynamic under the Ramsey plan and dynamic under a strict inflation targeting rule, with the latter identified by the following rule: $\ln\left(\frac{1+r_t^n}{1+r^n}\right) = \left(3\ln\left(\frac{\pi_t}{\pi}\right) + \frac{0.5}{4}\ln\left(\frac{y_t}{y}\right)\right)$