

The Welfare Consequences of Monetary Policy and the Role of the Labor Market*

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Preliminary draft: June 2008

Abstract

We explore the nature of the distortions in sticky-price, labor friction models, and characterize the trade-offs faced by the monetary policymaker in terms of the missing tax instruments that would implement the first best. Our results show that: 1) large welfare gains may be available relative to price stability, depending on the characteristics of the labor market; 2) rigid wages alone do not rationalize deviations from price stability; 3) welfare outcomes can strongly benefit from the coordination between monetary policy and subsidy policies that affect the steady state; 4) economies with more volatile labor flows, as the US, stand to gain more by deviating from price stability.

*Preliminary draft prepared for the Fifth International Research Forum on Monetary Policy, 26-27 June 2008.

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1 Introduction

In standard new Keynesian models, deviations from price stability generate distortions associated with the dispersion of relative prices. However, the baseline model enjoys a property that Blanchard and Gali (2005) have labeled the “divine coincidence;” once the steady-state effects of imperfect competition are corrected through a fiscal subsidy, price stability eliminates the dispersion of relative prices while also ensuring output is at its efficient level.

In the presence of labor market frictions, a steady-state subsidy to firms combined with price stability may not restore the economy to its efficient equilibrium. Additional distortions arise. For example, in the search and matching model of Mortenson and Pissarides, equilibrium unemployment and vacancies can deviate from their efficient levels. And if wages are assumed to be sticky, the economy’s behavior can move further from the efficient first best.

The existence of search frictions adds a novel dimension to the optimal policy problem: if search in the labor market is not efficient, the policymaker can correct the incentives of households and firms and generate the efficient level of employment. To this end, the volatility of inflation must increase, since the outcome of a price-stability policy is to replicate the inefficient equilibrium level of employment that would obtain with flexible prices.

Our objective in this paper is to explore the nature of distortions in sticky-price, labor friction models. What are the trade-offs for monetary policy in the presence of inefficient labor market outcomes? Are these trade-offs relevant for optimal monetary policy? Is price stability a close approximation to the optimal policy? And how do the answers to these questions depend on the structure of the labor market?

To answer these questions, we first derive the tax and subsidy policy that would replicate the efficient, social planner’s equilibrium in a search and matching model of the labor market with both intensive and extensive margins. Since the transfers across the economy are financed lump-sum, they do not generate additional distortions. We then consider the extent to which monetary policy can mimic this optimal tax policy. This allows to understand the exact nature of the distortions that might call for deviations from price stability, and to quantify the impact of these distortions on the dynamics of the economy over the business cycle.

We find that in general three policy instruments are needed to replicate the efficient

equilibrium. A tax on intermediate firms ensures efficient vacancy creation. By doing so, however, the tax distorts the hours choice and so a second tax is needed to ensure that hours are chosen optimally. Finally, fluctuations in the markup that lead to relative price dispersion when prices are sticky can be eliminated by a policy that cancels out retail firms' incentives to change prices.

We then examine how the competing policy goals affect the welfare implications of alternative policies, focusing on the role of wage setting in determining the costs of price stability. We distinguish between two different aspects of wage-setting that are often neglected. The first is whether wage dynamics are consistent with efficient labor market outcomes. The second is whether the steady-state wage is efficient. In contrast to much of the previous literature, we find that a rigid wage has little implication for monetary policy if the wage is fixed at the efficient steady-state level. Since this is a common assumption in the literature, our results are relevant for interpreting previous findings. In contrast, if the wage is fixed at an inefficient level, the distortions generated by wage rigidity are much larger, and we find a correspondingly larger role for deviations from price stability. Our results show that deviating from price stability can yield welfare gains in the order of one half percent - an order of magnitude larger than in the standard new Keynesian model - simply because search frictions may prevent an efficient response to technology shock. In addition, the cost of suboptimal policies increases proportionally.

We discuss the impact of the novel trade-offs on the welfare results using the tax policy optimality conditions. We conjecture that in an inefficient steady state, whether deviations from price stability are welfare improving depends on two factors: the increasing inefficiency of the flexible price equilibrium as the economy moves away from the first-best steady state, and the cost from using symmetric policy rules when it would be optimal to respond asymmetrically to negative and positive shocks. We conclude that in an environment with search frictions, welfare outcomes can strongly benefit from the coordination between monetary policy and subsidy policies that affect the steady state.

Finally we explore how the role for monetary policy might vary across the US and the European Union, economies with important labor market differences.

Our paper is related to several important contributions in the literature. Erceg, Henderson and Levin (1999) and Levin, Onatski, Williams and Williams (2005) showed that inefficient wage dispersion can be as or more costly than inefficient price dispersion in a new Keynesian model with staggered wage and price setting.

A growing number of papers have attempted to incorporate search and matching

frictions into new Keynesian models. Examples include Walsh (2003, 2005), Trigari (2004), Christoffel, Kuester, and Linzert (2006), Blanchard and Galí (2006), Krause and Lubik (2005), Barnichon (2006), Thomas (2006), Gertler and Trigari (2006), Gertler, Sala, and Trigari (2007), and Ravenna and Walsh (2007). The focus of these earlier contributions has extended from exploring the implications for macro dynamics in calibrated models to the estimation of DSGE models with labor market frictions.

Blanchard and Galí (2006), like Ravenna and Walsh (2007), derive a linear Phillips curve relating unemployment and inflation. Like the present paper, Blanchard and Galí use their model to explore the implications of labor market frictions for optimal monetary policy. However, they restrict their attention to a linear-quadratic framework and to the efficient steady state.

In a sticky-price model with search and matching frictions, Faia (2008) finds price stability closely approximates the optimal policy. The welfare gains from deviating from price stability are small, and the central bank can replicate the loss achieved under the optimal policy by responding strongly to both inflation and unemployment. She argues that responding to unemployment fluctuations serves to offset externalities generated by the matching process.

Thomas (2008) introduces nominal price and wage-staggering à la Calvo in a business cycle model with search frictions in the labor market and finds that price stability is no longer the optimal policy. The cost of employing a price-stability policy reflects partly the cost already highlighted in Erceg, Henderson and Levin (inefficient wage dispersion) and partly the cost of inefficient job creation resulting from wage dispersion. The latter cost - which is the cost directly related to the existence of search frictions - plays only a minor role. In fact, introducing a constant wage norm results in price stability being virtually coincident with the optimal policy. Thus, it appears that search frictions themselves do not necessarily imply that the standard policy prescription of price stability should change.

In our model we take seriously the possibility that search frictions may have far-ranging implications for policymaking. Therefore we do not assume staggered wage setting, and depart from the Erceg, Henderson and Levin (1999) framework. Compared to the wage-staggering setup, the added value of our approach is threefold. First, policy prescriptions depend in a complex way on the interaction of the wage setting mechanism and the institutional incentives to search and post vacancies, and are thus likely to change across different economies. Second, the gain from optimal monetary policy may

be large, and the gain is not related to the degree of 'stickiness' in wage adjustment. Third, the gain from optimal policy is related directly to the behaviour of employment and unemployment.

The paper is organized as follows. In the next section, we develop the basic model. Section 3 describes the tax policy that would achieve the efficient equilibrium. We use the taxes and subsidies to identify the nature of the trade-offs a monetary authority faces. The welfare consequences of monetary policy are explored in section 4, while section 5 examines further the nature of the competing goals of monetary policy. Section 6 compares outcomes under alternative parameterizations of the model meant to capture key differences between the EU and the US labor markets. Conclusions are summarized in the final section.

2 Model economy

The model consists of households whose utility depends on the consumption of market and home produced goods. As in Mortensen and Pissarides (1994) households members are either employed (in a match) or searching for a new match. Households are employed by wholesale goods producing firms operating in a competitive market for the goods they produce. Wholesale goods are, in turn, purchased by retail firms who sell to households. The retail goods market is characterized by monopolistic competition. In addition, retail firms have sticky prices that adjust according to a standard Calvo specification. Locating labor market frictions in the wholesale sector where prices are flexible and locating sticky prices in the retail sector among firms who do not employ labor provides a convenient separation of the two frictions in the model. A similar approach was adopted in Walsh (2003, 2005), Trigari (2005), and Thomas (2006). The market clearing conditions are reported in the Appendix.

2.1 Labor Flows

At the start of each period t , N_{t-1} workers are matched in existing jobs. We assume a fraction ρ ($0 \leq \rho < 1$) of these matches exogenously terminate. To simplify the analysis, we ignore any endogenous separation.¹ The fraction of the household members who are

¹Hall (2005) has argued that the separation rate varies little over the business cycle, although part of the literature disputes this position (see Davis, Haltiwanger and Schuh, 1996). For a model with endogenous separation and sticky prices, see Walsh (2003).

employed evolves according to

$$N_t = (1 - \rho)N_{t-1} + p_t s_t$$

where p_t is the probability of a worker finding a match and

$$s_t = 1 - (1 - \rho)N_{t-1} \tag{1}$$

is the fraction of searching workers. Thus, we assume workers displaced at the start of period t have a probability p_t of finding a new job within the period (we think of a quarter as the time period). Note that unemployment as measured after period t hiring is equal to $u_t \equiv 1 - N_t$.

2.2 Households

Households purchase a basket of differentiated goods produced by retail firms. We assume standard Dixit-Stiglitz preferences. Since the problem of minimizing the cost of a given level of the consumption bundle and optimally allocating consumption over time are standard, we focus here chiefly on the decision that relate to labor market behavior.

Assume each worker values consumption and leisure according to the per-period separable utility function:

$$U_t = U(C_{zt}) - V(h_t)$$

where $h_t = 1 - l_t$ and l_t is hours of leisure enjoyed by the worker. Risk pooling implies that the optimality conditions for workers can be derived from the utility maximization problem of a large representative household choosing $\{C_{t+i}, h_t, B_{t+i}\}_{i=0}^{\infty}$ where C_t is average consumption of the household member, and in equilibrium is equal across all members:

$$\begin{aligned} W_t(N_t, B_t) &= \max U(C_t) - V(h_t, N_t) + \beta E_t W_{t+1}(N_{t+1}, B_{t+1}) \\ st \quad P_t C_t + p_{bt} B_{t+1} &\leq P_t [w_t h_t N_t + w^u (1 - N_t)] + B_t + P_t \Pi_t^r \\ V(h_t, N_t) &= N_t V(h_t) \\ &= N_t \frac{\ell h_t^{1+\gamma}}{1+\gamma} \\ C_t^m &\leq \left[\int_0^1 C_t^m(j)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}} \end{aligned}$$

where P_t is the price of a unit of the consumption bundle, Π_t^r are profits from the retail sector, and B_t is the amount of riskless nominal bonds held by the household with price equal to p_{bt} . Consumption of market goods supplied by the retail sector is equal to $C_t^m = C_t - (1 - N_t)w^u$. We include w^u as the home production of consumption goods. A similar specification would be obtained in a model where there is no household production but a separate fixed disutility of being employed is introduced along with the disutility of hours worked.

The intertemporal first order conditions yield the standard Euler equation:

$$\lambda_t = \beta E_t \{ R_t \lambda_{t+1} \},$$

where R_t is the gross return on an asset paying one unit of consumption aggregate in any state of the world and λ_t is the marginal utility of consumption.

From the perspective of a worker, the value of a filled job is given by

$$W'_{N_t} \equiv V_t^S = -w^u + w_t h_t - \frac{V'_{N_t}}{U'_{C_t}} + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^S (1 - \rho)(1 - p_{t+1})$$

where $p_t = \frac{M_t}{s_t} = \theta_t q(\theta_t)$ is the probability of a worker finding a position.

2.3 Wholesale Firms

Wholesale firms operate in competitive output markets and sell their production at the price P_t^w . Production by wholesale firm i is

$$\begin{aligned} Y_{it}^w &= f_t(A_t, N_{it} h_{it}) \\ \log(A_t) &= \rho_a \log(A_{t-1}) + \varepsilon_{at} \end{aligned}$$

f_t is a CRS production function. To post a vacancy, a wholesale firms must pay a cost $P_t \kappa$ for each job posting. Since job postings are homogenous with final goods, effectively wholesale firms buy individual final goods $v_t(j)$ from each j final-goods-producing retail firm so as to minimize total expenditure, given that the production function of a unit of final good aggregate v_t is given by

$$\left[\int_0^1 v_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}} \geq v_t.$$

Define $f'_t = \frac{\partial f_t}{\partial N_t h_t}$ as the marginal product of a work-hour. The firm's optimization problem gives the first order condition

$$V_t^J = \frac{\kappa}{q(\theta_t)} = \frac{f'_t h_t}{\mu_t} - w_t h_t + (1 - \rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{\kappa}{q(\theta_{t+1})}. \quad (2)$$

where V_t^J is the value to the firm of a filled vacancy.

2.4 Wages under Nash bargaining

Assume the wage is set in Nash bargaining with the worker's share equal to b . Nash bargaining implies

$$\frac{b\kappa}{q(\theta_t)} = (1 - b) \left(w_t h_t - w^u - \frac{V'_{N_t}}{U'_{C_t}} \right) + (1 - \rho) \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) [1 - \theta_{t+1} q(\theta_{t+1})] \frac{b\kappa}{q(\theta_{t+1})}.$$

Combining this equation with the wholesale firms' FOC, one obtains an expression for the real wage bill:

$$w_t h_t = (1 - b) \left(w^u + \frac{V'_{N_t}}{U'_{C_t}} \right) + b \left[\frac{f'_t h_t}{\mu_t} + (1 - \rho) \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \kappa \theta_{t+1} \right]. \quad (3)$$

The outcome of Nash bargaining over hours is equivalent to a setup where hours maximize the joint surplus of the match:

$$\frac{f'_t}{\mu_t} - \frac{V''_{N_t h_t}}{U'_{C_t}} = 0 \quad (4)$$

where $V''_{N_t h_t} = \partial V(h_t, N_t) / \partial N_t \partial h_t$.

2.5 Marginal cost

Define $\frac{P_t^w}{P_t} = \frac{1}{\mu_t}$ as the inverse of the retail sector markup. This quantity is at the same time the marginal revenue of the wholesale sector MR_t and the marginal cost of the retail sector MC_t . The intermediate firm's first order condition (2) can be rewritten as:

$$MR_t = \frac{1}{f'_t h_t} \left\{ w_t h_t + \frac{\kappa}{q(\theta_t)} - (1 - \rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{\kappa}{q(\theta_{t+1})} \right\} \quad (5)$$

$$= MC_t \quad (6)$$

In a model with both extensive and intensive margins, eq. (4) implies that $1/\mu_t = MC_t$ is also equal in equilibrium to the ratio of the marginal rate of substitution between hours and consumption for the worker, and the marginal product of labor of an additional hour. With $V(h_t, N_t) = N_t V(h_t)$ and $f_t = A_t N_t h_t$ we obtain:

$$MC_t = \frac{1}{\mu_t} = \frac{V''_{N_t h_t}}{U'_{C_t}} A_t^{-1} \quad (7)$$

Contrary to the standard new Keynesian model, $\frac{V''_{N_t h_t}}{U'_{C_t}} \neq w_t$. The equality between eq. (5) and (7) simply states that at optimum the cost of producing the marginal unit of output by adding an extra hour of work must be equal to the hourly cost φ_t/h_t in units of consumptions of producing the marginal unit of output by adding an extra worker:

$$MC_t = \varphi_t / A_t h_t$$

$$\varphi_t \equiv \frac{V'_{N_t}}{U'_{C_t}} + w^u + \left(\frac{1}{1-b} \right) \left\{ \frac{\kappa}{q(\theta_t)} - \beta(1-\rho) E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) [1 - b\theta_{t+1}q(\theta_{t+1})] \frac{\kappa}{q(\theta_{t+1})} \right\} \quad (8)$$

where eq. (8) follows from eqs. (2), (3). If the firm could freely choose to employ an additional hour of work, it would not pay any search cost - the match is already in place - and would have to compensate the worker with an hourly wage equal to mrs_t/f'_t where $mrs_t = \frac{V''_{N_t h_t}}{U'_{C_t}}$. With search frictions and Nash bargaining setting both hours and wage, the marginal cost cannot be interpreted any more as the derivative with respect to hours of a cost function faced by the firm.

2.6 Retail firms

Each retail firm purchases wholesale output which it converts into a differentiated final good sold to households and wholesale firms. The retail firms cost minimization problem implies

$$MC_t^n = P_t^w$$

where MC_t^n is the nominal marginal cost $P_t MC_t$.

Retail firms adjust prices according to the Calvo updating model. Each period a firm can adjust its price with probability $1 - \omega$. Since all firms that adjust their price are identical, they all set the same price. Given MC_t^n , the retail firm chooses $P_t(j)$ to

maximize

$$\sum_{i=0}^{\infty} (\omega\beta)^i E_t \left[\left(\frac{\lambda_{t+i}}{\lambda_t} \right) \frac{P_t(j) - MC_{t+i}^n}{P_{t+i}} Y_{t+i}(j) \right]$$

subject to

$$Y_{t+i}(j) = Y_{t+i}^d(j) = \left[\frac{P_t(j)}{P_{t+i}} \right]^{-\varepsilon} Y_{t+i}^d \quad (9)$$

where Y_t^d is aggregate demand for the final goods basket. The retail firm optimality condition can be written as:

$$P_t(j) E_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i} = \frac{\varepsilon}{\varepsilon-1} E_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) MC_{t+i}^m \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i} \quad (10)$$

If firms' price adjustment were not constrained, in a symmetric equilibrium all firms would charge an identical price, so as to meet the optimality condition:

$$MC_t = \frac{1}{\mu} \quad (11)$$

where $\mu = \frac{\varepsilon}{\varepsilon-1}$.

2.7 Efficient Equilibrium

The planner solves the problem:

$$W_t(N_t) = \max U(C_t) - V(h_t, N_t) + \beta E_t W_{t+1}(N_{t+1})$$

$$\begin{aligned}
st \quad C_t &\leq C_t^m + w^u(1 - N_t) \\
Y_t^w &\leq f_t(A_t, N_t h_t) \\
Y_t^w &= \int_0^1 Y_t^w(j) dj \\
Y_t^w(j) &= C_t^m(j) + \kappa v_t(j) \\
v_t &\leq \left[\int_0^1 v_t(j)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}} \\
C_t^m &\leq \left[\int_0^1 C_t^m(j)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}} \\
V(h_t, N_t) &= N_t V(h_t) \\
N_t &= (1 - \rho)N_{t-1} + M_t \\
M_t &= \eta v_t^\xi s_t^{(1-\xi)} \\
s_t &= 1 - (1 - \rho)N_{t-1}
\end{aligned}$$

where M_t is the number of new matches per period, and η measures the efficiency of the matching technology. The optimal choice of j -good consumption and firm's labor search input is given by:

$$C_t(j) = C_t \quad \forall j \in [0, 1] \quad (12)$$

$$v_t(j) = v_t \quad \forall j \in [0, 1] \quad (13)$$

The condition for efficient vacancy posting is:

$$\frac{\kappa}{M'_{v_t}} = f'_t h_t - \left(w_u + \frac{V'_{N_t}}{U'_{C_t}} \right) + \beta (1 - \rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (1 - M'_{s_{t+1}}) \frac{\kappa}{M'_{v_{t+1}}} \right\} \quad (14)$$

where M'_x is the derivative of the matching function with respect to its argument x . The condition for efficient hours choice is

$$f'_t N_t = \frac{V'_{h_t}}{U'_{C_t}}$$

which, given the disutility of labor is linear in N_t , gives

$$f'_t = \frac{V''_{N_t h_t}}{U'_{C_t}} \quad (15)$$

3 Trade-offs in an Economy with Search Frictions: a Tax Interpretation

In standard new Keynesian models where $\kappa = 0$ a constant tax policy is often assumed to eliminate the steady state distortion arising from monopolistic competition, allowing the single instrument of monetary policy to address the distortions generated by sticky prices. A policy of zero-inflation stabilizes the markup μ_t at its efficient steady state level. In turn, a constant markup $\mu_t = 1$ ensures that *all* the planner's first order conditions are satisfied:

$$\begin{aligned} f'_t &= \frac{V''_{N_t h_t}}{U'_{C_t}} \\ C_t(j) &= C_t \quad \forall j \in [0, 1] \end{aligned}$$

where $\frac{V''_{N_t h_t}}{U'_{C_t}}$ is the marginal rate of substitution between hours and consumption. With search frictions, eliminating the effects of imperfect competition and nominal rigidity does not necessarily generate the first best allocation unless the decentralized wage bargain replicates the planner's solution. In general, not only staggered wage-adjustment mechanisms but also period-by-period wage bargaining that is incentive-compatible from the perspective of the worker and firm but which result in deviations from the efficient vacancy posting condition (14) yield labor allocations that are socially inefficient. Within the search and matching model, the existence of search frictions implies monetary policy has to trade-off three separate goals: inefficient price dispersion, socially inefficient worker-firm matching that result in a misallocation of labor, and misallocation of labor hours. These inefficiencies can be described in terms of deviations from the first order conditions (12), (13), (14) and (15).

To highlight the role each trade-off plays in the choice of an optimal policy, we build the tax and subsidy policy that replicates the efficient equilibrium. We assume the policymaker can use as many instruments as necessary to correct the incentives of households and firms when the market equilibrium cannot deliver the efficient allocation. This policy is in effect a set of transfers across the economy that can be financed lump-sum. Therefore the policymaker is not solving an optimal taxation problem, and can always replicate the first best allocation. We will refer to this system of transfers as a tax policy, since the policy instruments are distortionary in order to affect the incentives of the private

sector. In the absence of the optimal set of taxes, monetary policy is constrained to rely on a single instrument. This limits the welfare improvement achievable through optimal monetary policy.

3.1 Tax Policy with Flexible Prices

In a labor market with search frictions, the probability of an unemployed worker finding a match depends negatively on the search effort of other workers. In the same way, the probability of a vacancy being filled depends negatively on the vacancy posting of other firms. In general, workers and firms ignore the impact of their choices on the transition probabilities of other workers and firms, resulting in a negative externality within each group. On the contrary, there exist positive externalities between groups, and each worker and firm would like the group where to find a match to be as full as possible. The planner's solution takes into account the externalities.

In the disaggregated equilibrium, the first order condition for retail firms is given by eq. (11). Provided an appropriate subsidy to retail production ensures the monopolistic distortion associated with a positive markup is eliminated ($\mu = 1$), the Hosios condition holds in our model: when the surplus share accruing to the firm ($1 - b$) is equal to the elasticity of the matching function ξ , the flexible-prices disaggregated equilibrium replicates the efficient allocation.

Whenever $(1 - b) \neq \xi$ the Nash-bargained real wage results in inefficient vacancy posting. Among the tax schemes that could correct this distortion, we choose a policy that modifies the intermediate firm's incentives by affecting its revenues. Assume after-tax revenues of the intermediate firm are given by $Y_{it}^w \frac{\tau_t}{\mu_t}$, where $(\tau_t - 1)$ is the tax rate. The tax policy results in an effective after-tax markup for the firm of $\mu_t^* \equiv \mu_t / \tau_t$. This specification implies that a monetary policy trying to replicate the allocation implied by the tax policy τ_t would need to generate the same time-varying markup μ_t^* as occurs under the tax policy. Thus, monetary policy can be described in terms of a rule for the retail markup. While the monetary authority does not control directly the markup, we find this interpretation appealing, since a constant markup corresponds to a policy of price stability. Therefore, deviations of the markup from a constant value map into deviations from price stability, and into CPI inflation volatility.

Once the tax policy is included, the first order condition for the intermediate firms is:

$$V_t^J = \frac{\kappa}{q(\theta_t)} = f_t' h_t \left(\frac{\tau_t}{\mu_t} \right) - w_t h_t + (1 - \rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{\kappa}{q(\theta_{t+1})}. \quad (16)$$

Using the planner first order condition (14) and the equilibrium conditions $q_t = \frac{M_{v_t}'}{\xi}$ and $p_t = \frac{M_{s_t}'}{1-\xi}$, the optimal tax policy for any hourly wage w_t is

$$\frac{\tau_t}{\mu_t} = \frac{w_t}{f_t'} + \frac{1}{f_t' h_t} \xi \left[f_t' h_t - \left(w_u + \frac{V_{N_t}'}{U_{C_t}'} \right) - \beta (1 - \rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{M_{s_{t+1}}' \kappa}{M_{v_{t+1}}'} \right\} \right]. \quad (17)$$

The disaggregated equilibrium condition (7) is identical to the planner's first order condition (15) once the monopoly distortion is corrected by a tax policy, so that conditional on C_t being at the first best level the hours choice is efficient. To this end, intermediate firms' revenues should be subsidized at a gross rate equal to μ_t . However, eq. (17) shows that in general $\tau_t \neq \mu_t$. To correct the resulting distortion in hours' choice, a second tax, τ_t^h , is required. This tax affects the household's opportunity cost of being employed $V(h_t, N_t)$ so that the hours optimality condition becomes:

$$f_t' \left(\frac{\tau_t}{\mu_t} \right) = \frac{V_{N_t h_t}'' \tau_t^h}{U_{C_t}'} \quad (18)$$

The optimal tax τ_t^h is given by

$$\tau_t^h = \frac{\tau_t}{\mu_t}. \quad (19)$$

The tax τ_t^h also affects the household's surplus from being in a match:

$$V_t^S \equiv w_t h_t - \tau_t^h \left(w_u + \frac{V_{N_t}'}{U_{C_t}'} \right) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^S (1 - \rho) (1 - p_{t+1}) \quad (20)$$

where, without loss of generality, we assume the gross tax rate also affects the value of home production w_u . Using eqs. (14), (16), (19) and (18), the optimal tax τ_t when wages are set according to Nash bargaining can be written as:

$$\begin{aligned} \frac{\tau_t}{\mu_t} &= \frac{1}{f_t' h_t} \left(\frac{\tau_t^h (1 - b) - \xi}{(1 - b)} \right) \left(w_u + \frac{V_{N_t}'}{U_{C_t}'} \right) \\ &+ \frac{\xi}{(1 - b)} \left\{ 1 - \frac{1}{f_t' h_t} \beta (1 - \rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(1 - \frac{b}{1 - \xi} \right) \frac{M_{s_{t+1}}' \kappa}{M_{v_{t+1}}'} \right] \right\} \end{aligned} \quad (21)$$

This can be simplified to derive a condition similar to eq. (17) :

$$\begin{aligned} \frac{\tau_t}{\mu_t} = & \frac{1}{f'_t h_t} \tau_t^h \left(w_u + \frac{V'_{N_t}}{U'_{C_t}} \right) + \\ & \frac{1}{f'_t h_t (1-b)} \left\{ f'_t h_t - \left(w_u + \frac{V'_{N_t}}{U'_{C_t}} \right) - \beta (1-\rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(1 - \frac{b}{1-\xi} \right) \frac{M'_{s_{t+1}} \kappa}{M'_{v_{t+1}}} \right] \right\} \end{aligned} \quad (22)$$

Finally, using eq. (19) the tax τ_t^h can be eliminated:

$$\frac{\tau_t}{\mu_t} = \frac{\xi}{(1-b)} \left\{ 1 - \left[f'_t h_t - \left(w_u + \frac{V'_{N_t}}{U'_{C_t}} \right) \right]^{-1} \beta (1-\rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(1 - \frac{b}{1-\xi} \right) \frac{M'_{s_{t+1}} \kappa}{M'_{v_{t+1}}} \right] \right\}$$

For $\xi = (1-b)$ the intermediate firms' tax is $\tau_t = \mu_t$. That is, when the Hosios condition holds, labor market outcomes are efficient so the tax policy should simply offset any time variation in the markup and ensure the after-tax markup μ_t^* remains constant and equal to one.

Retail pricing is efficient provided retail revenues are subsidized to offset the steady-state markup μ . This requires a gross subsidy rate τ_{ss}^f such that

$$\tau_{ss}^f = \mu. \quad (23)$$

In this case, the retail firm's first order condition becomes

$$\tau_{ss}^f = \mu (P_t^w / P_t), \quad (24)$$

implying $P_t^w = P_t$. As in standard new Keynesian models of optimal monetary policy, we will assume in the following the tax policy τ_{ss}^f is enforced in any equilibrium.

We assume all taxes (subsidies) are financed through lump-sum transfers to the household, so that the government budget constraint is balanced in each period. The Appendix derives the equilibrium transfers ensuring market clearing, and shows that the resulting equilibrium enforces the planner's (first best) allocation.

To summarize this discussion, there are three distortions in the model, and the policymaker needs to use three separate tax instruments τ_t , τ_t^h , and τ_{ss}^f to enforce an efficient equilibrium. τ_{ss}^f offsets the steady-state distortion from imperfect competition, τ_t ensures efficient vacancy posting, and τ_t^h corrects the distortions in hours that would otherwise

arise when τ_t differs from μ_t . These taxes modify the first order conditions for intermediate and final firms, eqs. (16), (18), (24).

3.2 Policy Trade-offs and Tax-equivalent Monetary Policies

When prices are set according to the Calvo adjustment mechanism, the first order condition for a retail firm is given by eq. (10) rather than by eq. (11). In this case, since the subsidy to retail firms τ_{ss}^f only ensures efficient pricing in the steady state, the two tax instruments τ_t and τ_t^h are not sufficient to enforce the efficient allocation. Monetary policy can be used as the third cyclical policy instrument. The efficient allocation is obtained when all retail goods are homogeneously priced and conditions (12), (13) are met. This can be achieved by completely stabilizing prices, that is, adjusting monetary policy until ²

$$\mu_t = 1. \tag{25}$$

In a new Keynesian model with search frictions, the markup μ_t affects equilibrium through two separate channels. First, variations in μ_t change the incentives for vacancies and hours choice in the intermediate sector. Second, variations in μ_t generate retail price dispersion. The tax τ_t corrects the impact of μ_t on the vacancies choice. The tax τ_t^h corrects the impact of τ_t/μ_t on the hours choice. While the tax policy provides the intermediate firm with the optimal level of real marginal revenue $MR_t = \tau_t/\mu_t$ (since each unit sold is subsidized at the gross rate τ_t), it still leaves the retail firm's marginal cost $MC_t = 1/\mu_t$ free to fluctuate inefficiently. The monetary policy in eq. (25) prevents the resulting inefficient price dispersion by canceling out the incentive to change prices.

Assume now that a tax policy is unavailable, so that $\tau_t = \tau_t^h = 1 \forall t$ in eqs. (16), (18), (20). The monetary authority can still choose to stabilize the markup as in the policy rule (25). The alternative choice of enforcing the vacancy posting condition given by eqs. (16) and (17) is also available. In fact, for any policy rule for μ_t , the quantity

²For a tax policy to enforce the efficient allocation conditional on *any* monetary policy, the retail firms input price should be taxed (or subsidized) at a gross rate τ_t^f so that, in equilibrium, $MC_t^m = \tau_t^f P_t^w$ is constant. Since a constant nominal marginal cost would not give any incentive to change prices (see eq. 10), this tax policy would ensure $P_t(i) = P_t(j) = P \forall i, j$ so that there is no price dispersion. This policy runs into two difficulties. First, for any policy resulting in non-stationary nominal quantities, τ_t^f would also be non-stationary. Second, retail firms need to predict that any future variation in P_t^w will be completely offset by the subsidy, since the pricing first order condition depends on the expected future stream of marginal costs. Any policy that would not completely stabilize prices would generate price dispersion because of the staggered pricing assumption.

μ_t^{gap} defined as

$$\mu_t^{gap} = \frac{\mu_t}{\mu_t^*},$$

where

$$\frac{1}{\mu_t^*} = \frac{w_t}{f_t'} + \frac{1}{f_t' h_t} \xi \left[f_t' h_t - \left(w_u + \frac{V_{N_t}'}{U_{C_t}'} \right) - \beta (1 - \rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{M_{s_{t+1}}'}{M_{v_{t+1}}'} \right\} \right], \quad (26)$$

is the distance between the markup resulting from the current monetary policy and the markup that would enforce the planner's vacancy posting condition. Thus, the policy rule given by

$$\mu_t = \mu_t^*$$

returns the first order condition that would obtain under the optimal tax policy τ_t/μ_t in eq. (17). Eq. (26) defines the 'notional tax' that the monetary authority could impose on intermediate firms.

Minimizing the volatility of the markup gap would impose only one of the three policies needed to enforce the efficient equilibrium. The monetary authority has two additional, competing goals. The first one is efficient hours choice. The second one is zero price dispersion. Neither of these two objectives can be achieved imposing the notional tax $1/\mu_t^*$ on intermediate firms.

Eq. (18) stipulates that efficient hours choice would call for an additional tax τ_t^h which is no longer available. Any choice of $\mu_t \neq 1$ then generates a gap between the actual hours/consumption marginal rate of substitution mrs_t and the marginal rate of substitution mrs_t^* that enforces the planner's first order condition (15):

$$mrs_t^{gap} = \frac{mrs_t}{mrs_t^*} = \frac{1}{\mu_t}$$

where the second equal sign follows from (18), $mrs_t^* = f_t'$. Notice that the markup gap is in fact equal to the optimal tax τ_t while the marginal rate of substitution gap is equal to the inverse of the markup μ_t .

Eq (25) requires monetary policy to set μ_t equal to a constant. This policy prevents inefficient price dispersion by canceling out the incentive to change prices. The monetary policy designed to get efficient unemployment behavior by ensuring $\mu_t = \mu_t^*$ might instead imply large movements in μ_t over the business cycle, resulting in volatile inflation,

significant price dispersion, and a reduction in the amount of final good available for consumption relative to the efficient equilibrium.³

A monetary policy that stabilizes prices, while failing to correct the distortion in vacancies posting, as the tax policy τ_t would call for, does allow for the hours' choice to be set in the same way as if the tax τ_t^h were available. As in the standard new Keynesian setup, zero-inflation and optimal hours allocation are not mutually exclusive goals. This is though the consequence of two simplifying assumptions: the separation between retail and intermediate firms, so that pricing decisions do not affect hours choice, and the Nash bargaining hours-setting mechanism.

Hence, within our simple setup, the monetary authority can pursue any of the two tax-equivalent policies. It can stabilize μ_t^{gap} or it can stabilize mrs_t^{gap} and π_t . It cannot enforce all of the three efficiency conditions simultaneously.

4 The Welfare Consequences of Monetary Policy

While there exists a potential role of monetary policy in eliminating the distortions in the economy, the actual welfare costs of relying on monetary policy when the full set of policy instrument is unavailable depends on the sensitivity of households' utility to each distortion. Since we wish to characterize not only the relative welfare cost of alternative policies, but also their absolute level, we resort to a numerical approach. Importantly, the numerical approach offers the possibility of investigating optimal monetary policy-making when the economy is away from the efficient steady state. Ravenna and Walsh (2008) derive analytical results for the optimal monetary policy in a model with only the extensive margin approximated around the efficient steady state.

4.1 Parameterization

We derive the parameters η , ℓ , and κ as implied by observable steady state values in the efficient equilibrium, and derive all welfare results assuming these parameters are unchanged. The consequence of this choice is that models with alternative wage setting mechanisms will result in different steady state values for variables such as unemployment, hours, labor market tightness. The volatility of the technology shock innovation is set so

³This is because $Y_t^w = Y_t^d \psi_t$ where ψ_t is defined as $\psi_t \equiv \int_0^1 \left[\frac{P_t(z)}{P_t} \right]^{-\varepsilon} dz$ and is equal to 1 only for constant zero inflation.

as to match the volatility of US non-farm business sector output over the post-war period conditional on the original Taylor rule (Taylor 1993).

Calibrated values of the parameters are reported in Tables 1 and 2. The parameterization is consistent with empirical evidence for the US postwar sample (for related parameterized business cycle models, see Blanchard and Gali, 2006, Christoffel and Linzert, 2005). Without loss of generality, we assume a zero-replacement ratio, implying $w_u = 0$ and an opportunity cost of labor that depends only on the disutility of labor hours.

Table 1: Efficient Equilibrium Parameter Values		
Exogenous separation rate	ρ	0.1
Vacancy elasticity of matches	ξ	0.5
Workers' share of surplus	b	0.5
Replacement ratio	ϕ	0
Steady state vacancy filling rate	q_{ss}	0.7
Steady state employment rate	N_{ss}	0.95
Steady state hours	h_{ss}	0.3
Steady state inflation rate	π_{ss}	0
Discount factor	β	0.99
Relative risk aversion	σ	1
Inverse of labor hours supply elasticity	γ	0.5
AR(1) parameter for technology shock	ρ_a	0.95
Volatility of technology innovation	σ_{ε_a}	0.55%
<i>Calvo pricing parameter values</i>		
Price elasticity of retail goods demand	ε	6
Average retail price duration (quarters)	$\frac{1}{1-\omega}$	3.33
Steady state markup	μ	1

Table 2: Implied Parameter Values from Efficient Equilibrium		
Efficiency of matching technology	η	0.677
Scaling of labor hours disutility	ℓ	6.684
Job finding probability	p_{ss}	0.65
Cost of vacancy posting	κ	0.087

4.2 Welfare Measure and Policy Rule

To measure the welfare implications of alternative policies, we compare the welfare level generated by policy a with a reference level of welfare r which is generated by a given benchmark policy. Consider our specification with separable preferences in consumption $U(C_t)$ and hours worked $V(h_t, N_t)$. Under the policy regime r and a the household welfare is, respectively:

$$\begin{aligned} V_0^r &= E_0 \sum_{t=0}^{\infty} \beta^t \{ \ln C_t^r - V(h_t^r, N_t^r) \} \\ V_0^a &= E_0 \sum_{t=0}^{\infty} \beta^t \{ \ln C_t^a - V(h_t^a, N_t^a) \} \end{aligned}$$

Following Schmitt-Grohe and Uribe (2007) we measure the welfare cost of policy a relative to policy r as the fraction λ of the expected consumption stream under policy r that the household would be willing to give up to be as well off under policy a as under policy r :

$$V_0^a = E_0 \sum_{t=0}^{\infty} \beta^t \{ \ln C_t^r (1 - \lambda) - V(h_t^r, N_t^r) \}$$

The fraction λ is computed from the solution of the second order approximation to the model equilibrium around the deterministic steady state.

We derive the optimal policy by searching over all possible parameterizations of ω_n, ω_a belonging to the set P for the policy rule

$$\dot{i}_t = \omega_n n_{t-1} + \omega_a a_t \tag{27}$$

where lower-case letters indicate the log-deviation of a variable from the steady state. The numerical search covers the interval $[-2, 2]$ for ω_n and ω_a . While we restrict our attention to a simple linear policy rule, notice that any Markovian policy can be written as eq. (27) up to first order since n_{t-1} and a_t are the only state variables of the model. This family of policies includes the time-consistent optimal policy obtained in the familiar linear-quadratic setup (see Blanchard and Gali, 2006, Woodford, 2001). Our assumption for the policy rule implies we are not in a position to find the global optimal policy, which we recognize as an important benchmark but often yielding complex, highly model-dependent

policies (the welfare implications of Ramsey policies in a model with search frictions are described in Faia, 2008). We will show that, in some instances, simply adding a partial interest rate adjustment mechanism delivers a welfare improvement.⁴

Our analysis is focused on the implications of labor market frictions for the cyclical behaviour of monetary policy. We assume that the monetary authority in steady state pursues a constant (zero) inflation policy. This assumption reflects the long-term commitment of the vast majority of central banks to price stability.

4.3 Welfare Results and Optimal Monetary Policy

If nominal rigidities exist, monetary policy may achieve an equilibrium close to the planner solution by deviating from price stability. Large welfare gains can arise only if the gap between the efficient and inefficient flexible-price equilibrium - which can always be achieved with a policy of price stability - is large. Let $W^s(p)$ denote the welfare of the representative household under policy p when prices are sticky, and let W^f denote welfare under flexible prices. Finally, let W^* denote welfare in the planner allocation. We can write

$$W^* - W^s(p) = W^* - W^f + [W^f - W^s(p)].$$

We define $W^* - W^f$ as the "**search gap**", the welfare distance between the planner solution and the flexible-price solution for any alternative inefficient wage setting mechanism. Define $W^f - W^s(p)$ as the "**nominal rigidity gap**", the welfare distance between the flexible price allocation and the allocation conditional on the alternative policy p . $W^f - W^s(p)$ is the welfare gap created by sticky prices. Standard prescriptions calling for price stability aim at eliminating this gap, but if the search gap is large, an optimal policy should aim to minimize the sum of the two gaps, and this may not involve completely eliminating the sticky-price distortion. If the Hosios condition is satisfied, then $W^* - W^f = 0$ and the optimal monetary policy would be aimed at counteracting the distortions originating from the nominal price rigidity.

A large search gap is not a sufficient condition for optimal monetary policy to deviate from price stability. It may very well be the case that cyclical monetary policy is not an appropriate instrument to close the search gap, and the welfare gain from a cyclical policy

⁴To avoid equilibrium indeterminacy, we include in our search a positive feedback coefficient to current inflation, so that the policy rule can be written as $i_t = \omega_n n_{t-1} + \omega_a a_t + \omega_\pi \pi_t$. We verified that the welfare level delivered by this policy is not inferior to the welfare level obtained for any policy within the set of determinate equilibria with $\omega_\pi = 0$.

to reduce distortions in job creation is dominated by the welfare loss from generating inefficient price dispersion in order to influence the real allocation.

If the search gap is small, or if price stability turns out to be the optimal policy even with a large search gap, the welfare consequences of monetary policy can still be radically different than in the standard new Keynesian framework. Because even a policy of price stability will influence the division of the surplus from a match between worker and firm, the welfare loss from a sub-optimal policy may be larger than in a model without search frictions. The nominal rigidity gap will exist even if wage setting is efficient and the search gap is zero. A large nominal rigidity gap implies that, while the optimal policy prescription may be not different from a new Keynesian model, the welfare consequences of deviating from the optimal policy may be much more pronounced.

The magnitude of the search gap, and the incentive for monetary policy to deviate from price stability, is directly related to the institutional setup of the labor market. As is well known, the nature of the wage setting process can be important for generating the vacancy and unemployment volatility observed in the data (Shimer 2005). Consequently, we consider equilibria characterized by different assumptions about wage setting. First we consider wage renegotiation through Nash bargaining, but allow the bargaining weight to be inefficient. For $b > 0.5$ unemployment will be inefficiently high and firms' incentive to post vacancies will be too low. The second case we consider constrains the real wage to be constant. This assumption generates an economy where wages are incentive-compatible, but the surplus share accruing to firms and workers fluctuates inefficiently over the business cycle.

4.3.1 Nash Bargaining

In an equilibrium with flexible prices and no steady state monopolistic distortion, the first best is attained when wages are set according to Nash bargaining and the Hosios condition holds. In this case, the share of total surplus generated by a match accruing to workers is $b = 1 - \xi$. When staggered pricing is introduced, a policy of price stability results in the first best level of welfare since the search gap is zero for $b = 0.5$.

Table 3 summarizes the welfare results under labor market setups that generate inefficient surplus sharing. When wages are renegotiated every period, and the worker's share of surplus increases from the efficient level $b = 0.5$ to $b = 0.7$, the search gap λ is equal to 0.80%, and it increases to 2.11% for $b = 0.8$. A search gap of similar magnitude

obtains for values of b smaller than 0.5. While the search gap is large when bargaining is inefficient, price stability is still the optimal policy when compared to the optimized simple policy rule. As it turns out, virtually all of the search gap arises from the welfare difference in the steady state. For $b = 0.7$, for example, the steady state employment rate falls to 88.4% from a first best level of 95%. Steady state consumption falls by over 3%. Thus, policies designed to affect the cyclical behavior of the economy and the nominal rigidity gap have little affect in reducing the search gap.

Table 3: Welfare Results			
	Search gap λ	Optimal policy gain λ relative to price stability	Simple policy rule history-dependent
		Simple policy rule	
<i>Nash bargaining</i>			
$b=0.5$	0	0	
$b=0.7$	0.80%	0	
$b=0.8$	2.11%	0	
<i>Wage norm</i>			
$w_t = w_{ss}^{eff} = w_{ss}(0.5)$	0.27%	-0.012%	-0.04%
$w_t = w_{ss}(0.3)$	0.81% (<i>steady state gap: 0.71%</i>)	0	0
$w_t = w_{ss}(0.7)$	1.62% (<i>steady state gap: 0.81%</i>)	-0.32%	-0.47%
$w_t = w_{ss}(0.7)$, $\mu = 1.2$	3.25% (<i>steady state gap: 2.55%</i>)	-0.33%	-0.51%

Note: the search gap is the welfare distance $W^* - W^f$ between the planner solution and the flexible-price solution for any alternative inefficient wage setting mechanism.

This result arises because the Nash bargaining wage-setting mechanism generates very little volatility of labor market variables. Our choice of technology shock volatility σ_a results in a volatility of output consistent with US data, but gives a volatility of employment N in the first best which is about 8 times smaller (table 4). The model generates the well-known 'Shimer puzzle', compounded by the fact that firms can expand output also along the intensive margin. Therefore, even if the volatility of employment increases by 30% with inefficient Nash bargaining, the welfare loss from cyclical movements in N is comparatively small. In terms of welfare, this translates into a large, but acyclical, wedge between the efficient and inefficient allocation.

Table 4: Nash Bargaining Model: Second Moments			
$b=0.5$ <i>(first best)</i>	Final output volatility	σ_y	1.78%
	Relative employment volatility	σ_n/σ_y	0.08
$b=0.7$ <i>(optimal policy: price stability)</i>	Final output volatility	σ_y	1.81%
	Relative employment volatility	σ_n/σ_y	0.11

Inefficient Nash bargaining has a relatively minor impact on the volatility of the economy, though a large impact on welfare through changes in the steady state. This suggests that for monetary policy to have a larger role in a search friction model, and for price stability to be a welfare-dominated policy, a model generating plausible volatility in employment is necessary.

4.3.2 Wage Rigidities

We examine the case of a wage norm, where the wage w_t is fixed at an exogenously given value, such that it will be an incentive-compatible wage with probability approaching 1 given the volatility of the economy. The idea of a wage norm that is insensitive to current economic conditions, but incentive-compatible so that inefficient separations are ruled out, has a long history in the literature, and has been integrated in search and matching models in recent research (Hall, 2005). Across OECD economies aggregate

wages are often very persistent, especially in European countries where collective wage bargaining is pervasive (Christoffel and Linzert, 2005).

First, consider a wage fixed at the steady-state level associated with a worker's surplus share equal to $b = 0.5$. We denote this wage as $w_t = w_{ss}(0.5)$, where w_t is the per-hour wage and $w_{ss}(0.5)$ is its steady state level for $b = 0.5$. Recall that under Nash bargaining, $b = 0.5$ satisfies the Hosios condition; hence, the wage norm is fixed at the efficient steady state level. In this economy, volatility increases dramatically, and the volatility of employment is of the same order of magnitude as output (table 5).⁵

Table 5: Wage Norm Model: Second Moments			
$w_t = w_{ss}^{eff} = w_{ss}(0.5)$	Final output volatility	σ_y	3.85%
<i>(optimal policy: price stability)</i>	Consumption volatility	σ_c	2.62%
	Relative employment volatility	σ_n/σ_y	0.99

Despite this large volatility in employment, table 3 shows the loss attributed to the search gap amounts to only 0.27%. Clearly the business cycle behaviour of labor market variables is very different compared to the first best, yet because the search gap is small, price stability closely approximates the optimal policy. This result is consistent with previous literature on search and matching models where the wage fluctuates inefficiently around the efficient steady state. Thomas (2008) finds that in new Keynesian model with labor frictions, optimal policy deviates from price stability only if nominal wage updating is constrained, so that the monetary authority has leverage on the prevailing real wages - a leverage that is lost if real wages are exogenously set equal to a norm. Shimer (2004) obtains a similar result in a simple real model with search and sluggish wage adjustment, where he shows that the loss relative to Nash bargaining is negligible. In contrast with the results of Blanchard and Gali (2006), the mere existence of wage

⁵The volatility of consumption does not increase as much as output. As the wage is fixed, following a technology shock the surplus share of firms and workers changes, leading to large swings in the incentive to post vacancies. Since search costs are procyclical, the volatility of consumption is reduced. In the first best, the steady state share of output spent in search is equal to $\kappa v/y = 4.16\%$.

rigidity is not sufficient to prescribe significant deviations from price stability, even if, as in their model, the volatility of employment increases the least flexible is the wage.

This outcome seems to undercut the rationale for the monetary authority to take into account search frictions – or wage rigidity, and the resulting fluctuations in involuntary unemployment – when setting the optimal policy. Consider though that the previous result, and analogous results in the literature, assume a wage norm set at the *efficient* level. A wage norm set far from the efficient level may have very different implications for optimal monetary policy. Additionally, there is no obvious reason why a wage-adjustment mechanism different from Nash bargaining necessarily delivers a welfare higher than a wage norm. In new Keynesian models with nominal wage and price rigidity, such as Erceg, Henderson and Levin (1999), additional wage stickiness is always welfare-decreasing. The reason is that the more constrained is the wage adjustment, the larger is wage dispersion and the loss from inefficiency. In our model the magnitude of the distortion arising in the labor market depends on the distance between the efficient wage and actual wage, which need not increase with wage stickiness.

For any wage norm $w_{ss}(b)$, the further b is from the efficient surplus-sharing level, the closer the norm is to the reservation wage of either the firm or the worker. In the case of a wage norm $w = w_{ss}(0.7)$ set at the steady-state level corresponding to labor receiving a larger share of the surplus, the loss due to the search gap is 1.62%. Table 3 shows the optimal simple policy rule increases welfare by about a third of a percentage point of the consumption stream level that is achieved under a price-stability policy. Adding some history dependence by allowing for interest rate smoothing increases the welfare gain in terms of consumption to about half a percentage point. Conditional on the chosen wage setting mechanism, not only is the search gap large and the optimal policy deviates from price stability, but a large welfare gain can be achieved. Given US per-household average GDP in 2007, the optimal policy gain translates in about \$626 per household, per year.⁶ The loss due to the nominal rigidity gap is also large. Table 6 shows that the original policy rule proposed by Taylor (1993) would result in a welfare loss of 0.054% relative to the optimal policy, if the labor market did not have search frictions and all fluctuations happened at the intensive margin (that is, for $\kappa = 0$ and $N_t = N_{ss}$). When departing

⁶This calculation assumes annual *GDP* at current dollars of 14,704.2 billion dollars (2007 fourth quarter) and a number of household projected by the Census Bureau at 112,362,848 for 2008. The dollar gain is an upper bound, since in the model part of output is consumed in search activity, and a calibration conditional on the wage norm consistent with US output volatility would result in a smaller volatility for the technology shock, hence in a smaller welfare gain.

from this economy and allowing for involuntary unemployment, the loss from using the Taylor rule increases about tenfold, to 0.468%.

Table 6: Nominal Rigidity Gap		
	Search gap λ	Taylor rule policy loss λ relative to optimal simple policy
<i>Calvo-limit model</i>	0	0.054%
<i>Wage norm</i> $w_t = w_{ss}(0.7)$	1.62%	0.468%

Note: the search gap is the welfare distance $W^* - W^f$ between the planner solution and the flexible-price solution for any alternative inefficient wage setting mechanism. The nominal rigidity gap is the welfare distance $W^f - W^s(p)$ between the flexible price allocation and the allocation conditional on policy p .

Few results are available in the literature on the size of the welfare gains available to the policymaker once search frictions are introduced in the labor market. Faia (2008) finds that, with Nash Bargaining, price stability yields a welfare level that is about 0.004% worse than the Ramsey optimal policy in terms of expected consumption stream. This results is consistent with our finding that Nash Bargaining - even if inefficient - does not allow a simple policy rule to improve on price stability. Comparison with work using the linear-quadratic approach of Rotemberg and Woodford (1997) is difficult, since this framework assumes an efficient steady state. Blanchard and Gali (2006) find that, with a substantial degree of wage rigidity, inflation stabilization can yield a loss 25 times larger than the optimal policy. This measure though is not scaled by the steady state welfare level; therefore we have no way to measure the significance of the differences between the two policies.

5 Competing Goals and Policy Outcomes

The results in the previous section presented us with three questions. The first is why does inefficient Nash bargaining have virtually no impact on the optimal policy relative to a new Keynesian model without search frictions. The second is why deviations from price stability are in most cases suboptimal, and when optimal the welfare gain is a small share of the search gap. The third is why does an inefficient steady state wage call for deviations from price stability. We turn now to these questions, and use the tax-policy framework developed in section 3 to discuss the rationale for deviations from price stability.

5.1 Steady State Tax Policy vs. Cyclical Policy

We use the optimal tax policy to measure the deviation from the inefficient equilibrium first order conditions required to replicate the efficient allocation. This in turn provides a measure of the task faced by the (more constrained) monetary policy. Deviations from the standard prescription of price stability may produce only small welfare gains if the monetary policy does not face a sizeable trade-off - as would be the case if the optimal tax policy turns out to have little volatility - or if the trade-off is sizeable up to first order, but not costly in welfare terms.

Table 7 shows the behaviour of τ_t under different assumptions for wage setting. Since we assume the full set of three policy instruments is available, τ_t is set according to eq. (17) or (21), τ_t^h follows eq. (19) and monetary policy sets $\mu_t = 1$.

In the inefficient Nash bargaining case for $b = 0.7$, the optimal policy calls for a steady state subsidy to intermediate firms equal to 115% of revenues. If the wage were not Nash bargained but fixed at the inefficient steady state level, the optimal steady state subsidy rate would drop by about 98.5%. This is because when $\tau_t > 1$ in the steady state Nash bargaining endogenously leads to an increase in the wage that dampens the impact of the subsidy on the firm's surplus share. To achieve the efficient (equal) surplus sharing with workers, the subsidy must be large. This feedback mechanism is absent when the wage is fixed at the norm, and a much smaller subsidy is sufficient to ensure efficiency. By construction, when the wage norm is fixed at the efficient level, no steady state subsidy is needed to achieve labor market efficiency.

When wages are Nash-bargained, the volatility of the tax rate is less than one-twentieth of output volatility. Nash bargaining generates very little volatility in employment over the business cycle. Since the steady state distortion is corrected by the

steady state subsidy, the volatility of the subsidy rate is very small, as it needs to ensure only small changes in the dynamics of v_t , N_t , and h_t . The policy implication is that price stability is a close approximation to an optimal policy since the notional tax τ_t/μ_t , and the tax-equivalent markup $1/\mu_t^*$, in the intermediate firm's optimality condition has very low volatility. On the contrary, when the wage is fixed at the wage norm, the volatility of vacancies and employment increases many times over. While this volatility allows a better match with the empirical evidence on labor market quantities, it generates sizeable deviations from efficiency and requires a much higher volatility in the optimal subsidy rate.

Table 7: Intermediate Sector Optimal Subsidy τ_t				
	Steady state tax rate	Volatility		
		σ_τ	σ_τ/σ_y	
$b=0.7$ <i>Nash bargaining</i>	115%	0.08%	0.04	
$w_t = w_{ss}^{eff} = w_{ss}(0.5)$ <i>Wage norm</i>	0	1.72%	0.96	
$w_t = w_{ss}(0.7)$ <i>Wage norm</i>	1.65%	1.72%	0.96	

Figure 1 plots impulse response functions to a 1% productivity shock when $w_t = w_{ss}(0.5)$ and the optimal fiscal and monetary policy is implemented. The subsidy rate τ_t decreases on impact by about one percentage point. A productivity increase calls for a higher wage in the efficient equilibrium, in order to increase proportionally the firms' and workers' surplus share. Since the wage is inefficiently low, too many vacancies are posted, and the surge in employment is inefficiently high. The optimal policy calls for taxing the firms' revenues, therefore increasing the workers' surplus share which is below the efficient level. The plot also shows the response of τ_t when wages are Nash bargained and $w_t = w_{ss}(0.7)$. The response decreases by an order of magnitude.

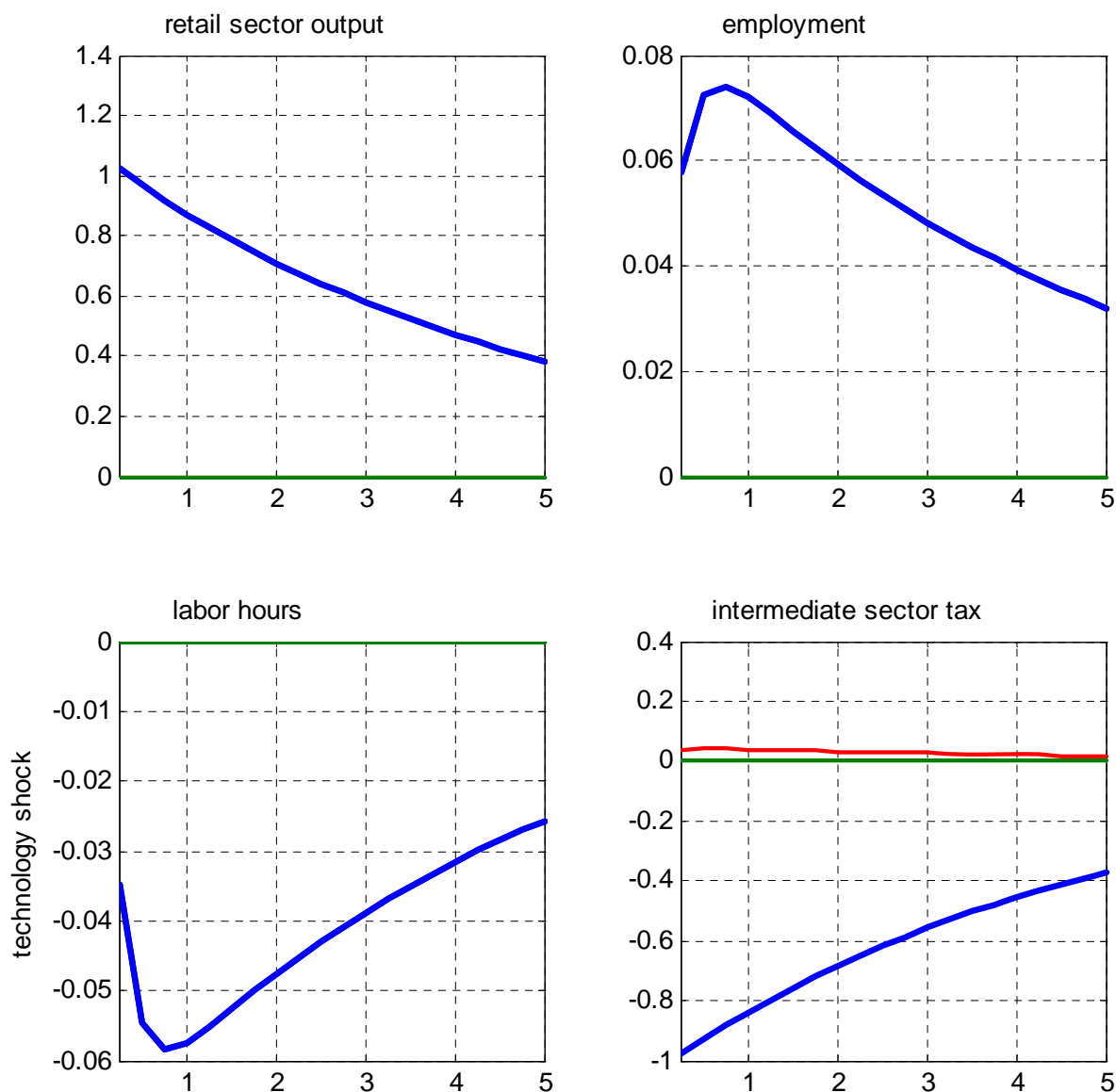


Figure 1: Impulse response function to 1% technology shock in intermediate production sector conditional on optimal tax policy enforcing first best allocation. Wage is set at norm $w_t = w_{ss}(0.5)$. Thin line shows optimal tax policy for Nash bargaining wage-setting and $b = 0.7$. Variables plot in log-deviations from steady state. Scaling in percent.

In a world where the cyclical tax policy using the instruments τ_t and τ_t^h can be enforced, the business cycle behaviour of the real variables is identical up to first order regardless of the monetary policy rule. The reason is the following. The tax policy τ_t and τ_t^h enforce the planner equilibrium - and this includes correcting the distortion in the choice of N_t , h_t , and v_t stemming from the volatility of the markup μ_t in the intermediate firms' first order condition. Given the production function for wholesale good depends only on N_t and h_t , the intermediate goods output Y_t^w must also be at the efficient level. Since up to first order $Y = Y^w$, the budget constraint implies that C_t is also at the efficient level. A more accurate approximation would instead imply $Y \neq Y^w$ because of price dispersion, potentially resulting in a large welfare loss.

When $w_t = w_{ss}(0.5)$ and the policymaker is restricted to the single monetary policy instrument, the first best allocation cannot be implemented. To illustrate the trade-offs, figure 2 displays the behaviour of the economy following a 1% productivity shock under a policy of price stability and under the tax-equivalent policy $\mu_t = \mu_t^*$. In the first case, vacancy creation is inefficiently high and the markup gap μ_t^{gap} is negative. The extent of the deviation from the steady state is large, as the markup gap drops on impact by 4%, suggesting that a policy aimed at least in part at correcting the labor market inefficiencies may be welfare-improving. Under the tax-equivalent monetary policy $\mu_t = \mu_t^*$, the impulse response of employment is reduced by factor of 10 and the response of employment is close to the first best. At the same time, the allocation is different from the efficient one (see figure 1). Since μ_t responds to the technology shock, the mrs_t^{gap} is non-zero, the hours choice is inefficient, inflation volatility is high.

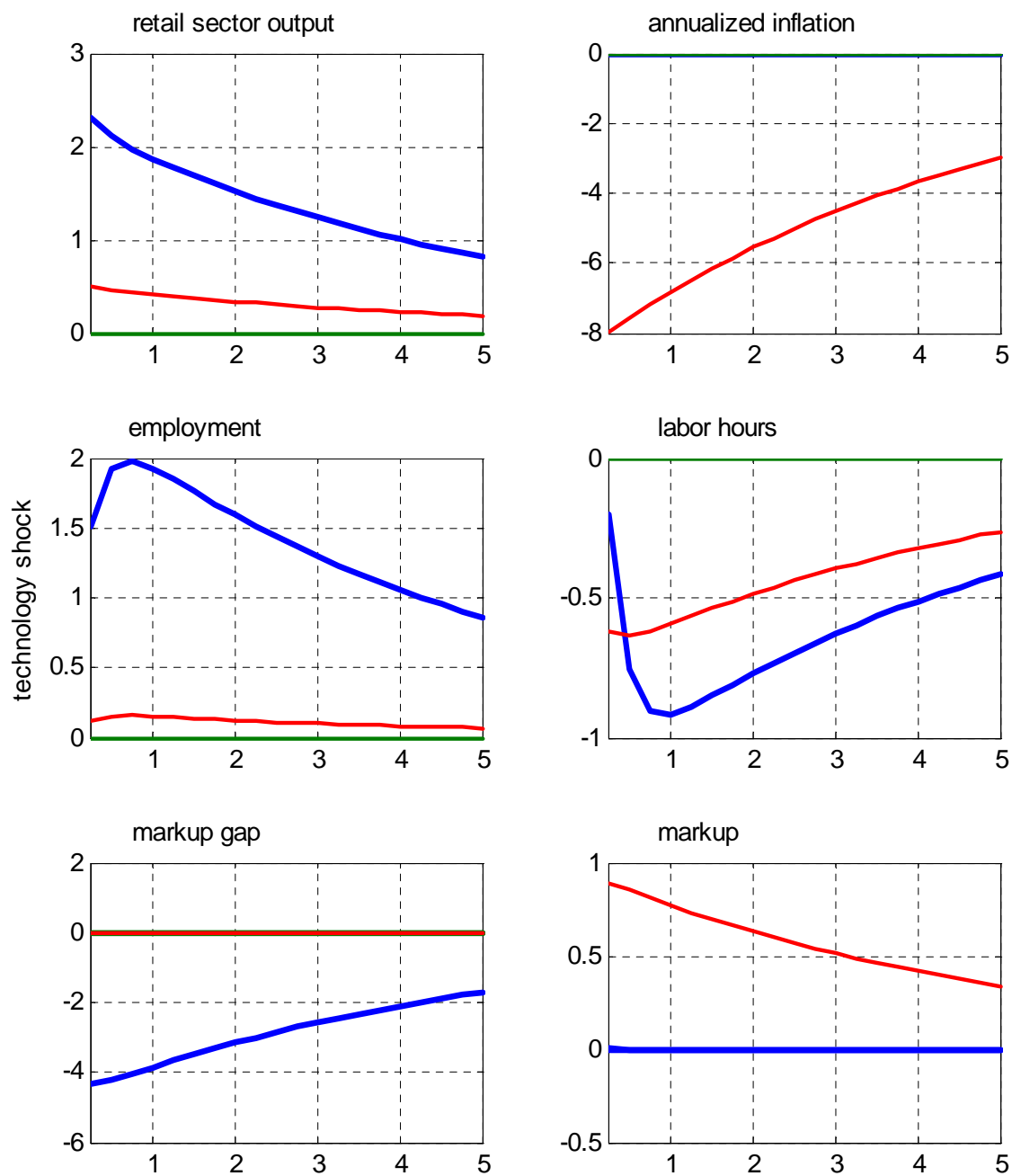


Figure 2: Impulse response function to 1% technology shock in intermediate production sector. Wage is set at norm $w_t = w_{ss}(0.5)$. Thick line: Price stability monetary policy. Thin line: Tax-equivalent monetary policy $\mu = \mu^*$. Variables plot in log-deviations from steady state. Scaling in percent.

The dynamic behaviour of the economy under the policy that maintains $\mu_t = \mu_t^*$ is closer to the efficient equilibrium compared to the price-stability policy. Yet the first-order result do not give an indication as to the relative weights the monetary authority should assign to each goal. In fact, for the economy in figure 2, price stability is virtually the optimal policy within the family of policy rules examined, despite delivering business cycle dynamics very far from the first best.

These results lead to two conclusions. First, the optimality of price stability under Nash bargaining can be explained by the low volatility of the optimal tax-equivalent markup μ_t^* . Second, large deviations in business cycle dynamics do not necessarily translate in large deviations of optimal policy from price stability.

5.2 The Welfare Cost of Distortions

Table 8 shows that the $\mu_t = \mu_t^*$ policy performs poorly when compared to a policy of price stability (i.e., the constant μ_t policy). Since μ_t^* fluctuates over the business cycle, this policy generates a high volatility in the markup, which translates into high inflation volatility. The allocation in the labor market is not efficient because of the remaining hours and price distortions.

Table 8: Welfare Results: Tax-equivalent Policies		
	Intermediate sector tax-equivalent policy loss λ relative to price stability	Relative inflation volatility σ_π/σ_y
<i>Nash bargaining</i> $b=0.7$	0.0003%	0.22
<i>Wage norm</i> $w_t = w_{ss}^{eff} = w_{ss}(0.5)$	2.33%	4.11
$w_t = w_{ss}(0.7)$	1.65%	3.28

Intuitively, closing the markup gap μ^{gap} is among the goals of monetary policy, though in terms of welfare the weight the monetary authority should give to this goal is limited. We can shed light on this result by selectively using tax policy to correct in turn one of the remaining two distortions that monetary policy leaves unaddressed. It is tempting to think of this experiment as replicating economies where only one distortion at a time is operating. This interpretation is misleading. To see why, consider an economy where monetary policy sets $\mu_t = 1$ so that firms in the retail sector have no incentive to change prices. Assume now that a tax policy τ_t enforces the planner's vacancy posting condition. Since $\tau^h = 1$, only the first order condition for hours choice deviates from the first best efficiency conditions. This does not mean though that v_t and N_t behave efficiently, since given the lack of the third policy instrument there is no guarantee the economy is operating in a second best equilibrium.

Suppose instead the monetary authority stabilizes prices while $\tau_t = 1$. In this case, vacancy posting is distorted, but there is no need for a second instrument to replicate the hours efficiency condition, as the market equilibrium sets the correct incentives for the choice of hours.

Finally, consider an economy where the policy $\mu_t^{gap} = 1$ is enforced, and the tax τ^h enforces the planner's first order condition for the hours choice. The only distortion that is unaddressed is price dispersion.

Table 9 summarizes the welfare outcomes in these three economies. The wage is set at a norm, which corresponds to the efficient ($b = 0.5$) or inefficient ($b = 0.7$) steady states. The three economies are indexed by the distortion that would need to be corrected to replicate the first best.

Table 9: Welfare Loss in Three Economies						
	Vacancy posting distortion		Retail price setting distortion		Hours setting distortion	
<i>Wage norm: $w_t = w_{ss}(b)$</i>	$b = 0.5$	$b = 0.7$	$b = 0.5$	$b = 0.7$	$b = 0.5$	$b = 0.7$
<i>Loss relative to first best</i>	0.27%	1.62%	3.06%	3.78%	0.008%	0.81%
<i>Steady state loss</i>	–	0.79%	–	0.79%	–	0.79%

The hours inefficiency turns out to be of little consequence. When the labor’s share of the steady state surplus is inefficiently high, the loss is considerable, but nearly all of it depends on the steady-state level of hours, rather than on the cyclical behaviour of hours.

In contrast, the price setting distortion is very costly. It is interesting to see that all of the costs stems from price dispersion. In a standard new Keynesian model, fluctuations in prices correspond to 1) a smaller consumption basket per dollar spent; 2) inefficient fluctuations in the marginal revenue of the intermediate firm per unit of output sold, or, if workers sell labor hours directly to retail firms, inefficient fluctuations of the real wage paid per unit of effective labor-hour. In our thought experiment, monetary policy ensures the intermediate sector is insulated from fluctuations in marginal revenues. Yet the intermediate sector does not achieve the planner’s choice of vacancies, since price dispersion also reduces consumption and changes both the marginal rate of substitution that enters in the hours choice and the marginal utility of consumption that enters in equation (26) defining the notional tax level, or μ_t^* .

In summary, correcting the vacancy posting distortion requires large movements in prices, which are costly. When the tax instruments are not available, the monetary authority can only enforce a second best, and the optimal policy closes only partially the search gap. The distortion in hours choice plays only a marginal role in the welfare results.

5.3 The Role of the Steady State

[TO BE ADDED]

6 Policy Options and the Structure of Labor Markets

While it is common to see discussions comparing European and American labor markets, there is little analysis of how these differences might affect either the monetary transmission mechanism or the design of optimal monetary policy. When compared to the U.S., individual unemployment duration in Europe is substantially longer and the flows in and out of employment are substantially lower (Blanchard 2006). Differences between the U.S. and European labor market behaviour have been large for decades. In 1979 and 1995 the share of total unemployed individuals who had been searching for a job longer than a year was respectively 30.3% and 45.6% in France. For the same years, the U.S. share was 4.2% and 9.7% (Sargent, 1998). The four largest Euro-zone economies - France, Germany, Spain and Italy - also have high inactivity rates and low employment rates.

The search and matching model incorporates several parameters that capture various aspects of the economy's labor market structure. These include the cost of posting vacancies, the exogenous rate of job separation, the replacement ratio of unemployment benefits, the relative bargaining power of workers and firms, the wage setting mechanism. In this section we address the optimal policy problem from a perspective that accounts for the structural characteristics of the European labor market.

Our approach is to take as given the structural features of the labor market - including the high level of average unemployment observed in France, Germany, Spain and Italy - and study the implications for cyclical monetary policy. Following the empirical evidence, we characterize the European Union labor market by assuming a lower steady state employment rate, and a larger share of the available time devoted to leisure. Additionally, we assume a separation rate equal to about a third of the one found in US data, reflecting higher firing costs. These assumptions in turn imply a larger utility cost of hours worked, a lower efficiency of the matching technology, and a cost of vacancy posting which is about twice as large as in the US parameterization. The Appendix contains the model parameter values.

Table 10 reports the welfare results. The search gap is about of the same size as in the US case when wages are Nash-bargained, but is substantially smaller when they are set

at the wage norm level. Importantly, the simple policy rule does not manage to improve on price stability under any circumstance, while the welfare gain from a simple history-dependent rule is in between 0.10% and 0.15%, about a third of the welfare improvement for the US. Table 11, showing the nominal rigidity gap, confirms that price stability is a better approximation to the optimal policy than in the US case.

Table 10: European Union Parameterization: Welfare Results			
	Search gap λ	Optimal policy gain λ relative to price stability	
		Simple policy rule	Simple policy rule history-dependent
<i>Nash bargaining</i>			
$b=0.5$	0	0	0
$b=0.7$	0.79%	0	0
$b=0.8$	2.06%	0	0
<i>Wage norm</i>			
$w_t = w_{ss}^{eff} = w_{ss}(0.5)$	0.11%	0	-0.004%
$w_t = w_{ss}(0.3)$	0.63% (<i>steady state gap</i> : 0.58%)	0	0
$w_t = w_{ss}(0.7)$	1.13% (<i>steady state gap</i> : 0.80%)	0	-0.13%
$w_t = w_{ss}(0.7)$, $\mu = 1.2$	2.81% (<i>steady state gap</i> : 2.53%)	0	-0.15%

Table 11: European Union Parameterization: Nominal Rigidity Gap		
	Search gap λ	Taylor rule policy loss λ relative to optimal simple rule inertial policy
<i>Calvo-limit model</i>	0	0.043%
<i>Wage norm</i> $w_t = w_{ss}(0.7)$	1.13%	0.27%

Note: the search gap is the welfare distance $W^* - W^f$ between the planner solution and the flexible-price solution for any alternative inefficient wage setting mechanism. The nominal rigidity gap is the welfare distance $W^f - W^s(p)$ between the flexible price allocation and the allocation conditional on policy p .

In the EU case the scope for monetary policy to correct for inefficient search frictions is relatively small. Consider that the parameterization implies labor flows are reduced relative to the US. The quarterly job finding probability drops from 76% to 25%. The lower separation rate implies that firms cannot shed easily excess workers during a downturn (nor lower the wage bill, since the wage is fixed), and will therefore increase the workforce more moderately in an expansion. Additionally, the cost of vacancy posting is also higher since the first best calls for lower job creation. As the volatility of hiring decreases, the improvement available from a monetary policy deviating from price stability to correct for inefficient vacancy posting also decreases. Ironically, the same labor market characteristics that lower steady state employment, and leave more to be gained from long-term policy intervention, make the cyclical policy less effective.

This suggests that in a model with search frictions there exists much scope for coordinating monetary policy with policy instruments that affect the steady state. As we have seen in section 4, of a search gap equal to 1.62% when $w_t = w_{ss}(0.7)$ the optimal monetary policy can only gain 0.47 percentage points, while a steady state subsidy to firms can gain an additional 0.88 percentage points.

Table 12 summarizes the policy options available in the EU and the US. We computed the *cumulative* impact on welfare of the different policies. The first policy to be implemented is the optimal monetary policy. The welfare gain is nearly three times as large for the US, and nearly seven times as large for the EU, once the monetary policy is combined with a subsidy to correct for the inefficient steady state sharing of match surplus. The welfare gain is large also in absolute value, equal to 1.37% in the US and 0.89% in the EU. Notice that once the subsidy is introduced, the optimal policy becomes price stability: the monetary authority does not have any more to fill-in for the missing tax instruments. The large welfare improvement of the steady state subsidy comes mainly by increasing the employment level. Reforming the bargaining environment so that wages can be efficiently renegotiated each period yields an additional, non-negligible gain. The gain from Nash bargaining works exclusively by affecting the business cycle dynamics, since the subsidy already ensures the efficient steady state. Unfortunately Nash bargaining also requires that the steady state subsidy rate be increased from less than 2% to over 100%. Next, we consider the extent of labor market reforms. These, together with the subsidy, are the only policies that can affect the steady state. Their impact is very large: a 10% improvement in the matching technology leads to a welfare gain of over three quarters of a percentage point, in both the US and EU case. Any policy that decreased the search cost by 10% would allow for an additional substantial welfare improvement.

The welfare gains allowed by the subsidy and structural policies are remarkable, compared to what can be achieved by monetary policy. Obviously, this welfare analysis is abstracting from the problem of financing any subsidy or structural reform, that in itself would generate distortions in the economy. But this exercise points out that economies where labor markets are flexible, and labor flows are volatile over the business cycle, are more responsive to monetary policy, and deviations from price stability can play an important role. Relative to the US, in the EU price stability approximates much more closely the optimal policy.

Table 12: EU vs. US Policy Options: the Case of an Inefficient Wage Norm

Policy	Steady State subsidy rate		Cumulative Welfare gain relative to price stability		Steady State Employment rate	
	US	EU	US	EU	US	EU
Optimal Monetary Policy			-0.47%	-0.13%	88% $\sigma_n/\sigma_y = 1.51$	84% $\sigma_n/\sigma_y = 1.18$
Steady State subsidy	1.64%	1.75%	-1.37%	-0.89%	95% $\sigma_n/\sigma_y = 0.99$	90% $\sigma_n/\sigma_y = 0.77$
Nash Bargaining	115%	114%	-1.65%	-1.01%	95% $\sigma_n/\sigma_y = 0.051$	90% $\sigma_n/\sigma_y = 0.050$
10% Increase in Matching Efficiency	115%	116%	-2.47%	-1.75%	96.4% $\sigma_n/\sigma_y = 0.044$	91.2% $\sigma_n/\sigma_y = 0.042$
10% Decrease in Vacancy Cost	117%	117%	-2.90%	-2.14%	97.1% $\sigma_n/\sigma_y = 0.045$	91.8% $\sigma_n/\sigma_y = 0.040$

Note: welfare computed for model with wage norm $w_t = w_{ss}(0.7)$.

7 Conclusions

We briefly summarize our results here.

1. In the face of inefficiency in the labor market due to search frictions, the monetary authority faces a trade-off. Policy can stabilize the retail price markup to ensure stable prices and eliminate costly price dispersion, or policy can move the markup to mimic the cyclical tax policy that would lead to efficient vacancy posting.
2. However, in an economy where wages are very flexible and adjust efficiently, or in an economy where they are very inflexible but set at a level that is close to the

steady-state efficient level, the role of monetary policy should be to stabilize price inflation. Thus, rigid wages themselves do not rationalize policies that deviate from price stability.

3. The business cycle dynamics of macroeconomic variables may be quite different in an economy where wages are very flexible and adjust efficiently relative to an economy where they are very inflexible but set at a level that is close to the steady-state efficient level. This though has little implication for welfare or monetary policy.
4. The gains from cyclical monetary policy are largest when wages are inflexible at a level that corresponds to workers receiving a larger share of the surplus that would occur in the efficient steady-state level. Thus, it is not wage inflexibility alone that matters, but whether wages are rigid around an efficient level or not.
5. There exist gains to account for labor market in selecting monetary policy even without introducing an explicit cost of wage dispersion.
6. The hours margin plays a minor role. The explicit introduction of overtime labor would likely change this result.
7. Monetary policy interacts in complex way with fiscal and labor market policies. The best policy mix will depend on the institutional labor market setup of a country. How fiscal and monetary policies should coordinate once the distortions from the financing of taxes and subsidies is taken into account is a question left open for future research.
8. US vs. EU: the welfare gain of deviation from price stability is larger, the more volatile are labor market flows over the business cycle. Higher firing and hiring costs, as in the EU, make price stability a relatively closer approximation to the optimal policy.

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8 Appendix

Pricing Dynamic Equations Write eq. (10) as:

$$\begin{aligned} P_t(j) &= \frac{\hat{G}_t}{\hat{H}_t} \\ \hat{G}_t &= \frac{\varepsilon}{\varepsilon - 1} \lambda_t M C_t^n P_t^{\varepsilon-1} Y_t + E_t \omega \beta \hat{G}_{t+1} \\ \hat{H}_t &= \lambda_t P_t^{\varepsilon-1} Y_t + E_t \omega \beta \hat{H}_{t+1} \end{aligned}$$

Define $\tilde{G}_t \equiv \frac{\hat{G}_t}{P_t^\varepsilon}$, $\tilde{H}_t \equiv \frac{\hat{H}_t}{P_t^{\varepsilon-1}}$. The inflation rate is then given by:

$$[(1 + \pi_t)]^{1-\varepsilon} = \omega + (1 - \omega) \left[\frac{\tilde{G}_t}{\tilde{H}_t} (1 + \pi_t) \right]^{1-\varepsilon}$$

Market Clearing Conditions Aggregating the budget constraint over all households yields

$$P_t C_t^m = P_t w_t N_t + P_t \Pi_t^r.$$

Since the wholesale sector is in perfect competition, profits Π_{it} are zero for each i firm and

$$\frac{P_t^w}{P_t} Y_t^w = w_t N_t + \kappa v_t.$$

In turn, this implies

$$C_t^m = \frac{P_t^w}{P_t} Y_t^w - \kappa v_t + \Pi_t^r. \quad (28)$$

Profits in the retail sector are equal to

$$\begin{aligned} \Pi_t^r &= \int \left[\frac{P_t(j)}{P_t} - \frac{P_t^w}{P_t} \right] Y_t^d(j) dj \\ &= \frac{1}{P_t} \int P_t(j) Y_t^d(j) dj - \frac{P_t^w}{P_t} \int Y_t^d(j) dj \end{aligned}$$

Since for each good j market clearing implies $Y_t^d(j) = Y_t(j)$, and since the production function of final goods is given by $Y_t(j) = Y_t^w(j)$, we can write profits of the retail sector as

$$\Pi_t^r = Y_t^d - \frac{P_t^w}{P_t} Y_t^w,$$

where $Y_t^w = \int Y_t^w(j) dj$. Then (28) gives aggregate real spending:

$$Y_t^d = C_t^m + \kappa v_t. \quad (29)$$

Finally, using the demand for final good j in (9), the aggregate resource constraint is

$$\begin{aligned} \int Y_t(j) dj &= \int Y_t^w(j) dj = Z_t \int N_t(j) dj = Z_t N_t \\ &= \int \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon} Y_t^d dj = \int \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon} [C_t^m + \kappa v_t] dj, \end{aligned}$$

or

$$Y_t^w = Z_t N_t = [C_t^m + \kappa v_t] \int \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon} dj. \quad (30)$$

Aggregate consumption is given by

$$C_t = C_t^m + w^u(1 - N_t).$$

A more compact way of rewriting the resource constraint can be obtained by writing (29) and (30) as:

$$\begin{aligned} Y_t^d &= C_t^m + \kappa v_t \\ Y_t^w &= Y_t^d f_t, \end{aligned}$$

where f_t is defined as

$$f_t \equiv \int_0^1 \left[\frac{P_t(z)}{P_t} \right]^{-\varepsilon} dz$$

and measures relative price dispersion across retail firms.

Optimal Tax Policy Equilibrium Conditions [TO BE ADDED]

European Union Parameterization

Table A1: European Union Parameterization: Efficient Equilibrium

Exogenous separation rate	ρ	0.037
Steady state vacancy filling rate	q_{ss}	0.7
Steady state employment rate	N_{ss}	0.9
Steady state hours	h_{ss}	0.25
AR(1) parameter for technology shock	ρ_a	0.95
Volatility of technology innovation	σ_{ε_a}	0.55%

Table A2: European Union Parameterization: Implied Parameter Values

<i>Implied parameter values from efficient equilibrium</i>	Efficiency of matching technology	η	0.4182
	Utility cost of one labor hour	ℓ	9.2325
	Cost of vacancy posting	κ	0.1760
	Job-finding steady state probability	p_{ss}	0.25