The Welfare Consequences of Monetary Policy and the Role of the Labor Market: a Tax Interpretation

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Abstract

We explore the distortions in business cycle models arising from inefficiencies in price setting and in the search process matching firms to unemployed workers, and the implications of these distortions for monetary policy. To this end, we characterize the tax instruments that would implement the first best equilibrium allocations and then examine the trade-offs faced by monetary policy when these tax instruments are unavailable. Our findings are that the welfare cost of search inefficiency can be large, but the incentive for policy to deviate from the inefficient flexible-price allocation is in general small. Sizable welfare gains are available if the steady state of the economy is inefficient, and these gains do not depend on the existence of an inefficient dispersion of wages. Finally, the gains from deviating from price stability are larger in economies with more volatile labor flows, as in the U.S.

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1 Introduction

This paper explores optimal monetary policy in business cycle models with staggered price adjustment and inefficiencies in the search process that matches job vacancies with unemployed workers. In this environment the markup in the final-goods producing sector affects equilibrium through three separate channels. First, it affects the incentive for firms to post job vacancies. Second, it influences the equilibrium hours per employed worker. Finally, it affects the marginal cost of retail firms and generates a dispersion of relative prices. It is feasible for monetary policy to completely undo the distortions associated with sticky prices and replicate the flexible-price equilibrium. However, such a policy of price stability cannot ensure efficient outcomes in the labor market. Because monetary policy can affect the incentive to post vacancies when prices are sticky but not when prices are flexible, we find that the policymaker can achieve higher welfare in an economy with staggered price setting than in a flexible-price economy.

At the same time, while the cost of inefficient vacancy posting is large, the welfare attained by the optimal policy deviates very little from the one achieved under flexible prices. In practice, the policymaker finds little incentive in trying to correct for the search inefficiency by deviating from price stability. Introducing real wage rigidity does not, in itself, modify this result. Finally, we find that a higher cost of search, resulting in lower steady-state employment, has two opposing effects on policy. Structural policies addressing labor markets distortions can bring larger gains, but cyclical monetary policy becomes less effective, thus making the policy implementing the flexible price allocation a closer approximation to the optimal policy.

The result that replicating the allocation obtained when nominal rigidities are absent is not optimal is similar to Adao, Correia, Teles (2003), and carries the same intuition. Real distortions exist that cannot be affected by monetary policy under flexible prices. Staggered price setting offers the policymaker an instrument to correct for these distortion. The existence of multiple distortions implies that under either flexible or staggered prices the optimal policy can only attain a second best. Among the second best allocations, it turns out that eliminating one distortion can be welfare decreasing. In our model, which includes the search and matching labor market of Mortensen and Pissarides (1994), equilibrium unemployment and vacancies can deviate from their efficient levels, and a policy of price stability replicates the inefficient equilibrium level of employment that would obtain with flexible prices. If search in the labor market is inefficient, staggered price setting gives monetary policy the opportunity to correct the incentives of households and firms and generate an efficient level of employment.

The result that the flexible price allocation may be feasible but suboptimal is well understood in the literature on monetary policy in the presence of nominal rigidities (Blanchard and Galí, 2007). Much of this literature though assumes an efficient steady state achieved through fiscal transfers. In this case, eliminating all nominal rigidities achieves the first best and is always welfare-improving (as in the sticky price and wage model of Erceg, Henderson and Levin, 2000 or the sticky price-cost channel model of Ravenna and Walsh, 2006).

Our second set of result sheds light on the nature of the distortions in models with staggered price setting and labor market frictions. For reasonable model parameterizations, the welfare loss from search inefficiencies is large under the flexible price allocation. Thus it appears there is ample space for monetary policy to improve on the allocation that would obtain by fully stabilizing prices. While this 'search gap' is large, monetary policy is able to close only a tiny fraction of it. The monetary policy outcome hinges *both* on the wage-setting process *and* on the efficiency of the steady state. When wages are Nash-bargained in every period but set at a socially inefficient level, nearly all of the search gap can be explained by inefficiency in the steady state. This is the welfare implication of the low relative volatility of employment and output generated by this family of models (Shimer, 2004): inefficient but small fluctuations of employment result in a small welfare loss. In this economy, movements in unemployment become virtually a sideshow as far as the policymaker is concerned: focusing on the inefficiency from nominal rigidities should be the primary policy concern.

Adding wage rigidities does not, in itself, change this result. With real wages fixed at a wage norm, the volatility of unemployment increases substantially, and so does the welfare loss generated by the business cycle. But the trade-off faced by the monetary authority is extremely unfavorable, so it is optimal not to deviate much from price stability. It is only with a wage fixed at a level very different from the efficient steady state that deviations from price stability yield high return in terms of welfare. We find that the optimal policy can yield welfare gains on the order of one half percent of steady-state consumption. This improvement derives entirely from correcting for search frictions that would otherwise prevent an efficient response to technology shocks under the flexible price allocation. Since it is common in the literature to assume the steady-state wage is efficient, our results are relevant for interpreting previous findings.

In our framework, monetary policy is of limited effectiveness because it can only affect markups, and these markups directly affect *all* of the distortions present in the economy. In effect, monetary policy is a blunt instrument - and, ironically, especially so when the cost of search is higher. This is illustrated clearly by our analysis, which maps monetary policy into a tax policy. We first derive the tax and subsidy policy that would replicate the efficient, social planner's equilibrium in an economy with sticky prices, search frictions, and a labor market that allows adjustment to occur on both the intensive and extensive margins. We then consider the extent to which monetary policy can mimic this optimal tax policy. This allows us to focus on 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 three policy instruments are generally needed to replicate the efficient equilibrium. A tax on intermediate firms can ensure efficient vacancy creation. However, such a tax distorts the hours choice and so a second tax instrument 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.

Our paper is related to several important contributions in the literature. Khan, King and Wolman (2003) discuss optimal momentary policy in an economy with staggered price setting and multiple distortions, finding that the optimal policy does not result in large deviations from the flexible price allocation. They also study the steady state impact of each distortion by introducing a tax and subsidy policy, but do not investigate the tax policy replicating the first best. Erceg, Henderson and Levin (2000) and Levin, Onatski, Williams and Williams (2006) show that inefficient wage dispersion can be more costly than inefficient price dispersion in a new Keynesian model with staggered wage and price setting. These papers assumed labor markets are characterized by monopolistic competition among households supplying labor and that wages were set according to a Calvo-type mechanism. Compared to the standard wage-staggering setup, the added value of our approach is threefold. First, we show that policy prescriptions depend in a complex way on the interaction of the wage setting mechanism and the incentives to search and post vacancies. In itself, the degree of wage rigidity does not play an important role. Second, we find that the gain from optimal monetary policy may be large, and the gain is not related to the degree of 'stickiness' in wage adjustment, since we assume wage dispersion is always zero. Third, since the efficiency of the search process depends on the institutional structure of the labor market, policy prescriptions change widely across different economies.

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 (2007), Thomas (2008), Gertler and Trigari (2006), Gertler, Sala, and Trigari (2007), and Ravenna and Walsh (2008a). 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 (2008a,b), derive a linear Phillips curve relating unemployment and inflation in models with labor frictions. Like the present paper, Blanchard and Galí use their model to explore the implications of these frictions for optimal monetary policy. However, they restrict their attention to a linear-quadratic framework and to efficient steady states.

Thomas (2008) introduces nominal price and wage-staggering a 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 of wage dispersion already highlighted in Erceg, Henderson and Levin (2000) and partly the cost of the resulting inefficient job creation. 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. In a related model, Faia (2008) finds that the welfare gains from deviating from price stability are small regardless of the steady state efficiency, and the central bank can replicate the loss achieved under the optimal policy by responding strongly to both inflation and unemployment.

The paper is organized as follows. In the next section, we develop the basic model. The welfare consequences of monetary policy are explored in section 3. Sections 4 and 5 describe the tax policy that would achieve the efficient equilibrium, and uses notional taxes and subsidies to identify the trade-offs a monetary authority faces and the impact of alternative parameterizations of the labor market. Conclusions are summarized in the final section.

2 Model economy

The model consists of households whose utility depends on leisure and 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 firms producing intermediate goods that are sold in a competitive market. Intermediate 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 (2004), and Thomas (2008).

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

[1] Hall (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).

Letting v_t denote the number of vacancies, we define $\theta_t = v_t/u_t$ as the measure of labor market tightness. If M_t is the number of matches, $p_t = M_t/u_t$. The probability a firm fills a vacancy is $q_t = M_t/v_t$. We assume matches are a constant returns to scale function of vacancies and workers available to be employed in production:

$$\begin{aligned} M_t &= M(v_t, s_t) \\ &= \eta v_t^{\xi} s_t^{(1-\xi)} \end{aligned}$$

where η measures the efficiency of the matching technology and ξ the elasticity of M_t with respect to posted vacancies.

2.2 Households

Households purchase a basket of differentiated goods produced by retail firms. Assume each worker k values consumption and leisure according to the per-period separable utility function:

$$\cup_{k,t} = U(C_{k,t}) - V(h_{k,t})$$

where $h_{k,t} = 1 - l_{k,t}$ and $l_{k,t}$ is hours of leisure enjoyed by the worker. Risk pooling implies that the optimality conditions for the worker can be derived from the utility maximization problem of a large representative household choosing $\{C_{t+i}, N_{t+i}, h_{t+i}, B_{t+i}\}_{i=0}^{\infty}$ where C_t is average consumption of the household member, equal across all members in equilibrium, h_t is the amount of work-hours supplied by each employed worker, and B_t is the household's holdings of riskless nominal bonds with price equal to p_{bt}. The optimization problem of the household can be written as:

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

where w_t is real hourly wage, h_t is hours, P_t is the price of a unit of the consumption bundle, and Π_t^r are profits from the retail sector. Consumption of market goods supplied by the retail sector is equal to $C_t^m = C_t - (1 - N_t)w^u$ and is a Dixit-Stiglitz aggregate of the consumption from individual retail firm j:

$$C_t^m \leq \left[\int_0^1 C_t^m(j)^{\frac{\varepsilon-1}{\varepsilon}} dj \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

We include w^u as the home production of consumption goods. Similar equilibrium conditions would be obtained in a model where there is no household production but with a fixed disutility of being employed along with the disutility of hours worked.

The intertemporal first order conditions yield the standard Euler equation:

$$\lambda_t = \beta R_t E_t \left(\lambda_{t+1} \right),$$

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.

Letting G_{X_t} denote the partial derivative of G with respect to X_t, the value of a filled job from the perspective of a worker is given by

$$W_{N_t} \equiv V_t^S = -w^u + w_t h_t - \frac{V(h_t)}{U_{C_t}} + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^S (1-\rho)(1-p_{t+1}).$$

2.3 Intermediate Goods Producing Firms

Intermediate firms operate in competitive output market and sell their production at the price P_t^w. Production by intermediate firm i is

$$Y_{it}^w = f_t(A_t, L_{it})$$

f_t is a CRS production function and $L_{it} = N_{it} h_{it}$ is the firm's labor input. A_t is an aggregate productivity shock that follows the process

$$\log(A_t) = \rho_a \log(A_{t-1}) + \varepsilon_{a_t},$$

where ε_{a_t} is a white-noise innovation.

An intermediate firm must pay a cost $P_t \kappa$ for each job vacancy that it posts. Since job postings are homogenous with final goods, these firms effectively 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 $f_{L_t} = \partial f_t / \partial N_t h_t$ as the marginal product of a work-hour. The firm's profit-maximization problem gives the first order condition

$$V_t^J = \frac{\kappa}{q(\theta_t)} = \frac{f_{L_t} h_t}{\mu_t} - w_t h_t + (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \frac{\kappa}{q(\theta_{t+1})}. \tag{2}$$

where V_t^J is the value to the firm of a filled vacancy, $q(\theta_t)$ is the probability of filling a vacancy, and $P_t^w / P_t = 1/\mu_t$ is at the same time the real marginal cost of the retail sector, MC_t^r, equal to the inverse of the retail markup μ_t, and the marginal revenue of the intermediate sector, MR_t^w. The intermediate firm's first order condition (2) can be rewritten as:

$$MR_t^w = \frac{1}{f_{L_t} h_t} \left\{ w_t h_t + \frac{\kappa}{q(\theta_t)} - (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \frac{\kappa}{q(\theta_{t+1})} \right\} = MC_t^r \tag{3}$$

For $\kappa = 0$, the marginal cost would be equal to the wage rate per unit of output.

2.4 Wages under Nash bargaining

Assume the wage is set by Nash bargaining with the worker's share of the joint surplus equal to b. This implies

$$\frac{b\kappa}{q(\theta_t)} = (1-b) \left(w_t h_t - w^u - \frac{V(h_t)}{U_{C_t}} \right) + (1-\rho) \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \left[1 - \theta_{t+1} q(\theta_{t+1})\right] \frac{b\kappa}{q(\theta_{t+1})}.$$

Combining this equation with the intermediate firms' first order condition (2), one obtains an expression for the real wage bill:

$$w_t h_t = (1-b) \left(w^u + \frac{V(h_t)}{U_{C_t}} \right) + b \left[\frac{f_{L_t} h_t}{\mu_t} + (1-\rho) \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \kappa \theta_{t+1} \right]. \tag{4}$$

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

$$\frac{f_{L_t}}{\mu_t} = \frac{V_{h_t}}{U_{C_t}}. \tag{5}$$

Eqs. (3) and (5) imply that, at an optimum, the cost of producing the marginal unit of output by adding an extra hour of work must be equal to the hourly cost in units of consumption of producing the marginal unit of output by adding an extra worker.

2.5 Retail firms

Each retail firm purchases intermediate goods which it converts into a differentiated final good sold to households and intermediate goods producing firms. The nominal marginal cost of a retail firm is just P_t^w, the price of the intermediate input. 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^r, the retail firm chooses $P_t(j)$ to maximize

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

subject to

$$Y_{t+i}(j) = Y_{t+i}^d(j) = \left[\frac{P_t(j)}{P_{t+i}} \right]^{-\varepsilon} Y_{t+i}^d \tag{6}$$

where NMC_t^r is the nominal marginal cost and Y_t^d is aggregate demand for the final goods basket. The retail firm's optimality condition can be written as:

$$P_t(j) E_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i} = \frac{\varepsilon}{\varepsilon - 1} E_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) NMC_{t+i}^r \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i} \tag{7}$$

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

$$MC_t^r = \frac{1}{\mu} \tag{8}$$

where $\mu = \frac{\varepsilon}{\varepsilon - 1}$ is the constant retail price markup.

2.6 Efficient Equilibrium

To characterize the efficient equilibrium, we solve the social planner's problem. This problem is defined by

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

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

The optimal choice of $j-$good consumption and firm's labor search input is given by:

$$\begin{aligned} C_t(j) &= C_t \;\forall\; j \in [0,1] && (9) \\ v_t(j) &= C_t \;\forall\; j \in [0,1] && (10) \end{aligned}$$

The condition for efficient vacancy posting is:

$$\frac{\kappa}{M_{v_t}} = f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) + \beta (1-\rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (1 - M_{s_{t+1}}) \frac{\kappa}{M_{v_{t+1}}} \right\} \quad (11)$$

The condition for efficient hours choice is

$$f_{L_t} N_t = \frac{N_t V_{h_t}}{U_{C_t}}$$

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

$$f_{L_t} = \frac{V_{h_t}}{U_{C_t}}. \quad (12)$$

The Appendix shows that the efficient allocation can be enforced in the disaggregated equilibrium provided the price adjustment constraint is not binding, wages are set through Nash bargaining, the retail markup μ is equal to 1 and the surplus share accruing to the firm $(1-b)$ is equal to the elasticity of the matching function ξ. The latter condition, discussed by Hosios (1990), results in efficient wage bargaining. In the following we will assume that a steady state subsidy to retail firms τ_{ss}^r ensures $\mu = 1$, so that the Hosios condition holds when prices can be reset in every period.

3 The Welfare Consequences of Monetary Policy

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 results in a misallocation of workers between employment and unemployment, and variable retail-firm markups that result in inefficient allocation of labor hours.

With search frictions, a policy 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. The probability an unemployed worker finds a match depends negatively on the number of other job searchers. In the same way, the probability a firm fills a vacancy depends negatively on the number of vacancies posted by other firms. 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. At the same time, there exist positive externalities between groups. The planner's solution takes into account these externalities. Period-by-period wage bargaining that is incentive-compatible from the perspective of the worker and firm but which results in deviations from the efficient vacancy posting condition (11) yields labor allocations that are socially inefficient.

In this section we examine the optimal policy and the role of alternative assumptions about wage setting. 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). First we consider wage renegotiation through Nash bargaining, but allow the bargaining weight to be inefficient. For $b > (1-\xi)$ steady-state unemployment will be inefficiently high and firms' incentive to post vacancies will be too low. The second case we consider introduces real wage rigidity. We follow Hall (2005) in introducing a wage norm $\bar{w}$ fixed at an exogenously given value. The idea of a wage norm that is insensitive to current economic conditions, but is incentive-compatible from the perspective of the negotiating parties has a long history in the literature and has been integrated in search and matching models in recent research (Hall, 2005, Shimer, 2004). Across OECD economies, aggregate wages are often very persistent, especially in European countries where collective wage bargaining is pervasive (Christoffel and Linzert, 2005). While several authors have postulated that actual real wages are a weighted average of the wage norm and the Nash equilibrium wage we focus on the extreme case in which the actual wage equals the wage norm and is therefore completely insensitive to labor market conditions. We view this as a useful benchmark for assessing the welfare implications of sticky real wages. The model parameterization is summarized in Tables 1 and 2, and is discussed in detail in the Appendix.

3.1 Welfare Measure

To measure the welfare implications of alternative policies, we compare the welfare level generated by policy p with a reference level of welfare r which is generated by a given benchmark policy. Under the policy regimes p and r the household conditional expectation of lifetime utility are, respectively,

$$\begin{aligned} W_{p,0} &= E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_{p,t} - N_{p,t} V(h_{p,t}) \right\} \\ W_{r,0} &= E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_{r,t} - N_{r,t} V(h_{r,t}) \right\} \end{aligned}$$

As Schmitt-Grohe and Uribe (2007), we measure the welfare cost of policy p 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 p as under policy r:

$$W_{p,0} = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln C_{r,t}(1-\lambda) - N_{r,t} V(h_{r,t}) \right\}$$

The fraction λ is computed from the solution of the second order approximation to the model equilibrium around the deterministic steady state. We assume at time 0 the economy is at its deterministic steady state.

The optimal policy is derived by solving the problem of a benevolent government maximizing the household's objective function conditional on the first order conditions of the competitive equilibrium. This approach provides the equilibrium sequences of endogenous variables solving the Ramsey problem.[2]

3.2 Search and Nominal Rigidity Gaps

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's allocation. We can write

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

We define $W^* - W^f$ as the **"search gap"** – the welfare difference between the planner allocation and the flexible-price allocation. Given our assumptions, this gap will depend exclusively on search inefficiencies. 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 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 an optimal policy should aim to minimize the sum of the two gaps. Even if the search gap is zero, the search and matching process in the labor market may affect the nominal rigidity gap. This is because any suboptimal policy results in volatility in the markup, and thus influences the total surplus $V_t^J + V_t^S$ generated in the economy.

3.2.1 Welfare Results Under Nash Bargaining

When wages are set by Nash bargaining with fixed shares and the Hosios condition holds ($b = 1 - \xi$), a policy of price stability results in the first best level of welfare. The Hosios condition ensure $[W^* - W^f] = 0$, while price stability ensures $\left[W^f - W^s(p) \right] = 0$. When the Hosios condition is not met, the search gap will deviate from zero and it may be optimal for policy to partially offset the search gap by deviating from price stability.

[2] Results on the welfare implications of Ramsey policies in a related model with search frictions are described in Faia (2008). For a discussion of the Ramsey approach to optimal policy, see Schmitt-Grohe and Uribe (2005), Benigno and Woodford (2006), Kahn et al. (2003).

Table 3 summarizes the welfare results for $b = 0.5$, the value that satisfies the Hosios condition, and for values of b that exceed $1-\xi$. With flexible prices and wages renegotiated every period, the search gap rises from zero to 0.80% of the expected consumption stream as b is increased from 0.5 to 0.7, and it rises further to 2.11% for $b = 0.8$. However, as the second column of table 3 shows, the corresponding welfare loss when policy stabilizes prices is virtually nil. Thus, even though the search gap can be large when b deviates significantly from $1 - \xi$ so that bargaining is inefficient, policies optimally designed to affect the cyclical behavior of the economy have a negligible advantage relative to price stability.

3.2.2 Wage Rigidities

A common response to the Shimer puzzle is to introduce some form of real wage rigidity. The second case we consider constrains the real wage to be constant, implying the surplus share accruing to firms and workers fluctuates inefficiently over the business cycle.

Given the assumption that real wages equal a wage norm, the question remains as to the level at which to set the wage norm. We consider wage norms set equal to the steady-state wage level for different values of the bargaining share b. Define $w_{ss}(b)$ as the steady-state wage level associated with a worker's surplus share equal to b. When $\bar{w} = w_{ss}(0.5)$, the wage norm is fixed at the efficient steady-state level. However, while the business cycle behavior of labor market variables is very different with a wage norm compared to the first best, table 3 shows the loss attributed to the search gap amounts to only 0.27% of the expected consumption stream, and price stability continues to closely approximate the optimal policy. A policy of price stability leads to only a 0.05% rise in our measure of welfare loss relative to 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 a new Keynesian model with labor frictions, optimal policy deviates from price stability only if nominal wage updating is constrained in such a way that the monetary authority has leverage on prevailing real wages - a leverage that is lost if real wages are exogenously set equal to a norm as we have assumed. Shimer (2004) obtains a similar result in a simple real model with search and sluggish real wage adjustment, where he shows that the loss relative to Nash bargaining is negligible. In contrast to the results of Blanchard and Gali (2006), the mere existence of wage rigidity is not sufficient to justify significant deviations from price stability, even if, as in their model, the volatility of employment increases significantly as the real wage becomes less flexible.

These authors have assumed the actual real wage is constrained to fluctuate around the *efficient* steady state wage level. We can allow the wage norm to deviate from the efficient steady-state wage level by setting it based on a value of b that differs from $1 - \xi = 0.5$. As the bargaining parameter b deviates from the efficient surplus-sharing level $1 - \xi$, the wage norm $\bar{w}$ set equal to $w_{ss}(b)$ moves closer to the reservation wage of either the firm or the worker.

Suppose, for example, that the wage norm $\bar{w}$ equals $w_{ss}(0.7)$, a level that corresponds to a larger share of the surplus going to labor. The loss due to the search gap rises to 1.62%. Table 3 shows that the optimal policy increases welfare by about a fourth of a percentage point relative to price stability. Increasing the steady-state surplus share of workers from 0.7 to 0.8 increases the welfare gain from an optimal policy to over one half of a percentage point. Given US per-household average GDP in 2007, the gain from the optimal policy translates to about \$626 per household, per year.[3] Thus, we conclude real wage rigidity matters, but primarily when the wage norm corresponds to an inefficient level of steady-state wages.

Few results are available in the literature on the size of the welfare gains available to the policymaker once search frictions in the labor market are introduced. 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 streams. This results is consistent with our finding that Nash bargaining - even if inefficient - does not allow monetary policy much room to improve on price stability. Comparisons with work using the linear-quadratic approach of Woodford (2003) is difficult, since most of the literature utilizing this framework assumes an efficient steady state. Blanchard and Gali (2006) find that, with a substantial degree of real 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.

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

We have shown that search and matching frictions, even with a wage norm, offer little call for deviating from a policy of price stability if the real wage is fixed at the efficient steady-state level. When the wage norm is set at an inefficient level, the gains from allowing prices to fluctuate are larger. In this section, we focus on the sources of the inefficiencies faced by the monetary authority. These inefficiencies can be described in terms of deviations from the first order conditions (9), (10), (11) and (12). To highlight the role each distortion plays in affecting optimal policy, we build a tax and subsidy policy that replicates the efficient equilibrium. In doing so, we assume the policymaker

[3] This calculation assumes annual GDP at current dollars of $14,704.2$ billion dollars (2007 fourth quarter) and 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.

can use as many instruments as necessary to correct the incentives of households and firms when the market equilibrium, in the absence of taxes and subsidies, fails to deliver the efficient allocation. This policy is in effect a set of transfers across the economy that we assume can be financed by lump-sum taxes. By assuming revenue can be raised from nondistorting sources, the policymaker can always replicate the first best allocation; thus we are not solving a constrained optimal taxation problem. We will refer to this system of transfers as a tax policy, since the policy instruments create distortions in private sector behavior by affecting the incentives faced by households and firms.

4.1 The Optimal Intermediate Sector Tax Policy

Conditional on policy correcting for all remaining distortions, the Hosios condition holds in our model. Thus, whenever $b \neq 1-\xi$ 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. This tax policy results in an *effective* after-tax revenue from selling a unit of the intermediate good of $1/\mu_t^* \equiv \tau_t/\mu_t$ in final consumption units.

Conditional on this tax policy, the first order condition (2) for the intermediate firms becomes

$$V_t^J = \frac{\kappa}{q(\theta_t)} = f_{L_t} h_t \left(\frac{\tau_t}{\mu_t}\right) - w_t h_t + (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \frac{\kappa}{q(\theta_{t+1})}. \tag{13}$$

Using the planner's first order condition (11) and the equilibrium conditions $q_t = M_{v_t}/\xi$ and $p_t = M_{s_t}/(1-\xi)$, the tax policy consistent with efficient vacancy posting for any hourly wage w_t is

$$\frac{\tau_t}{\mu_t} = \frac{w_t}{f_{L_t}} + \frac{\xi}{f_{L_t} h_t}\left[f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}}\right) - \beta\,(1-\rho)\,E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right\}\right]. \tag{14}$$

Introducing the tax τ_t corrects the intermediate firms' incentives to post vacancies, but it distorts these firms' choice of hours, resulting in a new inefficiency. To see this, note that (5) becomes $f_{L_t}(\tau_t/\mu_t) = V_{h_t}/U_{C_t}$ while the efficient condition (12) for hours allocation requires $f_{L_t} = V_{h_t}/U_{C_t}$. To correct the distortion in hours would require that $\tau_t/\mu_t = 1$. However, unless vacancy posting is efficient to start with (see eq. 19 below), $\tau_t \neq \mu_t$. Thus, conditional on any level of the tax τ_t, a second tax instrument must be introduced to eliminate the distortion in hours created by the tax on intermediate firms. We impose a tax τ_t^h on households' opportunity cost of being employed so that the hours optimality condition becomes:

$$f_{L_t}\left(\frac{\tau_t}{\mu_t}\right) = \left(\frac{V_{h_t}}{U_{C_t}}\right)\tau_t^h. \tag{15}$$

The optimal tax τ_t^h on households is therefore given by

$$\tau_t^h = \frac{\tau_t}{\mu_t}. \tag{16}$$

Of course, the tax τ_t^h also affects the household's surplus from being in a match, which now becomes

$$V_t^S \equiv w_t h_t - \tau_t^h \left(w^u + \frac{V(h_t)}{U_{C_t}} \right) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^S (1-\rho)(1-p_{t+1}) \tag{17}$$

where, without loss of generality, we assume the gross tax rate τ_t^h also affects the value of home production w^u.

Using (11), (13) and (17), the optimal tax τ_t when wages are set according to Nash bargaining can be written as

$$\begin{aligned} \frac{\tau_t}{\mu_t} &= \frac{1}{f_{L_t} h_t} \left[\frac{\tau_t^h (1-b) - \xi}{(1-b)} \right] \left(w^u + \frac{V(h_t)}{U_{C_t}} \right) \\ &\quad + \frac{\xi}{(1-b)} \left\{ 1 - \frac{1}{f_{L_t} h_t} \beta (1-\rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(1 - \frac{b}{1-\xi} \right) \frac{M_{s_{t+1}} \kappa}{M_{v_{t+1}}} \right] \right\} \end{aligned} \tag{18}$$

Using (16) to eliminate τ_t^h, we obtain

$$\frac{\tau_t}{\mu_t} = \frac{\xi}{(1-b)} \left\{ 1 - \beta (1-\rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(1 - \frac{b}{1-\xi} \right) \frac{M_{s_{t+1}} \kappa}{M_{v_{t+1}}} \right] \left[f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) \right]^{-1} \right\}. \tag{19}$$

If $\xi = (1-b)$, (19) reduces to $\tau_t/\mu_t = 1$ and $\tau_t^h = 1$. 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^* driving the decisions of intermediate firms' remains constant and equal to one.

4.1.1 Efficient Policy with Flexible Prices

In the disaggregated equilibrium, the first order condition for retail firms when prices can be reset in every period is given by eq. (8). All retail firms set the same price, and while the retail goods price P_t is higher than the perfect competition level since $\mu > 1$, the welfare loss due to relative price dispersion is absent. In this flexible-price environment, the tax τ_t ensures that the first order condition for vacancy posting is identical to the planner's first order condition, that is, it corrects both for $b \neq (1-\xi)$ and for the monopolistic distortion $\mu_t = \mu \neq 1$ in the intermediate firms' vacancy posting condition. The tax τ_t^h ensures hours allocation is efficient. Monopoly power in the retail sector has the effect of increasing both retail prices and profits, while leaving the efficiency conditions and aggregate resource constraint unchanged.

To summarize this discussion, there are three potential distortions in the model –

vacancy posting, hours, and relative price dispersion. The policymaker needs two separate tax instruments τ_t and τ_t^h, to enforce an efficient equilibrium: τ_t ensures efficient vacancy posting, which also calls for offsetting the steady-state distortion from imperfect competition; 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 retail firms, given by equations (13), (15). The Appendix provides detailed derivations of the tax policy and equilibrium transfers ensuring market clearing, and shows that the resulting equilibrium enforces the planner's allocation.

4.1.2 Efficient Policy with Staggered Pricing

When prices are set according to the Calvo adjustment mechanism, the first order condition for a retail firm is given by (7) rather than by (8). In this case the two tax instruments τ_t and τ_t^h are no longer sufficient to enforce an efficient allocation. The efficient allocation is obtained when all retail goods are homogeneously priced and conditions (9), (10) are met. This can be achieved by completely stabilizing prices, that is, by employing monetary policy to ensure

$$\mu_t = \mu. \tag{20}$$

Monetary policy plays a role as a third cyclical policy instrument.

The markup μ_t affects equilibrium through three separate channels. First, variations in μ_t change the incentives for intermediate firms to post vacancies. Second, it influences equilibrium hours in the intermediate sector. Finally, variations in μ_t affect the marginal cost of retail firms and generates a dispersion of relative prices. The tax τ_t on the revenues of intermediate firms corrects the impact of μ_t on the vacancies choice. The tax τ_t^h on households 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 $MR_t^w = \tau_t/\mu_t$ (since each unit sold is subsidized at the gross rate τ_t), it still leaves the retail firm's marginal cost $MC_t^r = 1/\mu_t$ free to fluctuate inefficiently. Monetary policy that stabilizes the markup prevents the resulting inefficient price dispersion by canceling out the incentive to change prices.[4]

4.2 Policy Trade-offs and Tax-equivalent Monetary Policies

We now consider the role of monetary policy in an environment in which the tax policies are unavailable, so that $\tau_t = \tau_t^h = 1 \; \forall \; t$ in (13), (15), and (17).[5] The monetary authority

[4] Alternatively, Khan, King and Wolman (2003) eliminate the relative price distortion by reducing the amount of wasteful government spending to exactly offset the loss of output available for consumption. This fiscal policy is effective because relative price dispersion affects the resource constraint but not the firms' efficiency conditions, and can be interpreted as an additive productivity shock (see the Appendix).

[5] When a tax policy is not available, we assume retail revenues are subsidized to offset the steady-state markup μ. This requires a gross subsidy to retail firms τ_{ss}^r such that $\tau_{ss}^r = \mu$. In this case, the retail firm's first order condition under flexible prices becomes $\frac{\tau_{ss}^r}{\mu} = \frac{P_t^w}{P_t}$ implying $P_t^w = P_t$. The tax τ_{ss}^r ensures the

can still choose to stabilize the markup as in (20). This policy would generate price stability but inefficient labor market outcomes (unless, of course, the Hosios condition holds). Rather than stabilize prices, the monetary authority could choose to subsidize the intermediate firms' revenues by mimicking the effects of τ_t. A monetary policy that attempts to replicate the allocation implied by the tax policy τ_t would need to generate the same time-varying retail-price markup $\mu_t^* = \mu_t/\tau_t$ as occurs under the tax policy. From (14) this markup is given by

$$\frac{1}{\mu_t^*} = \frac{w_t}{f_{L_t}} + \frac{1}{f_{L_t}h_t}\xi\left[f_{L_t}h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}}\right) - \beta(1-\rho)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right\}\right]. \quad (21)$$

Thus, monetary policy can be described in terms of a rule for the retail markup; eq. (21) defines the 'notional tax' that the monetary authority could impose on intermediate firms. 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 therefore into inflation volatility (and relative price dispersion).

A monetary policy that stabilizes prices by ensuring μ_t remains constant, while failing to correct the distortion in vacancies posting, does allow for the hours' choice to be set in the same way as if the tax τ_t^h were available. This implies that, conditional on wage setting enforcing efficient vacancy posting, zero-inflation and optimal hours allocation are not mutually exclusive goals. The same result, which Blanchard and Galí (2007) label the 'divine coincidence', holds unconditionally in the standard new Keynesian setup. Within our framework, the 'divine coincidence' is the consequence of two simplifying assumptions: the separation between retail and intermediate firms, so that pricing decisions do not affect directly vacancy posting and hours choice, and the Nash bargaining hours-setting mechanism.

5 Competing Goals and Policy Outcomes

The results in section 3 showed that conditional on policies correcting all remaining distortions, the welfare loss from inefficient search (the search gap) can be sizable, more than 2% of the expected consumption stream when $b = 0.8$ and $\xi = 0.5$. This section uses the tax-policy framework to discuss why, despite the existence of a large search gap, inefficient wage setting in most cases has virtually no impact on the optimal policy relative to a model with Walrasian labor markets. The answer to this question is directly related to the Shimer's puzzle, in the case of Nash bargaining, and is the consequence of the unfavorable trade-off faced by the monetary authority, in the case of a wage norm.

Hosios condition applies under a monetary policy that delivers price stability. Therefore the incentive to deviate from price stability depends exclusively on the distortions in vacancy posting and hours whenever $b \neq (1-\xi)$.

The analysis also illustrates why under a wage norm an inefficient steady-state wages call for deviations from price stability.

5.1 Steady-State vs. Cyclical Tax Policy

We use the optimal tax policy to measure the deviations from the first-order conditions in the inefficient equilibrium that are required to achieve the efficient allocation. We find that the intermediate tax is large but displays low cyclical volatility under (inefficient) Nash bargaining. However, with wages set equal to a fixed wage norm, the tax is much smaller but highly volatile.

Table 4 shows summary statistics for τ_t under different assumptions on wage setting. Since we assume the full set of three policy instruments is available, τ_t is set according to (14) or (18), τ_t^h follows (16) and monetary policy sets $\mu_t = 1$. By construction, when the wage norm is fixed at the efficient level, no steady-state subsidy is needed to achieve labor market efficiency. For $b = 0.7 > 1 - \xi$, the optimal steady-state subsidy rate would be 115%. To understand the reason for such a high subsidy rate, recall that if wages are set by Nash-bargaining, workers and intermediate firms agree on a rule to share the job surplus. This surplus depends on τ_t, implying that the steady state wage, conditional on b, differs from its value in the absence of the subsidy. For $b > (1 - \xi)$ we have that $\tau > 1$ in the steady state, increasing the firms' surplus for a given wage relative to the case without a subsidy. Under Nash-bargaining the wage will be higher too since the total surplus increased, and the resulting increase in the real wage dampens the impact of the subsidy on the firm's surplus share. For the firm to achieve the efficient level of surplus share (equal to ξ times the surplus generated under the planner allocation) the subsidy must be large. In an economy where the wage were fixed *exogenously* at a value equal to the Nash bargaining steady state, rather than fixed at the *endogenously* derived value of the Nash bargaining steady state, this feedback mechanism would not operate. In this case the intermediate tax implementing the optimal tax policy would be two orders of magnitude smaller, and equal to 1.65%.

When wages are determined by Nash bargaining, the volatility of the tax rate is less than one-twentieth that of output. 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 display very little volatility.

The result that price stability generates a level of welfare nearly identical to the constrained first best 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 in the first best which is about 8 times smaller (see table 5). The model produces the well-known 'Shimer's puzzle' – productivity shocks generate large movements in real wages but little volatility in employment and vacancies. This effect is compounded in our model by the fact that firms can expand output along the intensive margin without changing employment. Since the volatility of employment is low regardless of the surplus' share assigned to workers and firms, the welfare loss from inefficient search over the business cycle is comparatively small. This translates into a large, but acyclical, wedge between the efficient and inefficient allocations, and into a low volatility for τ_t, as the tax needs to ensure only small changes in the dynamics of v_t, N_t, and h_t.

In contrast, when the wage is fixed at the wage norm, the volatility of vacancies and employment increases many times over. Conditional on a policy of price stability, the relative volatility of employment is $\sigma_n/\sigma_y = 0.99$.[6] 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.

Figure 1 plots impulse response functions to a 1% productivity shock when $\bar{w} = w_{ss}(0.5)$ and the optimal fiscal (tax) and monetary policy is implemented. 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 after the positive productivity shock, too many vacancies are posted, and the surge in employment is inefficiently high. The optimal policy calls for taxing the firms' revenues, and the subsidy rate τ_t decreases on impact by about one percentage point. This increases the workers' surplus share which would otherwise be below the efficient level. The plot also shows the response of τ_t when wages are Nash bargained and $b = 0.7$. The response decreases by an order of magnitude.

5.2 Monetary Policy and Notional Taxes

When the policymaker is restricted to the single monetary policy instrument and wages are fixed by the wage norm, the first best allocation cannot be implemented. To illustrate the trade-offs present in this case, figure 2 displays impulse responses following a 1% productivity shock under a policy of price stability and under the tax-equivalent policy $\mu_t = \mu_t^*$, that is, under the monetary policy that replicates the efficient vacancy condition. The experiment assumes a wage norm $\overline{w} = w_{ss}(0.5)$. First, consider the dynamics under price stability. Vacancy creation is inefficiently high in response to the rise in productivity. If the first best fiscal policy could be implemented, the tax τ_t would increase relative to the steady state level. The behaviour of the notional tax can be translated into the distance between the markup resulting from the enforced monetary policy and the markup that would enforce the planner's vacancy posting condition. For

[6] While the volatility of output nearly doubles compared to the Nash bargaining case, the volatility of consumption does not increase as much. When the wage is fixed, technology shocks lead to large swings in vacancy postings, and in search costs, reducing output available for consumption. In the first best, the steady state share of output spent in search is equal to $\kappa v/y = 4.16\%$.

any monetary policy p, this 'markup gap' is defined as

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

Notice that the markup gap is in fact equal to the optimal notional tax τ_t. Under price stability, the deviation of the markup gap from the steady state is large, and μ_t^{gap} drops on impact by 4%. This large movement in the markup gap suggests 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 response of employment to the productivity shock is reduced by a factor of 10 and the response of employment is close to the first best. Since the tax equivalent policy calls for imposing a notional tax, rather than a subsidy, the markup increases, resulting in negative inflation. The dynamic behavior of the economy under the policy that maintains $\mu_t = \mu_t^*$ is closer to the efficient equilibrium (displayed in figure 1) compared to the price-stability policy. At the same time, the allocation is different from the efficient one, since μ_t responds to the technology shock, the hours choice is inefficient, and inflation volatility is high, leading to a reduction in the amount of the final good available for consumption relative to the efficient equilibrium.[7]

Table 6 reports the welfare cost of implementing a monetary policy that deviates from price stability and instead imposes the efficient vacancy posting condition by ensuring the markup equals μ_t^*. Under Nash bargaining, this policy is essentially equivalent to a policy of price stability. Expressed differently, with Nash bargaining, there is little loss from adopting a policy of price stability. However, with a wage norm, even one set at the efficient steady-state level $w_{ss}(0.5)$, the $\mu_t = \mu_t^*$ policy performs poorly compared to price stability (i.e., the constant μ_t policy). Since μ_t^* fluctuates over the business cycle, letting the actual markup track μ_t^* generates high volatility in the markup, and this translates into high inflation volatility. Additionally, the allocation in the labor market is not efficient because of the remaining hours distortion. Intuitively, closing the markup gap μ^{gap} to achieve the same job posting condition as in the planner's equilibrium is among the goals of monetary policy, though in terms of welfare the weight the monetary authority should give to this goal is limited.

5.3 The Welfare Cost of Distortions

We can shed light on the unfavorable trade-off faced by the policymaker by allowing for the existence of two policy instruments, and assuming the policymaker would employ the instruments as it would under the policy implementing the first best. Thus we can build three economies, where in turn all but one of equilibrium conditions are identical to the planner's equilibrium. Note that the *allocation* itself can be different for all of the

[7] This 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.

endogenous variables. Therefore, as is common when examining second-best equilibria, the one-distortion economy equilibrium need not welfare-dominate the economy where additional distortions are introduced. 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 τ_t^h is not used (i.e., $\tau_t^h = 1$), only the first order condition for hours choice deviates from the first-best efficiency condition. But the presence of this remaining distortion means that v_t and N_t do not behave efficiently, since the third policy instrument needed to support the efficient equilibrium is missing.

Suppose instead that $\tau_t = 1$, while the monetary authority continues to stabilize prices. 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 ensures $\mu_t^{gap} = 1$ (i.e., $\mu_t = \mu_t^*$) and the tax τ_t^h enforces the planner's first order condition for the hours choice. In this case, monetary policy is replacing the tax τ_t, and the only distortion that is unaddressed arises from price dispersion associated with the deviation from price stability.

These alternative economies, each with only one distortion, are useful in gauging the cost of leaving unaddressed one of the three distortions in our basic model. We focus on the case with a wage norm, and the norm corresponds to either 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. Results are summarized in Table 7.

As shown by the last two columns of the table, the hours inefficiency turns out to be of little consequence for welfare. When the labor's share of the steady-state surplus is inefficiently high ($\bar{w} = w_{ss}(0.7)$), the loss relative to the first best is considerable, but this welfare loss is generated almost entirely by an inefficient steady-state level of hours. The steady-state loss amounts to 0.79% of steady-state consumption while it increases only to 0.81% in the stochastic equilibrium. Thus, the loss in the stochastic equilibrium where the cyclical behavior of hours is also inefficient is only marginally higher than in the steady state.

In contrast, the price setting distortion is very costly in the stochastic equilibrium. In standard models with staggered price adjustment, 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 into (21) 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 appropriate tax instruments are not available, the monetary authority can only enforce a second best, and the optimal policy only partially closes the search gap. The distortion in hours choice plays only a marginal role in the welfare results.

5.4 The Steady State and the Gain from Optimal Policy

Using the tax-policy instruments, we can interpret the numerical welfare results obtained in the previous section. The welfare cost of the search distortion is illustrated in figure 3. The welfare loss under a policy of price stability is plotted against the steady state surplus share b accruing to workers. If wages are Nash-bargained, the surplus share is constant over the business cycle. When wages are set according to a norm $\overline{w}$, the surplus share is time-varying, and b corresponds only to the steady state share. Since a policy of price stability replicates the flexible price equilibrium, the first best allocation is obtained for $b = (1 - \xi)$ under Nash-bargained wage, and the distance between the welfare level for each b and the first best corresponds to our definition of the search gap $[W^* - W^f]$.

This gap sets an upper bound for the welfare improvement that can be obtained by deviating from price stability whenever $b \neq (1 - \xi)$. For a given search gap, deviations from price stability can bring about a smaller or larger welfare improvement depending on the wage setting mechanism. Consider the case $b = 0.8$. Under Nash bargaining, the optimal tax policy in the steady state would call for a large subsidy to intermediate firms since $b > (1 - \xi)$. Once stochastic shocks are added to the model, the total search gap is approximately equal to the steady state gap. This results in a small volatility of the intermediate firm's subsidy under the optimal tax policy. Regardless of whether the tax policy is available, the optimal steady state monetary policy is price stability, a result that we discuss in detail in the following. The optimal cyclical tax policy calls for very small movements in the effective markup $1/\mu_t^* = \tau_t/\mu_t$. Note that the optimal τ_t ensuring efficient vacancy posting is derived under the assumption that the remaining distortions in the economy are corrected by additional policy instruments, and thus no trade-off exists between policy objectives. In the absence of such tax instruments, the monetary authority is constrained by the trade-offs when setting the policy, and thus has an even smaller incentive to deviate from price stability over the business cycle. With a wage norm, instead, the loss from cyclical volatility is a substantial portion of the search gap - while the steady state gap is identical regardless of wage-setting - and there is room for monetary policy to improve over the flexible-price allocation.

The efficiency of the steady state plays a pivotal role in the welfare results. Under a wage norm, as b becomes progressively larger than $(1-\xi)$ implying a higher real wage and a smaller share of the surplus for firms, the search gap increases, but the loss from cyclical fluctuations also increases, as shown in figure 3. This provides a progressively stronger incentive for the policymaker to deviate from price stability as the search inefficiency becomes larger.

Yet even under the conditions most favorable to deviating from price stability, only a fraction, albeit a significant one, of welfare loss due to the search gap can be recovered using monetary policy. We showed earlier that using the tax-equivalent policy to subsidize vacancy creation required large movements in the markup μ_t, generating costly inflation volatility and hours misallocation. Vacancy postings are too low also in the steady state when $b > 1-\xi$, so there should be an incentive for the policymaker to subsidize vacancy creation even in the absence of business cycle shocks. While this long-run trade off exists, it turns out not to provide an incentive to deviate from price stability under the Ramsey policy. The solution to the optimal policy problem yields a steady-state inflation rate of zero. This result is analogous to the one obtained in models with staggered price adjustment by King and Wolman (1999) and Adao, Correia and Teles (2003), and discussed in Woodford (2001).

While the Ramsey steady state calls for price stability, it is instructive to consider the optimal policy if the monetary authority were constrained to choose a constant inflation rate - therefore maximizing steady state welfare, rather then the discounted value of the household's utility. The literature refers to these distinct concepts of optimal policy in the steady state as the 'modified golden rule' and the 'golden rule'. Under the golden rule, the optimal inflation rate would be very close to zero. The steady state markup μ and gross inflation rate Π are linked by the relationship:

$$\frac{1}{\mu} = \frac{\varepsilon - 1}{\varepsilon}\tau_{ss}^{r}\left[\frac{\Pi^{1-\varepsilon}-\omega}{1-\omega}\right]^{\frac{1}{1-\varepsilon}}\frac{1}{\Pi}\frac{(1-\omega\beta\Pi^{\varepsilon})}{(1-\omega\beta\Pi^{\varepsilon-1})} \tag{22}$$

where a steady-state subsidy $\tau_{ss}^{r} = \varepsilon/(\varepsilon-1)$ ensures that in the zero-inflation steady state the markup is equal to 1. If all tax instruments were available to the policymaker, the optimal intermediate steady state subsidy rate in our parameterized model with Nash-bargained wages and $b = 0.7$ would be 115%, or $\tau = 2.15$ (see table 4). In the absence of tax instruments, the tax-equivalent monetary policy would set μ equal to μ^*. Defining $\widetilde{\mu}$ as the steady state markup that would obtain under the full tax policy we obtain:

$$\frac{1}{\mu^*} = \frac{\tau}{\widetilde{\mu}}$$

Since $\widetilde{\mu} = \tau_{ss}^{r}(\varepsilon-1)/\varepsilon = 1$ the tax-equivalent policy would call for an effective markup in the intermediate firm's revenue function $\mu^* = 1/2.15$. Given our parameterization and (22), such a value of μ^* would not be profit-maximizing for any steady state inflation Π.

In fact, it would generate a negative profit. For $b < (1 - \xi)$ the tax-equivalent policy would call for a markup $\mu^* > 1$ (which is always feasible in the steady state equilibrium) so as to tax the intermediate firm's revenues and discourage vacancy creation. Equation (22) implies that the elasticity of the markup with respect to inflation is very small, so it turns out the optimal steady-state policy is approximately equal to price stability even in this case. As μ^* increases, price dispersion increases, but also hours are misallocated. Additionally, both distortions reduce the total surplus. These distortions need to be traded off with the more efficient division of the surplus achieved by a higher markup. In summary, monetary policy is not an appropriate tool to correct the steady state search inefficiency.

5.5 Policy Options and the Structure of Labor Markets

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, and the wage-setting mechanism. Our baseline parameterization is designed to represent US labor markets. We also consider a labor market characterized by a lower steady-state employment rate, and a larger share of the available time devoted to leisure. For this alternative parameterization, we additionally 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 a large as in the US parameterization. This parameterization delivers substantially lower flows in and out of employment and longer average unemployment, two regularities associated with the labor market dynamics of the four largest Euro-zone economies - France, Germany, Spain and Italy - over the last three decades. The Appendix contains the model parameter values.

Table 8 reports the welfare results. The search gap is about of the same size as under the US parameterization when wages are Nash-bargained, but it is substantially smaller when wages are set at the wage norm level. Importantly, the welfare gain from the optimal policy relative to price stability is tiny, on the order of one hundredth of a percentage point.

In a model where labor flows are small, the scope for monetary policy to correct inefficient search activity is also reduced. The quarterly job finding probability drops from 76% to 25% under our alternative parameterization. The lower separation rate implies that firms cannot easily shed excess workers during a downturn (nor lower the wage bill, since the real wage is fixed), and therefore firms will increase the workforce more moderately in an expansion. Additionally, the cost of vacancy posting is higher since the first best calls for lower job creation. As the volatility of hiring decreases, the improvement available from a monetary policy that deviates from price stability to correct for inefficient vacancy posting also decreases. The same labor market characteristics that lower steady-state employment, and leave more to be gained from long-term policy intervention, make cyclical monetary policy less effective. It is in economies where labor markets are more flexible, and labor flows are volatile over the business cycle, that deviations from price stability can lead to important welfare gains.

6 Conclusions

Our objective in this paper is to explore the nature of the distortions that arise in models with sticky prices and labor market frictions with both intensive and extensive margins. To study the welfare loss generated by various distortions, we derive the tax and subsidy policy that would replicate the efficient equilibrium, and characterize the trade-offs using tax-equivalent monetary policies. Whereas three policy instrument would restore the first best, 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.

Our results can be summarized as follows. In our model, it is feasible for monetary policy to completely undo the price setting restriction. However, because the incentive to search responds to movements in the markup, but not to movements in nominal variables, we find that the policymaker can achieve higher welfare in the economy with staggered price setting rather than in one where price setting is unconstrained and one of the distortions relative to the first best is absent.

At the same time, while the cost of the search inefficiency is large, the welfare attained by the optimal policy deviates very little from the one achieved under flexible prices. In practice, the policymaker finds little incentive in trying to correct for the search inefficiency, and to deviate from a policy of price stability. Monetary policy is of limited effectiveness because it works through the retail sector markup, which simultaneously affects *all* of the distortions present in the economy, and because Nash bargaining implies low volatility of employment. In this sense, our result is the welfare implication of the Shimer's (2004) puzzle. Yet, introducing real wage rigidity does not, in itself, modify this result. This is in stark contrast with models including staggered wage and price contracts (Erceg, Henderson and Levin, 2000, Thomas, 2008). It is only with a wage norm fixed at a level very different from the efficient steady state that deviations from price stability yield high return in terms of welfare, and the trade-off faced by the policymaker can be favorably exploited to increase search efficiency. In this case, there exist gains from accounting for the labor market's structure in selecting monetary policy, even without introducing an explicit cost of wage dispersion. Additionally, in our model the hours margin plays a minor role in the welfare results. We conjecture that the explicit introduction of overtime labor would change this result.

Monetary policy interacts in complex way with fiscal and labor market policies. We find that 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. The same labor market characteristics that lower steady-state employment, and leave more to be gained from long-term policy intervention, make cyclical monetary policy less effective. 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.

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7 Appendix 1: Pricing and Market Clearing Conditions

7.1 Pricing Dynamic Equations

Write eq. (7) as:

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

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:

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

7.2 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

$$C_t^m = \frac{P_t^w}{P_t} Y_t^w - \kappa v_t + \Pi_t^r. \tag{23}$$

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 (23) gives aggregate real spending:

$$Y_t^d = C_t^m + \kappa v_t. \tag{24}$$

Finally, using the demand for final good j in (6), 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

$$Y_t^w = Z_t N_t = [C_t^m + \kappa v_t] \int \left[\frac{P_t(j)}{P_t}\right]^{-\varepsilon} dj. \tag{25}$$

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 obtaining be writing (24) and (25) 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.

8 Appendix 2: Parameterization

8.1 US Parameterization

Households' preferences are assumed logarithmic in consumption, and the disutility of work is given by:

$$N_t V(h_t) = N_t \left(\frac{\ell h_t^{1+\gamma}}{1+\gamma}\right).$$

Labor hours supply elasticity $1/\gamma$ is set equal to 2. The exogenous separation rate ρ and vacancy elasticity of matches ξ are set respectively equal to 0.1 and 0.5. This 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). We derive the parameters η, ℓ, and κ as implied by observable steady state values in US data for the vacancy filling rate q_{ss}, the share of working hours h_{ss}, and the employment rate N_{ss} when the economy is in the efficient steady state. This occurs for Nash wage bargaining with $1 - b = \xi$, zero inflation, and a unitary markup. Without loss of generality, we assume a zero-replacement ratio, implying $w_u = 0$. Staggered price setting is characterized by two parameters, ω and ε. We set ω so that the average price duration is 3.33 quarters and we set ε so that the flexible-price markup is 20%. The volatility of innovations to the technology shock is set so the model matches the volatility of US non-farm business sector output over the post-war period conditional on monetary policy being conducted according to the Taylor rule (Taylor, 1993).

8.2 High Cost of Search Parameterization

Table A1: High Cost of Search Parameterization

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: High Cost of Search: Implied Parameter Values

Implied parameter values	Efficiency of matching technology	η	0.4182
from flexible-price equilibrium	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

9 Appendix 3: Tax Policy

9.1 Efficient Nash bargaining and vacancies allocation

The value V_t^S of a filled position for the household is equal to the derivative with respect to N_t of the value function $W_t(N_t, B_t)$, derived in Section 2:

$$V_t^S = -w^u + w_t h_t - \frac{V(h_t)}{U_{C_t}} + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^S (1-\rho)(1-p_{t+1}). \tag{26}$$

The value V_t^J of a filled position for the intermediate firm is equal to the derivative with respect to N_t of the value function $W_t(N_t)$:

$$\begin{aligned} W_t(N_t) &= \max \quad f_t(A_t, N_t h_t)\mu_t^{-1} - w_t h_t N_t - \kappa v_t + E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) W_{t+1}(N_{t+1}) \\ st \quad N_t &= (1-\rho)N_{t-1} + q(\theta_t) v_t \end{aligned}$$

Then:

$$V_t^J = \frac{f_{L_t} h_t}{\mu_t} - w_t h_t + (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^J. \tag{27}$$

The first order condition with respect to vacancies v_t gives:

$$-w_t h_t \frac{\partial N_t}{\partial v_t} - \kappa + E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t} \right) V_{t+1}^J \frac{\partial N_{t+1}}{\partial N_t} \frac{\partial N_t}{\partial v_t} + \frac{f_{L_t} h_t}{\mu_t} \frac{\partial N_t}{\partial v_t} = 0$$

Using this result together with eq. (27) we obtain $V_t^J = \frac{\kappa}{q(\theta_t)}$, and finally

$$\frac{\kappa}{q(\theta_t)} = \frac{f_{L_t} h_t}{\mu_t} - w_t h_t + (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \frac{\kappa}{q(\theta_{t+1})} \tag{28}$$

The Nash bargaining solution for the surplus sharing requires:

$$\frac{(1-b)}{U_{C_t}} V_t^S = b V_t^J \tag{29}$$

Since the total surplus in consumption units is given by $\frac{V_t^S}{U_{C_t}} + V_t^J$, this implies the firm receives a share $(1-b)$:

$$(1-b) V_t^J + \frac{(1-b)}{U_{C_t}} V_t^S = V_t^J$$

Using eqs. (26), (28) and (29) we can write the share, one obtains an expression for the real wage bill:

$$w_t h_t = (1-b)\left(w^u + \frac{V(h_t)}{U_{C_t}}\right) + b\left[\frac{f_{L_t} h_t}{\mu_t} + (1-\rho)\beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \kappa \frac{p_{t+1}}{q_{t+1}}\right]. \tag{30}$$

The condition for efficient vacancy posting is obtained from the solution to the planner's problem in section 2:

$$\frac{\kappa}{M_{v_t}} = f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}}\right) + \beta (1-\rho) E_t \left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1 - M_{s_{t+1}}) \frac{\kappa}{M_{v_{t+1}}}\right\} \tag{31}$$

To obtain the efficient vacancy allocation in the market equilibrium, use the matching function to obtain:

$$q_t = \frac{M_{v_t}}{\xi}$$

$$p_t = \frac{M_{s_t}}{1-\xi}$$

Substituting the latter two equations substitute (30) in (28) results in:

$$\frac{\kappa}{M_{v_t}} = \frac{(1-b)}{\xi}\left[\frac{f_{L_t} h_t}{\mu_t} - w_u - \frac{V(h_t)}{U_{C_t}}\right] + \frac{\beta(1-\rho)}{\xi} E_t \left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(1 - b\frac{M_{s_{t+1}}}{1-\xi}\right)\frac{\kappa\xi}{M_{v_{t+1}}}\right\} \tag{32}$$

The RHS of eqs. (31) and (32) are equal for $\mu_t = 1$ and $b = (1-\lambda)$. Under flexible prices, or with staggered pricing and a zero-inflation monetary policy, the efficient allocation is generated by the Nash bargaining competitive equilibrium when the surplus share b accruing to the household is equal to the elasticity $(1-\xi)$ of the matching function with respect to vacancies, and an appropriate policy ensures the markup is equal to 1.

9.2 Tax policy enforcing the efficient allocation under Nash bargaining

Assume the intermediate firms' revenues are taxed at the gross tax rate τ_t. Then

$$V_t^J = \frac{\kappa}{q(\theta_t)} = f_{L_t} h_t \left(\frac{\tau_t}{\mu_t}\right) - w_t h_t + (1-\rho) E_t \beta \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \frac{\kappa}{q(\theta_{t+1})}. \tag{33}$$

Assume there exists a policy instrument τ_t^h affecting the households' opportunity cost of having an additional member in a match providing h_t hours of work. We will later show that in the efficient allocation $\tau_t^h \neq 1$. From the perspective of the household, the value of a match is

$$V_t^S \equiv w_t h_t - \tau_t^h \left(w^u + \frac{V(h_t)}{U_{C_t}}\right) + \beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) V_{t+1}^S (1-\rho)(1-p_{t+1}) \tag{34}$$

Using eqs. (33) and (34) the Nash-bargained wage is:

$$w_t h_t = (1-b)\tau_t^h \left(w^u + \frac{V(h_t)}{U_{C_t}}\right) + b\left[f_{L_t} h_t \left(\frac{\tau_t}{\mu_t}\right) + (1-\rho)\beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \kappa \frac{p_{t+1}}{q_{t+1}}\right] \tag{35}$$

Substitute (35) in (33), using the equilibrium values of p_t and q_t. Equating the RHS of the resulting equation with the RHS of eq. (31) gives:

$$\begin{aligned} & \frac{(1-b)}{\xi}\left[f_{L_t} h_t \left(\frac{\tau_t}{\mu_t}\right) - \tau_t^h \left(w^u + \frac{V(h_t)}{U_{C_t}}\right)\right] + \frac{(1-\rho)}{\xi}\beta E_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(1 - b\frac{M_{s_{t+1}}}{1-\xi}\right)\frac{\kappa\xi}{M_{v_{t+1}}} \\ = \quad & f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}}\right) + \beta(1-\rho) E_t \left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1 - M_{s_{t+1}})\frac{\kappa}{M_{v_{t+1}}}\right\} \end{aligned}$$

For any b and τ_t^h, the equality is satisfied for:

$$\begin{aligned} \frac{\tau_t}{\mu_t} \quad = \quad & \frac{1}{f_{L_t} h_t}\left[\frac{\tau_t^h (1-b) - \xi}{(1-b)}\right]\left(w^u + \frac{V(h_t)}{U_{C_t}}\right) \\ & + \frac{\xi}{(1-b)}\left\{1 - \frac{1}{f_{L_t} h_t}\beta(1-\rho) E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(1 - \frac{b}{1-\xi}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right]\right\} \end{aligned} \tag{36}$$

where

$$\frac{M_{s_{t+1}}}{M_{v_{t+1}}} = \theta_{t+1}\frac{(1-\xi)}{\xi}$$

The tax τ_t ensures that the first order condition for vacancy posting is identical to the planner's first order condition, that is, it corrects both for $b \neq (1-\xi)$ and for the monopolistic distortion $\mu_t \neq 1$.

9.3 Tax policy enforcing the efficient allocation conditional on wage-setting

Divide both sides of eq. (33) by ξ, and equate the RHS to the RHS of (31):

$$\begin{aligned}
&\xi^{-1}\left[f_{L_t}h_t\left(\frac{\tau_t}{\mu_t}\right)-w_th_t+(1-\rho)E_t\beta\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{\kappa}{q(\theta_{t+1})}\right]\\
=\;& f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)+\beta\left(1-\rho\right)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-M_{s_{t+1}})\frac{\kappa}{M_{v_{t+1}}}\right\}
\end{aligned}$$

For any hourly wage w_t, the equality is satisfied for:

$$\frac{\tau_t}{\mu_t}=\frac{w_t}{f_{L_t}}+\frac{\xi}{f_{L_t}h_t}\left[f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)-\beta\left(1-\rho\right)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right\}\right]. \quad (37)$$

Note that in this case τ_t^h does not appear in the tax policy condition, since the wage w_t is taken as given and V_t^S is not used at any point in the derivation of eq. (37).

The tax (37) works by generating the correct surplus for the firm, conditional on all endogenous variables being at their first best level. The firm receives a subsidy S_t per unit of output Y_t^w, or per effective worker, equal to:

$$\begin{aligned}
S_t &= \frac{\tau_t f_{L_t}h_t}{\mu_t}-\frac{f_{L_t}h_t}{\mu_t}\\
&= w_th_t+\xi\left[f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)-\beta\left(1-\rho\right)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right\}\right]-\frac{f_{L_t}h_t}{\mu_t}
\end{aligned}$$

The firm's surplus V_t^{*J} is equal to the sum of the un-subsidized surplus V_t^J obtained in eqs. (27), (28) and the subsidy S_t, and can be rewritten as:

$$\begin{aligned}
V_t^{*J} &= \frac{f_{L_t}h_t}{\mu_t}-w_th_t+(1-\rho)E_t\beta\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\frac{\kappa}{q(\theta_{t+1})}+S_t\\
&= \xi\left[f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)-\beta\left(1-\rho\right)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-M_{s_{t+1}})\frac{\kappa}{M_{v_{t+1}}}\right\}\right]
\end{aligned}$$

But this is equal to the firms' surplus share ξ of the total surplus V^{*total} in the efficient equilibrium

$$\xi\frac{V_t^{*total}}{U_{C_t}}=\xi\left[f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)-\beta\left(1-\rho\right)E_t\left\{\left(\frac{\lambda_{t+1}}{\lambda_t}\right)(1-M_{s_{t+1}})\frac{\kappa}{M_{v_{t+1}}}\right\}\right]$$

This implies the subsidy S_t can be rewritten as

$$S_t=-V_t^J+\xi\frac{V_t^{*total}}{U_{C_t}}$$

The intermediate tax τ_t conditional on Nash bargaining is conceptually different from the tax τ_t conditional on a given wage process w_t. This is more easily seen comparing a steady state where agents agree on a fixed wage (a norm) equal to the Nash bargaining steady-state outcome for a given b, and a steady state where agents agree to set the wage by Nash bargaining. If the agents are Nash-bargaining, they agree on a rule to share the surplus. The total surplus changes with τ_t, so the steady state wage ends up being different from the steady state wage in the absence of the surplus, conditional on b. For $b > (1-\xi)$ we have that $\tau > 1$ in the steady state. Under Nash-bargaining, the tax enforcing the first best will be higher than under a wage norm. The wage also will be higher, though this is irrelevant for the allocation. All that is needed for efficient vacancy posting is that the firm receives a share of the total surplus equal to ξ times the surplus generated in the first best. The wage is only a transfer through the economy, and any wage payment to the household in excess of the first-best wage is absorbed by the lump-sum transfer to fund the intermediate firms' subsidy.

9.4 Efficient hours choice

The intermediate tax τ_t will generate the first best level of vacancy posting only conditional on the choice of hours being efficient. As discussed in the main text, this can be achieved imposing a tax τ_t^h affecting the households' opportunity cost of work. Then the FOC for hours' choice is

$$f_{L_t}\left(\frac{\tau_t}{\mu_t}\right) = \left(\frac{V_{h_t}}{U_{C_t}}\right)\tau_t^h \tag{38}$$

and the optimal tax τ_t^h on households is

$$\tau_t^h = \frac{\tau_t}{\mu_t}. \tag{39}$$

Using eq. (39) to eliminate τ_t^h in eq. (36) we obtain

$$\frac{\tau_t}{\mu_t} = \frac{\xi}{(1-b)}\left\{1-\beta(1-\rho)E_t\left[\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(1-\frac{b}{1-\xi}\right)\frac{M_{s_{t+1}}\kappa}{M_{v_{t+1}}}\right]\left[f_{L_t}h_t-\left(w_u+\frac{V(h_t)}{U_{C_t}}\right)\right]^{-1}\right\}.$$

9.5 Tax-equivalent policy

The tax-equivalent policy enforcing the intermediate sector tax $\frac{\tau_t}{\mu_t}$ (36) or (37) is given by

$$\begin{aligned}\frac{1}{\mu_t^*} &\equiv \frac{\tau_t}{\mu_t}\\ \mu_t &= \mu_t^*\\ \tau_t^h &= 1\end{aligned}$$

Whenever a tax policy scheme is not available, we assume a steady state subsidy to retail firms τ_{ss}^r ensures $\mu_{ss} = 1$, so that the Hosios condition holds when prices can be reset in every period, or the monetary authority targets $\pi_t = 0$.

9.6 Market clearing with tax policy

9.6.1 Household utility

To affect the household's opportunity cost of work so that the disutility of working hours in eq. (38) is given by $\left(\frac{V_{h_t}}{U_{C_t}}\right)\tau_t^h$ we assume the household has to supply $(\widetilde{\tau}_t^h - 1)h_t$ hours of work per employed worker to the government. These hours are transformed by the government in utility-providing services G_t rebated to the household. [8] The household utility is then:

$$
\begin{aligned}
\cup_t &= U(C_t) - N_t\widetilde{V}(h_t) + G_t \\
\widetilde{V}(h_t) &= V(\widetilde{\tau}_t^h h_t) \\
V(\widetilde{\tau}_t^h h_t) &= \frac{\ell(\widetilde{\tau}_t^h h_t)^{1+\gamma}}{1+\gamma} \\
\widetilde{\tau}_t^h &= (\tau_t^h)^{\frac{1}{1+\gamma}} \\
G_t &= \frac{N_t\ell(\widetilde{\tau}_t^h h_t)^{1+\gamma}}{1+\gamma} - \frac{N_t\ell {h_t}^{1+\gamma}}{1+\gamma} \\
&= \frac{N_t\ell\left[(\widetilde{\tau}_t^h)^{1+\gamma} - 1\right]{h_t}^{1+\gamma}}{1+\gamma}
\end{aligned}
$$

This rebate scheme ensures that $\frac{\widetilde{V}_{h_t}}{U_{C_t}} = \left(\frac{V_{h_t}}{U_{C_t}}\right)\tau_t^h$ and at the same time the utility of the household is unaffected by the tax in the aggregate equilibrium. Therefore conditional on the first best choices of C_t, N_t, h_t the utility $\cup_t$ is also at the first best level.

9.6.2 Budget constraint

The derivation of eq. (34) and of the intermediate tax conditional on the Nash-bargained wage assumes that the household pays a tax rate $(\tau_t^h - 1)$ also on the home production of consumption goods $w_u(1-N_t)$. This assumption is made for analytical convenience, and is not central to any of the results. All profits and taxes are rebated (or levied) lump-sum on the household's. The budget constraint can be written as:

$$
P_tC_t + p_{bt}B_{t+1} \leq P_t[w_th_tN_t + \tau_t^h w^u(1-N_t)] + B_t + P_t\Pi_t^r - P_t\left[T_t^h + T_t + T_t^r\right]
$$

T_t^h rebates to the household the tax τ_t^h levied on $w_u(1-N_t)$:

$$
T_t^h = (\tau_t^h - 1)w_u(1-N_t) \tag{40}
$$

T_t rebates to the household the tax τ_t levied on the intermediate sector (or taxes the household

[8] For $\widetilde{\tau}_t^h < 1$ the interpretation of the tax is identical, while the channels through which the hours' exchange is transformed into utility for the household are reversed.

for the subsidy to the intermediate sector):

$$\begin{aligned}
T_t &= (\tau_t - 1)\frac{f_{L_t} h_t N_t}{\mu_t} \\
&= S_t N_t \\
&= N_t w_t h_t + N_t \xi \left[f_{L_t} h_t - \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) - \beta (1-\rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{M_{s_{t+1}} \kappa}{M_{v_{t+1}}} \right\} \right] - \frac{f_{L_t} h_t N_t}{\mu_t}
\end{aligned}$$

Given $Y_t^w = f_{L_t} h_t N_t$, $Y_t = Y_t^w$ and $\Pi_t^r = Y_t \left(1 - \frac{1}{\mu_t}\right)$ we can write explicitly the retail firms' profit Π_t^r, summarized in the last term of the following equation:

$$\begin{aligned}
T_t &= N_t w_t h_t + N_t \left[(\xi - 1) f_{L_t} h_t - \xi \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) - \xi \beta (1-\rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \frac{M_{s_{t+1}} \kappa}{M_{v_{t+1}}} \right\} \right] \\
&\quad + f_{L_t} h_t N_t \left(1 - \frac{1}{\mu_t} \right)
\end{aligned}$$

Rewriting the term in square brackets using the equilibrium conditions for p_t, q_t:

$$\begin{aligned}
T_t &= N_t w_t h_t + N_t \left[(\xi - 1) f_{L_t} h_t - \xi \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) - \xi \beta (1-\rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \kappa \frac{p_{t+1}}{q_{t+1}} \frac{(1-\xi)}{\xi} \right\} \right] \\
&\quad + f_{L_t} h_t N_t \left(1 - \frac{1}{\mu_t} \right)
\end{aligned}$$

Reorganizing terms:

$$\begin{aligned}
T_t &= N_t w_t h_t - N_t \left[\xi \left(w_u + \frac{V(h_t)}{U_{C_t}} \right) + (1-\xi) \left(f_{L_t} h_t + \beta (1-\rho) E_t \left\{ \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \kappa \frac{p_{t+1}}{q_{t+1}} \right\} \right) \right] \\
&\quad + f_{L_t} h_t N_t \left(1 - \frac{1}{\mu_t} \right)
\end{aligned}$$

The term in square brackets is equal to the efficient (Nash-bargained) wage $(w_t^* h_t^*)$, while the last term is the real profit of the retail sector. The we can rewrite T_t as

$$T_t = N_t w_t h_t - N_t \left(w_t^* h_t^* \right) + \Pi^r \tag{41}$$

Using eqs. (40) and (41) the budget constraint becomes:

$$\begin{aligned}
& P_t C_t + p_{bt} B_{t+1} \\
\leq\ & P_t [w_t h_t N_t + \tau_t^h w^u (1 - N_t)] + B_t + P_t \Pi_t^r - P_t T_t^r - P_t [(\tau_t^h - 1) w_u (1 - N_t) + N_t w_t h_t - N_t \left(w_t^* h_t^* \right) + \Pi^r]
\end{aligned}$$

Market clearing implies $B_t = 0\ \forall\ t$. Therefore:

$$C_t \leq [N_t \left(w_t^* h_t^* \right) + w^u (1 - N_t)] - T_t^r \tag{42}$$

Since the complete tax policy ensures the FOCs for the market economy are identical to the planner's one, N_t and h_t will be at their first-best level, and eq. (42) implies the consumption level C_t will also attain its efficient level for $T_t^r = 0$.

The tax T_t^r is nonzero only when the tax instruments τ_t and τ_t^h are not available, and funds the transfer to the retail firms ensuring that in a zero-inflation equilibrium the markup μ is equal to 1. This allows the market allocation to be efficient if $\pi_t = 0 \; \forall \; t$, wages are Nash-bargained and the Hosios condition $b = (1-\xi)$ is met. The net subsidy to retail firms is equal to $(1-\tau_{ss}^r)Y_t$ and $\tau_{ss}^r = \mu = \frac{\varepsilon}{\varepsilon-1}$. In a zero-inflation equilibrium

$$\frac{P_t^w}{P_t} = \frac{\tau_{ss}^r}{\mu}$$

The optimal gross subsidy per unit of output is

$$\tau_{ss}^r = \mu$$

The retail sector total profits are given by

$$\begin{aligned} \Pi_t^r &= \tau_{ss}^r Y_t - \frac{\tau_{ss}^r}{\mu} Y_t \\ &= (\mu - 1) Y_t \end{aligned}$$

Therefore the tax on the household sector is equal to:

$$T_t^r = (\mu - 1) Y_t$$

Table 1: Parameterization		
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%
Calvo pricing parameter values		
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

Model parameters. Subscript ss indicates a steady state value.

Table 3: Welfare Results		
	Search gap λ	Optimal Policy loss λ relative to price stability
Nash bargaining		
b=0.5	0	0
b=0.7	0.80%	$< -0.01\%$
b=0.8	2.11%	$< -0.01\%$
Wage norm		
$\bar{w} = w_{ss}^{eff} = w_{ss}(0.5)$	0.27%	-0.05%
$\bar{w} = w_{ss}(0.3)$	0.81%	-0.02%
$\bar{w} = w_{ss}(0.7)$	1.62%	-0.22%
$\bar{w} = w_{ss}(0.8)$	3.85%	-0.57%

Note: the search gap is the welfare distance $W^* - W^f$ between the planner's equilibrium and the competitive flexible-price equilibrium conditional on the wage setting mechanism indexed by bargaining power b. Welfare distances are expressed in terms of λ, the fraction of the expected consumption stream in the reference economy that the household would be willing to give up to be as well off as in the alternative economy. A value of $\lambda < 0$ indicates an improvement in welfare relative to the reference economy.

Table 4: Intermediate Sector Optimal Subsidy τ_t			
	Steady-state subsidy rate	Volatility	
		σ_τ	σ_τ/σ_y
b=0.7	115%	0.08%	0.04
Nash bargaining			
$\bar{w} = w_{ss}^{eff} = w_{ss}(0.5)$	0	1.72%	0.96
Wage norm			
$\bar{w} = w_{ss}(0.7)$	1.65%	1.72%	0.96
Wage norm			

Note: percent rate and volatility for subsidy paid to wholesale-goods producing firms. Table assumes a complete set of policy instruments is available to attain the first best allocation.

Table 5: Nash Bargaining Model: Second Moments			
b=0.5	Final output volatility	σ_y	1.78%
(first best)	Relative employment volatility	σ_n/σ_y	0.08
b=0.7	Final output volatility	σ_y	1.81%
(price stability policy)	Relative employment volatility	σ_n/σ_y	0.11

Second moments computed for alternative surplus share gained by employed workers. In either case the monetary policy enforces the flexible price allocation.

Table 6: Welfare Results: Tax-equivalent Policies		
	Intermediate sector tax-equivalent policy loss λ relative to price stability	Relative inflation volatility σ_π/σ_y
Nash bargaining		
b=0.7	0.0003%	0.22
Wage norm		
$\bar{w} = w_{ss}^{eff} = w_{ss}(0.5)$	2.33%	4.11
$\bar{w} = w_{ss}(0.7)$	1.65%	3.28

Note: welfare results conditional on monetary policy rule $\mu_t = \mu_t^*$ where μ_t^* is defined in eq. (21). Welfare distances are expressed in terms of λ, the fraction of the expected consumption stream in the reference economy that the household would be willing to give up to be as well off as in the alternative economy.

Table 7: Welfare Loss in Three Economies						
	Vacancy posting distortion		Retail price setting distortion		Hours setting distortion	
Wage norm: $\bar{w} = w_{ss}(b)$	$b = 0.5$	$b = 0.7$	$b = 0.5$	$b = 0.7$	$b = 0.5$	$b = 0.7$
Loss relative to first best	0.27%	1.62%	3.06%	3.78%	0.008%	0.81%
Steady state loss	–	0.79%	–	0.79%	–	0.79%

Note: welfare results in an economy where policy implements two of the three conditions (14), (16), (20) that result in the first best equilibrium. Steady state is assumed identical across the three economies and is given by price stability and no tax instrument.. Welfare distances are expressed in terms of λ, the fraction of the expected consumption stream in the reference economy that the household would be willing to give up to be as well off as in the alternative economy.

Table 8: High Cost of Search Parameterization: Welfare Results

	Search gap λ	Optimal policy loss λ relative to price stability
Nash bargaining		
b=0.5	0	0
b=0.7	0.79%	$< -0.01\%$
b=0.8	2.06%	$< -0.01\%$
Wage norm		
$\bar{w} = w_{ss}^{eff} = w_{ss}(0.5)$	0.11%	$< -0.01\%$
$\bar{w} = w_{ss}(0.3)$	0.63%	-0.01%
$\bar{w} = w_{ss}(0.7)$	1.13%	-0.01%

Note: the search gap is the welfare distance $W^* - W^f$ between the planner's equilibrium and the competitive flexible-price equilibrium conditional on the wage setting mechanism indexed by bargaining power b. Welfare distances are expressed in terms of λ, the fraction of the expected consumption stream in the reference economy that the household would be willing to give up to be as well off as in the alternative economy. A value of $\lambda < 0$ indicates an improvement in welfare relative to the reference economy. Parameterization contained in Tables A1, A2.

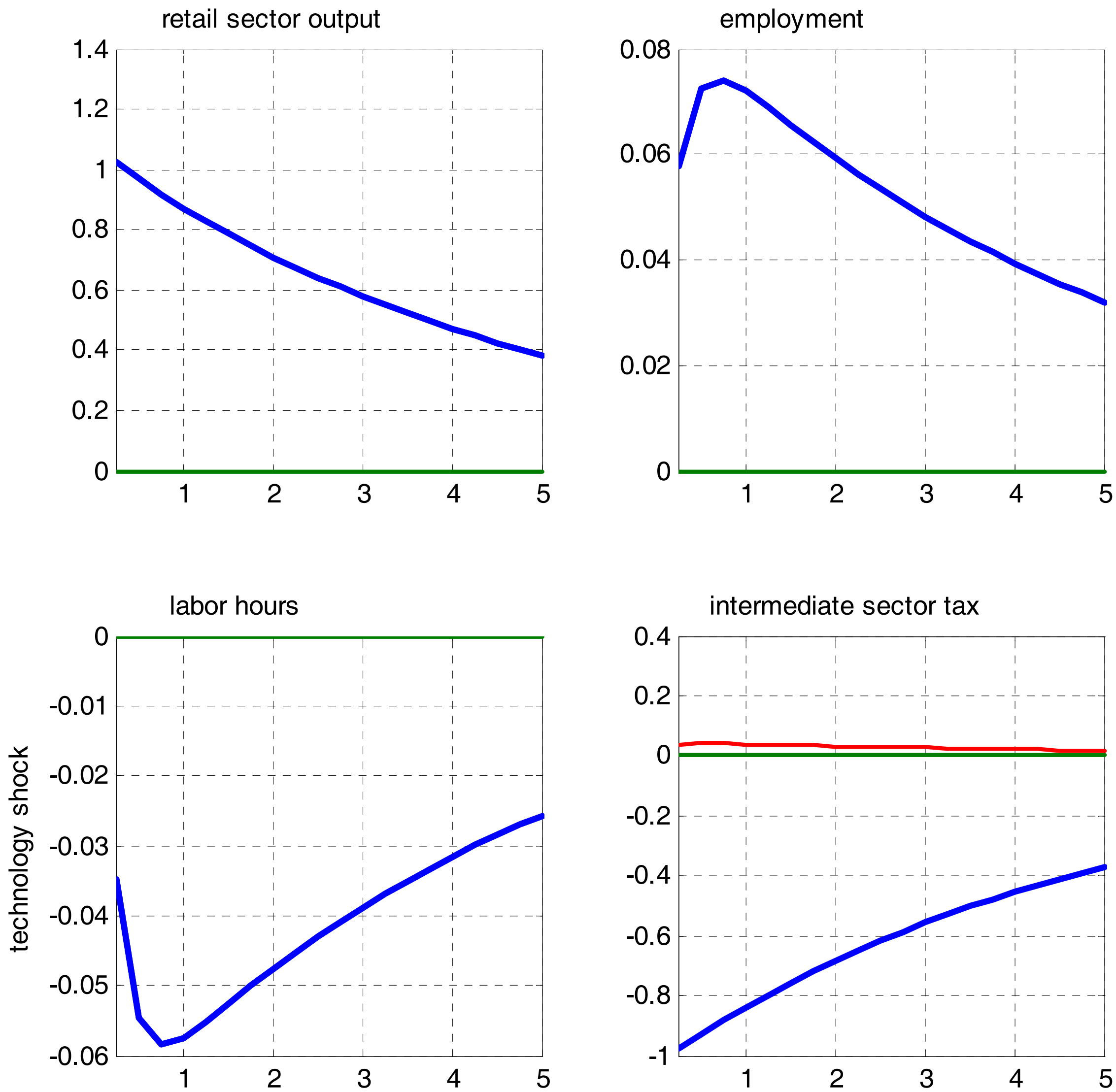

Figure 1: Impulse response function to 1% technology shock in intermediate production sector conditional on optimal tax policy enforcing first best allocation. Wage is set at norm $\bar{w} = w_{ss}(0.5)$. Thin line shows optimal tax policy for Nash bargaining wage-setting and $b = 0.7$. Variables plotted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

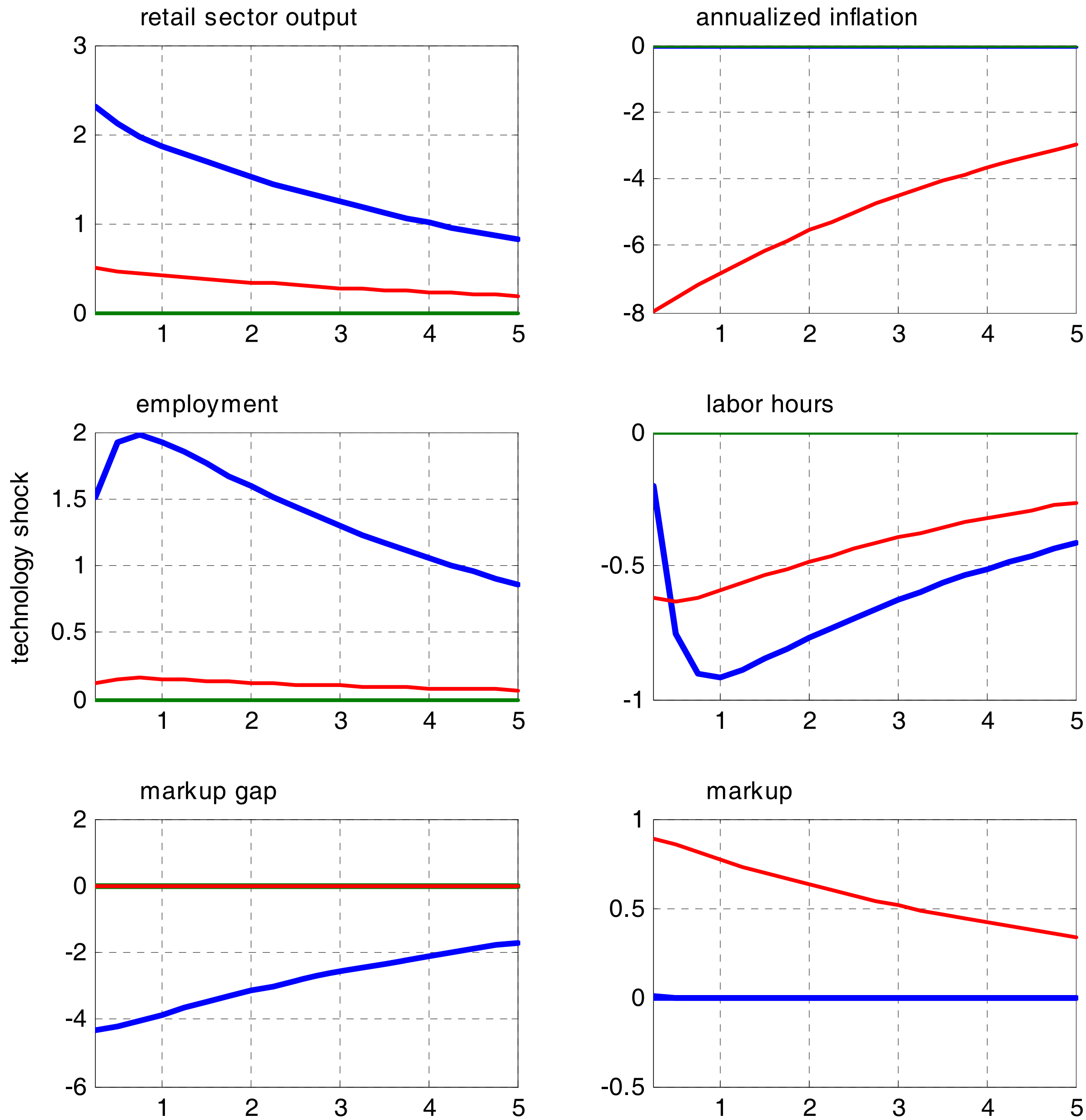

Figure 2: Impulse response function to 1% technology shock in intermediate production sector conditional on two alternative monetary policies. Wage is set at norm $w_t = w_{ss}(0.5)$. Thick line: Price stability monetary policy. Thin line: Tax-equivalent monetary policy $\mu = \mu^*$.Variables plot in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

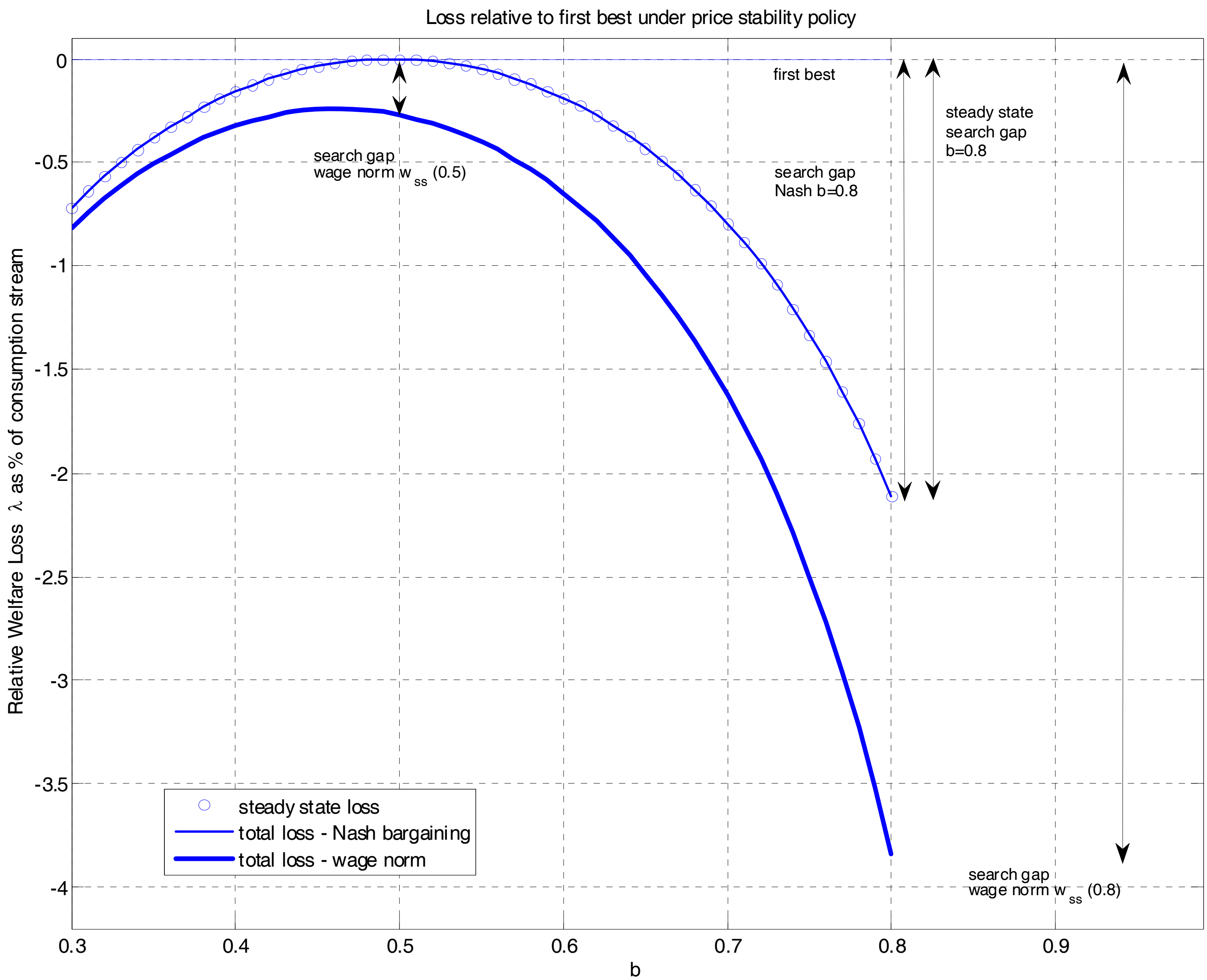

Figure 3: Search gap as a function of bargaining weight b. First best is attained for $b = (1 - \xi) = 0.5$. For wage norm case, b indicates the surplus share accruing to workers in steady state.