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

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Abstract

We investigate the implications for monetary policy of nominal rigidities that lead to inefficient price setting and labor market frictions that lead to inefficient matching of unemployed workers with job vacancies. We characterize the tax instruments that implement the first best equilibrium allocations and then examine the trade-offs faced by monetary policy when these tax instruments are unavailable. Our tax interpretation helps explain why the welfare cost of inefficient labor market search can be large while the incentive to deviate from price stability is generally small. We find that 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

The existence of real distortions in models with nominal rigidities - such as markup shocks in the baseline new Keynesian model - imply that even if replicating the flexible price allocation is feasible, doing so is generally not desirable. In fact, in the face of multiple distortions, staggered price setting can improve welfare relative to the flexible price equilibrium, since it offers monetary policy the opportunity to correct the incentives of households and firms that generate an inefficient level of employment.[1] In a model with nominal price rigidities and search and matching in the labor market, Ravenna and Walsh (2011) show that random deviations from efficient wage setting play the same role as markup shocks in standard new Keynesian models with Walrasian labor markets. Thus, search frictions endogenously generate a trade-off between using monetary policy to address the inefficiency due to staggered price adjustment and using it to offset deviations from efficient wage setting. Yet in several calibrated variations of the basic search and matching new Keynesian model (e.g., Faia 2008, Thomas 2008, Ravenna and Walsh 2011), the level of welfare attained by optimal monetary policy appears to deviate very little from the level achieved under a policy of price stability.[2]

Why is price stability close to optimal even when labor market distortions are present? This is a question the existing literature has failed to answer clearly, yet the answer is important for understanding whether monetary policy should attempt to correct inefficient labor outcomes, and if so, under what circumstances it should.

We address this question in the present paper. To do so, we employ a model characterized by sticky prices and search and matching frictions in the labor market, where distortions in wage and price setting result in wedges between the first order conditions in the distorted economy and the corresponding conditions in the efficient competitive equilibrium. Each wedge can be corrected by an appropriately designed tax, but with multiple distortions, multiple tax instruments are needed to implement the first-best allocation. It is not surprising therefore that the single instrument of monetary policy is unable to replicate the first best allocation. However, understanding how tax instruments

[1] Adao, Correia, Teles (2003) discuss a model with multiple distortions and nominal price rigidity where this intuition applies.

[2] Justiniano, Primiceri, and Tambalotti (2011) estimate a DSGE model using U.S. data and also find that optimal policy is close to price stability, though they adopt a sticky-wage model based on Erceg, Henderson, and Levin (2000) rather than the search frictions approach adopted here. Shimer (2004) finds that in the basic Mortensen-Pissarides search and matching model, under some conditions, a constant real wage has a negligible welfare cost.

would need to move to achieve the first best allocation gives insight into how the different distortions affect the trade-offs faced by the monetary authority.

By deviating from price stability, monetary policy affects incentives by moving markups, and markups simultaneously affect *all* the efficiency wedges in the economy. The markup in the final-goods producing sector affects the incentive for firms to post job vacancies, the equilibrium choice of hours per employed worker, and the marginal cost of retail firms and therefore price setting behavior. If labor matching is inefficient, monetary policy can move markups to eliminate the efficiency wedge in the vacancy posting condition, but we show that in doing so, the choice of hours per employed worker is distorted. Thus, deviating from price stability can lessen one distortion but it simultaneously introduces a new distortion.

We show that price stability delivers a level of welfare close to the level achieved under an optimal monetary policy. This is true not because the search and matching inefficiency causes negligible welfare losses, but because monetary policy is not the appropriate instrument to address this inefficiency. For reasonable model parameterizations, the welfare gap between the first best and the flexible price allocation is large, so there is ample potential to improve on the flexible price allocation. However, monetary policy is able to close only a small fraction of the welfare gap by deviating from price stability.

This outcome depends on the nature of the distortion in the wage-setting process. When wages are Nash-bargained but do not satisfy the Hosios (1990) condition for efficiency, the optimal tax that corrects for inefficient hiring by firms is large in the steady state but displays very little volatility over the business cycle. This finding is basically a reflection of the Shimer puzzle; Nash bargaining generates small volatility of labor market variables. The low volatility of the optimal tax implies that, if monetary policy is used to replicate the effects of the optimal tax policy to correct inefficiencies in hiring decisions, deviations from price stability would be small. In contrast, when wages are fixed at a wage norm, the optimal tax that corrects inefficiencies in hiring is small in the steady state but very volatile over the business cycle. A monetary policy that attempts to address hiring inefficiencies would, in this case, need to let markups fluctuate significantly to replicate the optimal tax policy. Such a policy would widen the inefficiency wedge in the choice of hours worked as well as increase relative price dispersion. Thus the monetary authority faces a very unfavorable trade-off, and a policy of price stability does nearly as well as the optimal policy.

We investigate the sensitivity of our conclusions to the parameterization of labor market flows. In our parameterization based on US data, the improvement achieved under optimal monetary policy when the wage is fixed at a wage norm far from the efficient steady state represents only a small fraction of the welfare loss due to labor market inefficiencies. Yet this improvement is not negligible in absolute terms, amounting to about two tenths of a percentage point of the representative household's expected consumption stream. Under an alternative parameterization based on EU data that yields a higher unemployment duration and smaller labor market gross flows, the welfare improvement from optimal monetary policy relative to price stability is negligible, both as a share of the loss due to labor market inefficiencies and in absolute terms. Thus, when the matching efficiency is lower and hiring costs higher as under the EU calibration, there is virtually no incentive for the monetary authority to focus on the labor market and deviate from price stability. In fact, we show that fiscal and labor market policies are much more effective in our model than monetary policy at improving the efficiency of the equilibrium. This result has implications for the role of unemployment in monetary policy design in the US and Europe and suggests that price stability is closer to optimal in the face of a less flexible labor market.

Our paper is related to several important contributions in the literature. Khan, King and Wolman (2003) discuss optimal monetary 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 they do not investigate the tax policy that replicates the first best. Our approach is closer to the one used in Chari, Kehoe and McGrattan (2007), who discuss how to represent deviations from a prototype growth model caused by inefficient frictions as wedges in the first order conditions. 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 assume labor markets are characterized by monopolistic competition among households supplying labor and that wages are set according to a Calvo-type mechanism. In our model, wage dispersion plays no role in welfare outcomes. Moreover, we show that wage rigidity per se is not key in explaining why price stability approximates the optimal policy in a model with search inefficiencies.

A growing number of papers have attempted to incorporate search and matching frictions into new Keynesian models. Examples include Walsh (2003, 2005), Trigari (2009), Christoffel, Kuester, and Linzert (2009), Blanchard and Galí (2010), Krause and Lubik (2005), Barnichon (2007), Thomas (2008), Gertler and Trigari (2009), Gertler, Sala, and Trigari (2008), and Ravenna and Walsh (2011). 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 (2010), like Ravenna and Walsh (2008, 2011), derive a linear Phillips curve relating unemployment and inflation in models with labor frictions. These papers explore the implications of labor frictions for optimal monetary policy. However, they both restrict their attention to a linear-quadratic framework in which the steady state is efficient. Compared to Ravenna and Walsh (2011), our model allows for both an extensive employment and an intensive hours margin. While the introduction of an intensive margin makes the linear-quadratic analysis impractical, our model maps the different objectives the monetary authority has to trade off into a set of taxes that would replicate the first best, with each tax correcting a specific inefficiency. In addition, our setup helps to characterize the relationship between the policy maker's objectives in the labor market search and matching model and in the more standard new Keynesian Walrasian model.

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 in his model partly reflects the cost of wage dispersion already highlighted in Erceg, Henderson and Levin (2000) and partly reflects the cost of inefficient job creation. The latter cost - which is the cost directly related to the existence of search frictions - plays only a minor role. In a related model, Faia (2008) finds that the welfare gains from deviating from price stability are small regardless of whether the steady state is efficient, 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. Section2, develops the basic model, describes the tax policy that would achieve the efficient equilibrium, and relates taxes and markups to identify the trade-offs for the monetary authority. The welfare consequences of monetary policy are explored in section 3. Conclusions are summarized in the final section.

2 The 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, and 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), Thomas (2008), and Ravenna and Walsh (2011).

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 terminate exogenously. To simplify the analysis, we ignore any endogenous separation.[3] The fraction of the household members who are employed evolves according to

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

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

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

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).

If M_t is the number of new matches, then $p_t = M_t/u_t$. Let v_t denote the number of job vacancies, and define $q_t \equiv M_t/v_t$. We assume matches are a constant returns to scale

[3] 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).

function of vacancies and workers available to be employed in production:

$$M_t = M(v_t, u_t) = \eta v_t^{1-a} u_t^a = \eta \theta_t^{1-a} u_t, \tag{2}$$

where η measures the efficiency of the matching technology, ξ the elasticity of M_t with respect to posted vacancies, and we define $\theta_t \equiv v_t/u_t$ as the measure of labor market tightness. Given (2), $p_t = \eta\theta_t^{1-a}$ and $q_t = \eta\theta_t^{-a}$.

2.2 Households

Households purchase a basket of differentiated goods produced by retail firms. Risk pooling implies that the optimality conditions for the individual household members 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 in terms of the value function $W_t(N_t, B_t)$ defined as

$$W_t(N_t, B_t) = \max\left[U(C_t) - N_t H(h_t) + \beta \mathrm{E}_t W_{t+1}(N_{t+1}, B_{t+1})\right]$$

where U (H) is increasing and concave (convex). Consumption consists of market goods supplied by the retail sector plus home production: $C_t = C_t^m + w^u(1 - N_t)$ where w^u is the (fixed) productivity of workers in home production. The household faces a budget constraint that takes the form

$$\left(1 + \tau_t^C\right) P_t C_t^m + p_{bt} B_{t+1} \leq P_t[(w_t h_t N_t + B_t + \Pi_t + T_t)\,.$$

where w_t is the real hourly wage, h_t is hours, P_t is the price of a unit of the consumption bundle, Π_t are profits from the firm sector, and T_t are lump-sum transfers. We assume households face a tax on market-produced consumption that makes the gross price per unit of market consumption equal to $\left(1 + \tau_t^C\right) P_t$. Expressed in terms of total consumption, we can write the budget constraint as

$$\left(1 + \tau_t^C\right) P_t C_t + p_{bt} B_{t+1} \leq P_t[w_t h_t N_t + \left(1 + \tau_t^C\right) w^u(1 - N_t)] + B_t + P_t \Pi_t + P_t T_t.$$

Consumption of market goods is a Dixit-Stiglitz aggregate of the consumption from individual retail firm j:

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

The intertemporal first order conditions yield the standard Euler equation:

$$\lambda_t = \beta R_t \mathrm{E}_t \left(\lambda_{t+1} \right), \tag{3}$$

where $R_t = 1/p_{bt}$ is the gross return on an asset paying one unit of the consumption aggregate in any state of the world and λ_t is the marginal utility of income. The first order conditions also imply the relationship between the marginal utility of income and the marginal utility of consumption is

$$\lambda_t = \frac{U_C(t)}{1 + \tau_t^C}.$$

Let V^E and V^U denote the value to the worker of being employed or unemployed, and let $V^S \equiv V_t^E - V_t^U$ denote the match surplus to the worker. Because a worker who experiences the exogenous separation hazard has a probability p_{t+1} of finding a new match and earning V_{t+1}^E, the surplus value of an employment match from the perspective of a worker is given by

$$\begin{aligned} V_t^S &= \left\{ w_t h_t - \frac{H(h_t)}{\lambda_t} + \beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[(1 - \rho + \rho p_{t+1}) V_{t+1}^E + \rho \left(1 - p_{t+1} \right) V_{t+1}^U \right] \right\} \\ &\quad - \left\{ \left(1 + \tau_t^C \right) w^u + \beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left[p_{t+1} V_{t+1}^E + (1 - p_{t+1}) V_{t+1}^U \right] \right\} \\ &= w_t h_t - \left(1 + \tau_t^C \right) w^u - \frac{H(h_t)}{\lambda_t} + \beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t} \right) (1 - \rho)(1 - p_{t+1}) V_{t+1}^S. \end{aligned} \tag{4}$$

2.3 Intermediate goods producing firms

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

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

where f is a CRS production function and $L_{it} = h_{it}N_{it}$ 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. We assume gross revenues are taxed at the rate τ_t^f such that the firm's after-tax revenues from output Y_t^w expressed in terms of consumption goods are $\left(1-\tau_t^f\right) P_t^w Y_t^w / P_t = \left[\left(1-\tau_t^f\right)/\mu_t\right] Y_t^w$, where $\mu_t \equiv P_t/P_t^w$ is the retail price markup. Given our definition of taxes, a tax rate $\tau_t^f < 0$ implies intermediate firms receive a subsidy.

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

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

Define $f_L(t) = \partial f(A_t, L_t)/\partial L_t$ as the marginal product of a worker-hour. The value of a filled job is

$$V_t^J = \left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t)h_t - w_t h_t + \beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right) \left[(1-\rho)V_{t+1}^J + \rho V_{t+1}^V\right].$$

where V_{t+1}^V is the future value of an unfilled vacancy. With the probability of filling a vacancy equal to q_t and the cost of posting it equal to κ, free entry implies that vacancies will be posted until $q_t V_t^J = \kappa$ and the value of a vacancy is equal to zero. Hence,

$$V_t^J = \frac{\kappa}{q_t} = \left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t)h_t - w_t h_t + (1-\rho)\beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{\kappa}{q_{t+1}}\right). \tag{5}$$

The value of a vacancy from the perspective of the firm is distorted by both the tax τ_t^f and the markup μ_t in the price of retail goods. For $\kappa = 0$, (5) implies that the real marginal cost of the retail sector, net of the tax τ_t^f, is equal to the wage rate per unit of output, as in the standard new Keynesian model.

2.4 Wages and hours choice under Nash bargaining

Assume the wage is set by Nash bargaining with the workers share of the joint surplus equal to b. Thus,

$$V_t^S = b\left(V_t^S + V_t^J\right).$$

From (4) and (5), the joint surplus is

$$\begin{aligned} V_t^S + V_t^J &= \left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t)h_t - (1+\tau_t^C)w^u - \frac{H(h_t)}{\lambda_t} \\ &\quad +(1-\rho)\mathrm{E}_t\beta\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left[(1-p_{t+1})V_{t+1}^S + \left(\frac{\kappa}{q_{t+1}}\right)\right], \end{aligned}$$

and the real wage bill consistent with the sharing rule for the match surplus is

$$w_t h_t = (1-b)\left[(1+\tau_t^C)w^u + \frac{H(h_t)}{\lambda_t}\right] + b\left[\left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t)h_t + \kappa(1-\rho)\beta\mathrm{E}_t\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\theta_{t+1}\right]. \tag{6}$$

The outcome of Nash bargaining over hours is equivalent to a setup where hours maximize the joint surplus of the match. Thus, the optimal choice of hours satisfies

$$\begin{aligned} \left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t) &= \frac{H'(h_t)}{\lambda_t} \qquad (7) \\ &= (1+\tau_t^C)\frac{H'(h_t)}{U_C(t)}. \end{aligned}$$

The left side of this expression is the after-tax real value of the marginal product of an additional hour. The right side is the disutility of this additional hour relative to the marginal utility of income.

2.5 Retail firms

Each retail firm j 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. A retail firm able to adjust its prices chooses $P_t(j)$ to maximize

$$\sum_{i=0}^{\infty} (\omega\beta)^i \, \mathrm{E}_t \left[\left(\frac{\lambda_{t+i}}{\lambda_t} \right) \left(\frac{(1-\tau^\mu)P_t(j) - P^w_{t+i}}{P_{t+i}} \right) Y_{t+i}(j) \right]$$

subject to the demand for good j

$$Y_{t+i}(j) = Y^d_{t+i}(j) = \left[\frac{P_t(j)}{P_{t+i}} \right]^{-\varepsilon} Y^d_{t+i}, \tag{8}$$

where Y^d_t is aggregate demand for the final goods basket. Revenues are taxed at the rate τ^μ. Define $\mu \equiv \varepsilon/(\varepsilon - 1) > 1$ as the flexible-price markup in the absence of the tax τ^μ and $\bar{\mu} \equiv \mu/(1-\tau^\mu)$. The the retail firm's optimality condition can be written as

$$P_t(j)\mathrm{E}_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i} = \bar{\mu}\mathrm{E}_t \sum_{i=0}^{\infty} (\omega\beta)^i \left(\frac{\lambda_{t+i}}{\lambda_t} \right) P^w_{t+i} \left[\frac{P_t(j)}{P_{t+i}} \right]^{1-\varepsilon} Y_{t+i}, \tag{9}$$

Since price adjustment is staggered, market clearing implies $Y^w_t = Y_t \Delta_t$ where Δ_t is a measure of price dispersion defined as:

$$\Delta_t \equiv \int_0^1 \left[\frac{P_t(j)}{P_t} \right]^{-\varepsilon} dj \tag{10}$$

If price adjustment were not constrained, all retail firms would charge an identical price equal to a constant markup $\bar{\mu}$ over the intermediate good price. In this case, $\Delta_t = 1$ and

$$\frac{P_t}{P^w_t} = \bar{\mu}. \tag{11}$$

2.6 The efficient equilibrium

The solution to the planner's problem maximizing household utility subject to the production and matching technology constraints requires that the following four conditions be met[4]:

[4] In the Appendix, we characterize the problem of the social planner and the conditions under which a competitive equilibrium delivers the first best allocation.

$$C_t^m(j) = C_t^m \ \forall\ j \in [0,1] \tag{12}$$

$$v_t(j) = v_t \ \forall\ j \in [0,1] \tag{13}$$

$$\frac{\kappa}{q_t} = (1-a)\left(f_L(t)h_t - w^u - \frac{H(h_t)}{U_C(t)}\right) + \beta\,(1-\rho)\,\mathrm{E}_t\left[\frac{U_C(t+1)}{U_C(t)}\right](1-ap_{t+1})\,\frac{\kappa}{q_{t+1}} \tag{14}$$

$$f_L(t) = \frac{H'(h_t)}{U_C(t)}. \tag{15}$$

Equations (12) and (13) ensure that demand for each j consumption and production input good is identical, (14) is the condition for efficient vacancy posting, and (15) is the condition for efficient hours choice.

2.7 Achieving the efficient equilibrium through tax policy

In general, the competitive equilibrium of our model in the absence of taxes results in an inefficient allocation. Inefficiencies can be described in terms of deviations, or wedges, between the first order conditions characterizing the market equilibrium and the social planner's first order conditions (12), (13), (14) and (15). To highlight the role each wedge plays in affecting the optimal monetary policy, we construct a tax and subsidy policy that replicates the efficient equilibrium. 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 non-distorting sources, the policy maker 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 and to the policy adopted by the monetary authority as a 'tax policy'. The Appendix provides detailed derivations of the equilibrium transfers ensuring market clearing, showing that the resulting equilibrium enforces the planner's allocation.

The tax policy requires four policy instruments (the two time-varying taxes τ_t^f and τ_t^C, the constant tax τ^μ and monetary policy) to address the four distortions in the economy (imperfect competition, price dispersion in retail goods due to staggered price adjustment, and the distortion in vacancy posting and hours choice). The four distortions result in three wedges between the planner's and the competitive equilibrium first order conditions. First, the efficient allocation is obtained when all retail goods are homogeneously priced and conditions (12), (13) are met. This can be achieved by completely stabilizing prices, that is, by employing monetary policy to ensure

$$\mu_t = \bar{\mu}.$$

Thus, monetary policy plays a role as a cyclical policy instrument if nominal rigidities constrain the adjustment of prices.

Second, recall from (5) that since $\lambda_t = U_C(t)/(1+\tau_t^C)$, vacancy posting in the competitive equilibrium satisfies

$$\frac{\kappa}{q_t} = \left(\frac{1-\tau_t^f}{\mu_t}\right) f_L(t)h_t - w_t h_t + (1-\rho)\beta \mathrm{E}_t \left(\frac{U_C(t+1)}{U_C(t)}\right)\left(\frac{1+\tau_t^C}{1+\tau_{t+1}^C}\right)\left(\frac{\kappa}{q_{t+1}}\right), \quad (16)$$

while from (14) efficiency requires

$$\frac{\kappa}{q_t} = (1-a)\left(f_L(t)h_t - w^u - \frac{H(h_t)}{U_C(t)}\right) + \beta\,(1-\rho)\,\mathrm{E}_t\left(\frac{U_C(t+1)}{U_C(t)}\right)(1-ap_{t+1})\,\frac{\kappa}{q_{t+1}}. \quad (17)$$

Using (16) and (17) we obtain

$$\begin{aligned} \frac{1-\tau_t^f}{\mu_t} \quad = \quad & \frac{w_t}{f_L(t)} + \left(\frac{1-a}{f_L(t)h_t}\right)\left\{ f_L(t)h_t - w^u - \frac{H(h_t)}{U_C(t)} \right. \\ & \left. -\beta\,(1-\rho)\,\mathrm{E}_t\left(\frac{U_C(t+1)}{U_C(t)}\right)\left[ap_{t+1} - \left(\frac{\tau_{t+1}^C - \tau_t^C}{1+\tau_{t+1}^C}\right)\right]\frac{\kappa}{q_{t+1}}\right\} \end{aligned} \quad (18)$$

as the condition that the tax on the intermediate goods firms τ_t^f must satisfy to close the vacancy posting wedge for any wage-setting mechanism.

Third, note that while the tax τ_t^f can correct intermediate firms' incentive to post vacancies, it also affects and potentially distorts these firms' choice of hours. To see this, note that (15) requires $f_L(t) = H'(h_t)/U_C(t)$ while (7) implies this condition is replicated if and only if

$$1+\tau_t^C = \frac{1-\tau_t^f}{\mu_t}. \quad (19)$$

Thus, unless $\left(1-\tau_t^f\right)/\mu_t = 1$, a second tax instrument τ_t^C satisfying (19) must be introduced to close the inefficiency wedge in hours choice.[5]

Finally, imperfect competition in the retail sector, resulting in a steady state markup,

[5]Since τ^C appears in (18), (18) and (19) jointly determine the two taxes.

also generates a wedge in the vacancy posting and in the hours choice first order conditions. While the taxes τ_t^f and τ_t^C can potentially compensate for all of the inefficiency wedge in these two first order conditions, we introduce a fourth policy instrument τ^{μ} to subsidize retail firms at the constant rate

$$\tau^{\mu} = 1 - \mu \rightarrow \bar{\mu} = 1$$

and correct for the imperfect competition distortion, as usually assumed in the standard new Keynesian model. Therefore, the taxes τ_t^f and τ_t^C only correct for inefficient matching on the labor market, while τ^{μ} corrects the steady-state inefficiency due to imperfect competition among retail firms.

Since the distortion due to imperfect competition is well understood in the new Keynesian literature, and is orthogonal to our results, we assume throughout the paper that the subsidy τ^{μ} is always set at the optimal level to ensure $\bar{\mu} = 1$ (Woodford 2003). Thus, we are left with three potential distortions in the model – in vacancy posting, hours, and dispersion of relative prices. With flexible prices (or price stability), relative price dispersion disappears, but the other two distortions remain. Therefore, even with flexible prices, the policy maker generally needs two separate tax instruments, τ_t^f and τ_t^C, to enforce an efficient equilibrium: τ_t^f to ensure efficient vacancy posting, and τ_t^C to correct the distortion in hours that would otherwise arise when $1 - \tau_t^f$ differs from μ_t.

2.8 Taxes and markups

We first show that if wages are Nash-bargained and the Hosios condition ($a = b$) holds, then despite the existence of search frictions in the labor market, the first best allocation requires the same tax policy as in the standard new Keynesian model with Walrasian labor markets. This policy takes the form of a steady-state subsidy τ^{μ} to offset the effects of the markup μ and of a price-stability monetary policy.

When wages are set by Nash bargaining, (6) can be used to eliminate the wage from

(18). In this case, one obtains

$$
\begin{aligned}
\frac{1-\tau_t^f}{\mu_t} \;=\;& \left(\frac{1-a}{1-b}\right) + \left(\frac{1}{f_L(t)h_t}\right)\left[1+\tau_t^C - \left(\frac{1-a}{1-b}\right)\right]\left(w^u + \frac{H(h_t)}{U_C(t)}\right) \\
& + \left(\frac{1}{f_L(t)h_t}\right)\beta\left(1-\rho\right)\left(\frac{1}{1-b}\right)\mathrm{E}_t\left(\frac{U_C(t+1)}{U_C(t)}\right) \\
& * \left\{\left(b\frac{1+\tau_t^C}{1+\tau_{t+1}^C} - a\right)p_{t+1} - \left(\frac{1+\tau_t^C}{1+\tau_{t+1}^C} - 1\right)\right\}\frac{\kappa}{q_{t+1}}.
\end{aligned}
\tag{20}
$$

If the Hosios condition $a = b$ and (19) hold, this reduces to

$$
\begin{aligned}
\frac{1-\tau_t^f}{\mu_t} \;=\;& 1 + \left(\frac{1}{f_L(t)h_t}\right)\left(\frac{1-\tau_t^f}{\mu_t} - 1\right)\left(w^u + \frac{H(h_t)}{U_C(t)}\right) \\
& - \left(\frac{1}{f_L(t)h_t}\right)\beta\left(\frac{1-\rho}{1-a}\right)\mathrm{E}_t\left(\frac{U_C(t+1)}{U_C(t)}\right) \\
& * \left[\frac{\left(1-\tau_t^f\right)/\mu_t}{\left(1-\tau_{t+1}^f\right)/\mu_{t+1}} - 1\right]\left(1 - ap_{t+1}\right)\frac{\kappa}{q_{t+1}},
\end{aligned}
\tag{21}
$$

which is satisfied for $\left(1-\tau_t^f\right)/\mu_t = 1$ for all t. Thus, when the Hosios condition holds and the retail subsidy τ^μ ensures $\bar{\mu} = 1$, price stability ($\mu_t = \bar{\mu}$), $\tau_t^f = 0$ (from 21), and $\tau_t^C = 0$ (from 19) enforces the efficient allocation. Additionally, there is no trade-off between efficient hours and zero-price dispersion since both can be achieved with a policy that enforces price stability. Blanchard and Galí (2007) label this result in the standard new Keynesian model the 'divine coincidence'. Thus, as in the standard new Keynesian model, the efficient allocation only requires a monetary policy that produces price stability and the *steady-state* tax instrument τ^μ. The steady state tax closes the inefficiency wedge in hours choice (common to the new Keynesian model and to an economy with search frictions in the labor market) and in the vacancy posting condition (relevant only in an economy with search frictions).

When wage setting is not efficient and the surplus shares are not allocated according to the Hosios condition, a *cyclical* tax policy is generally necessary to achieve the first best allocation. In this case, $\left(1-\tau_t^f\right)/\mu_t$ must deviate from one to ensure (18) is satisfied to support efficient labor market outcomes. When no cyclical tax instrument is available, the monetary authority would need to deviate from price stability to ensure $1/\mu_t$ satisfies

(18). If the monetary authority wishes to eliminate the vacancy posting wedge, monetary policy would need to generate a time-varying retail-price markup μ_t^* such that the after-tax revenue from selling a unit of the intermediate good is equal to the quantity that would occur conditional on the optimal tax policy. This markup is given by (18) as

$$\begin{aligned} \frac{1}{\mu_t^*} &= \frac{w_t}{f_L(t)} + \left(\frac{1-a}{f_L(t)h_t}\right)\left\{f_L(t)h_t - w^u - \frac{H(h_t)}{U_C(t)}\right. \\ &\quad \left. -\beta\left(1-\rho\right)\mathrm{E}_t\left(\frac{U_C(t+1)}{U_C(t)}\right)\left[ap_{t+1} - \left(\frac{\tau_{t+1}^C - \tau_t^C}{1+\tau_{t+1}^C}\right)\right]\frac{\kappa}{q_{t+1}}\right\}. \end{aligned} \tag{22}$$

We label this as the 'efficient employment' monetary policy.[6] However, while this monetary policy eliminates the inefficiency wedge in hiring, it does not result in the first-best level of employment. Unless the consumption tax τ_t^C is also available, deviating from price stability so that $1/\mu_t$ satisfies (18) implies from (7) that

$$\left(\frac{1}{\mu_t^*}\right) f_L(t) = \frac{H'(h_t)}{U_C(t)}$$

This condition is inconsistent with (15) which must be satisfied to eliminate the hours choice wedge. Thus, even if a steady-state subsidy τ^μ offsetting the steady state markup is available, the monetary authority is faced with a trade-off between, on one hand, achieving an efficient hours choice and eliminating price dispersion, and, on the other hand, ensuring efficient vacancy posting.

This trade-off arises because the markup μ_t affects equilibrium through three separate channels. First, it influences equilibrium hours in the intermediate sector through (7). Second, markup movements are associated with staggered changes in retail pricing, resulting in relative price dispersion. However, achieving efficient hours and eliminating price dispersion are not mutually exclusive goals, even with search frictions, since conditions (12), (13), and (15) can be met if $\mu_t = \bar{\mu} = 1$.[7] Third, the markup also affects vacancy postings and variations in μ_t change the incentives for intermediate firms to post vacancies (see 5).

[6] In evaluating eq. (22), we assume the monetary authority takes into account the lack of a fiscal policymaker imposing the consumption tax τ^C.

[7] With search frictions in the labor market, 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.

While the monetary authority does not control the markup directly, we find this interpretation of monetary policy in terms of the behavior of the markup appealing, since a constant markup corresponds to a policy that puts all weight on the objectives of zero-price dispersion and eliminating the hours choice wedge. Deviations from price stability map into fluctuations of μ_t^* around $\bar{\mu}$ and therefore also into deviations from the efficient hours condition. Using monetary policy to guarantee $\mu_t = \mu_t^*$ defined in (22) represents a policy that puts all weight on the objective of eliminating the vacancy posting wedge.

3 Monetary policy trade-offs in an economy with search frictions

In this section we examine optimal monetary policy and the role of alternative assumptions about wage setting. We show that the welfare costs of inefficient unemployment fluctuations are large, but the incentive for the monetary authority to deviate from price stability to address this inefficiency is, in most cases, small. We then use the tax policy framework to analyze the trade-off faced by the monetary authority.

To assess alternative policies, we evaluate the conditional expectation of the representative household's lifetime utility. This welfare measure is affected by labor market frictions and nominal price rigidity. Let W_t^{opt} be the household's conditional expectation of lifetime utility under the optimal monetary policy. Define W_t^f as the utility in the flexible-price equilibrium, and W_t^* as the utility in the planner's allocation. We can decompose the difference in welfare between the first and second best allocation as

$$W_t^* - W_t^{opt} = \left(W_t^* - W_t^f\right) + \left(W_t^f - W_t^{opt}\right) \geq 0. \tag{23}$$

The gap $W_t^* - W_t^f$ reflects the difference between the planner's allocation and the flexible-price equilibrium. This difference may be nonnegative if wage-setting deviates from efficient Nash bargaining, resulting in an inefficiency wedge in vacancy posting. It would also be nonnegative due to the presence of imperfect competition, but in all our policy experiments we continue to assume there is a constant subsidy τ^μ that offsets the impact of the flexible-price markup. Thus, when wages are set by Nash bargaining and the Hosios condition holds ($a = b$), the flexible-price equilibrium delivers the planner's level of welfare, so $W_t^* - W_t^f = 0$. Since $W_t^* - W_t^f$ depends exclusively on inefficiencies in the search and matching process, we label it the **"search gap"**.

The second term on the right-hand side of (23) measures the difference in welfare between the flexible-price allocation and the optimal policy. When nominal rigidities are the only distortion in the economy, the search gap is zero ($W_t^* - W_t^f = 0$) and a policy of price stability that ensures $W_t^f - W_t^{opt} = 0$ is optimal, since it replicates the flexible-price equilibrium and delivers the planner's allocation. However, when the search gap deviates from zero, it may be optimal for policy to offset partially the search gap by deviating from price stability. The term $W_t^f - W_t^{opt}$ is negative if the policy maker can improve on the flexible-price allocation attained under price stability, and the absolute size of this term measures the resulting welfare gain, which can be no larger than the search gap.

We compare three monetary policies: a policy focused exclusively on eliminating the distortion due to nominal rigidity (a policy of *price stability*), a policy focused exclusively on eliminating the wedge between the planner's and the competitive equilibrium vacancy posting condition (the *efficient employment* monetary policy), and the optimal monetary policy trading off these two objectives.

Table 1 provides an overview of the alternative policies we consider. Rows 1 and 2 represent cases in which we assume all necessary policy instruments are available. Row 1 corresponds to the case in which wages are Nash-bargained and the Hosios condition is satisfied; row 2 corresponds to the case in which wage-setting is inefficient. In either case, the first-best allocation is attainable. Columns 4-7 show the values of the policy instruments (τ^μ, τ_t^f, τ_t^C and monetary policy) that are necessary to achieve the first best. When wage setting is efficient, the market equilibrium achieves the first best as long as a constant τ^μ is used to subsidize retail production and monetary policy ensures price stability (a constant markup). In this case, monetary policy is the only cyclical instrument needed. When wage setting is inefficient, τ_t^f must vary to ensure vacancy postings are at their first-best level and τ_t^C eliminates the inefficiency wedge in hours choice. Monetary policy is still used to maintain price stability and ensure the markup remains constant.

Rows 3-5 of Table 1 consider the cases in which monetary policy is the only tool available to respond to exogenous shocks, and wage-setting deviates from efficient Nash-bargaining. Row 3 shows that when monetary policy aims solely at achieving price stability (a constant markup), a wedge in the vacancy posting condition arises. Row 4 describes the case of a monetary policy that focuses on eliminating the vacancy-posting wedge. Since this policy results in markup fluctuations, it generates both price dispersion and a wedge in the hours-setting condition.[8]

Rows 3 and 4 of Table 1 illustrate the trade-off faced by the monetary authority when wage-setting deviates from efficient Nash bargaining. Monetary policy can maintain price stability at the cost of generating labor market inefficiencies. Or it can address distortions in the labor market but at the cost of distorting hours and causing inflation to fluctuate. Optimal monetary policy (row 5) will need to sacrifice price stability to gain some improvement in labor market outcomes and will generally not close any of the wedges fully. To assess the quantitative implications for welfare of labor market inefficiencies and deviations from price stability, we employ a calibrated version of the model.

3.1 Calibrated assessment of alternative policies

Our basic calibration is presented in Table 2 and reflects standard choices in the literature. We assume per-period utility is given by

$$U(C_t) = \ln C_t \quad ; \quad H(h_t) = \frac{\ell h_t^{1+\gamma}}{1+\gamma}$$

and set the labor hours supply elasticity $1/\gamma$ 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 Galí, 2007, Christoffel and Linzert, 2010). We derive the parameters η, ℓ, and κ as implied by values for the steady-state vacancy filling rate q_{ss}, the share of working hours h_{ss}, and the employment rate N_{ss} consistent with US postwar data, and assuming the economy is in the efficient steady state. Without loss of generality, we assume $w_u = 0$. 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 μ 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] It is important to note, however, that while the policies in rows 3 and 4 close wedges, they do not imply that the first-best level of hours or vacancy is attained. That is, in row 3, for example, the choice of hours is optimal, conditional on employment, but because vacancy posting is inefficient, both employment and hours differ from their value in the first-best allocation.

Table 3 provides welfare outcomes in our model. We report the two welfare gaps on the right-hand side of (23), expressed in terms of the fraction λ of the expected consumption stream that the household would be willing to give up to attain the same welfare as in the reference economy (given by W_t^* in the first column and W_t^f in the second column)[9].

The first row of Table 3 shows the outcomes under Nash bargaining when the Hosios condition is satisfied ($a = b = 0.5$). In this case, only a steady-state subsidy equal to $1 - \mu$ and price stability are needed to achieve the first-best allocation under which both welfare gaps are zero (see row 1 of Table 1). Row 2 of Table 3 shows a case in which the Hosios condition is not satisfied and $b > a$. In this case, steady-state unemployment will be inefficiently high and firms' incentive to post vacancies will be too low. The search gap rises from zero to 0.80% of the expected consumption stream as b is increased from 0.5 to 0.7. However, as the second column of Table 3 shows, the corresponding welfare improvement under an optimal monetary policy is virtually nil compared to a policy that maintains price stability. Thus, even though the search gap can be large when the Hosios condition is not met, monetary policy optimally designed to affect the cyclical behavior of the economy has a negligible advantage relative to price stability.

Rows 3 and 4 provide evidence on the welfare effects of real wage rigidity. Real wage rigidity potentially addresses the counterfactually low unemployment volatility occurring in the standard search and matching model (Shimer, 2005). We follow Hall (2005) in introducing a wage norm $\bar{w}$, fixed at an exogenously given value. A wage norm that is insensitive to current economic conditions but is incentive-compatible from the perspective of the negotiating parties has been frequently adopted in recent research (Blanchard and Galí, 2010, Hall, 2005, Shimer, 2004, Thomas, 2008). Across OECD economies, aggregate wages are often very persistent, especially in European countries where collective wage bargaining is pervasive (Christoffel and Linzert, 2010). Focusing on the case of a wage that is completely insensitive to labor market conditions provides a useful if extreme benchmark for assessing the welfare implications of sticky real wages.

We consider two cases under a wage norm. Letting $w_{ss}(b)$ denote the steady-state wage level associated with a worker's surplus share equal to b, the first case we consider sets the wage norm equal to $\bar{w} = w_{ss}(0.5)$. We refer to this case as the steady-state

[9] 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. For a discussion of the Ramsey approach to optimal policy, see Schmitt-Grohe and Uribe (2005), Benigno and Woodford (2006), Kahn et al. (2003).

efficient wage norm since the wage is fixed at the efficient steady-state level associated with the Hosios condition ($a = b = 0.5$). In this case, shown in row 3 of Table 3, the business cycle behavior of labor market variables is very different compared to the first best, but the loss attributed to the search gap amounts to only 0.27% of the expected consumption stream (Table 3, row 3, column 1). The optimal policy leads to a small welfare gain of 0.05% relative to a policy of price stability.

The second case, shown in row 4, sets the wage norm equal to $w_{ss}(0.7)$, the steady-state wage when $b = 0.7$. With $b > a$, this case implies a larger share of the surplus goes to labor than would be efficient in the steady state. The loss due to the search gap now rises to 1.62%. Table 3 shows that optimal monetary policy can increase welfare by 0.22% relative to price stability. In absolute terms, this gain is non-negligible, yet it corresponds to only about one-seventh of the search gap. [10]

Our numerical results are consistent with the existing literature. Faia (2008) finds that, with inefficient Nash bargaining, price stability yields a welfare level that is only about 0.004% worse than the Ramsey optimal policy in terms of expected consumption stream. Thomas (2008) finds that in a new Keynesian model with labor frictions, optimal policy deviates significantly 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) finds that in the basic Mortensen-Pissarides search and matching model, under some conditions, a constant real wage has a negligible welfare cost relative to efficient Nash bargaining. Blanchard and Galí (2010) find that, with a substantial degree of real wage rigidity, inflation stabilization can yield a loss several times larger than the optimal policy. Since their measure is not scaled by the steady-state level of utility, it is not directly comparable in terms of its implications for welfare, and so we cannot draw inferences about whether the gain they find for deviations from price stability translate into a large welfare gain in consumption units.

What is clear from Table 3, and is a new result in the literature, is the finding that there is little benefit from deviating from price stability even in the extreme case of a fixed real wage *if the wage is fixed at a level consistent with steady-state efficiency.* Large welfare losses are incurred when wages are fixed at a level that is not consistent with

[10] Additional numerical experiments confirm this result. With $b = 0.8$, Nash bargaining yields a search gap of 2.11%, and a distance $W_t^f - W_t^{opt}$ of about -0.01% in terms of consumption. Under a wage norm $w_{ss}(0.8)$ the search gap and the distance $W_t^f - W_t^{opt}$ are respectively equal 3.85% and -0.57%.

steady-state efficiency. In this case, the benefits of deviating from price stability are larger, but monetary policy alone is ineffective in eliminating much of the welfare loss.

3.2 The optimal cyclical tax policy

While Table 3 suggests that even when the search gap is relatively large, monetary policy can mitigate only a small fraction of the welfare loss by deviating from price stability, it does not provide insight into why monetary policy is relatively ineffective. To investigate this issue further, we examine the role played by the various distortions in the model by investigating the behavior of the tax τ_t^f required to achieve the efficient allocation.

Table 4 shows summary statistics for this tax rate under different assumptions on wage setting. Since we assume the full set of four policy instruments is available, τ_t^f is set according to (20), τ_t^C follows (19), monetary policy sets $\mu_t = \bar{\mu}$ (i.e., maintains price stability), and $\tau^\mu = 1 - \mu$. Let τ^f without a time subscript denote the steady-state value of the tax on intermediate firms. A negative τ^f indicates it is optimal to provide a subsidy to intermediate firms (in addition to the subsidy τ^μ to retail firms).

If wages are set through Nash bargaining and the Hosios condition holds, the efficient allocation is obtained with a zero steady-state subsidy to intermediate firms combined with price stability. In this case, τ_t^f is constant, and row 1 shows the standard deviation of τ_t^f as equal to zero. Row 2 considers the case of Nash-bargained wages with $b = 0.7 > a$. Now, efficiency requires that firms post more vacancies in the steady state than they would in the market equilibrium. To achieve the efficient allocation requires a large steady-state subsidy, with $\tau^f = -115\%$. 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 match surplus. As the subsidy to firms increases, the total surplus rises and so the wage also increases. The rise in the wage dampens the impact of the subsidy on the surplus accruing to the firm and on the incentive to post vacancies. For the firm to achieve the efficient surplus (equal to $1-a$ times the surplus generated under the planner's allocation), the subsidy must be large enough to compensate for the endogenous increase in wages.

As the last two columns of row 2 in Table 4 indicate, however, there is very little variation in the subsidy. Almost all the welfare loss due to the violation of the Hosios condition is generated by the steady-state loss. Nash bargaining generates very little volatility of labor market variables (a result known as the 'Shimer's puzzle') and so requires very little volatility in the subsidy. Our choice of technology shock volatility σ_a results in a volatility of output equal to 1.78%, consistent with US data, but it gives a volatility of employment in the planner's allocation which is about 8 times smaller. The impact of Nash bargaining on employment is compounded in our model by the fact that firms can also expand output along the intensive (hours) margin. Since the volatility of employment is low regardless of the surplus share assigned to workers and firms, the volatility of the intermediate and consumption tax rates under Nash bargaining is less than one-twentieth that of output, as the tax policy needs to ensure only small changes in the dynamics of vacancies, employment, and hours to achieve an efficient response to productivity shocks. In turn, this explains why, in the absence of the tax policy, a monetary policy that achieves price stability is almost as good as the optimal policy, as found in Table 3, row 2. Essentially, μ_t^* is almost constant and a policy that maintains a constant markup, as occurs under price stability, is almost optimal.

Now suppose that rather than being *endogenously* determined, the wage is fixed at a norm equal to the efficient steady-state value $\bar{w} = w_{ss}(0.5)$. Because steady-state vacancy posting is efficient, the steady-state intermediate firm tax τ^f is, as in row 1, equal to zero. The fourth row of Table 4 shows the case when the wage norm is set at a level that differs from the steady-state efficient level. The welfare loss resulting from this distortion is large, as was shown by row 4 of Table 3, but the steady-state intermediate sector subsidy that implements the optimal policy would be two orders of magnitude smaller, and equal to 1.64%, relative to the case of inefficient Nash bargaining (row 2 of Table 4). However, while the average subsidy falls, a wage norm calls for much larger fluctuations in τ_t^f in the face of productivity shocks under the optimal policy. Its standard deviation increases by a factor of 20. It is also nearly as volatile as output.

A wage set at a fixed norm results in a much larger volatility in employment, consistent with empirical evidence in the US. The implied employment fluctuations generate sizeable deviations from efficiency and require much greater volatility in the optimal tax. Figure 1 plots impulse response functions for a 1% productivity shock when the optimal tax policy is implemented and monetary policy ensures price stability. A productivity increase calls for a higher wage in the efficient equilibrium in order to increase proportionally the firms' and workers' surplus share. Under the steady-state efficient wage norm, $\bar{w} = w_{ss}(0.5)$, the wage is inefficiently low after the positive productivity shock, so too many vacancies are posted, and the surge in employment is inefficiently high.[11] The optimal policy calls for increasing the tax on firms' revenues, and τ_t^f increases (i.e., the subsidy rate falls relative to the steady state) by about one percentage point. This increases the workers' surplus share, which would otherwise be below its efficient level. Since under the optimal tax policy the monetary authority ensures the markup is constant, the consumption tax τ_t^C response is equal to $-\tau_t^f$ to ensure the efficient hours setting condition (15) is met. Under inefficient Nash bargaining, Figure 1 shows that the response of τ_t^f, and symmetrically the response of τ_t^C, decreases by an order of magnitude relative to the fixed norm case.[12]

In summary, we find that the optimal tax rates τ_t^f (and τ_t^C) are large but display low cyclical volatility under (inefficient) Nash bargaining. However, with wages set equal to a fixed norm, the subsidy is much smaller on average but highly volatile.

3.3 Monetary policy and trade-offs

The previous section showed that under price stability and a wage norm, τ_t^f must move significantly to achieve the efficient response to productivity shocks. To analyze the trade-off faced by the policy maker when monetary policy is the only instrument, we study outcomes when monetary policy deviates from price stability to instead achieve the efficient condition for vacancy posting given by (14). This monetary policy can be enforced by ensuring the markup equals μ_t^* defined in (22). With this policy, the monetary authority can provide to firms the same incentive to post vacancies as the optimal tax τ_t^f would. At the same time, it introduces a distortion in the choice of hours as well as generating an inefficient dispersion of relative prices.

Table 5 shows the consequences for welfare and inflation volatility of this policy. Row 1 of the table repeats the earlier result that with wages set by Nash bargaining and the Hosios condition satisfied, price stability coincides with the optimal policy.[13] Now consider the case in which wages are determined by Nash bargaining but $b = 0.7 > a$. Row 2 of Table 4 showed that the optimal τ_t^f needed to compensate for a large, but basically acyclical, wedge between the efficient and inefficient allocations. Row 2 of Table 5 shows that the efficient employment monetary policy generates approximately the same

[11] This would also be the case qualitatively if the real wage were sticky as opposed to fixed.

[12] In the case of inefficient Nash bargaining with $b > a$, the optimal policy calls for a decrease in the tax rate τ_t^f, so as to provide incentives to intermediate firms to post more vacancies than in the competitive equilibrium.

[13] We continue to assume that the steady-state effects of the markup are offset by appropriately setting τ^{μ}.

level of welfare as price stability. The low volatility of the optimal tax τ_t^f translates into low volatility of the efficient employment markup μ_t^*. Therefore, the deviations from price stability necessary under the efficient employment policy are small, even if monetary policy focuses solely on the objective of closing the vacancy posting wedge. In other words, the monetary authority faces a welfare function which is close to flat with respect to the alternative objectives of labor market efficiency and price stability, and so the optimal, efficient employment, and price stability policies deliver similar welfare outcomes. The search gap is large, but most of it – both in terms of the size of the tax τ_t^f that would be needed to compensate for the inefficiency wedge in the vacancy posting condition and in terms of how this wedge translates in welfare loss – depends primarily on the steady state inefficiency, and this steady-state inefficiency cannot be addressed by monetary policy.[14] This explains why previous papers that assume Nash bargaining find that price stability is close to the optimal policy (i.e., Faia 2008, Ravenna and Walsh 2011).

Intuitively, the impact of a productivity shock with inefficient Nash bargaining is akin to its impact under the efficient allocation, coupled with a temporary deviation of the bargaining share b from its efficient level. Since workers and firms are concerned with the present value of the match surplus, which has a high probability of lasting several periods, temporary deviations from efficient bargaining do not have a large welfare cost. This argument is closely related to the argument made by Goodfriend and King (2001) that the long-term nature of employment relationships reduces the welfare costs of temporary deviations of the contemporaneous marginal product of labor from the marginal rate of substitution between leisure and consumption.

The welfare results change significantly under a wage norm. When wages are set according to a wage norm, even one set at the efficient steady-state level $w_{ss}(0.5)$, the efficient employment monetary policy that sets $\mu_t = \mu_t^*$ performs poorly compared to price stability. Row 3 of Table 5 shows that this policy would yield an additional welfare loss equal to 2.33% of consumption and lead to high inflation volatility. Even when the wage norm is set at the steady state level $w_{ss}(0.7)$, implying a larger search gap, and a larger share of the search gap being explained by inefficient cyclical fluctuations as opposed to the steady state loss, row 4 of Table 5 shows that the efficient employment

[14] The solution to the optimal policy problem yields a steady-state inflation rate of zero, similarly to the steady state result obtained in models with staggered price adjustment by King and Wolman (1999) and Adao, Correia and Teles (2003).

policy delivers a very substantial loss relative to the price-stability policy, amounting to 1.65%.

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 efficient employment monetary policy. First, consider the dynamics under price stability. Vacancy creation is inefficiently high in response to the rise in productivity since the wage does not rise. If the first best fiscal policy could be implemented, the subsidy τ_t^f would fall relative to the steady state level. The log-difference between the constant markup under price stability and the markup that would enforce the planner's vacancy posting condition μ_t^* (labeled as the markup gap in figure 2) rises on impact by 4%. This large movement suggests that price stability would result in a very large inefficiency wedge in the job posting condition (5) if the direct subsidy τ_t^f cannot be varied. Under the efficient employment monetary policy, this wedge is closed and $\mu_t = \mu_t^*$. 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 efficient employment monetary policy calls for taxing the revenues of the firm and reducing vacancy postings, the markup increases, resulting in a prolonged deflation. At the same time, the large response of the markup to the productivity shock results in a large fall in hours through the first order condition (7), and in a large deviation of hours from its efficient level shown in figure 1. Thus, the monetary policy replicating μ_t^* so as to close the inefficiency wedge in the vacancy posting condition results in an inefficiency wedge in hours, in addition to increasing price dispersion.

When tax instruments are available, the policy maker is not faced with this trade-off since the consumption tax τ_t^C compensates for the inefficiency in hours setting driven by the intermediate sector tax τ_t^f. In the case of inefficient Nash bargaining, the wage does move in response to the productivity shock, so only small movements in the markup are needed to mimic the optimal tax policy. And in this case, the absence of a second tax instrument has little bearing on the welfare outcome.

In summary, even with inefficient Nash bargaining there is little need for any cyclical policy to correct labor market inefficiencies, while with rigid wages the monetary policy maker finds little incentive to correct for the search inefficiency by deviating from price stability. This is so even though a tax policy could yield large welfare gains and a substantial portion of the search gap arises from cyclical inefficiencies.

3.4 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 be consistent with US labor markets data. In this section, we 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 also assume a separation rate equal to about a third of the one found in US data. 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 (see the Appendix for details on the parameter values). This parameterization delivers substantially smaller flows in and out of employment and longer average unemployment duration, 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 reports details on this alternative parameterization.

Table 6 shows the welfare results for this alternative parameterization. The search gap is about 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, with Nash bargaining the welfare gain from the optimal policy relative to price stability is minimal, on the order of one hundredth of a percentage point. Contrary to the US parameterization case, the welfare gain is minimal also in the case of a wage norm.

When the model is parameterized to deliver a longer unemployment duration, gross labor flows are small, and the scope for monetary policy to correct inefficient search activity is also reduced. Under our alternative parameterization, the quarterly job finding probability drops from 76% to 25% , and the volatility of employment in response to productivity shocks falls. As the volatility of hiring decreases, the welfare gain that could be achieved from a monetary policy that deviates from price stability to correct for inefficient vacancy posting also decreases. Thus, in our new Keynesian model with search frictions, the same labor market characteristics that lower steady-state employment can make cyclical monetary policy less effective. In economies where labor flows are more volatile, cyclical deviations from price stability can instead deliver meaningful welfare improvement, and at least partially close the search gap.

Next, we examine the performance of alternative policy instruments (steady state taxes and policies directly affecting matching on the labor market) once they are combined with optimal monetary policy. Table 7 reports the cumulative impact of monetary, fiscal and labor market policies under the two parameterizations, which we label US and EU. We report the cumulative welfare improvement relative to a price-stability policy for the case of an inefficient wage norm. The first row of Table 7 shows the welfare gain when monetary policy is the only available instrument other than the steady-state subsidy τ^{μ} correcting for imperfect competition. Row 2 reports the gain when, in addition to monetary policy, the optimal steady-state subsidy τ^{f} correcting for all of the vacancy posting wedge, and the symmetric steady-state subsidy τ^{C} that generates efficient steady-state hours choice, are used. The welfare gain in this case is nearly six times as large relative to row 1 for the US, and vastly larger for the EU. The welfare gain is large also in absolute value, equal to 1.37% of expected consumption in the US and 0.89% in the EU case. The large welfare improvement from the steady-state subsidy is correlated with an increase in the steady-state employment level.

Reforming the bargaining environment so that wages can be renegotiated each period, while still allowing for the steady state tax policy τ^{f}, τ^{C} and for the optimal monetary policy yields an additional gain, even if the surplus share $b = 0.7$ exceeds the efficient level (see row 3). Relative to the case examined in row 2, the gain from Nash bargaining comes exclusively from reducing the cyclical inefficiency gap, since the subsidy already ensures that the steady state is efficient. Nash bargaining also requires that the steady-state subsidy rate be increased from less than 2% to over 100%.

Finally, we consider the impact of policies directly affecting matching on the labor market. An improvement in the efficiency of the matching technology has a considerable impact on welfare. A 10% rise in the matching function TFP leads to a welfare gain of over three quarters of a percentage point, in both the US and EU cases (row 4). A policy that lowered search frictions decreasing the vacancy posting cost by 10% would allow for an additional substantial welfare improvement. Overall, the welfare gains from the steady state tax policy and the labor market policies are remarkable in magnitude compared to what can be achieved by cyclical monetary policy alone. Obviously, this welfare analysis is abstracting from the problem of financing any fiscal policy or structural reform, and that in itself would generate distortions in the economy.

4 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. To study the trade-off generated by the distortions in the economy, we derive the tax policy that corrects the inefficiency wedges in the competitive equilibrium first order conditions. We show that monetary policy can be interpreted as a way to manipulate markups and correct for the inefficiency wedges in the same way as a tax instrument would. In common with standard new Keynesian models, we assume a subsidy to retail firms is available to eliminate the steady-state distortion arising from imperfect competition. In addition to this standard subsidy, we show that three policy instrument would restore the first best. Absent these three instruments, the monetary authority, using only a single instrument, faces a trade-off. Policy can stabilize the retail price markup to eliminate costly price dispersion and at the same time eliminate the inefficiency wedge in hours setting, 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. While the cost of labor search inefficiency can be large, the welfare attained by optimal monetary policy deviates very little from what is achieved under price stability. The explanation for this outcome depends on the nature of the inefficiency in the wage-setting process. When wages are Nash-bargained in every period but set at a socially inefficient level, the optimal tax correcting for inefficient hiring by firms is large in the steady state but displays very little volatility over the business cycle. This outcome is a reflection of the fact that Nash bargaining generates only a small volatility of labor market variables. The low volatility of the optimal tax implies that there is little need for any cyclical policy to correct labor market inefficiencies, regardless of the number of instruments available; hence, price stability is close to optimal.

When wages are rigid and fixed at their steady state value, the optimal tax correcting for inefficient hiring is small in the steady state but very volatile over the business cycle. A monetary policy that lets markups fluctuate so as to replicate the optimal tax policy for firms, reduces the inefficiency wedge in hiring but increases the inefficiency wedge in the first order condition for the choice of hours worked, as well as increasing price dispersion. Thus the monetary authority faces a very unfavorable trade-off, and price stability does nearly as well as the optimal policy.

We find that the welfare gain of deviating from price stability is larger the more volatile labor market flows are over the business cycle. When the matching efficiency is lower and the hiring cost higher, there is virtually no incentive for the monetary authority to deviate from price stability. The same labor market characteristics that lower steady-state employment, and leave more to be gained from long-term policy interventions, 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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Table 1: Alternative policies

		Wedges between planner and market FOC			Instruments			
		(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Wage setting	Vacancies	Hours	Price dispersion	τ^{μ}	τ_t^f	τ_t^C	Monetary Policy
All instruments								
(1) 1^{st} best	efficient	0	0	0	$1-\mu$	0	0	$\bar{\mu}$
(2) 1^{st} best	inefficient	0	0	0	$1-\mu$	$1-\left(\frac{\bar{\mu}}{\mu_t^*}\right)$	$\frac{1}{\mu_t^*}-1$	$\bar{\mu}$
Monetary policy								
(3) Price stability	inefficient	$\neq 0$	0	0	$1-\mu$	–	–	$\bar{\mu}$
(4) Efficient employment	inefficient	0	$\neq 0$	$\neq 0$	$1-\mu$	–	–	μ_t^*
(5) Optimal policy	inefficient	$\neq 0$	$\neq 0$	$\neq 0$	$1-\mu$	–	–	$\mu_t \neq \mu_t^*$

Note: Efficient wage-setting requires Nash-bargained wages with a constant worker surplus' share $a = b$. Column (1), (2), (3) refer to the wedge between the conditions enforcing the planner's allocation and the competitive equilibrium for vacancy posting (respectively eqs. 14 and 5), hours choice (respectively eqs. 15 and 7), and retail pricing (respectively $\Delta_t = 1$ and eq. 10 evaluated at an equilibrium where $P_t(j) \neq P_t$). In all cases we assume a retail subsidy $\tau^{\mu} = 1 - \mu$ such that $\bar{\mu} = \mu/(1-\tau^{\mu}) = 1$.

Table 2: 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
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
After-tax steady state markup	$\overline{\mu}$	1
Implied Parameter Values from steady state		
Matching technology efficiency	η	0.677
Scaling of labor hours disutility	ℓ	6.684
Vacancy posting cost	κ	0.087

Note: Subscript ss indicates a steady state value.

Table 3: Welfare results under optimal monetary policy

	Search gap	Optimal Policy: loss relative to price stability
	(1)	(2)
Nash bargaining		
(1) b=*0.5*	0	0
(2) b=*0.7*	0.80%	$< -0.01\%$
Efficient wage norm		
(3) $\bar{w} = w_{ss}(0.5)$	0.27%	-0.05%
Inefficient wage norm		
(4) $\bar{w} = w_{ss}(0.7)$	1.62%	-0.22%

Note: the search gap is the welfare distance $W_t^* - W_t^f$ between the planner's equilibrium and the competitive flexible-price equilibrium conditional on the wage setting mechanism indexed by bargaining power b. The optimal policy loss relative to price stability is the welfare distance $W_t^f - W_t^{opt}$. 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. The wage norm $w_{ss}(0.5)$ is equal to the wage level that delivers an efficient steady state.

Table 4: Intermediate Sector Optimal Tax τ_t^f

	Steady-state tax rate (negative value implies a subsidy)	Volatility σ_τ	σ_τ/σ_y
Nash bargaining			
(1) *b=0.5*	0	0	0
(2) *b=0.7*	−115%	0.08%	0.04
Efficient wage norm			
(3) $\bar{w} = w_{ss}(0.5)$	0	1.69%	0.95
Inefficient wage norm			
(4) $\bar{w} = w_{ss}(0.7)$	−1.64%	1.69%	0.95

Note: steady state rate and volatility for subsidy paid to intermediate sector firms. Optimal tax policy implies $(1-\tau_t^f)/\mu_t = 1+\tau_t^C$, $\tau^\mu = 1-\mu$ and $\mu_t = \bar{\mu}$. The results in the table are obtained assuming a complete set of policy instruments is available to attain the first best allocation.

Table 5: Welfare Results: Efficient Employment Monetary Policy

	Loss relative to price stability λ	Relative inflation volatility σ_π/σ_y
Nash bargaining		
(1) *b=0.5*	0	0
(2) *b=0.7*	0.0003%	0.22
Wage norm		
(3) $\bar{w} = w_{ss}(0.5)$	2.33%	4.11
(4) $\bar{w} = w_{ss}(0.7)$	1.65%	3.28

Note: welfare results conditional on monetary policy rule $\mu_t = \mu_t^*$ where μ_t^* is defined in eq. (22). 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 6: Welfare results under optimal monetary policy
High Unemployment Duration Parameterization

	Search gap	Optimal Policy: loss relative to price stability
	(1)	(2)
Nash bargaining		
(1) b=*0.5*	0	0
(2) b=*0.7*	0.79%	$< -0.01\%$
Wage norm		
(3) $\bar{w} = w_{ss}(0.5)$	0.11%	$< -0.01\%$
(4) $\bar{w} = w_{ss}(0.7)$	1.13%	-0.01%

Note: the search gap is the welfare distance $W_t^* - W_t^f$ between the planner's equilibrium and the competitive flexible-price equilibrium conditional on the wage setting mechanism indexed by bargaining power b. The optimal policy loss relative to price stability is the welfare distance $W_t^f - W_t^{opt}$. 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 reported in Table A1.

Table 7: EU vs. US Policy Options: the Case of an Inefficient Steady State Wage Norm						
	Steady-state tax rate τ^f		Cumulative welfare loss λ relative to price stability		Steady-state employment rate	
Policy	US	EU	US	EU	US	EU
(1) Optimal monetary policy	0	0	-0.22%	-0.01%	88% $\sigma_n = 1.51$	84% $\sigma_n = 1.18$
(2) Optimal steady-state subsidy	-1.64%	-1.75%	-1.37%	-0.89%	95% $\sigma_n = 0.99$	90% $\sigma_n = 0.77$
(3) Nash Bargaining	-115%	-114%	-1.65%	-1.01%	95% $\sigma_n = 0.051$	90% $\sigma_n = 0.050$
(4) 10% increase in matching efficiency	-115%	-116%	-2.47%	-1.75%	96.4% $\sigma_n = 0.044$	91.2% $\sigma_n = 0.042$
(5) 10% decrease in vacancy cost	-117%	-117%	-2.90%	-2.14%	97.1% $\sigma_n = 0.045$	91.8% $\sigma_n = 0.040$

Note: Table compares welfare under the baseline parameterization (US) and a parameterization implying longer unemployment duration (EU). Constant wage norm set at inefficient steady-state level $w_t = w_{ss}(0.7)$. Row (1): monetary policy is the only instrument. Row (2): monetary policy is combined with the optimal steady-state tax policy. Rows (3) to (5): monetary policy and steady-state tax policy are combined with labor market policies. Welfare distances are expressed in terms of λ, the fraction of the expected consumption stream in the economy under a price-stability monetary policy and zero τ^f, τ^C tax rates 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. Optimal steady-state tax policy implies $(1-\tau^f)/\bar{\mu} = 1+\tau^C$. In all cases we assume a retail subsidy $\tau^{\mu}= 1-\mu$ such that $\bar{\mu} = 1$. Employment standard deviation σ_n is scaled by output standard deviation.

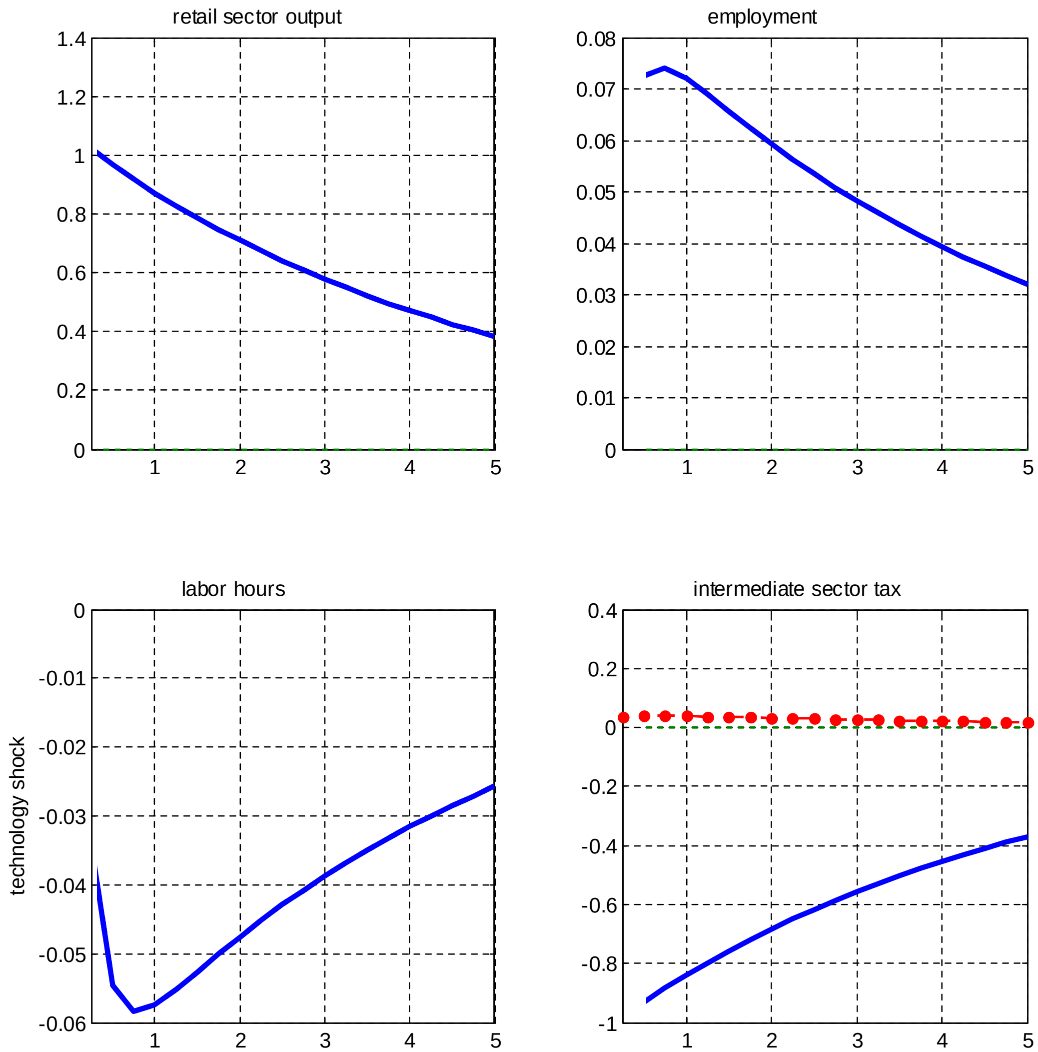

Figure 1: Impulse response function to 1% technology shock in intermediate production sector conditional on optimal tax policy enforcing the first best allocation. Variables plot in log-deviations from steady state. Scaling in percent. Optimal intermediate sector tax shows deviation of τ_t^f from steady state, in percent of steady state gross tax rate $(1-\tau^f)$. Full line: optimal tax for wage set at efficient steady state norm $w_t = w_{ss}(0.5)$. Dotted line: optimal tax for inefficient Nash-bargained wage with weight $b = 0.7$. The optimal policy implies a constant markup $\overline{\mu}$ and log-deviations of the consumption tax rate τ_t^C equal to $-\tau_t^f$.

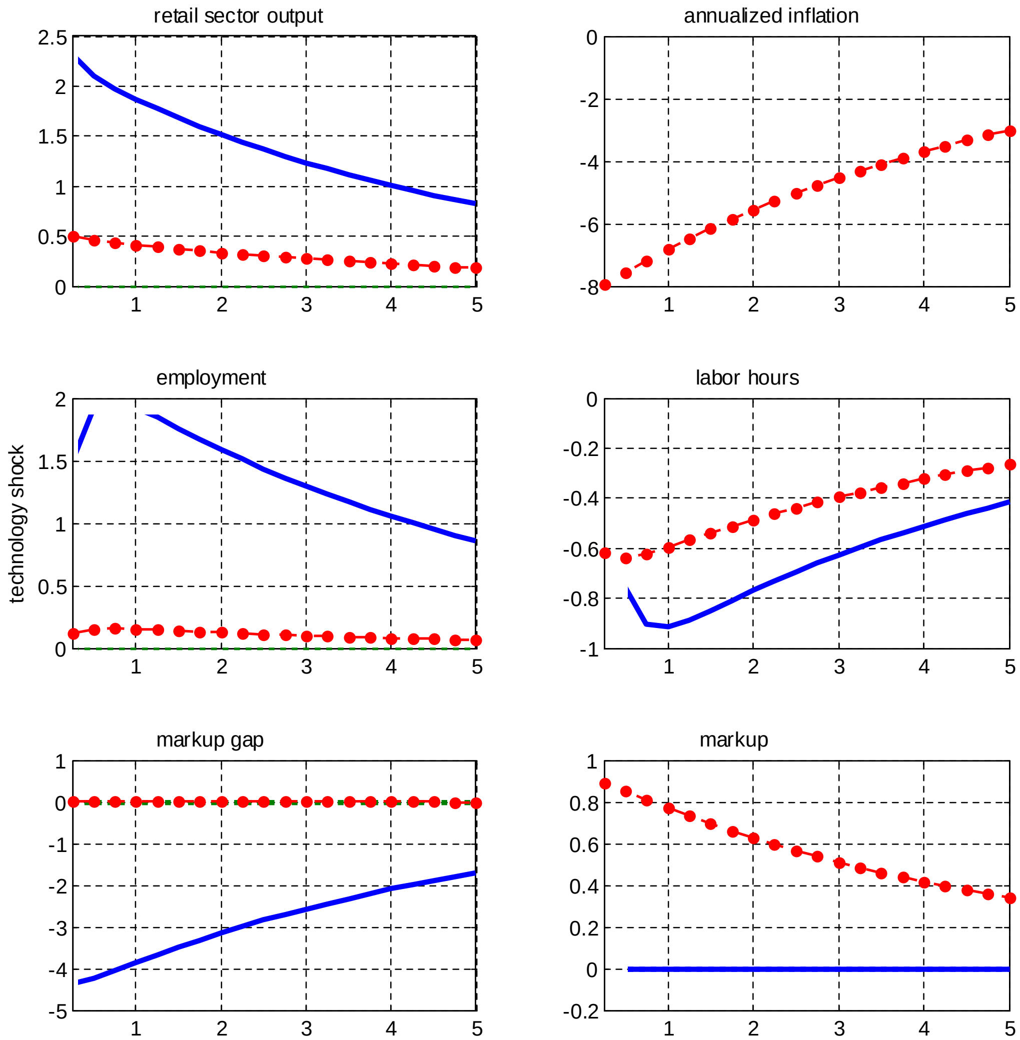

Figure 2: Impulse response function to 1% technology shock in intermediate production sector conditional on two alternative monetary policies. Wage is set at efficient steady state norm $w_t = w_{ss}(0.5)$. Full line: Price stability monetary policy $\mu_t = \overline{\mu}$. Dotted line: Efficient employment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

5 Appendix

5.1 High unemployment duration parameterization

Table A1 reports the steady state values, and the implied parameter values conditional on the efficient allocation, used for the high unemployment duration parameterization in Tables 5 and 6.

Table A1: High Unemployment Duration 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%
Implied parameter values		
Matching technology efficiency	η	0.4182
Scaling of labor hours disutility	ℓ	9.2325
Vacancy posting cost	κ	0.176

5.2 Planner's problem

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

$$W_t(N_t) = \max \ [U(C_t) - N_t H(h_t) + \beta E_t W_{t+1}(N_{t+1})] \tag{24}$$

where the maximization is subject to

$$C_t \leq C_t^m + w^u(1 - N_t)$$

$$Y_t^w(j) \leq f(A_t, L_t(j))$$

$$L_t(j) = h_t(j) N_t(j)$$

$$Y_t^w = \int_0^1 Y_t^w(j)dj$$

$$N_t = \int_0^1 N_t(j)dj$$

$$h_t = \int_0^1 h_t(j)dj$$

$$Y_t^w(j) = C_t^m(j) + \kappa v_t(j)$$

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

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

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

$$M_t = \eta v_t^{1-a} u_t^a$$

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

The solution to the planner's problem is given by eqs. (12), (13), (14), (15) and by the constraints to the optimization problem (24). Eq. (14) in the main text is obtained from the planner's first order condition with respect to vacancy posting:

$$\frac{\kappa}{(1-a)q_t} = f_L(t)h_t - w^u - \frac{H(h_t)}{U_C(t)} + \beta(1-\rho)\,\mathrm{E}_t\left[\frac{U_C(t+1)}{U_C(t)}\right](1 - ap_{t+1})\frac{\kappa}{(1-a)q_{t+1}} \quad (25)$$

where

$$q_t = \frac{\partial M_t}{\partial v_t}\frac{1}{(1-a)} \quad (26)$$

$$p_t = \frac{\partial M_t}{\partial s_t}\frac{1}{a} \quad (27)$$

5.3 Efficient competitive equilibrium with no cyclical tax instruments

The competitive equilibrium can replicate the planner allocation, under some condition. First, a price stability monetary policy results in a constant markup $\bar{\mu}$, and eliminates price dispersion. Thus, retail firms produce the same quantity of each variety, and conditions (12), (13) are met. Second, when wages are Nash-bargained the FOC for vacancy posting implies:

$$\begin{aligned}\frac{\kappa}{(1-a)q_t} &= \frac{(1-b)}{(1-a)}\left[\left(\frac{1}{\bar{\mu}}\right)f_L(t)h_t - w_u - \frac{H(h_t)}{U_C(t)}\right] \\ &\quad + \frac{\beta(1-\rho)}{(1-a)}E_t\left\{\left(\frac{U_C(t+1)}{U_C(t)}\right)(1 - bp_{t+1})\frac{\kappa(1-a)}{(1-a)q_{t+1}}\right\}\end{aligned} \quad (28)$$

where we substituted the Nash-bargained wage (6)

$$w_t h_t = (1-b)\left[w^u + \frac{H(h_t)}{\lambda_t}\right] + b\left[\left(\frac{1}{\bar{\mu}}\right) f_L(t) h_t + \kappa(1-\rho)\beta \mathrm{E}_t \left(\frac{\lambda_{t+1}}{\lambda_t}\right)\theta_{t+1}\right].$$

in eq. (5). The RHS of eqs. (25) and (28) are equal for $\left(\frac{1-\tau^f}{\bar{\mu}}\right) = 1$ and $b = a$.

The hours choice is given by

$$\left(\frac{1}{\bar{\mu}}\right) f_L(t) = \frac{H'(h_t)}{U_C(t)}$$

which is identical to the planner FOC (15) for $\bar{\mu} = 1$.

Finally, the transfer from firms to households of the profits in the production sector and the lump-sum rebate (payment) of the firms revenues' tax (subsidy) $\tau^{\mu} Y_t$ ensure that the planner resource constraint $Y_t^w = C_t^m + \kappa v_t$ is met. Thus in the competitive equilibrium the efficient allocation is generated by Nash bargaining with a surplus share b accruing to the household equal to the elasticity a of the matching function with respect to vacancies, a price stability policy resulting in a constant markup, and a subsidy $\tau^{\mu} = 1 - \mu$ to final firms to ensure that the retail markup net of subsidy $\bar{\mu} = \mu/(1-\tau^{\mu})$ does not distort the hours and vacancy posting conditions. The tax rate τ^{μ} is set such that the after-tax markup $\bar{\mu} = 1$.

5.4 Efficient competitive equilibrium under the tax policy

When the cyclical tax instruments τ_t^f and τ_t^C are available and set at the optimal level specified in eqs. (18), (19), they ensure that the competitive equilibrium replicates the efficient allocation when combined with a policy of price stability. First, price stability results in a constant markup $\bar{\mu}$, and eliminates price dispersion. Thus, retail firms produce the same quantity of each variety, and conditions (12), (13) are met. Second, the optimal tax τ_t^f is chosen to satisfy eq. (18). Since τ_t^f is obtained equating the competitive equilibrium FOC (5) and the planner FOC (14), in equilibrium the intermediate firm's vacancy posting FOC conditional on the optimal tax τ_t^f is identical to the planner FOC (14). Similarly, since τ_t^C is obtained equating the competitive equilibrium FOC (7) and the planner FOC (15), in equilibrium the intermediate firm's hours FOC conditional on the optimal tax τ_t^C is identical to the planner FOC (15).

Finally, lump-sum transfers to (from) the households of the profits from the production sector Π_t^f, Π_t^r, and of the taxes (subsidies) for the intermediate and final firms ensure that the planner resource constraint is met. The profits from the intermediate goods firms (in terms of final goods) are given by:

$$\Pi_t^f = \left(\frac{1-\tau_t^f}{\mu_t}\right) Y_t^w - w_t h_t N_t - \kappa v_t \tag{29}$$

while the retail sector produces profits equal to:

$$\Pi_t^r = (1-\tau^\mu)\, Y_t^d - \left(\frac{1}{\mu_t}\right) Y_t^w \tag{30}$$

Write the government budget constraint as:

$$\tau^\mu P_t Y_t^d + \tau_t^C P_t C_t^m + \tau_t^f \left(\frac{1}{\mu_t}\right) Y_t^w = T_t \tag{31}$$

where T is the net lump-sum transfer from the government to the household sector. Combining the household budget

$$\left(1+\tau_t^C\right) P_t C_t^m + p_{bt} B_{t+1} \leq P_t \left(w_t h_t N_t + B_t\right) + P_t \Pi_t^f + P_t \Pi_t^r + P_t T_t,$$

with eqs. (29), (30), (31) gives:

$$\left(1+\tau_t^C\right) P_t C_t^m + p_{bt} B_{t+1} \leq P_t \left(w_t h_t N_t + B_t\right) + P_t \Pi_t^f + P_t \Pi_t^r + P_t \left[\tau^\mu P_t Y_t^d + \tau_t^C P_t C_t^m + \tau_t^f \left(\frac{1}{\mu_t}\right) Y_t^w\right]$$

Since market clearing on the bond market requires $B_t = 0$ obtain:

$$\begin{aligned} P_t C_t^m \leq\ & P_t w_t h_t N_t + P_t \left[\left(\frac{1-\tau_t^f}{\mu_t}\right) Y_t^w - w_t h_t N_t - \kappa P_t v_t\right] \\ & + P_t \left[(1-\tau^\mu)\, Y_t^d - \left(\frac{1}{\mu_t}\right) Y_t^w\right] + P_t \left[\tau^\mu P_t Y_t^d + \tau_t^f \left(\frac{1}{\mu_t}\right) Y_t^w\right] \end{aligned}$$

The last equation simplifies to

$$P_t C_t^m \leq P_t \left[-\left(\frac{\tau_t^f}{\mu_t}\right) Y_t^w - \kappa v_t\right] + P_t Y_t^d - P_t \left[\tau_t^f \left(\frac{1}{\mu_t}\right) Y_t^w\right] = P_t Y_t^d - \kappa P_t v_t,$$

implying

$$Y_t^d = C_t^m + \kappa v_t$$

which holds for any τ^μ, τ_t^f and τ_t^C. Thus the tax policy ensures the competitive equilibrium is characterized by the planner FOCs (12), (13), (14), (15) and by the constraints to the planner's optimization problem (24), resulting in the efficient allocation regardless of the wage-setting process. The tax (18) and (20) works by generating the correct surplus for the firm, conditional on all endogenous variables being at their first best level.