ISSN 1936-5330

THE FEDERAL RESERVE BANK of KANSAS CITY
RESEARCH WORKING PAPERS

Search with Wage Posting under Sticky Prices

Andrew T. Foerster and José Mustre-del-Río

December 2015
RWP 14-17

Search with Wage Posting under Sticky Prices*

Andrew T. Foerster† José Mustre-del-Río‡

December 1, 2015

Abstract

We consider the interaction between nominal rigidities and labor market frictions in an environment where firms jointly make pricing and hiring decisions. In our New Keynesian framework, firms are subject to sticky prices and post take-it-or-leave-it contracts to attract workers in a frictional labor market. Relative to the standard model that separates search and pricing frictions between wholesale and retail firms, respectively, our model implies more adjustment along the intensive margin of labor demand and less along the extensive margin, hence less volatility in the vacancy-to-unemployment ratio. Nominal rigidities have a larger impact in our framework than the standard model, since firms face stronger trade-offs in their pricing and employment decisions.

Keywords: Search, Matching, Inflation, Sticky Prices

JEL: E10, E30, E50, J60.

*We thank Mark Bils, Yongsung Chang, Alejandro Justiniano, Greg Kaplan, Jonathan Willis, Peter Rupert, Sergio Afonso Lago Alves, and participants at the Stockman, Federal Reserve System Macroeconomics, XVII Annual Inflation Targeting, Midwest Macroeconomics, and Computing in Economics and Finance Conferences for valuable comments and discussions. Guangye Cao provided excellent research assistance. The views expressed in this paper are those of the authors and do not necessarily represent the views of the Federal Reserve Bank of Kansas City or the Federal Reserve System.

†Research Department, Federal Reserve Bank of Kansas City, 1 Memorial Drive, Kansas City, MO 64198, andrew.foerster@kc.frb.org.

‡Research Department, Federal Reserve Bank of Kansas City, 1 Memorial Drive, Kansas City, MO 64198, jose.mustre-del-rio@kc.frb.org.

1 Introduction

After the Great Recession, labor markets recovered at an anemic rate, with weak goods demand ostensibly being a reason for their sluggish recovery. According to this Keynesian view of the world, producers facing weak demand respond by lowering labor demand rather than lowering prices, as these are subject to nominal rigidities. However, most quantitative New Keynesian models limit the interaction between labor demand and pricing behavior by assuming these decisions are made by separate entities. This assumption contrasts with recent evidence suggesting strong linkages between the two (e.g. Klenow and Malin, 2010).

In this paper we unify pricing and labor demand in a model with sticky prices and search frictions in the labor market and consider the implications of this interaction for the macroeconomy. We develop a framework where firms jointly post vacancies, offer workers a compensation-hours contract, and make pricing decisions.

We show that the coupling of labor market and pricing frictions has important implications for the behavior of wages, hours, and unemployment when compared to a similar model that separates these two frictions using the traditional wholesaler-retailer construct. Our model shows more muted responses to technology and separation rate shocks and more amplified responses to monetary policy shocks than the alternative model with the wholesaler-retailer structure. We show some of this effect is because hiring firms face nominal rigidities, but the integration of search frictions into a firm with market power is critical. Indeed, even in the flexible price version of our economy, our baseline model still shows more muted responses to technology shocks compared to the alternative model with the wholesaler-retailer structure. This is because firms in our baseline model being price-takers still control their own output demand and hence their labor demand, whereas firms in the alternative model take output demand as given.

The mechanism behind our results can be understood by considering the comparative static exercise of varying benefits paid to unemployed workers in both models. The level of benefits affects the level of compensation that firms offer workers, so changing benefits alters firms' incentives to hire. In our baseline model, firms doing the hiring have market power, which generates less sensitivity of output and employment to unemployment benefits than

in an alternative model where hiring firms do not have market power.

Over the cycle, hourly wages are more volatile in our baseline model compared to the alternative model, which leads to less volatility in unemployment and vacancy creation. Price-setting firms respond to shocks by adjusting markups through changes in marginal costs. However, because the only marginal cost is the hourly wage paid to the existing worker, shocks pass-through into hourly wages. The degree of pass-through is naturally a function of the degree of price stickiness. As prices become more sticky firms respond more to shocks by adjusting hourly wages rather than changing prices. Overall, when firms are price-setters price stickiness does not lead to greater unemployment volatility even though wage and hour contracts are such that workers are always indifferent between employment and unemployment.

Key to our results is the assumption that firms post take-it-or-leave-it contracts. This contract ensures that all workers are offered their value of unemployment, which is independent of the firm's product price, and consequently independent of whether the firm is a price-setter as in our baseline model, or a price-taker as in our alternative model. Hence, comparing allocations across models is transparent as they solely reflect changes in firm behavior. By contrast, if wages were determined by commonly used Nash bargaining, the two models would trivially produce different allocations as hiring firms and workers would be splitting a surplus that varies based on the economy's structure.[1]

An additional by-product of wage posting is tractability. In combination with our assumption on preferences, wage posting eliminates the need for a representative household as workers who are indifferent across employment states do not save in equilibrium. On the firm side, the combination of wage posting and sticky prices subject to Calvo shocks also makes the firm's problem highly tractable, eliminating the need for approximation techniques like those of Krusell and Smith (1998) that are typically required to study business cycles with heterogeneity.

Our paper builds upon the literature analyzing the role of frictional unemployment for inflation dynamics by developing a framework that allows firms to jointly make pricing and

[1] See for example, Kuester (2010), Barnichon (2010), Thomas (2011), and Dossche et al. (2014), for papers that combine search and Calvo pricing frictions within the same firm when wages are Nash bargained. Krause and Lubik (2007) allow for surplus splitting and quadratic price adjustment.

hiring decisions. Typically, papers specify labor market arrangements that preclude the direct interaction of frictions stemming from the job search process and frictions associated with infrequent price adjustment. For example, Trigari (2006), Walsh (2005), and Christiano et al. (2013) assume a wholesaler-retailer structure, where hiring in the frictional labor market is done by wholesale firms, whereas prices are set separately by monopolistic retail firms. By separating these decisions, the wholesaler-retailer structure mutes the impact of their interactions. In our model, firms making the pricing decisions also make hiring and wage posting decisions, leading to a stronger degree of interaction between these frictions. In particular, because search frictions make labor a firm-specific factor in the short-run, pricing decisions at the firm-level critically depend on the curvature of labor disutility from the existing worker.[2]

The remainder of the paper is as follows. Section 2 describes our model of search with wage posting and sticky prices; we also outline an alternative model that separates search and pricing frictions into separate firms. Section 3 contains the main results, and compares our model with the alternative by examining the effects of changing the replacement rate, impulse responses to shocks, and key labor market ratios. Finally, Section 4 concludes.

2 Model

The model we present is a variant of the conventional New Keynesian monetary framework. The key changes involve the labor market and the contractual environment. Unemployment is modeled by introducing random search. Rather than assuming firms and workers bargain over wages, hiring firms post take-it-or-leave-it offers that stipulate compensation and hours worked. Nominal rigidities are introduced by assuming hiring firms set prices subject to Calvo frictions.

[2] Kuester (2010) obtains a similar result when wages and prices are infrequently bargained.

2.1 Individuals

There is a unit mass of individuals, indexed by $i \in [0,1]$, who consume $c_{i,t}$ and work hours $h_{i,t}$, obtaining utility from the period utility function

$$U\left(c_{i,t}, h_{i,t}\right) = \frac{\left(c_{i,t} - \varphi h_{i,t}^{1+1/\psi}\right)^{1-\gamma} - 1}{1-\gamma}. \tag{1}$$

The period utility function depends on the constant of relative risk aversion γ, the disutility of labor φ, and the Frisch elasticity ψ. Individuals discount future utility at rate β.

Preferences are of the form devised by Greenwood et al. (1988), which eliminate any wealth effect on the labor supply, an assumption that provides multiple benefits in our framework. First, it greatly simplifies the contractual environment, as the presence of wealth effects on labor supply would imply that firms would vary their wage offering depending upon the wealth of the worker. Wealth effects on labor supply would also counterfactually imply asset-rich individuals preferring unemployment over employment.[3] Second, along with the assumption on the contracting environment, it allows us to dispatch with perfect consumption insurance or a large household assumption typical in New Keynesian models with search (for example, Walsh (2005), Thomas (2011), Kuester (2010)). In these models, individuals typically are forced by the household to undertake potentially sub-optimal hours decisions from an individual standpoint to benefit the household as a whole and can use consumption obtained by other workers to bolster their outside option and hence bargained wage. Instead, our model has individuals optimizing their labor market choice without consideration for other individuals.[4]

Individuals purchase consumption goods at price P_t and buy nominal bonds B_t which have gross return R_t in period $t+1$. They also own shares in a mutual fund that owns all other firms in the economy; the mutual fund pays real dividends D_t.[5] Finally, they pay real

[3] In contrast, Mustre-del Río (2014) finds that for prime age males employment is roughly flat with household wealth.

[4] Given the contracting environment and utility specification, our model with individuals making independent choices would be equivalent to a large household model with perfect utility insurance, with all utility of individuals equalized. There has been some progress in considering sticky-price models with more general types of heterogenous consumers, but computational difficulties severely constrain the size of the model (Gornemann et al. (2012)).

[5] Given symmetric initial conditions, in equilibrium all individuals own equal shares in the mutual fund and

lump sum taxes equal to T_t.

The employment status $n_{i,t}$ of each individual varies between being unemployed ($n_{i,t} = u$) and employed ($n_{i,t} = e$). In each period a fraction n_t of individuals are employed, and $u_t = 1 - n_t$ are unemployed.

Unemployed individuals work zero hours $\left(h^u_{i,t} = 0\right)$, collect real unemployment benefits from the government equalling b, and search for employment the subsequent period, which occurs in equilibrium with probability s_t.[6] If $\mathbb{E}_t$ denotes the expectations operator conditional on time t information, an unemployed worker's problem is therefore

$$W^u_{i,t} = \max_{c^u_{i,t}, B^u_{i,t}} \left\{ \frac{\left(c^u_{i,t}\right)^{1-\gamma} - 1}{1-\gamma} + \beta \mathbb{E}_t \left[s_t W^e_{i,t+1} + (1 - s_t) W^u_{i,t+1} \right] \right\} \tag{2}$$

subject to

$$P_t c^u_{i,t} + B^u_{i,t} + P_t T_t = P_t b + R_{t-1} B_{i,t-1} + D_t. \tag{3}$$

Employed workers, on the other hand, work positive hours $h_{i,t}$ and are paid a real compensation level $\omega_{i,t}$. Their existing job ends with time-varying probability δ_t, in which case they enter unemployment the following period; with probability $(1 - \delta_t)$ they remain employed. An employed worker's problem is therefore

$$W^e_{i,t} = \max_{c^e_{i,t}, B^e_{i,t}} \left\{ \frac{\left(c^e_{i,t} - \varphi h^{1+1/\psi}_{i,t}\right)^{1-\gamma} - 1}{1-\gamma} + \beta \mathbb{E}_t \left[(1 - \delta_t) W^e_{i,t+1} + \delta_t W^u_{i,t+1} \right] \right\} \tag{4}$$

subject to

$$P_t c^e_{i,t} + B^e_{i,t} + P_t T_t = P_t \omega_{i,t} + R_{t-1} B_{i,t-1} + D_t. \tag{5}$$

Note that employed workers do not choose $h_{i,t}$, as hours are determined within the firm's contracting environment.

Standard optimality conditions for unemployed and employed individuals yield an Euler

no trading occurs, so we impose this result from the outset for notational simplicity. A technical appendix for the entire model is available upon request.

[6] For simplicity we abstract from the participation decision, hence all non-employed individuals are active searchers.

equation for the unemployed

$$\lambda_{i,t}^{u} = \beta \mathbb{E}_t \left[\frac{s_t \lambda_{i,t+1}^{e} + (1 - s_t) \lambda_{i,t+1}^{u}}{\Pi_{t+1}} \right] R_t, \tag{6}$$

and for the employed

$$\lambda_{i,t}^{e} = \beta \mathbb{E}_t \left[\frac{(1 - \delta_t) \lambda_{i,t+1}^{e} + \delta_t \lambda_{i,t+1}^{u}}{\Pi_{t+1}} \right] R_t, \tag{7}$$

where $\Pi_{t+1} = P_{t+1}/P_t$ is the gross inflation rate. The marginal utility of consumptions for the unemployed are given by

$$\lambda_{i,t}^{u} = \left(c_{i,t}^{u}\right)^{-\gamma},$$

and for the employed are

$$\lambda_{i,t}^{e} = \left(c_{i,t}^{e} - \varphi h_{i,t}^{1+1/\psi}\right)^{-\gamma}. \tag{8}$$

Given symmetric initial conditions on bond-holdings, the optimal contact to be discussed equalizes the value of employed and unemployed workers, which implies

$$c_{i,t}^{u} = c_{i,t}^{e} - \varphi h_{i,t}^{1+1/\psi}. \tag{9}$$

As a result, we get symmetry of the marginal utilities of consumption

$$\lambda_t = \lambda_{i,t}^{u} = \lambda_{i,t}^{e}. \tag{10}$$

2.2 Final Good Producers

Final good producers operate competitively, purchasing $Y_{j,t}$ from $j \in [0, n_t]$ operating intermediate goods firms and combine them into final output Y_t using a technology with constant elasticity of substitution ϵ :

$$Y_t = n_t \left(\frac{1}{n_t} \int_0^{n_t} Y_{j,t}^{\frac{\epsilon-1}{\epsilon}} dj \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{11}$$

Standard cost minimization implies that the demand for each intermediate good $Y_{j,t}^d$ depends on its relative price according to

$$Y_{j,t}^d = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} \frac{Y_t}{n_t}. \tag{12}$$

The aggregate price level is related to the individual prices by

$$P_t^{1-\epsilon} = \frac{1}{n_t} \int_0^{n_t} P_{j,t}^{1-\epsilon} dj. \tag{13}$$

2.3 Intermediate Goods Producers

Intermediate goods firms are indexed by j, and produce using the linear technology

$$Y_{j,t}^s = Z_t h_{j,t}, \tag{14}$$

where $h_{j,t}$ is hours at firm j and total factor productivity Z_t follows

$$\log Z_t = \rho_z \log Z_{t-1} + \sigma_z \varepsilon_{z,t}. \tag{15}$$

Firms sell their output at price $P_{j,t}$ and are subject to a Calvo friction when setting prices. Firms employ a single worker; conditional on being matched with a worker the firm negotiates a contract $\Upsilon_{j,t} = (\omega_{j,t}, h_{j,t})$ that determines a compensation level $\omega_{j,t}$ and an hours requirement $h_{j,t}$. Firms face a two-stage problem: in the first stage they set prices and in the second stage they contract with labor and produce.

In the second stage, given a price $P_{j,t}$, firms make a take-it-or-leave-it offer to their worker. They choose a contract $\Upsilon_{j,t}$ to maximize current period profits

$$D_{j,t} = \left(\frac{P_{j,t}}{P_t}\right) Y_{j,t}^d - \omega_{j,t} \tag{16}$$

subject to their demand (12), the constraint that they must meet demand at the posted

price $Y_{j,t}^{s} \geq Y_{j,t}^{d}$, and their matched worker's participation constraint

$$W_{i,t}^{u} \leq W_{i,t}^{e}. \tag{17}$$

Since the firm will always choose to make the participation constraint (17) bind, then for symmetric initial conditions on asset holdings, the value function for an unemployed individual (2) and an employed one (4) imply the optimal contract satisfies

$$\omega_{j,t} = b + \varphi h_{j,t}^{1+\frac{1}{\psi}}. \tag{18}$$

This equation reveals that the equilibrium compensation contract when firms make take-it-or-leave-it offers to workers is a special case of Nash bargaining when workers' bargaining weight is zero. Under this scenario individual wages no longer depend on aggregate labor market tightness. Thus, cyclical variation in compensation is solely due to changes in labor demand through hours worked $h_{j,t}$, which will also depend on the firm's set price.

Given the optimal contract, in the first stage a matched firm can re-optimize its price subject to a Calvo friction. The value of an operating firm with price $P_{j,t}$ is given by

$$J_t\left(P_{j,t}\right) = \left(\frac{P_{j,t}}{P_t}\right) Y_{j,t}^{d} - \omega_{j,t} + \beta\left(1-\delta_t\right)\mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t}\left[\zeta J_{t+1}\left(P_{j,t}\right) + \left(1-\zeta\right) J_{t+1}\left(P_{t+1}^{*}\right)\right], \tag{19}$$

where $\beta\frac{\lambda_{t+1}}{\lambda_t}$ denotes the stochastic discount factor, ζ the probability of not re-optimizing prices, and P_t^{*} denotes the optimal price set by a firm that can re-optimize in t. Since the optimal compensation scheme depends on hours, and firms must meet demand at the posted price, the value is given by

$$\begin{aligned} J_t\left(P_{j,t}\right) &= \left(\frac{P_{j,t}}{P_t}\right)^{1-\epsilon}\frac{Y_t}{n_t} - b - \varphi\left(\left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon}\frac{Y_t}{Z_t n_t}\right)^{1+\frac{1}{\psi}} \\ &\quad + \beta\left(1-\delta_t\right)\mathbb{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left[\zeta J_{t+1}\left(P_{j,t}\right) + \left(1-\zeta\right) J_{t+1}^{*}\right] \end{aligned} \tag{20}$$

where we have used the fact that prices, by pinning down demand, consequently pin down

hours, and hence total compensation, through the relationship

$$h_{j,t} = \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} \frac{Y_t}{Z_t n_t}. \tag{21}$$

A firm that can re-optimize prices, hence, takes this dependence of hours and compensation on the relative price, with the optimal reset price satisfying

$$P_t^* = \arg\max J_t\left(P_{j,t}\right). \tag{22}$$

2.4 Vacancy Posting and the Labor Market

Firms post vacancies at cost κ, which are filled with probability q_t and become productive the following period. At the beginning of $t+1$ price adjustment occurs, then contracting and production. New entrants inherit a price level in period t equal to the aggregate price level ($P_{j,t} = P_t$), and receive a Calvo shock before production in $t+1$. Because of free entry, firms post vacancies until the vacancy posting cost equals the expected return which implies

$$\kappa = q_t \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t}\left[\zeta J_{t+1}\left(P_t\right) + \left(1-\zeta\right) J_{t+1}\left(P_{t+1}^*\right)\right]. \tag{23}$$

Matches m_t depend upon the number of unemployed u_t and the number of vacancies v_t according to

$$m_t = \sigma_m u_t^{\alpha} v_t^{1-\alpha} \tag{24}$$

where σ_m governs the efficiency of the matching function, and α is the elasticity of matches with respect to the number of unemployed. The job filling rate is $q_t = m_t/v_t$.

New matches take one period to form, and existing matches are destroyed at an exogenous rate δ_t. Consequently, employment evolves according to

$$n_t = \left(1-\delta_{t-1}\right) n_{t-1} + m_{t-1}. \tag{25}$$

The separation rate δ_t is time-varying according to the process

$$\log \delta_t = \left(1-\rho_\delta\right)\log\bar{\delta} + \log\delta_{t-1} + \sigma_\delta \varepsilon_{d,t}. \tag{26}$$

Figure 1: Timing of the Model

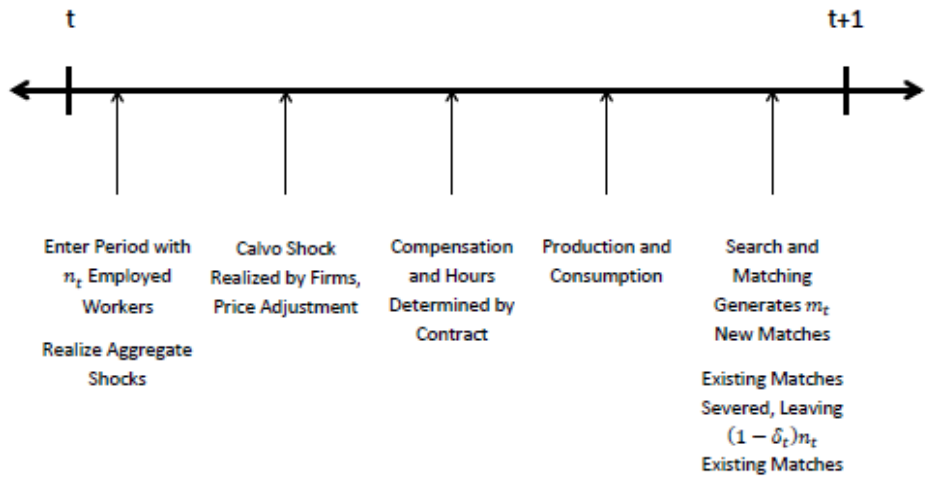


Figure 1 summarizes the timing of the model.

2.5 Monetary Authority and Government

Monetary policy follows a Taylor Rule, setting the nominal rate R_t according to

$$\frac{R_t}{R_{ss}} = \left(\frac{R_{t-1}}{R_{ss}}\right)^{\rho_r} \left(\frac{\Pi_t}{\Pi_{ss}}\right)^{(1-\rho_r)\gamma_\pi} \exp\left(\sigma_r \varepsilon_{r,t}\right), \tag{27}$$

where Π_{ss} indicates the inflation target, R_{ss} the nominal rate target, ρ_r the degree of interest rate persistence, γ_π the response to inflation, and $\varepsilon_{r,t}$ denotes a monetary policy shock.

Fiscal policy adjusts lump sum taxes to balance the budget. The government pays unemployment benefits b and interest on debt by issuing debt and collecting lump-sum taxes:

$$P_t u_t b + B_{t-1} R_{t-1} = B_t + P_t T_t. \tag{28}$$

2.6 Market Clearing

Market clearing requires that aggregate output equals aggregate consumption

$$Y_t = C_t, \tag{29}$$

while aggregate consumption is the consumption of all individuals

$$C_t = C_t^e + C_t^u. \tag{30}$$

Aggregate hours is defined as the hours worked by all employed individuals

$$H_t = \int_0^{n_t} h_{j,t} dj, \tag{31}$$

which is related to aggregate output by

$$Z_t H_t = \varsigma_t Y_t. \tag{32}$$

The rate of domestic absorption, also called the loss in output due to price dispersion, is defined as

$$\varsigma_t = \frac{1}{n_t} \int_0^{n_t} \left(\frac{P_{j,t}}{P_t} \right)^{-\epsilon} dj. \tag{33}$$

We can also define average compensation per worker as

$$\omega_t = \frac{1}{n_t} \int_0^{n_t} \omega_{j,t} dj, \tag{34}$$

which in turn gives an average hourly wage equal to

$$w_t = \frac{\int_0^{n_t} \omega_{j,t} dj}{\int_0^{n_t} h_{j,t} dj} = \frac{n_t \omega_t}{H_t}. \tag{35}$$

Lastly, we define the average markup of prices over marginal cost $MC_{j,t}$ as

$$markup_t = \frac{1}{n_t} \int_0^{n_t} \frac{P_{j,t}}{MC_{j,t}} \frac{Y_{j,t}}{Y_t / n_t} dj = \frac{1}{n_t} \int_0^{n_t} \frac{P_{j,t}}{P_t \varphi \left(1 + \frac{1}{\psi}\right) h_{j,t}^{\frac{1}{\psi}}} \frac{Y_{j,t}}{Y_t / n_t} dj. \tag{36}$$

2.7 Comparison with Wholesaler-Retailer Model

To isolate the importance of allowing pricing and labor market frictions to interact within the firm we outline an alternative model with the customary wholesaler-retailer structure and posted wages. Wholesale producers hire labor in the frictional labor market using wage

posting and produce a competitively priced good. Monopolistically competitive retail firms face Calvo price frictions and purchase the wholesale good and convert it into a differentiated good. The remaining aspects of the alternative model are the same as the baseline.

Focusing on the wholesaler problem, they operate a linear technology

$$Y_t^w = Z_t h_t. \tag{37}$$

Wholesalers take their price P_t^w as given and choose hours worked to maximize

$$J_t = \max_{h_t} \frac{P_t^w}{P_t} Z_t h_t - b - \varphi h_t^{1+1/\psi} + \beta(1-\delta_t)\mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1}. \tag{38}$$

Note that this expression already includes the definition of the optimal contract when firms offer take-it-or-leave-it contracts to workers. The first-order condition with respect to hours implies:

$$h_t = \left[\frac{\frac{P_t^w}{P_t} Z_t}{\varphi(1+1/\psi)} \right]^{\psi}. \tag{39}$$

For ease of comparison, consider the equations characterizing the hours choice of firms in each model. In logs, the hours choice in the baseline model (21) is

$$\log(h_{j,t}) = -\epsilon \log\left(\frac{P_{j,t}}{P_t}\right) + \log\left(\frac{Y_t}{Z_t n_t}\right), \tag{40}$$

and in the alternative model (39) is

$$\log(h_t) = \psi \log\left(\frac{P_t^w}{P_t}\right) + \psi \log Z_t + const. \tag{41}$$

In the baseline model, hiring firms are price setters and demand for their differentiated good is decreasing in their relative price, so are hours worked. In contrast, in the alternative model hiring firms are price takers and because supply for their good is increasing in the relative price of wholesale goods, so are hours worked. In partial equilibrium, technology shocks also have differential effects on hours worked across models. In the baseline model, because output is pinned down given relative prices, any increase in productivity is labor saving and

hence hours worked fall. Meanwhile, an increase in productivity in the alternative model increases hours since each existing employment match is more valuable given prices.

Next, under the alternative model the free-entry condition takes the usual form

$$\kappa = q_t \beta \mathbb{E}_t \frac{\lambda_{t+1}}{\lambda_t} J_{t+1} \tag{42}$$

Comparing this equation to (23), the free entry condition under the baseline model, highlights that frictions related to price adjustment do not directly affect vacancy creation in the alternative model. Similarly, in the baseline model any factors that alter how future profits are discounted, such as shocks to the discount factor or separation rate shocks, have differential impacts on firms who reset or inherit prices. In contrast, all firms are ex-post identical in the alternative model.

To close the alternative model, retailers face a standard problem summarized by the optimal reset price condition

$$\sum_{k=0}^{\infty} (\beta\zeta)^k \frac{\lambda_{t+k}}{\lambda_t} \left[\frac{P_t^*}{P_{t+k}} - \mu \frac{P_{t+k}^w}{P_{t+k}} \right] Y_{t+k} P_{t+k}^{\epsilon} = 0 \tag{43}$$

where $\mu = \frac{\epsilon}{\epsilon - 1}$ is the flexible price markup, Y_t is demand for the final good, and P_t is the aggregate price level. For comparison, the expression the optimal reset price satisfies in our baseline model is

$$\sum_{k=0}^{\infty} (\beta\zeta)^k \prod_{i=1}^{k} (1 - \delta_{t+k-i}) \frac{\lambda_{t+k}}{\lambda_t} \left[\frac{P_t^*}{P_{t+k}} - \mu \frac{\varphi(1 + 1/\psi) h_{j,t+k}^{1/\psi}}{Z_{t+k}} \right] \frac{Y_{t+k}}{n_{t+k}} P_{t+k}^{\epsilon} = 0. \tag{44}$$

There are two important differences between equations (43) and (44). First, in our baseline model because intermediate firms face pricing and labor market frictions they discount future revenues both by the expected duration of the current price, which depends on ζ, and the expected duration of the current match, which depends on δ_{t+k}. In contrast, in the alternative model retail firms do not care about match duration when setting their prices. Additionally, across the two models marginal costs are notably different. In the alternative model, marginal costs are simply given by the relative price of wholesale goods $\frac{P_{t+k}^w}{P_{t+k}}$, whereas

Table 1: Standard Calibrated Parameters

Parameter	Description	Value
β	Discount factor	0.9951
γ	Risk aversion	2
ψ	Frisch elasticity	0.5
ζ	Prob. not re-optimizing prices	0.66
ϵ	Elasticity of substitution	10
$\bar{\delta}$	Mean separation rate	0.1
α	Matching function elasticity	0.5
Π_{ss}	Inflation target	1
ρ_r	Policy persistence	0.6
γ_π	Response to inflation	1.5
ρ_z	Technology persistence	0.95
ρ_δ	Separation persistence	0.97
σ_r	Std Dev MP shock	0.0025
σ_z	Std Dev technology shock	0.01
σ_δ	Std Dev separation shock	0.015

in our baseline model marginal costs depend on the marginal disutility of hours worked $\varphi(1+1/\psi)h_{j,t+k}^{1/\psi}$.

2.8 Calibration

The parameters fall into two categories: parameters that are fixed at standard values and parameters that are chosen to match certain targets in steady state.

Table 1 lists the parameters fixed at standard values. The discount factor β is set to imply a model period of one quarter. The coefficient of risk aversion γ and the Frisch elasticity of labor supply ψ are set to standard values in the literature. The probability of not re-optimizing prices ζ is set to match a median price duration of six months as reported in Bils and Klenow (2004). Following Gertler et al. (2008), we set the elasticity of substitution across goods to $\epsilon = 10$.

Consistent with empirical estimates in Shimer (2005) and den Haan et al. (2000) we target a mean quarterly separation rate of 10 percent, so $\bar{\delta} = 0.10$. In line with Ramey (2007) and Fujita and Ramey (2009), we set the persistence and the standard deviation parameters for the separation rate process to be $\rho_\delta = 0.97$ and $\sigma_\delta = 0.015$. The elasticity of the matching function with respect to unemployment α is set to 0.5, which is the midpoint of

Table 2: Parameters Calibrated to Match Steady State Targets

Parameter	Description	Target	Baseline	Alternative
φ	Disutility of labor	$h_{j,ss} = 1/3$	2.7	2.7
b	Unemployment benefits	$b/\omega_{ss} = 1/2$	0.1	0.1
σ_m	Matching efficiency	$u_{ss} = 0.11$	0.7526	0.7526
κ	Vacancy posting	$q_{ss} = 0.70$	0.8895	0.6671

values typically cited in the literature. Lastly, the parameters governing shocks and monetary policy are also set to standard values.

Table 2 lists the parameters calibrated to match steady state values, and how these differ between our baseline and the alternative models. The disutility of hours worked φ is such that steady state hours worked per employed person equal 1/3. Given that preferences are identical across models, this implies $\varphi = 2.7$ in both the baseline and alternative. Following Blanchard and Diamond (1990) we target a steady state unemployment rate of 11 percent, which includes both individuals who are categorized as unemployed and those out of the labor force who want a job. Following den Haan et al. (2000), we target a steady state worker finding rate of 70 percent, so $q_{ss} = 0.7$. These assumptions directly pin down the matching efficiency parameter σ_m. Again, since the matching function and evolution of employment are identical across models, this produces $\sigma_m = 0.7526$ in both cases.

We calibrate b conservatively such that in steady state the replacement ratio, defined as the ratio of unemployment benefits to the average compensation in steady state, equals 1/2, which is roughly the mid-point between values in the literature.[7] By construction our model implies a replacement ratio of one if unemployment benefits include the consumption equivalent of the disutility of hours worked. Given our assumption on hours per worker and identical preferences across the two models, we have $b = 0.1$ in both cases.

Lastly, given our calibration and targets, the vacancy posting cost κ is implied from the steady state free-entry condition. This parameter is the only one that differs across models. In the alternative model, firms posting vacancies are attempting to enter a market in which they sell a good in a competitive market, whereas our baseline model has entering firms selling a differentiated product in a monopolistically competitive environment. For

[7] For example, Shimer (2005) considers a value of 0.4 while Hagedorn and Manovksii (2008) consider a value close to one.

this reason, the baseline model implies a higher vacancy posting cost than the alternative model.[8]

3 Results

We now turn to analyzing the differences between the baseline and alternative models. First, we consider how changing the level of the unemployment benefits affects the steady state of each economy. Second, we consider the impulse responses to the various shocks in the economy, and third we consider how key labor market ratios behave across models. In all these cases, our main focus is to contrast the baseline model with the alternative model, but we also highlight the effects of sticky prices–which are central to the mechanism–by discussing the results under flexible prices as well.

3.1 Unemployment Benefits and the Steady State

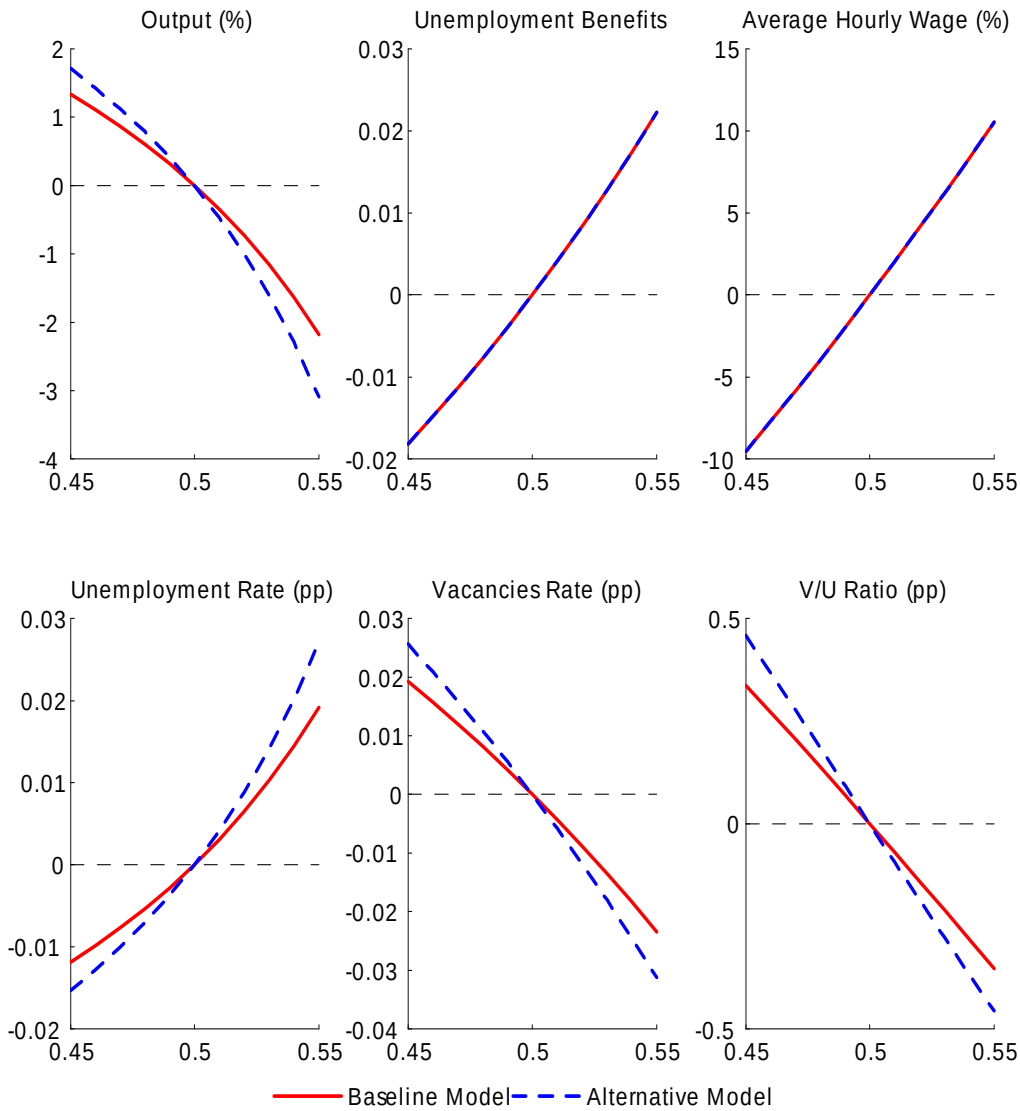
In order to gauge the importance of wage posting and search in our environment, we first analyze the steady state of the economy. The steady state of the model has no aggregate shocks, but with idiosyncratic firm- and individual-level shocks still operational. The result is an economy with a degenerate price distribution where all firms having the same price and the unemployment rate equalling its time invariant steady state value as gross flows in and out of employment net out.[9]

Figure 2 gives indication as to the differences between models. The figure shows the effect, in steady state, of changing the unemployment benefits b to vary the replacement ratio, relative to our calibrated replacement ratio of 1/2 ($b = 0.1$), holding preference parameters fixed. In both models, as unemployment benefits decrease, the base level of compensation decreases as well, which makes firms more willing to post vacancies, so unemployment declines, and aggregate output increases.

[8] Note that if we alternatively had fixed an identical value of κ across models, we would need to allow different steady state unemployment rates, as there would tend to be more entry and lower unemployment in our baseline model.

[9] Lago Alves (2012) considers the effects of different trend inflation rates in a model where firms jointly make pricing and hiring decision.

Figure 2: Change in the Steady State as the Replacement Ratio Varies



However, the relative elasticities of wages and other labor market variables to changes in b differ across models. Recall, profits in the baseline model (compared to the alternative model) are higher or equivalently, vacancy posting costs (κ) are larger to match an equal level of steady state unemployment across models. As a result, identical changes in b have different effects across models since the fixed cost of finding and employing a worker– the vacancy posting cost plus a base level of compensation–moves by a smaller relative amount in the baseline model. With lower vacancy posting costs, the alternative model shows bigger

effects of b on the labor market and output.

These results suggest that the implications of policies changing unemployment benefits may depend on modeling assumptions. Our analysis suggests that, once allowing for both price-setting and labor market decisions to be made within the same firm, the economy becomes less sensitive to the level of benefits. Consequently, decreases in benefits will imply a lower impact on unemployment in our model than the alternative.

3.2 Impulse Responses

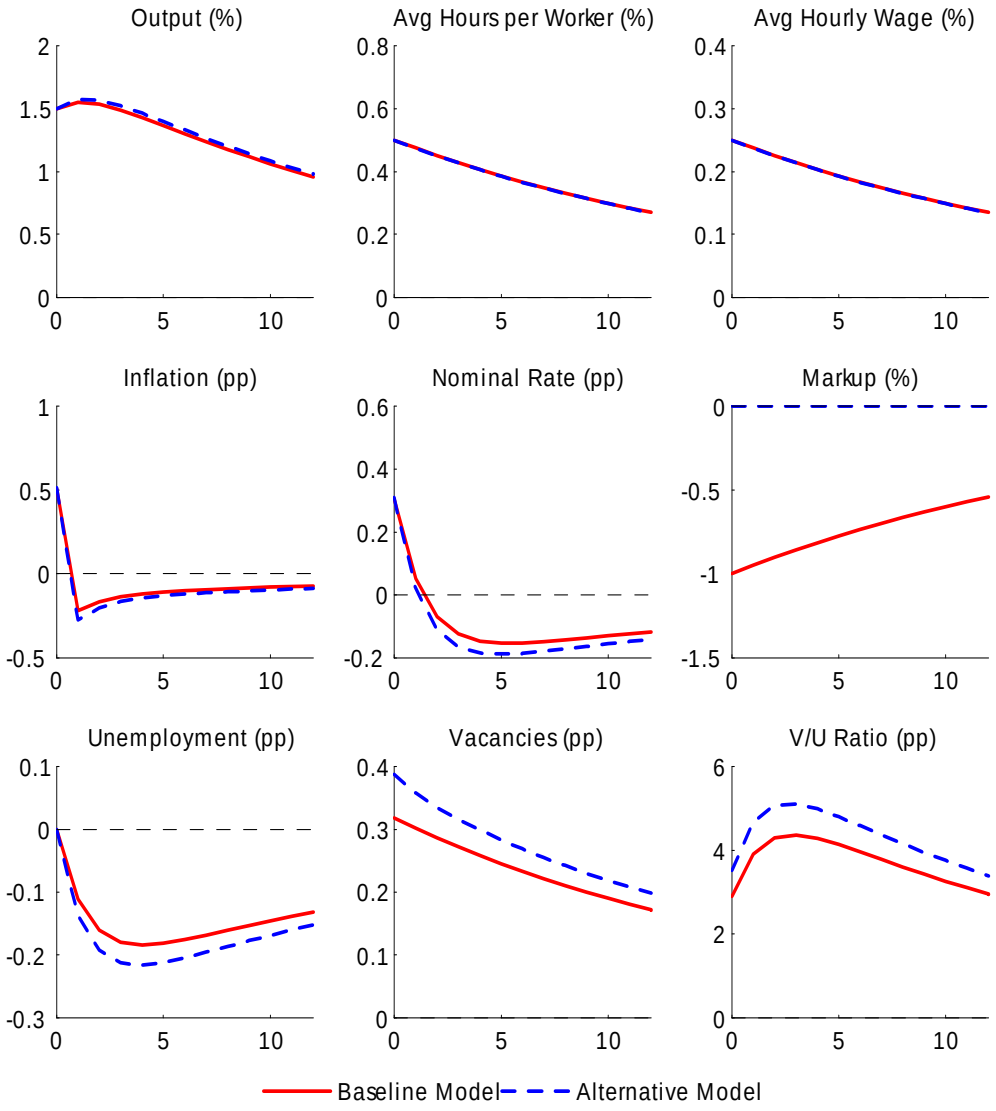
Having discussed some of the steady state properties of our model, we now turn to considering the dynamics associated with different shocks. Again we compare our baseline model of wage posting and search directly by firms that have pricing power and nominal rigidities with the alternative retailer-wholesaler environment that separates the these actions into different firms. The three shocks in the model are total factor productivity, separation rate, and monetary policy innovations; their effects differ in magnitude and persistence depending on the model assumptions. In addition, we consider the flexible price version of both the baseline and alternative models to highlight the importance of sticky prices for the propagation of shocks.

3.2.1 Technology Shock

Figure 3 shows the response to a one standard deviation positive innovation in total factor productivity under the assumption of flexible prices ($\zeta = 0$). The responses of both our baseline model and the alternative are similar qualitatively, although the magnitudes differ for the labor market variables.

In our baseline model, higher productivity expands output, induces firms to post more vacancies, and drives down unemployment. Firms face a trade-off between increasing their prices, which stifles demand but keeps hours low, and not increasing prices, which leads to high demand, a need for hours, and hence a high compensation level. Firms increase their prices, leading to an increase in inflation on impact. Higher prices tend to lead to lower average hours per worker, but higher demand overwhelms this channel, leading to more hours

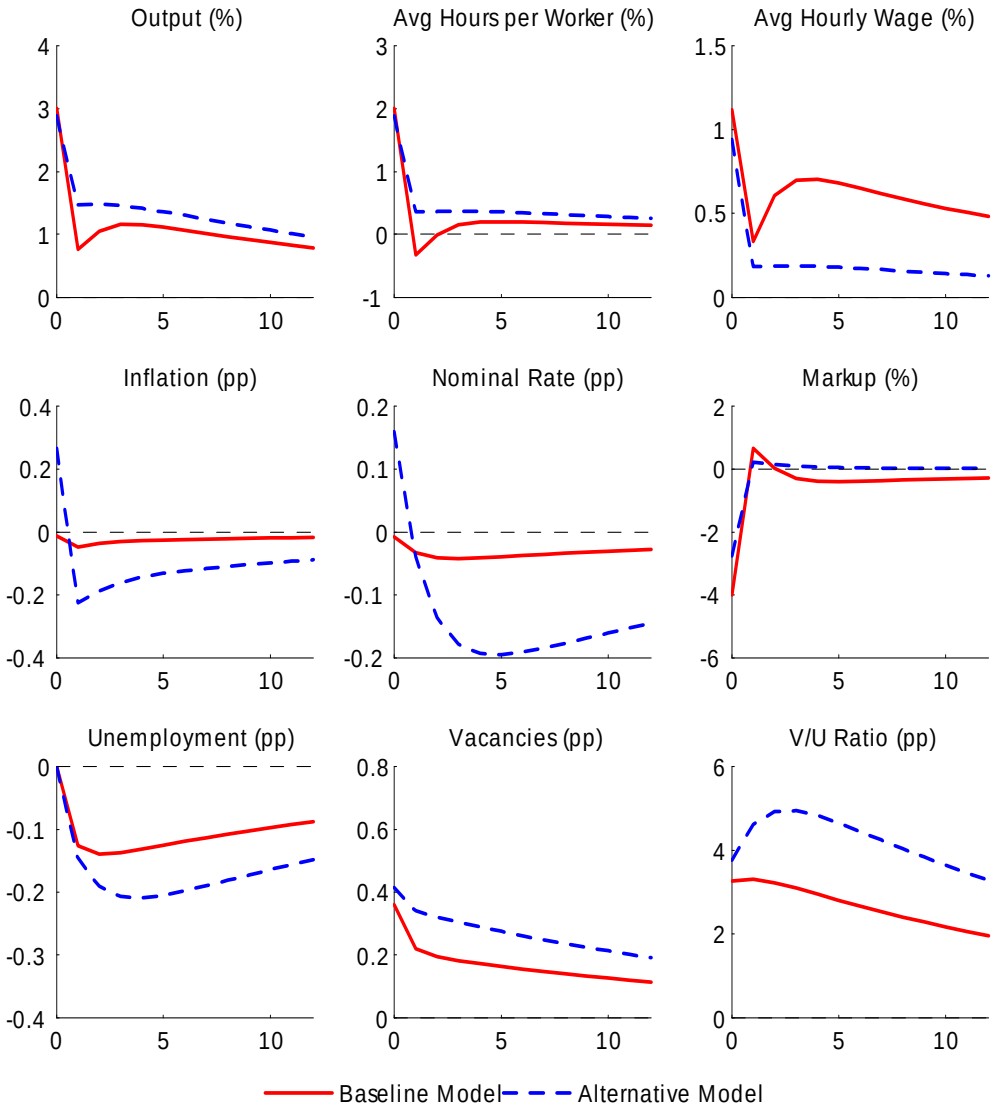
Figure 3: Response to a Technology Shock with Flexible Prices



and hence a higher compensation rate and higher average wage. Since firms' marginal costs are average hourly wages in this case, these changes in labor demand and prices on net lead to a decline in firms' markups. In periods after the shock, real activity gradually returns to normal, and inflation is slightly negative as prices decline in accordance with average hourly wages.

Many of the channels in the baseline model are present in the alternative model, but with varying magnitudes. Wholesale good firms receive the technology shock, which increases

Figure 4: Response to a Technology Shock with Sticky Prices



labor demand, but because they sell their product in a competitive market, they have no pricing power to offset the shock. As a result, vacancies, unemployment, output, and hours per worker move to a greater degree. The main difference relative to the baseline is that retail firms have unchanged markups reflecting a one-for-one change in the final good and wholesale good prices. This movement in wholesale prices is what generates the larger swing in labor market variables.

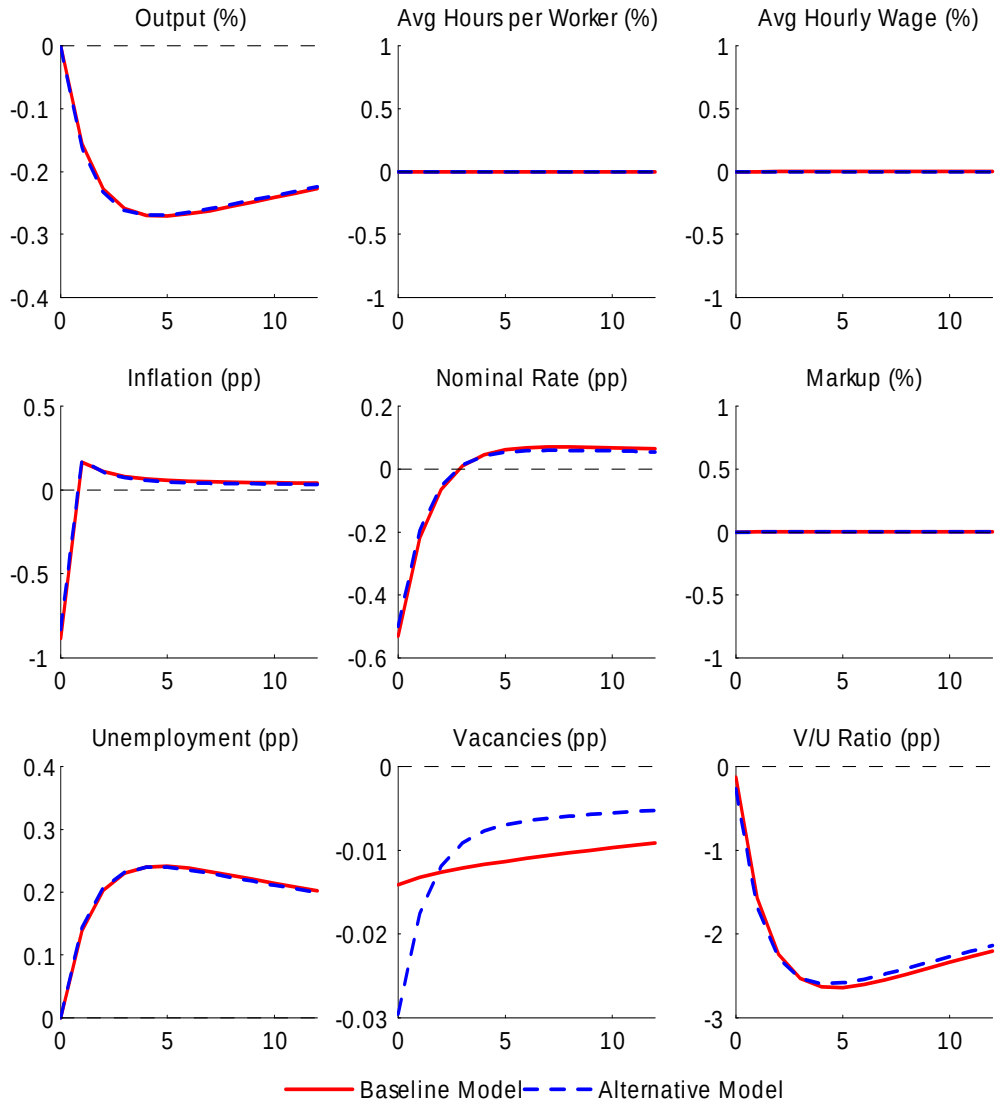
Now considering sticky prices, Figure 4 again shows the response to a one standard

deviation positive innovation in total factor productivity. Focusing first on our baseline model, output, average hours per worker, and the average hourly wage all show significantly larger movements upon impact than in the case with flexible prices, as the inability of a fraction of firms to re-optimize their prices in the period of a shock means relative demand increases significantly, which boosts their hours and compensation levels. Firms that can re-optimize face a similar trade-off between high prices with low hours and low prices with high hours as in the flexible price case. In the flexible price case, there was an initial surge in inflation followed by slight deflation; with sticky prices firms that can re-optimize are forward looking and hence hesitant to raise prices. Instead, prices decline slightly, feeding into the increase in average hours per worker, and compressing the markup. Vacancies shoot up upon impact leading to a sharp fall in unemployment in the following period, which compresses profits. In response, firms raise markups, which decreases hours and wages. As posting vacancies becomes less attractive in a tighter labor market and as the technology shock wanes, vacancies revert to a more normal path, which induces a correction in output, hours, and wages in periods following the initial shock.

The alternative model under sticky prices generates much bigger effects from a technology shock. Since firms searching in the labor market operate in a competitive market, they do not face the same pricing and compensation trade-off faced by firms in the baseline model. Retail firms with the opportunity to set their price do not have to worry about the effect of prices on compensation, and increase prices by a larger amount in response to the shock. Wholesale firms post more vacancies and demand more hours, which boosts average hours per worker and the average hourly wage. In subsequent periods, a higher number of wholesale firms produces more output and demands more hours from workers, but since they sell their product in a competitive environment, the wholesale good price declines, and retail firms that can re-optimize lower their prices significantly in order to stabilize markups. Because more adjustment occurs through prices, real variables exhibit less of a correction in subsequent periods compared to the baseline model. Lower inflation causes a larger decline in the nominal interest rate than in our baseline case.

To summarize, after a technology shock, while many of the responses are qualitatively similar, our baseline model has firms that use their combined pricing and hiring power to

Figure 5: Response to a Separation Rate Shock with Flexible Prices

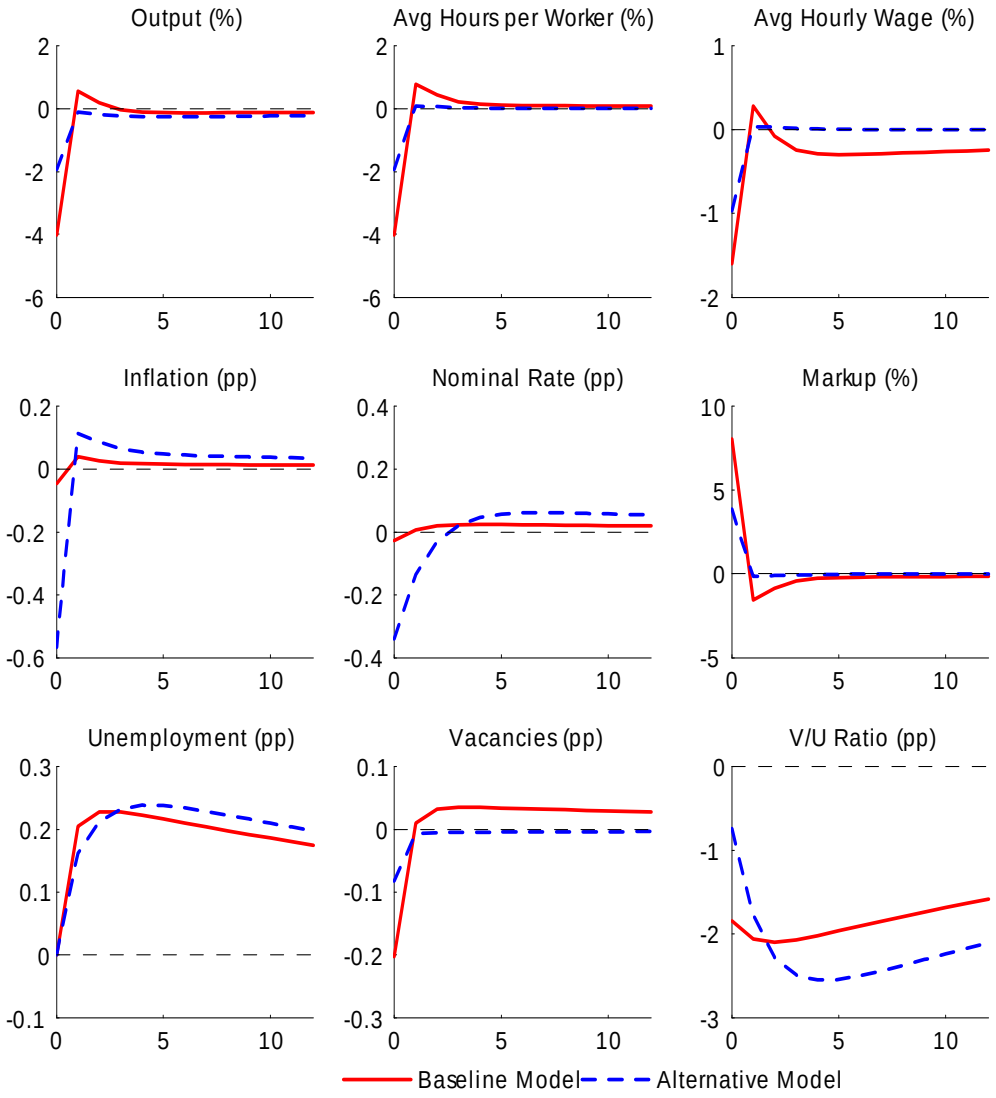


mute the effects of the shock. In contrast, the alternative model, with hiring firms operating in a competitive market and retail firms not facing hiring and employment decisions, sees larger initial swings in real and nominal variables.

3.2.2 Separation Rate Shock

Figure 5 shows the responses to a one standard deviation separation rate shock under the assumption of flexible prices. The responses of the variables across models are nearly identical,

Figure 6: Response to a Separation Rate Shock with Sticky Prices



as a separation rate shock leads to more unemployment. However, in the baseline model, firms with market power have a muted response in vacancy posting, reflecting a greater desire to enter because of monopoly profits. Wholesale firms in the alternative model, on the other hand, operate in a competitive environment, producing bigger swings in vacancy posting. The separation shock produces lower output and an initial decrease in inflation in both models.

Again moving to the sticky price case, Figure 6 shows the responses to a one standard

deviation separation rate shock. In contrast to the flexible price case, the baseline and alternative models show different responses to the separation rate shock. Upon impact the value of posting a vacancy in the baseline model falls as matches are expected to be shorter. As a consequence, the number of vacancies posted falls. This effect is short-lived because in subsequent periods the pool of unemployed grows, which drives up the probability of matching with a worker inducing firms to post more vacancies. In the baseline model hiring firms can also offset the impact of shorter duration matches by increasing their markups. They do this by decreasing marginal costs through lower hours worked and hence compensation. Allowing firms to adjust profit margins through marginal costs has important consequences. Lower marginal costs increases the value of forming a match which leads to vacancies temporarily overshooting their steady state level. Moreover, as markups adjust more through marginal costs than changes in the price level, inflation does not move much and the monetary authority leaves the nominal interest rate essentially unchanged.

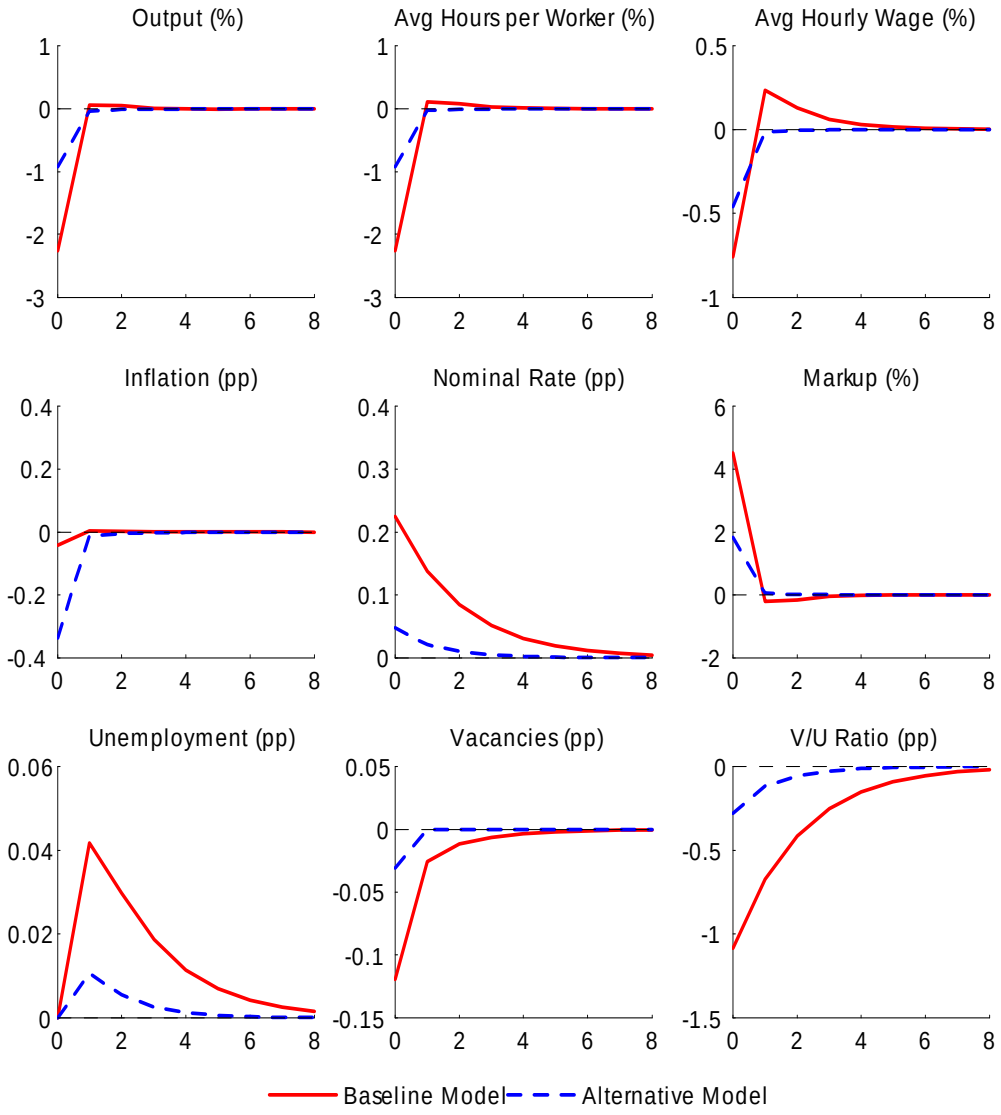
In contrast, in the alternative model wholesale firms cannot adjust prices in response to the separation rate shock. Vacancies fall on impact but revert to their steady state level without overshooting. As the pool of unemployed grows an increased job filling probability offsets the shorter duration of each match. Overall, labor market tightness falls more drastically in the alternative model. Since retail firms cannot control how the separation shock affects their marginal costs, their ability to control markups is diminished, and inflation moves a larger degree, leading to a larger movement in the nominal rate.

3.2.3 Monetary Policy Shock

Now, considering the effect of a monetary policy shock, we ignore the case of flexible prices, since in that case shocks feed directly into inflation and have no effect on any real variables.

Figure 7 shows the responses to a one standard deviation monetary policy shock and how, in contrast to technology shocks, our baseline model shows more responsiveness than the alternative model. In our baseline model, an increase in the interest rate lowers output, and affects the stochastic discount factor firms are using to discount profits. In an environment where firms make both the search and pricing decisions, firms that can re-optimize respond by increasing the size of their markup by lowering their hours and compensation in order to

Figure 7: Response to a Monetary Policy Shock with Sticky Prices



improve current margins. Potential entrants have a lower incentive to enter because expected profits are discounted more, so they post fewer vacancies leading to higher unemployment. Absent other frictions in the economy, the effects of monetary policy on variables such as output, hours, and inflation, are short lived. However, labor market variables show a longer lasting impact primarily because future profits are discounted more, which discourages vacancy posting.

The alternative model, by contrast, shows significantly smaller responses to an interest

Table 3: Labor Market Ratios with Flexible Prices

	$\frac{std(v/u)}{std(Y)}$	$corr\,(u,v)$	$std\,(Y)$	$\frac{std(n)}{std(Y)}$	$\frac{std(h)}{std(Y)}$	$\frac{std(w)}{std(Y)}$
All Shocks						
Baseline	11.9971	-0.5344	0.0168	0.7724	0.3176	0.2858
Alternative	12.9331	-0.5688	0.0171	0.7880	0.3113	0.2801
Tech Shock Only						
Baseline	9.8451	-0.9351	0.0164	0.4162	0.3255	0.2929
Alternative	11.2092	-0.9308	0.0168	0.4738	0.3185	0.2867
Separation Shock Only						
Baseline	32.8127	-0.9557	0.0037	3.0000	0	0
Alternative	32.3527	-0.7037	0.0036	3.0000	0	0

rate shock. Again, this result is due to the separation of labor search and pricing between two different firms. Since wholesale hiring firms operate in a competitive environment, an interest rate shock that distorts the stochastic discount factor cannot be offset by changing markups via hours worked. Additionally, an interest rate shock does not have a differential impact on incumbent and entering firms when prices are determined competitively, hence vacancies and unemployment respond less. In contrast, a monetary policy shock leads to a larger decline in inflation in the alternative model, as price-setting firms increase their markup but do not have to consider the direct implications of their relative price change on hours and compensation in the wholesale market. The result is that monetary policy shocks move inflation more in the alternative model, but aggregate quantities and labor market variables less.

3.3 Cyclical Properties

Save for the monetary shock, the previous results highlight that by giving hiring firms pricing power the labor market is more readily able to absorb shocks. We formalize this intuition by considering what our baseline and alternative models imply about important labor market ratios when all shocks are taken into account.

The top panel of Table 3 presents statistics summarizing the movement of key labor market variables in each model when prices are flexible. Because the volatility of output differs in each model all standard deviations are normalized relative to output. In both models wages are fairly stable and hence both models delivery significant labor market

Table 4: Labor Market Ratios with Sticky Prices

	$\frac{std(v/u)}{std(Y)}$	$corr\,(u,v)$	$std\,(Y)$	$\frac{std(n)}{std(Y)}$	$\frac{std(h)}{std(Y)}$	$\frac{std(w)}{std(Y)}$
All Shocks						
Baseline	7.1798	-0.1872	0.0206	0.5373	0.8405	1.0325
Alternative	11.2575	-0.5469	0.0193	0.6932	0.5480	0.4932
Tech Shock Only						
Baseline	7.5317	-0.8716	0.0152	0.3177	0.4717	1.0854
Alternative	10.2425	-0.9236	0.0179	0.4328	0.4364	0.3928
MP Shock Only						
Baseline	2.0559	-0.2291	0.0067	0.0841	1.1250	0.7230
Alternative	1.1382	-0.0101	0.0027	0.0458	1.1230	1.0107
Separation Shock Only						
Baseline	7.6067	0.5928	0.0122	0.8159	1.1353	1.0281
Alternative	17.4045	-0.2365	0.0067	1.6273	0.9610	0.8649

volatility. Importantly, both models generate greater volatility along the extensive relative to intensive margin of labor supply. Overall, when prices are flexible and both technology and separation shocks are active the volatility of key labor market variables is nearly identical across models.

The second panel of Table 3 shows the differences across models when technology shocks are the only source of aggregate uncertainty. In the baseline model pricing power by hiring firms leads hours and real wages to vary slightly more over the cycle and hence vacancies respond less when compared to the alternative model. As a result, the volatility of the v/u ratio in the baseline model is 88 percent of the alternative model's value.

The last panel of Table 3 considers separation shocks as the only source of aggregate uncertainty. As highlighted in Figure 5, this panel shows that the responses of both models to separation shocks are very similar when prices are flexible. With take-it-or-leave it offers, wages are isolated from labor market tightness and hence hourly wages do not respond to a separation shock. As a consequence, all adjustment occurs along the extensive margin and both models imply very volatile v/u ratios relative to output. The only major difference is the correlation between vacancies and unemployment, which is more muted in the alternative model due to larger swings in vacancies than in the baseline model.

Table 4 repeats the quantitative exercise when prices are sticky. Looking across panels of this table reveals that sticky prices, through there effects on markups or marginal costs,

accentuate the differences between our baseline model and the alternative model where hiring firms have no pricing power. In the first panel, considering all shocks produces a lower v/u volatility and Beveridge curve, along with lower volatility in employment and much higher volatility of hours and wages than the alternative model. The second, third, and fourth panels show the differential effects of the various shocks, but considering all shocks demonstrates that the technology and separation shocks primarily drive the aggregate moments.

Focusing on the second panel, the baseline model continues to deliver a relative volatility of the v/u ratio that is smaller, at roughly 73 percent of what the alternative model obtains. With sticky prices, price setting firms in the baseline model adjust their own marginal costs via the intensive margin. Greater volatility in hours leads to more volatility in hourly wages. In effect, wages are more flexible in the baseline model relative to the alternative model, which dampens fluctuations in labor market tightness.

The third panel of Table 4 considers monetary policy shocks as the only source of aggregate uncertainty. Echoing the results from the previous section, the baseline model is comparatively more responsive to monetary shocks than the alternative model. Recall that a monetary shock affects the stochastic discount factor used by hiring firms to evaluate future profits. In the baseline model, existing firms respond to this by increasing markups and new firms choose to post fewer vacancies as expected profits are discounted more. Overall, both models imply modest volatility in labor market tightness when monetary policy drives uncertainty. Since the monetary policy shock tends to move these moments in opposite directions of the technology shock and the separation shock, the only way we could possibly overturn the qualitative differences in our baseline and alternative models when considering all shocks is to have an economy that relies primarily on monetary policy shocks as a driver of fluctuations.

The last panel of Table 4 considers the effects of separation shocks. The alternative model delivers a very volatile v/u ratio as compensation is isolated from aggregate labor market tightness yet separation shocks affect the number of unemployed workers and hence the job filling probability. The alternative model, however, implies only a very modest Beveridge curve since vacancies quickly return to their steady state value. In the baseline model, while compensation is also isolated from labor market conditions hours are not. Firms adjust

markups by changing hours and hence the extensive margin and vacancies vary less. This model implies a counterfactually positive Beveridge curve as vacancies overshoot their steady state level as wages are temporarily depressed due to the change in hours.

4 Conclusion

We consider the macroeconomic implications of the interaction between pricing and labor market frictions. In our New Keynesian model, workers randomly search for jobs and monopolistically competitive firms post take-it-or-leave-it wage contracts taking into account infrequent adjustment of their own price. By allowing for wage posting by firms, the model provides a direct link between pricing and hiring behavior at the micro level.

A comparison of our baseline model with an alternative model that separates pricing and hiring across different sectors reveals key differences. We find that our baseline model is less sensitive to changes in benefits paid to unemployed workers because hiring firms, who have pricing power, adjust to workers' changing reservation wages by adjusting prices and in turn labor demand.

An analysis of the cyclical responses of the models reveals that the separation of pricing and hiring is not innocuous for labor market variables of interest. Over the cycle, price-setting firms in our baseline model use the intensive margin of labor more readily in response to shocks compared to price-taking firms in the alternative model. As a result, hourly wages are more volatile in the baseline model and vacancy posting activity is reduced. This finding is despite the fact that the take-it-or-leave-it assumption leaves workers indifferent between employment and unemployment, which would tend to increase the volatility of the extensive margin.

A key message from our analysis is that separating pricing and hiring frictions matters greatly even in our parsimonious framework. In the flexible price case of our model, incorporating labor market search decisions into a firm with market power alters the effects of shocks and changes the volatility of the labor market. The addition of sticky prices leads to further difference between our baseline model and the alternative. Our results suggest that heterogeneity in price stickiness or market power, for example across industries or countries,

may lead to different conclusions about the importance of the link between labor markets and inflation.

In addition, these results imply that the integration of pricing and hiring frictions affects the conduct of policy. In particular, our framework suggests changes in unemployment benefits may not have as strong an impact on labor markets and other aggregates, since firms with market power can offset these changes through their pricing choices. Lastly, the different effects of shocks imply possibly different stabilization roles for monetary policy, since our model suggest that policy surprises will have larger impacts on the economy when firms have make joint pricing and hiring decisions. Through this lens, our model suggests that if the zero lower bound on nominal rates acts as a contractionary monetary policy shock, then this constraint may explain the persistently high unemployment to a larger degree than if firms' pricing and employment decisions were less integrated.

References

Barnichon, R. (2010). Productivity and Unemployment Fluctuations over the Business Cycle. *Journal of Monetary Economics 57*(8), 1013–1025.

Bils, M. and P. Klenow (2004). Some Evidence on the Importance of Sticky Prices. *Quarterly Journal of Economics 111*(3), 719–751.

Blanchard, O. and P. Diamond (1990). The Cyclical Behavior of The Gross Flows of U.S. Workers. *Brookings Papers on Economic Activity 2*, 85–155.

Christiano, L., M. S. Eichenbaum, and M. Trabandt (2013). Unemployment and Business Cycles. NBER Working Papers 19265, National Bureau of Economic Research, Inc.

den Haan, Wooter, J., G. Ramey, and J. Watson (2000). Job Destruction and Propagation of Shocks. *American Economic Review 90*(3), 482–498.

Dossche, M., V. Lewis, and C. Poilly (2014). Employment, Hours and Optimal Monetary Policy. ECB Working Paper 1713.

Fujita, S. and G. Ramey (2009). The Cyclicality of Separation and Job Finding Rates. *International Economic Review 50*(2), 415–430.

Gertler, M., L. Sala, and A. Trigari (2008). An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining. *Journal of Money, Credit, and Banking 40*(8), 1713–1764.

Gornemann, N., K. Kuester, and M. Nakajima (2012). Monetary Policy with Heterogeneous Agents. FRB Philadelphia Working Paper No. 12-21.

Greenwood, J., Z. Hercowitz, and G. W. Huffman (1988). Investment, Capacity Utilization, and the Real Business Cycle. *American Economic Review 78*(3), 402–417.

Hagedorn, M. and I. Manovksii (2008). The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited. *American Economic Review 98*(4), 1692–1706.

Klenow, P. and B. Malin (2010). Microeconomic Evidence on Price-Setting. In B. Friedman and M. Woodford (Eds.), *Handbook of Monetary Economics*, Volume 3A, Chapter 6, pp. 231–284. Elsevier.

Krause, M. U. and T. A. Lubik (2007). The (ir)relevance of real wage rigidity in the New Keynesian model with search frictions. *Journal of Monetary Economics 54*, 706–727.

Krusell, P. and A. Smith (1998). Income and Wealth Heterogeneity in the Macroeconomy. *Journal of Political Economy 106*(5), 867–896.

Kuester, K. (2010). Real Price and Wage Rigidities with Matching Frictions. *Journal of Monetary Economics 57*, 466–477.

Lago Alves, S. (2012). Trend Inflation and the Unemployment Volatility Puzzle. Working Papers Series 277, Central Bank of Brazil, Research Department.

Mustre-del Río, J. (2014). Wealth and Labor Supply Heterogeneity. Forthcoming, *Review of Economic Dynamics*.

Ramey, G. (2007). Exogenous vs. Endogenous Separation. mimeo.

Shimer, R. (2005). The Cyclical Behavior of Equilibrium Unemployment, Vacancies, and Wages: Evidence and Theory. *American Economic Review 95*(1), 25–49.

Thomas, C. (2011). Search Frictions, Real Rigidities, and Inflation Dynamics. *Journal of Money, Credit and Banking 43*(6), 1131–1164.

Trigari, A. (2006). The Role of Search Frictions and Bargaining for Inflation Dynamics. IGIER WP 304.

Walsh, C. (2005). Labor Market Search, Sticky Prices and Interest Rate Rules. *Review of Economic Dynamics 8*, 829–849.